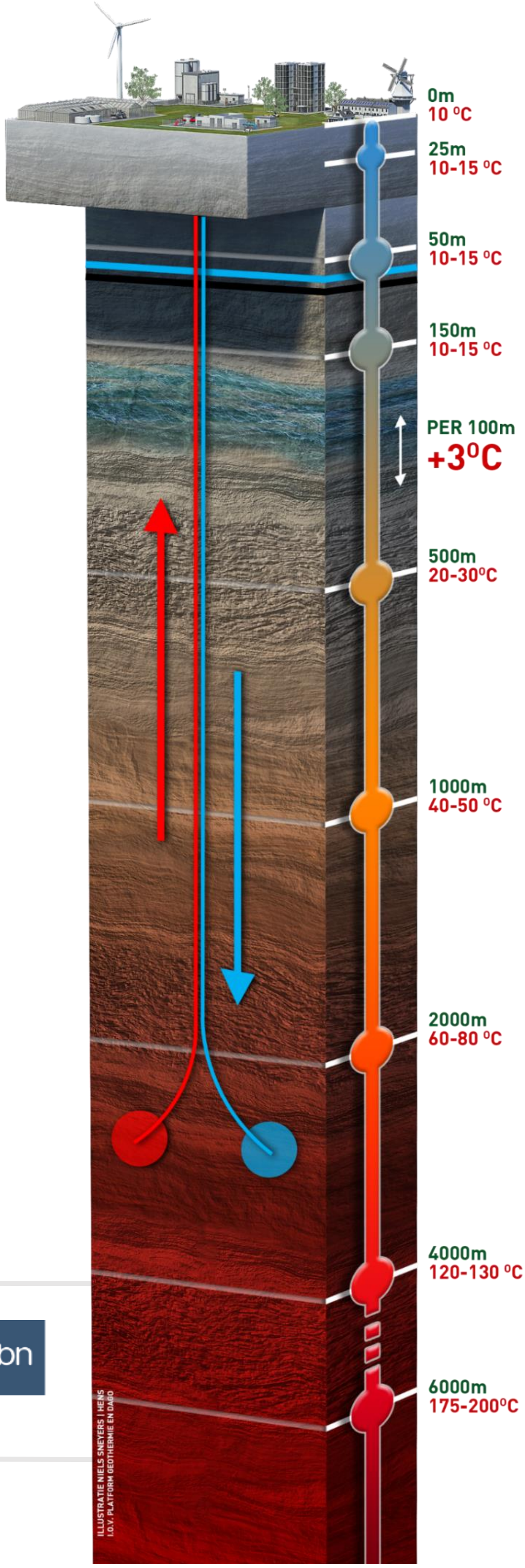
Master Plan Geothermal Energy in the Netherlands

A broad foundation for sustainable heat supply

May 2018



Platform Geothermie
DAGO Dutch Association Geothermal Operators
WARMTENETWERK Voor de energietransitie
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We would like to thank all organisations and other involved parties with whom we have spoken and who have contributed to this report.

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Foreword

The profile of geothermal energy in the Netherlands has increased in recent years. The declining production and consumption of natural gas and the increasing necessity of sustainable heat and energy sources require sustainable alternatives to natural gas. Geothermal energy offers a promising and sustainable alternative for heating buildings, greenhouses and for applications in industry. This requires proper agreements between groups such as residents, the relevant municipalities, energy suppliers and producers of geothermal energy. Eric Wiebes, the Minister for Economic Affairs and Climate, wrote in a letter to parliament earlier this year that geothermal energy has the potential "to play an important role in the development of sustainable heat supplies, and thus also in the transition to low-CO_2 energy supplies." In 2017, SodM (State Mining Regulator) published *Staat van de Sector Geothermie* (State of the Geothermal Sector). This document stated that the safe extraction of geothermal energy was a prerequisite for successful growth, and outlined the action required to achieve this. The sectoral round tables, which have contributed to the development of the 2018 *Klimaat- en Energieakkoord* with the objective of achieving a reduction in CO_2 emissions of 49% by 2030, have expressed a great deal of interest in geothermal energy as a sustainable source of heat.

Given these developments, the year 2018 is the key moment for us to develop a common ambition and associated action plan to scale up the geothermal energy sector responsibly during the coming years. We are proud to publish our Master Plan for Geothermal Energy in the Netherlands. In this plan, we describe how we can lay the foundations for increasing the current production of 3 petajoules of geothermal energy in the Netherlands to 50 petajoules in 2030, and more than 200 petajoules in 2050, in a sustainable, safe and socially responsible way[1]. The broad composition of the group that has initiated of this Master Plan ensures that it represents multiple perspectives and interests. Our ambition as a sector exceeds the ambitions described in the letter to parliament, as a result of the robust recent activities and the latest estimates of the potential.

The Dutch subsurface has a high potential for extracting geothermal energy: there is warm water present, stored in rock strata. The energy stored in this warm water is referred to as geothermal energy or geothermal energy. Depending on the depth, and thus the temperature of this warm water, the geothermal energy may be used to heat homes or greenhouses, or for industrial applications etc. Thanks to the first Dutch operators, vital pioneers in the period when geothermal energy was still in its infancy, geothermal energy is now a proven sustainable source of heat for the greenhouse horticultural sector. There is now a clear and rapid increase in customers in industry and the urban environment.

[1] For comparison: 1 petajoule per year can heat around 20,000 households, and the total demand for heat from the urban environment is around 400 petajoules per year.

We look forward to discussing and improving this Master Plan together with many stakeholders. The development of geothermal energy is greatly dependent on societal support, growth and roll-out of heat networks and further research into the subsurface potential. We will remain closely involved with this in the coming years. For us, this Master Plan represents a common starting point that we can build upon in a dynamic way in the years to come.

May 2018

Stichting Platform Geothermie

Frank Schoof, Chairman

Dutch Association of Geothermal Operators

Martin van der Hout, Secretary General

Stichting Warmtenetwerk

Jannis van Zanten, Board Member

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In collaboration with the Ministry of Economic Affairs and Climate
and the Ministry of the Interior and Kingdom Relations

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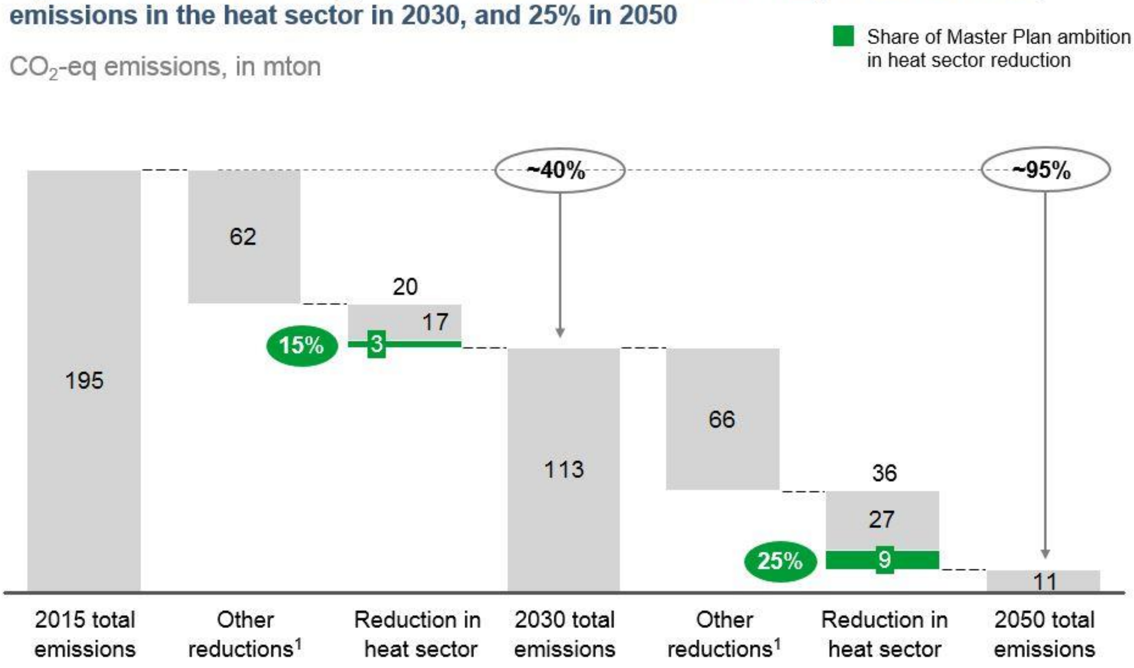
Management Summary

The Netherlands faces an important task: CO_2-equivalent emissions (CO_2-eq) must be reduced by ~40%[2] in 2030 compared to 2015, and by ~95% by 2050. This means not just 95% sustainable electricity, but also 95% sustainable heat. Around 40% of Dutch emissions are due to heat consumption. To meet the emission goals, the heating sector must achieve reductions of 20 megatonnes (mton) CO_2-eq emissions by 2030, after which an additional reduction of 36 mton is required by 2050.

Figure 1: Geothermal energy can contribute 15% to the necessary reduction in CO_2 emissions in the heat sector in 2030, and 25% in 2050



1 Including reduction due to decreasing demand for heat

SOURCE: Coalition Agreement 2017-2021

To achieve this goal at the lowest possible social costs, a diversity of sources of heat and technologies are required. It is expected that the demand for heat will fall from the current 960 petajoules (PJ) to 930 PJ in 2030 and 870 PJ in 2050 thanks to more efficient processes, improved insulation and limited population growth. Around half of the current demand for heat comes from the urban environment. Here, both individual heat solutions (e.g. electric heat pumps) and collective solutions via connection to a heat network are required. Another 40% of the total demand for heat comes from industry where, depending on the process temperatures, various technologies and sources such as electrification, biomass and hydrogen may be used. The remaining ~10% of

2 Or a 49% reduction by 2030 compared to 1990

total demand for heat comes from agriculture, with the same alternatives to natural gas as the urban environment. In all sectors, energy efficiency and better insulation will play an important role in reducing the demand for heat. The optimal solution depends on the local characteristics of the demand for heat. If collective solutions are preferable, then a combination of new infrastructure, sources and buffers will be required to deal efficiently with seasonal variations and peak demand.

We see that geothermal energy has an important role to play in the future sustainable energy mix, and can grow to 50 PJ of sustainable heat in 2030 and 200+ PJ in 2050. To achieve the CO_2 goals, it is necessary to use all available sustainable technologies (solar, wind, biomass, soil energy, geothermal energy) in as targeted a manner as possible. The contribution from geothermal energy will deliver a total CO_2 reduction of 3 mton in 2030 and 12 mton in 2050. Between now and 2030, the contribution of geothermal energy will increase from 0.5% of total heat production to 5%, with a further increase to 23% by 2050.

Figure 2: Seventeen active geothermal energy doublets in the Netherlands

Number of geothermal energy doublets, 2018

SOURCE: TNO (April 2018)

Geothermal energy is a technology that allows existing heat to be extracted from strata at depths between 500 and 4,000+[3] metres. This can be supplied to the greenhouse horticultural sector, the urban environment and industry. During the past ten years, the sector has developed rapidly in the greenhouse horticultural sector in particular, where geothermal energy is a priority as the sector works to become more sustainable. This development has been supported up to now by the Ministry of Agriculture, Nature and Food Quality and LTO Glaskracht Nederland within the public/private partnership *Kas Als Energiebron* (Greenhouse As Energy Source)[4]. There are now 17 active "doublets"[5] in operation, most between 2,000 and 3,000 metres deep, with a total capacity of around 3 PJ of sustainable heat. In certain local conditions, geothermal energy is the cheapest sustainable alternative to natural gas, with little or no CO_2 emissions[6] and constant heat supply (independent of the season) with high certainty. This means it is suitable as a baseload in combination with other sources or storage.

Our ambition is based oPOLICTn an estimate of the demand for geothermal energy as a baseload in existing and future heat networks in greenhouse horticulture, the urban environment and industry. We expect that 40% of the total demand for heat (~380 PJ) will be delivered by heat networks, provided that there are sufficient economical and sustainable sources of heat in the region. In addition to sustainable waste heat and biomass, geothermal energy can make an important contribution (estimated maximum ~230 PJ) to the combined total of ~380 PJ for heat networks.

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[3] Wells deeper than 4,000 metres are known as Ultra-Deep Geothermal (UDG) wells

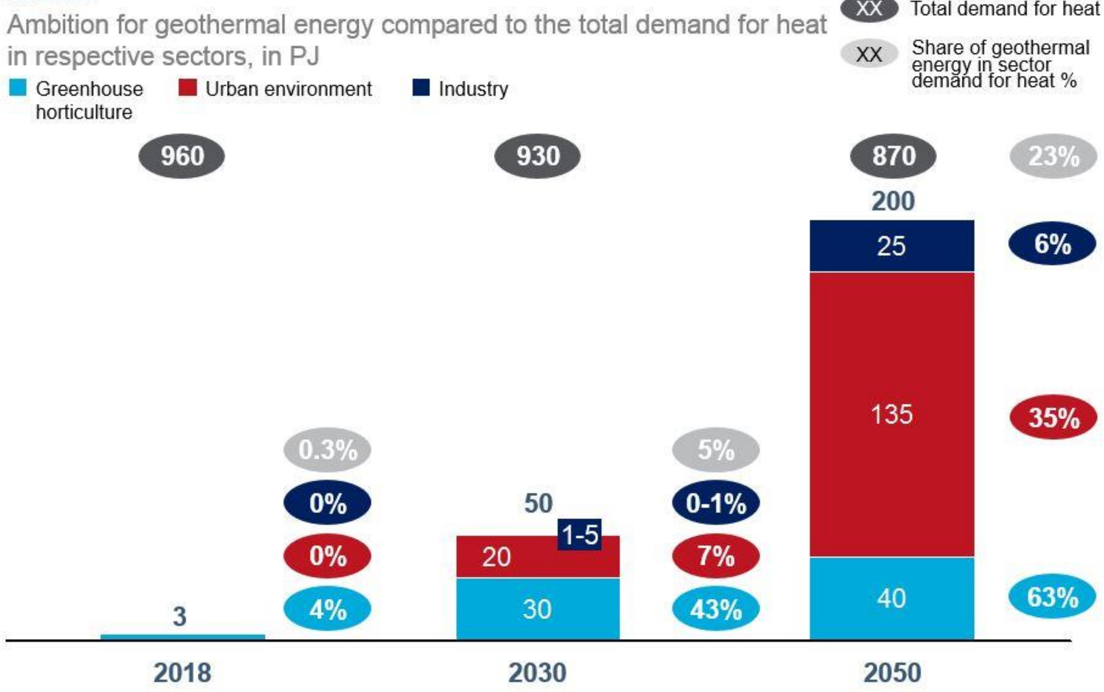
[4] Projects including the *Kennisagenda Aardwarmte* (Geothermal Energy Knowledge Agenda) and various long-term research projects have been financed from this

[5] Systems used to extract geothermal energy consist of two wells – see Chapter 2. What is geothermal energy?

[6] No emissions if the required electricity is also sustainably produced

In addition, to determine the ambition for consumption, we match the future above-ground demand for heat and the subsurface potential that is currently known[7]. Ongoing research into areas where there is less knowledge about the subsurface will improve this match. At the same time, the ambition is dependent on a cost reduction of 30-50% during the life cycle of a geothermal well, which is possible through scaling up and coordinated exploration and production. In this way, economies of scale will reduce costs, geological uncertainties and the technical risks of production. Further cost reductions are also possible through a structured approach to R&D and innovation etc.

Figure 3: Geothermal energy can meet 5% of the total demand for heat in 2030, and 23% in 2050



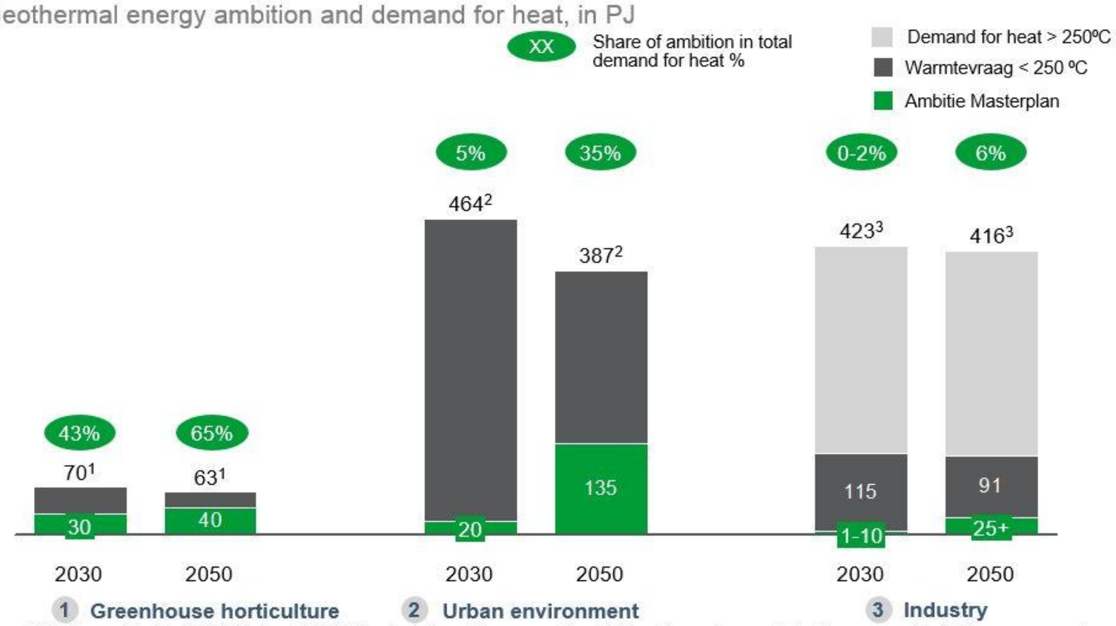
SOURCE: CE Delft, IF Technology, LTO Glaskracht, McKinsey Energy Insights

We see a future for geothermal energy in greenhouse horticulture, densely-populated neighbourhoods and non-residential construction in the urban environment and in industry using low/medium-temperature heat as the alternative to natural gas with the lowest social costs. Between now and 2030, it is important to scale up in greenhouse horticulture. In this sector, a limited number of "plays" (subsurface strata) should be developed where the potential is known with a high degree of certainty. At the same time, preparation for scaling up in the urban environment is essential from 2025 to connect with the growth and roll-out of existing and new heat networks and connections. Ultra-Deep Geothermal (UDG) pilots are also necessary to supply geothermal energy to industry using low/medium-temperature heat.

[7] IF Technology, CE Delft, Berenschot (2018), *"Opschaling geothermie"* (Scaling up geothermal energy)

Figure 4: Geothermal energy ambition compared to the demand for heat per end user sector

Geothermal energy ambition and demand for heat, in PJ



1 Source 2018 demand for heat LTO Glaskracht (75 PJ) and decline at the same rate as in the urban environment due to energy saving/efficiency assumed
2 Source 2050 demand for heat CE Delft and linear decline in demand for heat assumed
3 Source: McKinsey Energy Insights "Global Energy Perspective 2018"

SOURCE: LTO Glaskracht, CE Delft, IF Technology, McKinsey Energy Insights

Towards 2030, it is important to expand in greenhouse horticulture and to connect to new and existing heat networks in the urban environment.

- Further scaling up is possible in greenhouse horticulture in the short term, thanks to existing subsurface knowledge and experience. With this approach, it is possible to focus on a specific number of locations and known subsurface strata, which will achieve cost reductions more quickly. In the meantime, seismic surveys can be carried out in other areas, to prepare for scaling up in the urban environment. The current 3 PJ in greenhouse horticulture can be expanded to 30 PJ in 2030, or ~60% of the ambition of 50 PJ. In this sector, there is a good business case for geothermal energy due to the large number of full-load hours (6,000 per year) and concentrated demand. This means that geothermal energy is already the most economical solution if there is no sustainable waste heat available.

- In the urban environment, we expect to be able to supply 20 PJ of geothermal energy by 2030, depending on the growth of existing heat networks, the roll-out of new grids and the subsurface potential at these locations. We propose that the focus should be on making existing heat networks more sustainable in areas where the technical potential is known with a higher degree of certainty, such as in the area around The Hague and Rotterdam. Realising 5-10 successful pilots is crucial to ensuring that sufficient technical and organisational experience is accumulated in connecting existing and new heat networks to geothermal energy sources. Subsurface surveys are important at locations where new heat networks will be rolled out first, and where the greatest demand for heat is.

- In industry using low to medium-temperature heat, initiating pilots is particularly important between now and 2030 to accumulate experience with the depth of drilling and connecting to demand. We are working towards at least 5 successful pilots, to be able to supply 1-10 PJ of heat. It is also important to further explore the subsurface at potential industrial locations. In heavy industry (with temperatures above 250 ^{0}C), there is no role for geothermal energy due to the high temperatures required and the resulting extreme drilling depths required and associated costs.

Between 2030 and 2050, we will primarily scale up in the urban environment and also in industry using low/medium-temperature heat, depending on the results of UDG pilots.

- In the long term, the urban environment will be the largest consumer of geothermal energy, depending on the roll-out of new heat networks. In 2050, geothermal energy could supply 135 PJ to the urban environment, or ~65% of the ambition of 200+ PJ. This requires more than 100 PJ of new heat networks, which equates to connecting around 3.3 million home equivalents. In addition, ~15 PJ of geothermal energy can be used as a baseload in existing heat networks, with modifications necessary to the ~500,000 connected homes to accommodate the lower temperatures.

    - Our ambition for 2050 is based on the assumption that, for around half of the urban environment (~200 PJ), a collective heat solution (heat networks) will have lower social costs than individual solutions (electrification). This primarily applies to existing buildings in densely-populated areas and non-residential construction, due to the high density of heat consumption and the relatively low standard of insulation in these buildings (where electrification would lead to high costs for grid strengthening and insulation costs).

    - Geothermal energy is, after *sustainable* waste heat, the most economical source of heat as a baseload in heat networks. From a systems perspective, alternative such as biomass and biogas are limited by restricted availability and more efficient use for peak demand and higher temperatures, where there are no cheap alternatives (such as in heavy industry).

- In industry using low/medium-temperature heat, we expect that a heat supply of around 25 PJ will be possible by 2050, with a bandwidth of 1-60 PJ, depending on the success of Ultra-Deep Geothermal (UDG). In this sector, there is a greater degree of uncertainty about the potential of geothermal energy due to the limited knowledge about the subsurface at many industrial locations, and lack of experience with this end user. Geothermal energy is a possible economical solution for processes at up to 250 ^{0}C. This includes paper factories, milk factories and breweries, provided that no sustainable waste heat is available.

- In greenhouse horticulture, based on the expected availability of sustainable waste heat, a match between above-ground demand and potential subsurface geothermal energy can grow to 40 PJ in 2050 of a total demand of ~60 PJ. This builds on the strong start made in greenhouse horticulture and the ambition of the sector to meet around 50% of the demand for heat from geothermal energy by 2040.

To achieve these goals, the number of doublets must grow from the current 17 to ~175 in 2030, and later to ~700 in 2050[8]. In the coming years, four to six new geothermal plants will be developed. This number will grow to ten per year in the period 2020-2025. The strongest growth will occur from 2025, with a doubling to twenty new doublets per year up to 2030. This means that there will be an average of five simultaneous drillings from 2025 at various locations in the Netherlands to realise this number. At the same time, more than 100,000 homes per year must be connected to a heat network, so that almost 4 million households are connected by 2050.

This huge scaling up will create jobs. In the geothermal energy sector, we expect a growth from ~240 to ~2,400 FTE in 2030 and ~3,400 FTE in 2050. These include both direct and indirect jobs, of which one third are direct jobs and the rest are suppliers, consultants etc. In addition, new jobs will be created in government and in the heat sector (including as a result of the need to install heat networks), which are not included in these figures.

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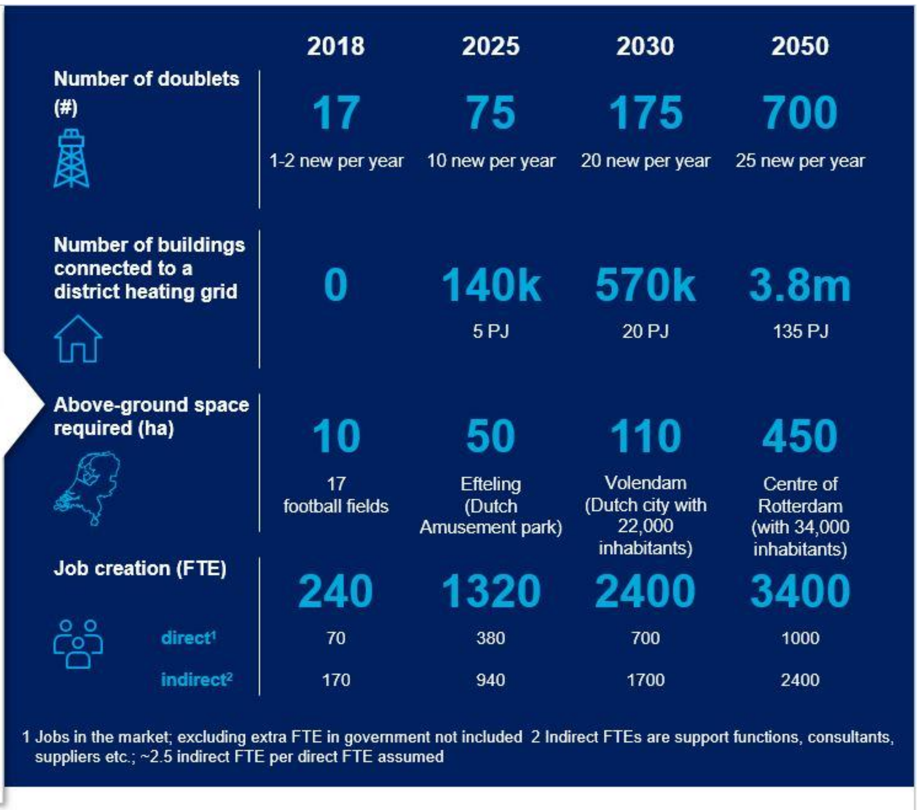
[8] Based on an average capacity of 0.3 PJ per year per doublet. The number of doublets required will be higher if smaller doublets are developed, for example for lower temperatures in the urban environment

Figure 5: Implications geothermal energy ambition

Geothermal energy ambition
- 50 PJ in 2030
- 200+ PJ in 2050



To achieve this considerable scaling up of geothermal energy in the Netherlands in a safe, responsible, sustainable and cost-effective manner, it is important to take action today. This is why the sector has already begun:

- **Actively developing a (geothermal) energy proposition with heat suppliers and the *Expert(ise)centrum Warmte* for (local) government.** This requires refining and improving the geothermal energy proposition for each target group. We are also developing structural partnerships with heat suppliers and starting pilots with existing and new heat networks in the urban environment. Due to the long-term contract structures in the urban environment, we must start developing a coordinated offer now to be ready for scaling up from 2025 onwards.

- **Broadening the basis of the sector, growing together and learning through doing, with the participation of EBN.**
  - The geothermal energy sector is growing across the entire value chain. There will be an increasing number of consumers of geothermal energy, and a diversification in the type of end user from the current focus on greenhouse horticulture to the urban environment and industry using low/medium-temperature heat. Secondly, the operator “landscape” is expanding, with an increasing the number of doublets and new players entering. Finally, there will be more market players such as suppliers and consultants, and more policy, advisory and regulatory roles.
  - Coordinated exploration and production of geothermal energy, in which the above-ground demand and the subsurface potential are optimised together (e.g. through a play-based portfolio approach), are necessary to lower the costs, geological uncertainty and technical risks as rapidly as possible. This will improve the business case and minimise the transition costs for society.

- EBN will participate in the geothermal energy sector. The exact form that this participation will take will be developed in a future letter to parliament from the Ministry of Economic Affairs and Climate Policy (EZK). The Master Plan will not contribute to this decision.

- **Further professionalisation of the sector across the entire value chain through further development of industry standards, knowledge sharing and transparency.**

    - Intensifying DAGO's activities around preparing and implementing industry standards is needed to further develop and implement industry standards and work plans. DAGO will coordinate these industry standards with policy makers, implementers and regulators as much as possible. The implementation of industry standards by the sector will determine the success of these efforts, and as such must also align with the various operators' organisations[9].

    - It is also important to have broad support for the implementation of a process for the expansion and continuous development of industry standards and work plans by DAGO, with recognition for all stakeholders. Insights from "best practices" and innovation can be utilised most effectively if these developments in industry standards proceed in parallel with developments in the sector and in society.

    - We will also work towards the expansion of knowledge sharing through increased collection, analysis and sharing of insights on the basis of "lessons learned" about safety and setting up a data infrastructure and partnership model, to allow various types of data to be used to optimise costs and efficiency. Insights will be shared not just with operators, but also across the chain with suppliers, consultants, (local) government and heat suppliers.

- **Ensuring a local and national conversation within society about geothermal energy in the context of the energy transition.** We are working to develop a broader definition of geothermal energy as a source of heat, and of what the technical and economic potential is in the context of the energy transition. The geothermal energy/heat proposition developed will form the basis for a broad conversation about geothermal energy with national and local stakeholders. The *Stichting Platform Geothermie* will expand its current role in this regard and will be the point of contact for general knowledge and information about geothermal energy in the Netherlands.

The sector needs the following from the national government: further investment in mapping the subsurface and completing the new Mining Act, including a new permits model, refining the SDE subsidy and consistent policy with associated implementation and regulation. These have been identified in part in the *Beleidsbrief Geothermie* of February in 2018 and set in motion.

- **Implementation of the new Mining Act by EZK and SodM (State Mining Regulator) for the effective extraction of geothermal energy and systematic management of geothermal energy sources in the Dutch subsurface.** The necessary amendments to the Mining Act include (technical and safety) requirements adapted to geothermal energy and a new permits model that better connects with geothermal energy in practice (for example, we see options such as tendering or permits applying to multiple doublets to make a play-based portfolio approach possible, a wider geographic spread without obstructing other projects, and a perspective is needed for unused permits).

- **Completing GTI seismic survey of "blanks spots"**[10] financed by EZK and carried out by EBN in partnership with TNO, to map the subsurface where there is still uncertainty, prioritised based on areas

[9]Active operators are those in possession of at least one permit under which activities are carried out that would be prohibited without a permit, such as drilling a borehole for the discovery or extraction of geothermal energy

[10] TNO/EBN (2017), *"Kader voor exploratiewerkprogramma geothermie in gebieden met lage datadichtheid"* (Framework for geothermal exploratory work programme in areas with low data density)

with the highest demand for heat and developed into an updated, public and easily-accessible database (ThermoGIS) by TNO.

- Expansion of the current subsidy scheme (SDE+) to cover the urban environment (and maintaining it in greenhouse horticulture) and segmenting drilling insurance (RNES[1]). It is important to expand the SDE+ so that it facilitates and encourages the production of geothermal energy in the urban environment, just as in greenhouse horticulture. In addition, it is important to offer a range of insurance policies against dry wells with differentiation based on the subsurface uncertainty and results of seismic surveys.

- **Ensuring that there is sufficient capacity** at EZK, SodM and in local government to be able to process permit applications promptly, unambiguously, systematically and transparently.

A decision is also necessary based on the *Klimaat- en Energieakkoord* about how heat supplies should be chosen optimally at the district level. Specifically, the following are required:

- **Installing heat networks on the basis of a district-focused approach and coordinated heat offer to local authorities.** This requires a fully-developed approach (in the 2018 *Klimaat- en Energieakkoord*) for the identification of districts, together with (local) government, building owners and/or residents, where a collective heat solution (heat network) is needed, including a perspective for ownership and funding. This is necessary to allow the heat supply with the lowest social costs to be chosen at local level.

- **Coordinating and optimising planning and environmental policy between various branches of government.** This is necessary to make optimal use of the subsurface at the lowest possible social costs. This requires coordination between the BKZ, EZK, I&W and LNV ministries and both local authorities and semi-public agencies such as drinking water companies.

- **Continued development and implementation of a participation model to create local public support for projects, in partnership with (local) government and heat suppliers etc.** Various parties will have to work together to reach building owners and other consumers effectively, and also to involve local residents in the right way in the various phases before the start of a geothermal energy project (or other type of sustainable energy in their surroundings) and during realisation and production.

- **Fixed and predictable long-term energy policy** to improve the business case for sustainable sources of heat. This may include end-user-specific saving goals, a CO_2 price and/or cost-plus model for heat.

[1] National Economic Affairs (EZ) Subsidies Scheme

In this Master Plan, these actions are developed in six thematic main goals:

A. **Profitable projects:** Ensuring that projects are profitable by reducing costs, uncertainties and risks and increasing returns across the entire life cycle of a project.

B. **Appropriate legislation and regulations, regulatory structure and policy:** Ensuring prompt processing of permit applications and regulation on the basis of agreed industry standards.

C. **Safe and effective operational activities:** Optimising investment decisions and operational activities across the entire life cycle through knowledge development and sharing, including standardisation.

D. **Robust public support:** Initiating a national and local conversation, and ensuring there is transparency about safety and risks.

E. **Innovation:** Innovating to achieve a better match with the demand for heat, to reduce costs across the entire value chain and life cycle and to further improve safety.

F. **Connecting to heat networks:** Structuring and consolidating the demand for heat so that it is suitable for the minimum profitable capacity of geothermal energy projects and associated sources during peak demand periods.

Action is required in all areas in both the short term and long term by the parties on both the demand side and supply side, and by national and local government. These are sketched for each chapter, with a summary of the priorities in the road map in Figure 6.

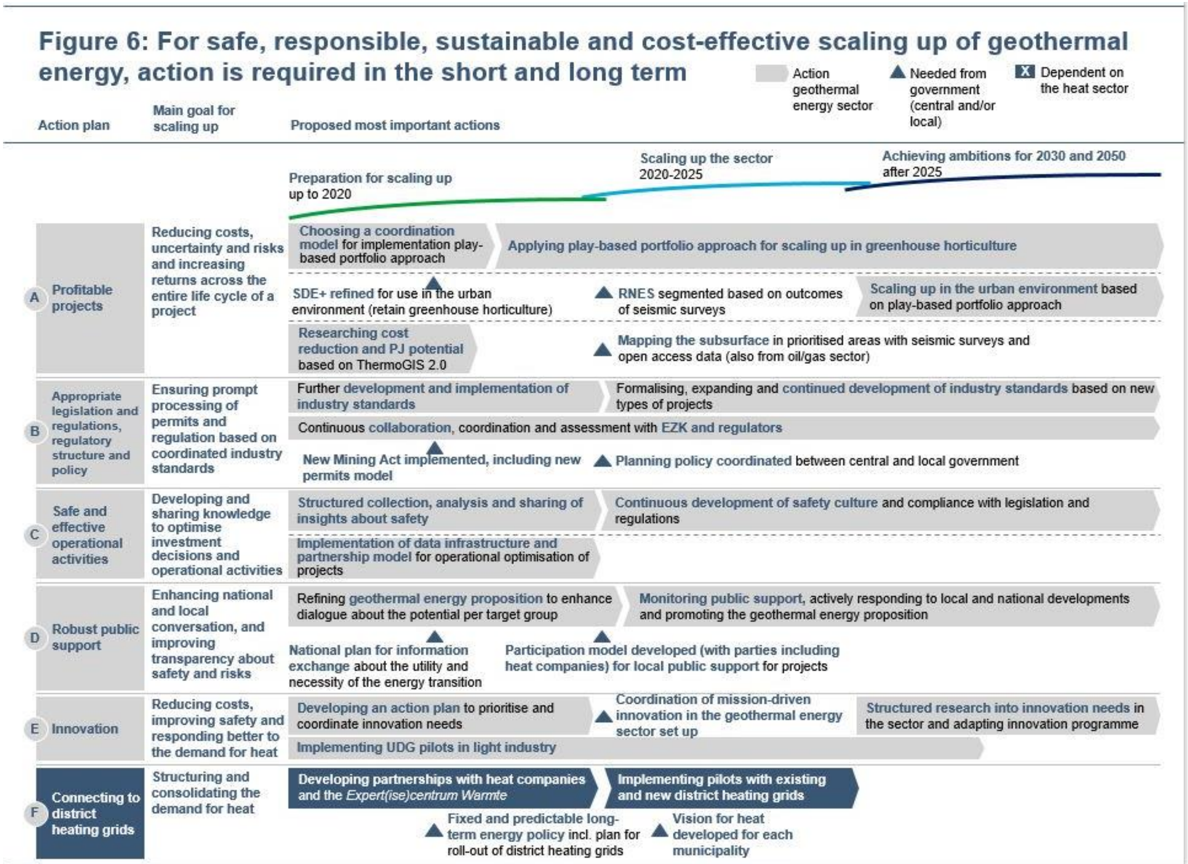


Figure 6: For safe, responsible, sustainable and cost-effective scaling up of geothermal energy, action is required in the short and long term

Specific roles and responsibilities have been defined in this Master Plan for the undersigned, DAGO, SPG, *Stichting Warmtenetwerk* and EBN, to facilitate the ambitions of the geothermal energy sector. During the coming period, together with the Ministry of Economic Affairs and Climate Policy (EZK) and the Ministry of the Interior and Kingdom Relations (BZK), these parties will work to further coordinate several of the most important required roles. These decisions are partly dependent on the results of the *Klimaat- en Energieakkoord* and the decision about which exact form EBN's participation will take, and as such cannot yet be made. The next steps will take place in the context of an ongoing partnership between the undersigned, in which we will ensure that this Master Plan is developed in a coordinated way. We will involve a broad group of stakeholders in the implementation of the Master Plan. In addition, we will organise an annual meeting for all parties involved with geothermal energy to discuss the progress of the Master Plan, and general developments in the geothermal energy sector. In this way, we can work together towards the safe, sustainable and cost-effective scaling up of geothermal energy in the Netherlands, with broad support from society.

I. Introduction

The Netherlands faces an important task: the goal of reducing CO_2-equivalent emissions (CO_2-eq) by 49% by 2030, and by 95% by 2050, in comparison to 1990. To achieve this, the Netherlands must undergo a sustainable transition six times faster than is currently ongoing. Around 40%, 960 petajoules (PJ), of current demand for energy in the Netherlands is for heat, resulting in around 40% of emissions (71 mton). A variety of solutions will be required to meet this demand for heat sustainably. Geothermal energy can make a contribution of 50 PJ in 2030 and 200+ PJ in 2050, i.e. a CO_2-eq reduction of 3 and 12 mton respectively.

Following the COP21 climate conference in Paris, 195 countries agreed to reduce emissions of greenhouse gases. The goal of this agreement is to combat further climate change as a result of human action and to limit the maximum increase in the average temperature on earth to 2 ºC, with an additional attempt to limit it to 1.5 ºC. The 2017-2021 Dutch Coalition Agreement contains guidelines for what this means for the Netherlands in 2030. These will be specified in a *Klimaat- en Energieakkoord* in 2018. This will occur via five “round tables”, which discuss the most important topics: the urban environment, industry, agriculture and land use, mobility and electricity. To achieve the goals, the current sustainable transition must be accelerated by a factor of six, and the same trend must continue until 2050.

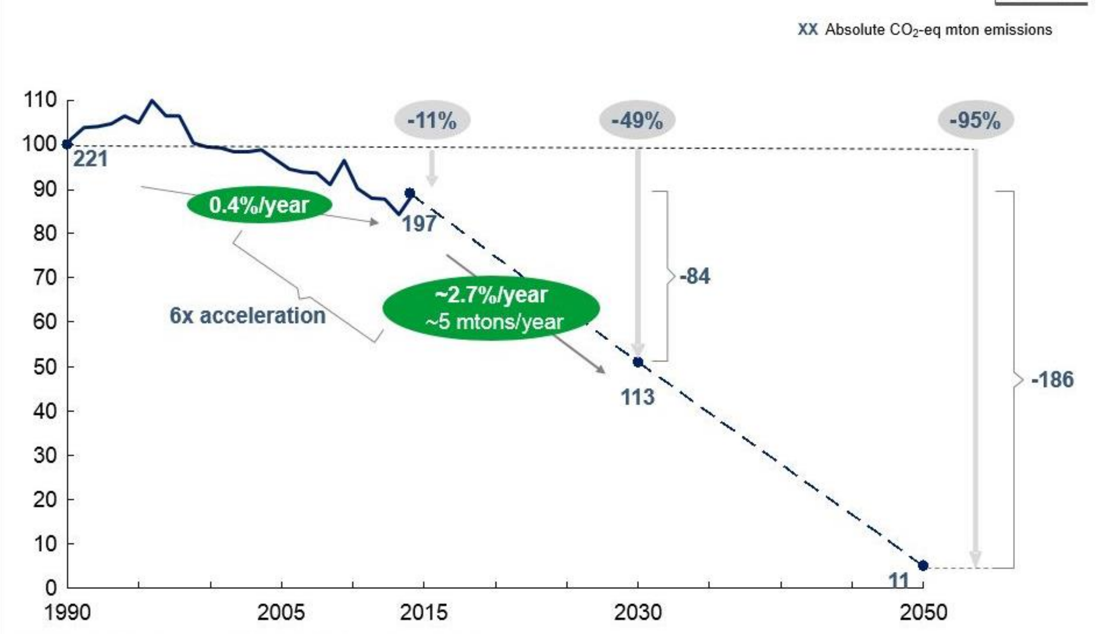


Figure 7: Goal Netherlands to reduce CO_2-eq emissions by 49% by 2030

CO_2-eq emissions, % change since 1990

SOURCE: Coalition Agreement 2017-2021, McKinsey Energy Insights

This will require a number of measures in the energy sector to reduce dependence on fossil fuels (e.g. green energy, electric cars, bioplastics, etc.), in which the heat sector will play a crucial role. The heat sector represents around 40% of the current demand for energy, and 45% of emissions, due to the dependence on natural gas (65%) and oil (11%). To achieve the above goals, the heat sector must achieve a reduction of ~20 mton by 2030, and an additional ~36 mton by 2050. This assumes that the demand for heat will fall from the current 960 PJ to 930 PJ in 2030, and 870 PJ in 2050, due to more efficient processes, better insulation of buildings, sustainable new construction and limited changes to the population and economic structure.

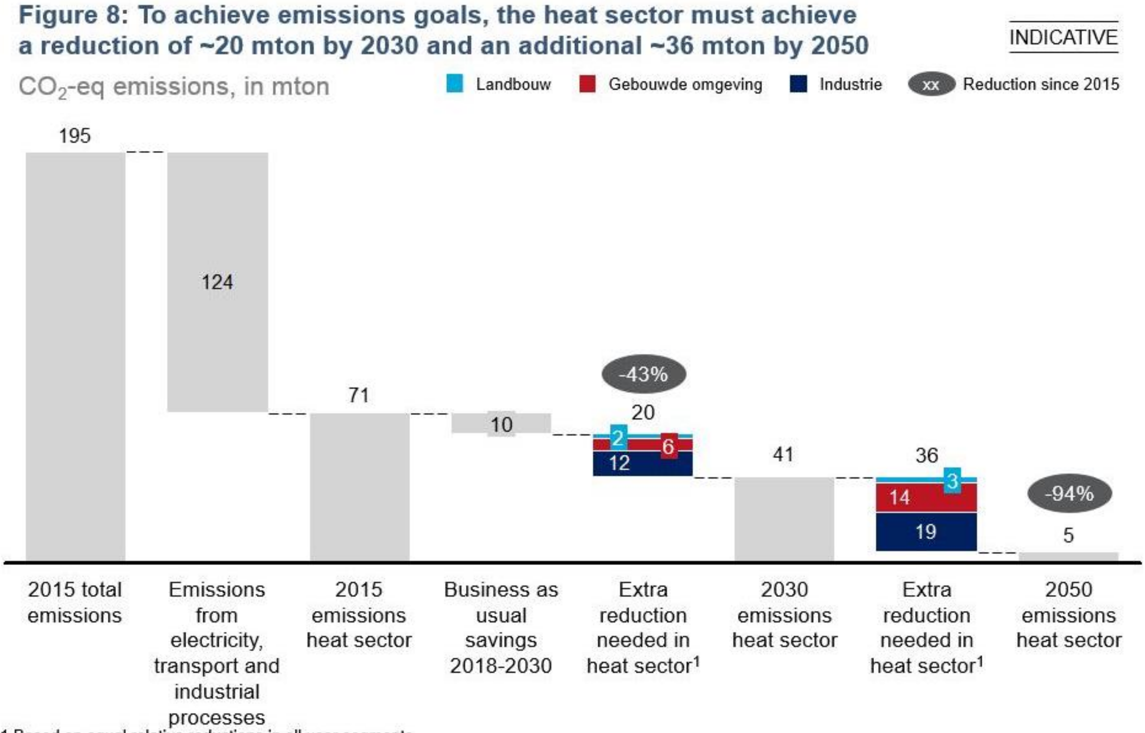


Figure 8: To achieve emissions goals, the heat sector must achieve a reduction of ~20 mton by 2030 and an additional ~36 mton by 2050

1 Based on equal relative reductions in all user segments

SOURCE: Coalition Agreement 2017-2021, McKinsey Energy Insights, ECN

To achieve the emission reduction goals, given the current intensity of emissions, ~400 PJ of heat production must become sustainable by 2030, with the entire demand for heat of ~870 PJ being made sustainable by 2050. This can be achieved with individual solutions such as electric heat pumps, or collective solutions via heat networks. Various sources can be connected to this: biomass, sustainable waste heat, hydrogen and/or geothermal energy. The optimum solution with the lowest possible social costs will vary for each location, depending on conditions such as the standard of insulation and available sources. There are various scenarios to arrive at a situation in which heat is supplied in a CO_2-neutral way. However, all these will involve a diverse range of solutions (sources of heat) and differences in the mix for the baseload and peak load.

Around half of the demand for heat comes from the urban environment, 40% from industry and 8% from agriculture. In the urban environment, the emissions goals mean that 100% of new construction must be fossil-fuel-free – around 1 million homes up to 2030, and an additional half million homes between 2030 and 2050. In addition, 1.6 million existing homes must cease using natural gas before 2030, with the remaining 4 million following after 2030. In agriculture, ~40% of greenhouses must be sustainably heated by 2030, and the rest by 2050.

With a contribution of 200+ PJ in 2050, geothermal energy will meet around 65% of the demand for heat in greenhouse horticulture, 35% in the urban environment and 6% in industry. At present, geothermal energy meets 0.5% of the total demand for heat. In 2030, this must be 5% of the ~930 PJ demand for heat, and 23% of the ~870 PJ demand for heat in 2050. This will deliver a CO_2-eq reduction of ~3 mton in 2030 and ~12 mton by 2050 (4% and 7% respectively of the necessary CO_2-eq reduction in the Netherlands).

This means scaling up from 17 doublets to ~175 in 2030 and ~700 in 2050, accelerated over time. Until 2020, ~3 doublets must be opened annually, and from 2021-2025 this must be ~10 doublets annually. Between 2025 and 2030, a rapid acceleration to ~20 doublets annually will be required, and to ~26 new doublets annually after 2030. By comparison, it is expected that five new geothermal plants will begin operation in 2018. For the heat sector, this means a scaling up of heat networks from the current 25 PJ to more than 150 PJ in 2050. Although this is technically possible, it will require major efforts in legislation and regulations, operational activities and generating public support to ensure that this occurs in a safe, responsible and sustainable way. This Master Plan explains how the sector aims to make this scaling up possible, and what this will require.

II. What is geothermal energy?

Geothermal energy can make an important contribution to making the supply of heat sustainable, as it has almost no CO_2 emissions. Geothermal energy is a local source of sustainable energy, which is not dependent on weather conditions, day/night or seasonal cycles. It is a proven technology that has been successfully deployed in Europe in countries such as Iceland, France, Germany and Italy for decades.

Below the surface of the Earth, from a depth of 500 metres to more than 4,000 metres, warm water is present in (porous) sandstone and limestone strata. This heat originates deeper in the Earth's crust, and arises due to currents and radiation in the outer crust of the Earth, which is several tens of kilometres thick in the Netherlands. There are various strata in the Netherlands, which differ depending on the period in which they were formed. These strata are also known as “plays”. The potential geothermal energy in these strata depends on the characteristics of the subsurface. The warm water is pumped to the surface and, via a heat exchanger, is used as a source of heat in greenhouse horticulture, the urban environment and in industry using low and medium-temperatures.

Various types of heat from the subsurface

There are various ways of using heat from the subsurface, depending on the depth and the technologies used (see Figure 9). The following technologies may be used in the Netherlands. In this Master Plan, geothermal energy and Ultra-Deep Geothermal energy are discussed.

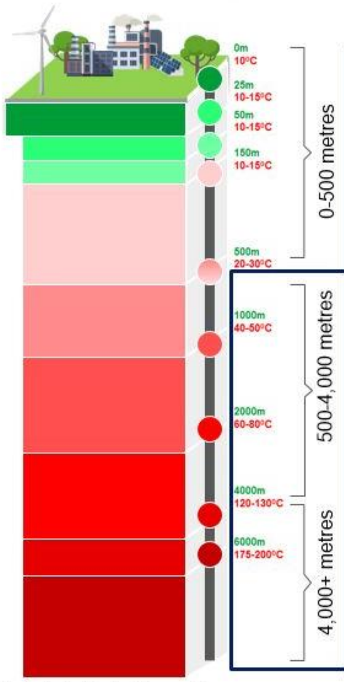
- Heat and Cold Storage (HCS): a buffer technology used to store heat or cold (in contrast to the production of heat). Excess heat or cold is stored in the ground (up to 500 metres) for use during periods of high demand for heat (in the winter) or cold (in the summer).

- Geothermal energy is existing heat that is extracted from strata at depths between 500 and 4,000 metres. At lesser depths (up to 1,000 metres), the temperatures (30-40 °C) are not always high enough for direct use with current technology, which means a heat pump is required to increase the temperature to the desired levels.
  From 2,000 metres, higher temperatures between 70 and 100 °C can be extracted. Geothermal energy can replace natural gas in greenhouse horticulture, industry etc. or to heat buildings. This technology has been used in countries such as France since the 1970s to heat homes in the Paris region. The water produced there has a temperature between 55-85 °C and is extracted from a depth of 1,500-2,000 metres.

- Ultra-Deep Geothermal (UDG) energy is extracted at depths of more than 4,000 metres. UDG is a method for producing heat with temperatures above 130 °C. The heat can be used for industrial processes, or to generate electricity. An important difference between geothermal energy and UDG is that there is more subsurface data available, and more experience with drilling, at depths less than 4,000 metres due to drilling for oil and gas (>3,000 boreholes on land in the Netherlands). There is much less knowledge about ultra-deep drilling: there are around seven boreholes at depths greater than 4,000 metres. This means that obtaining more knowledge about the deep subsurface and innovation will be more important for this technology.

Figure 9: Various types of heat from the subsurface

☐ Component Master Plan



Name	Goal	Typical end users
Heat and Cold Storage (HCS)	▪ Excess heat or cold is stored in the ground for use during periods of high demand for heat (winter) or cold (summer)	▪ Heating and/or cooling of buildings
Geothermal energy	▪ Up to depths of 2,000 metres, the temperature is between 30-60 ° C, which requires a heat pump to increase the temperature to the desired value (~80 ° C) ▪ Between 2,000-4,000 metres, higher temperatures can be extracted (60-120 ° C)	▪ Greenhouse horticulture ▪ Urban environment ▪ Light industry
Ultra-Deep Geothermal (UDG)	▪ UDG is a method of producing heat with temperatures from 120-250 ° C	▪ Light industry ▪ Generating electricity[1]

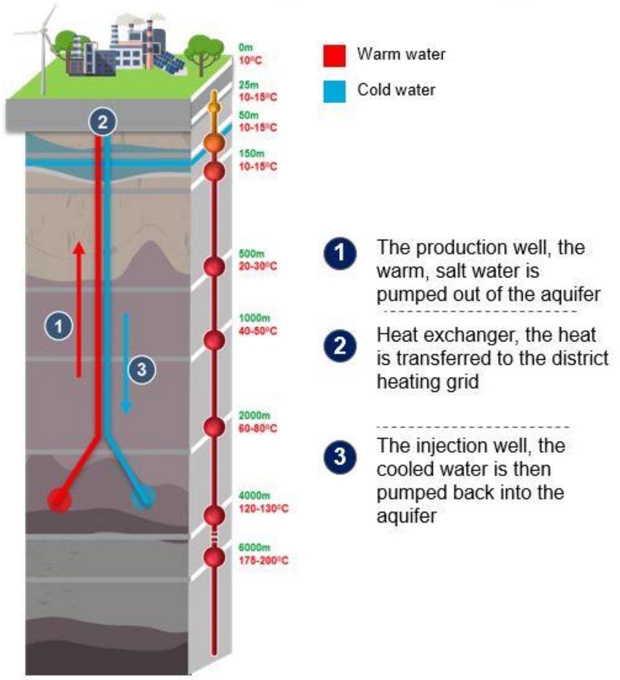
1 Not included in the Master Plan

SOURCE: www.hoewerktaardwarmte.nl

Production of geothermal energy via production and injection wells

To extract heat from the ground, boreholes are drilled into water-bearing strata (aquifers) (see Figure 10). The warm, salt water from these aquifers is pumped to the surface and the heat transferred to heat networks via a heat exchanger. The water that is pumped to the surface remains within a closed system, and circulates in a separate system to the water that reaches the end user. The cooled water is then pumped back (injected) into the aquifer and is heated again due to the constant heat from the Earth's core. A geothermal energy site thus consists of at least two wells (a doublet): at least one well is used to pump warm water to the surface (the producer), and at least one well is used to inject cooled water (the injector). Above ground, these wells are several metres apart. However, the ends of the wells are around 1 to 2 kilometres apart to prevent the rapid breakthrough of cooled water between the wells. Geothermal energy is a very stable source of heat. This means that a constant quantity of warm water can be extracted. The technical lifespan of a doublet is estimated to be around 30 years. After the extraction of warm water ceases, it is expected that the aquifer will have regained its original temperature after a few decades. For UDG, it is not yet known how many decades must pass before the aquifer returns to its original temperature.

Figure 10: Illustrative geothermal energy plant



Note: The horizontal and vertical scales are not the same.

SOURCE: www.hoewerktaardwarmte.nl

Scaling up on the basis of the "play-based portfolio approach"

To accelerate the development of geothermal energy in the Netherlands by reducing costs and risks, a play-based portfolio approach may be taken[11]. This involves seeking broadly comparable, homogeneous rock strata within the heterogeneous subsurface, which can be distinguished based on their composition and age. These homogeneous rock strata are also known as "plays". By considering the play as a whole, it is possible to apply knowledge and experience accumulated in one location in other (potential) geothermal energy projects within the same play.

If this approach is applied consistently across a portfolio with multiple projects within the same play, this will result in economies of scale, which can reduce the development costs of the jointly planned and developed doublets. Thanks to geological risk reduction, synergy, efficiency and standardisation, a reduction of ~30% can be achieved in 2030, depending on the number of doublets within a (sub)play. For example, major efficiencies can be achieved in contracts and procurement during the implementation phase, including allowing drilling rigs and teams to be used for several projects that follow in succession. In this way, drilling in "campaigns" also delivers cost and time savings by reducing the movement of drilling rigs, the re-use of "mud systems" and using high-voltage connections instead of diesel generators. Further cost reductions to 50% in 2040 are possible thanks to targeted innovation, integrated project development, optimisation of above-ground demand and infrastructure, and funding advantages.

In the Netherlands, there are seven strata that are potentially suitable for producing geothermal energy, namely the Rotliegend, Triassic, Jurassic/Chalk, Upper Carboniferous, the Chalk, the Tertiary and the Zechstein plays.

Important subsurface characteristics for geothermal energy and expected capacity of a geothermal energy project

To realise a geothermal energy project, knowledge of the subsurface is required. The capacity of an aquifer is strongly affected by the characteristics and composition of the rock stratum, such as:

- The depth correlates strongly with the temperature of the water: on average, the temperature of the water increases by 30˚C for each kilometre of depth[12].
- The thickness of the stratum determines the available quantity of water in the aquifer; the minimum thickness of an aquifer is 20-50 m[13].
- The quantity of water that can be produced is determined to a large extent by the porosity and permeability.

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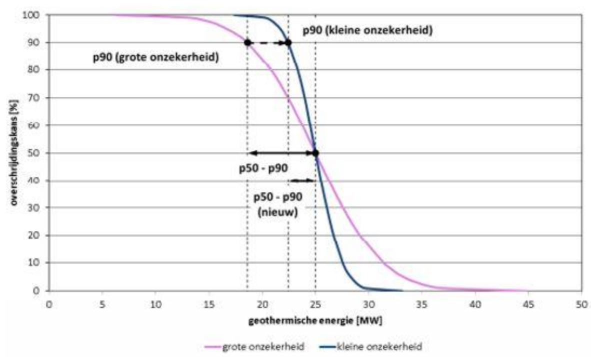
[11] For details, see EBN, TNO (2018), *"Het geheel is groter dan de som der delen (Play-based portfolio benadering)"* (The whole is greater than the sum of the parts (Play-based portfolio approach)) and IF Technology, CE Delft, Berenschot (2018), *"Opschaling geothermie"* (Scaling up geothermal energy)

[12] RVO (2010): *"Warmte uit de diepte"* (Heat from the deep), www.rvo.nl/sites/default/files/rvo_website_content/EOS/DEMO03034_0.pdf

13 TNO (2013): *"Hoge temperatuur opslag in ondiepe ondergrond"* (High-temperature storage in shallow subsurface)

Sandstone and limestone strata are strata with a suitable porosity and permeability, in which aquifers may be found. Before a geothermal energy project is realised, the subsurface remains unknown to a certain extent. This may be because there is not yet any drilling and/or seismic data. As long as the subsurface remains unknown, the extent of the available geothermal capacity is uncertain.

Figure 11: Expected curve of the capacity of a geothermal energy plant (doublet) before and after uncertainty reduction



SOURCE: TNO – Ultra-Deep Geothermal cases Almere and Barendrecht

Due to the uncertainty about the subsurface, account must be taken of various scenarios. For the feasibility study (business case), in addition to the expected capacity, the capacities in the most favourable and most unfavourable cases are important. Reducing the geological uncertainty can best be expressed as optimising the expected capacity curve. This curve is characterised by several commonly-used geological parameters, namely the P90, P50 and P10 values. The difference between the P90 and P10 is a measure of the uncertainty that a particular capacity can be realised. For example, an aquifer has an expected capacity of 5 MW with a P90 value (90% probability), when a different capacity is assumed the probability will also change as illustrated in Figure 11. If the subsurface is largely unknown, the uncertainty will be very large. This means that the probability of a large capacity is small, and that of (at least) a small capacity great. The play-based portfolio approach also focuses on reducing the geological uncertainty, and thus attempts to reduce the difference between the P10 and P90 values. Figure 11 shows that reducing the geological uncertainty causes the P90 value to increase.

The uncertainty about the subsurface can be reduced by studying the existing subsurface data, carrying out seismic surveys and exploratory drilling. All of these types of research increase knowledge about the subsurface, as explained in Figure 12.

Figure 12: Through seismic acquisition and exploratory drilling, the necessary knowledge of the entire subsurface can be determined with increasing accuracy

The necessary subsurface data can be obtained via

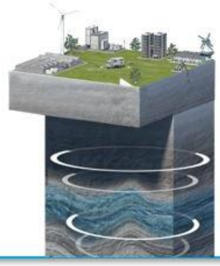
Data necessary for the realisation of geothermal energy projects

- The **depth** (important for the temperature of the water)
- The **thickness** of the aquifer, important for the volume
- The **porosity** (porosity determines the flow in the aquifer)
- The **permeability** (permeability of the rock)

It is important to take account of the presence of **drinking water, oil and gas fields and fault lines**

Research (seismic acquisition)

- Seismology is a method that allows a picture of the subsurface to be obtained using **vibrations/sound waves**
- **2D and 3D seismology** can give a good picture of the entire subsurface and the presence, continuity, depth and thickness[1] of an aquifer



Exploration (exploratory drilling)

- If there is a suspicion during the research phase that an aquifer is present, this can be tested using a **test borehole**
- During drilling, **measurements are made and samples taken** continuously, which allows accurate information to be obtained about the quality and temperature of the aquifer and the strata above it
- By **combining well results with seismic data**, it is possible to draw conclusions about the existence and quality of aquifers across a larger area than just the well, and drilling and seismic risks can be prevented and mitigated

1 Note: plays with a thickness less than 50 m are excluded from the potential calculations
SOURCE: TNO (2017), *"Kader voor exploratiewerkprogramma geothermie in gebieden met lage datadichtheid"* (Framework for exploratory geothermal work programme in areas with low data density)

Opportunities and risks in the production of geothermal energy

Using geothermal energy instead of gas as a source of heat results in a significant reduction in CO_2 emissions. For an average project, the CO_2 reduction is 88% compared to natural gas. For the sources realised so far, the CO_2 emissions have been 7 kg/GJ on average, compared to 57 kg/GJ for natural gas. The water is pumped out of the production well and pumped into the injection well using electric pumps. If these pumps are powered using green energy, CO_2 emissions are almost zero. Another benefit is that geothermal energy is a local source of sustainable energy, which is not dependent on weather conditions, day/night or seasonal cycles.

Safety is the top priority for geothermal energy companies. The risks are mapped beforehand, appropriate safety precautions are taken and lessons are learned from previous experiences. The risks vary for each project and location; not all risks arise with every project. The risks associated with producing geothermal energy are tremors, the escape of gases while drilling the doublets and the production of geothermal energy, natural radiation from the production water, pollution of the groundwater and subsidence.

- Drilling in the subsurface can cause tremors and earthquakes. By taking account of natural fractures in the subsurface, the probability of earthquakes is low. Once the doublets have been drilled, the pressure in the subsurface and fractures is checked to identify any deviations from the expected values. This determines whether production can be carried out responsibly.

- During drilling, there is a small chance of finding gas under pressure. Therefore, there are safety precautions on site, such as valves, that can withstand high pressures. There is often gas dissolved in the water pumped to the surface. If this is the case, it is captured in a gas separator and used or returned via the injection well. The well is not pressurised if the pump is not operational.

- There are small naturally-occurring concentrations of mildly radioactive particles in the subsurface. These can be brought to the surface and accumulate in the filters. Because of this, the companies where this occurs have undertaken special measures and dispose of the filter waste separately. The particles cannot enter the (heating tubes of the) greenhouses or homes. The water that is pumped to the surface remains within a closed system, and circulates in a separate system to the water that reaches the end user.

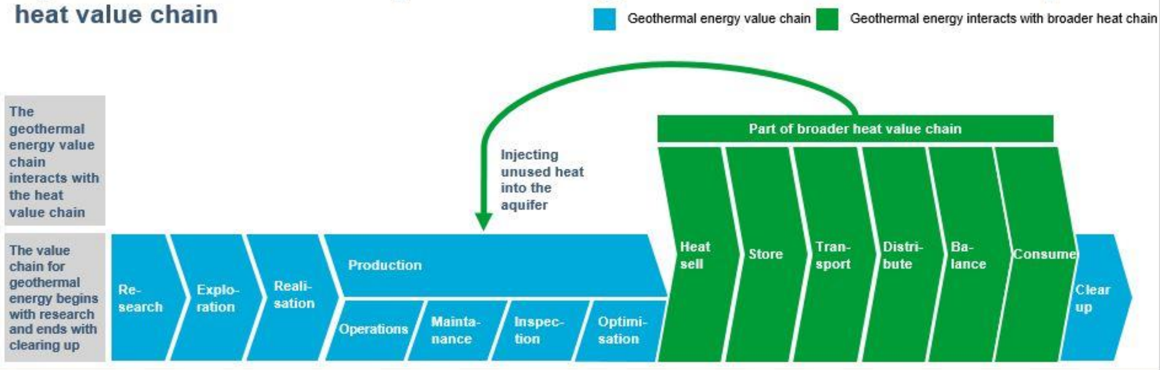
- The tubes are designed to prevent water from one stratum entering others. If they nevertheless leak, this can pollute the groundwater. Robust well design, regular maintenance and monitoring reduce the chance of leakage and ensure that faults are identified promptly, and thus reduce the effects if something does occur.

- During the production of geothermal energy, no material is removed from the subsurface: only the heat is extracted, and the cooled water is pumped back. This means that the average pressure remains unchanged, and the probability of subsidence is minimal.

The geothermal energy value chain

The geothermal energy value chain begins by carrying out research into the subsurface and ends with the dismantling of the geothermal energy site once the aquifer has cooled at that location, as visualised in Figure 13. There is a strong dependence on the broader heat value chain, shown here in green.

Figure 13: The value chain for geothermal energy interacts with the broader and separate heat value chain



1. The **research phase** consists of carrying out seismic surveys to map the subsurface. The subsurface data obtained is used to estimate where there are rock strata from which geothermal energy can be extracted. In parallel to this process, the demand for heat at the locations in question must be determined, to match the above-ground demand for heat and the subsurface supply of heat.

2. The **exploratory phase** begins once a geothermal energy operator has identified a suitable location to drill for geothermal energy based on the subsurface data. An exploration permit (drilling permit) and an environmental permit are then required. The company requests these permits from the Minister of Economic Affairs and Climate (EZK). Once the exploration and environmental permits are issued, the operator may commence the realisation of the geothermal energy project.

3. The **realisation** of geothermal energy projects involves developing an organisation model, carrying out a risk assessment, organising the funding, and designing, drilling and installing the doublets, site and heat networks. The design must allow production to continue for as long as possible, while being as cost-efficient and safe as possible. The well design must be submitted to the regulator (SodM), where the design is checked for compliance with the required characteristics and safety qualifications.

4. The **production phase** consists of four elements, namely the operational, maintenance, inspection and optimisation elements:
    a. In the first step of the **production phase**, the productivity and injectivity of the aquifer is tested and improved if possible. In addition, this phase is intended to determine the (other) characteristics of the formation water, the reservoir and the doublets. Based on this data, step two can start, in which the heat is produced safely and responsibly over a long period of time.
    b. An adequate **maintenance programme** is important to prevent corrosion and scaling (choking of systems) of the wells and above-ground site. By carrying out regular inspections, the maintenance plan can be optimised.
    c. **Inspection** involves an independent party monitoring the safe operation of the geothermal energy site during its development and production. This also means that detailed measurements of the wells are carried out, and that the water reservoir is used without affecting its integrity.
    d. Reservoir management is essential to optimise the yield and lifespan. The goal of reservoir management is to manage operations based on facts, information and knowledge, to obtain as great an economic yield as possible from a reservoir in a safe and sustainable manner.

5. Geothermal energy is part of the **broader heat value chain**, which consists of the sale, storage, transport, balancing and consumption of heat:
    a. **Sale**, when the heat is sold, the owner of the source supplies the geothermal energy to the distribution grid.
    b. The **storage** of unused heat has not been economically viable up to now. There are systems that make it technically possible to store heat in the ground, such as HCS (Heat and Cold Storage). To store greater quantities of heat at higher temperatures, more innovation is required.
    c. The **transport** of heat to end users occurs via well-insulated heat networks. The transport of warm water occurs via primary supply pipelines to distribution grids close to end users. The Warmtealliantie Zuid-Holland regional heat network is one example of a large-scale heat network that is to be set up. This system will transport heat from the port of Rotterdam to the urban environment and greenhouse horticulture.
    d. **Distribution** to the urban environment, greenhouse horticulture and/or **industry** from the transport grid in smaller pipelines, including cascading between different required temperatures.
    e. **Balancing** the demand for heat and heat supply by making use of other heat and energy sources to cover peaks in demand and to guarantee a backup.
    f. **Consumption** to heat the urban environment and greenhouse horticulture, and in suitable (lower) temperature processes in industry.

6. The clear-up of the doublets is necessary once the end of the life cycle has been reached. The way in which wells (or boreholes) must be sealed, removed and then tested is mandated by legislation. During the sealing process, multiple “cement plugs” of several tens of metres are inserted into the well. These close off the well and form a pressure-tight barrier. The wells are sealed off several metres below the ground and sawn off, and the above-ground site is also removed. When designing geothermal plants, it is essential to think about how the doublet can be cleared up safely and in the most cost-efficient manner.

Various stakeholders are involved with this geothermal energy value chain. These are explained in the organisational chapter.

III. GEOTHERMAL POTENTIAL AND OUR AMBITION

A. Technical potential of geothermal energy

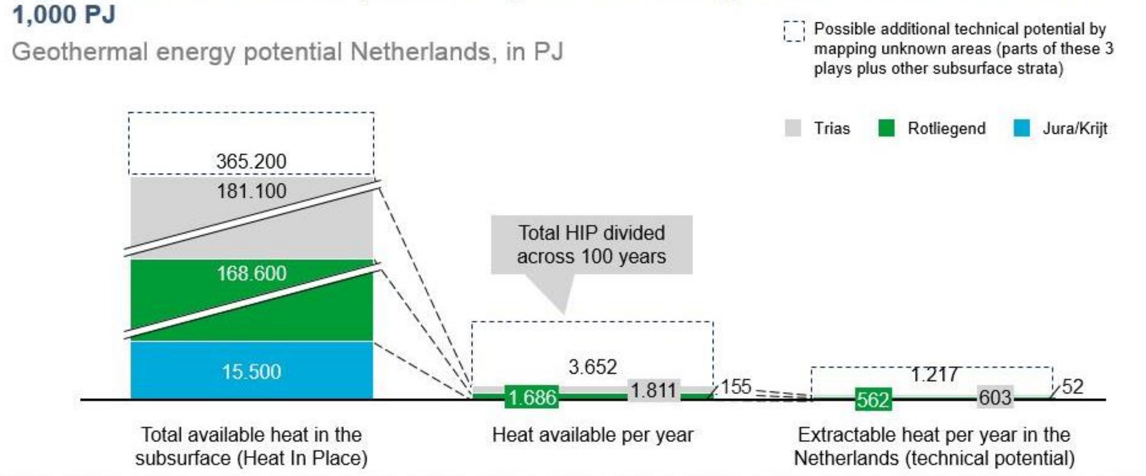
A geothermal energy project can be realised if the subsurface is suitable and there is appropriate above-ground demand. Seismic data and test drilling are required to determine whether the subsurface is suitable for producing geothermal energy. There are a variety of estimates of the quantity of geothermal energy that could be produced annually in the Netherlands (85 to >1000 PJ)[14]. This is because only part of the Dutch subsurface has been mapped. Even if information is available about the subsurface, uncertainty remains about the final capacity of the geothermal energy source. We expect a technical potential of more than 1,000 PJ of viable geothermal energy in the Netherlands annually.

Due to exploration and production activities in the oil and gas industry during the past 70 years, the subsurface in the north and south-west of the Netherlands is relatively well understood. Some of the geothermal energy potential will not be extracted, as the sources of geothermal energy are in natural parks or in areas where drinking water is extracted. In addition, the extraction of geothermal energy may be restricted due to fault lines in the underground reservoirs or natural gas extraction (for example in parts of the province of Groningen).

Based on the data in ThermoGIS 1.2, the potential heat that can be extracted is more than 1,000 PJ during a period of 100 years (see Figure 14). This is a conservative estimate, as it only includes (a limited number of) areas where there is good knowledge of the subsurface. Therefore, considering only the areas for which there is a high degree of certainty that the potential can be realised, there is sufficient technical potential to achieve the goals of 50 PJ in 2030 and 200+ PJ in 2050.

[14] PBL (2017): *"Toekomstbeeld klimaatneutrale warmtenetten in Nederland"* (Future picture of climate-neutral heat networks in the Netherlands)

Figure 14: Known technical potential of geothermal energy in the Netherlands is more than 1,000 PJ



Most important assumptions

- Heat in Place based on ThermoGIS 1.2
- Calculated for three of five plays (Rotliegend, Triassic, Jurassic-Chalk)[1]
- Heat In Place extracted over 100 years
- ~1/3 of Heat in Place can be extracted due to geometric limitations

1 ThermoGIS 1.2 contains out-of-date data for three of the five most important plays in the Netherlands and no data for the other two plays; Update (ThermoGIS 2.0) expected (see Chapter 4A)

SOURCE: Berenschot, IF Technology, CE Delft (2018), *"Opschaling geothermie"* (Scaling up geothermal energy).

For the vast majority of the subsurface, there is insufficient knowledge about the potential for geothermal energy – these areas are known as "blanks spots" (see Figure 15). The Ministry of Economic Affairs and Climate Policy (EZK) has commissioned EBN and TNO to map these areas. Nine areas have been identified in which the technical potential is currently estimated as low due to a lack of seismic surveys and drilling. Further exploration of these blanks spots will increase the accuracy of these estimates, which will allow the true technical potential in the Netherlands to be determined[15].

It is important to prioritise subsurface research based on the above-ground demand for heat and expected number of plays in the subsurface. Around half of the demand for heat is located in just three blanks spots: The Haarlem–Nijmegen axis (C), Oost-Brabant and Noord-Limburg (F) and West-Brabant (E). While mapping the blanks spots, synergies can be achieved where seismic surveys and exploratory drilling for plays that lie above one another can be combined. In addition, as much existing knowledge from oil, gas and geothermal energy projects and subsurface data as possible must be used. The more information is available, the greater the probability of a successful doublet.

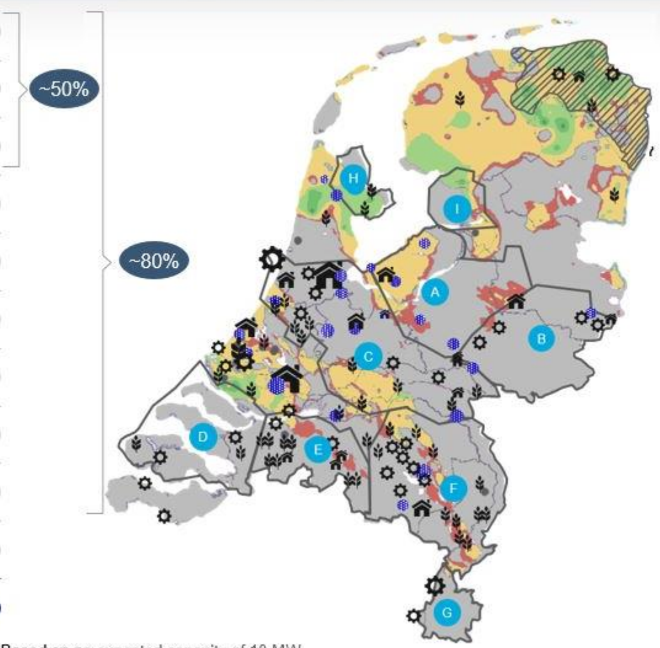
[15] TNO (2017), *"Kader voor exploratiewerkprogramma geothermie in gebieden met lage datadichtheid"* (Framework for exploratory geothermal work programme in areas with low data density)

Figure 15: Around 80% of the demand for heat in the Netherlands exists in areas where there is little or no subsurface knowledge

White spots in the Netherlands to demand for heat in 2015[1], PJ

Axis Haarlem–Nijmegen	C	172	25%
Oost-Brabant and Noord-Limburg	F	85	13%
West-Brabant	E	83	12%
Zeeland and Zuid-Holland Islands	D	42	6%
Noord-Gelderland and Zuidoost-Flevoland	A	40	6%
Zuid-Limburg	G	40	6%
West-Friesland	H	31	4%
Achterhoek and Zuid-Twente	B	26	4%
Noordoostpolder	I	17	2%
Areas already known		146	21%
Total		682	100%

Technical potential and demand for heat per sector in 2015



1 White spots defined based on TNO/EBN 2017 2 Based on an expected capacity of 10 MW
SOURCE: CE Delft, TNO/EBN (2017), *"Kader voor exploratiewerkprogramma geothermie in gebieden met lage datadichtheid"* (Framework for geothermal exploratory work programme in areas with low data density)

B. Our ambition

In 2050, a mix of sustainable technologies will be necessary to supply the ~870 PJ of demand for heat. Part of this demand will be met with solutions such as electric heat pumps and green gas, and part with heat via heat networks. Individual and collective solutions are both still being developed, and the future availability and costs are uncertain. For example, for collective heating, there is uncertainty about the economically-available heat in the long term, and electric solutions with green energy may require major investments to strengthen electric grids and to insulate homes.

Around 40% of the demand for heat (~380 PJ) in the necessary mix can be met via heat networks, provided that there are sufficient economical and sustainable sources of heat available in the region (see Figure 18). Of this, ~60 PJ is for greenhouse horticulture, ~120 PJ for industry (where heat networks can meet low and medium-temperature industrial demand, up to 250 °C) and the largest part, ~200 PJ, is for the urban environment.

Geothermal energy can make an important contribution (estimated at max. ~230 PJ) to the ~380 PJ in all heat networks. It is estimated that around ~100 PJ of sustainable waste heat[16] and ~50 PJ from biomass[17] will be available in 2050 as sources of heat for these grids. For the remaining 200+ PJ, geothermal energy is the only sustainable alternative available in sufficient quantities[18]. It is particularly suitable as a baseload. The variation in demand for heat during the year limits the number of peak-load hours for geothermal energy. This can be solved by connecting a portfolio of sources to a heat network, and using (for example) extra biomass during times of peak demand (see Figure 16). The dependence between geothermal

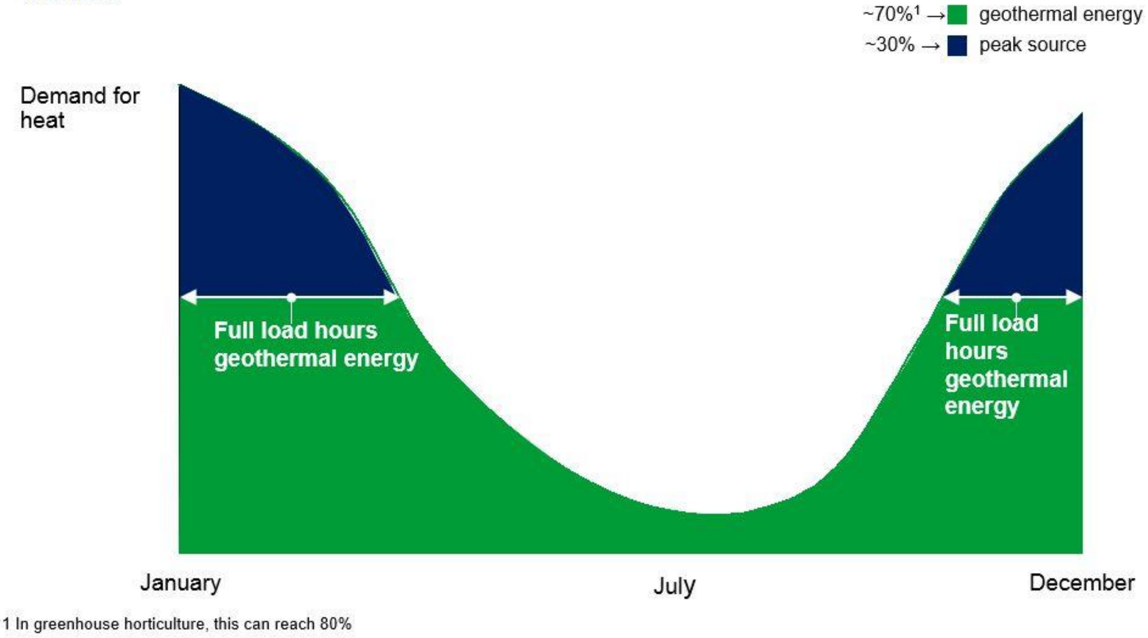
16 PBL (2017), *"Toekomstbeeld klimaatneutrale warmtenetten in Nederland"* (Future picture of climate-neutral heat networks in the Netherlands). Assumption: 50% consumption at own location and 50% equal relative distribution between greenhouse horticulture and the urban environment

17 PBL (2018), Topic site *"Biomassa wensen en grenzen"* (Biomass wishes and boundaries). Assumption: equal relative distribution across total demand for energy, use during peak demand

18 See Chapter 3A on Technical Potential

energy sources and heat networks for the urban environment is discussed further in Chapter 4F. "Connecting to heat networks".

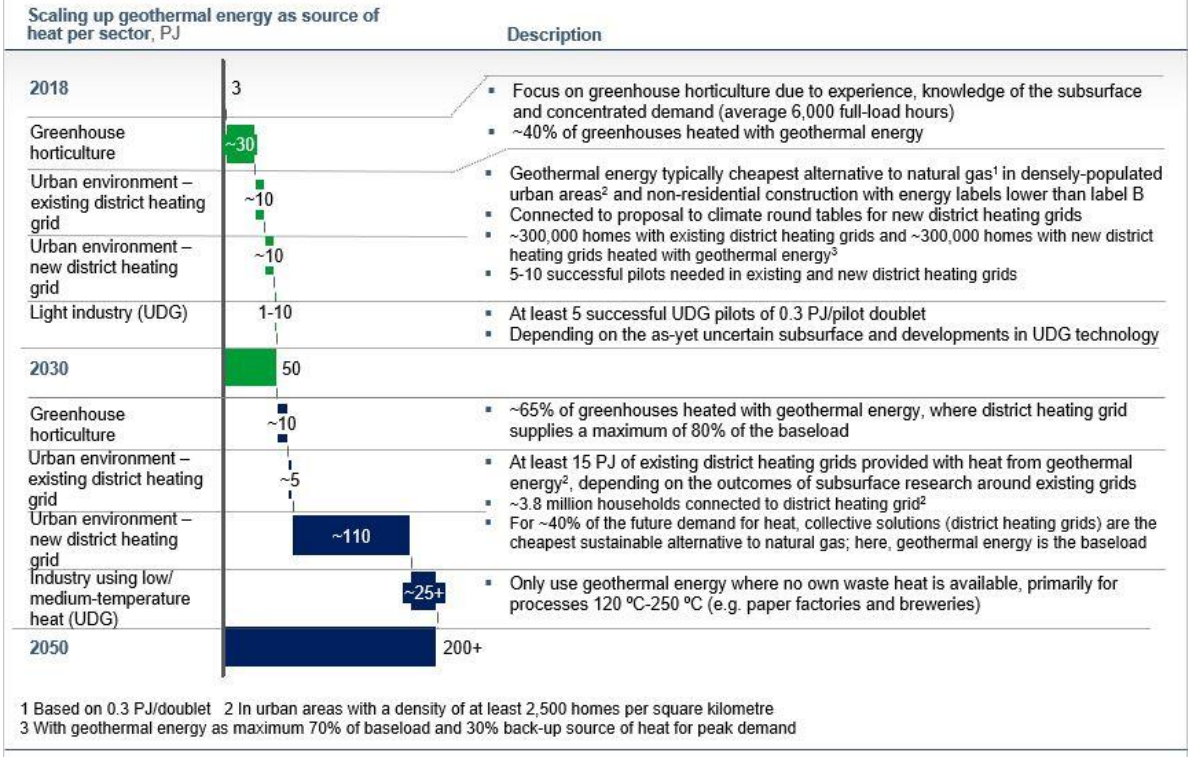
Figure 16: Geothermal energy as baseload supplemented with flexible source during times of peak demand



To take the right steps towards meeting this demand, we have set an ambition for 2030 (50 PJ) and for 2050 (200+ PJ). The ambition of 50 PJ for 2030 is in line with the potential identified by CE Delft and IF Technology of 38-75[19] that can be extracted economically. The ambition of 200+ PJ is a distant goal, which connects with the total estimated demand for geothermal energy but which requires sufficient economically-viable geothermal energy. To achieve this, it is necessary to explore the subsurface, to systematically map above-ground demand and to use the subsurface supply optimally (e.g. by cascading between various end users). These subjects are all covered in the following chapters.

[19] Preliminary results based on a match between the known subsurface potential in ThermoGIS 1.2 and the above-ground demand for heat and with limited cascading (only between greenhouse horticulture and the urban environment). See also IF Technology, CE Delft, Berenschot (2018), *"Opschaling geothermie"* (Scaling up geothermal energy) and EBN, TNO (2018), *"Het geheel is groter dan de som der delen (Play-based portfolio benadering)"* (The whole is greater than the sum of the parts (Play-based portfolio approach))

Figure 17: Scaling up geothermal energy begins with the greenhouse horticulture industry, and after 2030 the urban environment will deliver the largest contribution



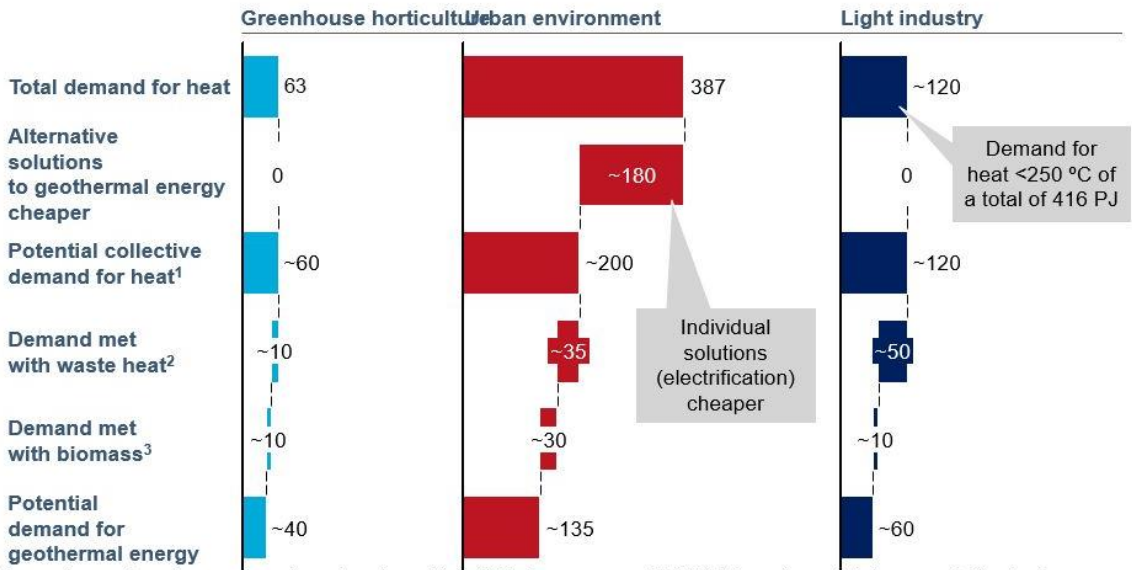
Before 2030, the majority of this ambition (~30 PJ) will be realised in greenhouse horticulture. The existing experience and concentrated demand for heat above a subsurface that is largely understood offers the opportunity to accumulate experience with play-based production. We aim for an accelerated realisation of LTO Glaskracht's climate-neutral ambition (25-30 PJ in 2040 or 2050).

For the urban environment and industry, pilots will be initiated before 2025, with ~20 PJ being supplied in 2030 for connection to expanded heat networks. We will simultaneously map demand and supply and will work together with heat companies, so that we can scale up after 2030 where the long-term estimated demand for geothermal energy is greatest. At present, one geothermal energy doublet has been drilled, which will supply the heat network in The Hague from the end of 2018: Haagse Aardwarmte Leyweg. Suitable locations for doublets are already being sought in Tilburg and Leeuwarden, and a (partly) new heat network will also be installed in Leeuwarden.

In industry, we are developing existing pilots as part of the Green Deal for UDG, in which we are starting an exploration programme with six consortia of market players to determine whether geothermal energy can be used successfully in industry using low/medium temperatures. Depending on the success of this and the subsurface potential, we expect that 1-10 PJ can be supplied in 2030.

The ambition of 200+ PJ in 2050 will require a major scaling up in the urban environment. The largest part of the ambition (~135 PJ) will be supplied as a baseload, supplemented with sustainable waste heat and biomass (~65 PJ). In addition, geothermal energy can play a role in industry with a temperature demand up to 250 ºC. Due to uncertainty about the development of waste heat, the extent to which the role of geothermal energy can grow will become clear in the coming years. This may be up to ~60 PJ. For higher temperatures (>250 ºC) in industry (~70% of industrial emissions), we do not believe it is possible to use geothermal energy.

Figure 18: Possible demand for geothermal energy in 2050 per end user sector INDICATIVE

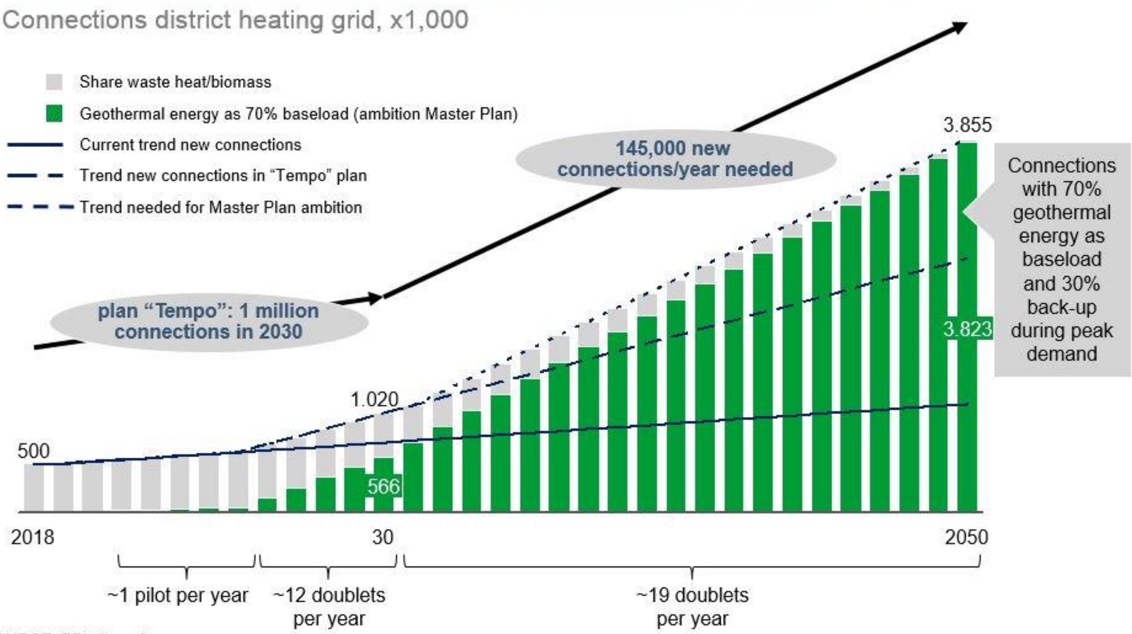


1 Assumption: geothermal energy everywhere where demand is available for an average of 7 EUR/GJ, but varies strongly between neighbourhoods
2 100 PJ waste heat available (PBL, 2017), assumption: 50% use at own location, rest divided relatively between greenhouse horticulture and urban environment
3 200 PJ biomass available (PBL, 2018), assumption: equal relative division across total demand for energy

SOURCE: CE Delft, LTO Glaskracht, McKinsey Energy Insights

In the Netherlands, ~500,000 homes are connected to a heat network, with ~20,000 more being connected each year. To supply ~135 PJ to the urban environment, this process must be accelerated. Aedes and the five largest heat companies will submit a proposal to realise a million connections by 2030 (plan "Tempo"). In this plan, 80,000 extra homes would be connected annually from 2025. The regional grid operators are also bidding to realise almost 1.2 million connections in 2030. After 2030, this must be accelerated to ~145,000 homes per year to achieve the ambition (see Figure 19).

Figure 19: With the plan "Tempo" and 145,000 new connections annually from 2030, there will be sufficient connections to achieve the ambition in the Master Plan



SOURCE: PBL, interviews

IV. Technical action plans

Our ambition for the geothermal energy sector in 2030 and 2050 can only be realised through the correct involvement of a broad group of stakeholders. Action is required in the short, medium and long term by the sector, as well as government, heat companies and knowledge institutes. We have determined a primary goal, a vision for the future and actions for six different topics, for the sector and for outside the sector:

A. **Profitable projects:** Profitable projects by reducing costs and increasing revenues across the entire life cycle of a doublet

B. **Effective legislation and regulations, regulatory structure and policy:** Prompt processing of permits and ensuring regulation can be planned

C. **Safe and effective operational activities:** Optimising investment decisions and operational activities to ensure safe and effective implementation

D. **Robust public support:** Intensifying national and local dialogue about the energy transition and the role for geothermal energy in this transition

E. **Innovation:** Innovation to better match subsurface heat supply with the demand for heat

F. **Connecting to heat networks:** Consolidating and structuring the demand for heat

The above topics are each covered in a chapter below to provide answers to the following questions:

- What is the vision for the future for this topic?
- What action is required from the sector?
- What is required from outside the sector?

The most important goals and actions are summarised in each chapter in a road map, which describes which parties will carry out which actions, and in which time period (short, medium and long term).

A. Profitable projects

i. Vision for the future for scaling up geothermal energy

To realise 160 doublets between now and 2030, an estimated investment of around two billion Euros is required. Even if the costs of realisation can be reduced by 40% thanks to growing experience within the sector and through coordinated exploration and production, around another four billion Euros will be required between 2030 and 2050 to realise at least 450 extra doublets.

To ensure that sufficient investors can be found to finance this scaling up, and to comply with the additional financial assessment criteria announced in the *Beleidsbrief Geothermie*, the projects must deliver a stable yield and the financial risks must be reduced. Profitable projects require both secure revenues, for example with the help of subsidies, and reductions in the development and operational costs. Financial risks can be reduced by reducing the probability of low-yield projects and mitigating the impact of these. The former requires more knowledge and experience of the subsurface and geothermal energy, while the latter can be achieved with sufficient capital and insurance systems.

ii. What the sector will do

To improve the business case for projects, the sector will undertake five steps:

1. **Sharing more subsurface data faster via a central party**

By systematically organising the collection and sharing of subsurface data, the probability of low-yield projects can be reduced. At present, operators of geothermal energy doublets must supply research, production and injection data to TNO-AGE. To reduce uncertainty about the subsurface, the sector must share more data, and do so faster, via a data management system that connects with the needs of the various geothermal energy players:

- The period for releasing research data will be shortened from five years after the completion of the acquisition to six months.

- EBN or TNO-AGE will collect more detailed production and injection data for future doublets *(see Chapter 4C. Safe and effective operational activities for details).* This data can be used to optimise production, or to analyse the reasons for downtime and to learn from this. The easier it becomes to predict the performance of as-yet unrealised doublets in advance, the less uncertain the business case will be.

2. **Research into the financial risks of geothermal energy that operators can and/or must be insured against, and establishing a fund for this if necessary**

Some of the financial risks associated with geothermal energy projects can be covered by public and private insurance. The three greatest financial risks are:

a. Risk of dry wells.

b. Risk of technical failure during the production phase.

c. Liabilities of third parties during exploration or production.

At present, the public RNES guarantee scheme covers the risk of dry wells. Operators can use this scheme to insure themselves against a realised capacity lower than the expected P90 value for the well. There is a huge local variation in the knowledge of (and uncertainty about) the subsurface. It is expected that knowledge will increase once particular plays are further developed, or blank spots are mapped. Because the risks vary, a single scheme for the risk of dry wells is insufficient. Instead of this, we will investigate the possibility of offering various different insurance schemes (segmented RNES), which will allow operators to choose the P-value and associated capacity that they wish to insure. In addition, it is important to investigate whether insurance schemes against technical failure during the production phase and liabilities of third parties during exploration or production are desirable, and how these can best be organised (e.g. by the government, the sector, via a revolving fund or by the market).

3. Coordinated exploration and operation of sub-plays

A coordinated approach will lead to more knowledge of the characteristics of the local subsurface, and will facilitate cost reductions. This may be carried out by competing operators. A large part of the cost reductions can be achieved by combining the necessary activities, by optimising the doublet and site specifications and standardising repetitive activities. In addition, there is a greater probability of a successful project within a play where doublets have already been realised than in an unknown play, thanks to the greater knowledge of the subsurface. The larger the plays, the greater the optimisation. The first step is to select a sub-play based on technical potential and sufficient above-ground demand for heat. Greenhouse horticulture in the Westland region appears to be particularly suitable. A plan for a portfolio must then be developed, with various options for coordination:

a) A tendering process (possibly with a several scenarios) that ensures market organisation, tendering and innovation and linking to legislation and regulations (see Figure 20 for a comparison with scaling up offshore wind farms)

b) Larger operators that develop further or enter the market to realise a portfolio with a large number of doublets

c) A central party that coordinates the development of portfolios (by multiple operators)

d) Multiple operators that work together closely to develop a common portfolio

Depending on what is permitted by legislation, the participation level and the number of projects in which EBN participates, EBN may be able to fill role “c”. For example, EBN may participate in all projects within a chosen sub-play, so that as much of the knowledge accumulated via EBN as possible may be shared *(see Chapter 4C. Safe and effective operational activities for details)* and the design and location of new doublets can be centrally coordinated. If this role does not exist, or exists in a different form, then we will examine how we can support operators in implementing another option.

4. Increasing the financial basis of operators

Operators require a sufficient financial basis, and thus capital, to cover unplanned events during the entire life cycle of a project. In the amended Mining Act, the financial health of operators will therefore be assessed at several stages. This is also important to ensure the proper clear-up of the doublets etc. Operators can achieve a sufficient financial basis, and continue to guarantee this, if their projects are sufficiently profitable. The consolidation of operators may contribute to this. One option is to supplement operators' capital via a joint venture with capital invested by EBN through a stake in the venture. This is easier to arrange for future companies than for existing operators.

5. **Further cost reduction through asset management and innovation etc.**

Thanks to research and knowledge sharing within DAGO into maintenance costs and optimising systems, operators can make a better estimate of the required works and associated costs during the lifespan of the system. Due to the increase in the number of realised projects, this benchmark will become broader over time and can lead to further improvements in asset management. This is described in more detail in chapter C. Costs can also be reduced via targeted innovation, for example in the field of developing materials with longer lifespans or improving ESPs (electric pumps) *(see Chapter 4E. Innovation).*

Figure 20: Comparison between offshore wind and geothermal energy

[dashed box] Made possible with targeted government policy

	Offshore wind	Geothermal energy
Preliminary research	▪ Necessary physical data (wind, waves, sea bed) are part of the tendering system	▪ Acquiring and sharing (better) seismic data (e.g. GTI "white spots" research)
Policy objectives	▪ Measurable objectives (4450 MW in 2023) are contained in the *Energieakkoord voor duurzame groei*	▪ No hard objectives specifically for geothermal energy/heat, and not "translated" to districts/areas
Legislation and permits	▪ Necessary permits are prepared and part of the tendering system based on centrally-allotted locations	▪ Permits issued on request of operators for individual projects ▪ Existing Mining Act not geared towards (large-scale, portfolio) geothermal energy and tendering ▪ Local consultation with local authorities and residents required
Infrastructure	▪ TenneT is legally mandated to be grid operator at sea and to connect wind farms ▪ Costs of connection socialised	▪ Insufficient existing district heating grids (~25 PJ in urban environment) ▪ Ownership and funding project-specific/not uniform (high transaction costs)
Demand/sales	▪ Subsidy via SDE ▪ Uniform product, with demand and price mechanism known	▪ Subsidy via SDE ▪ Non-uniform product, sales determined locally ▪ Demand dependent on planning policy ▪ Price mechanism in development
Supply	▪ Wind data known and stable	▪ Existing geological (subsurface) risks, which diminish as the number of projects grows ▪ Local storage and back-up required
Operators	▪ Consortia of parties with much experience and capital (e.g. Shell, Van Oord, Eneco)	▪ No major parties enter ▪ Current parties have experience with 1-2 doublets and relatively little capital

iii. What the sector needs

The role of the government in scaling up geothermal energy is currently much smaller than in scaling up offshore wind, for example, where as well as subsidies, the infrastructure costs are socialised and the required permits are part of the tendering process (see Figure 20 for a more extensive comparison). It is important to also consider the role that the government can play and wishes to play in scaling up geothermal energy. There are three preconditions that the sector certainly needs to be met for profitable projects:

1. **Mapping the blank spots**

The uncertainty about the subsurface can be reduced by mapping the "blank ", areas where there is insufficient knowledge about the technical potential. This research is already being carried out by EBN and TNO, and is financed by EZK. It is also important to prioritise research into blank based on the above-ground demand for heat and the number of plays in the subsurface, to maximise the probability of discovering technical and economic potential. In addition, preliminary and final results of this research must be published as rapidly as possible and must be easily searchable at a central location (ThermoGIS from TNO) by all stakeholders and potential operators. Parallel to the further mapping of the subsurface, we can evaluate whether the existing RNES scheme must be segmented to connect better with the differences in subsurface uncertainty at different locations.

2. **A clear and predictable long-term energy policy, including agreements about CO_2 prices and subsidies**

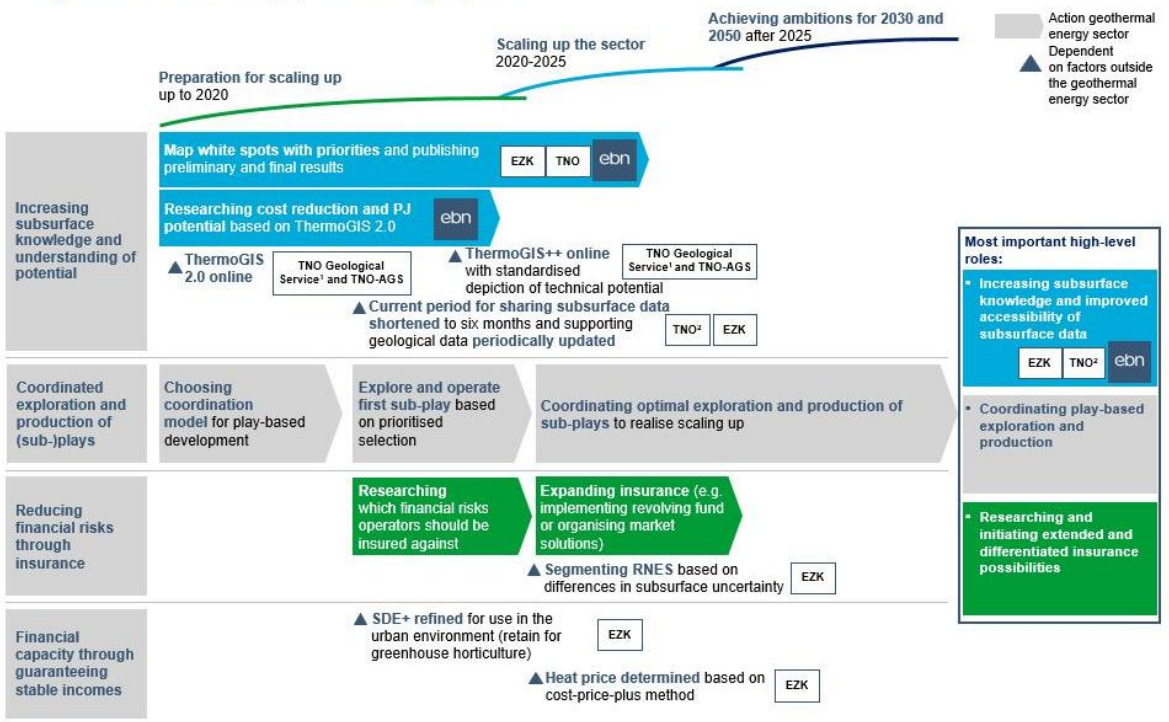
The *Klimaat- en Energieakkoord* can contribute to a more stable and clear energy policy. The geothermal energy sector requires clear policy goals for CO_2 reduction per end user, and associated CO_2 prices and/or subsidies for sustainable sources that will make a systematic contribution to increasing sustainability. The latter requires that the SDE+ subsidy be adapted to geothermal energy in the urban environment specifically, as the business case is most uncertain in this segment, and the demand for heat the greatest. In addition, developing geothermal energy for the urban environment is more complex than for greenhouse horticulture, due to the need for heat networks, a lower number of operating hours, the possibility of cooling and the requirements of the Heat Act ("Warmtewet"). The amended SDE+ must take account of a model in which sales gradually increase and the return temperature is gradually lowered, e.g. with a sliding scale subsidy scheme.

3. **A heat price determined based on a cost-price-plus method**

It would benefit all sustainable sources of heat if the no-more-than-elsewhere principle in the current Heat Act no longer applied. End users should pay a price based on the cost of heat production plus a mark-up for the suppliers, instead of the natural gas price. To achieve this improvement, a decision must be made as to whether a (fully) regulated heat price is logical, or whether the market should always determine the price. Sustainable sources of heat, including geothermal energy, may also be facilitated through income compensation, as there are no alternatives (yet) that compete with natural gas.

iv. Road map

Figure 21: Road map profitable projects



1 *Data en Informatie Nederlandse Ondergrond* (DINO, Dutch Subsurface Data and Information) and mapping department 2 Including "ECN part of TNO"

B. Appropriate legislation and regulations, regulatory structure and policy

i. Description of goals

The geothermal energy sector is still young and growing, which means there are opportunities to adapt legislation and regulations, the regulatory structure and policy to better match developments in the geothermal energy sector in the coming years. Where possible, the geothermal energy sector wishes to work towards three goals:

- **Appropriate legislation and regulations:**
  - Adapting existing legislation and regulations to fit the working procedures that can be applied during geothermal energy projects in practice.
  - Developing industry standards and work plans based on clear and targeted legislation and regulations tailored to the geothermal energy sector. These industry standards permit the speed and flexibility needed to facilitate scaling up, as the sector can implement best practices and innovation faster. This required speed and flexibility are lacking in a system of prescriptive legislation and regulations. In addition, a regulatory structure based around a "best practice operator" can lead to division within the sector.
  - Rapid and transparent processing of the necessary permits. In the coming years, this means that all parties that play a role in applications, advising and approval of permits must have the necessary FTEs, knowledge and resources.
  - Facilitating a play-based portfolio approach in legislation and regulations to allow the ambitions for 2030 and 2050 to be realised. When amending legislation and regulations, the requirements of these must be considered, such as the possibility of requesting a single permit for several doublets within an area, optimising multiple permit applications for the same play and accelerating the release of permits in cases of inactivity.
- **Appropriate policy:** policy that promotes the development of geothermal energy.
  - At central level: this is already occurring through measures such as the blank plan to map the subsurface, and various Green Deals. A long-term vision for subsidies will also help.
  - At local authority level: weighing up various interests, such as interference between drinking water and geothermal energy. Optimisation and better collaboration between various (sustainable) energy sources where necessary.
- **Appropriate regulatory structure:** Transparent and clearly-explainable assessment frameworks and a risk-based regulatory structure, based on a thorough risk assessment.

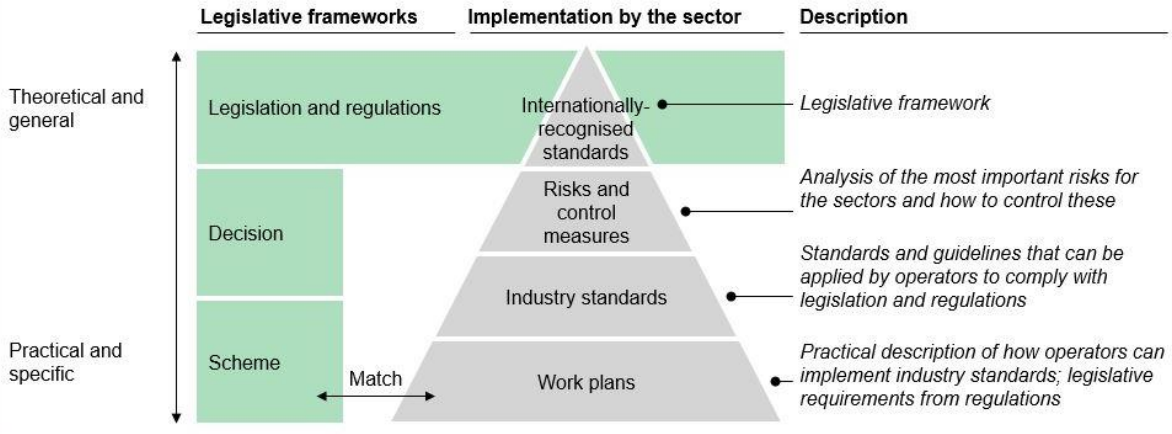
ii. What the sector will do

To ensure that legislation and regulations, the regulatory structure and policy are better adapted to the geothermal energy sector, we will undertake the following two actions:

1) **(Further) development and implementation of industry standards and work plans**

The (further) development of industry standards and work plans will allow the geothermal energy sector to standardise various phases of geothermal energy projects, which will lead to continuous quality improvements in geothermal energy projects and systematic regulation by regulators. To this end, various types of standards and work plans will be developed, both in practical terms (work plans, instructions) and more specific and theoretical (industry standards) and general (health and safety system). Particular attention will be paid to developing and implementing industry standards. These represent the practical implementation by the sector of legislation and regulations such as the Working Conditions Act and the Mining Act, based on analyses of risks and control measures, in the form of standards that the sector must comply with. Figure 22 explains the relationship between the legislative frameworks and how these are put into practice by the sector.

Figure 22: Relationship between legislative frameworks and implementation by the sector



To develop industry standards and other guidelines, the geothermal energy sector will undertake the following steps:

- **Achieving agreement with the regulator about the subjects covered by industry standards** (e.g. risks and control measures, sector standards, work plans, developing internationally-recognised standards such as *ISO well integrity*).
- **Subsequently prioritising and developing the necessary standards.**
- **Assessing the standards during various phases with EZK, ANVS, SodM and possibly other competent authorities,** so that regulation occurs on the basis of agreed standards, frameworks are established by legislation and regulations, and that these are also made known publicly and unambiguously. See *iii. What the sector needs* about the necessary assessment frameworks.
- **Implementation of stated guidelines by operators.** This means complying with standards, as well as actively reporting on compliance with the standards to the regulator. Account can also be taken of the (financial and staffing) capacity of various operators, and a distinction made between various segments of operators (such as existing operators with a single doublet, existing operators with multiple doublets and new operators). DAGO will develop this further in more detail.
- **Continuous development of standards based on shared insights and knowledge from the sector.** New types of projects will emerge, which may require new legislative frameworks to be defined. To

make optimal use of the insights from best practices and innovation, it is important that developments in industry standards and work plans run in parallel to developments within the sector. To achieve this, the sector will:

- Use the more structured feedback moments that DAGO will set up with a broad group of stakeholders to connect with relevant developments in the sector *(see Chapter 4C)*.

- Initiate structured consultation between operators and regulators via DAGO.

With all the above steps, it is important that the development and implementation of (higher) industry standards continuously takes account of current operators. This may include a temporary policy framework and/or “transition standards”.

2) Collaboration with EZK, ANVS, SodM and other competent authorities to facilitate both the rapid and transparent processing of permit applications and the necessary amendments to legislation and regulations

The sector wishes to discuss amendments to current legislation and regulations and accelerating permit applications by:

- Taking the initiative by presenting a summary of bottlenecks in current legislation and regulations, and proposals to remove these bottlenecks. For example, a proposal will be made to allow the play-based portfolio approach to be facilitated through amendments to legislation and regulations. DAGO has a key role in maintaining contact with EZK about operational policy, legislation and regulations, based on their role in developing and implementing industry standards.

- Continuing dialogue from the sector with ANVS about effective implementation of the Euratom in the new Basic Safety Standards for Radiation Protection Decree, views about the limiting values for certain substances and the development of a package of measures for geothermal energy that permits effective risk control within nuclear energy legislation.

- Giving advice to local authorities about permits, for example by proposing assessment frameworks for local authorities together with the competent authorities, which will allow them to fulfil their advisory role more easily and unambiguously. This may for example involve developing criteria and bandwidths that municipalities can use to assess permit applications. Developing an AMvB (General Administrative Regulation) for geothermal plants can contribute to this.

- Ensuring that submitted permit applications are of sufficient quality to be processed quickly. More knowledge and assistance from the sector when applying for permits not only ensures that these can be processed more rapidly, but also means that EZK and SodM will receive fewer questions about permits. Improving and standardising permit applications is part of the development of industry standards and work plans, and requires the standardised reporting requirements and support for (future) operators as described above to allow these to be implemented in the correct manner. This role will be filled by DAGO.

- Research into improved methods for single removal of test water for new geothermal energy doublets. The current possibilities are limited, and storing and transporting test water in the urban environment leads to disruption. Improvement requires that all involved parties develop specific solutions.

iii. What the sector needs

To improve industry standards and work plans, and to make the processing of permit applications faster and more transparent, the sector requires three important actions:

1) **Coordination and optimisation of planning and environmental policy between various branches of government**

Various branches of government are currently involved with planning and environmental policy. The sector would benefit from more coordination between these. Energy policy affects planning, and central and local government (municipalities, provinces, water management agencies) all have a role to play. In this coordination, it is important that:

- Various branches of government work together effectively to coordinate national, regional and local policy. Policies must not be contradictory, and the right stakeholders must be involved with the development of this policy. Collaboration during the development of planning and consultation involving all stakeholders is very important. The various branches of government reach agreement about optimal use of the subsurface. This also means that geothermal energy projects must be coordinated in the correct way, and that the subsurface is not exhausted but can be used optimally. This will require further development of ThermoGIS etc.

- Consultation where there are policy conflicts or conflicting visions for policy is necessary to permit local, regional and national interests to be properly weighed up.

- In the future, the various advisory roles during permit applications will be optimised further. In this regard, it is particularly important that the various advisers clearly understand what they must give advice about, and what the assessment criteria are.

- For example, where possible, subsurface potential should be actively utilised by structuring zoning plans such that greenhouse horticulture or industries that require heat can develop easily in the vicinity of attractive aquifers/(sub)plays.

The sector itself will also be able to make a contribution to coordinating between various branches of government, for example through joint research ("joint fact finding"). Collaboration between the market, (local) government and drinking water companies in geothermal energy projects and research will contribute to transparency about the risks and benefits of geothermal energy. The sector will also initiate periodic consultation with drinking water companies, provinces and municipalities.

2) **Adapting legislation and regulations and permit models to the geothermal energy sector**

EZK is currently amending legislation and regulations to accommodate the geothermal energy sector. In this innovative sector, the majority of legislation and regulations are still in development or are based on hydrocarbons (oil and natural gas), and as such are not always suitable for the geothermal energy sector. The necessary changes encompass various types of legislation and regulations, including:

- **Amendments to the Mining Act, Mining Decree and Mining Regulations.** This process has now begun and the revised Mining Act will be put out for consultation in the spring of 2018. EZK has indicated that it will make a procedural amendment that will ensure that a single approval decision is sufficient for all major phases of a project, instead of an exploration permit, extraction permit and an extraction plan. It is also important to implement the following amendments:
    - Facilitating a play-based portfolio approach to allow optimal use of the subsurface, by allowing permits to apply to multiple doublets, through a wider geographical (above-ground) and layered (subsurface) spread without obstructing other projects, and by offering a perspective for how to deal with unused permits. More innovative permit models, such as via tendering

and the possibility of registering for permits, are also possible (see also the comparison with the permit models for offshore wind farms, see Figure 20)

- Giving specific descriptions of the content and assessment criteria for plans to be submitted in the Mining Decree.
- Optimising the Mining Regulations for water wells that are not self-flowing and that have a geothermal energy-specific well design

- **Amending the Heat Act** (“Warmtewet”) *(see Chapter 4A. Profitable projects).*
- **Amendment and optimisation of additional legislation and regulations that apply to geothermal energy and heat networks.** When geothermal energy is used more often in the urban environment, a dependence on heat networks will arise. In this respect, the same advice applies – the necessity of appropriate legislation (including with regard to the combination of heat networks and geothermal energy), clear assessment frameworks and an effective regulatory structure.
- The desirability of **coordination with the Building Decree (“Bouwbesluit”)** (specifically in relation to the necessary energy labels) to ensure that the development of the demand for heat in the urban environment matches the (possible) supply.
- The desirability of **amending the Nuclear Energy Act** for geothermal energy operators will be determined based on the dialogue with ANVS.

The sector would like to see the necessary amendments to legislation and regulations implemented in the short term. Depending on the time period needed for this, a temporary policy framework may be desirable. This applies in particular to the Mining Act and the Nuclear Energy Act.

To implement amendments to legislation and regulations, and also to process applications promptly, sufficient knowledge and staffing (FTE) are required within various branches of government. The level of knowledge and staffing required in each case depends on the efficiency of collaboration between these various branches. The necessary FTEs in local government (provinces, water management agencies, municipalities) depends in part on how their future advisory role in respect of permit applications takes shape.

3) Developing (amended) legislation and regulations into clear assessment frameworks, clear and appropriate policy and a transparent regulatory structure

To implement industry standards and work plans, it is important to develop legislation and regulations into clear frameworks and criteria. It is also important that the underlying policy and regulatory processes are assessed in parallel and transparently by the responsible authorities to guarantee impartiality. In addition, legislation and regulations and the standards must always be proportional to the actual risks. For example, this means that SodM should translate the legislative, policy and acceptance frameworks sketched by EZK into standardised assessment criteria. These frameworks and criteria give operators guidance about how they must comply with the legislative frameworks. As part of the revised Mining Act, EBN will propose clear financial assessment criteria. EZK has proposed advising EBN about a financial assessment for permit applicants. In the case of any (compulsory) participation by EBN in geothermal energy projects, this advisory role in respect of the financial assessment of operators may be filled in another way.

Clear and appropriate policy includes a clear and fixed long-term energy policy, including agreements about CO_2 prices and subsidies *(see Chapter 4A. Profitable projects).* It is also important that EZK initiates a conversation about the socially-acceptable level of risk.

iv. Road map

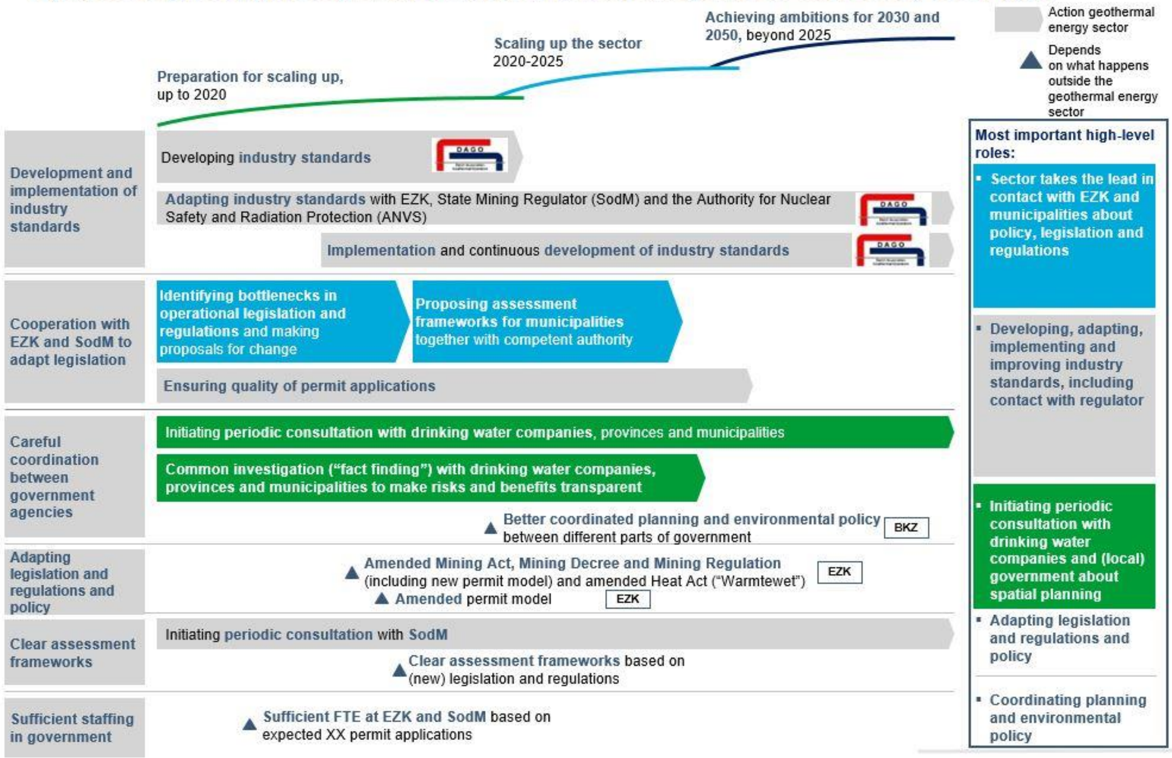


Figure 23: Appropriate legislation and regulations, regulation and policy road map

C. Safe and effective operational activities

i. Vision for the future for scaling up geothermal energy

The geothermal energy sector wishes to work towards safer and also more effective operational activities. This includes preventing incidents and also lower production costs, more and clearer investment decisions and higher productivity. This requires more understanding of matters such as costs across the entire life cycle of a well, investments and efficiency, and also how safety should be defined in precise terms, how we can establish a conversation about what an acceptable safety level is and how we can reach that level. This applies to all operational activities, from research in the form of seismic surveys to clearing up a geothermal well.

In addition to the health of staff and local residents, safety also includes the environment and subsurface, such as preventing earthquakes and leaks. The goals for the coming years are to reach a broadly-accepted definition of what is safe and acceptable, and that the geothermal energy sector is not only safe, but is also seen as such.

Increasing effectiveness includes investment decisions and the design of geothermal energy doublets, as well as lowering costs across the entire life cycle etc. It is possible to extend the lifespan of geothermal wells and to reduce the costs during production either through optimised maintenance, or through reducing the non-operational time of wells. The efficiency of (newly-constructed) wells can also be improved. Coordinating and optimising the demand for heat to permit optimal use of the extracted heat can also improve efficiency. The goals for efficiency and investment decisions apply in particular to new doublets that are yet to be developed, as they cannot be applied retrospectively to existing doublets.

ii. What the sector will do

In the coming years, the sector will work to develop ways of continuously implementing improvements in costs, safety and efficiency, across the entire value chain and life cycle. The concerns about issues such as safety are well known, as described in publications such as the *Staat van de Sector* (State of the Sector). In this publication, the regulator (SodM) concluded in 2017 that the relatively young and small geothermal energy sector has difficulty in mobilising and applying expertise and experience, and consolidating this for future projects. SodM also concluded that safe extraction of geothermal energy is a prerequisite for success, but that the focus on costs has an impact on the safety culture and the recognition and control of safety and environmental risks. These (and other) concerns about safety must be continually addressed in the coming years. There are initiatives ongoing to map and mitigate the risks, such as joining the *Technisch Platform Aardbevingen* (TPA, Technical Platform for Earthquakes) to continuously learn more about seismic activity. Collecting and analysing data, and sharing insights based on this data, are particularly important here. The sector distinguishes three important actions here:

1) **Collecting, analysing and sharing insights and "lessons learned" to improve safety in the sector, to ensure compliance with legislation and regulations at all times and to improve the risk awareness of operators**

Collecting, analysing and sharing sector-wide knowledge and experience about safety is of great importance for scaling up the geothermal energy sector. For example, based on this knowledge and experience, industry standards and work plans can be improved, as well as helping individual operators to work in accordance with legislation and regulations. To this end, the sector will work to:

- **Improve the safety culture, behaviour and compliance with legislation and regulations.** The geothermal energy sector struggles with the perception that legislation and regulations are not always respected, despite the fact that no serious incidents have occurred. In *De Staat van de Sector Geothermie* (The State of the Geothermal Energy Sector), the regulator (SodM) describes aspects of compliance with legislation and regulations and safety where the geothermal energy sector must improve. External factors may be identified to some extent, such as legislation and regulations that were not designed for the geothermal energy sector, and the lack of definitions of an acceptable level of safety. But this does not explain everything: the geothermal energy sector must also make regular improvements in the safety culture, behaviour and compliance with legislation and regulations in the coming years.

To this end, DAGO will develop a code of conduct in the framework of the Green Deal for Participation. This process will increase awareness of risks and safety among operators (*see Chapter D. Robust public support*). In addition, operators are encouraged to comply with legislation and regulations to prevent measures being imposed by SodM. Via the knowledge management system described below, operators can share their insights about safety and risks and further improve their operational activities, as desired by the regulator and legislators.

- **Further development of a knowledge management system to collect sector-wide insights about safety:** To collect lessons learned and sector-wide insights, DAGO has set up an online platform (SharePoint) and arranges regular evaluation meetings with operators, which allow these lessons to be built upon. DAGO has also developed measures such as a standard health and safety system[20]. The knowledge management system could serve as a means to implement the sharing of knowledge and insights about safety. This may be done by setting up evaluation sessions after various phases of a project (e.g. the drilling process, after construction of the above-ground site), to which operators and other stakeholders such as local authorities, consultants and suppliers are invited. During the production phase, it is also desirable that operators take the initiative in a continuous improvement process such as a PDCA cycle ("plan-do-check-act" improvement cycle), for example by evaluating the lessons learned with involved parties twice annually and looking forward to the coming period. DAGO's online platform can be further improved to make it easier to share "lessons learned" about safety (such as the drilling hazards database).

- **Analysing sector-wide insights:** DAGO will further analyse the lessons learned and develop the industry standards based on these, in partnership with operators *(see Chapter 4B. Appropriate legislation and regulations, regulatory structure and policy).*

- **Publicising and sharing insights about safety with third parties:** In addition to those directly involved, it is also important to share knowledge and insights about safety with other stakeholders. This may include:

    - Training, for example by setting up various courses for operators, consultants, suppliers and government. By developing a shared understanding of risk and safety in particular, communication between operators and government etc. will improve. Suppliers and consultants also contribute to safe and effective operational activities, and must therefore be aware of the latest insights in this area.

    - Broader dialogue with, and transparency towards, society about safety and the acceptance of risks based on the accumulated knowledge and insights. This will be considered in more detail in *D. Robust public support.*

    - Continuing to develop, share and implement the above sector standards.

Of course, safety is also important during the construction, use and maintenance of heat networks. A similar approach to collecting, analysing and sharing insights about safety is also important for heat networks.

[20] Within the *Kennismedewerker* (Knowledge Worker) project 2014-2017

2) **Setting up a data management system to collect and analyse various types of data and to share insights from this to optimise individual doublets in terms of costs and efficiency, without limiting competitive advantages**

As well as sector-wide knowledge and insights about safety, operators also own other data that can be collected about matters such as the subsurface, injection and production. Figure 24 gives a summary of a number of important data types, with examples of current and future applications.

Figure 24: Examples of types of data and their applications FIRST VERSION

Not sensitive (green) · Somewhat sensitive (yellow) · Sensitive (red)

Type data	Current collection and sharing	Possible future sharing	Sensitivity of data
▪ Seismic data (raw data, first processing, reprocessing)	▪ Seismic data publicly accessible after 5 years (raw data, first processing) or 10 years (reprocessing)	Making seismic data, from the geothermal energy sector and from oil and gas, more centrally available	Not sensitive
▪ Demand for heat	▪ CBS publishes the total demand for heat per end user, RVO publishes *Warmteatlas* (Heat Atlas) at district level	Demand for heat publicly available with more detail (e.g. at district level, divided by time)	Not sensitive
▪ Permit applications	▪ Available via NLOG	Open platform where permits can be viewed	Somewhat sensitive
▪ Subsurface data obtained via (exploratory) drilling	▪ Accurate data available via TNO (AGE) and public after 5 years, non-detailed data in NLOG	Data obtained from drilling shared with the involved parties after six months	Sensitive
▪ Design data (of well, of above-ground plant)	▪ Confidential well design data (with SodM) as part of work plan	Ideally, initial design and modifications centrally and more easily accessible	Somewhat sensitive
▪ Insights into realisation of wells	▪ Daily drilling reports with insights into drilling process shared with SodM and TNO-AGE, but remain confidential ▪ DAGO's SharePoint contains lessons learned	Further standardised and centralised collection of insights	Somewhat sensitive
▪ Data and innovation from other industries	▪ -	For example: NOGEPA makes available accumulated knowledge about exploration and production to DAGO	Somewhat sensitive
▪ Production data	▪ Monthly quantity of extracted geothermal energy issued to TNO	Detailed data used to optimise costs, safety, well design and efficiency, for example using knowledge and data management system	Sensitive
▪ Geophysical research ▪ Geochemical research ▪ Geological research ▪ Borehole measurements ▪ Production and injection testing ▪ Rock samples	▪ Shared once with TNO		
▪ Other (operational) data, such as: – Injection data – Maintenance data – Broad operational data (FTE, costs) – Incidents and risks	▪ Data known to operator, but not shared		

Subject to certain preconditions, this data can be used to achieve ongoing improvements in increasing effectiveness, cost reductions and asset management. This is necessary to realise the scaling up of the geothermal energy sector up to 2030 and 2050. The sector will continue to investigate preconditions for collecting, analysing and sharing data. These preconditions include:

- The owner of the data has a clear motivation to share certain data (e.g. directly applicable insights that the owner receives in return for sharing the data).
- Data confidentiality is protected and ownership is recognised (e.g. there are clear agreements about who has access to which data).
- Gaining a competitive advantage over other operators is not hindered.
- Collecting data is feasible for the owner of the data (e.g. it does not take too much time).
- The agreed data types are collected for the agreed goals, and in a consistent manner, to guarantee a fair comparison between multiple data sources.
- Analyses based on the data are carried out in a consistent and transparent manner.

- There are clear agreements about with whom the insights derived from the data are shared.

To achieve continuous improvements based on data, under the above conditions, it is important to set up a data management system. The data management system will consist of two components. The first component is a data infrastructure that permits easy sharing and analysis of data, and that can provide access to data and insights. The second component is a partnership model that defines agreements about who shares and analyses which data, and who may view the insights derived from this.

The best way to meet the above preconditions in the short term and to achieve continuous cost and efficiency improvements is to allow a single party to take the initiative and responsibility for meeting all these preconditions. This party will then be able set up a data infrastructure and partnership model, to generate insights based on data, and to share these with the data owners, to help them reduce costs and improve efficiency. Possible alternative models, such participation by operators in one another's projects, do not for example guarantee that analyses will be carried out in a consistent way. Nevertheless, research may be conducted in the long term into possible alternatives to the described centralised approach to setting up a data management system.

Depending on the possibilities afforded by legislation and the level of participation in the projects that EBN is part of, a (legislative) motivation for operators to share various types of data could be created. This data could be analysed and could then form the basis for doublet-specific recommendations in the field of costs, investments, effectiveness and safety. This participation will not apply retrospectively to existing doublets, and the role played by current operators in sharing data and insights must therefore be developed further.

3) Setting up broader sharing of knowledge from abroad, innovation and other industries.

In addition to more intensive data collection within the sector, expertise from oil and gas, innovation and abroad will also be utilised. This allows data from Dutch activities to be compared, and can provide inspiration for future operational decisions. EBN will take the lead in this, given its experience in the oil and gas sector. EBN will work together with DAGO and will share insights from other sectors, innovation and abroad with DAGO, which will be responsible for sharing sector-wide insights with (future) operators.

iii. What the sector needs

To facilitate safer and more effective operational activities in the future, the sector needs the following:

1) Definition of safe areas for production based on clear criteria

Improving safety within the geothermal energy sector is dependent not just on the geothermal energy sector itself, but also on a better definition of safe areas for production. Broadly-supported criteria must be established to determine which areas are and are not safe for geothermal energy extraction, based in part on ongoing research being carried out to better map the subsurface (*see Chapter 3 Potential and our ambition*). These criteria must provide guidance about where projects can and cannot be started (e.g. distance to fault lines, distance to groundwater areas).

2) Optimising data supply to various government agencies

It is necessary to optimise the supply of data to the various government agencies, so that operators can deal with various information requests more efficiently. At present, operators must supply data to various government agencies, e.g. to TNO-AGE in the context of the Mining Act and to RVO for the SDE subsidy, to ECN, CertiQ and CBS. The supply of data that this requires from operators can be improved, to reduce operators' workload. This may include standardised formats for delivering production data, and later also integration with the above data infrastructure. Various branches of government would have “rights” to access various data within this infrastructure.

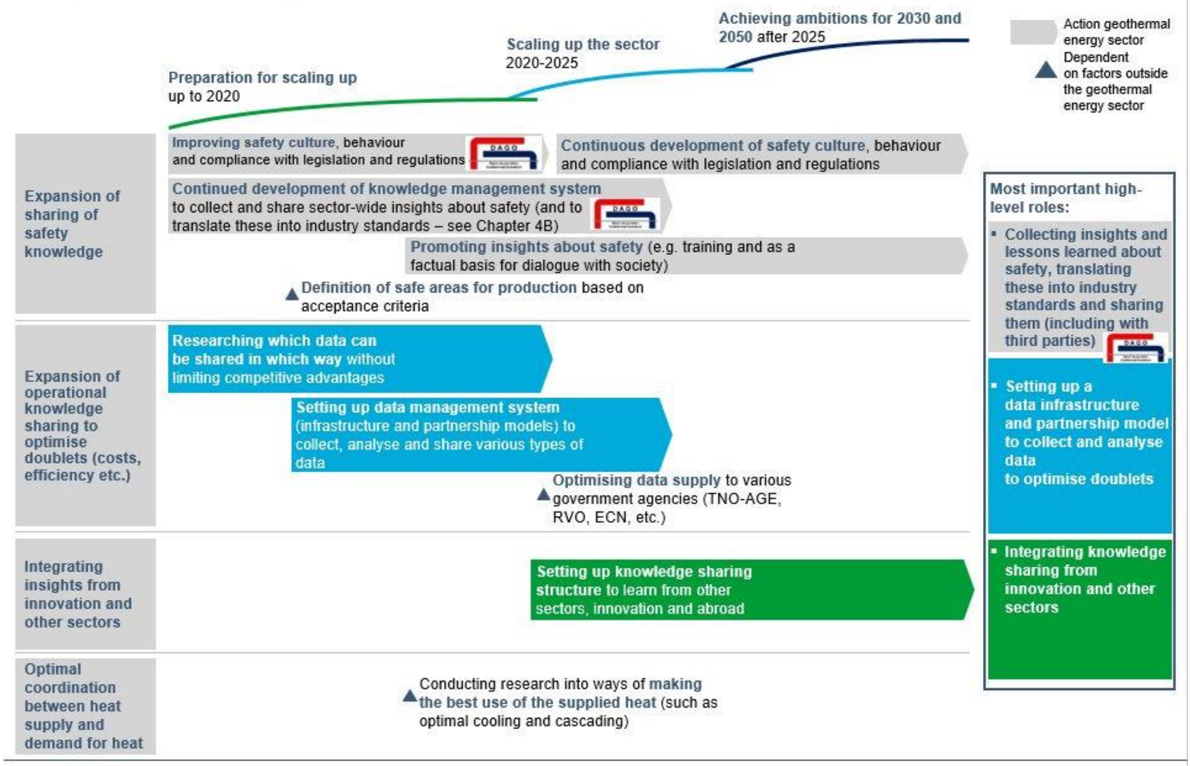
3) Research and innovation to improve efficiency through optimal use of heat supplies

Coordinating and optimising the demand for heat to permit optimal use of the extracted heat can also improve efficiency. Optimal coordination between the supply of heat and the demand for heat means that the injection flow is cooled to an optimal point and that the “delta” between injection and production temperature is as high as possible. This is because using the total potential of a geothermal well to heat a cold injection flow to a warm production flow, without cooling the reservoir too rapidly, means that the geothermal well is used efficiently. To achieve this, it is important that there is actual demand for the entire heat production. The following may also be considered:

- How can lower temperatures be utilised?
- How can cascading be set up? *(See also Chapter 4E. Innovation about these areas)*

iv. Road map

Figure 25: Road map for safe and effective operational activities



D. Robust public support

i. Vision for the future for scaling up geothermal energy

At present, geothermal energy is relatively unknown among the wider Dutch public. The ambitions for 2030 and 2050 require such a scaling up in the number of geothermal energy doublets that this will not go unnoticed by the wider public. As such, broad support is required. The sector wishes to work towards a future in which:

- Geothermal energy is a known and valued source of heat, both among the wider public and in the market and in government. Geothermal energy must obtain a logical place within the context of the utility and necessity of the energy transition, and the broader range of alternative sources of heat. The development of the sector in the coming years offers an opportunity to increase support for geothermal energy.

- Safe and sustainable production is a necessary precondition. In particular, safety and the perception of safety play an important role in winning support, as incidents will reduce support for geothermal energy. This applies to the support among the wider public and local residents, as well as (local) government.

- This requires clear, open and transparent dialogue and communication, and the local involvement and contribution of industry, government and citizens in projects. A lack of clear information and honest dialogue with citizens can lead to local or national concerns among those affected, while geothermal energy projects in fact create local job opportunities and allow them to influence their own sustainable energy supply.

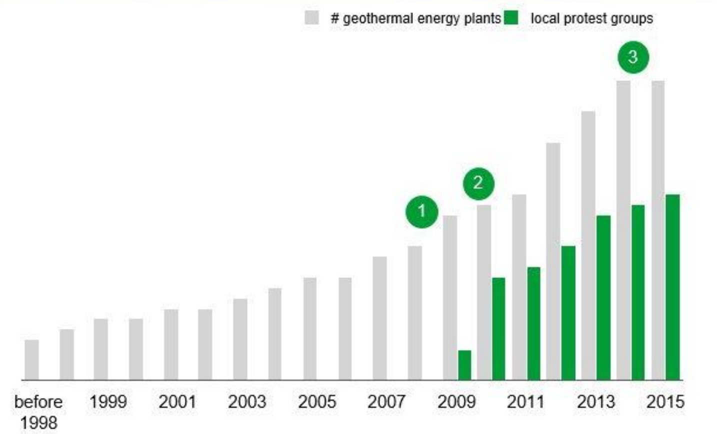
A comparison with neighbouring countries shows that generating public support is essential when setting up geothermal energy projects, particularly in the urban environment. Examples from Germany and Italy shown in Figures 26 and 27 show that involving the local population in the development of geothermal energy projects generates public support, enthusiasm for the production of geothermal energy and jobs.

Figure 26: German acceptance of geothermal energy and investment in the sector remains high despite the establishment of protest groups

Protest groups started following earthquakes

1. From **1984 to the end of 2008**, 13 geothermal energy plants were developed **without** any **protests**
2. Following a **series** of **earthquakes** in Basel (2006) and Duttweilen (2009), **local protest groups** against geothermal energy have been set up **since 2010**. Protest initiatives were also set up in the period without incidents
3. Since 2014, a national network against geothermal energy has attempted to link local protest groups

- The 18 **protest groups** have **achieved little recognition**in Germany to date



German acceptance of geothermal energy remains high

- There are **34 geothermal energy plants** in Germany, of which 25 produce heat, four produce electricity, and five are combined plants that supply both heat and electricity
  - In total, the geothermal energy plants produce **302 MW of heat** and **50 MW of electricity**. At present, there are around **30 other plants planned or under construction**
- **€1 billion** is invested annually in the geothermal energy sector by the public and private sector
- The prestige project is located close to Munich. Here, **€52 million** has been invested in a **geothermal energy plant** and associated **district heating grid**
- The **most important insights** from this project are:
  - **German acceptance** of **geothermal energy** was **high**, because **the wells were drilled by the community** and not an energy company
  - 3D **seismic acquisition in urban areas** with thousands of geophones and vibrating trucks during a period of more than **6 months** was **broadly accepted** by the public as it was **their project**

SOURCE: IEA Geothermal, 2016 Germany Country Report, LIAG, Deep Geothermal Energy, and media research based on public sources

Figure 27: With the help of creative ideas, not just public support but also enthusiasm for geothermal energy is generated

ENEL, Larderello

- In Larderello, ENEL has a **network** of **32 geothermal energy plants**, **492 extraction wells** and 500 km of pipelines of various sizes
- In addition, ENEL Green Power coordinates a European project (DESCAMBLE), to **test innovative drilling technologies** for drilling in **supercritical conditions** (with temperatures higher than 374 ° C and pressures higher than 22 Mpa)
- The **goal** is to **reduce the number** of **wells** required for the same energy production, which leads to **cost savings**

Insights

To generate public support, it is important that geothermal energy plants promote sustainable development in the region without disrupting the identity and culture of the landscape

Details

- To **improve** the **acceptance** and **integration** of **geothermal energy plants** in the region, a number of projects have been started
  - The ENEL **Geothermal Museum** was established in 2013, and has already attracted more than 25,000 visitors (schools, researchers and tourists)
  - A **geothermal energy plant is open to visitors**
- ENEL's **geothermal energy plants** not only form part of the renewable energy portfolio, but also of **culture**, **tourism**, **food** and **wine** and **sustainable agriculture**
  - In addition to basil, cheese and salami produced with the aid of geothermal energy, the "**geothermal table**" also features beer.
  - The beer labels state: **"Beer fully produced with geothermal energy from ENEL"**

"*Geothermal beer, taste from the earth; it is 20 times more sustainable than beer produced using fossil fuel sources*"
– **Intoscana Aug/2017**

"*Geothermal energy has brought more than 60 thousand tourists to Tuscany in the past year*" – **Il Tirreno Apr/2018**

"*Geothermal energy: a totally Tuscan speciality*"
– **ARPAT Mar/2018**

SOURCE: Media research based on open sources, ENEL Green Power, Thinck GeoEnergy

ii. What the sector will do

The sector will work to actively generate local and national public support for geothermal energy by undertaking the following actions:

1) Promoting safe production and risk control

In addition to the actions described above to improve safety and risk control *(see Chapter 4C. Safe and effective operational activities)*, it is important that both individual operators and the sector as a whole implement these improvements. This involves various actions for the sector:

- **Developing and implementing a code of conduct**. During the coming period, in the framework of the Green Deal for Participation, DAGO will develop a geothermal energy code of conduct in partnership with operators, which will be accepted and signed by all operators. As a sector, we will publish how we work safely and responsibly, and how we will involve the local area. The process of developing this code of conduct will lead to more awareness of the importance of operators' own behaviour, and of public support and environmental management among current operators. This will give future operators clear guidelines from the start about involving the local area in their initiatives.

- **Developing a "database" with facts about safety.** This database will focus on areas including quantifying risks, recording incidents and building up a record of risks. This will provide a shared and publicly-accessible source of knowledge, which stakeholders can build on. This will not only contain the risks of current activities, but will also anticipate future operations. The risks of UDG and drilling geothermal wells closer to the urban environment etc., should be mapped proactively, to allow measures to be taken to control these risks.

- **Developing and implementing a damage protocol** that specifies the steps that various stakeholders will undertake in the event of damage. To make this protocol effective, a financial support framework must be agreed, either within the sector or with the help of government.

- **Developing existing crisis communication and coordinating it with (new) parties.** Attention will also need to be paid to who will play which communication roles in the event of an incident.

- **Developing training for operators about dealing with the media/press and questions from citizens about risks and safety.**

2) Improving basic knowledge of geothermal energy among society, government and the market, within the context of the energy transition

To improve the basic knowledge of geothermal energy among society, government and the market, and thus to generate public support, two components are important:

- **Improving, refining, updating and publicising a geothermal energy proposition, differentiated by target group.** The sector is aware of the importance of public support, and various parties are already contributing to sharing information about geothermal energy, for example via the website www.hoewerktaardwarmte.nl, set up by SPG, DAGO and EBN, and via the website geothermie.nl. The same parties and others are also working on informative materials, communication plans and knowledge sharing, principally based on their own knowledge, experience and expertise. All these efforts must be coordinated further in the coming years within the sector to achieve a consistent geothermal energy proposition, with associated standard communication materials (e.g. downloadable from www.hoewerktaardwarmte.nl). These materials must devote attention to such subjects as the recently-implemented Nuclear Energy Act and the resulting requirement for operators to request a nuclear energy permit. We will also consider which aspects of geothermal energy should be emphasised here, such as a transparent dialogue about risks, and taking care not to over-emphasise the large-scale potential of the technology. Appointing a first point of contact for generic questions about geothermal energy will also help to effectively promote the geothermal energy proposition. The geothermal energy proposition can also be used as a:

    - Contribution to a national plan for information exchange about the energy transition (see below).

    - Contribution to the national conversation about geothermal energy from the sector, such as actively approaching potential (industrial) end users, or writing opinion pieces in the national media.

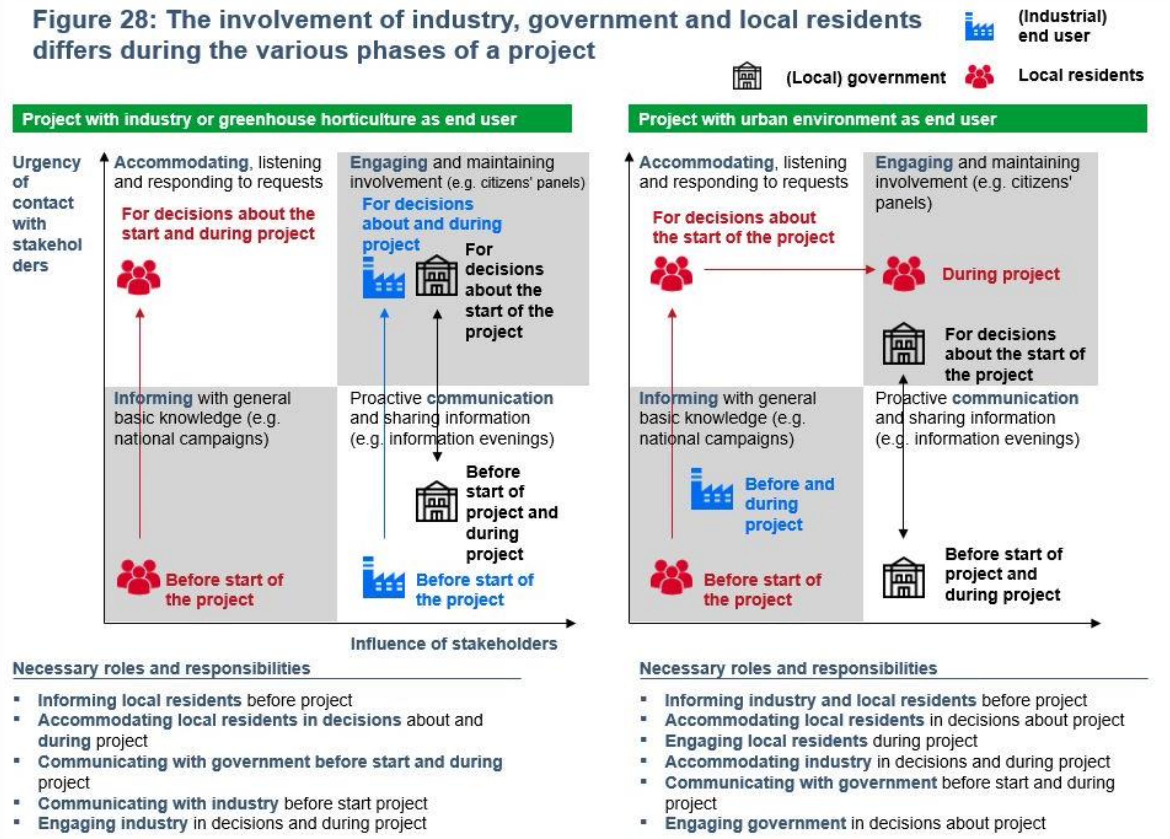
- **Taking the lead in contributing to a national plan for information exchange and dialogue with various target groups about the energy transition.** The geothermal energy sector itself is not "impartial" enough to play a leading role nationally in improving basic knowledge about the utility and necessity of the energy transition and geothermal energy compared to other sources of heat. Nevertheless, we believe it is necessary to break with the (cost) comparison with natural gas to make a success of geothermal energy, and other alternative sources of heat. The sector will contribute to a national communication plan in partnership with EZK, BZK, the *Expert(ise)centrum Warmte*, NVDE, heat companies and/or many others about how target-group-specific versions of the geothermal energy proposition can be publicised in practice nationwide. The consistent proposition for geothermal energy described above will form the basis for the knowledge and information that this requires.

3) Developing partnership and participation models for local public support and local involvement of all stakeholders before the start of geothermal energy projects, when choosing geothermal energy and during geothermal energy projects

It is essential to generate local public support before the start of a project, and during realisation and production, but it is not immediately clear which parties should play which role. The geothermal energy sector will take the initiative in developing partnership models for local public support with a division of roles between the operator, (local) government, heat companies, end users and/or local residents. In these partnership models, the partnership with heat companies will be particularly important. Figure 28 demonstrates the complexity in the diversity of roles on the basis of two dimensions: the type of end user (industry/greenhouse horticulture or urban environment) and type of stakeholder (local authorities, local industry/greenhouse horticulture or citizens). Proper agreements must be made between the various involved parties about who will take on which role, and the sector will take the lead in developing a general plan for this.

There are already several initiatives to generate local public support that the sector can join. As mentioned, the geothermal energy sector is closely involved with the Green Deal for Participation, which aims to involve the local area more closely with sustainable energy projects. At present, the Ministry of Economic Affairs and Climate Policy (EZK) is working on an Expert Centre for heat, specifically for questions from (local) government and providing active support in areas such as environmental management. Outside the sector, examples may be sought from organisations such as the NWEA, which has prepared a participation plan to improve and standardise collaboration between various stakeholders in wind projects. When generating local public support, the focus will mostly be local residents. For example, the 2017 *Nationaal Warmtenet Trendrapport* (National Heat network Trend Report) shows that support among stakeholders from the heat world (suppliers of heat, government, operators etc.) is already strong: the majority of these parties believe that geothermal energy will be the most important source of heat in 2050.

Figure 28: The involvement of industry, government and local residents differs during the various phases of a project



4) **Monitoring local and national public support**

Monitoring local and national public support will provide insights into the effects of efforts to improve public support, and will also offer an opportunity to respond promptly to developments in public support. Several steps can be identified in this regard:

1) The sector will develop a method to monitor public support, both nationally and locally. This may include questionnaires and interviews, as well as monitoring messages on social/traditional media and setting up a (local) process for reporting and adequately dealing with complaints and disruption.
2) A "baseline measurement" of public support will be carried out to help generate a better picture of the current level of public support for geothermal energy.
3) Based on this baseline measurement, it will be possible to actively respond to the level of public support, either locally or nationally, via the communication plan.
4) Following this, it will be possible to continuously monitor public support and to respond to local and national developments.
5) Researching the effect of possible synergies with the oil and gas sector on public support for geothermal energy.

The entry of (major) players from the oil and gas sector (such as Vermilion, Shell, EBN) or re-use and "dual play" with gas drilling may affect the public image of geothermal energy. As such, it is important to research this potential impact. This research can assess what the possible impact of collaboration with the oil and gas sector may be on public support for geothermal energy, and how to respond to this.

iii. What the sector needs

To generate public support, the geothermal energy sector needs the following:

1) **National conversation about the utility and necessity of the energy transition, focusing on heat networks, the heat sector and various sources of heat**

The energy transition affects many sectors, ministries (EZK, BZK, I&W, LNV), local authorities and agencies (municipalities, drinking water companies). This means that a coordinated strategy to initiate a broad conversation about the transition and a clear, consistent and transparent narrative are very important. Not just geothermal energy, but also heat networks and the broader heat sector must play a role in this dialogue.

The geothermal energy sector can join existing initiatives that aim to generate public support for sustainable energy, such as the previously-mentioned Green Deal for Participation. This Green Deal is supported by 27 sector and umbrella organisations that combine their knowledge and experience to promote the further development, shaping and improvement of participation processes for sustainable energy projects. This includes the further development of the *Expert(ise)centrum Warmte*, which will be able to contribute to generating support in (local) government.

2) **Dialogue with a broad group of stakeholders about roles, responsibilities and partnership models in generating local public support**

As mentioned, to generate local public support, agreement must be reached between various stakeholders, such as heat companies, provinces, municipalities and operators about who should play which role in generating public support, and how cohesion can be safeguarded in this process. The decision-making process must operate in parallel with the supply of heat in each district.

iv. Road map

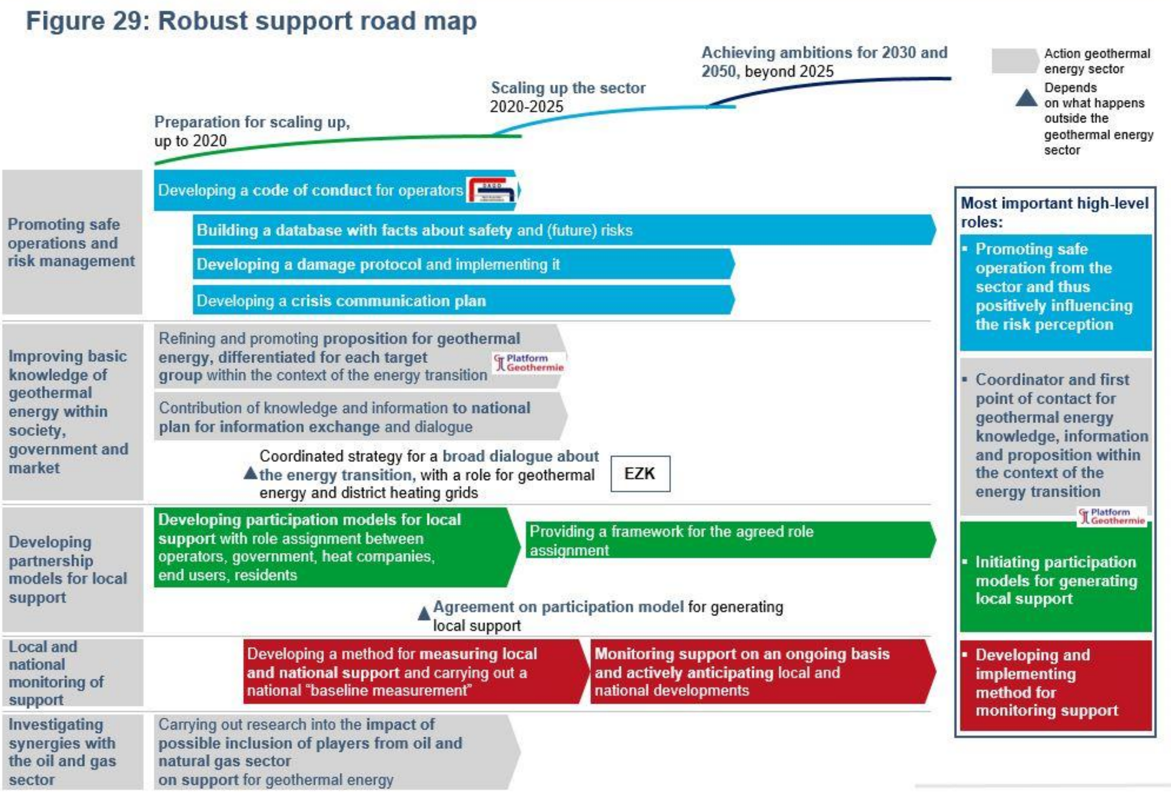


Figure 29: Robust support road map
Preparation for scaling up, up to 2020
Scaling up the sector 2020-2025
Achieving ambitions for 2030 and 2050, beyond 2025
Action geothermal energy sector
Depends on what happens outside the geothermal energy sector
Promoting safe operations and risk management
Developing a code of conduct for operators
Building a database with facts about safety and (future) risks
Developing a damage protocol and implementing it
Developing a crisis communication plan
Improving basic knowledge of geothermal energy within society, government and market
Refining and promoting proposition for geothermal energy, differentiated for each target group within the context of the energy transition
Contribution of knowledge and information to national plan for information exchange and dialogue
Coordinated strategy for a broad dialogue about the energy transition, with a role for geothermal energy and district heating grids
EZK
Developing partnership models for local support
Developing participation models for local support with role assignment between operators, government, heat companies, end users, residents
Providing a framework for the agreed role assignment
Agreement on participation model for generating local support
Local and national monitoring of support
Developing a method for measuring local and national support and carrying out a national "baseline measurement"
Monitoring support on an ongoing basis and actively anticipating local and national developments
Investigating synergies with the oil and gas sector
Carrying out research into the impact of possible inclusion of players from oil and natural gas sector on support for geothermal energy
Most important high-level roles:
Promoting safe operation from the sector and thus positively influencing the risk perception
Coordinator and first point of contact for geothermal energy knowledge, information and proposition within the context of the energy transition
Initiating participation models for generating local support
Developing and implementing method for monitoring support

E. Innovation

i. Vision for the future for scaling up geothermal energy

Innovation is important to accelerate the geothermal energy sector in multiple dimensions, and in various different components of the value chain. Innovation offers the opportunity to further reduce risks and costs safely, and can ensure a better connection with end users and other sources of heat by optimising the value chain. In addition, innovation can increase the potential of the technology, for example by broadening applications. In the short term, this will not just involve innovation in the form of fundamental and applied research and demonstration projects (pilots), but also sharing existing knowledge, for example from abroad and from other sectors. In the long term, it important that the right innovation is continuously prioritised. The Netherlands has a good starting point for these various types of innovation, including by existing suppliers and existing innovation from other subsurface users, such as the oil and gas sector.

In the field of fundamental and applied research and demonstration projects, we can identify several areas requiring innovation that are achievable and that have the potential to accelerate the geothermal energy sector in the Netherlands towards 2030 and 2050:

- **Innovation in the field of safety and risk reduction:**
    - Increasing understanding of the emergence and mitigation of induced seismic activity (such as better understanding of the effects of thermal reservoir stimulation and the effects of water injection along fractures, and reducing disruption in the urban environment).
    - Safe abandonment (e.g. by including this step in the value chain in the well design and specifying it for various geological formations).
    - Dealing safely and sustainably with test water and “bycatch” (subsurface gas that may be extracted along with water).
- **Innovation in the field of value chain optimisation and increasing effectiveness:**
    - Coordinating geothermal energy with other heat and energy sources (such as using hybrid grids and system integration with other types of energy).
    - Making maximum use of heat (e.g. cascading, using smart heat networks to predict demand for heat better etc., using heat storage).
    - Demonstrating applications using various temperatures (such as low-temperature and high-temperature supply).
- **Innovation in the field of cost reduction:**
    - Extending the lifespan of geothermal wells (such as improving electric pumps (ESP) and using alternative production methods, developing materials with longer lifespans, monitoring and preventing corrosion and/or scaling (choking of systems)).
    - Innovation in drilling geothermal wells (such as improving drilling technology, organising more coordinated drilling campaigns and improved spatial planning in the subsurface). This may also include collaboration and innovation with suppliers, such as building fit-for-purpose rigs.
    - Designing fit-for-purpose wells more effectively (including re-use of existing infrastructure, horizontal drilling, adapting designs to take better account of safety risks (also innovation in the field of safety)).
    - Improving reservoir management (such as an approach for specific geological formations in the Netherlands, extending production by delaying “cold breakthrough” etc.).

These areas where innovation is required were identified in the framework of the innovation road map for geothermal energy, which EZK asked EBN to develop in close collaboration with RVO in a letter to parliament in February 2018. For more details, see the innovation road map developed by Royal HaskoningDHV. In addition to coordination with heat networks, innovation will also be possible in the safe and efficient installation of heat networks, although this will not be considered further in this Master Plan.

To use innovation to accelerate the geothermal energy sector, in addition to prioritising the above innovation needs, it is important to:

- Establish proper management to allow continuous prioritising of projects that contribute to the overall vision for geothermal energy. This involves not just the developing and implementing innovation through an effective partnership between knowledge institutes and operators etc., but also directing innovation based on a social mission (*mission-driven innovation*). This requires innovation policy that goes further than just individual technologies, and instead examines which innovations are desired by and applicable to society.

- Continuously sharing insights derived from innovation with the right stakeholders, to ensure that these are quickly integrated into operations.

ii. What the sector will do

Innovation is largely dependent on players outside the geothermal energy sector, such as RVO, TNO, TKI, universities and NWO, but the sector itself can contribute to innovation in three ways:

1) Developing an action plan to prioritise innovation needs and to coordinate them with relevant stakeholders (such as EZK, RVO and TKI)

A clear picture of innovation needs will help to prioritise research that has the most potential to accelerate and facilitate scaling up. In the coming period, we will appoint a coordinating party to collect innovation needs from the operators, DAGO, SPG and EBN and to translate these into an action plan, which will be coordinated with relevant stakeholders (such as EZK, RVO and TKI). In the short and long term, this will involve:

- **In the short term, this coordinating party will further develop the current innovation road map in practical terms with innovation needs.** This may include:

    - Prioritising innovation needs with all relevant market players, such as operators, DAGO, SPG and EBN. This will allow progress to be made based on the road map that has already been developed by EBN in close collaboration with RVO.

    - Weighing up which of the prioritised innovation needs may have the greatest short-term impact on safety, cost reductions or value-chain optimisation, in terms of feasibility and funding.

    - Writing an action plan describing how we can meet these innovation needs in practice. This action plan will state the long-term financial requirements for meeting these innovation needs, as many of the current ways of promoting innovation require a contribution from the market (such as 50% funding from the market required by TKI). Given the current scale of the sector and the (financial) capacity of many of the parties, we will search for a solution that will make it possible to implement innovation projects. The action plan will also consider the organisational aspects, such as the leadership necessary to design the innovation process for these priorities.
- **In the long term, this coordination process between the relevant market players and financiers, knowledge and research institutes and government must occur on an ongoing basis.** This may take the form of a monthly consultation based on a coordinated list of subjects for innovation. The (financial) needs that must be met to support market players in the future will also change if larger parties, such as operators or housing corporations, play a role in the sector.

2) Playing an active role in innovation projects, particularly demonstration projects

Operators are often involved with innovation projects, and they will continue to occupy this role in the future, particularly by playing an important role in demonstration projects/pilots. In the short term, we see a number of demonstration projects that may have a major impact on the geothermal energy sector, and which are also feasible in the short term:

- Connecting new geothermal energy doublets to an existing heat network– *see Chapter 4F. Connecting to heat networks.*

- Pilot projects around low-temperature geothermal energy (such as Zevenbergsehoek, with a temperature of 30-40 degrees).

- Pilot projects around seasonal storage and flexible sustainable sources of heat for peak loads. These pilots are necessary to gain experience with subsurface or other forms of storage, and energy-neutral ways of responding rapidly to peaks in the demand for heat.

- Continuing UDG pilots for industry using low/medium-temperature heat.

- Pilot projects around re-use and “dual play” with gas drilling (*depending on the aforementioned research into the impact of this on public support, see Chapter 4D. Robust public support).*

In the short term, it is expected that knowledge institutes in particular will take the initiative in starting these pilots, in partnership with operators. In the long term, operators themselves may become more familiar with the possibility of applying for funding for innovation, and they may also have the financial and organisational resources to initiate research and innovation.

3) Contributing to the implementation of insights from innovation

Innovation can only accelerate the geothermal energy sector if insights reach the right stakeholders and are actually implemented. Sharing knowledge and insights is not just the responsibility of the sector, but also of the initiators of innovation projects. For example, DAGO will translate the insights gained through innovation into industry standards. In addition, we will develop an action plan to share insights from innovation more broadly, with attention for:

- Sharing accumulated knowledge and understanding from demonstration projects/pilots within the sector.

- Developing training programmes and workshops etc. to facilitate further knowledge sharing with various interested parties (such operators, consultants and suppliers). This will also contribute to a greater availability of expert personnel.

iii. What the sector needs

The geothermal energy sector requires adequate leadership in knowledge and innovation, with leadership in implementing the current innovation road map in the short term. The innovation road map developed at the start of 2018 indicates the most important innovation needs of the sector at this time. In particular, the needs with the greatest feasibility and impact must be met in the short term, for which the sector will develop the aforementioned action plan. Adequate leadership is needed to implement the current innovation road map in the short term, and to guarantee continuous mission-driven innovation in the long term. As described in the letter to parliament in February 2018, this involves ensuring cohesion and that coordination can occur with similar programmes abroad and with innovation programmes in the energy sector, with the active involvement of the geothermal energy sector.

To make mission-driven innovation a success, a party must be appointed to continuously coordinate innovation. At present, RVO occupies this role to a large extent, as they are the most important party in awarding various innovation funds. This coordinator must not only ensure coordination and coherence with other industries and countries (such as is currently performed via RVO in the framework of GEOTHERMICA), but also with other stakeholders such as TNO, universities, NWO and TKIs. In the long term, the various knowledge agendas, TKIs and knowledge institutes will coordinate their activities, and the various parties will continue to work together on a single mission for the future.

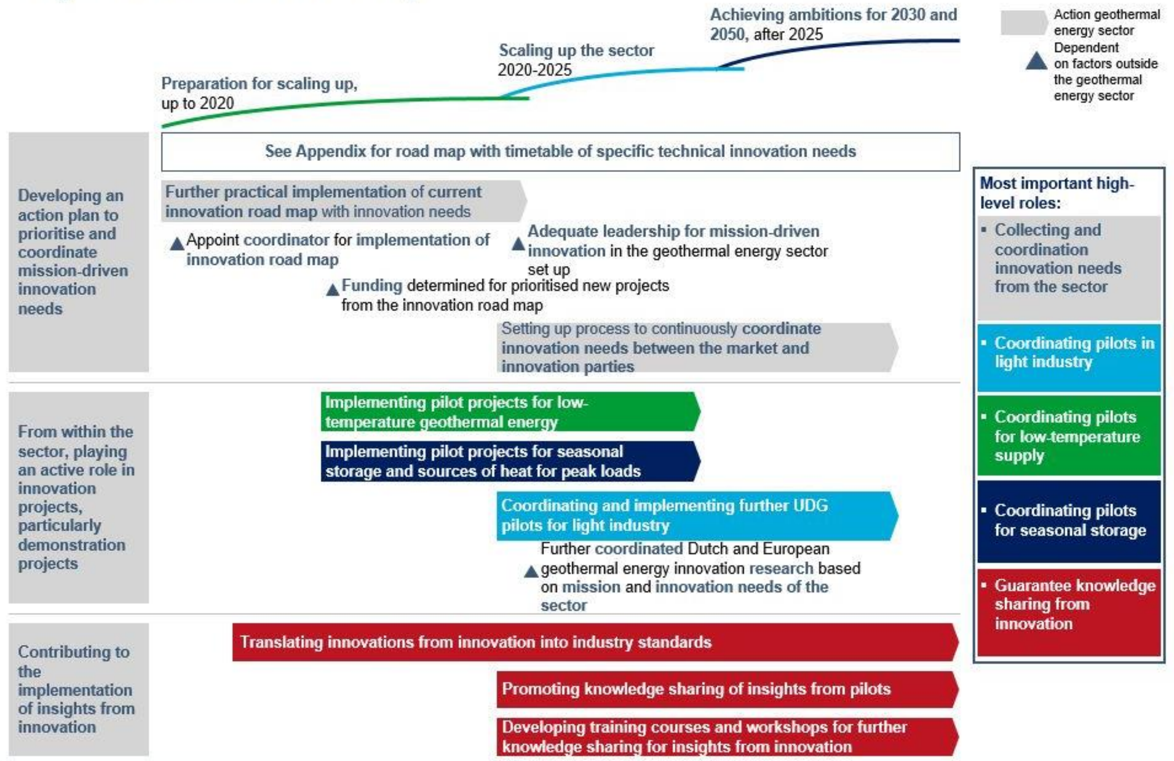
As well as leadership, current innovation projects must also be continued and further investment is need for new innovation projects:

- **Ongoing innovation projects that are very important,** such as the development of materials with a longer lifespan and other innovations to extend the lifespan of geothermal wells, and to improve water injection to prevent a decrease in the injection capacity during production.
- **Necessary innovation projects that require further (financial) support,** such as:
    - Researching the emergence and mitigation of induced seismic activity.
    - Improving drilling techniques to allow faster and more effective drilling of geothermal wells.
    - Developing and implementing (high-temperature) storage concepts for buffering heat in the subsurface.
    - Demonstrating high-temperature supply to industry with ultra-deep geothermal energy.

The innovation road map contains the expectation that around €200-€600 million will be required for the full implementation of the road map. This road map anticipates funding for around half of the projects from the market. In the short term, it is most likely that financial support for the above innovation projects will come from existing programmes and subsidies (such as TKI/HER, DEI, Horizon2020). In the longer term, the sector itself may be able to provide more (financial) support for innovation.

iv. Road map

Figure 30: Innovation road map



See the appendix for reference to the innovation road map and the time scale of the innovation needs it describes.

F. Connection to heat networks

i. Vision for the future for scaling up geothermal energy

To achieve emission-reduction targets for 2030 and 2050, alternatives to the gas-fired central heating boiler are required in the urban environment. One alternative to this is a connection to a heat network. New, fossil-fuel-free sources of heat, such as geothermal energy, are required for these heat networks. As such, the installation of heat networks is crucial for the supply of geothermal energy in the urban environment. In this way, the otherwise fragmented demand from thousands of households is structured and collected in a quantity that permits a viable business case for geothermal energy. This dependency and uncertainty about both the source of geothermal energy and the availability of demand creates a "chicken and egg problem", which must be resolved by a central coordinator.

The 2018 *Klimaat- en Energieakkoord* will describe how this decision for a specific local heat solution will be taken. In addition, municipalities will develop visions for heat for 2021. To facilitate this process, we will work closely together with heat companies (including grid operators) and the *Expert(ise)centrum Warmte* to deliver a clear proposition for a collective heat solution. It is expected that these parties will serve local authorities that are interested in a collective heat network, with end users as customers.

From exploration to realisation, installing a heat network often takes many years. Given these long time scales and the limited experience with geothermal energy and heat networks, we must begin connecting geothermal energy sources to existing heat networks as soon as possible. Because the capacity of the existing heat networks is only 25 PJ, partnerships must also be established for heat networks to be realised in the future. In this way, the ambition of 20 PJ of geothermal energy in the urban environment can be achieved by 2030, and scaled up to 135 PJ after 2030.

ii. What the sector will do

To realise the connection of geothermal energy to heat networks for the urban environment, we will undertake three actions:

1. **starting ~10 pilots** to connect geothermal energy to existing and new heat networks in the urban environment

   To gain experience with collaboration and with the technical and social challenges associated with geothermal energy and heat networks in the urban environment as quickly as possible, it is important to start with pilots. This can be realised more quickly for existing heat networks, and as such will begin with these. One example of a technical barrier is the difference in temperature. The geothermal energy sources developed so far operate at around 70°C. This temperature is primarily suitable for the current grids that have been designed for this relatively low temperature. Older grids operate at a higher temperature of around 90°C. Technical solutions will be developed to deal with this.

   The first step is to determine which existing heat networks exist in areas with known subsurface potential. The necessary technical adaptations to the grids, and with end users, to permit connection to geothermal energy sources will subsequently be determined in partnership with the relevant heat companies at these locations. Pilots will then be started at the selected locations, in which actions 2 and 3 from this chapter will be implemented in practice. There are currently several projects ongoing in Pijnacker-Nootdorp, The Hague and Leeuwarden to supply geothermal energy (in the future) to the urban environment, with several projects planned by Hydreco and HVC. It is important to collect the "lessons learned" here and to share them with other operators.

2. **Preparing principles for transparent agreements with heat companies** about contracts and tariffs for the supplied heat

   Geothermal energy producers and heat companies must prepare standardised principles for contracts and tariffs between each other. Producers need these to be able to prepare a business case for doublets that produce (in part) for the urban environment, and heat companies need to know how geothermal energy compares to other potential sources of heat. The principles for the contracts must answer the question of how to deal with changes in the supplied power (at the start and during the production phase), changes in the supplied temperature and the period during which supply and/or sales are guaranteed. The principles for tariffs must lead to a transparent tariff structure, which depends on factors including the supplied power, the supplied temperature, the number of peak-load hours and/or the baseload and the cooling of the water in the heat networks. It is also important that the developer of the geothermal energy source can be sufficiently certain of achieving a return on the investment. This means that new sources can only be added to a heat network following consultation (negotiated TPA).

3. **Collaboration with heat companies and the *Expert(ise)centrum Warmte*** to be able to make a coordinated offer to local authorities and building owners

   The geothermal energy sector will work closely together with heat companies and the *Expert(ise)centrum Warmte*, so that they can present a clear proposition to local authorities. This will involve agreeing how they wish to inform local authorities about the potential geothermal energy, which data is needed to prepare transparent business cases, and which agreements about spatial adaptations are needed to create space for geothermal energy projects. In this way, geothermal energy can be optimally integrated into the total heat supply. The geothermal energy sector will intensify collaboration with heat companies (including HVC, Nuon, Eneco, Ennatuurlijk) and will actively approach heat companies to make concrete agreements about how the sector can best assist in making an offer to local authorities. Regions with a high technical and economic potential will be prioritised.

iii. What the sector needs

1. **Construction of new heat networks**

   Heat networks are needed in areas where a collective heat solution is the most economical alternative to natural gas. A variety of sources of heat must be connected to these heat networks (depending on local conditions and price) with an increasingly sustainable mix (e.g. by replacing heat from coal-fired or gas-fired power stations with geothermal energy). The capacity of existing heat networks is ~25 PJ. To supply 20 and 135 PJ of geothermal energy to the urban environment in 2030 and 2050 respectively, this capacity must be increased. To achieve this, it is important that a newly-developed heat network has sufficient volume within a reasonable time frame to successfully make use of a geothermal energy source. The connection rate of homes and buildings must match this.

   The choice of an alternative heat supply is preceded by preparing an inventory of existing and future sources of heat, and a careful participation process (see also Chapter 4D). It is crucial that the 2018 *Klimaat- en Energieakkoord* identifies how this decision for a specific heat solution will be taken. The important outcomes of the development of this (district-based) approach are who will initiate heat networks, who will own them, and how to finance them. Once the decision to install a heat network has been taken, a clear request to the market is essential. This must state the preconditions that the system must meet. By specifying these preconditions, the relevant district or municipality can promote priorities such as sustainability or cost effectiveness. Various sources, including geothermal energy, can then supply heat to the heat networks.

2. **Further development of the *Expert(ise)centrum Warmte***

   To ensure that the local approach to the energy transition is successful, it is important that local authorities are sufficiently supported in preparing their visions for heat. In the first instance, the *Expert(ise)centrum Warmte* must make a comparison available of the various sustainable options that municipalities may choose for local heat supplies. It must then refer municipalities with an interest in a heat network to the heat companies. These can propose a local solution, including a proposal for which sources should be connected, and at which moments.

3. **Heat companies that coordinate supply to local authorities**

Supplementary to the general and national approach of the *Expert(ise)centrum Warmte*, it is important that there is a clear coordinator to lead the heat offer to local authorities (to support municipalities, which will determine how to make heat supplies sustainable through a district-based approach in visions for heat). Heat companies (including grid operators) could logically take on this role. After all, they are capable of combining a range of sources (e.g. geothermal energy as baseload and waste heat as back up) and also designing how this will change over time. This also means that the heat companies must be aware of the spatial adaptations needed for geothermal energy, so that they can impose these as preconditions in regions where they plan new sources and/or grids. It is then the task of the municipalities and provinces to facilitate the spatial adaptations for the necessary projects, and to reserve the necessary space in land-use plans.

4. **Policy that promotes the use of green heat**

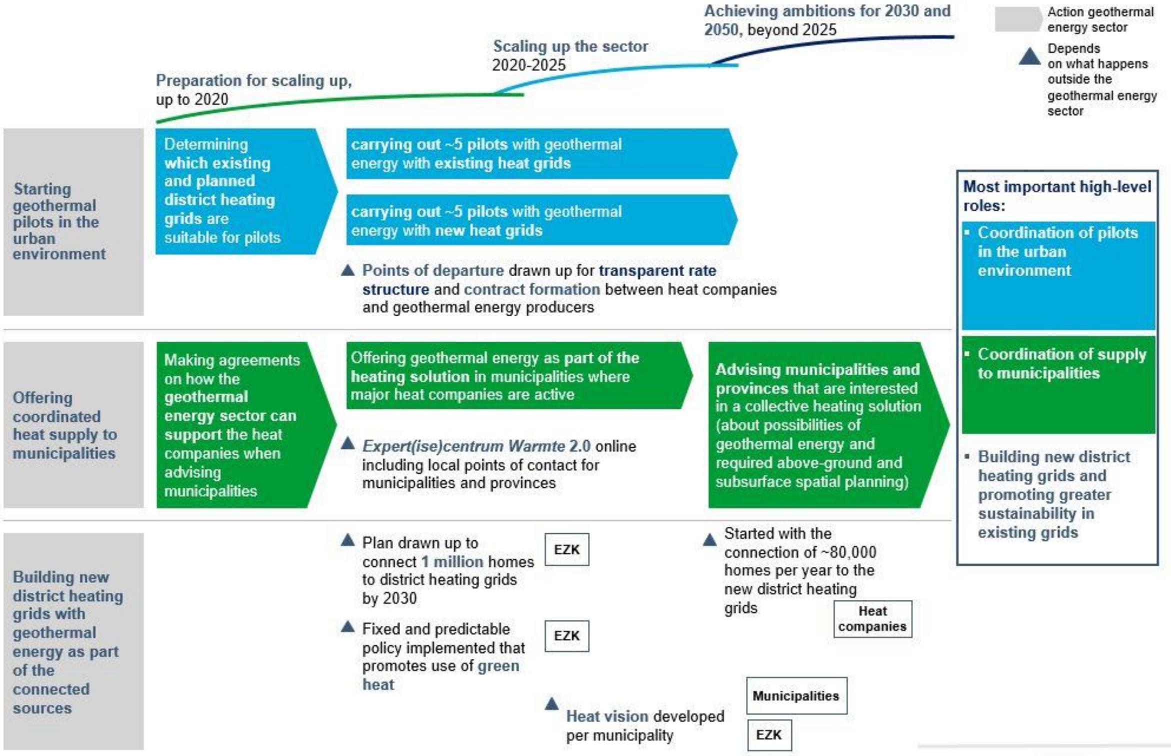
If companies, government and households wish to comply with sustainability goals, policy is needed that recognises the use of green heat via certification. It is important that it is possible to supply/sell 100% green heat to end users, including when the supplied heat is from multiple sources for technical reasons. The same rules must apply as those for green electricity. The heat industry prepared a voluntary code of conduct for this in October 2017.

In addition, pumps (and possibly heat pumps) are needed to use geothermal energy. As long as the average mix for electricity is not 100% sustainable, the electricity required for this must be produced more sustainably.

Finally, coordination with the Building Decree ("Bouwbesluit")**,** specifically in relation to the necessary energy labels, is important to ensure that the development of the demand for heat in the urban environment matches the (possible) supply.

iv. Road map

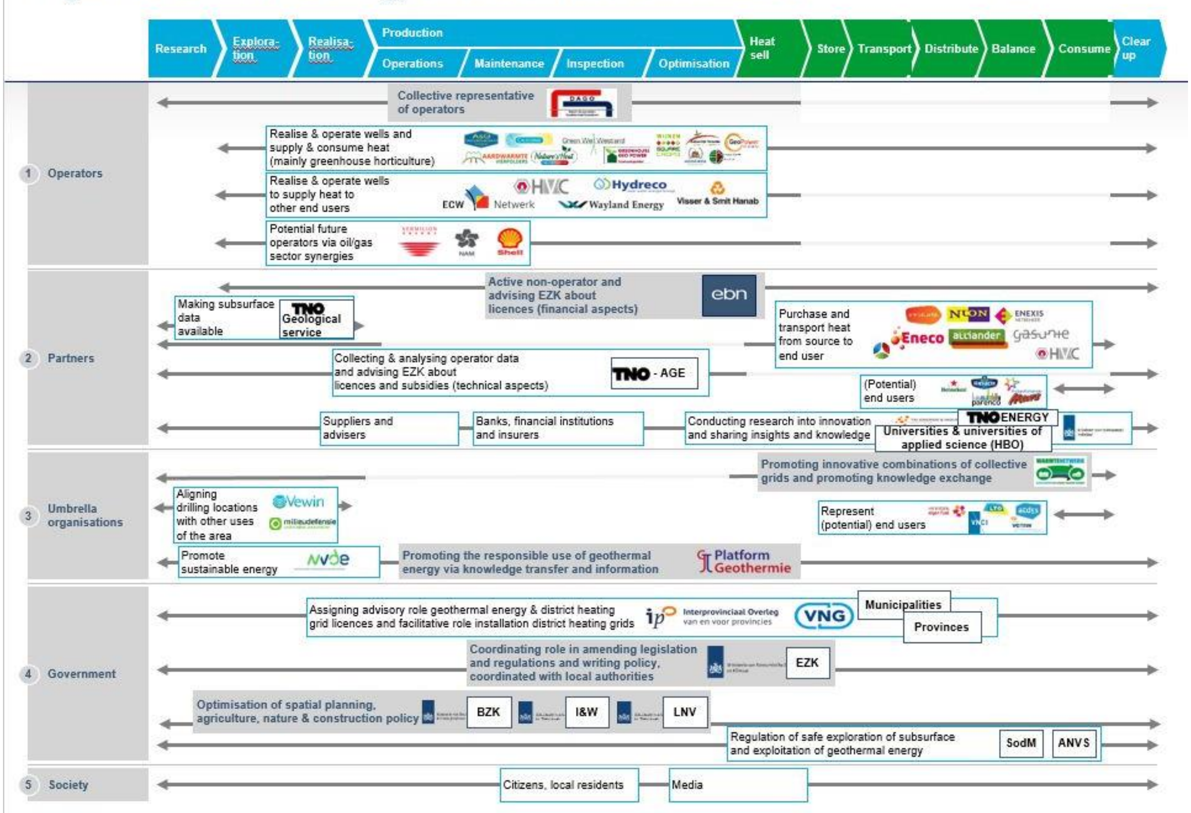
Figure 31: Connection to district heating grids road map



V. Organisational implications

In the coming years, we will realise the Master Plan, with important contributions from the sector and elsewhere. While DAGO, SPG, EBN, *Stichting Warmtenetwerk*, EZK and BZK will all play important and specific roles, all parties in the value chain can make a contribution. The summary below indicates which parties will play which role in each part of the value chain.

Figure 32: Geothermal energy value chain and stakeholders



For example, in addition to current and future operators, various partners will also play a role. These include suppliers and consultants, as well as companies that purchase heat and transport it from the source to the end user. (Potential) end users and the knowledge and research parties are also partners in the scaling up of geothermal energy in the Netherlands. Various umbrella organisations may play a role 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 also 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 accepting geothermal energy in the Netherlands.

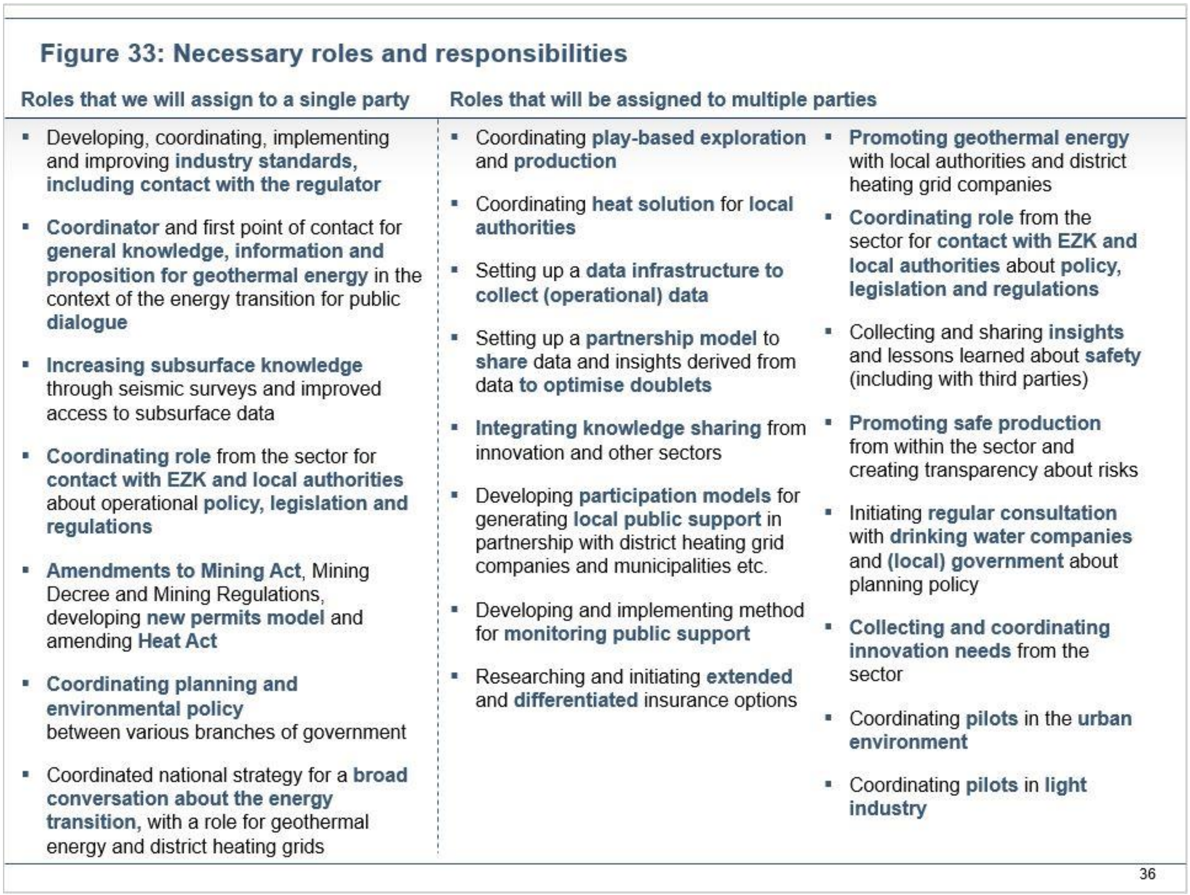
i. High-level roles for scaling up (within the sector)

The road maps that have been prepared for the various topics contain high-level roles, which will be operationalised. Various types of roles can be defined:

- Roles that will be occupied by a single party in the future, with this party keeping other parties informed.
- Roles that will be occupied by multiple parties:

- o Either coordinated by one party in consultation with other parties.
- o Or collectively and with the full support and agreement of all parties.
- o Or with multiple parties that play the same role individually.

Based on the road maps, the following high-level roles have been identified, which will be occupied by one or more parties:



The most important roles that are now assigned to all parties are:

- DAGO will take on the role of developing, coordinating, implementing and ensuring the ongoing development of industry standards, including the associated contact with the regulator and (local) government.

- EBN and TNO will take responsibility for increasing knowledge of the subsurface through seismic surveys and improving access to subsurface data.

- SPG will play a coordinating role in a national strategy for a broad conversation about geothermal energy and the energy transition. This means that SPG will be the first point of contact for general questions about geothermal energy, information and the geothermal energy proposition.

The most important roles that have been clearly defined, but not yet assigned, are primarily:

- Coordinating play-based exploration and production. Assigning this role is closely connected to the decision as to whether EBN may (financially) participate in geothermal energy projects, and as such cannot be completed now.
- Coordinating heat solutions for local solutions, including collaboration with heat companies.

- The two roles connected with setting up a data infrastructure on the one hand, and on the other a partnership model for sharing data, and insights gained from data, in the correct way.

ii. Coordinating roles

Coordinating roles between various stakeholders will occur on the basis of capacities, experience and interests. This may include:

- **DAGO:** As a sectoral organisation for operators of geothermal energy projects (permit holders) in the Netherlands, DAGO represents the collective interests of operators, by safeguarding the collective "licence to operate" through profitable and safe operations. DAGO can promote and represent a common perspective for operators with geothermal energy experience, through knowledge and expertise. In this context, they are already developing industry standards, and will continue to do so in the future. This is logically followed by the necessary coordination and active dialogue with both SodM and various branches of (local) government, with an emphasis on contributions to ensure members conduct operations properly (safety, certainty, affordability, reliability and conformity).
- ***Stichting Platform Geothermie* (SPG):** As a non-profit organisation, SPG focuses on the most socially-responsible use of geothermal energy in the Netherlands through a strong sector and the involvement, knowledge and expertise of government and society. With their heterogeneous membership consisting of parties from the public sector (including municipalities, provinces and knowledge institutes) and the private sector (including current and future operators, engineering firms and energy suppliers), they aim for "objectivity through intersubjectivity". This means that the Platform represents both the demand and supply side, and that everyone with an interest in geothermal energy can join and take part in work groups and other activities.

- **EBN:** EBN was established by the Dutch government to obtain maximum social and economic value from the Dutch subsurface, and as such EBN will also play a part in the geothermal energy sector. Thanks to its involvement in the oil and gas sector, EBN has a great deal of knowledge about doing business in the subsurface, as well as experience with collaboration with operators, innovation, data acquisition and analysis and contact with (local) government. For this reason, EBN is part of the Green Deal for Brabant and the Green Deal for Ultra-Deep Geothermal Energy. EBN also has access to considerable financial and organisational resources. The role to be played by EBN is further developed in the February 2018 *Beleidsbrief Geothermie* from EZK, which will be followed up shortly. Tasks from the February policy paper are:
  - Advice to EZK about a financial assessment for permit applicants.
  - Developing a plan for the national collection of detailed seismic data (GTI data). These works have now begun, in partnership with TNO.
  - A road map for knowledge and innovation tasks in the geothermal energy sector in respect of safety, cost and risk reduction and system optimisation has now been completed, in partnership with RVO.
  - The exact form of participation of EBN will be developed in a subsequent letter to parliament. In the event of any participation, EBN primarily wishes to contribute towards profitable, safe and responsible projects and portfolios of projects. Additional specific roles that involve EBN depend on the decision about participation.

- ***Stichting Warmtenetwerk*:** The *Stichting Warmtenetwerk* is a broad platform, which aims to reduce the use of fossil fuels and emissions of greenhouse gases by promoting collective heat and cold grids. Geothermal energy is one of the sources that can make this a reality and that will make a contribution, with high supply certainty at the lowest price. Its participants include heat grid operators, government, research institutes and industry players, which gives the foundation a broad membership. As well as collecting knowledge and information, the foundation also wishes to actively promote research and innovation and economic viability by developing cost-saving technologies.

On the basis of these capacities and interests, the above parties will further coordinate which of the described high-level roles will be assigned to which parties. The various stakeholders will also further coordinate the roles that cannot be assigned to a single party. In addition, the parties will agree how they wish to assign the role in the future:

- For roles that are coordinated by one party in consultation with other parties:
  - Agreeing which party is the coordinating party.
  - Consulting with other parties continuously.

- For roles that are assigned collectively with the full support and agreement of all parties:
  - Agreeing how the role will be occupied operationally by the various parties.
  - Coordinating how the roles are filled through ongoing meetings or in other ways.

- For roles that are occupied by multiple parties on an individual basis, the other stakeholders will be informed.

iii. Subsequent steps for the Master Plan

In the coming years, the undersigned will work to fully develop and put into practice the ambitions and actions in the Master Plan, in partnership with EZK and BZK. The above parties will involve other stakeholders in the further operationalisation of the Master Plan. We will undertake the following steps to this end:

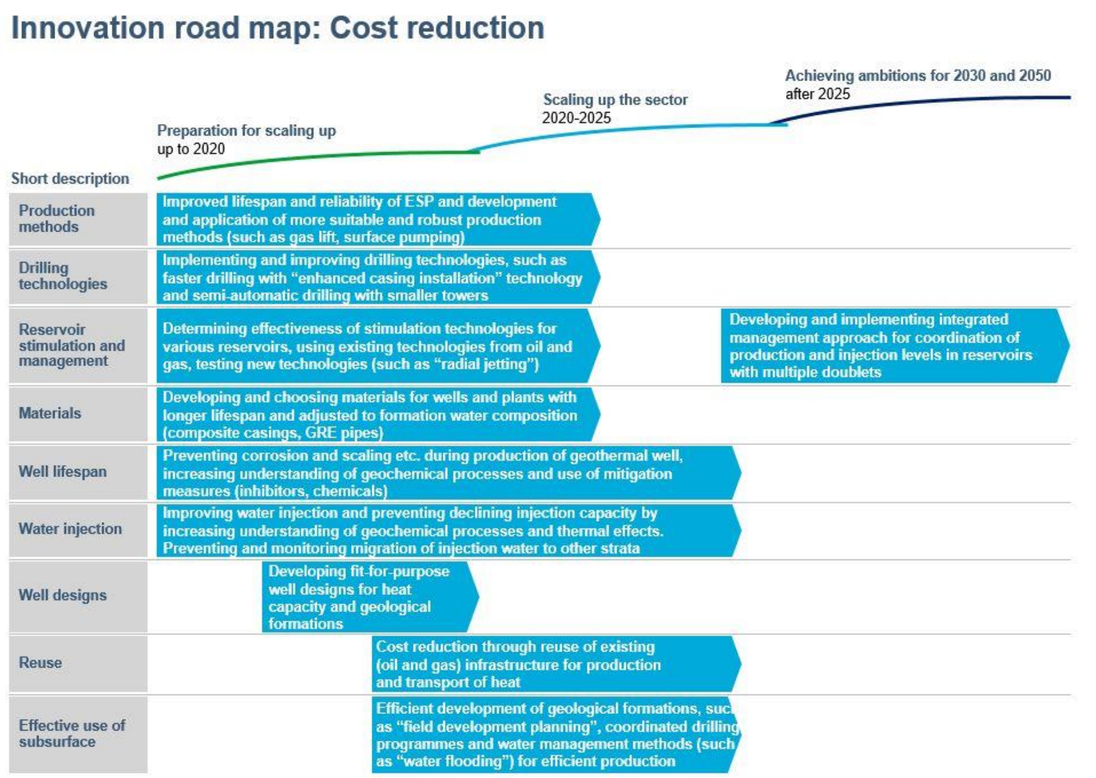
- **Aggregating and integrating activities for each stakeholder.** The undersigned will translate the Master Plan into specific activities, and will integrate it into their own organisational and business plans. This may include:
  - The specific mission and role that the party wishes to play in the geothermal energy sector.
  - Activities that the party will no longer undertake because, for example, they no longer match the mission and the role that the party wishes to play.
  - Implementing organisational changes, such as the necessary additional FTEs.

- **Coordinating implementation of the road maps.** Various parties will implement the activities identified in the road maps, and will coordinate these among themselves as agreed where necessary. A standardised cycle will help the various parties coordinate, and will further refine these road maps and roles where necessary.

- **Monitoring implementation of the Master Plan.** The progress of the implementation of the Master Plan will be monitored on an annual basis, so that adjustments can be made where necessary, or the Master Plan amended. This cycle will also facilitate a dialogue between the involved parties about successes and bottlenecks, for example via:
  - An annual report by the geothermal energy sector about the state of the sector.
  - Meetings for the entire geothermal energy sector.

We look forward to discussing and improving this Master Plan together with many stakeholders. For us, this Master Plan represents a common starting point that we can build upon in a dynamic way in the years to come.

VI. Appendix


Innovation road map: Cost reduction
Achieving ambitions for 2030 and 2050
after 2025
Scaling up the sector
2020-2025
Preparation for scaling up
up to 2020
Short description
Production methods
Improved lifespan and reliability of ESP and development and application of more suitable and robust production methods (such as gas lift, surface pumping)
Drilling technologies
Implementing and improving drilling technologies, such as faster drilling with "enhanced casing installation" technology and semi-automatic drilling with smaller towers
Reservoir stimulation and management
Determining effectiveness of stimulation technologies for various reservoirs, using existing technologies from oil and gas, testing new technologies (such as "radial jetting")
Developing and implementing integrated management approach for coordination of production and injection levels in reservoirs with multiple doublets
Materials
Developing and choosing materials for wells and plants with longer lifespan and adjusted to formation water composition (composite casings, GRE pipes)
Well lifespan
Preventing corrosion and scaling etc. during production of geothermal well, increasing understanding of geochemical processes and use of mitigation measures (inhibitors, chemicals)
Water injection
Improving water injection and preventing declining injection capacity by increasing understanding of geochemical processes and thermal effects. Preventing and monitoring migration of injection water to other strata
Well designs
Developing fit-for-purpose well designs for heat capacity and geological formations
Reuse
Cost reduction through reuse of existing (oil and gas) infrastructure for production and transport of heat
Effective use of subsurface
Efficient development of geological formations, suc as "field development planning", coordinated drilling programmes and water management methods (such as "water flooding") for efficient production


Innovation road map: Safety and risk reduction
Achieving ambitions for 2030 and 2050
after 2025
Scaling up the sector
2020-2025
Preparation for scaling up
up to 2020
Short description
Induced seismic activity
Increasing understanding of the emergence and mitigation of induced seismic activity. Researching the interaction between geothermal energy and other mining activities. Researching the effects of using fractures for water injection
Abandonment
Safe (and cost-effective) abandonment by including this in the well design and taking account of specific geological conditions
Well designs
Developing fit-for-purpose well designs for specific safety risks (such as extra wall where there is a greater risk of leakage)
Test water and bycatch
Dealing safely and sustainably with test water and "bycatch" (formation gas that may be extracted along with water) – feasibility and timing to be determined later
34

Innovation road map: Value chain optimisation

- Preparation for scaling up: up to 2020
- Scaling up the sector: 2020-2025
- Achieving ambitions for 2030 and 2050: after 2025

Short description	
Hybrid grids	Demonstrating geothermal energy and other sources of heat, connected to a single district heating grid. Diversification of concepts for heat supply in the urban environment, such as combining heat production, supply and return. Demonstrating modification of existing grids for geothermal energy
High-temperature supply	Demonstrating high-temperature supply (UDG) for supplying geothermal energy to industry
Natural gas and geothermal energy	Developing and implementing combination of natural gas and geothermal energy for more effective realisation and production of wells and locations (including "dual play")
Low-temperature supply	Demonstrating low-temperature geothermal energy projects, shallower than 1,500 metres, and use in local district heating grids in the urban environment. Increasing understanding of the movement of cold front and re-heating rate
Storage	Further development and demonstration of underground storage, such as HTS in salt-water aquifers and storage in underground voids. Making above-ground and shallow heat storage cheaper, such as the Ecovat concept
Smart grids	Developing and testing smart district heating grids, in which supply and demand are closely coordinated for efficient supply
Maximum heat usage	Further development of cascading (maximum cooling through making stepwise use of various users). Maximising operating hours
Integration of energy forms	Developing ways of using geothermal energy to generate other forms of energy, such as hydrogen, using excess heat for cooling