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The Dutch Geothermal Resource Base: Classified Using UNFC Resource Classification System and its Potential to meet The Dutch Geothermal Ambition.

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ABSTRACT

Within the Netherlands, 24 geothermal systems have been realized of which 18 added to production of 3.7 PJ of heat in 2018. The main application domain is horticulture. The ambition of the Dutch government is to increase the production of geothermal energy in the Netherlands to 15 PJ in 2030, subsequently 110 PJ in 2050 and to expand the application domain to district heating and industry. Kramers et al. (2012) published an article on the direct heat resource assessment stating that the recoverable heat amounts to just over 63000 PJ, assuming a reinjection temperature of 35 °C. This resource estimate combines all direct heat projects regardless of their maturity. 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.

In January 2019, 78 exploration licenses are active or have been applied for. At least one geothermal project is defined in each of these licenses, at different levels of advancement. Outside the existing licenses and licenses applied for, The Netherlands provides ample space for geothermal development by geothermal projects, yet in a conceptual stage. At the moment, there are no tools or practical methodology to integrate all the available information in a coherent and automated manner. Furthermore, 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 relieve the obstruction issues to reach the 2030-2050 geothermal ambitions.

In this study, we show the 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 webtool ThermoGIS. ThermoGIS which uses information on the Dutch subsurface derived from the regional mapping by the Geological Survey and which is updated by incorporating newly gained insights and data, provides a comprehensive overview of the geothermal potential for a selected set of aquifers.

The resource estimate, including the uncertainty range related to these figures, at the status date 1-1-2019 of the Dutch geothermal “project portfolio” is 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. Furthermore, some additional development options are introduced like installing heat pumps on relevant projects and stimulation on projects with poor productivity to increase the resource potential. Next level analysis envisages that future projects are given an attractivity attribute reflecting, amongst others, proximity to areas of favourable heat demand, proximity to heat network, which will guide the order of the exploration drilling sequence. An estimate on the geothermal portfolio maturation speed will then reflect on the minimum number of wells to be drilled to reach the geothermal ambition.

1. INTRODUCTION

Over a period of 12 years, the geothermal energy production developed from none in 2007 to 3.7 PJ in 2018 (Figure 1) (MEA 2019). At the status date (01-01-2019), there are 24 geothermal systems realized of which 16 were producing, two are put on hold, two temporarily suspended and four are starting up (MEA 2019). 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 Netherlands has ample geothermal resources in Hot Sedimentary Aquifer plays (Kramers et al. 2012). Kramers et al. state that the recoverable heat amounts to just over 63000 PJ, assuming a reinjection 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.

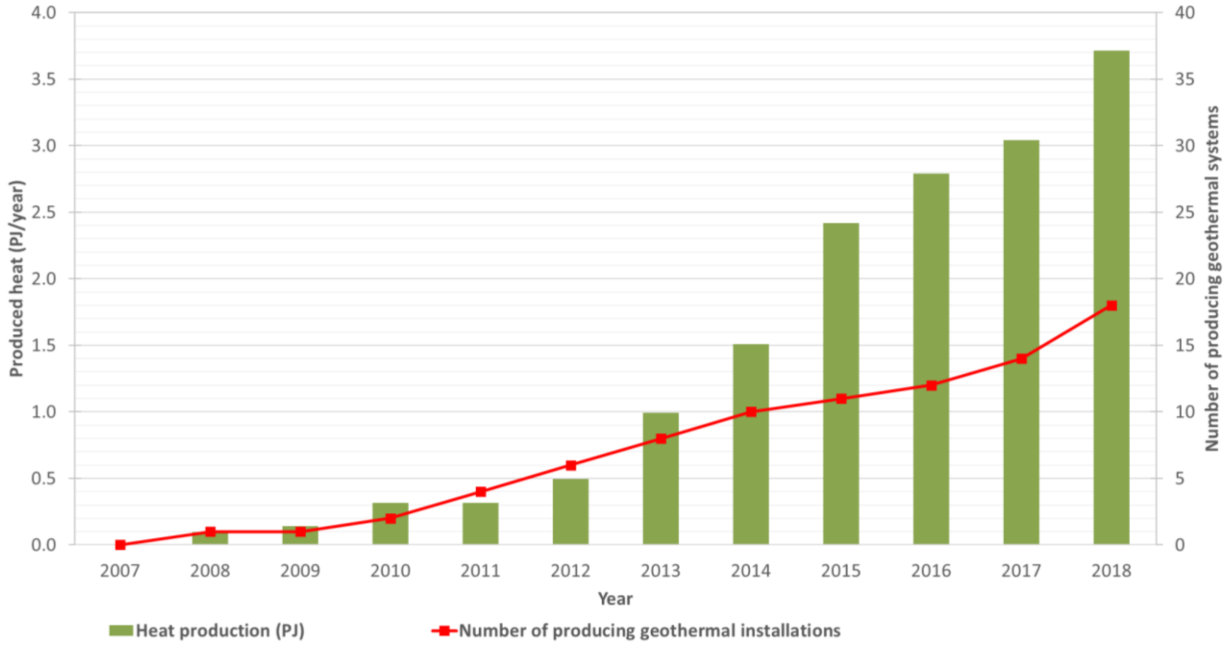

Figure 1: Yearly Dutch geothermal heat production from 2007 till 2018 and the number of geothermal systems which added to the heat production. (status date 1-1-2019, from MEA 2019)

The sustainable energy ambition of the Dutch government is to be independent of fossil fuels such as 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: 15 PJ in 2030, subsequently 110 PJ of yearly energy supply of geothermal energy in 2050 (Figure 2). Additionally, the Geothermal sector has communicated more ambitious goal in the Masterplan (EBN et al. 2018): 50 PJ in 2030, subsequently 200 PJ of yearly energy supply of geothermal energy in 2050.

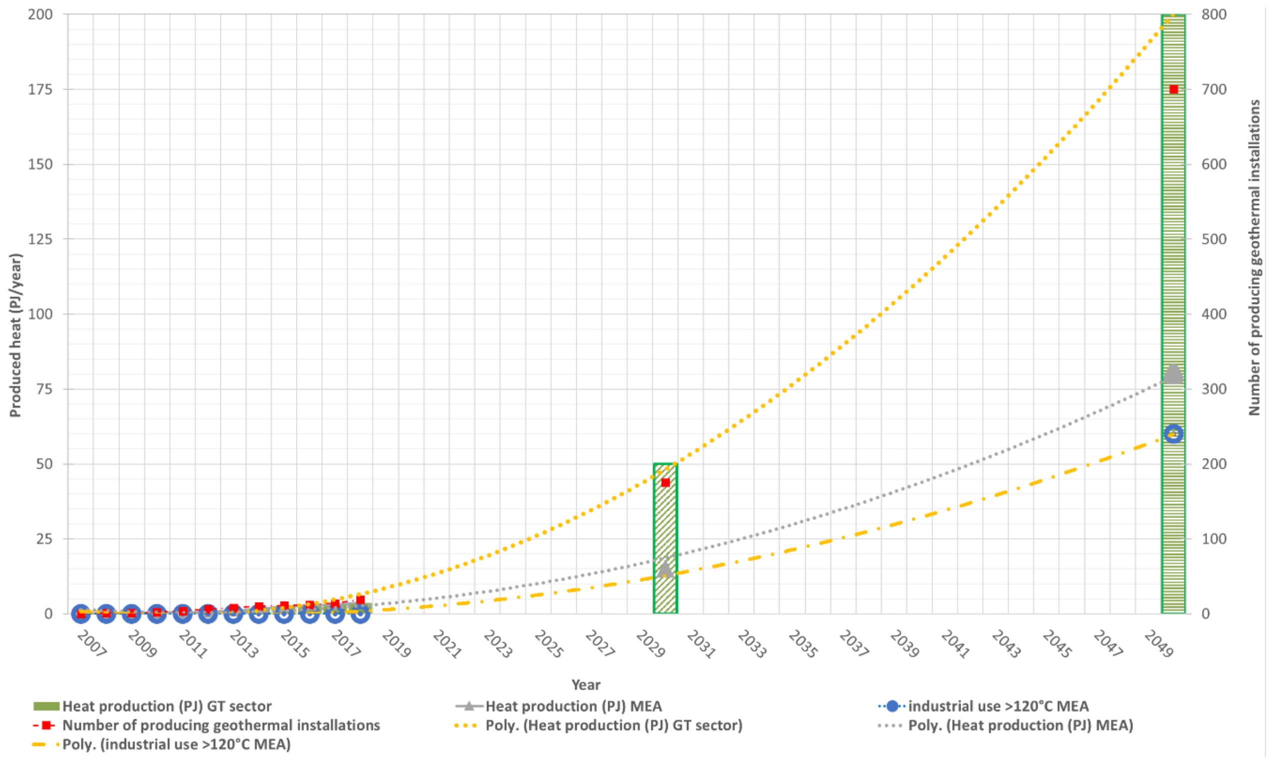

Figure 2: Extrapolation of geothermal production: historic production to ambitions of MEA and geothermal sector.

The rate of the realization of projects and the increase in production of geothermal energy in the Netherlands lags compared to power generation from solar and wind as well as compared to biomass for heat (Figure 3), 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 the uncertainty around potential energy production due to geologic uncertainty but also the uncertainty in the off-take of the produced heat are perceived as the main reasons.

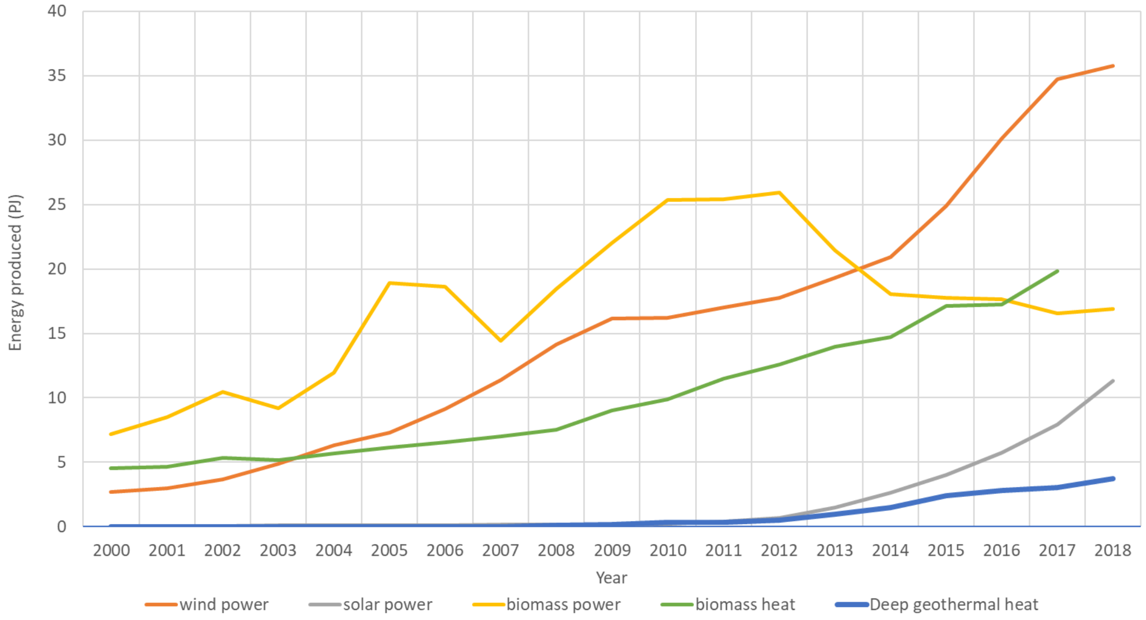

Figure 3: Comparison of Sustainable energy production types in the Netherlands: Wind, solar and biomass Power generation and Biomass and geothermal heat production. (sources: CBS and MEA)

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.

Geothermal resources are defined conform UNECE 2016 "*... the cumulative quantities of Geothermal Energy Products that will be extracted from the Geothermal Energy Source, from the Effective Date of the evaluation forward (till the end of the Project Lifetime/Limit), measured or evaluated at the Reference Point*.". UNFC is a project-based classification scheme. Resources are linked to a project and "the project" comprises all activities and hardware which link the geothermal source (subsurface heat) to the product (heat or power) delivered to the user or market (resource). Consequently, resources are a prediction of future production quantities, and as the well-known quote states "*Prediction is very difficult, especially about the future*", we will present our attempt to estimate the Dutch geothermal resource base, considering geological uncertainty and subsequently classify them based on project maturity which essentially relates to the uncertainty of project maturation.

2. GEOTHERMAL RESOURCE QUANTIFICATION

Before resource classification can be carried out, the resources 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 whether a project is in the production phase, commissioning phase or the exploration phase. Depending on the project's maturity class, we have defined a quantification method specifically geared to the availability, detail and type of relevant data, which is of course dependent on the project maturity stage. The project characteristics necessary for E and F-axis classification are described at a general, high level adequate for maturity evaluation. Environmental and data technical considerations like proximity to nature reserves, drinking water protection areas, or poor subsurface data coverage are assigned to projects using GIS.

2.1 Resource quantification and general project description of the producing geothermal systems

The uncertainty of subsurface parameters relevant in estimating the geothermal resources of 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 conditions, we use historical production figures and reservoir characteristics to predict the future production profile. Under the Dutch mining law operators must submit their monthly production figures including energy produced (GJ) and number of operational hours (flow >0 through the system) (Figure 4A). As can be seen from Figure 4A and B the typical yearly production profile has a seasonal swing: in winter approaching max capacity and in summer with low heat demand relatively low capacity. From there the average monthly energy per operational hour is calculated over the operational life of the system. The low and high estimates for the hourly production volume are taken as plus or minus 10% of the average value. The number of operational hours per year is calculated averaging the yearly operational hours of years without periods of unintentional system shutdown (normal maintenance shut-downs are included). We assume the system will perform under similar conditions until life-end.

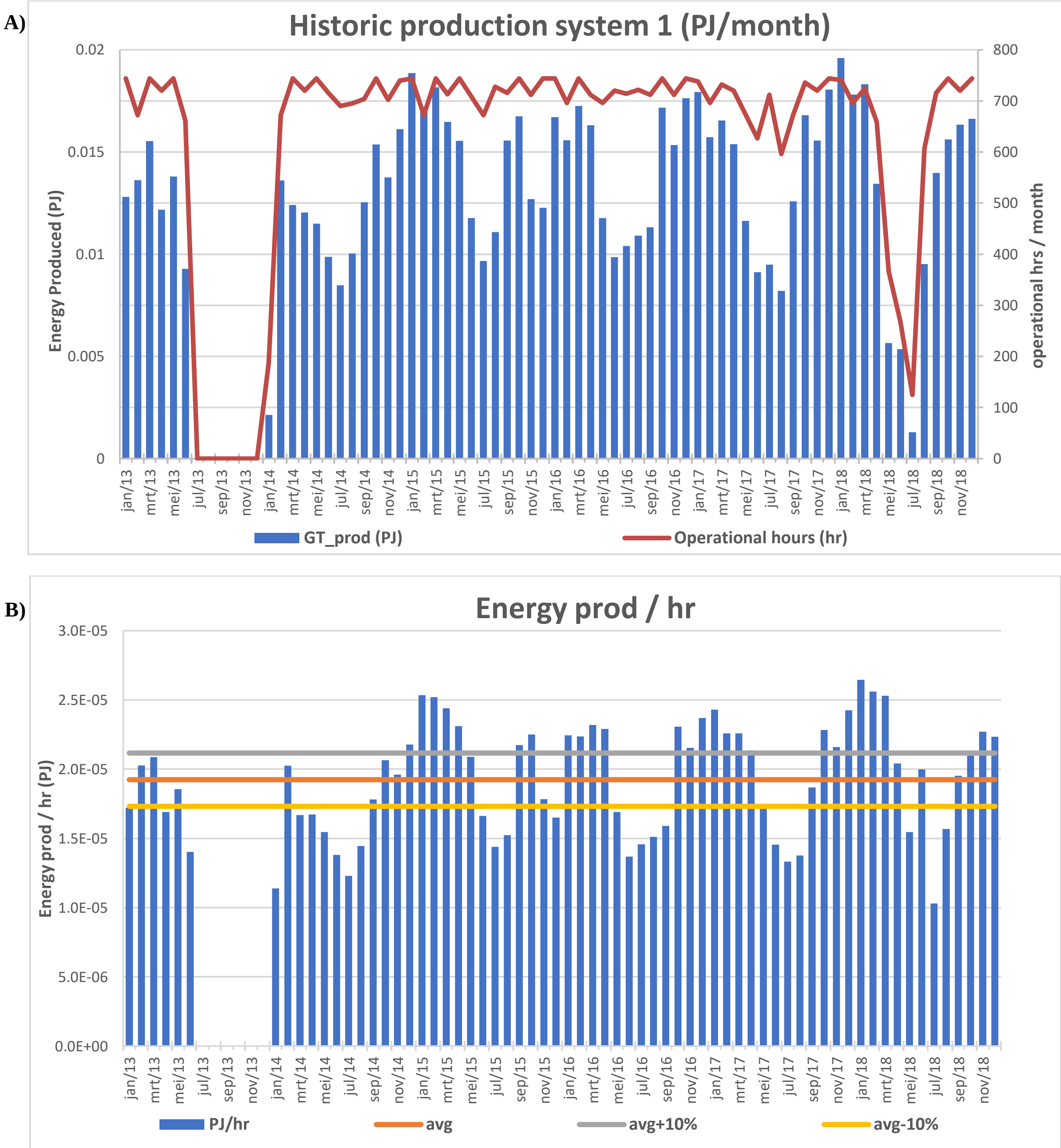

Figure 4: Production data analysis of a producing geothermal system. A) the monthly energy produced and the number of operational hours. B) figure A converted to monthly energy produced per hour (blue bars) and the average energy production per hour over the operational time plus & minus 10%.

The project lifetime depends on the temperature breakthrough, the economic limit, design life, contract period and entitlement period. For this study, firstly we assume the project economics will not be adversely influenced when for example the feed-in premium is ended because the project economics are designed for the 15-years grant period. After the 15-year feed-in premium period, only OPEX and routine maintenance are expected to be the main expenditure which is assumed to be profitable against future heat energy price. Secondly, the standard production license period in the Netherlands is 35 years. We assume that, if needed, an extension of the production license will be granted if the resource is not exhausted, as is the case with Dutch oil & gas production licenses. Thirdly, 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 a function of thermal breakthrough. 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.

For each project the resources are calculated by stochastically multiplying the hourly energy production (range), the average operational hours and the expected lifetime. At each stochastic draw, the resources of each project are added giving one resource estimate of the producing geothermal system class. Thousand of these realisations will provide the resource estimate, including an adequate uncertainty range, pertaining to this class. Additionally, the energy to be produced in the coming 50 years is captured as well (Figure 5).

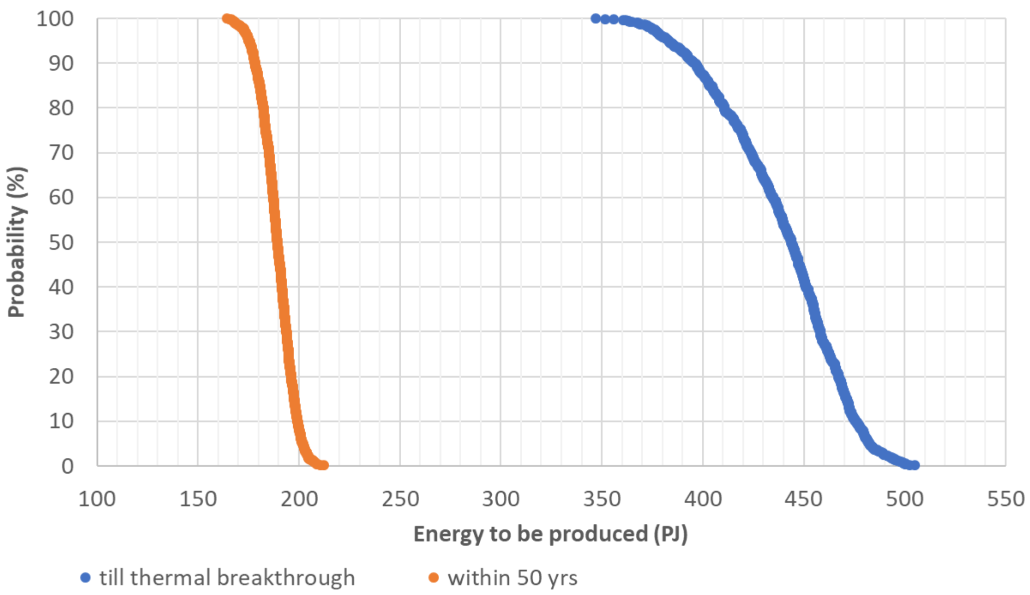

Figure 5: Example Probability Function of the geothermal resources from producing geothermal systems. Two scenario's a) till cold water breakthrough (blue curve) and b) within the coming 50 yrs under the present operating conditions (orange curve).

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. The reservoir is known because it has been drilled and the reservoir properties pertaining to the project are based on the production test results and well log data. The installation power is calculated using DoubletCalc1D (Mijnlieff et al. 2014) using the reservoir parameters as encountered in the wells, including an updated (narrower than pre-drill) uncertainty range. Additionally, the thermal breakthrough time is estimated using a deterministic static reservoir model in DoubletCalc2D (Veldkamp, 2015, Pluymaekers et al. 2016) based on the most likely reservoir parameters encountered in the wells. The anticipated future energy production of this "not yet producing geothermal system class" is calculated like the producing systems. For each project the resources are calculated by stochastically multiplying the geothermal thermal power estimate (assumed to be the name plate capacity of the system), 6000 yearly full load hours and the expected lifetime. At each stochastic draw the resources of each project are added giving one resource estimate of the "not yet producing geothermal system class". Thousand of these realisations will provide the resource estimate, including an adequate uncertainty range, pertaining to this class. Additionally, the energy to be produced in the coming 50 years is captured as well. Like the producing systems, it is assumed that the project will still be economic after the 15 years feed-in premium period and that after the generally 35 years production license period an extension will be granted if needed. The projects implement proven techniques, no technical hurdles are foreseen. 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 et al., 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 (6000 hrs being the feed-in premium scheme default value) and the systems life time of the future energy production are calculated for these projects and thus the resources. The procedure is similar to the realised but yet to be commissioned projects. The main difference is the larger uncertainty of the power estimate as a result of the still unknown reservoir properties because the reservoir is undrilled at the project location. It is assumed that after drilling when the project is realised, the area of influence of the geothermal doublet will be granted as a production licence and that similar to the producing systems, it is assumed that the project will still be economic after the 15 years feed-in premium period and that after the generally 35 years production license period an extension will be granted if needed. The projects implement proven techniques, no technical hurdles are foreseen.

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 v2.1 (Pluymaekers et al. 2012 and Vrijlandt et al. (2019, this volume)) to assess the geothermal potential. ThermoGIS provides nationwide geothermal potential maps on a 1km x 1km grid. On each of the grid cells a 'notional project' is defined. These are projects with a default project setup. ThermoGIS v2.1 (see www.thermogis.nl) provides geothermal power maps for six major geothermal plays: Cenozoic (N), Lower Cretaceous (KN), Upper Jurassic (SLDN), Triassic (TR), Rotliegend (RO) and Upper Carboniferous (DC). The Geothermal Power maps are calculated using a stochastic techno-economical module, based on a geothermal development with two wells (doublet), which is similar to the approach explained in Van Wees et al. (2012). This module uses, as input, subsurface, technical and economical parameters. Most of the input parameters are constant except for two optimized parameters and reservoir properties for which nationwide maps were created (per play): depth, thickness, net-to-gross, permeability, and temperature. Low (P90) and high (P10) estimates are available for the thickness and permeability, which results in P90, P50 and P10 expected power maps. The injection-production well distance and drawdown pressure are optimized, per location, per play. The well distance is minimized while having a maximum decrease in temperature difference (production-injection) of 10% after 50 years of production. The drawdown pressure is optimized using three subsequent steps: 1) flow/injection pressure is optimised minimizing unit technical cost; 2) injection pressure is capped not to overstep the legal, depth dependent, maximum injection pressure threshold (Mining Authority (State Supervision of the Mines) 2016) and 3) flow rate is capped at 500 m^3/hr (Vrijlandt et al. (2019, this volume)). The techno-economical model also yields levelized cost of energy maps in €ct/kWh.

The ThermoGIS power maps, together with an assumed 6000 annual load hours, a lifetime of 50 years and a sorting factor of 1, can be used to calculate geothermal resources per grid cell. The sorting factor determines how well the doublets are organised geographically. Side by side ordering results in a sorting factor of 1 and a random distribution corresponds to a sorting factor of about 0.6. For this evaluation a sorting factor of 1 is used. The calculated resource is then inversely weighted by the influence area of the geothermal doublet (two times the square of the optimized well distance for that doublet, (TNO 2014)). The grid cells of the resulting weighted geothermal energy maps can subsequently be summed to obtain a geothermal resource estimate for the P50 case. For the P90 and P10 cases this is not possible: if one project finds the P90 energy estimate, it does not mean that all the other projects find the P90 energy estimate as well. But the result of a project will influence other projects in the vicinity of that project, in the same play. Geothermal prospects have a certain lateral dependency related to the lateral predictability of the reservoir properties e.g. the range in kriging routine.

To include the lateral dependency of the geothermal prospects, we use the methodology as depicted in Figure . Per play, we create a set of 1000 random P-value maps, one for each stochastic realisation, which captures the lateral dependency. It is constructed using 2D spectral simulation using Gaussian variograms which are defined by a range, anisotropy value and anisotropy direction. These parameters are set per play. For instance, the Rotliegend play has a large range to account for its lateral continuity. This will result in a P-value map with large scale undulations. Next to the P-value maps, energy distributions are created per grid cell based on the P90, P50 and P10 energy (resource) maps using a double triangular distribution (see Figure 8). Subsequently, per stochastic realisation, per grid cell, the P-value is used to draw an energy value from the energy distribution. This energy value is then the resource of the incipient exploration project at that specific grid cell and stochastic realisation. Next, a selection of grids cells is made that have a levelized cost of energy, which is lower than the feed-in premium amount, meaning that the project is economic. These selected grid cells are summed to obtain the resource number for the realisation, whereby the areas covered by existing geothermal projects (producing, commissioned or defined exploration) are removed. These 1000 realisations form a geothermal resource distribution from which the P90 and P10 resource numbers can be obtained. This procedure is done per play. The plays are summed, assuming that they vary independently from each other, to obtain the total geothermal resources numbers for the Netherlands.

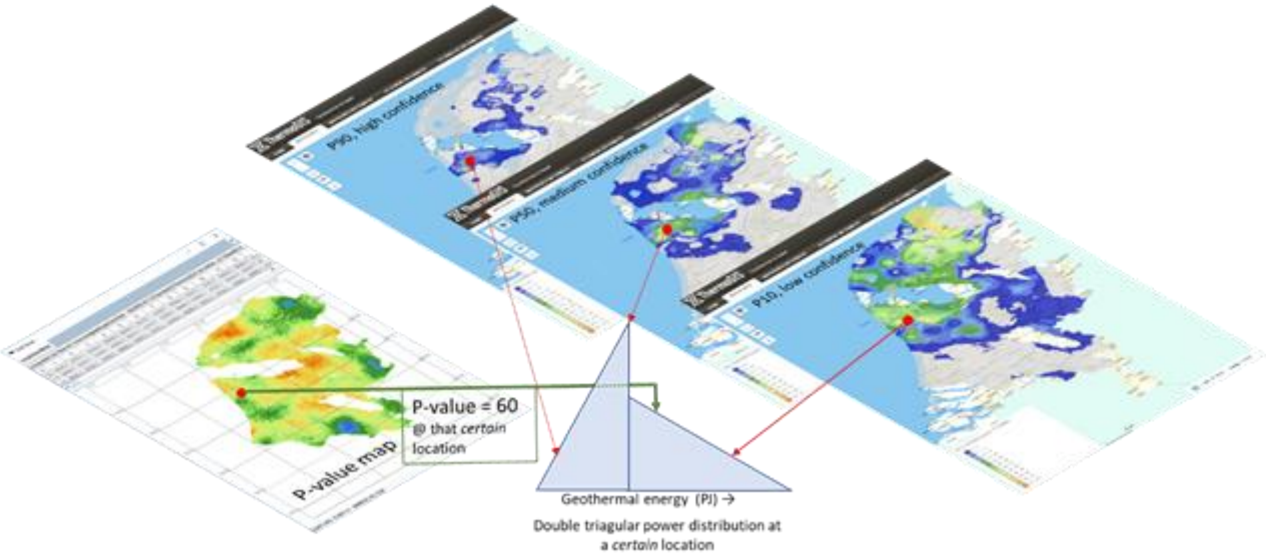

Figure 6: Method to stochastically aggregate the exploration resources taking into account lateral dependency of exploration results.

These total geothermal resources numbers, excluding areas where producing systems, to be commissioned systems and defined exploration projects are situated, will give the basis of the yet undefined exploration projects or notional projects.

Additionally, the amount of resources that fall into certain areas, which could affect the project maturity rate, are calculated. These areas are for example:

- the location in or outside a nature reserve,
- large bodies of water,
- drinking water production or protection areas
- low data density areas.

This is used to sub-divide the notional project portfolio in, for example, ones situated in low or high data density areas or situated in nature protected areas. It provides the option to assign geothermal resources to specific types of ‘difficult’ areas.

3. GEOTHERMAL RESOURCE CLASSIFICATION: DUTCH GEOTHERMAL RESOURCES AND UNFC

In the previous paragraphs the resource quantification is explained. Additionally, per quantified class of projects a very generalised project definition and description is provided essential for the classification. 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 all type of resources UNFC-2009 (UNECE, 2013, UNECE 2016a). 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]):

1. the E-axis referring to social, environmental and economic issues -i.e. the license to operate.
2. the F-axis referring to geologic, geophysical, geochemical, geomechanical and installation technical issues -i.e. 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 geothermal projects of the various project maturity classes are quantified as presented in the previous paragraphs. These resource estimates are classified on the G-axis. Because in the UNFC the G1, G2 and G3 are incremental to one another the G1 will be the low (P90) estimate, G1+G2 the mid (P50) estimate and the high (P10) estimate as G1+G2+G3.

At the status date (01-01-2019), there are 24 geothermal systems realized of which 16 were producing, two were put on hold in 2018 for a prolonged period of time, two were temporarily suspended pre-2018 and four realised projects which are not in production yet and are waiting to be commissioned (MEA 2019). Restart of the two projects on hold may occur when underlying issues have been resolved adequately. Furthermore, a relatively large set of defined exploration projects in exploration licenses exists. Supplementing the realised projects and defined exploration project portfolio we defined numerous notional exploration projects in areas within existing exploration licenses and the 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).

This study is revisiting and expanding the nationwide case study (UNECE 2017) with real data to result in a preliminary, state of the art geothermal resource estimate. Based on the project maturity we can define and code five main maturity classes for the Dutch geothermal resources according to UNFC for 2019. Conform UNFC we divide the geothermal project resource portfolio in "known" and unknown resources. The former are all resources from projects in which the geothermal target aquifer has been drilled. The latter include all exploration projects for which the geothermal target still needs to be drilled. This twofold classification is further detailed along project maturity lines.

3.1 Known reservoirs

The projects which have drilled (reservoir known) are either producing, in the commissioning phase or on hold. Finalised projects where the wells are plugged and abandoned are not yet seen in the Netherlands.

For the Dutch geothermal projects on production, it is observed that project economics rely on the feed-in premium scheme. As stated in paragraph 2.1 all licenses to operate are in place and the systems are on production. Subsequently, the coded UNFC classification for this project class on the E and F axis is E1.2; F1.1 meaning commercial projects on production. The resource estimate is classified on the G-axis along the lines explained above. The results are given in Table 1.

At the status date two geothermal systems which were producing are forced to be on hold due to seismicity. The license to operate is (temporarily) suspended. Studies are done which need to prove that restart of operations are feasible and viable within set hazard and risk thresholds. In UNFC terms "activities are ongoing to justify restart of production in the foreseeable future" resulting on the E and F axis in an UNFC coded class: E2; F2.1 meaning potentially commercial projects for which development is on hold. The resource estimate is classified on the G-axis along the lines explained above. The results are given in Table 1.

At the status date, six geothermal are nearing commissioning. The reservoir is drilled, the licenses to operate are granted or in the process of being so. No unresolvable technical issues are foreseen as the systems rely on proven techniques in well known reservoir intervals. Thus, all licenses to operate are (nearly) in place, production is economic with governmental support and will commence within a reasonable timeframe. In other words, implementation/commission of the projects is underway. This results on the E and F axis in an UNFC coded class: E1.2; F1.2 meaning commercial projects approved for development. The resource estimate is classified on the G-axis along the lines explained above. The results are given in Table 1.

[1] In this chapter sentences in italic are taken from UNECE 2016b

3.2 Unknown reservoirs

Within all the geothermal exploration licenses we know of some 44 defined exploration projects. Those projects have submitted detailed location specific geological and technical studies including a DoubletCalc1D power estimate. All licenses to explore are in place. Drilling will commence in the foreseeable future (some 5 years) and when successful the grant of further necessary licenses as e.g. the production license is expected to be in place in the foreseeable future as well. All technical studies are done or being worked at. The project relies on proven techniques. By drilling a well, the presence of the source and resources must be proven. Therefore, the coded UNFC classification for this exploration project class on the E-axis is E2, *(Extraction and sale is expected to become economically viable in the foreseeable future.*) and on the F axis F3.1, (*Where site-specific geological studies and exploration activities have identified the potential for an individual deposit with sufficient confidence to warrant drilling or testing that is designed to confirm the existence of that deposit in such form, quality and quantity that the feasibility of extraction can be evaluated*) resulting in E2;F3.1. The resource estimate is classified on the G-axis along the lines explained above. The results are given in Table 1.

In Table 1 the subsets of the "undefined exploration class" are listed.

Table 1: Preliminary figures of the classified Dutch resource portfolio in PJ of the 6 major Dutch geothermal plays. The figures are valid for a 50 years lifetime independent of thermal breakthrough. Note these are preliminary figures.

<table>
<tr><th colspan="4">UNFC Classes Defined by Categories and Sub-categories</th><th colspan="5">Resource</th></tr>
<tr><td>Extracted</td><td colspan="3">Cumulative Sales Production (2007 – 2018)</td><td colspan="5">16 PJ</td></tr>
<tr><td colspan="2" rowspan="2">Class</td><td colspan="2" rowspan="2">Sub-class</td><td colspan="5">Geothermal resource Categories (@2019)</td></tr>
<tr><td>E</td><td>F</td><td>G1</td><td>G1+G2</td><td>G1+G2+G3</td></tr>
<tr><td rowspan="3">Known Geothermal source</td><td rowspan="2">Commercial Projects</td><td colspan="2">On Production</td><td>E1.2</td><td>F1.1</td><td>159</td><td>167</td><td>175</td></tr>
<tr><td colspan="2">Approved for Development</td><td>E1.2</td><td>F1.2</td><td>232</td><td>267</td><td>299</td></tr>
<tr><td>Potentially Commercial Projects</td><td colspan="2">Development On Hold</td><td>E2</td><td>F2.1</td><td>29</td><td>30</td><td>31</td></tr>
<tr><td colspan="2">Class</td><td colspan="2">Sub-class description</td><td>E</td><td>F</td><td>G4.1</td><td>G4.1+G4.2 = G4</td><td>G4.1+G4.2+G4.3</td></tr>
<tr><td rowspan="7">Potential Geothermal source</td><td rowspan="7">Exploration Projects</td><td colspan="2">Defined, exploration projects: good data position, no sensitive area, LTO OK, drilling in foreseeable future (FF)</td><td>E2</td><td>F3.1</td><td>773</td><td>825</td><td>878</td></tr>
<tr><td colspan="2">Undefined exploration projects, drilling not in foreseeable future</td><td>E3</td><td>F3</td><td>27000</td><td>30000</td><td>34000</td></tr>
<tr><td colspan="2"></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Subsets of Undefined exploration projects, drilling not in FF and in difficult areas</td><td>Undefined exploration projects, in data poor areas</td><td>E3.2</td><td>F3.3</td><td>?</td><td>2663</td><td>?</td></tr>
<tr><td>Undefined exploration projects, drinking water protection areas</td><td>E3.3</td><td>F3.2</td><td>?</td><td>803</td><td>?</td></tr>
<tr><td>Undefined exploration projects, in nature reserves</td><td>E3.3</td><td>F3.2</td><td>?</td><td>2291</td><td>?</td></tr>
<tr><td>Undefined exploration projects, seismically active area</td><td>E3.3</td><td>F3.2</td><td>?</td><td>?</td><td>?</td></tr>
</table>

As explained in section 2.4 there is ample space in the Dutch geothermal plays to define notional geothermal projects. The evaluation resulted in more the 20,000 notional projects in the 6 geothermal plays mapped in ThermoGIS. These projects are very immature. Licenses should be applied for, social acceptance arranged, location specific geological and technical studies being performed. It is expected those will not be finalised soon and production will not start within the foreseeable future (5 yrs.). In our evaluation approach we have implemented drilling and operational strategies using proven techniques. The UNFC classification for these exploration project class on the E respectively F axis is: E3, *Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability* and F3 *feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data*. Thus resulting in E3;F3.

Some of these notional exploration projects lie in areas of low to very low data density. The E3 class may then be refined to E3.2 *Economic viability of extraction cannot yet be determined due to insufficient information (e.g. during the exploration phase)*. If these notional exploration projects lie in, colloquially named, difficult areas with restricted access to the land for this purpose, like nature reserves and dinking water protection areas, an even lower E-sub-class is applicable E3.3; *On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for extraction and sale in the foreseeable future. (amended UNECE 2016*).

ThermoGIS adequately addresses the regional geothermal potential. In the data poor areas, the resource estimates have a large spread typical for regional resource mapping results. The F3.3 class is the best characterisation of the project on technical maturity axis, *At the earliest stage of exploration activities, where favourable conditions for the potential discovery of deposits in a geological province may be inferred from regional geological studies*. Where the data position is good the geothermal power estimates form ThermoGIS maps show generally a less large spread, the F3.2 category is best applicable; *Where local geological studies and exploration activities indicate the potential for one or more deposits in a specific part of a geological province, but requires more data acquisition and/or evaluation in order to have sufficient confidence to warrant drilling or testing that is designed to confirm the existence of a deposit in such form, quality and quantity that the feasibility of extraction can be evaluated (UNECE 2016*)).

Table 1 provides preliminary figures for a default project lifetime of 50 years. All but the notional exploration projects may have longer lifetimes (Figure) the figures might prove to be an underestimation. Additionally, especially for the shallow Cenozoic reservoir with low temperatures, the resource can be boosted using a heat pump. ThermoGIS can provide the resource map of this play incorporating a heat pump scenario. Similarly, ThermoGIS can provide resources after stimulation of tight reservoirs. Scenario's including these proven techniques will increase the resource portfolio.

All figures are preliminary, definitive figures will be presented through MEA reports and at the conference.

4. 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) resources of geothermal projects. 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. Adding attributes to the projects denoting the proximity to difficult areas or data position further refines the classification and as such becoming useful in the policy domain. Adding these attributes to the classified resources, as a 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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