European Geothermal Congress 2022
Berlin, Germany | 17-21 October 2022
www.europeangeothermalcongress.eu

Conversion of Oil Brownfield into a Geothermal Sustainable and Renewable Energy Field

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Keywords: Wells, Reservoir, Plant, Usage, Generation, Heat.

ABSTRACT

The potential of integrating fields such as geothermal power generation, carbon capture and storage, and oil and gas production, bring together the technical expertise of the subsurface with the experience of the energy markets needed to facilitate geothermal deployment and the transition to a decarbonised economy.

The outcome of this project directly aids in the demonstration of highly innovative technologies, processes and products that are sufficiently mature, by setting a pilot testing ground that multiple EU manufacturers can use to demonstrate Organic Rankine Cycle (ORC) systems, and will significantly reduce greenhouse gas emissions by replacing thermal power generation with base-load, emissions-free geothermal energy, and by producing a domino effect where the technical and economic performance of low-temperature geothermal systems is demonstrated and use to catalyse worldwide conversion of old oil and gas fields into geothermal power generation assets..

1. INTRODUCTION

Geothermal is a natural step for the energy industry in a decarbonized energy future. Basically no research and development is needed to make this happen, just the deployment of proven process flow and power generation technologies. Without exploration or new drilling costs, the economics of low-temperature geothermal are attractive. In a world where energy is sold at 20 Euro cents per kilowatt-hour, cost control and operational scale, as well as the sale of additional fluid stream products, are important to a positive economy. It is important to appreciate that experience in the subsoil is only part of the solution to making low temperature geothermal work.

A well is reusable for geothermal energy when it meets the operating characteristics for this purpose. The isolation of the prospects and the integrity of the coating are paramount.

RamRei Energy gathers an excellent team of professionals, technicians and managers from the geosciences and well construction area that add an experience of more than 300 years in the oil and energy sector, allowing us to add value and innovation in the way of supplying geothermal energy and its integration into the European energy system of the future.

RamRei Energy is developing and offering its studies and knowledge to ensure that existing wells and infrastructure in the sedimentary basins of mature oil and gas fields are transformed into geothermal energy producing assets in a profitable manner.

Mature oil and gas fields can be analysed and converted to base load power at rates competitive in costs with wind and solar, and as an advantage they do not have the need for energy storage that intermittent sources of electrical power require, such as Wind and Photovoltaic.

ORC technology is experiencing a suitable moment of push for a generalized implementation.

Electricity production depends largely on the characteristics of the field, such as the temperature and the flow rate that can be obtained from the wells, and each ORC system manufacturer's equipment configuration, working fluid and system specifications.

RamRei Energy's approach is that many oil fields have the potential to become enviable Geothermal spots, by being able to use them as a laboratory for testing, piloting and proving Geothermal technologies. Existing well infrastructure and facilities could be used to undertake geothermal projects, combining financial resources and knowledge of geothermal energy research and innovation programs to validate novel concepts such as low enthalpy hybrid systems, drilling of new wells, harnessing oil and / gas wells and converting them into clean energy sources, geothermal energy deployment systems within the energy system, and identifying paths for large-scale commercial implementation.

2. THE PROJECT

Oil production produces a large amount of an underutilised resource: hot water.

In a manner similar to how associated gas was considered a nuisance in early oil production and flared or vented before it was used as an energy resource, produced water is typically seen as a cost: it is removed from the oil and it has to be treated before being re-injected underground or treated and cooled before disposal. In this process, the energy of the water is wasted. Gluyas et al (2018) estimated that at least 15,000 MW could be produced from oilfield wastewater alone through ORC technology. Giardinella, and the team at Ecotek Investments Inc (2014), a partner to this project, evaluated the feasibility of implementing ORC at three Colombian oilfields, finding an interesting potential and setting plans for future implementation of geothermal energy systems at Colombian oil production.

Geothermal is a natural step for the energy industry in a decarbonized energy future. Basically no research and development is needed to make this happen, just the deployment of proven process flow and power generation technologies. Without exploration or new drilling costs, the economics of low-temperature geothermal are attractive. In a world where energy is sold at 20 Euro cents per kilowatt-hour, cost control and operational scale, as well as the sale of additional fluid stream products, are important to a positive economy. It is important to appreciate that experience in the subsoil is only part of the solution to making low temperature geothermal work.

A well is reusable for geothermal energy when it meets the operating characteristics for this purpose. The isolation of the prospects and the integrity of the coating are paramount. Since geothermal energy requires higher flow rates than oil and gas, the larger the diameter of the production pipe, the higher the flow rate and the better use of each well. That is why the opportunity is in any sedimentary basin. Most basins have conditions in one or more underground areas where the temperature and flow are adequate to generate energy.

For RamRei Energy and its partners, the potential of integrating fields such as geothermal power generation, carbon capture and storage, and oil and gas production, bring together the technical expertise of the subsurface with the experience of the energy markets needed to facilitate geothermal deployment and the transition to a decarbonised economy.

With this background, the general objective of this project is to develop a geothermal ORC pilot testing facility at the Ayoluengo Oil Field in Spain. The specific objectives are to: 1) characterise the geothermal potential of ageing wells at the Ayoluengo Oil Field in Spain, 2) select a number of wells that can be used for long-term geothermal energy production at different temperatures and flow rates, and 3) develop an Organic Rankine Cycle (ORC) pilot testing facility that can be used by manufacturers to conduct trials of different technologies and optimize their systems.

To evaluate the geothermal potential of existing wells, the key performance indicators are fluid flow rates with electric submersible pumps; the temperatures flowing through the system and how the reservoir fluid chemistry interacts with the system (for example if scale formation in pipes and pumps would result in a bigger problem). Once these variables are measured and adequate wells are selected, aboveground facilities (piping, process equipment, reinjection pumps, electrical distribution and export facilities, automation and controls, instruments and civil infrastructure) will be developed to accommodate permanent ORC systems that would produce energy onsite, and temporary ORC systems used for pilot testing.

In theory, several ORC units in series and several series in parallel could be run to generate one megawatt or more in production. When well reuse is an option, the capital cost of the well is minimal, incurring only costs related to the final adequacy of the well (completion and repair services). The ORC pilot testing facility would receive income from energy sold to the grid via Power Purchase Agreements (PPA) and fees received from ORC manufacturers to conduct testing at the site. ORC manufacturer customers include an increasing number of established companies and start-ups that seek to demonstrate their technologies.

The outcome of this project directly aids in the demonstration of highly innovative technologies, processes and products that are sufficiently mature, by setting a pilot testing ground that multiple EU manufacturers can use to demonstrate ORC systems, and will significantly reduce greenhouse gas emissions by replacing thermal power generation with base-load, emissions-free geothermal energy, and by producing a domino effect where the technical and economic performance of low-temperature geothermal systems is demonstrated and use to catalyse worldwide conversion of old oil and gas fields into geothermal power generation assets.

2.1 Technical characteristics and scope

The plan to develop a project shall be developed in two stages.

A first stage that would serve to confirm the assumptions of our model in the fastest and most economical way possible, confirming the assumptions of the reservoir model and actual production against the estimates of modelled or predicted geothermal resources.

The well reuse proposal also needs to be confirmed and financial funds are required for this.

An alternative is to raise funds from the oil and gas industry itself.

Unfortunately, this technological advancement and the geothermal market are much marginalized, despite the fact that Geothermal Energy meets all the clean energy requirements established in the Climate change initiatives worldwide, and would help the state to reach its renewable energy goal by 2040.

Much of the effort is going into accessing the funds to execute our first-stage power generation goals, where we would not only demonstrate that low-temperature geothermal is perfectly feasible, but help us to understand the operating conditions of mature oil and gas fields before scaling up to megawatt-scale power production. To awaken the interest, comments and participation of government entities, study centres, private companies and oil and gas companies with the guarantee of diversifying the flows of sustainable and clean

The second stage is the construction of the installations and facilities to prove the modelling of the first stage. The facilities will include turbines, heat exchangers, pumps, piping, filtration units, Instrumentation and control room, wells new completions for production and injection, among other details.

The stage two shall be the pilot project implementation and laboratory for the field research and development of Geothermal in a particular region.

The project organization will be comprised of:

- A surface facilities team, who will be responsible for the engineering, procurement, construction, operations and maintenance of the aboveground installations, which comprise the ORC power island (evaporator, turbine-generator, condenser and circulation pump), balance-of-plant (utilities, buildings and electrical interconnection infrastructure).
- A well technology and operations (WTO) team, who will be responsible for ensuring the proper safety and continued operation of the production and injection wells.
- A reservoir and subsurface team, who will generate and validate production profiles and determine optimum conditions to ensure long-term sustainability of production.
- An administrative and support staff team, which will include managerial functions, such as finance, legal, human resources, health safety and environment, environmental social and governance.

Figure 1 shows the general scope of each team's responsibility in a general facilities process flow sketch.

2.2 GHG EMISSION AVOIDANCE POTENTIAL

The emission avoidance potential of the project was calculated using the USAID Clean Energy greenhouse gas (GHG) projections calculator Version 1.2 (USAID, 2018), assuming 1 MW installed power output at 0.85 capacity factor with 10% annual capacity additions and 0.5% degradation rate, to replace combined marginal grid electricity at 6.5% grid losses and default emission factors for the location.

With these assumptions, the estimated Total GHGs Reduced/Avoided for 10 years duration is 22,717.8 tons of CO_2 equivalent (tCO_2e), as the sum of stage 1 and stage 2 emission reductions:

GHGs Reduced/Avoided (stage 1): to be 5,094.2 (tCO_2e)

GHGs Reduced/Avoided (stage 2): 17,623.5 (tCO_2e)

These estimates do not include potential for further reductions arising from integrating the project with carbon capture and storage (CCS).

3. DEGREE OF INNOVATION

Geothermal heating is an underutilized energy source in many places. Having a place where oil and gas production is on the wane, the repurposing of old wells to take advantage of the internal heat of the planet represents a renewable energy source with zero emissions, with the added advantage of avoiding costs and risks associated with exploration and drilling.

Previous discussions (Conser, A. (2013)., RamRei. (2020, 11 26), Ritcher, A. (2020, 03 31), Robert A. Caulk, M. I. (2016), to name a few) have proposed or evaluated the conversion of specific fields, or made general estimations based on the produced wastewater (Gluyas et al (2018)), but they have remained isolated and not nearly tapping the enormous potential of converting Brown Oil Fields to Geo Thermal Units (BOF-to-GTUs). Figure 2 (Ecotek, 2014) shows one concept that sought to revamp an existing oilfield with 80-95% water-cut and 100-120C temperature produced fluids to simultaneously generate electricity using 50-120 kWe ORC units, and condense light hydrocarbon vapours that were being flared at the moment.

RamRei has developed generalized rules-of-thumb that can be applied to BOF-to-GTUs prospecting as the result of decades of experience in the oil and gas sector coupled with knowledge and alliances in the geothermal energy sector. For instance:

- Geothermal heat and power technology works when the temperature gradient is sufficiently large between the two fluids during the heat exchange (RamRei's model can be used to select the optimum gradients for different well conditions).

- Well depths of about 1,000 meters deep with temperatures reaching at least 70 Celsius (even at less than the boiling point) allow for the heat transfer to be harvested effectively.

- Other operational considerations favour temperatures that remain fairly consistent, showing only a small drop of 2 Celsius over a 10 year period.

- Further aspects associated to the condition of the wells, casing, underground reservoir, production profiles, etc.

These rules can be used, through a proprietary computer model, to screen the geothermal potential of ageing oil and gas wells based on their physical characteristics and data gathered throughout their production history. The model can also be used to determine possible combinations of geothermal system configurations (including using different working fluids in series, depending on the system characteristics) to increase the overall efficiency, as well as other combined services, such as:

- Using heat from wells for district, industrial and agricultural heating.

- Combining geothermal with carbon dioxide (CO_2) capture and storage to improve the medium and achieve a higher heat retention than water. In this sense, reducing carbon footprint and capturing and storing CO_2 while generating heat and electricity would kill two birds with one stone. Figure 3 shows a concept where either a point-source CCS or a Direct Air Capture (DAC) unit is integrated with the geothermal project. The University of Illinois Urbana-Champaign (UIUC) is currently coordinating a Front-End Engineering Design (FEED) study for the integration of a DAC unit with an existing geothermal power plant, where waste heat and clean electricity from the power plant provide the energy required by the DAC unit, which is able to capture and permanently store over 5,000 tCO_2e net per year.

The accuracy of the model can be greatly improved by including real-life data from operating BOF-to-GTUs, thus using the parameters from the readings to reduce uncertainty in the predictions. The model can also be enriched by creating an extensive library of performance data with different system configurations, working fluids, capacities and equipment.

The development of a pilot BOF-to-GTU site with the capability of testing different geothermal systems and configurations can thus have the following benefits: 1) reduction of emissions derived from fossil fuels use in power generation, 2) sales of affordable energy, 3) compilation of substantial data for improvement of prediction formulas, 4) technical demonstration of successful conversion of hydrocarbon production wells to geothermal energy wells, at reduced costs and timeframes for implementation.

By also developing testing infrastructure, the pilot facility can be used by third-parties (such as geothermal equipment manufacturers) to field-test their designs and make adjustments as needed to improve their performance when handling oil & gas well fluids (which may not be entirely clean fluids), or demonstrate performance for potential customers.

This project can propel the Brown Oil Field to Geo Thermal Unit (BOF-to-GTU) technology to become a common new practice in places where fossil fuels were extracted in the past. It can serve as a platform for close to 80 companies in Europe working on different geothermal designs to test new products or validate new applications for their existing products in the not-yet explored ageing hydrocarbon wells sector.

In economic terms, the impact of the innovation can lead to:

- Millions of EUR in savings associated with field abandonment costs, by adding 2 or more decades to their useful lives as repurposed, zero-emissions renewable energy sites.

- Millions of EUR of revenue, taxes and jobs created at the local level to support the local economies of sites where these fields would otherwise be abandoned, helping to migrate local resources from hydrocarbons to clean energy.

- Millions of EUR and years of time saved in geothermal prospecting, by applying a field-tested model with available historic data for existing wells, versus completely new developments.

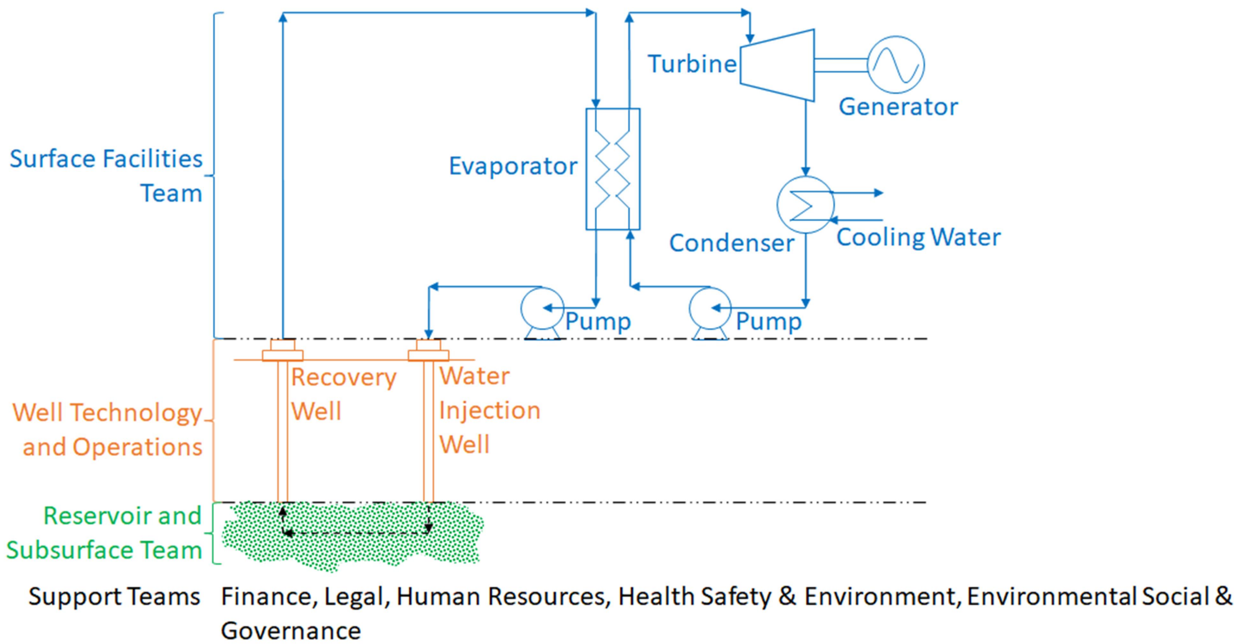

Figure 1 Project Process Flow Sketch Showing Division or Responsibilities

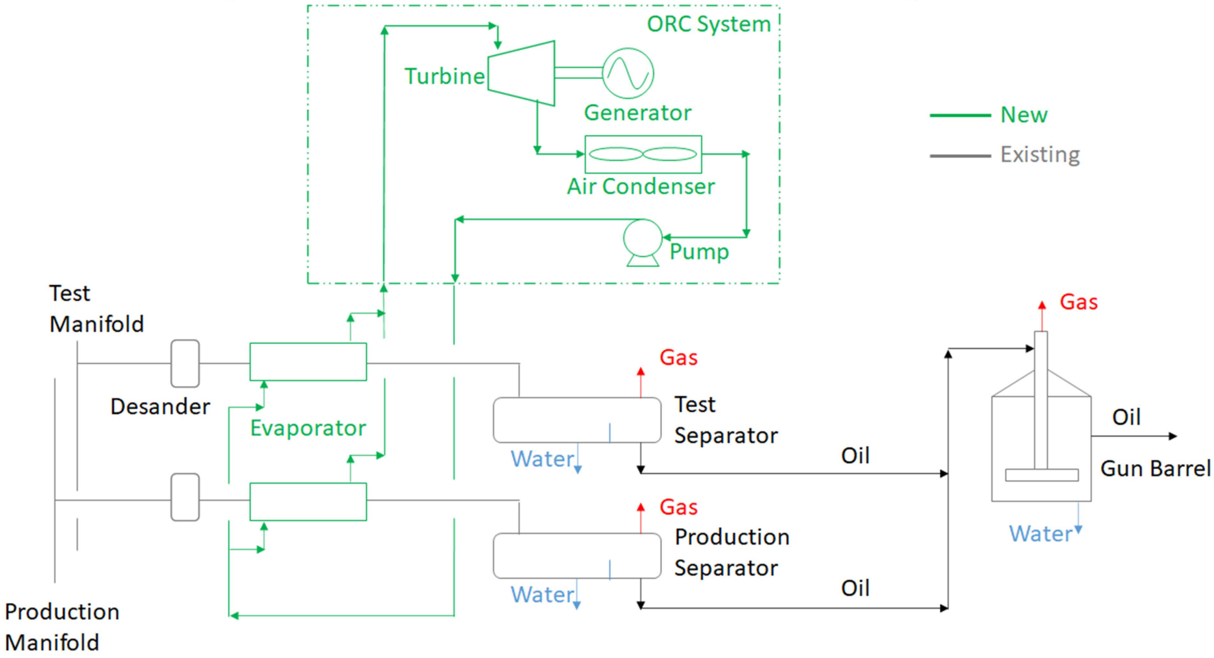

Figure 2 Surface Facilities Sketch for Mature Oil and Gas Production Facilities with Thermal Energy Recovery at Production Manifold (Ecotek, 2014)

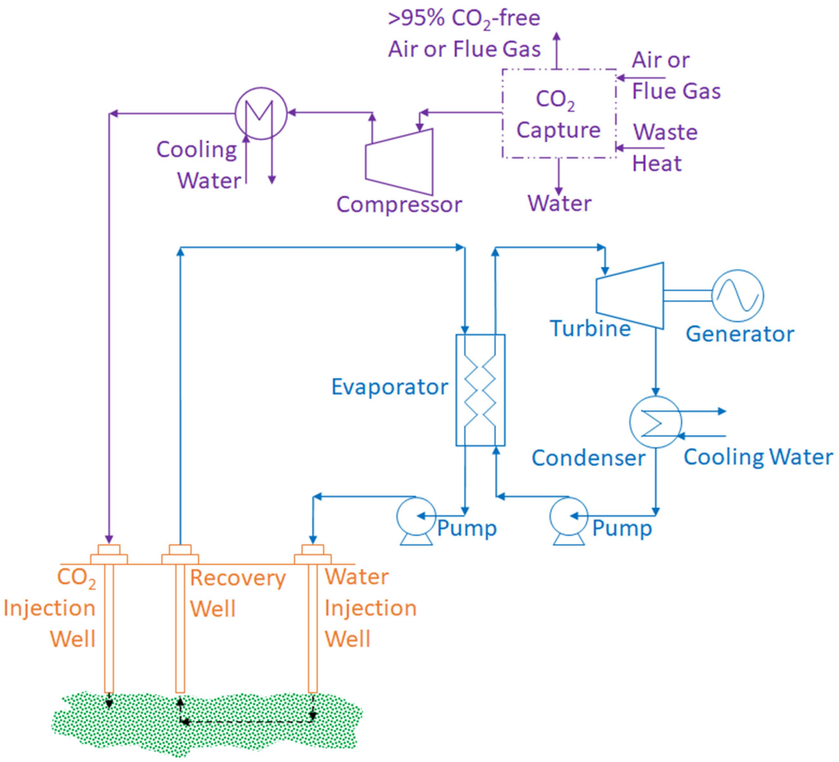

Figure 3 Process Flow Sketch Showing Integration with Carbon Capture Project

3. CONCLUSIONS

This methodology for a typical Project has the potential to deliver net carbon reductions, by:

1) Substituting base-load power and heating from hydrocarbon sources

2) Avoiding carbon intensive activities, such as drilling and well completion for new geothermal projects, as well as decommissioning of old oil&gas fields by demonstrating the feasibility to use brown oilfields to generate green energy using the existing geothermal energy.

Geothermal technology applied to ageing oil&gas wells in production can be considered to be at TRL5 or TRL6, given that the components (geothermal systems) have been demonstrated in relevant environments with only water as the produced fluid, showing the ability to sustain power generation in an economically-feasible environment, but they have not been entirely demonstrated commercially with non-clean fluids such as those found in ageing wells.

There are technical factors such as two or three-phase heat transfer, fouling, plug flow, frothing, or other aspects associated with presence of liquid and gas hydrocarbons in combination with the gas that impact the efficiency of conversion. Hence, the evaluation of the model to extract energy requires it to be tested with binary proven systems.

A feasibility study conducted by RamRei based on computer modelling and thermodynamic optimization results for the proposed location, shown in terms of reduced variables, allow definition of some rules for the selection of the optimal combination of working fluid and cycle configuration. Depending on the design arrangements, conditions, and proposed equipment characteristics, it is expected that each well could produce up to 1 MW by fitting Organic Rankine Cycle (ORC) systems of different working fluids in series, with several trains in parallel.

The variables that are fed into the model have some uncertainty in terms of the flow rates, temperatures, extraction rates and quality of the fluids that will be ascertained in the initial stage of the project. Once the input parameters are identified, the project will determine which configurations based on supercritical cycles, employing fluids with a critical temperature slightly lower than the temperature of the geothermal source, lead to the highest efficiencies.

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