TECHNICAL REVIEWERS' RATING SUMMARY

R027-D

Commercial Demonstration of Geothermal and Hybrid Electricity using Produced Fluids at Existing Wellsite

TerraCOH

Principal Investigator: Jimmy Randolph

TerraCOH's responses to Reviewers 1D, 2D & 3D comments are included in Red.

TerraCOH would like to thank the three reviewers for their diligent reviews and thoughtful comments. We have endeavored to address all comments below.

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Renewable Energy Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 1D (Rating: 4)
Consistent with the stated goals, with opportunities to extend to other regions of the U.S. with significant hydrocarbon activity (perhaps Texas, Colorado, Louisiana, etc.). Business model of $.05 kWh that also addresses carbon sequestration is attractive, even on smaller scales, if upfront capital is manageable.
COMMENT -- (no comment)

Reviewer 2D (Rating: 4)
Very clearly articulated and generally a good match. Only marked down to a 4 because of the proposed use of hydrocarbons in the hybrid solution, but I wouldn't personally mark them down much since the explicit goal is to use stranded resources and avoid flaring, to be advantaged versus traditional hydrocarbon-based generation.
COMMENT – As the reviewer notes, the hybrid solution is considered only where there are stranded hydrocarbon resources. At such locations, using the resource to produce electricity is preferable to flaring; TerraCOH's focus is on geothermal resources.

Reviewer 3D (Rating: 2)
The objectives of this project are clear however, they may not be consistent with the Council's goals. Geothermal technology listed as a focus area for the council. This project is closely tied to oil & gas development. This project could not exist without oil and gas development and therefore defining this project as "renewable" may be a stretch.
COMMENT – The power generated by TerraCOH's proposed systems will use primarily, and will generally use exclusively, geothermal energy. The geothermal industry is very small compared to other renewables, such as wind and solar, and new geothermal technologies are in the early stages of development. In order for geothermal energy to play a significant role in the US and world energy landscape, the projects that are developed now, and especially those

projects that employ new technologies, must be successful and demonstrate competitive economics. The most significant single cost and risk in traditional, legacy geothermal systems is the drilling of wells – if that cost and risk can be avoided during the demonstration phases of new geothermal technologies, then it is in the best interest of the industry and those states with geothermal resources that such costs and risks be avoided.

TerraCOH certainly could drill our own wells. However, the hydrocarbon industry in North Dakota has already drilled hundreds, if not thousands, of wells that intersect the state's vast geothermal resources. By making use of existing wells, TerraCOH can demonstrate the geothermal opportunity in North Dakota for a fraction of the cost of drilling new wells. Furthermore, it is in the interest of the state of North Dakota to identify secondary uses for existing hydrocarbon wells in the state. Such wells have a limited lifespan as hydrocarbon production sites, but they provide a much longer-term opportunity as geothermal wells. Thus, old hydrocarbon wells can be converted from liabilities to renewable energy assets.

TerraCOH's patented technologies can make use of shallower, cooler geothermal resources than legacy geothermal technologies; therefore, we can take advantage of more existing well infrastructure, permitting cost-effective and widespread geothermal development.

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Reviewer 1D (Rating: 2)
The objectives may be possibly achievable (2) as planned, but could be increased to Most Likely Achievable (4) with some modifications:

1. Recommend commencing full project upon selection/confirmation of the well site provider. This task is currently allotted 4 months from well identification to selection of site. To meet this timeline would presume current involvement/participation of candidate well operators.
COMMENT – TerraCOH is already working to confirm an operator in North Dakota. In addition, we have allowed flexibility in the schedule should additional time be required to finalize site selection. Most of the Williston Basin has appropriate geothermal heat flow for power production using TerraCOH's technology, thus there are many, many potential locations for development. North Dakota is the perfect place to implement TerraCOH's technology.

2. Recommend extending the demonstration period to a minimum of 9 months (versus the proposed 6 months of June through November) to capture both a full winter and a full summer of operations; temprature extremes key to evaluating ongoing production conditions. The proposed plan calls for 13 months of budgeted activities (Oct '16 - Nov '17) with 18 months total for project duration so could make this modification to the schedule and remain at ~ 18 months.
COMMENT – We are happy to extend the demonstration period to 9 months; we anticipate operating the site beyond the duration of the proposed project, as well. Our system is designed to account for all temperature extremes, and it will be particularly valuable to demonstrate the geothermal system performance during cold months, when other types of

distributed power systems (such as diesel generators) are difficult to operate. The TerraCOH CO2 power system should have improved performance during the winter, a benefit of using CO2 as the heat transfer fluid.

Reviewer 2D (Rating: 4)
The specifics of the proprietary technology are unclear here, so it's hard for me to judge how much difficulty there will be in applying that technology to this application for these objectives. Other than that, this seems very well thought out and has some buffer.
COMMENT – The TerraCOH CO2 power system has been demonstrated in waste heat-to-power applications under similar temperature conditions. While there will certainly be challenges in implementing the proposed system, they should be manageable. Moreover, we have assembled a team with considerable experience, including experts from the University of North Dakota, who have installed a legacy-style geothermal system in the state. Thus, our team will be able to anticipate and address many of the challenges of installing our system in advance.

Reviewer 3D (Rating: 4)
The budget is clear and the timeline seems reasonable.
COMMENT – (no comments)

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 1D (Rating: 3)
1. As stated previously, need a longer period of operational demonstration for validation.
COMMENT – We are happy to oblige.

2. Would like to see more detail for the plan to transition from 10 KW to 50 KW, or beyond. The budget is for a 10 KW, though the project description states 10 to 50 in several places. Does 50 KW presume a larger piece of equipment, or multiple sites? If the former, are there noise considerations? If multiple sites, what are the complexities associated with that?
COMMENT – We allowed for some flexibility in the size of the power system because, if the site we choose to use has a sufficient geothermal resource, we may put additional private capital towards a 50kW system, rather than using a 10kW system. Regardless of the size of the system, only one site will be used. The 50kW system will consist of five 10kW turbine-generators operated in parallel. This approach allows TerraCOH to capture five times as many operational hours on turbines, enhancing the value of the proposed project as a demonstration facility. The power system will be housed in an insulated container, minimizing noise, amongst other benefits.

3. What is the cooling system plan? Air versus water or another approach? May be site specific, which is why important to know before commencement of full project. Could impact budget considerably.
COMMENT – We are planning on air cooling. However, should water for cooling be available and the budget permits, we may use water cooling during the hottest period of the year. Air cooling is generally preferred as it does not vary by site.

4. What is the source of the CO2? Is there a cost associated with it?
COMMENT – The proposed system will use only a small amount of CO2 within the closed-

cycle power system itself and will have a minimal cost. CO2 currently costs approximately $40 per ton, and the power system will need far less than a ton.

5. What is the connection to the grid, if any?
COMMENT – We prefer not to connect to the grid but rather provide power to an onsite user. If there is no on-site user, a grid connection could be pursued but is not necessary. We are currently connecting with the utilities in North Dakota, and TerraCOH has a former VP of Generation at a Midwest utility as a consultant.

6. Is there a blueprint/schematic of the equipment to be installed?
COMMENT – This material is confidential, however, we could provide a very basic schematic. We would be happy to provide more detailed materials under a confidentiality agreement.

7. Need additional detail for plan to enhance education, research, development and marketing of ND's renewable resources. Will require the hydrocarbon well owner/operator's support for press access to their facilities, a limiting factor in other geothermal projects in ND.
COMMENT – As noted elsewhere, TerraCOH will present the results of the proposed project at well-known industry and academic conferences such as the Geothermal Resources Council annual conference and the Stanford University annual geothermal conference. Additionally, we will work with the press departments of the University of Minnesota, Lawrence Livermore National Lab, and the University of North Dakota to publicize the proposed project and all successes. We are pursuing small operators who are anticipated to see value in marketing the renewable energy aspects of their projects, unlike the other geothermal project in ND.

Reviewer 2D (Rating: 5)
From the available information this appears to be a very well-planned and feasible effort, led by a team with a well-matched background.
COMMENT – (no comments)

Reviewer 3D (Rating: 4)
This a well written and clear proposal and it described the methodology well.
COMMENT – (no comments)

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Renewable Energy Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 1D (Rating: 4)
In terms of scientific and/or technical contribution, the potential is very significant. While there are many hydrocarbon wells in ND, each system is small (10-50 KW), requiring a large number of installations to truly impact the grid.
COMMENT – Our initial installations will be small, but we plan to increase power system size substantially after demonstration of the first few. We have identified numerous wells in North Dakota that could support multi-megawatt geothermal installations.
In addition, TerraCOH is exploring clustering numerous small power systems, located at multiple sites, into a single power purchase agreement. This model is commonly used in the

solar industry and may be well-suited for geothermal in North Dakota.

Reviewer 2D (Rating: 5)
If this research could help unlock a more rapidly-growing geothermal power industry in ND by leveraging the existing oilfield industry, it would be potentially quite valuable.
One concern unaddressed here would be whether the technology, in this application, could actually increase fugitive methane emissions from other nearby "dry" wells. As I understand it they will be injecting CO2 into one well to be recovered (along with hydrocarbons) at a nearby well. What if there is a third well nearby? This is probably a very answerable question but it's not really addressed here.
COMMENT – The proposed project will demonstrate a significant novel invention – the use of a CO2-based power system in geothermal systems. For the proposed project, we will use CO2 in the power system rather than in the subsurface. This approach has been chosen to minimize complexity – geologically, technically and as concerns regulations – for the proposed project. Injection of CO2 will take place in the future, however TerraCOH's development plan increases system complexity in a stepwise, intentional manner. As such, wells near the well selected for the proposed project are unlikely to be impacted.

Reviewer 3D (Rating: 4)
This project has the potential to provide some new and innovative contributions to the scientific and technical aspect electricity generation from geothermal resources.
COMMENT – (no comments)

5. The principal investigator's 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: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 1D (Rating: 3)
The Principal Investigator has a body of published work, including patent applications and awards. The proposal states TerraCOH has 'exclusive rights to below-ground use of non-water based working fluids for geothermal power production and energy storage.
COMMENT – TerraCOH has licensed and has exclusive worldwide rights to the original CO2 geothermal technology developed at the University of Minnesota. This body of intellectual property includes 16 issued patents in the US and in key countries. In addition, TerraCOH is licensing additional intellectual property from Lawrence Livermore National Lab, which covers multifluid geothermal power production and energy storage. Consequently, TerraCOH has extremely broad patent protection, together with university and national lab support to enforce this intellectual property coverage, for new geothermal technology.

Additionally, TerraCOH is teamed with the majority of CO2 and multifluid geothermal researchers from the US, and many internationally, as well as numerous experts in traditional geothermal technology. These include geoscientists from the University of North Dakota, Lawrence Livermore National Lab, Cornell University, and ETH in Zurich; mechanical engineers from the University of Minnesota; economics and public policy specialists from Ohio State University. This team has published the vast majority of all work done on the subjects of CO2 and multifluid geothermal systems -- a selection of said work is included as an appendix.

Reviewer 2D (Rating: 5)
Via both the principal investigator himself, and the network of advisors engaged, they do seem to be on top of the necessary research.
COMMENT – (no comments)

Reviewer 3D (Rating: 2)
The proposal includes few references to published literature. It is possible that the investigators are highly aware of the literature but that cannot be determined from the proposal.
COMMENT – Please see the comment to reviewer 1D, as well as the Appendix of relevant references published by the Principal Investigator and colleagues.

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 1D (Rating: 4)
The P.I. (Jimmy Randolph) and the advisors have the specialized educational background necessary to evaluate the success of this novel proposed system in terms of geophysics. Proposal does not contain enough information to ascertain the capabilities of the team with regard to promotion of the project if successful.
COMMENT – One employee of TerraCOH, Steven Price, has a long history in marketing and will be essential in promoting the proposed project. In addition, TerraCOH, as a licensee of University of Minnesota and Lawrence Livermore National Lab technologies, works closely with the press departments of both institutions to promote all company news and successes. With the collaboration of the University of North Dakota for the proposed project, we will do the same with that institution. In addition, TerraCOH has a long history of promoting CPG™ and multifluid geothermal via press interviews with such publications as Forbes, the Huffington Post, and Finance & Commerce.

Reviewer 2D (Rating: 5)
Seems very well-matched to this specific endeavor.
COMMENT – (no comments)

Reviewer 3D (Rating: 3)
The background of the team seems quite strong in the area of mechanical engineering, physics, chemical engineering and earth sciences. A notable area of weakness is in the electrical engineering side of the project.
COMMENT – TerraCOH's consultants include a former VP of Generation at a Midwest utility, and he has an extensive electrical engineering background. In addition, the project partner Wenck has extensive electrical engineering expertise, and the geothermal team at the University of North Dakota has experience in electrical hook-ups for geothermal installations. Finally, TerraCOH is working on forming partnerships with an additional two oilfield and geothermal services companies to ensure we have full access to all specialties that will be required in the proposed (and future) projects.

7. 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: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very

good; or 5 – exceptionally good.

Reviewer 1D (Rating: 3)
Recommend insertion of a go/go-no decision point after selection of a site. See concluding comments as well.
COMMENT – TerraCOH is happy to include a phase 1/phase 2 structure, if that is preferred by the funders.

Reviewer 2D (Rating: 5)
Achieving this over 18 months seems quite feasible.
COMMENT – (no comments)

Reviewer 3D (Rating: 4)
The overall project management plan seems well thought out and has some extra time built in for unforeseen delays.
COMMENT – (no comments)

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 1D (Rating: 3)
Obviously the equipment is necessary, but additional detail would be helpful. The largest equipment item is the 10 kw power system and attached boiler. The summary budget lists the total cost as $200,000, but this is likely a typographical error, since the two shares are each $50,000, the detailed budget lists this item as $100,000, and the project total cost would be off by $100,000 if it were in fact $200,000.
COMMENT – We apologize for the error in the budget summary, the detailed budget provided with the original proposal has the correct power system cost of $100,000.

There *may* be additional equipment needed that has not been included in the budget. Piping specifics, cooling methodology, source and potential transportation of CO2, grid connection if any, and equipment necessitated by permitting agencies cannot be known with certainty until a final site is selected. For example, there is justification provided for the piping consultant, but there is no line item in the budget for the piping itself. It could be in the 'equipment and fees' line item, but the justification states that is for remote monitoring and makes no mention of the piping expense.
COMMENT – For the proposed project, the cooling system is included in the power system cost, as are the small volumes of CO2 used in the power system itself. No grid connection in anticipated. Project partner Wenck is well versed in permitting in North Dakota and will assist in that effort; permitting and similar costs are grouped within the "equipment and fees" line item in the detailed budget.

The applicant does indicate that they will not request additional funding if project tasks increase, which is reassuring.
COMMENT – TerraCOH will not request additional funds for the proposed project from the North Dakota renewable energy fund.

Reviewer 2D (Rating: 5)
The proposed equipment purchases are very specific to the goals of this project.
COMMENT – (no comments)

Reviewer 3D (Rating: 4)
The proposed equipment purchases seem well supported by the proposal. I am not in a position to comment whether the proposed budget for equipment is reasonable based on market prices for this type of equipment.
COMMENT – TerraCOH has endeavored to source as much off-the-shelf, demonstrated equipment as possible in order to minimize costs and maximize potential for success. The equipment for the proposed project is somewhat more expensive than equipment for later projects, when economies of scale from increased production will take place.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 1D (Rating: 3)
Difficult to assess the adequacy given the following:

1. Detailed equipment specifics are beyond the expertise of this reviewer, but the equipment and or services required should all be obtainable on the open market for use here.
COMMENT – All system components can indeed be obtained "off-the-shelf," as they have been demonstrated in various applications (some, including the power system, very recently). TerraCOH is assembling them for a new, renewable energy application.

2. The supplier of the power system equipment was not specified by name, thus unable to ascertain what exactly is provided by them, versus the components provided by NetPower and/or L&M Radiator.
COMMENT – NetPower will supply a hydrocarbon combustor, if a hybrid design in employed, in addition to system engineering. L&M Radiator will supply the primary system heat exchanger, while the power system supplier (proprietary currently) will supply the remaining components, including the turbine, generator, pumps, and cooling units.

Reviewer 2D (Rating: 4)
Hard to give a 5 rating without better understanding the specific generation technology itself, and how well proven they are.
COMMENT – As noted above, all system components have been demonstrated in various applications, helping minimize technical risk for the proposed project

Reviewer 3D (Rating: 4)
Again, this area of the project is well supported by the proposal.
COMMENT – (no comments)

10. The proposed budget "value"[1] relative to the outlined work and the financial commitment from other sources[2] is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)

Reviewer 1D (Rating: 4)

High value – full 50% match and funding available from other sources to ensure completion.
COMMENT – (no comments)

Reviewer 2D (Rating: 3)
50/50 split seems adequate but could be hopefully enhanced via additional outside capital into the proposed ND-based projectco if the initial indications bear fruit.
COMMENT – TerraCOH intends to contribute more than 50% of outside capital towards the project, with the submitted proposal being the most efficient and conservative design. As previously noted, additional capital will be directed towards any cost overruns and/or a larger capacity power system.

Reviewer 3D (Rating: 3)
The proposal and budget seem to be well justified and this project leverages existing knowledge developed by the project team on related projects.
COMMENT – (no comments)

[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.*

[2] *Financial commitment from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Higher priority is to be given if the application has private industry investment equal to or at least 50% or more of total cost.*

Section C. Overall Comments and Recommendations:
Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.
Reviewer 1D ***(Funding May Be Considered)***
This reviewer ***would*** like to see this project get funded, due to the significance of the impact of $.05 kWh baseload renewable electricity that also addresses carbon sequestration. In order to improve the likelihood of achieving the goals, recommend funding with some modifications to the methodology and project plan as described in the review.
COMMENT – The reviewer suggests very reasonable modifications. If the committee would prefer to fund the proposed project with such modifications included, TerraCOH would be happy to make these changes.

Specifically, define two phases and fund with a go/no-go decision point for remainder the full funding upon successful completion of Phase 1. Phase 1 would go through and including the milestone 'Determine Demo Site'. Recommend adding another task, also to Phase 1, that would refine the budget to the site specific characteristics. In Phase 2, extend the test period to a minimum of 9 months so as to capture a full winter and a full summer season of use. Finally, recommend that the applicant provide additional detail on:

• the plan to grow the capacity from 10 kw to 50 kw, including footprint size, noise estimation, etc.
COMMENT – As previously noted, a larger, 50 kW power system will be installed if the selected site has a sufficient geothermal resource and if TerraCOH raises additional private capital that can be directed towards the proposed project. The 10 kW power system will be housed in a 20ft shipping container (with room to spare), and a 50 kW system will require at most two 40ft shipping containers, for a footprint of approximately 40ft by 18ft. We

anticipate that the system will be located in a very remote location, and the shipping container(s) will be heavily insulated to minimize noise concerns.

• a schematic of the major equipment components
COMMENT – This can be provided, however, it is confidential.

• the impact of flare gas availability as it relates to thing the $.05 kWh target and/or the to the availability of the CO2 working fluid.
COMMENT – The power pricing target of $0.05 per kWh is anticipated without any flare gas being available; flare gas is anticipated to lower the price further. As previously noted, the proposed project will use CO2 in the power system, which can be readily obtained. The use of a CO2-based power system in a geothermal setting is a significant novel invention, and the anticipated successful demonstration through the proposed project will allow rapid and expansive deployment of geothermal power generation throughout North Dakota.

• the plans for sharing the results beyond press releases or newspaper interviews.
COMMENT – Beyond press release and interviews, which will be broadly circulated with the assistance of University of Minnesota and Lawrence Livermore National Lab press departments, results will be presented via academic and industry publications and conference. These include the Geothermal Resources Council annual conference, the Stanford University Geothermal Conference, and the Southern Methodist University annual geothermal conference. We may also present at the World Geothermal Conference. All of these conferences involve both presentations and journal publications, and the Principal Investigator has attended and/or prepared a publication for all of them.

This reviewer believes that these suggestions would move the Achievability criteria from a score of 'possibly achievable' (2) up to 'most likely achievable' (4), resulting in the total score moving from 'consider funding' into 'fund'.
COMMENT – We are happy to make such changes, if requested.

Reviewer 2D ***(Fund)***

Very impressive effort to make use of an underutilized resource. Seems well thought out by a well-matched team. The potential weak link is the reliance upon proprietary technology from a startup, TerraCOH, and it's hard to assess the risk factor there. But the effort to prove out the potential for that technology in this context seems pragmatic, and if successful could provide compelling opportunities for ND.

I recommend funding.
COMMENT – (no comment).

Reviewer 3D ***(Funding May Be Considered)***
This is a well written and thought out proposal in many ways. The team assembled to complete this project is very well qualified on the mechanical, physical and finance aspects of the projects. Two areas of the project concern me. The first is the "renewable classification" of the project. The second is the fact that the proposal hardly addresses electricity markets or policies.
COMMENT – (please see below)

The project's renewable nature is certainly debatable. Geothermal technologies have long been viewed as renewable resources. However, when 100% of the wells used for heat exchange are being drilled for oil and gas production the "renewable" label is now questionable. If the project proves profitable it has the potential for wide spread adoption and could encourage the development of "marginal oil or gas wells" or possibly extend the productive life of a well due to the additional revenue stream. The co- generation with low value natural gas also stretches the "renewable" label to a great extent. The project definitely blurs the line between renewable and non-renewable.
COMMENT – Regarding making use of natural gas to supplement the geothermal heat in the proposed project, first, if gas is used the gas would constitute a minor portion of the total energy used. Any gas used is currently being flared, and a hybrid geothermal-gas system would put this otherwise-wasted energy to use. Thus, even if a hybrid system is employed and uses a minor portion of gas in the energy mix, TerraCOH will create no new emissions. The geothermal fraction of the energy can contribute to the state of North Dakota's renewable energy standards – this model is used for power plants in California and Nevada, for instance.

As noted previously, the geothermal industry contributes only a very small fraction of the energy in the US. For geothermal to grow, new technologies such as that developed by TerraCOH have to be demonstrated with as little risk as possible. Well drilling is the single most costly and risky element of legacy geothermal development, therefore, that cost and risk should be avoided if possible. TerraCOH certainly could drill wells ourselves, but the cost of testing the technology would double or more; once the technology is demonstrated, TerraCOH anticipates eventually drilling our own wells. When used to optimize geothermal production, wells are operated very differently from wells optimized for oil, thus marginal oil wells cannot necessarily be brought online to provide both substantial geothermal and oil revenues.

TerraCOH's geothermal technology can serve to transform the energy economy of North Dakota from fossil fuels to renewable energy. The wells developed by the oil industry, which often have a limited lifespan of 5-7 years for oil production, can be repurposed for geothermal using TerraCOH's technology and have a 30-40 year life, or more. Repurposed wells could help make North Dakota a hub of renewable, geothermal power production.

The market for electricity is very complex. Utilities, electric generators and other players in electricity markets all must operate under a highly developed set of rules and regulations designed to keep the electric grid stable, safe, environmentally friendly and affordable. The proposal indicates a "growing electricity demand" and existing emission- free electricity sources (wind and solar). The electricity demand in the US is below 2007 demand and nuclear and hydro power options are also emission-free. The proposal also indicates this power could be used to meet state renewable electricity standards, without any discussion of how the natural gas used in the process would impact the project's eligibility for meeting this requirement. The project also does not discuss what type of contract this electricity will be sold to the utility company. Would the contract be net metering, PURPA, etc? This aspect of the project is not well developed and has the potential to limit or completely halt the implementation of this type of project. This issue is too important to overlook. This project could be strengthen significantly from an electrical engineer and an electrical utility partner joining the project.
COMMENT – The Reviewer's comments are well noted; TerraCOH has some team

members with electrical engineering and utility experience, but we are working to add additional partners to help with future development. For the proposed project, TerraCOH partner Wenck has extensive electrical engineering experience, including grid interconnects for oilfield projects. Moreover, the TerraCOH team includes a specialist on electricity markets from Ohio State University, Dr. Jeffrey Bielicki. Finally, TerraCOH has a consultant, and potential board member, who is a former VP of Generation at a Midwest utility, and he is very experienced in all the issues that the reviewer outlines.

To help with long-term development, TerraCOH is working to develop relationships with Montana Dakota Utilities, Basin Electric, and Black Hills Corp, as these will be critical partners, particularly as future projects are developed.

APPENDIX

Selected Publications: **ARTICLES IN PREPARATION**

Garapati, N., B.M. Adams, **J.B. Randolph**, T.H. Kuehn, and M.O. Saar. Auxiliary heating of geothermally preheated brine or CO2 to boost electricity production.

J.B. Randolph, N. Garapati, B.M. Adams, and M.O. Saar. Hybrid CO2 and brine geothermal systems.

J.B. Randolph, A. Gustin, S. Alexander, and M.O. Saar. Advection-dominated geothermal/groundsource heat pump systems: Experimental and analytical comparison to conduction-dominated systems.

REFERRED JOURNAL PUBLICATIONS (published)

Garapati, N., **J.B. Randolph**, and M.O. Saar. Brine displacement by CO2, energy extraction rates, and lifespan of a CO2 -limited CO2 -Plume Geothermal (CPG) system with a horizontal production well. Geothermics, 55, 182-194, 2015.

Adams, B.M., T.H. Kuehn, J.M. Bielicki, **J.B. Randolph**, and M.O. Saar. A comparison of electric power output of CO_2 Plume Geothermal (CPG) and brine geothermal systems for varying reservoir conditions. Applied Energy, 140, 2015.

Adams, B.M., T.H. Kuehn, J.M. Bielicki, **J.B. Randolph**, and M.O. Saar. On the importance of the thermosiphon effect in CPG (CO_2 Plume Geothermal) power systems. Energy, 69, 409-418, 2014.

Randolph, J.B. and M.O. Saar. Combining geothermal energy capture with geologic carbon dioxide sequestration. Geophysical Research Letters, 38: L10401, 2011.

REFERRED/PEER-REVISED CONFERENCE PUBLICATIONS (published)

Garapati, N., **J.B. Randolph**, S. Finsterle, and M.O. Saar. Simulating reinjection of produced fluids into the reservoir. Proceedings of the Forty first Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 2015.

Saar, M.O., T.A. Buscheck, P. Jenny, N. Garapati, **J.B. Randolph**, D.C. Karvounis, M. Chen, Y. Sun, and J.M. Bielicki. Numerical study of multi-fluid and multi-level geothermal system performance. Peer-Reviewed Proceedings of the World Geothermal Congress, Melbourne, Australia, 19-25 April 2015.

Buscheck, T.A., J.M. Bielicki, M. Chen, Y. Sun, Y. Hao, T.A. Edmunds, **J.B. Randolph**, and M.O. Saar. Multi-fluid sedimentary geothermal energy systems for dispatchable renewable electricity. Peer-Reviewed Proceedings of the World Geothermal Congress, Melbourne, Australia, 19-25 April 2015.

Garapati, N. **J.B. Randolph**, M.O. Saar. Superheating of Low-Temperature Geothermal Working Fluids to Boost Electricity Production: Comparison between Water and CO2 Systems. Proceedings of the Fortieth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 2015.

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