A Green solution for depleted oil wells integrating it in the territory

Raffaele Calvo[1], Claudio Alimonti[1,2], Davide Scrocca[2]

[1] Sapienza Università di Roma - DICMA, Via Eudossiana, 18 – 00184 Roma (I)

[2] Consiglio Nazionale delle Ricerche - IGAG, Piazzale Aldo Moro 5 – 00185 ROMA

claudio.alimonti@uniroma1.it

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ABSTRACT

The ongoing acceleration of the transition from traditional fossil fuels to renewable energy sources will entail the progressive phase-out of hydrocarbon production. This process will possibly also involve the gradual shut-in of hydrocarbon producing wells, which will eventually be plugged and abandoned. In this context, the objective of this paper is to demonstrate the existence of valid alternatives to avoid such an irreversible process. Indeed, the availability of existing deep wells corresponds to an avoided cost for geothermal applications and it is an opportunity for the community to develop new green businesses.

The case study considered is the Irminio field located in Southern Italy. In this field several wells are currently producing oil and gas and the co-produced gas is used in a cogeneration plant. This solution has been adopted to integrate a cogenerator into the production process to make the best use of the tail gas of the plant, which currently cannot be released into the atmosphere or flared.

The basic idea is to integrate the present plant into a circular economy. The proposed solution is based on an Anaerobic Digestion plant for the production of Biogas that will be exhausted and biogas will replace it in the cogenerator.

This study analyses two different scenarios to provide a complete view of the potential of this solution. The first scenario is “as it is” and the second one requires the improvement of the production from well.

Improving the thermodynamic conditions of the well requires the installation of a pump. This will enable to use of the well stream for anaerobic digestion with a thermophilic process increasing the biogas production. The biomass used for the process allows the development of a possible collaboration between the owning company and the province of Ragusa (RG), in compliance with the circular economy principles.

A possible improvement of the plant is the use of combustion gases and a part of the thermal stream in algae cultivation to be fed to the nearby plant for biofuel.

1. INTRODUCTION

The decarbonisation strategy for climate change control implies the phase-out of the hydrocarbon production which will result in a large number of well abandonments. However, a well that is plugged and abandoned will be closed permanently. Therefore, before making this irreversible decision that also involves significant costs, it is advisable to evaluate all the possible solutions for alternative use of existing wells such as their reuse for geothermal applications.

According to estimates in 2018 the well decommissioning and restoration costs have amounted to 11.7 billion US dollars for the global oil and gas industry. In 2019-2021 around 32-36 billion US dollars have been spent worldwide (Khalidov et al. 2021). The median cost for decommissioning onshore wells is roughly $20,000 for plugging only and $76,000 for plugging and surface reclamation in the U.S.(Raimi et al. 2021). Additional costs should be considered for natural gas wells and older wells.

Moreover, it must be considered that the economics of a geothermal project is generally less profitable than an oil&gas one. Thus, the reduction in costs is fundamental to realise a bankable project. The drilling of a new well has a cost between € 3,000,000 and € 9,000,000 depending on depth and location. Comparing those costs and the investment for the plant it becomes clear the opportunity to re-use the wells giving them a new life. The repurposing of oil&gas wells will increase the economic viability of the geothermal project, reducing investment costs even by up to 50%. (Chmielowska et al. 2019).

The target of this work is to demonstrate that there might be valid alternatives to the irreversible permanent closure of the existing wells. For these purposes, the Irminio hydrocarbon field has been selected in Sicily (Southern Italy) where the present activity is the production of oil and the use of the co-produced gas in a cogeneration plant.

The basic idea is to integrate the present plant into a circular economy asset by looking at the emerging problem of continuous increasing production of municipal solid waste in cities and therefore a search for new types and methods of disposal. The proposed solution is based on an Anaerobic Digestion plant for the production of Biogas. Seeing to the future, the production of gas from the wells will be exhausted and biogas will substitute it in the cogenerator supply.

The low temperature of the stream suggests using it in a direct application. A solution has been proposed to integrate the actual cogenerator which exploits and makes the best use of the tail gas of the plants. The approach to identifying the most promising solution is given by the circular economy. Reuse of existent equipment and find a continuity solution from the past to the future. Assuming as the key point the cogenerator, it was decided on the production of Biogas. Biogas is one of the most economically viable and environmentally friendly renewable energy resources (Deublein and Steinhauser, 2011). Biogas is produced during anaerobic digestion (AD) of organic matter. The more promising organic matter is food waste having a high biomethane production potential. Biogas should be upgraded to biomethane before use as a fuel (Mirmohamadsadeghi et al., 2019). The food wastes are often disposed of as municipal solid waste (MSW). Food wastes are the main components of MSW, accounting for 20–54% of it (Yasin et al., 2013). Moreover, AD of food wastes has less environmental impact compared to the other processes, e.g., incineration and landfilling (Aghbashlo et al., 2019).

2. GEOTHERMAL REPURPOSING OF OIL AND GAS WELLS

Several works in the literature report the evaluation of possible conversion of oil&gas assets for geothermal applications. Often the first approach in introducing geothermal was the co-production principle. This is based on the combined production of hydrocarbons and heat like in the pilot project in the Pleasant Bayou field, wherein 1980 a 1 MW hybrid cycle power plant was built (Riney, 1991), demonstrating the possibility of producing both gas and hot water and generate electricity. In 2000, Barbacki estimated the thermal power production from the abandoned oil and gas wells of Grobla field (Poland). Zhang et al. (2008) proposed to obtain in-situ combustion and the increase of pressure and temperature via the injection of air followed by water, to produce geothermal power (Johnson and Walker, 2010; Nordquist and Johnson, 2012). Limpasurat et al. (2010) studied the opportunity to harness the heat accumulated in heavy oil reservoirs under steam flooding: the results indicated that a single doublet could produce around 14 kW of net power. According to Sanyal et al. (2010), using an abandoned gas well in Texas can produce a net power of 340 kW. Alimonti and Gnoni (2015) have studied the oilfield of Villafortuna-Trecate (Italy) estimating a net power of around 400÷500 kW per well. Gosnold (2017) reports about the use of 98 °C water from the waterflood wells in the Williston Sedimentary Basin in western North Dakota. Several authors (Xin et al. (2012), Wang et al. (2016) Hu et al. (2017), and Yang et al. (2017) have studied the use of hot brines coproduced in the Huabei oilfield in China. The paper of Li et al. (2012) illustrates the possibility of a combined heat and power plant composed of an ORC system, a gathering heat system and an oil recovery system.

Different studies evaluate the heat recovery potential from oil and gas fields worldwide. McKenna et al. (2005) estimated that the co-produced fluids in oilfields along the Gulf Coast allow for the installation of over 1 GW of electric power. Bennett et al. (2012) report the possibility to generate 7.43 MW of net electrical power using oilfields in the Los Angeles area. Wang et al. (2018) reported an estimate of recoverable geothermal energy from Chinese oilfields of 424·1018 J. Wang et al. (2018) also reported a summary of oilfield geothermal direct use projects worldwide. The paper of Watson et al. (2020) reports on the onshore hydrocarbons wells in the UK with the geothermal potential resource of the area while a geothermal potential assessment for oil & gas fields in Italy has been carried out by Alimonti et al., (2000).

3. CASE STUDY

The Irminio oil field (Figure 1) has been selected as our case study. This field is located in Sicily, near the Irminio River, between the Municipality of Ragusa and Scicli.

The South Eastern Sicily (Hyblaean domain also known as Ragusa Basin) and the adjoining offshore area represent a proven petroleum province where an Upper Triassic - Lower Jurassic petroleum system has been recognized (e.g., Granath & Casero, 2004; Bertello et al., 2020; and references therein). Oil accumulations in this petroleum system have generally low API° gravity with a few noticeable exceptions among which is the Irminio light oil field. This field was discovered in 1982 in an upper Triassic reservoir at a depth of about 2500 m. According to Frixa et al. (2000, 2013), the reservoir of the Irminio field is made up of Rhaetian microbial mounds (Mila Member of the Noto Fm.) developed along SW-NE oriented ridges. These ridges originated following a Norian-Rhaetian extensional tectonic phase that disrupted the pre-existing thick dolomitic peritidal platform known as Sciacca Fm. (which represents the main regional reservoir of this petroleum system). These ridges separated two basins with mixed carbonate-terrigenous sedimentation where, due to the anoxic conditions, the two main regional source rocks developed (Noto Fm. in the northern and shallower basin and Streppenosa Fm. in the southern and deeper basin).

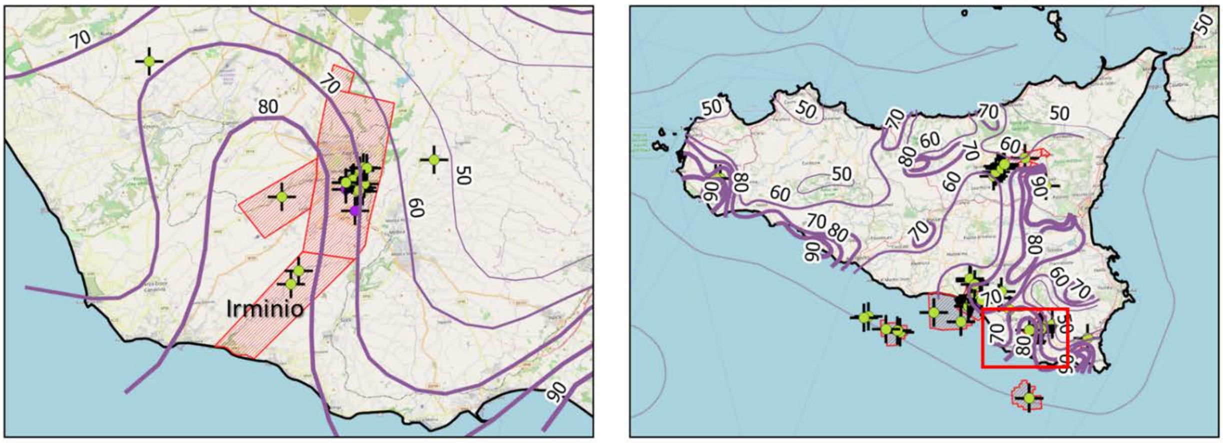

Figure 1: Location of the Irminio field in the Sicily island and temperature mapping at 2000 m.b.s.l.

The poor poroperm properties of the Iriminio reservoir are improved by hydrothermal dolomitization close to the major faults (Frixa et al., 2013): based on the analysis of bottom cores, porosity is 3% on average and 8% maximum and permeability is 4 mD on average and 1D maximum (vuggy and fractured samples).

A highlight on the favourability to have geothermal systems in the study area is reported in Trumpy et al. (2015). The level of favourability is comprised of low and medium, with very interesting aspects concerning permeabilities and geochemistry.

In the Irminio field, there are currently four wells and an oil centre, where oil is separated from natural gas and water, and stored before marketing. Two wells are producing and the other two are non-productive. The oil company installed a cogeneration unit (CHP) with thermal power of 570 kW and electrical production of 360 kW to use the produced natural gas instead to inject it into the reservoir (Tab. 1).

Table 1: Technical characteristics of the CHP plant.

Rating [%]	Electrical Power [kWel]	Thermal Power [kWth]	Gas Consumption [Nm^3/h]	Hot Water [°C]
100	981	1008	239	90
50	560	580	158	90
40	392	406	138	90

The oil production occurs with pumping and a part of the produced electricity is supplied to the pump and other services. The maximum allowable flow rate is 122 m^3/d with a wellhead temperature of about 40 °C (Soldo et al., 2000).

4. A GREEN WAY TO CONVERSION

An evaluation of possible use in a greener way of wells has been proposed. The circular economy approach is to reuse the existing infrastructure and recycle local biomass to produce biogas. The biogas, after the upgrading process, will be supplied to the CHP plant building a closed-loop.

The AD plant foresees two different scenarios:

1. Scenario 1: “as it is” conditions, AD with a mesophilic process.
2. Scenario 2: well-improved conditions, AD with a thermophilic process.

Scenario 1

The first scenario considers the implementation of an AD plant in the actual operational area of the field. In the same place is present the CHP plant.

For the case study, a single non-productive well has been considered. The well produces a brine with a flow rate of 5 m^3/h at a temperature of 40 °C. To satisfy the thermal power demand of the AD plant, a part of the produced heat from the CHP is also supplied. The process temperature is around 38 °C, working with mesophilic bacteria.

For the sizing of the digester, data relating to the situation of waste sorted collection in the Sicilian Region were used, and in detail the estimated values of MSW in the province of Ragusa.

The data show an estimated production of about 16,000 tons for 2018. The analysis highlights a net growth in the sorted collection and therefore in the collection of the potential organic matrix to be sent to the digester, which is consequently oversized in this project. We can suppose that the MSW production will increase in the next years, due to the modularity of the plant, it can be able to work until 35,000 t/y. As stated above, the plant has been sized with a mass flow rate of 16.000 t/y of MSW collected in the Ragusa area. The AD plant requires heat for the homogenization tank (HT) where the organic substrate is prepared before entering it into the digester and to regulate its water content. The largest need for heating is required by the HT.

In this scenario, the heat required by the HT is 420,997.5 kWh/y. comparing it with the heat that could be extracted from the available well equal to 152,790.2 kWh/y, is clear that the contribution is limited and it is required an upgrading of the well to improve the mass flow rate. The rest of the required heat, in this scenario, is obtained from the CHP plant from the thermal output.

Scenario 2

To improve the plant the evaluation of possible greater mass flow from the same well, with the replacement of the extraction pump, leads us to build the second scenario. In fig. 2 is reported the trend of increase in wellhead temperature versus the flow rate. For flow rates greater than 36 m^3/h, the temperature tends to stabilise between 80 and 90 °C.

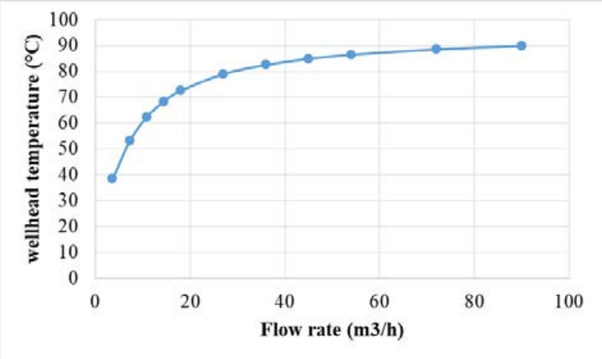

Figure 2: Wellhead temperature curve vs. flow rate.

In this scenario, a greater thermal power to feed the AD is obtained and this improvement leads us to upgrade our process to a thermophilic one using a temperature in the digester of 55 °C. The upgrade involves the increase of the flow rate up to 25 l/s, and the increase also of the wellhead temperature from 40 °C to 90 °C. This allows having enough thermal energy to adopt a thermophilic process with a preheating temperature of the substrate of 38 °C. The required heat for this process is 563,791.4 kWh/y and from the well, we can obtain 560,230.0 kWh/y which is the 99.6% of the required. The small part of the required heat can be supplied by the cogenerator. Instead, the electrical power produced can be sold and uploaded into the grid.

3. CONCLUSIONS

The implementation of an AD plant in the Irminio field area has been considered. The present plant uses the produced tail gas in a CHP to produce electrical energy and heats only partially used. To maintain this plant in operation in the future, it has been considered the opportunity to convert a non-productive well into a "geothermal well and supply the harvested heat to the AD plant. Two different scenarios have been considered. The first one is "as it is" and it allows to partially supplying heat to the AD plant. This scenario will cover 30% of the required biomethane for the CHP plant. In the second scenario, on the contrary, the implementation of a new pump increases the production of the well, as well as, the temperature allows to adopt a higher efficient process and the production of biomethane will cover the 40% of the capacity for the CHP plant.

Furthermore, a possible improvement of the plant is the use of combustion gases in algae cultivation to be fed to the nearby plant for biofuel.

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