GRC Transactions, Vol. 42, 2018

Design of New Oil and Gas Wells Fit for Geothermal Applications

Hussain Al Ramis and Catalin Teodoriu

University of Oklahoma

Keywords:

Geothermal well, drilling, oil and gas well

ABSTRACT

In 2016, World Oil expected that the number of drilled wells in US will rise by 26.8 % in 2017 to a total of 18,552 wells. The number of active oil and gas wells in the United States changed from a total of 1.6 million in 2015 to 1.2 million in 2016 according to the FRACTRACKER, 2017. However, many newly drilled wells has shale as a target which has a lower production average life and a rapid decline in production. Therefore, more mature unproductive wells are planned to be plug and abandonment in the near future. Looking at the calculated cost that may exceed 25 billion dollars for decommissioning and plugging wells under the current method worldwide. Those wells are a great target for geothermal well.

Re-designing the wells from the beginning and considering the design of the wells to reflect a future utilization of geothermal power will add more life to those wells for energy production.

The average production size for oil and gas nowadays is 7”- 4 ½”. When the geothermal factor is considered, the design of the well should be a bigger hole casing design. Converting to the larger hole wells for geothermal is a turn idea and can be beneficial to the energy industry.

1. Introduction:

In 1960, geothermal development begun around the world. Geothermal drilling evolved in 1970 in Geysers field in Northern California. Designing the geothermal casing well required special consideration to the thermal expansion and its effect on the casing strength. Around 40% - 60% is the total cost contribution of drilling new geothermal wells to generate power (Kipsang, Carolyn, 2015) (Culver, G, 1997).

A system has been put in place to operate geothermal wells known as the binary system which is a great advancement in the geothermal energy field. The ORC generators create pressure by boiling various chemical working fluids, i.e. refrigerants, into high pressure gas. The gas then expands in a one-route system and helps turn the expander or high-speed turbine driving the generator to create the electricity. The produced water from the well will then enter the heat exchanger where the hot water pressurizes the working fluid driving the twin screw expander, i.e. power block, to create electricity. The working fluid will then expand across the twin screw expander, and the low pressure vapor will condense to a liquid to begin a new cycle (Vajayee et al. 2016).

The target zone for geothermal wells are usually deeper than those in the oil and gas industry. These wells also need larger hole for accommodate more energy capacity and higher flow rate. The proposed method in this paper is to initiate the typical fossil fuel wells at a larger hole size to achieve two goals. First, increase heat transition with larger flow rate between fluid and to create more electric energy. Second, have the capacity to deepen the well to reach the geothermal energy production target. For example, starting the conventional well (for oil, gas or water) with hole size 9 5/8" that accommodates a 7" tubing, instead of the 5 ½ '' and 4 ½'' tubing, will allow for future simple workover operations to deepen the well. Therefore, using the advanced binary system after deepening the oil and gas wells or just changing the completion, will turn oil and gas existing wells into geothermal wells after they ceased production. Typically, oil and gas wells are completed in 6 ¾"-6 ¼" or 5- 4 ½" but geothermal ones require larger completion design 10 ¾"- 8 ½" or 9 5/8" 7". The large diameter driller means larger rig, larger bottom hole assembly and more volume of cement and mud. The functionality of this process is to produce geothermal energy during the final stage of the wells life, thus converting it into a geothermal well, making it one of the most innovative ways of getting renewable energy in a highly cost-effective way.

2. Geothermal Wells and Design

The number of plugged and abandoned wells are increasing around the world yearly. Utilizing the oilfield wells give a courage to study the geothermal wells economically and technically especially in low temperature environment. The collective information and date from the reservoir along with readiness of the wellsite and the hole drilled will save a lot of money for the geothermal wells. In addition, considering the environmental impact obtained by reducing the CO_2 from drilling new wells and preparing the site are worth of rethinking about a longer usage of them. Moreover, the legal issue with leaving the well opened is a great risk toward polluting the environment and a governmental concern toward those wells.

Using the existing oilfield wells will be a very cost-effective way for generating electricity by converting them to geothermal wells. This will reflect in reducing the possibilities of pollution and reducing the footprint of oil and gas waste created by open or plugged hole. Considering Texas State alone, plugged well in 2016 was 10,370 wells according to Texas Railroad Commission. There are more than 147,000 wells abandoned and plugged in California according to the California Department of Conservation, Division of Oil and Gas and Geothermal Resources (Cheng, Li, Nian, & Wang, 2013)(Wang, Yuan, Ji, & Wu, 2018).

The cost of drilling new wells in Marcellus shale for example has jumped to 609.6 $/ft and can reached up to $10M (Brown, 2016). The price fluctuation in the recent years play a great factor in plugging a lot of well and has put a lot of pressure to maintain profitability for the companies. Further advancement such as the Enhanced Geothermal System (EGS) can be used for the environment of low temperature and low pressure to extract energy from the geothermal well (Caulk and Tomac, 2017).

Drilling geothermal wells is a similar process as traditional hydrocarbon drilling. The advancement in technologies and the overall improvements in extracting the heat from the ground for electricity production encouraged the proposal to drill deeper wells for that purpose. Starting from selecting the mud and the wellbore diameter at the beginning moving to select the type of casing and the maximum pressure anticipated. Cement and the completion program should also be evaluated.

One of the major spending for geothermal energy is drilling new wells. Existing or planned hydrocarbon wells can save that cost. In addition, benefits of the expertise associated with drilling for oil and gas could be utilized as a resource when planning geothermal wells. The Oil and gas industry design wells require detailed investigation at many factors to satisfy the production and the long life of the wells. Geothermal wells plan could take a step ahead by being involved in the early design of the fossil fuel wells with the objective of taking over the wells after a period.

Assuming the average oil and gas wells are between 10-20 years, the potential of re-establishing the well for more energy is a viable concept. The cost association of closing the wells, plugged and decommission it, is a capital spending that most of the companies are concerned about.

The Plug and abandonment operation is a permanent barrier that installed on the well for different objectives. The government regulation compliances and regulations, isolate the fresh water zone and plug any reservoir that has pressure and prevent any kind of surface pollution are important goals in plug and abandonment wells.

Looking at the calculated cost that may exceed 25 billion dollars for decommissioning wells under the current method, indorsed the researcher to search for new plug materials and more cost effective one. P&A operations in offshore Norway for example cost roughly 25% of the total drilling and exploration wells (Khalifeh & Saasen, 2013). Knowing that 53% of all deep water are utilizing the cement as plug, raised more concerns about the P&A failure that occurred in the past (Bogaerts et al., 2012). Barrier used in P&A operations should account for all the stress and temperature that the barriers are exposed to. However, failure in the barrier can still be caused by fracture or tectonic stress (Khalifeh & Saasen, 2013). Taking advantage of the well before it reached to decommission time will be a great saving for both oil and gas industry and the geothermal energy.

Drilling oil and gas wells requires several technical considerations including reservoir, formation pressure and expected production. Through the years, the drilling capabilities has improved considerably. Increasing the casing strength, drilling within a narrow pore pressure and fracture pressure of the rock and directional and horizontal drilling were all advancement in well construction. These advancements enable delivering wells in faster and more economic manners.

These huge advancements allowed the industry to reach deeper and produces from more critical environment such as High Pressure and High Temperature (HPHT) wells.

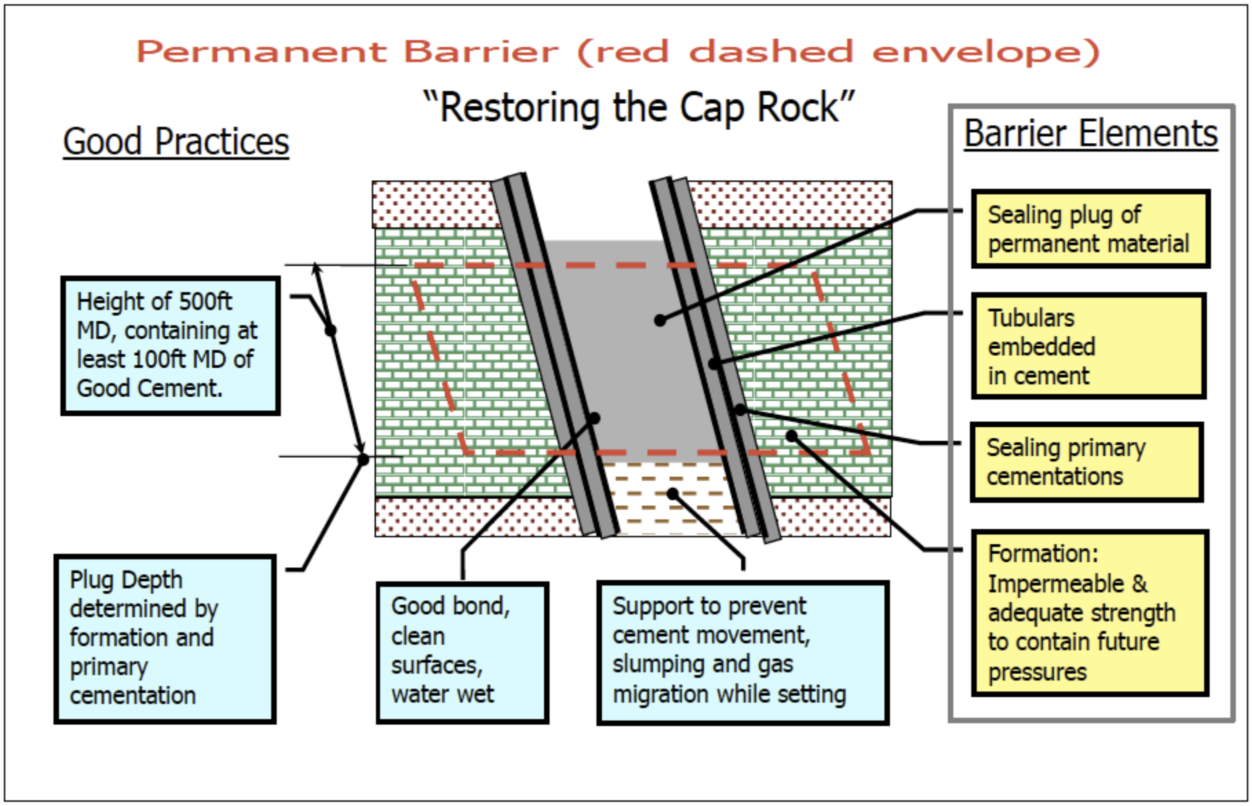

Figure 1: General Guideline for P&A (Schoenmakers, 2013)

Well planning is the first step in executing the well construction because it gathers the principles from both experiences, requirements, company standard and the available technologies. Designing the wells are done form bottom to surface by knowing the target hole size and completion first. Then, considering the casing design of the upper formations all the way to the surface. This is done by taking the available geological mapping and the seismic survey to collect all the data about the formation and the history of the area. Furthermore, the formation pressure is collected, critical zones are identified, temperature and the unusual formation within the section are considered for the well execution design. After that the mud design is implemented knowing all the previous critical zone and conditions. The last stage of the design is the selection of casing and cementing for the whole well.

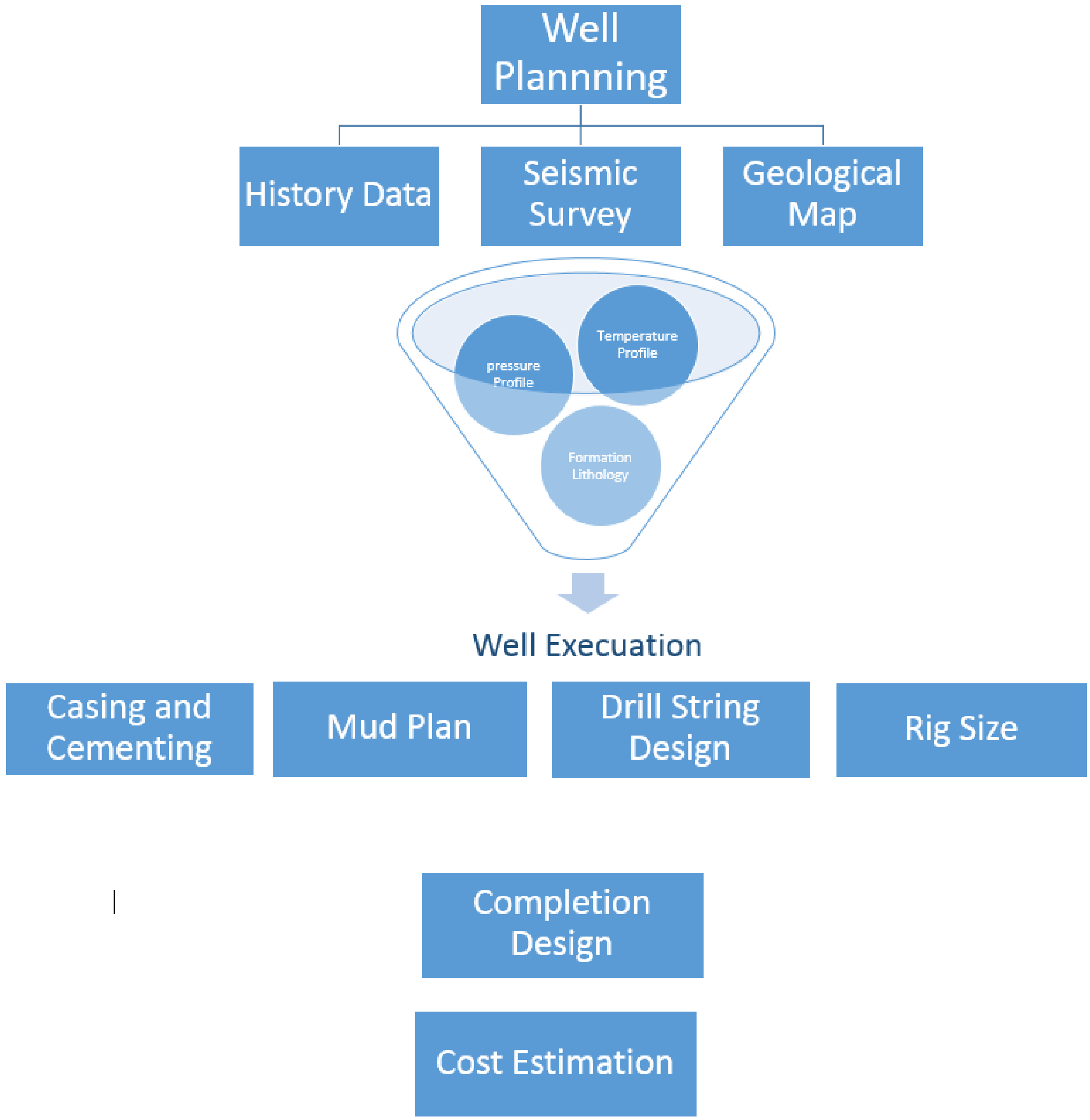

Figure 2: The steps diagram for designing the oil and gas wells

Figure 2 summarizes the hole drilling process down to the cost estimation point. The typical design of production tubing is 5”- 2 7/8” or 7”-5” production casing. The wells will be profitable for certain period then it may require some stimulation especially if it is unconventional. After the production declines from a decided profitably threshold, the well is plugged and abandonment in most of the case. The cost associated with this operation and the regulations for the decommission is very costly.

The proposed new idea is to redesign the potential oil and gas wells at an early stage of planning to fit and support geothermal production in the future. Looking at the practices and well design today; increasing the hole size or modifying the casing design to a bigger hole design will support the idea. Since the normal practices in drilling of oil and gas wells will not differ from the geothermal wells except at the completion stage, applying the new design will be more beneficial for both parties. The production casing and tubing should be large enough to support the production at the geothermal wells.

Currently the most common design in Bakken, Eagle Ford or Marcellus shale drilling consider starting the conductor size of 20”-16” then 9 5/8” as surface casing then 7”- 5 ½ ” as production casing. Finally, the completion casing is either 5 ½” or 2 7/8”.

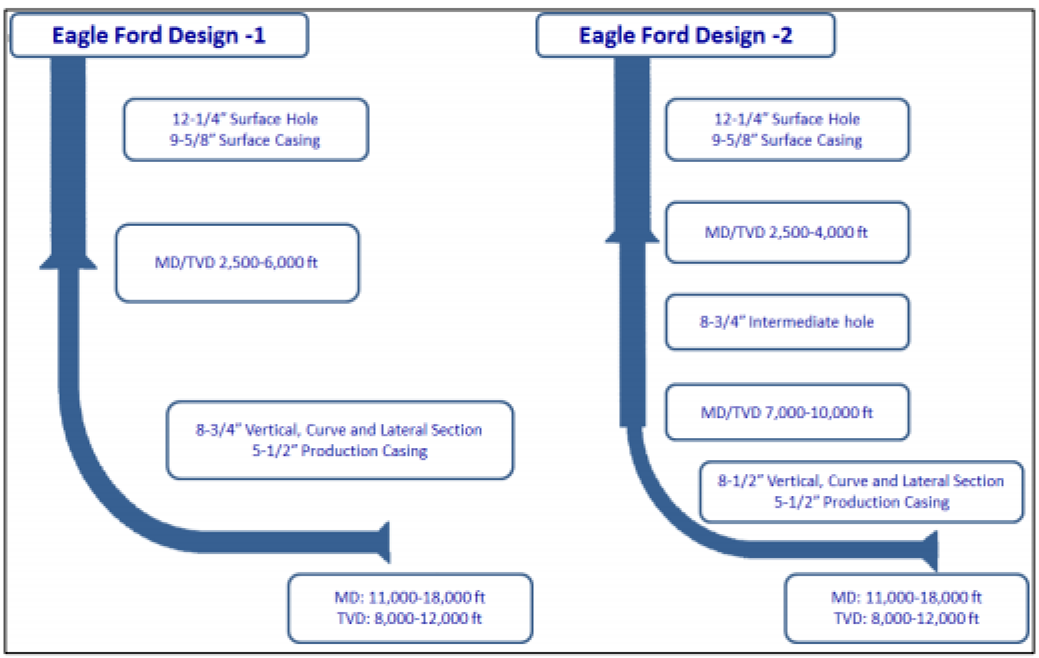

Figure 3: Eagle Ford early well design 270-315 F (Guo *et al.*, 2012)

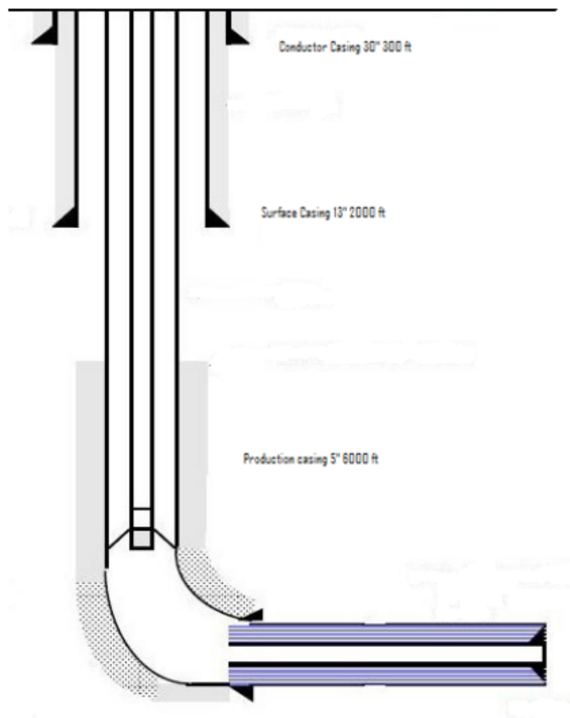

Figure 4: Marcellus well design 120-150 F (Armstrong, L. and Park, 2009)

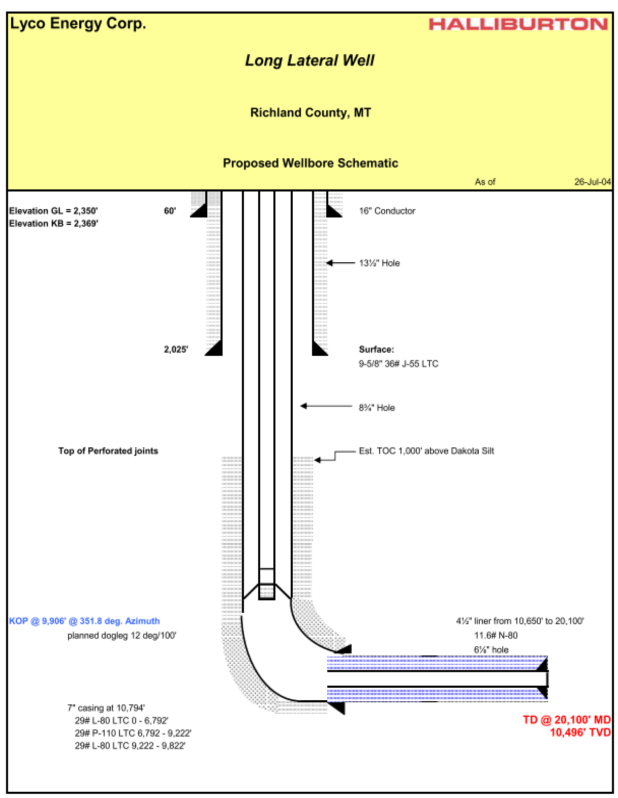

Figure 5: Bakken well design 165 - 400+ F (Barree, Bob at al 2005)

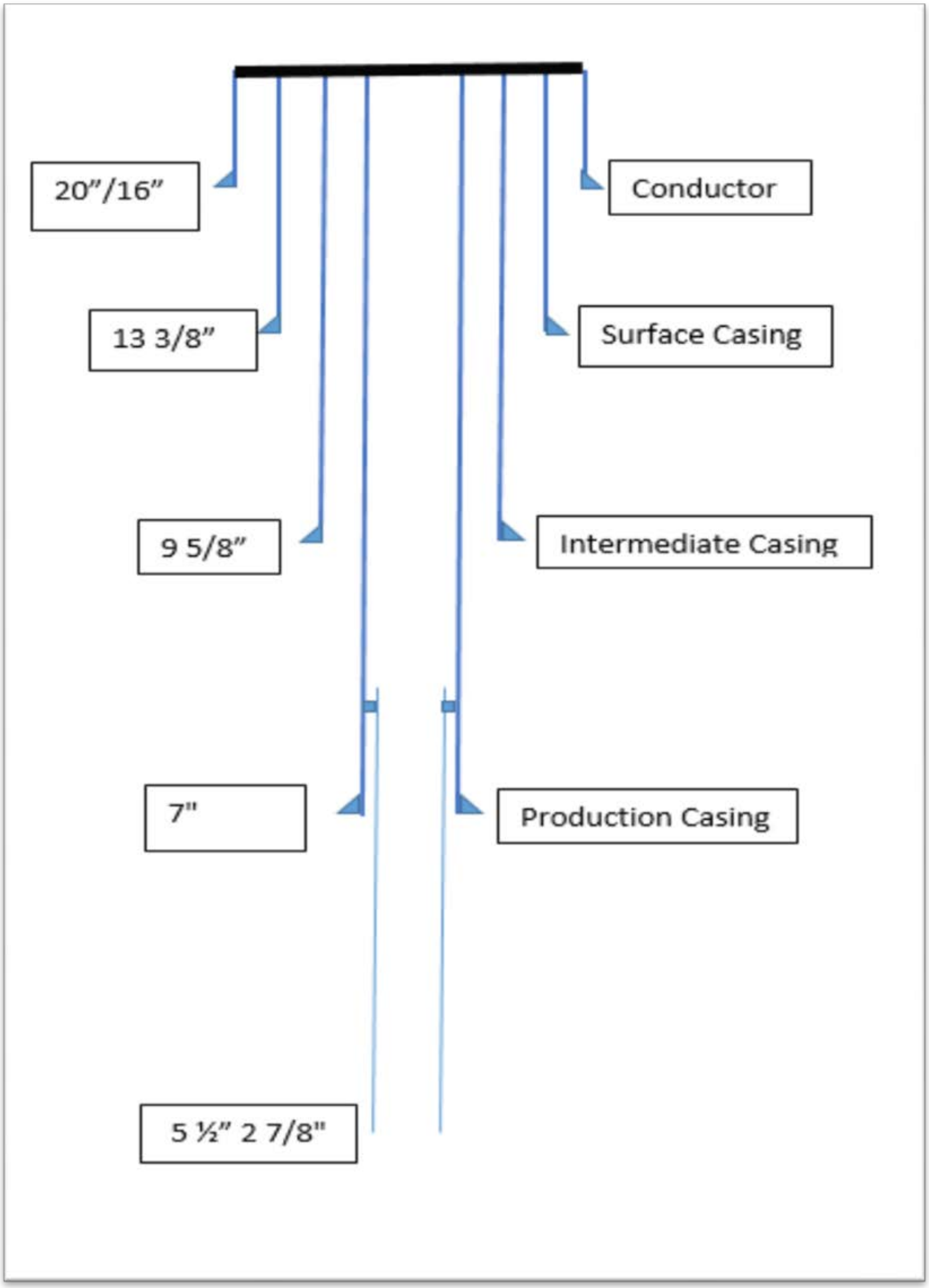

Figure 6: The general casing design for shale (oil and gas) wells

In this paper the proposed new design is calling for running 18 5/8” or 13 3/8” as surface casing then continue the design to have the production casing as 9 5/8”-7”. This design will allow to install 7” or 5 ½” production tubing for geothermal at a later stage of the well life. Moreover, starting the conductor with 26” also will serve the goal of having 7” or 5 ½” tubing at the bottom. The concept design is showed below for both large conductor and different surface casing.

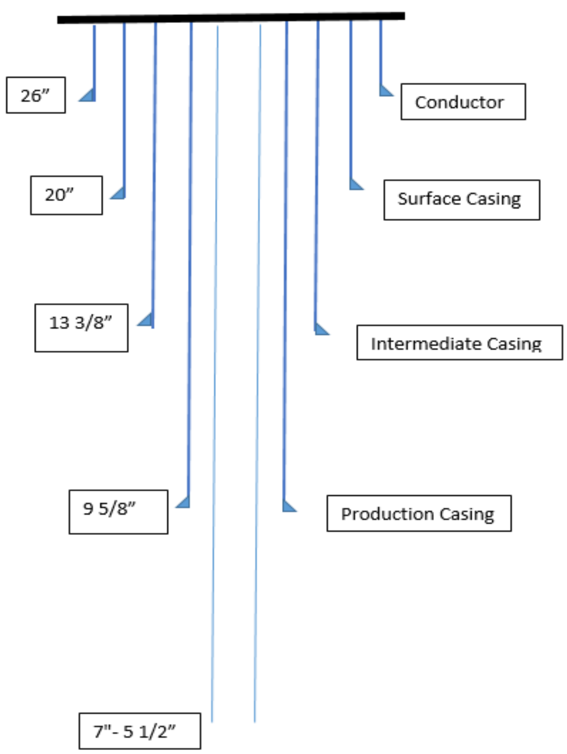

Figure 7: The proposed big hole casing design

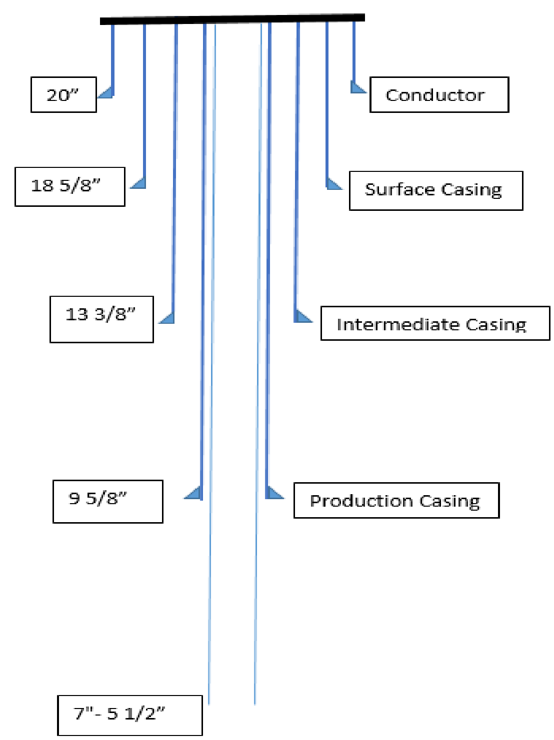

Figure 8: The proposed modify hole casing design

Assuming the temperature of 100-200 °C for 10,000+ft, the production of geothermal will be sufficient to produce 100- 4600 kW within 5”-7 7/8” as shown in detailed below for different temperature.

The data in the table has been obtained from the maximum attainable flow rate pumps with respect to well diameter (Pritchett, 1997). Then the net value of electrical capacity of the planet in relation with temperature was taken in kW/kg/s (Pritchett, 1998) and then multiplied by the flow rate to get the optimum kW.

The flow rates used for the data in table one are shown in table 2.

Table 1: Different electricity output (kW) for different temperature with different hole size

Temperature °C	T °F	5.9 in	kW	6.89 in	kW	7.87 in	kW	8.86 in	kW
100	**212**		115.44		209.04		349.5		550.02
150	**302**		577.2		1045.2		1747.5		2750.1
175	**347**		962		1742		2912.5		4583.5
200	**392**		1539.2		2787.2		4660		7333.6

Table 2: Hole size with flow rate selection

Hole Size in	Flow Rate kg/s
5.9	19.24
6.89	34.84
7.87	58.25
8.86	91.67

The selection of the flow rate in Table 2 fits within the range that will not affect the pressure drop highly as described by Srivastava and Teodoriu (2018) see Table 3:

Table 3: Optimum pressure drop in green for different hole size and different flow rate (Srivastava and Teodoriu, 2018)**.**

Flow rate	***Pressure drop due to flow rate -> Depth = 10 000 ft.*** Diameter (ID) of production casing 4-1/2 in 0.104 m	5 in 0.116 m	5-1/2 in 0.128 m	6-5/8 in 0.156 m	7 in 0.166 m	8-5/8 in 0.205 m,	9-5/8 in 0.230 m
l/s	bar	bar	bar	bar	bar	bar	bar
30	29.64	17.16	10.35	3.91	2.85	0.99	0.57
40	51.49	29.73	17.89	6.72	4.89	1.70	0.97
50	79.22	45.65	27.42	10.25	7.46	2.58	1.48
60	112.83	64.91	38.92	14.51	10.54	3.63	2.08
70	152.29	87.51	52.41	19.49	14.15	4.86	2.77

The deeper the geothermal wells are, the more costly it will become. Considering the cost of the casing alone, starting the wells with a bigger hole size may cost $75,000 more only per well.

Considering the production from 200 °C geothermal well eliminating the drilling costs resulting from re-using the oil and gas well will lead to shorter payback period to 4.5 years as shown below in the Figure 9. The NPV has been calculated by subtracting the initial capital cost of the project from the summation of the total cost of the systems (turbine, pump, gathering, civil, maintenance and wellhead cost) over (1+ discount rate) for the years as shown in the equation:

$$\text{NPV} = -Co + \sum_{t=1}^{n} \frac{Cnet}{(1+r)^t}$$

Where t, n, Co, C_{net}, r represents the time of the project, life of the project, initial capital cost and discount rate respectively.

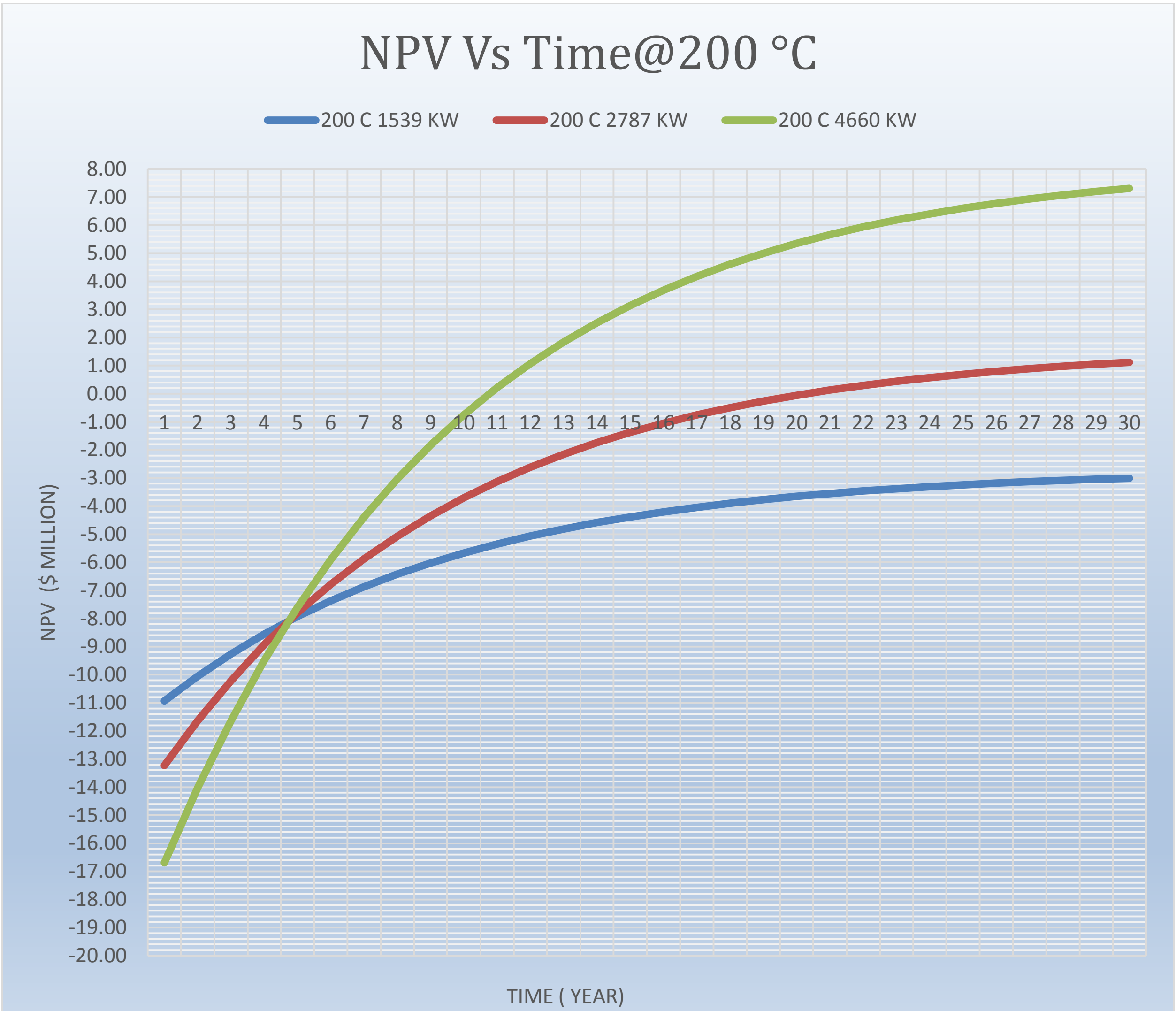

Figure 9: Net Present Value (NPV) vs. time represent the payback period for 200 °C.

3. Conclusion

The concept idea of converting oil and gas wells to geothermal wells when hydrocarbon production has ceased is an initiative worthy studying. With the very high cost of drilling geothermal well, using the oil and gas wells will help reduced the cost per MW for geothermal considerably. The intervention with the oil and gas planning from the early design stage is the key principle in going forward with this initiative. So, designing the wells from beginning with an idea of future utilization for geothermal is very cost effective when compared to plugging the well. A single converted well can produce as high as 4 MW (for 7 7/8” hole size with 392 °F) with a payback period of 4.5 years.

REFERENCES

Armstrong, a, et al. *Sustainable Development and Design of Marcellus Shale Play in Susquenanna PA*. 2009, p. 149.

Barree, Bob (Barree & Associates), Charles Wiley (Lyco Energy Corportation), Mike Eberhard (Halliburton Energy Services), Tom Lantz (Landmark). “Bakken Horizontal Best Practices Review.” *Bakken Horizontal Best Practices Review*, no. September, 2005.

Bogaerts, M., et al. “Challenges in Setting Cement Plugs in Deep-Water Operations.” *Society of Petroleum Engineers - SPE Deepwater Drilling and Completions Conference 2012*, no. June, 2012, pp. 484–97, http://www.scopus.com/inward/record.url?eid=2-s2.0-84866454967&partnerID=40&md5=55d0b1150ca78480aba60378ad9f7d50.

Brown, Daniel Paul. *The Graduate School College of Earth and Mineral Sciences A PRELIMINARY FEASIBILITY STUDY OF GEOTHERMAL AND MINERAL EXCTRACTION APPLICATIONS OF HYDROCARBON WELLS A Thesis in Energy and Mineral Engineering by Submitted in Partial Fulfillment of the Require*. no. May, 2016.

Caulk, R., and I. Tomac. “A Geothermal Perspective on Abandoned Oil and Gas Wells in Sedimentary Georeservoirs Located in California, USA.” *Geotechnical Special Publication*, no. GSP 280, 2017, pp. 143–52, doi:10.1061/9780784480472.015.

Cheng, W. L., Li, T. T., Nian, Y. Le, & Wang, C. L. (2013). Studies on geothermal power generation using abandoned oil wells. *Energy*, *59*, 248–254. https://doi.org/10.1016/j.energy.2013.07.008

Culver, G. “Drilling and Well Construction.” *Geothermal Direct Use Engineering and Design Guidebook*, 1997, pp. 129–64.

Guo, Quan, et al. “Shale Gas Drilling Experience and Lessons Learned from Eagle Ford.” *SPE Americas Unconventional Resources Conference*, 2012, doi:10.2118/155542-ms.

Hance, C. “Factors Affecting Costs of Geothermal Power Development.” *Geothermal Energy*, no. August, 2005, p. 64.

Khalifeh, Mahmoud, and Arild Saasen. “OTC 23915 Techniques and Materials for North Sea Plug and Abandonment Operations.” *Otc*, 2013, doi:10.4043/23915-MS.

Kipsang, Carolyn. “Cost Model for Geothermal Wells.” *World Geothermal Congress 2015*, no. April, 2015, p. 12.

MIT. “Drilling Technology and Costs.” *Chapter 6 of The Future of Geothermal Energy – Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century Report Issued by MIT.*, 2007.

Osundare, Olusegun, et al. “Estimation of Plugging and Abandonment Costs Based on Different EU Regulations with Application to Geothermal Wells.” *43rd Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California*, 2018, pp. 1–13.

Parada, Angel Fernando Monroy. “Geothermal Binary Cycle Power Plant Principles , Operation and Maintenance.” *Unu-Gtp*, vol. 20, no. 20, 2013, p. 34.

Pritchett, John. W. “Mathematically Modeling Downhole Pump Performance in Geothermal Wells from 150 to 300 Millimeters Inside Diameter”. Report Series Contract No. DE-FG 961D13455. U.S. Department of Energy, 1997.

Pritchett, John. W. “Electrical Generating Capacities of Geothermal Slim Holes.” Report Series MSTD-DFR-98-16223. U.S. Department of Energy, 1998.

Rubright, Sam. *34 States Have Active Oil & Gas Activity in U.S. Based on 2016 Analysis*. 2017, https://www.fractracker.org/2015/08/1-7-million-wells/.

Schoenmakers, Jules. “Oil and Gas UK Workgroup Well Suspension and Abandonment (WSA) Well Life Cycle Practices Forum (WLCPF).” *4th European Seminar on Well Abandonment Aberdeen*, no. April, 2013, pp. 1–23.

Srivastava, Saket, and Catalin Teodoriu. “Gas Well Conversion To Geothermal : A Case Study For Oklahoma.” *Gas Well Conversion To Geothermal : A Case Study For Oklahoma*, Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, 2018, pp. 1–9, doi:SGP-TR-213.

Wang, K., Yuan, B., Ji, G., & Wu, X. (2018). A comprehensive review of geothermal energy extraction and utilization in oilfields. *Journal of Petroleum Science and Engineering*, *168*(April), 465–477. https://doi.org/10.1016/j.petrol.2018.05.012