DUTCH GEOTHERMAL RESOURCE REPORTING. A FIRST ATTEMPT OF DUTCH NATIONWIDE GEOTHERMAL RESOURCE USING THE UNFC RESOURCE CLASSIFICATION SYSTEM. STATUS DATE JANUARY 2019.

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ABSTRACT

Within the Netherlands, 24 geothermal systems have been realized of which 16 are operational, together producing 3.4 PJ of heat in 2018 (status date 1-1-2019). The main application domain is horticulture. The ambition of the Dutch government is to see production of geothermal energy increase in the Netherlands to 50 PJ in 2030, subsequently 200 PJ in 2050 and also to expand the application domain to district heating and industry. A state of the art resource assessment can support the Dutch government policy to realize its ambition. By classifying the resources based on project maturity including reference to the obstructing issues in the maturation of projects such as technical, financing, licensing and or social and environmental complexities targeted policy can be drafted. As of January 2019, 51 exploration licenses have been granted, and 31 more have been applied for (MEA2019). At least one geothermal project is defined in each of these exploration licenses, at different levels of advancement. Outside the boundaries of existing licenses and licenses under application, the Netherlands provides ample space for geothermal development. At the moment, there are no tools or practical methodologies to integrate all available information in a coherent and automated manner. As such, a method to quantify the geothermal energy resources of projects ‘not yet realized’ using the United Nations Framework Classification (UNFC) resource classification system would help policymakers to decide upon the most appropriate measures to remove obstructions for reaching the 2030-2050 geothermal ambitions. In this study, we show the initial results of a resource assessment and classification system for geothermal energy while incorporating environmental and social issues in the classification, as required by the UNFC-2009. As basis for this resource assessment, we use the web tool ThermoGIS-v2.1 (Vrijlandt et al. 2019). ThermoGIS-v2.1 using information on the Dutch subsurface derived from the regional mapping by the Geological Survey. It is updated through incorporation of newly gained insights and data and provides a comprehensive overview of the geothermal potential for a selected set of aquifers. The resource estimates, including the uncertainty range related to these figures, at the status date 1-1-2019 of the Dutch geothermal “project portfolio” are classified using UNFC, resulting in a set of resource figures per resource class according to project maturity: commercial, potentially commercial, non-commercial and exploration projects. The figures will be presented at the conference.

1. INTRODUCTION

The Netherlands has ample geothermal resources in Hot Sedimentary Aquifer plays (Kramers et al. 2012). The authors state that the recoverable heat amounts to just over 63000 PJ, assuming an injection temperature of 35 °C for direct heat applications. In 2007, the first geothermal system was commissioned producing heat from Upper Jurassic – Lower Cretaceous terrestrial and marine sandstones at a depth of approximately 1800 m. The geothermal gradient in the Netherlands averages at 31 °C/km with an average surface temperature of 10 °C. Consequently, the production temperature is some 60 °C which is appropriate for heating greenhouses. This innovative project attracted a suite of early adopters and followers.

Over a period of 12 years, the geothermal energy production developed from none in 2007 to just over 3.4 PJ in 2018 (Figure 1) (MEA 2019). To the status date (01-01-2019), there are 24 geothermal systems realized of which 16 are in the production phase and the others are starting up. All geothermal systems are for ‘Direct Use’, predominantly heating greenhouses and one of the 24 exclusively for district heating. The Dutch geothermal plays cover the stratigraphic sequences from Cenozoic down to Lower Carboniferous/Devonian strata (MEA 2019, Mijnlieff, 2019 in prep).

The sustainable energy ambition of the Dutch government is; to be independent of fossil fuels like coal and natural gas. In the realization of this ambition, geothermal energy has a major role in the supply of heat for direct use in horticulture, district heating as well as in the process industry: 50 PJ in 2030, subsequently 200 PJ of yearly energy supply of geothermal energy in 2050 (Masterplan 2018).

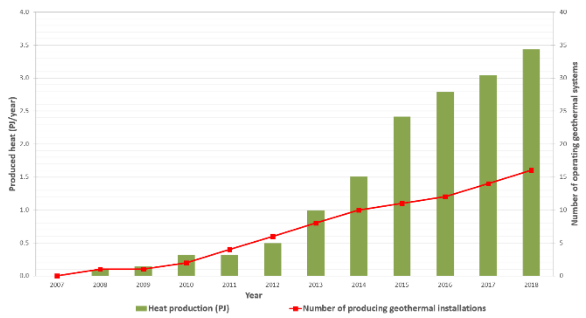

Figure 1: Yearly heat production and number of operational geothermal systems.

The rate of the realization of projects and the increase in production of geothermal energy the Netherlands lags behind compared to power generation from solar and wind and also compared to biomass for heat (Figure 2) despite the availability of financial support measures like the feed-in premium scheme and the geologic risk insurance scheme (Mijnlieff et al. 2013). Amongst others, the complexity of a geothermal project, the high investment costs and an uncertainty around potential energy production due to geologic uncertainty are seen as the main reasons.

Classifying the geothermal resources according to their (incipient) project maturity while identifying hurdles in the maturation pathway (legal, technical, data) will support informed policy decisions to efficiently unlock geothermal resources.

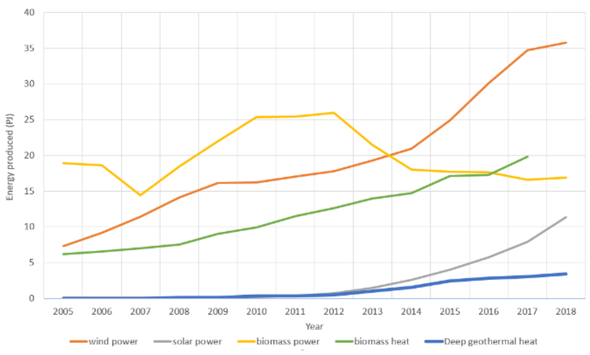

Figure 2: Produced renewable energy (PJ) from 2005 to 2018 (sources CBS & TNO).

2. GEOTHERMAL RESOURCE QUANTIFICATION

Before resource classification can be carried out, the resources first must be defined, described and quantified UNECE 2016b. Therefore, for the nation-wide resource estimate, a resource quantification methodology is set-up for each project maturity class. The project maturity class reflects weather a project is in the production phase, commissioning phase or an exploration phase. To determine the projects' maturity class, we have defined four different quantification methods specifically geared to the availability of detail and type of relevant data which is dependent on the project maturity stage.

2.1 Resource quantification of the producing geothermal systems.

The uncertainty of subsurface parameters relevant to a geothermal system is reduced to its minimum once two wells have been drilled and circulation through the system including the reservoir is proven to occur under stable injection and production pump pressures. For projects in such condition, we use historical production figures and reservoir characteristics to predict the future production profile.

The project lifetime is dependent on the temperature breakthrough, the economic limit, design life, contract period and entitlement period. However, we assume the project economics will not be adversely influenced when for example the feed-in premium is ended because the economics of the project is designed for the 15-years grant. After the 15-year feed-in premium period, only OPEX and routine maintenance are expected to be the main expenditure. The standard production license period in the Netherlands is 35 years. We assume that, if needed, an extension of the license will be granted if the resource is not exhausted, as is the case with Dutch oil & gas production licenses. For the modelled project lifetime the system breakdown or design lifetime is not taken into account as we assume make-up wells will be drilled when well failure occurs and surface facilities will be replaced, modified or repaired when needed. Therefore, the lifetime of the project is predominantly a function of thermal breakthrough.

The average yearly energy yield multiplied by the systems lifetime will result in the most likely production profile from which the most likely resource estimate can be deduced. The lifetime used here is the thermal breakthrough, defined as the moment when the production temperature has declined by 10%, meaning that the difference between the production and injection temperature is 90% of the initial difference. The minimum (without the months of malfunctioning) and maximum historic energy production multiplied by the system's lifetime will result in the low and high estimates respectively.

2.2 Resource quantification of geothermal systems to be commissioned.

For geothermal systems, which have been realised (drilled) under an exploration licence and are in the process of finalising the installation and procedures for commissioning, no historic production data is available yet. For these, a static reservoir model, DoubletCalc2D (Veldkamp, 2015, Pluymaekers et al. 2016), is used. The models are based on the well data and production test results and are used to construct a forecasted production profile, assuming realistic operating conditions. The Possibility of Maturation of these projects is regarded to be 100%.

2.3 Resource quantification of defined exploration projects within exploration licenses

For undrilled (to be realised) geothermal projects situated in exploration licenses, which have detailed location-specific geological and geophysical studies to warrant further development, the geothermal power (heat) (MW_{th}) is calculated using DoubletCalc1D (Mijnlieff, 2014). The power estimates for these defined projects are reported to the Dutch government as part of an application for the feed-in premium scheme (Mijnlieff et al. 2013). Using the P90, P50 and P10 power estimates of this calculation, the expected full load hours (SDE+ values) and the systems life time future production profiles are constructed for these projects and subsequently the resources.

2.4 Resource quantification of play areas without defined exploration projects

For the remainder of the play areas where no defined exploration projects are known we use ThermoGIS-2.1 (Vrijlandt et al. (2019, this volume)) to assess the geothermal potential. ThermoGIS-2.1 provides a geothermal power map for five geothermal plays: Cenozoic, Lower Cretaceous, Upper Jurassic, Triassic, Rotliegend and Upper Carboniferous. Figure 3 gives the Rotliegend example, the others can be found in on www.thermogis.nl. The Geothermal Power map is compiled/calculated using the reservoir property maps: depth, thickness, net-to-gross, permeability, and temperature. These are combined with depth-related salinity estimates and together with a techno-economic model based on development with a geothermal well pair (doublet). The calculation procedure is similar to the approach explained in Van Wees et al. (2012). The injection-production well distance is dependent on a production life time of 50 years. Energy yield is assumed to become uneconomic when a 10% decline in production water temperature as a result of thermal breakthrough occurs. Flow/injection pressure is optimised minimizing unit technical cost and capped not to overstep the regulators' maximum injection pressure threshold. The geothermal power map gives the power (in MW) of a possible geothermal doublet for each 1x1 km grid cell.

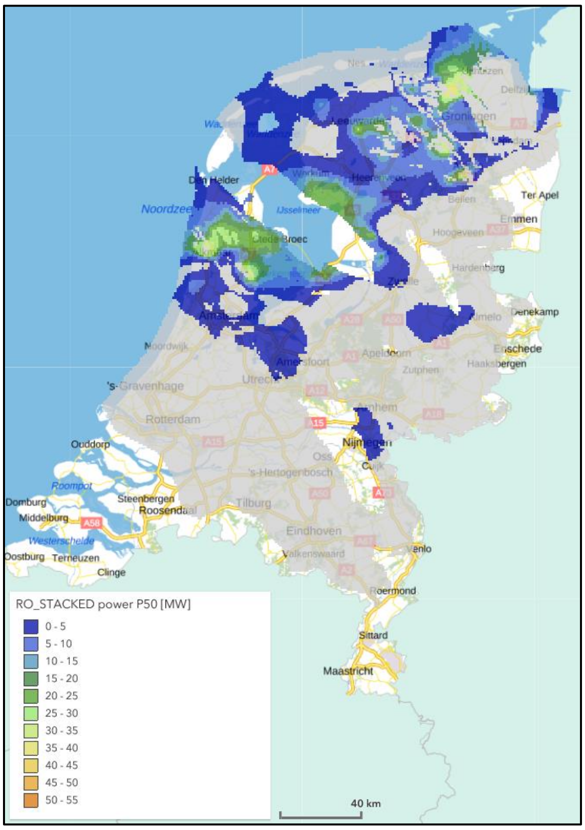

Figure 3: geothermal power distribution of the Rotliegend hot sedimentary aquifer (grey is no flow or hydrocarbon accumulation).

For the calculation of the resources, we start with the ThermoGIS-v2.1 power maps of the five plays**.** To be able to add all the grid cells for resource classification, the power needs to be divided by the area of the geothermal doublet, which is the well distance squared times two. This gives the power per area in MW/km^2. The amount of geothermal systems fitting in the geothermal play area is dependent on the organisation of the projects: if they are all aligned side by side the "sorting factor" is 1, if they are randomly distributed and not overlapping the sorting factor is around 0.6. The sorting factor is used in the next step to recalculate "doublet power map" is thus taking into account the geothermal systems layout. The aggregation of the grid cells, excluding those where producing systems, to be commissioned systems and defined exploration projects are situated, will give the basis of the resource calculation of the yet undefined exploration projects or notional projects. We assume 6000 full load hours per year (SDE 2019) during the 50 years modelled lifetime to calculate the resources for this project maturity class. The resulting grid has a dimension of PJ/km^2 over a period of 50 years. This procedure is done for all 5 geothermal plays.

To all grid cells (effectively notional project resources) attributes are assigned which influence the project maturation rate. These are for example:

- the location in or outside a nature reserve,
- large bodies of water,

- low data density area's.

This is used to sub-divide the notional project portfolio in for example ones situated in low or high data density area's or situated in nature protected areas.

3. GEOTHERMAL RESOURCE CLASSIFICATION: DUTCH GEOTHERMAL RESOURCES AND UNFC

Several local Geothermal resource classification schemes have been developed: e.g. the Australian code (AGRCC, 2010), the adapted Australian code for Canada (CGCC 2010), the GeoElec scheme (van Wees et al. 2013) and the recently issued US GeoReport (Young et al. 2018). In the same timeframe, the UNECE developed a resource classification scheme for resources UNFC-2009 (UNECE, 2013). In 2016, UNFC application specifications for geothermal were issued to consistently and uniformly classify geothermal resources worldwide (UNECE, sept. 2016b). In this exercise, we attempt to classify the quantified Dutch geothermal resource portfolio using UNFC.

The project resources are classified along three axes UNECE, 2013, UNECE 2016b):

1. the E-axis referring to social, environmental and economic issues - license to operate.
2. the F-axis referring to geologic, geophysical, geochemical, geomechanical and installation technical issues - the ability to operate.
3. the G-axis denotes the confidence in the estimates of the resource quantity.

The basis for this classification scheme is "the project", all activities and hardware which link the geothermal source (subsurface heat) to the product (heat or power) delivered to the user or market (resource). The resources linked to the project are classified. Within The Netherlands we have 16 producing projects, 8 realised projects which are not in production yet and are waiting to be commissioned. Furthermore, a relatively large set of defined exploration projects in exploration licenses exists. Supplementing the realised projects and defined exploration project portfolio we define numerous notional exploration projects in areas within exploration licenses without defined exploration projects and a large "open" area. To all projects, all relevant information to perform a classification routine is added using the geothermal resource mapping results from ThermoGIS and auxiliary maps (e.g. licenses, nature reserves, topography, heat grids and other large heat demand sites). An example of a UNFC classified Dutch geothermal project is given in UNECE (2017). Case study 4 Rotliegend-3 Geothermal project and subsequently a case study example of how UNFC can be applied for nationwide geothermal resource reporting (case study 5) Dutch Rotliegend Play area – Nationwide. Case study 4 is loosely based on the Koekoekspolder Geothermal project of which the resources were classified (E2;F3;G4) as being a very mature exploration project of which the resource will be delivered to the consumer within the foreseeable future (5 years). The Koekoekspolder geothermal project has matured to a producing project, delivering heat to a number of greenhouses. Consequently, the resources of this project moved up to a higher mature resource classes: E1;F1;G1, E1;F1;G2, E1;F1;G3 for respectively the low, medium and high resource estimates. Figure 3 graphically depicts the UNFC project fingerprint of the Koekoekspolder project in the exploration and production phase.

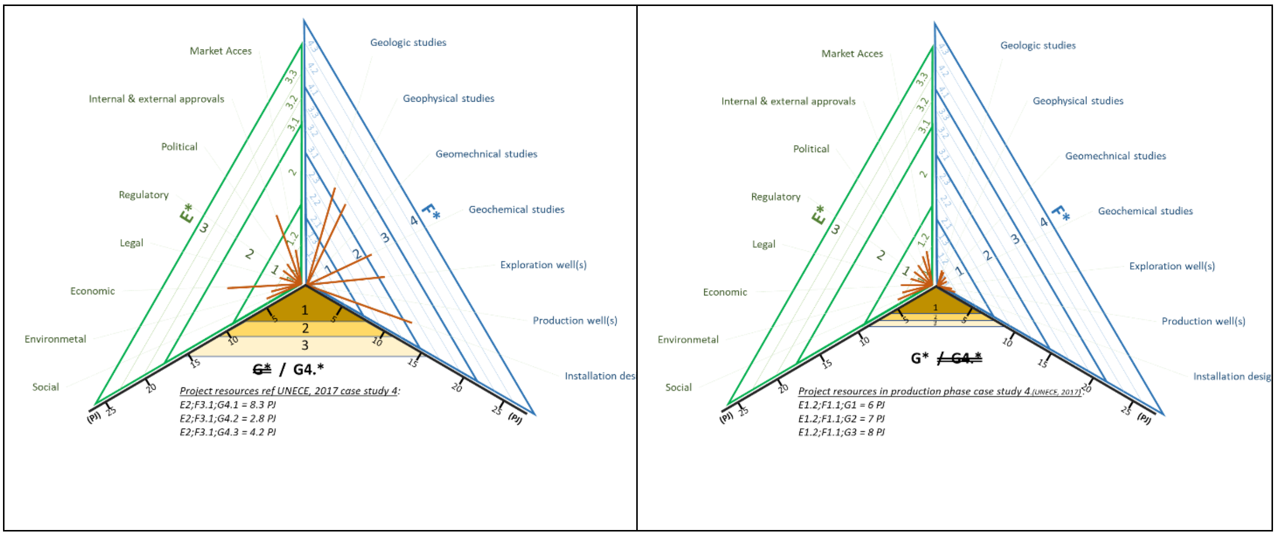

Figure 3: UNFC-project fingerprint of the same case study project before drilling in the exploration phase and after in the production phase. Uncertainty in the latter is related to the project lifetime.

This study is revisiting and expanding the nationwide case study (UNECE 2017) with real data to result in a state of the art geothermal resource estimate. Based on the quantification methods for the different projects and the attributes assigned to all notional and defined project locations we can define and code the following set nine maturity classes for the Dutch geothermal resources according to UNFC for 2019:

- Known Geothermal resources (drilled)
  - Commercial projects on production (E1.2;F1.1;G*)
  - Commercial projects approved for development (E1.2;F1.2;G*)
- Exploration projects (E2;F3.1:G4 or E3.*;F3.*;G4) whether they are:
  - Defined or undefined (notional) and
  - in data-rich or poor area and
  - in or outside the environmentally sensitive area and
  - developed within the foreseeable future or not

*the * gives the position for definition of more detailed sub-classes: E3.2, E3.3, F3.1, F3.2 or F3.3* (UNECE 2016b)

Definitive figures will be presented through MEA reports and at the conference.

3. CONCLUSIONS

The nationwide resource reporting in the Netherlands using the UNFC resource classification scheme provides an adequate level of structuration to consistently and unambiguously classify quantified geothermal project resources. The project maturity, given by its position on the E- and F-axis, gives an indication of the likelihood when the resources come to the market. In the nationwide Dutch geothermal projects portfolio projects grade from highly mature, commercial, producing geothermal systems to very immature, notional exploration projects in hot sedimentary geothermal play areas. A fingerprint plot illustrates the amount of resources that are characterized using the socio, environmental and economic issues as well as the technical issues on the E- and F-axis respectively. Adding the resources with a specific project fingerprint and reporting them discloses the amount of missed potential in energy (PJ or MWh) related to the inhibiting factor as for example “low data density”, or nature reserves.

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