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Accelerating the Development of Geothermal Energy in the Netherlands

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ABSTRACT

To achieve the Dutch policy objective to reduce carbon emissions by 49% in 2030 and 95% in 2050, a shift from fossil towards renewable energy resources is required. Within the Netherlands, geothermal energy is a proven renewable energy resource for heat, but currently only with a limited number of operating installations focussing on temperatures between 60-100 ˚C in permeable aquifers. An acceleration of the development of the relatively young geothermal industry is required to make a significant contribution. It is predicted that geothermal energy could potentially provide around 20-25% of Dutch heat demand. The Dutch subsurface is well-known due to decades of hydrocarbon exploration and production resulting in a large public knowledge database of the subsurface, providing an almost ideal starting point for the development of geothermal projects. Integration of the knowledge and experience gained from the hydrocarbon era is very useful and needed for safe and responsible growth of the geothermal industry. A Master Plan Geothermal Energy Netherlands has been compiled by the market outlining the challenges to be addressed, the organizations that lead each challenge and the stakeholders involved in achieving an ambitious goal of 30PJ geothermal heat production in 2030 and 200PJ in 2050. Activities are distributed within 6 main focus areas: Improving profitability; suitable legislation and supervision; safe and effective operations; public support; innovation and heat (distribution) networks. In the coming years geothermal industry representatives will work together on each focus area to accelerate the development of safe and responsible geothermal activities. The Dutch government has already existing supporting measures in place for the development of individual geothermal projects ranging from a guarantee fund to a public-private partnership with the state-owned company EBN. However, in parts of the Netherlands, the amount of subsurface data is sparse and thus the uncertainty is deemed too high for the development of geothermal projects. The Dutch government has acknowledged this issue and is supporting several new data acquisition projects to reduce subsurface uncertainty. These projects follow the play-based portfolio approach, originating from the hydrocarbon industry. To investigate the potential of geothermal heat for industrial use, an Ultra Deep Geothermal Programme has been initiated. The development of deep geothermal energy projects is coordinated within this Ultra Deep Geothermal (UDG) Programme. Five consortia work closely together in the exploration and development of the first pilot projects and thereby reduces the risk of each individual project. Knowledge and expertise from the hydrocarbon industry is also brought into the UDG Programme to ascertain a safe and responsible development of the pilots. In central parts of the Netherlands, areas with high uncertainty with respect to the subsurface exist. These areas are typically densely populated with high heat demand but, to date, it remains unknown whether geothermal energy could be used. To further develop these areas, the Dutch government has initiated the SCAN ((a Dutch acronym which translates as; Seismic Campaign for Geothermal Energy in the Netherlands) programme. Within that programme, regional 2D seismic lines are acquired and geothermal exploration wells are planned to reduce subsurface uncertainty for future geothermal projects in these areas. By applying the play-based portfolio approach, better investment decisions can be made with regard to exploration wells and data acquisition. This will contribute significantly to the development of future projects in large areas.

1. INTRODUCTION

The Netherlands faces an important task: the goal of reducing CO2-equivalent emissions by 49% by 2030, and by 95% by 2050, in comparison to 1990 which requires, a shift from fossil fuels towards renewable energy resources. To achieve these targets, Netherlands must undergo a sustainable transition six times faster than is currently ongoing. Around 40% of the current energy demand in the Netherlands is used for heat, amounting up to 960 PJ and resulting in 71 Mton of CO2 which is around 40% of the total Dutch CO2 emissions. It is estimated that heat demand will decrease from the present day 960 PJ to 930 PJ in 2030 and 870 PJ in 2050 due to more efficient processes, increasing insulation and limited population growth. In 2050, a mix of sustainable technologies will be necessary to supply the ~870 PJ of demand for heat. A variety of solutions will be required to sustainably meet this demand for heat. Geothermal energy can play an important role as one of the solutions.

Within the Netherlands, geothermal energy is a proven renewable energy resource, even though it is a relatively new industry (Provoost et al., 2019, Vrijlandt et al, 2019, Bakema and Schoof, 2016). The regulation in the Netherlands makes a clear distinction in depth between the use of geothermal energy shallower than 500 m depth and the use of geothermal energy at depths greater than 500m. This paper focusses on the use of geothermal energy below a depth of 500 m. The number of operating installations with depths greater than 500 m is very limited compared to those needed to meet the challenge ahead (Bakema et al.,2020). In 2018, the sector contributed 3.6 PJ or 317 MWth towards the total heat demand of 960 PJ. The current growth is approximately 3-5 systems a year (Bakema et al., 2020). An significant acceleration of the development of the relatively young geothermal industry is required to make a material contribution to the carbon emission reduction in 2030 and 2050.

The Dutch subsurface is well-known and developed for decades due to hydrocarbon exploration and production resulting in a large subsurface knowledge database, providing an almost ideal situation for the development of geothermal projects. The Mining Act of the Netherlands states that data acquired in the Netherlands is made publicly available after five years, creating a relatively unique situation in the world. The Dutch geothermal sector has benefitted enormously from this data availability. However, the Dutch

subsurface is very heterogeneous and displays a complex variability in composition, complicating the development of geothermal projects.

This paper gives an overview of the acceleration steps identified by the sector and the steps already taken by the Dutch Government to increase the contribution of geothermal to the energy mix in the Netherlands.

2. MASTER PLAN GEOTHERMAL ENERGY IN THE NETHERLANDS

The Master Plan Geothermal Energy in the Netherlands is the result of collaboration within the geothermal sector itself, consisting of DAGO (Dutch Association of Geothermal Operators), SPG (Stichting Platform Geothermie), Stichting Warmtenetwerk and EBN (Energie Beheer Nederland). The Master Plan describes the potential and associated action plan for geothermal heat in the Netherlands, district heating networks and heat demand with the aim to accelerate the development of geothermal energy in a safe, responsible, sustainable and cost-effective manner (SPG et al., 2018).

To take the appropriate steps towards meeting the heat demand in the future, the partners in the Master Plan strive for 50 PJ in2030 and 200+ PJ of heat in 2050 as part of a fully renewable energy system. Towards 2030, it is important to expand in greenhouse horticulture and to connect to new and existing district heating networks in the urban environment. Between 2030 and 2050, the plan focusses primarily on the upscaling in the urban environment (district heating) and in industry using low/medium-temperature direct heat, depending on the results of UDG pilots. This possible contribution of geothermal energy in 2050 of the Master Plan was input for the Dutch Climate Act. As a result of the robust recent activities and the latest estimates of the potential, the targets of the Dutch Government has set for geothermal energy in the Netherlands has been set at 15 PJ for 2030 and 110 PJ for 2050.

Activities defined in the Master Plan are distributed within 6 main areas: Improving profitability; suitable legislation and supervision; safe and effective operations; public acceptance; innovation and heat (distribution) networks. In the coming years the sector will jointly work on each area to accelerate the development of a safe and responsible geothermal sector. Figure 1 shows an overview of the action plans.

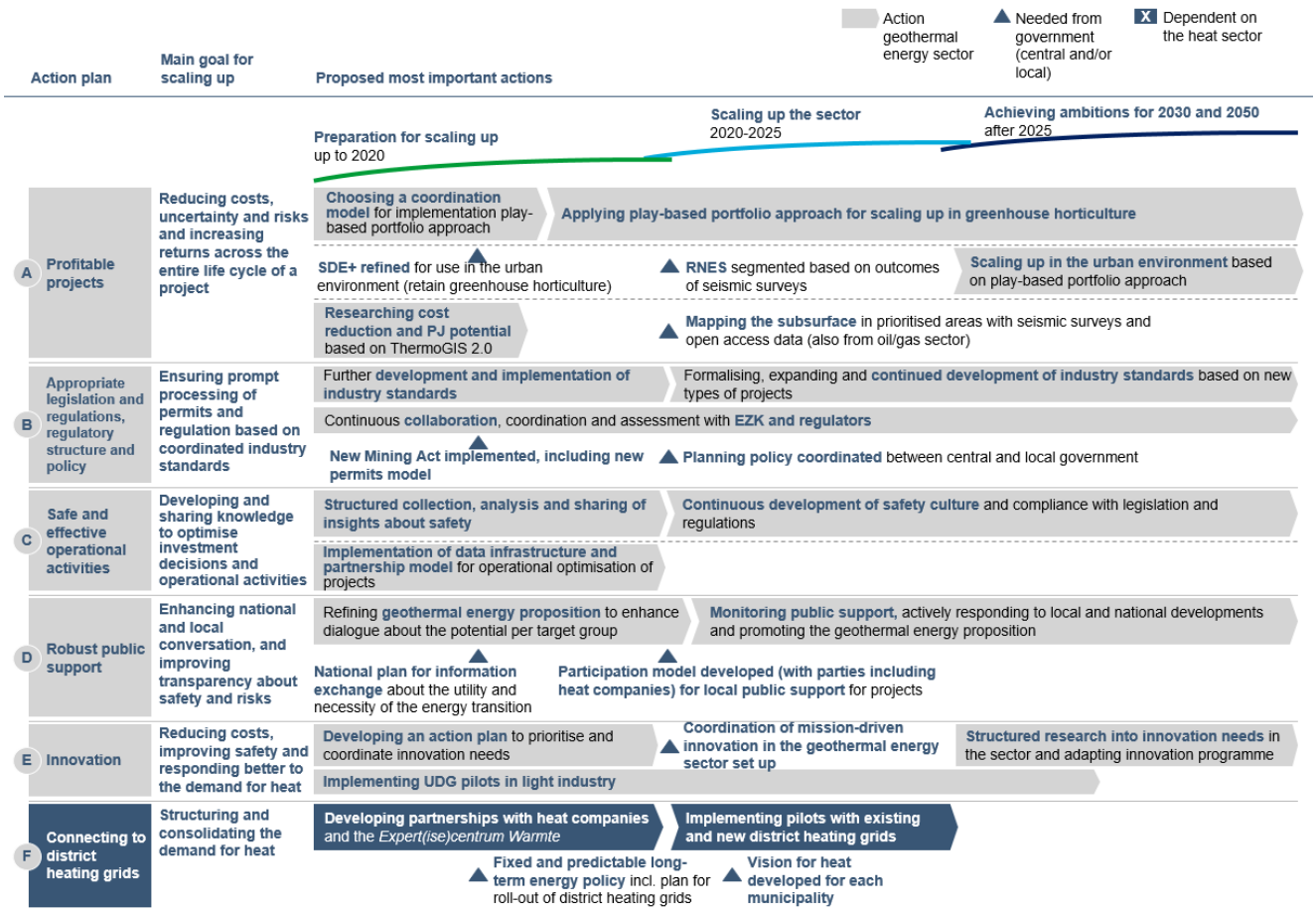


Figure 1: Summary of the priorities of the Master Plan Geothermal Energy in the Netherlands. For safe, responsible, sustainable and cost-effective up-scaling of geothermal energy, action is required in both the short and long term (SPG et al., 2018).

In the coming years, the Master Plan will be realised with important contributions from the sector and a broader field of stakeholders in and beyond the value chain. While the authors of the Master Plan will all play important and specific roles, all parties in the value chain can contribute. Figure 2 indicates the stakeholder field and value chain. Various stakeholders can be identified such as suppliers and consultants, as well as companies that purchase heat and transport it from the source to the end user. Anticipated end users together with knowledge and research parties are also partners in the scaling up of geothermal energy in the Netherlands. Various umbrella organisations also play a role e.g. in promoting and coordinating geothermal energy with other forms of sustainable energy

and industries. Central government and local authorities define and implement the necessary policy, legislation and regulations and regulatory structure, and offer advice about matters such as permit applications. Society at large, including citizens, local residents and the media will also play an essential role in shaping the demand for geothermal energy and in the social acceptance of geothermal energy in the Netherlands.

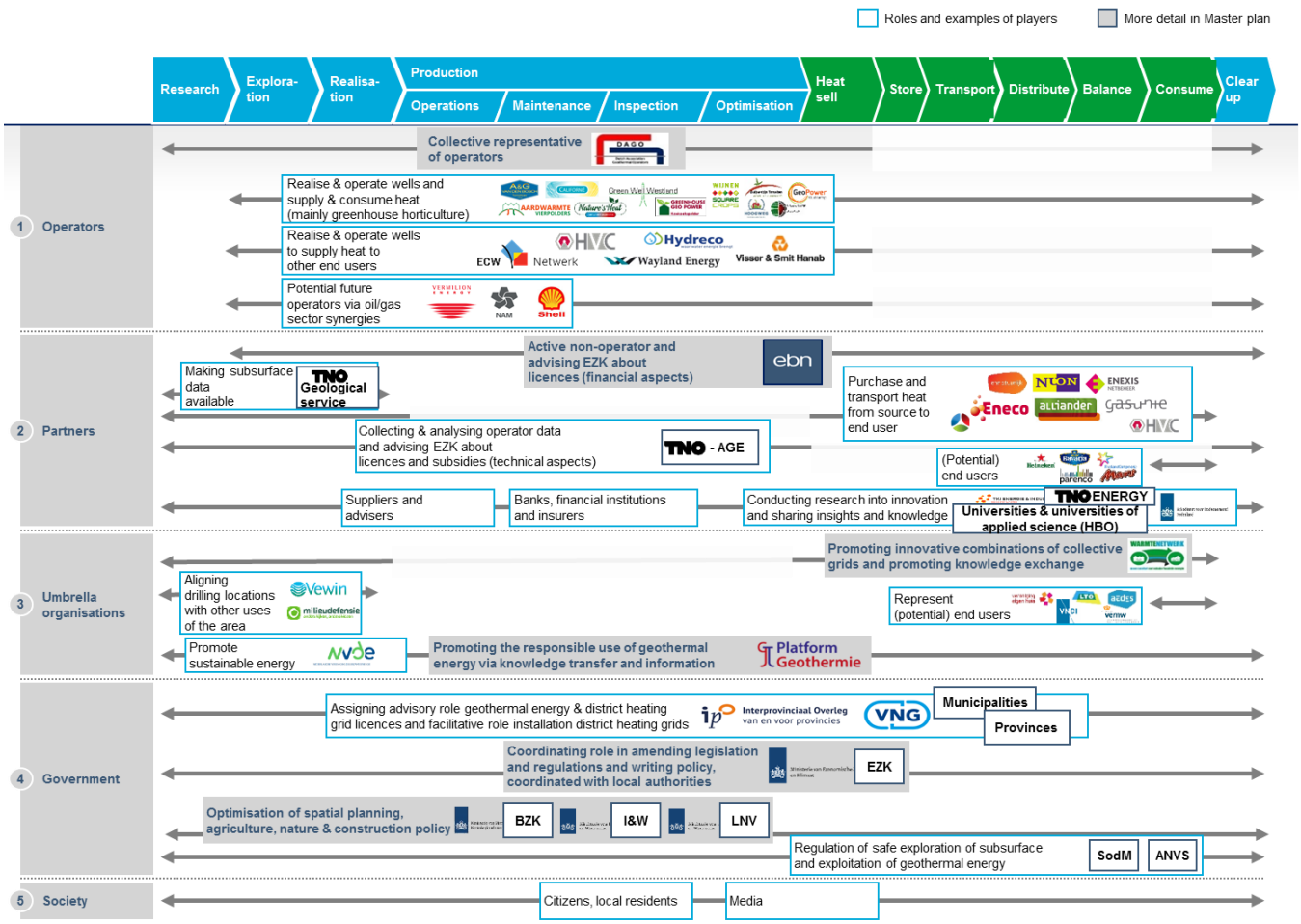


Figure 2: Geothermal energy value chain and stakeholders within the Netherlands (SPG et al., 2018).

The Master Plan has been evaluated in October 2020 which resulted in a positive view of how the sector has developed in the two years since the publication of the Master Plan. A lot of actions have been undertaken, and some of the major actions are still in progress. The different parties are working more closely together on different subjects, identifying bottlenecks and finding solutions in dialog with each other. This resulted in the completion of multiple activities and a better understanding throughout the sector. An update of the Master Plan is foreseen for 2021 in which the same six themes will be followed and priorities will be made to be able to focus on the most important actions.

3. ACCELERATION ROUTE BUILT ENVIRONMENT

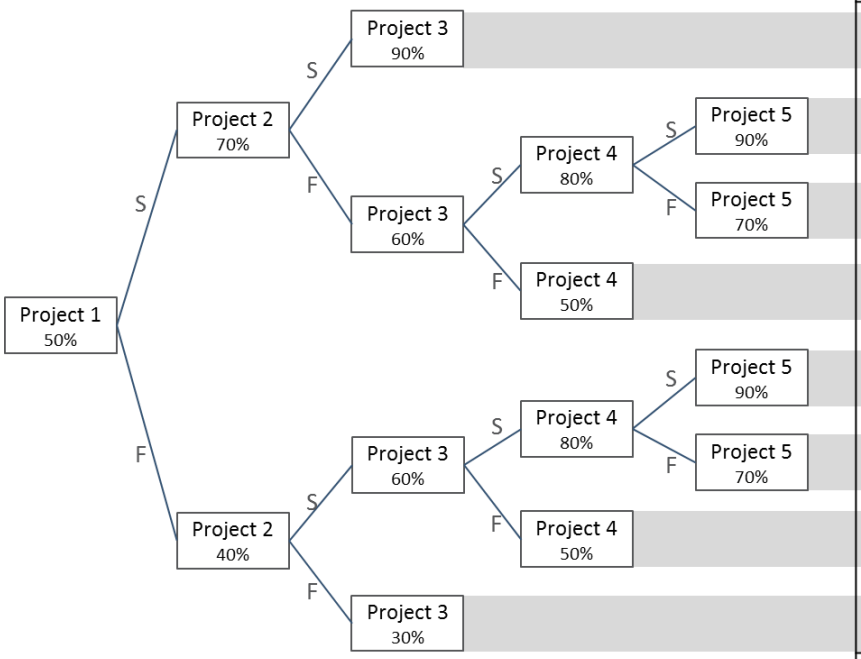
In spring 2020, the Ministry of Economic Affairs started together with people from the industry the core team for the acceleration of geothermal energy specifically in the built environment. The core team will deliver a report that encourages both the sector as well as the government to take action and that offers action perspectives for the acceleration of geothermal energy in the built environment for the next ten years. A broad group of stakeholders is involved such as operators, energy companies, network operators, corporations, financial institutions, sector organisations, governments and social organisations. Three subgroups work on the challenges specific for the built environment. The subgroup working on proposition of geothermal for the built environment works on the lowering of the costs, an increase in sustainability and what support is necessary for the upscaling of geothermal energy in the built environment. The subgroup public support focusses on the worries of the residents and what municipalities corporations and utility companies need to give residents a positive opinion about geothermal energy as a heat source. The third subgroup is working on the governance and focusses on the legislation round the heat-transition and geothermal as well as a good cooperation between all stakeholders. The report is expected to be published at the end of February 2021.

4. PLAY-BASED PORTFOLIO APPROACH

One of the actions for profitable projects within the Master Plan is scaling up the sector. There are significant advantages of developing geothermal by a collective approach compared to the development of single doublet. A play-based portfolio approach, which is common in the oil and gas industry, can help in accelerating the development of the geothermal industry. A geothermal play is defined as geothermal potential based on the presence of water in a formation with comparable geological characteristics and circumstances. The basis of the methodology is a subsurface play-based approach, which enables geological uncertainty identification

and reduction by leveraging the value of subsurface information for the portfolio of the play with the uncertainty of the first strategically placed higher uncertainty wells.

The added value of the portfolio approach is demonstrated by Veldkamp et al., (2019) where the approach is compared to the development of a single 'stand-alone' project. The development of 'stand-alone' project will have the consequence that each new project will be equally risky since they are developed independent from one another. In the case of a portfolio approach, all experience about the play is used optimally for de-risking. In case of success, subsequent projects will have a higher chance of being successful, due to the experience gained in previous projects. Even in case a project fails, this may help in increasing the probability of success for subsequent projects. For plays that are initially considered too risky for market development, the value of information of a play-based portfolio approach will help by de-risking the play to such an extent that it becomes attractive for the market to develop, even at high initial risk. It is demonstrated by Veldkamp et al. (2019) for the Cretaceous/Jurassic, Triassic and Permian plays that by adopting the portfolio approach, the probability of a play being developed becomes higher, the number of successfully developed projects increases, and the average profitability of the project will also be higher.



Likelihood [%]	Number of projects	Number of successful project	NPV scenario [M€]	Weighted NPV marked [M€]	Repeat potential in play	Number of projects realised	Total NPV potential [M€]
35	2	2	2	0.70	8	10	3.5
7	4	3	-2.5	-0.18	6	9	0.23
2	4	2	-9	-0.16		2	-0.16
6	3	1	-10	-0.60		1	-0.60
10	4	3	-2.5	-0.24	6	9	0.34
2	4	2	-9	-0.22		2	-0.22
8	3	1	-10	-0.80		1	-0.80
30	2	0	-11	-3.30		0	-3.3
100	*26*	*14*		*-4.80*			*-0.99*

Figure 3: Probability tree for an optimal play approach for a hypothetical scenario for 10 MWth projects in a play with the repeat potential of 10 projects starting with a probability of 50% of 10 MWth for the first project where S: success, F: failure. After two failures, further development is stopped. Assumed is a NPV of +1 million euro after success and an NPV of -5.5 million euro (M€) after failure (adapted from Veldkamp et al., 2019).

Besides the geological uncertainty reduction, other advantages can be realised when following the play-based portfolio approach. These advantages include continuous improvement by integrated project development where all activities during the lifetime of projects are considered and continuously optimized based on experience gained from comparable projects. Cost reduction through synergy, efficiency and standardization has added value only when developing multiple projects. The surface heat demand and heat infrastructure in an area can be optimised when taking into account future projects making it easier to feed-in their heat. Structural research and development and innovation can be realised when operators are applying the portfolio approach and thus have the interest in reducing costs and increasing the profitability for the next projects. Finally, when adapting the portfolio approach, there are financing advantages since the risk is spread among multiple projects increasing in turn the trust of the financers in larger and more experiences sector and operators which in turn increase the possibilities for financing as more parties become involved in the sector. These five advantages, taken as a whole, reinforce each other.

There is a whole scale of intermediate options in developing geothermal projects in between a stand-alone project or the play-based portfolio approach. These two extremes have been used the purpose of demonstrating the added value of play-based portfolio development. Developing a portfolio of projects distributed over different plays also adds value compared to a stand-alone project but will be less in value than when the play-based element is added. Veldkamp et al. (2019) show that with about 200 doublets being developed, the value of the advantage of the play-based portfolio approach has been estimated at up to 2 billion euros for the three main plays in the Netherlands; Rotliegend, Triassic and Jurassic/Cretaceous. The learning effects of synergy, efficiency and standardization have been estimated at another billion euros. When considering all the advantages, the play-based portfolio approach

can significantly contribute to the acceleration of geothermal projects itself. This approach forms the basis for further exploration programmes in the Netherlands.

5. ULTRA DEEP GEOTHERMAL PROGRAMME

The application of geothermal energy from existing projects in the Netherlands is not sufficient to provide high-temperature heat for, as an example, the process industry where temperatures over 130°C are required. It is anticipated that ultra deep geothermal (UDG) energy can potentially make a substantial contribution to the transition towards a sustainable heat supply. To reach these temperatures in the Netherlands, geothermal reservoirs at depths over 4 km are required. The existing amount of data and knowledge available is too limited to obtain an economic viable p90 value. Project initiatives in the past have been stalled in the pre-feasibility phase due to the large investments and the high geological uncertainty which is not covered by insurances or the guarantee fund.

In 2016, the Ministry of Economic Affairs and Climate, EBN and TNO, together with industry consortia, screened the present status of UDG in the Netherlands. Seven consortia, consisting of several companies, were all in the same phase of project development, i.e. the formation of the consortium, the knowledge of the potential reservoir, identification of potential customers and their requirements. The Dinantian Carbonates play was identified as the most promising play in terms of matching heat demand while having repetitive potential to exploit for Ultra Deep Geothermal energy (Boxem et al., 2016). As a result of this process, the Green Deal UDG was signed by the seven consortia, EBN, TNO, the Ministry of Infrastructure and Water Management and the Ministry of Economic Affairs and Climate (Green Deal UDG, 2017).

The target of the Green Deal UDG parties is the safe and sustainable realization of one or more pilot UDG projects, ideally divided across three geological regions. The realization of these pilot projects should provide insight into the feasibility of further geological and technological risk reduction and safe, sustainable and cost-effective development of UDG in the Netherlands. The existing knowledge of the hydrocarbon industry will be integrated into the programme. Because of the anticipated variation in reservoir characteristics at Dinantian level in the Dutch subsurface, it is expected that the realisation of more than one project is required to determine the feasibility and contribution of UDG to the sustainable energy supply across the Netherlands.

The consortia have committed themselves to cooperate to increase, share and apply the knowledge required for UDG activities in the Netherlands. The consortia are spread across the country, each of them consisting of different parties with a demand for high temperature energy, such as the process industry (producing amongst others paper, beer, cheese or candy bars), utility companies, hospitals, district heating network, etc. The consortia work together not only on the exploration and development of the subsurface, but also on subjects like stakeholder management and integration of the subsurface heat into the surface facilities. The government is contributing financially to the programme and has committed itself to look for options for the coverage of the geological uncertainty. The programme is currently ongoing, and the first results are publicly available (Heijnen et al, 2019) and can be found on www.nlog.nl/scan. Five of the seven original consortia are currently looking into further steps within this programme and are working towards the first pilot well, which is expected around 2022-2023.

6. SCAN PROGRAMME

In some parts of the Netherlands the subsurface is relative unknown and thus the uncertainty is deemed too high for the development of geothermal projects. These are densely populated areas with high heat demand, but it remains unknown whether geothermal energy can be used. The Dutch government has acknowledged this barrier and has set up a data acquisition project SCAN (a Dutch acronym which translates as; Seismic Campaign for Geothermal Energy in the Netherlands) to reduce the uncertainty of the subsurface. Figure 4 shows the focus areas of SCAN.

The purpose of this national programme is to increase knowledge about the subsurface in order to be able to answer the question as to whether and where the subsurface in the Netherlands may be suitable for geothermal. The focus is on the commonly known reservoirs in the Netherlands including the Paleogene, Lower Cretaceous/Upper Jurassic, Permian and in a lesser extent the Dinantian. With this knowledge, the potential of geothermal in the Netherlands can be better estimated and the existing data barrier for developing new projects can be lowered.

SCAN started in 2019 and consists of reprocessing existing seismic data from the subsurface and the acquisition of new data by seismic acquisition and research wells. The acquisition and reprocessing of seismic is taking place within the first three years of the programme and has reached its 1000 km in November 2020. The seismic campaign is expected to finish around the end of 2021. The planning of the research wells has started. By applying the play-based portfolio approach, smart investments on the realisation of the exploration wells and data acquisition can be made. The actual progress of the SCAN Programme can be followed on the project website www.scanaardwarmte.nl. Due to full government support, SCAN data will be made publicly available as soon as quality checks have been performed. This is in contrast with the Mining Act, which state that a private person or company acquiring new data should make the data publicly available after 5 years after concluding acquisition. The data can directly be used for further studies by project developers and policy makers as input for their decision on the role of geothermal energy in their regional and municipal energy strategies which they have to define as an action part of the Climate Act.

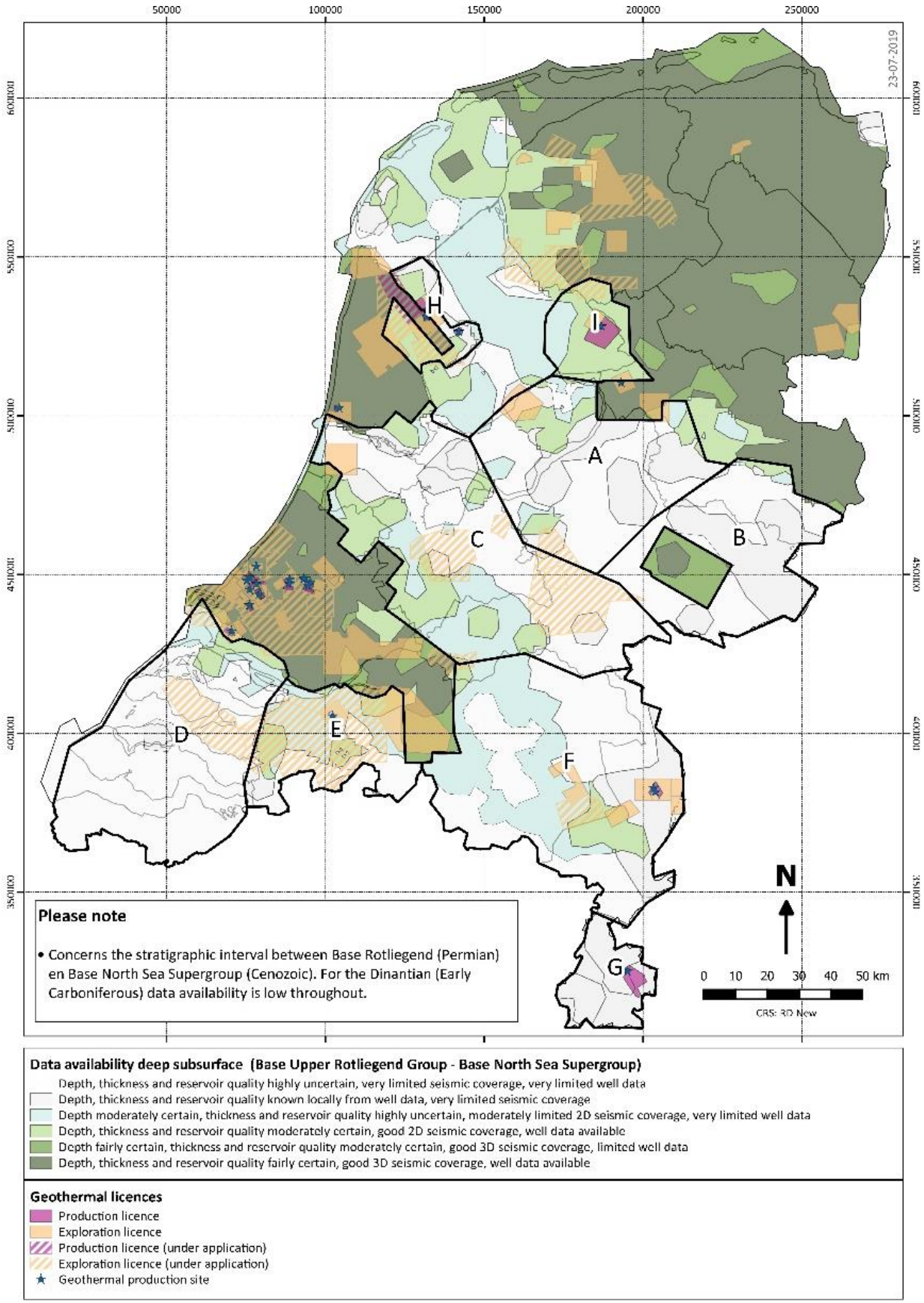


Figure 4: Figure showing the areas of the SCAN project for further data gathering labelled A-H. This figure does not include the Paleogene and Dinantian plays which are both considered as relatively unknown in almost all of the Netherlands.

7. ADDITIONAL SUPPORTING MEASURES

Additional to the data acquisition programmes, the Dutch government has existing arrangements in place to support the development of geothermal energy. These include the guarantee fund, SDE+ subsidy and the participation of EBN.

7.1 Guarantee fund

One of the main risks in geothermal energy within the Netherlands is the uncertainty of the yield before drilling. Even though the Dutch subsurface is a mature hydrocarbon province and the amount of knowledge gained by > 6000 onshore wells and numerous seismic surveys is enormous, an uncertainty on the expected flow rate and thus revenues remains when developing geothermal projects in the Dutch subsurface. The Dutch Government has set up a guarantee fund in 2009 that covers the financial risk of an unsuccessful geothermal well, the scheme is opened periodically for projects to subscribe to. A premium is paid in advance of the drilling phase by the exploration license holder. The fund reimburses the project if a well has a yield which is less than the pre-drill defined p90 yield. This means there has to be 90% certainty that the amount of PJ will be met before drilling the project. A lower temperature or flow rate can result in a reimbursement of the project. An application to the guarantee fund has to meet certain conditions, consisting of a report with a predefined format and the applicant will need to be in the possession of an exploration license. There are criteria to be met for the well testing programme and the interpretation of the data. The application will be reviewed by the Netherlands Enterprise Agency on behalf of the Ministry of Economic Affairs and Climate and the Ministry of Agriculture, Nature and Food Quality (RVO, 2019).

7.2 SDE+(+) subsidy

Sustainable energy projects can apply for a feed-in premium subsidy called SDE+, for the production of sustainable electricity and heat including wind, solar, biomass, etc. and thus geothermal. The geothermal category includes direct use only, the scheme does not apply for the production of electricity. The subsidy compensates the difference between the cost price of renewable energy and the market value of the energy supplied; unprofitable top. It is an exploitation subsidy which means a geothermal project will only receive the amount of subsidy related to the amount of geothermal energy produced and is granted over a period of 15 years. A geothermal project has to meet certain requirements for an application to the SDE+ which are comparable to the guarantee fund. The nominal capacity in an application for geothermal is determined by the p50 of the expected yield. The SDE+ conditions are reviewed on a yearly basis (RVO, 2019). In the fall of 2020, the subsidy scheme has been broadened to allow incorporation of CO2 reduction techniques into the SDE++.

7.3 State Participation of EBN

EBN is established by the Dutch government to obtain maximum social and economic value from the Dutch subsurface. The company is fully owned by the Dutch state and the tasks of EBN are defined in the Mining Act. Until 2016, EBN mainly focused on the exploration, production, distribution and storage of oil and gas. As a non-operating partner, EBN is involved in almost all oil and gas projects in the Netherlands where the interest in these activities varies from 40 to 50 percent. All profits are for the benefit of the Treasury and therefore for the Dutch society as a whole. Thanks to this involvement, EBN has an in depth knowledge about doing business in the subsurface, as well as experience with collaboration with subsurface operators, collaboration within public-private partnerships, innovation, data acquisition and analysis and contact with (local) government. EBN integrates this knowledge in new solutions such as geothermal energy and CO2 storage.

Since the spring of 2019, EBN is able to financially participate in geothermal projects as a non-operating partner. For the time being EBN can participate for 20% to 40% in geothermal projects to which the Mining Act applies. The participation of EBN in geothermal projects will be evaluated after five years. To allow EBN to participate risk-bearing, EBN must be given a statutory task in the field of geothermal energy. This is regulated through an amendment to the Mining Act expected to take place in 2021. In anticipation of this change, the Minister has given EBN permission to engage in activities that focus on geothermal energy. Until the Mining Act has been amended, participation is on a voluntary basis, which means that it is up to the initiator to request EBN to participate. The Minister must give permission for participation per project until the amendment to the Mining Act comes into effect. With the participation of EBN, the Minister hopes for a professional strengthening and acceleration of the number of projects in the geothermal sector. By participating in the development of geothermal energy EBN will be able to continue to deploy its integrated knowledge and expertise of the subsurface. Through the planned, efficient and sustainable management of the subsurface, EBN, together with is (operating) partners, aims to mitigate the risks of geothermal energy projects for people, the environment and nature and to reduce costs.

CONCLUSIONS

Geothermal energy is a proven low enthalpy resource within the Netherlands. An acceleration of the development of the relatively young geothermal industry is required to make a significant contribution to the supply of sustainable energy. It is predicted that geothermal heat could provide for around 20-25% of the Dutch heat demand in 2050. Even though the Dutch subsurface is well-known through decades of hydrocarbon exploration and production activities, the potential for geothermal energy cannot currently be estimated for the whole of the country. Therefore, the UDG and SCAN programmes contribute to a broader knowledge base and create opportunities for the geothermal sector to accelerate. Integration of the knowledge and experience gained from the hydrocarbon era is very useful and needed for a safe responsible growth of the geothermal industry.

For the acceleration of the geothermal energy in the Netherlands, steps are taken by both the government and the geothermal sector that include financial support systems, data acquisition programmes, cost reduction initiatives, innovation and robust public support. All actions listed in this paper of both public and private partners are required and need to be successful to meet the targets of producing 15 PJ for 2030 and 110 PJ for 2050 from geothermal energy in the Netherlands.

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