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Development of resource metrics for high and low temperature fields

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ABSTRACT

Reykjavík Energy (OR) is the largest geothermal energy company in Iceland. Through its subsidiaries, Veitur utilities and ON Power, the company provides about 70% of Icelandic homes with district heating and about 30% with electricity.

ON Power and Veitur utilities operate three high temperature fields which provide 423 MWe and 560 MWth and 19 low temperature fields that provide hot water for space heating. Good reservoir management and a monitoring plan for the key parameters of the resources are vital to ensure long term usage of the resources and the right planning for future resources.

Status, productivity and the health of each reservoir is of high importance as it, together with the forecasted need for more capacity, affects the need to invest in increased resource capacity. OR has developed resource metrics that consider the most important parameters for each resource. The metrics are different for low and high temperature fields as the important parameters are not the same. The resource metrics are updated twice a year and are key to summarize the status of each of the resource areas in use

The resource metrics have been updated twice a year since 2015 and during that time they have been developed and refined. Better definition of the metrics has been applied, subjective evaluation has been eliminated as much as possible, the appearance has changed, and parameters have been added or removed. Updating the metrics has proven to be valuable for resource scientists to formally discuss the status of the resources and to create a simplified tool to talk about the status of our resources with internal and external stakeholders. Updating the resource metrics supports the best prioritization of projects and puts focus on the right projects to secure successful geothermal utilization for future generations.

1. INTRODUCTION

Reykjavík Energy (OR) is the primary geothermal energy company in Iceland. Through its subsidiaries, Veitur utilities and ON Power, the company provides the large part of the population if Iceland with heat and electricity. ON Power operates two geothermal power plants in Hellisheiði and Nesjavellir with a combined power output of 423 MW_e 550 MW_{th}. Veitur operates 13 district heating systems with a combined installed capacity of more than 1200 MW_{th}.

To provide all this energy ON power and Veitur utilize two high temperature fields in Hengill area where electricity and hot water are produced and 18 low temperature fields that provide hot water for space heating (Fig. 1). Most of the waters form the low temperature fields are used directly for space heating except where composition of the waters provides challenges with direct use. Hot water production in the power plants in Hengill is produced by heating fresh groundwater.

The need for hot water for space heating in Iceland is grooving at a rate what provides challenges in terms of increasing the capacity both form current geothermal fields and new fields (Þorbergsson et al, 2023). Good reservoir management and a monitoring plan for the key parameters of the resources are vital to ensure long term usage of the resources and the right planning for future resources. A key factor there is a good estimate of the production capacity of each field and close monitoring of the status of the fields currently being utilized.

For a company that relies on natural resources for its operation a good overview of the status of those resources is of importance. Resource metrics that provide a clear simplified overview of the status of the resources was implemented at Reykjavík Energy in 2015. The goal was to be able to communicate with internal and external stakeholders the status of all the geothermal resources being utilized within the company. The metrics highlight what are the most important factors concerning each type of geothermal reservoir. In this paper we present the development of the metrics, how they have developed since their first use and what challenges have been met during their development.

2. RESOURCE METRICS

ON Power and Veitur utility use both high and low temperature resources for their operation. The challenges in utilizing the two types are not in all cases the same. How the temperature evolves is for example important in both cases but it would be difficult to define a scale that fits both types of reservoir. Pressure and water level are important in both types but the water level in low temperature fields fluctuates depending on the rate of production whereas high temperature fields usually have a steady declining pressure. Some factors are also different, for example re-injection which is usually don don't in our low temperature fields but very important in our high temperature field operation. Another example of an incompatible parameter is discharge enthalpy. The discharge enthalpy is a factor dominated by temperature in low temperature fields but in high temperature fields it is affected by both pressure, temperature and reservoir characteristics (Arnórsson et al., 2010, Scott et al., 2014) The resource metrics are therefore different for high and low temperature fields and focused on what is considered to be the most important parameters for each type of reservoir.

The metrics are evaluated on the bases of prescribed condition and deductions are made if conditions are met described in the evaluation criteria. The marks for each parameter can either be green if that parameter is in good condition, yellow if the condition is considered to be cautionary and needs further attention or red if the condition of the parameter for the reservoir in not good or is evolving into something that might be problematic for production.

Figure 1. Resource fields used by Reykjavík Energy and its subsidiaries ON power and Veitur. The fields are used for water works, low temperature district heating systems and electricity production form high temperature fields. Two cold water resources, Grámelur and Engidalur are used for hot water production in Hellisheiði and Nesjavellir power plants.

2.1 High temperature resource metrics

High temperature fields the metrics are divided into eight individual parameters considered important for long term successful production of electricity and hot water from the fields. Five of them focus on the geothermal reservoir condition and changes in the reservoir related to production while the other three focus on the cold-water supply associated with the geothermal utilization and planning for future production. The parameters are:

1. **Enthalpy**: Weighted average of annually measured well discharge enthalpy from all wells. This factor is evaluated based on the changes in measured enthalpy with time but not the absolute measured enthalpy values as those are field specific.
2. **Production density**: This parameter considers both the maximum and average production of the production field. Deductions are made if either average or maximum production density is above certain limits or if both are above the limits.
3. **Pressure drawdown**: This parameter is based on the annual or bi-annual down-hole pressure measurement preformed in selected monitoring wells. Deviations from predicted pressure drawdown result in yellow or red based on the severity of the pressure drop.
4. **Temperature**: Based on annual or bi-annual downhole measurements performed in selected monitoring wells as well as the quarts geothermometer calculated from annual chemical samples from all wells. Deductions are made if either or both temperature limits are met.
5. **Re-injection**: This parameter is based on both the impact of re-injection on the reservoir and the environmental effects of the injected fluid whether in a deep or shallow reservoir.
6. **Cold-water reservoir**: Both high temperature power plants utilize cold groundwater for cooling and production of hot water for district heating. This parameter evaluates the status of the cold-water reservoir and if the cold-water reservoir can supply water to the power plant in the foreseeable future.
7. **10 year production capacity**: This parameter is evaluated based on how long the reservoir can maintain installed production capacity of the power plants. Both power plants are observing declining steam flow due to pressure drops in the reservoir and this parameter is based on how long maintenance drilling can be done to maintain full capacity, both power and heat, at the power plants.
8. **Research and development**: This parameter evaluated based on if necessary studies are being done for future addition to the power plant and if those areas have been approved as a production area by Icelandic authorities.

An example of the high temperature resource metrics is given in Figure 2. The colors for each parameter are not based on actual evaluation but are only for demonstration purposes.

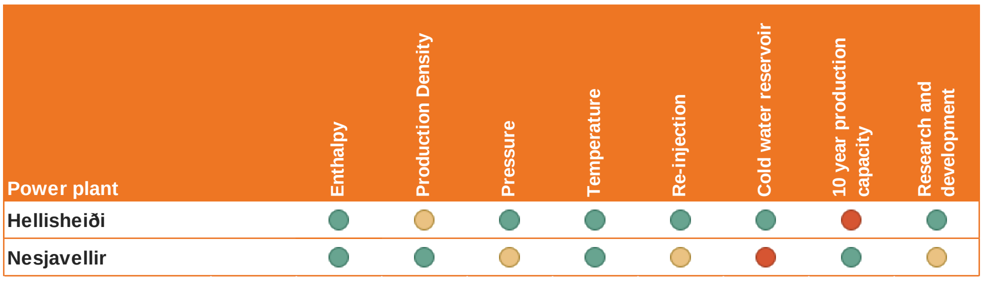

Figure 2. Resource metrics for high temperature power plants. The green, yellow and red dote shown here are just an example and are not based on actual evaluation of the fields.

2.2 Low temperature resource metrics

Low temperature field resource metrics are divided into seven parameters that have been identified as most important for successful long-term production from a low temperature field and for operation of a district heating system. Two parameters are evaluated for the whole hot water utility and the current installed capacity and future resources to meet future growth in the distribution system. These two parameters are done for the whole hot water utility. Five parameters are done for individual low temperature fields.

1. **Installed production capacity:** This metric considers an estimate of the need for hot water in the utility and the installed production capacity. Green rating indicates production capacity 10% (or 3% for the capital area) above the estimated demand for hot water. Yellow rating indicates production capacity higher that estimated demand but lower than 10% above production capacity (3% for the capital area). Red rating indicates lower production capacity that estimated demand. This parameter is evaluated for the district heating system as a whole.
2. **Long term plan for resource development:** This metric considers if there is a plan to meet the heat demand for the utility for the next 30 years. This parameter is evaluated for the district heating system as a whole.
3. **Heat use efficiency:** Efficiency of use of the heat of the geothermal water is the base of the metric. Boiling of the water prior to distribution or large scale disposal of hot water to maintain hot enough water in the distribution system are for example considered factors for subtraction. That is irrelevant of whether there are enough resources in the utility. This parameter is evaluated for each low temperature field supplying the district heating system with hot water.
4. **Data quality:** Are all the necessary data being collected to be able to estimate the status of the resources supplying the utility with energy. This parameter is evaluated for each low temperature field supplying the district heating system with hot water.
5. **Temperature:** Is the reservoir cooling? Are there signs of a cold inflow into the reservoir. This parameter is evaluated for each low temperature field supplying the district heating system with hot water.
6. **Fluid composition:** Chemical composition of the low temperature water plays an very important role in operation of the distribution system. This factor considers the quality of the water in the system. Does the water contain oxygen or is the scaling potential in the waters are examples of factors considered in this metric. This parameter is evaluated for each low temperature field supplying the district heating system with hot water.
7. **Water level:** The water level of low temperature fields fluctuates in accordance with the level of production from the field. This results in higher water levels during the summer when the thermal demand is low and lower water level during the winter the demand is high. This factor considers the long term trends in water level. If the water level during the summer is progressively lower than previous summers, when the production rate from the field is not sustainable and this metric becomes negative. This parameter is evaluated for each low temperature field supplying the district heating system with hot water.

An example of the low temperature field resource metrics is given in Figure 3. The colors for each parameter are not based on actual evaluation but are only for demonstration purposes.

3. CONCLUSION AND DISCUSSION

Challenges with designing and implementing metrics are making them meaningful and at the same time simple enough for stakeholders to engage with them. Too much attention to detail can make them miss their mark as a tool communicate the status of the resource and oversimplification can make them irrelevant. Just the right amount of detail to make them interesting and relevant is the goal that is aimed for. The development is a back and forth process and feedback form the stakeholders has been a key ingredient in their development.

The resource metrics were first implemented in 2015 with the goal of providing a clear overview of the status of the 20 geothermal fields utilized by ON Power and Veitur. Since their implementation they have been under constant development and refinement. Parameters have been changed, added and removed. The definition of how the parameters are rated has been changed with the aim of removing subjective evaluation and make them better comparable between different geothermal fields. The appearance of the metrics was changed with time from being a spider diagram to the traffic light system that are shown in figure 2 and 3. Development of the metrics is not a completed task as they are under constant reevaluation to make the more focused of what matters in geothermal utilization.

The metrics are updated twice a year by a group of geothermal scientists and operators of the utilities. Updating the metrics has proven to be a valuable platform to formally discuss the status of the resource and utility. During the process differences in opinions regarding the parameters of the metrics are discussed and common ground settled upon on the differences. The metrics help to prioritize projects and puts focus on the right projects to secure successful geothermal utilization for future generations.

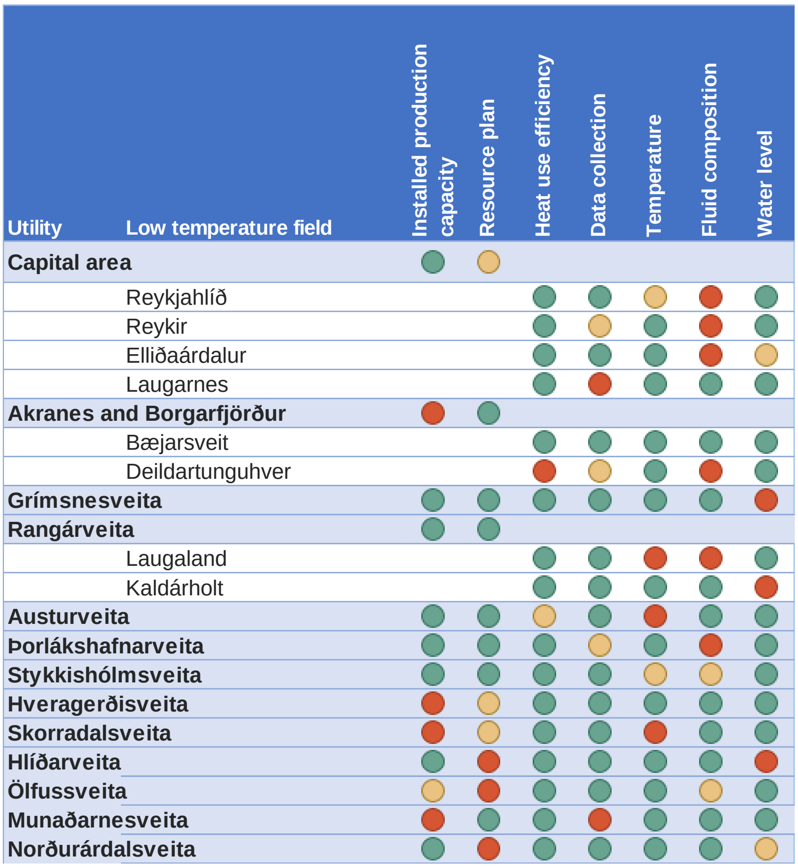

Figure 2. Resource metrics for low temperature fields. The green, yellow and red dote shown here are just an example and are not based on actual evaluation of the fields.

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