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Geothermal Energy Utilization of Multi-Well Oil Pads via the Application Of Organic Rankine Cycle Systems

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Keywords

Geothermal, Co-production, Oil and Gas

ABSTRACT

Due to lack of a power grid infrastructure in the Bakken oil play in the Williston Basin, oil field operators currently rely on diesel, propane, or gasoline-powered generators for electricity at costs up to 28 ¢/kWh. We show that co-production from the hot fluids produced by oil wells fitted with Organic Rankine Cycle (ORC) engines can supply power to the Bakken play at a cost of 8.15¢/kWh. We used the Banks Bakken field as a test case and found that approximately 25% of the multi-wells pads in the field can produce at least 20 kW of power. The electricity generated by the ORCs can power on-site well operations, such as the running of pump jacks and Electric Submersible Pumps (ESPs). Economic evaluation using the Cost of Renewable Energy Spreadsheet (CREST) model, demonstrates that the Nominal Levelized Cost of Energy (LCOE) for the ORC systems in ¢/kWh is significantly lower than the average cost for on-site diesel-powered generators. The installation of small ORC systems on the multi-well pad scale presents a unique opportunity within the Bakken and other oil plays for lowering the electrical costs of wellsite operations.

1. Introduction

The rapid development of tight oil resources in the Bakken Oil Play has quickly outpaced the construction of necessary electrical infrastructure. The growing electrical power demands of the oil industry have led to expensive and suboptimal solutions to their power needs. Currently, the means of satisfying electrical demands in isolated regions of the Bakken are limited to diesel generator usage. New electrical infrastructure construction for linking remote well sites to electrical grids is costly and when the Bakken play is depleted, will be “power to nowhere.” Due to the transient nature of oil production, the more permanent measures offered by electrical utilities cannot be economically justified. Thus, companies, resulting in the suboptimal practice of burning fossil fuels, often favor generators. Because both current options are not particularly favorable, there is a need for portable and more cost-effective energy sources for isolated well sites in the Bakken and other oil plays. Geothermal applications present one such solution. Developing a method to utilize the heat generated from oil and gas wells in the Bakken has been an important topic of research in recent years, the utilization of Organic Rankine Cycles (ORCs) power plants provides a possible mechanism for transforming the thermal resource into an affordable power source (Gosnold et al. 2015). While current research has focused on 0.1 to 1 MW systems utilizing the production of whole fields, implementation on the scale of a single multi-well pad has great promise for future development. Due to current infill drilling practices, multi-well pads with tens of wells are becoming commonplace, resulting in the significant production of thermal energy laden fluids within a small surface footprint. Furthermore, ORC manufacturers are providing more technologically advanced systems capable of processing oil-water mixtures at smaller scales then were previously available. Implementing these systems on a single multi-well pad provides an economical means of producing electricity in the Bakken.

2. Geological/Energy Evaluation-Banks Oil Field

Our study focuses on the Banks field owing to its relative high Bakken Formation temperature compared to other oil fields in the Williston Basin region of North Dakota. Its geologic setting puts its wells above the 120℃ temperature contours in a kriged Bakken Formation temperature map of North Dakota (Figure 1).

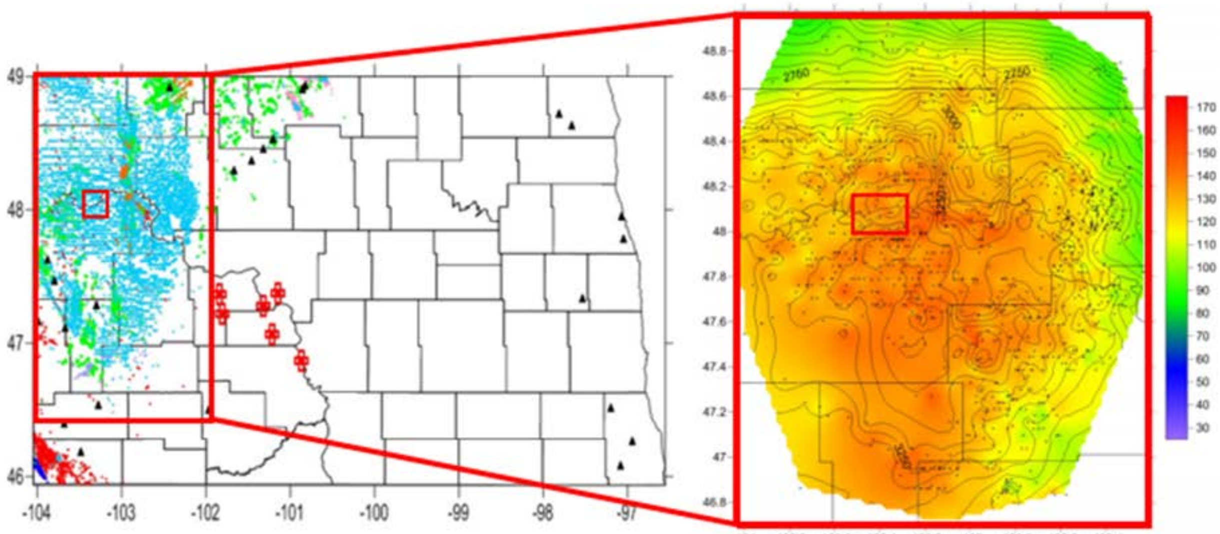

Figure 1: Bottom hole temperature map of North Dakota indicating location of the Banks Oil Field (adapted from Gosnold et al. 2015).

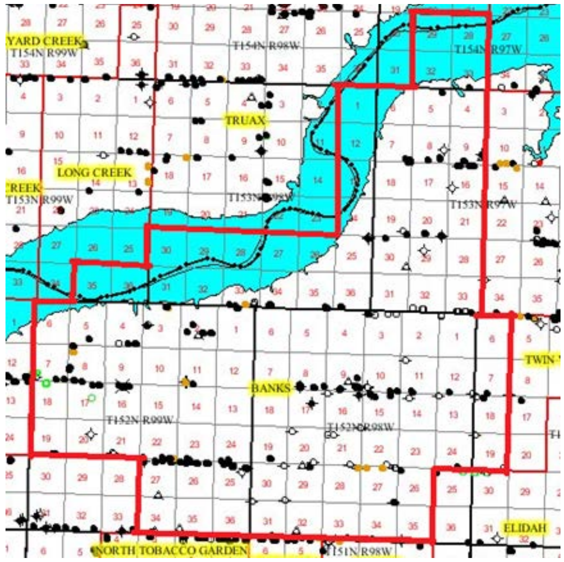

Figure 2: Delineation of the banks oil field and the wells contained within it displayed by dots (NDIC 2019).

Using the most recent production data from December 2018, the Banks produced 1,924,766 BBLS of oil and 2,352,577 BBLS of water from 267 active wells (NDIC 2019). The field's wells comprise ninety-six multi-well and single-well pads. A well pad's thermal power production in terms of kWth is a function of the produced fluid's density, the specific heats of the oil and water produced, the flow rate, the water-oil ratio (WOR) of the mixture, and the expected temperature drop. The specific heat and density of the oil-water mixture are impacted by the WOR as oil has a much lower specific heat than water at 1.988 kJ/kgK as compared to 4.186 kJ/kg K, and a slightly lower density at 881 kg/m^3 as compared to 981 kg/m^3. The equation for thermal power produced is.

$$E_{th} = (\rho_{oil}c_{poil}+WOR*\rho_{water}cp_{water})\ Q_t\Delta T/(WOR+1)$$

where ρ is the density of the given fluid, c_p is that fluid's specific heat, Q_t is the quantity of fluid flow, ΔT is the fluids' change in temperature, and WOR is the fluids' water-oil ratio.

3. Evaluated ORC Systems

We considered seven ORC systems (Table 1) for their suitability in operating with the fluid flow rates and temperatures expected from a typical multi-well pad located in the Banks field. The systems differ significantly in requirements for fluid temperature, flow volume, and composition and in power output and price. Some units require greater thermal inputs than the average well in the Banks could supply and some handle water only. The WOR of Bakken wells is about 1:1 and the ability of a system to derive thermal power from the combined water and oil flow is critical. Flow rate is impacted by this water-oil ratio as the Bakken wells are pumped slowly to purposefully yield a low WOR.

Table 1. Data for selection of ORC systems for small-scale power production using multi-well pads.

Company	Unit	Power Generation (kWe)	Oil Tolerance	Price ($)
Enogia	10Lt, 20Lt, 40Lt	10, 20, 40	Yes	108,000
Enerbasque	HRU-25	22	Yes	113,000
Access Energy	ThermaPower 125 XLT	≤125	Yes	250,000
SRM	Powerbox	300	Yes	-
ElectraTherm	4200	35	No	183,000
Orcan	eP 20.30	20	-	-
Durr Cyplan	-	40	-	-

The ThermaPower 125 XLT was initially considered, as it had been the chosen ORC for a previous study of geothermal energy in the Williston Basin (Gosnold et al. 2015). However, due to this study's focus on multi-well pads rather than joint well pad systems, the Thermalpower 125 XLT required inputs were found to be too large. The Powerbox model was not considered for similar reasons. Orcan’s eP 20.30 and Durr-Cyplan’s model were not considered due to a lack of information. ElectraTherm’s 4200 cannot use an oil-water mixture. Enerbasque and Enogias models each had the ability to tolerate an oil-water mixture and had input thermal energy specifications that matched with the Banks oil field. Therefore, Enerbasque’s HRU-25 and Enogia’s 20Lt were considered for further geological and economic analysis.

4. Power Potential-Banks Oil Field

Based upon communications with Enogia and Enerbasque concerning their systems viability, 20 kW and 23 kW could be produced by each manufacturer's system respectively under sufficient thermal inputs. Due to the variance of WOR and flow rates at each given well pad, a general input of 295 kWth is required to produce these kW values at all sites. Of the previously mentioned ninety-six pads, there are twenty-four which have the flow rate and water to oil ratios that can power either the Enogia 20Lt or the Enerbasque HRU 25. The criterion for assessing the thermal power production of each multi-well pad consisted of a compilation of the December 2018 production of each well, with a daily production value determined for oil and water based upon the total production of each, and the number of days the well operated.

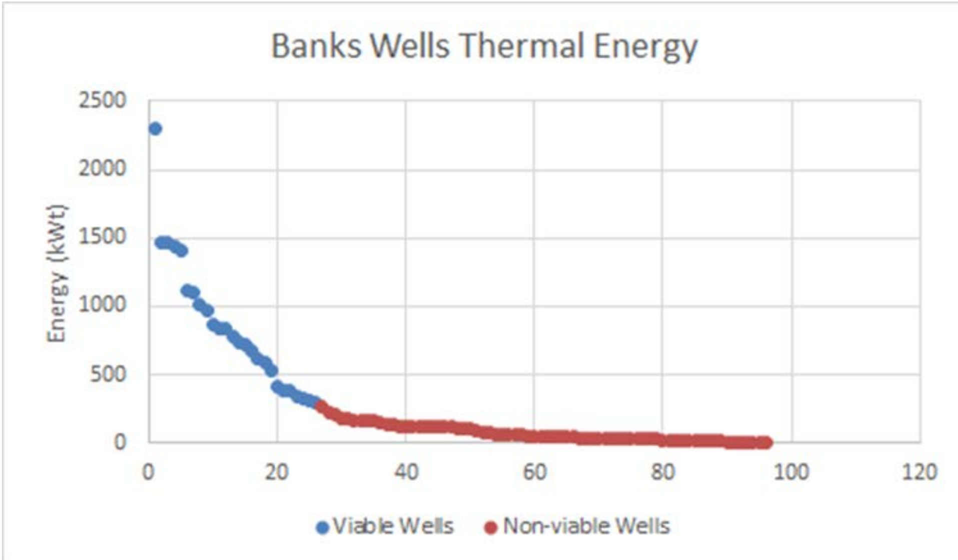

Figure 4: Thermal energy potential of each well pad in the Banks Oil Field based upon December 2018 NDIC production data.

5. Economic Analysis

Evaluation of the economic feasibility of the Enogia system was conducted utilizing the Cost of Renewable Energy Spreadsheet (CREST) model created by the National Renewable Energy Laboratory in conjunction with other government agencies. Assuming an interest rate of 8%, a minimum and average Debt Service Coverage Ratio of 1.1 and 1.2 respectively, varying Internal Rates of Return (IRR) and percentages of debt versus investment as indicated in Figure 5, the Nominal Levelized Cost of Energy (LCOE) was calculated. The LCOE is the price the producer must obtain for their electricity over the lifespan of the project to meet the IRR of the project's investors. It should be noted that IRR in the oil industry range from 14-16%, and that the small-scale diesel generators currently powering well pads produce electricity at around 28¢/kWh. Based upon the calculated results, the Enogia system can produce 20kW at as low as 8.15¢/kWh, while the Enerbasque system can produced 23kW at rates as low as 6.75¢/kWh, both assuming the lowest IRR of 12%. These prices can be competitive even within grid-supported regions, as the average price per kW in the industrial sector for North Dakota is 8.24¢/kWh (EIA 2019).

6. Conclusions

The Enerbasque's HRU-25 and Enogia's 20Lt have the ability to produce power in the range of 20-23 kW from individual multi-well pads in the Banks field. This is sufficient power to operate a single ESP pump or possibly multiple pump jacks, as well as miscellaneous onsite operations. Based on our analysis, twenty-four of the ninety-six multi-well and single well pads within the Banks Oil Field have sufficient production to power one of these ORC systems. Furthermore, based upon our CREST analysis the electricity produced by these systems is cheaper than that produced by currently used diesel generators. As such, there exists potential for small-scale ORC systems to reduce the cost of wellsite electricity.

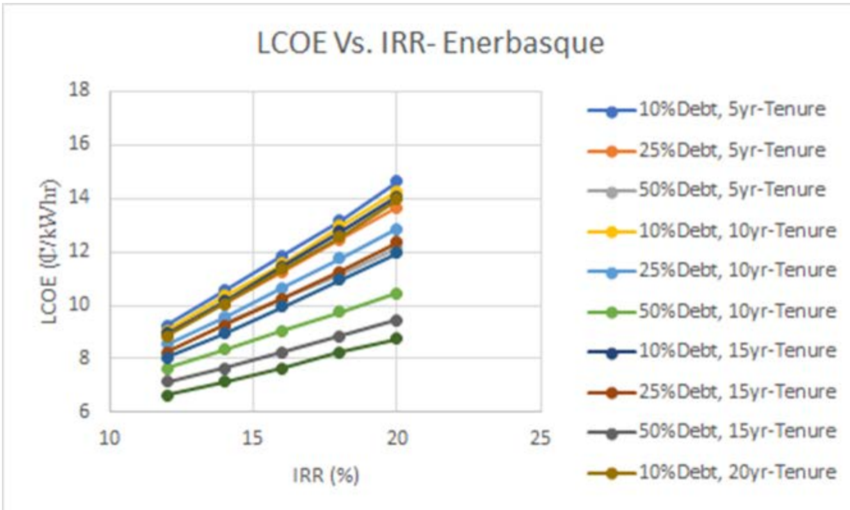

Figure 5: Graph displaying the variations in ¢/kWh assuming varying percentages of debt and loan tenure for the Enerbasque ORC.

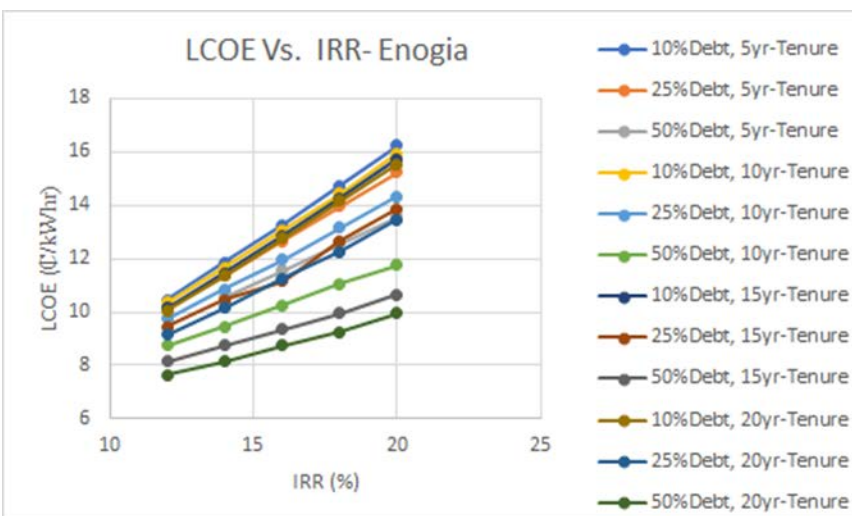

Figure 6: Graph displaying the variations in ¢/kWh assuming varying percentages of debt and loan tenure for the Enogia 20Lt ORC.

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