Radarweg 60
1043 NT Amsterdam
The Netherlands

www.tno.nl

T +31 88 866 50 10

ECN part of TNO report

TNO 2018 P10795 | Final report

Assessment of Green Deals related to sustainable heat

Date	October 2018
Author(s)	R.J.M. Niessink; A. Uslu
Copy no	
No. of copies	
Number of pages	30 (incl. appendices)
Number of appendices	1
Sponsor	
Project name	Sustainable Heat Knowledge Project
Project number	060.33941

Summary

Green Deals are agreements between the national government and other parties (such as companies, civil society organizations and local authorities) to realize a sustainable and green economy in the Netherlands. Green Deals are meant to support innovative and sustainable initiatives by removing the bottlenecks in laws and regulations, creating new markets, providing useful information and ensuring optimal partnerships. The government plays a supporting role in Green Deals.

This study has looked into past and ongoing Green Deals relevant to sustainable heat supply in the Netherlands. Green Deals were assessed to provide information related to the characteristics of sustainable heat projects planned or implemented in the Netherlands, the barriers they have faced and the possible linkages they have experienced among the different sectors. This information would provide insights into the possibilities, limitations and dilemmas in future choices regarding the introduction of sustainable heat options to decarbonise the heat sector in the Netherlands.

Among the Green Deals analysed, 30 of them appear most relevant to the sustainable production and/or supply of heat. These Deals are very diverse with regard to sectors involved, technologies and heat sources considered. They either focus on knowledge building on certain technologies or investigate the business cases through feasibility studies and in some cases implement them. The main heat sources/fuels included in the Green Deals are green gas, biogas (e.g. from fermentation of biogenic residues from own processes), use of biomass and/or waste streams in CHP/power plants or heat installations, (deep) geothermal, aquifer thermal storage (ATES), and use of residual heat from industrial processes.

In terms of heat supply, which can be alternatively expressed as natural gas savings in petajoules (PJ), most of the Green Deals can be considered small scale projects. This is typically the case with individual point sources of residual heat from local (industrial) companies (<<1PJ). Green Deals can go as small as a company that ferments its own organic waste into biogas and supplies it to local consumers, or an ice-skating rink that is looking for ways to supply waste heat from its cooling installations to neighbouring buildings.

Regarding sectors, application of geothermal sources is mainly seen in the horticultural sector. The greenhouse horticulture sector has been very active over the last years in identifying and exploiting locations for geothermal energy. In fact, 10 of the current 12 geothermal wells were laid out in this sector. Most of the Green Deal projects in the built environment relate to the expansion of (existing) heat networks and use of renewable and residual heat sources (e.g. geothermal, residual heat from industry or waste incineration plants). At the provincial level, large scale (sustainable) heat supply via heat networks is also the centre of attention. Green Deals at the provincial level aim to define strategies for making heat supply more sustainable, realize new heat networks and increase the sustainability of existing heat networks by the use of residual and renewable heat. Utilisation of residual heat from industry appears as one of the most important components of these strategies. For instance, it is mentioned that the yearly heat cooled down in the Rotterdam harbour is equal to 12% of the amount of gas the Netherlands uses yearly. The Province of Limburg Green Deal indicates a residual heat supply potential to 30,000 homes equivalent

(equivalent to around 1 PJ of natural gas saving per year). Another Green Deal, the Hengelo heat network project indicates that low temperature heat available from nearby industry is about 3 PJ.

Given the very diverse nature of Green Deals it is not possible to draw concrete conclusions and lessons learned for sustainable heat supply in the Netherlands in general. Nevertheless, this study finds the main determinants to the successful implementation of sustainable heat projects. These can be summed up as follows:

- The feasibility of business cases is determined by three main factors: resource availability, distance to the demand centres and the existence of the necessary infrastructure. Whether a project can be successful or not depends on the local circumstances.
- Sufficient technical knowledge and knowledge about infrastructure (e.g. heat transport and residual heat infrastructure) is essential to implement sustainable heat projects. Sufficient geological knowledge about the (deep) subsurface is required in case of geothermal projects, otherwise this could become a barrier for implementation.
- Finding (improved) ways of financing and the availability of governmental subsidies play a crucial role in making the business case more attractive.
- Clarity on legislation and/or regulations and ease of permitting rules when it comes to small scale renewable heat generation and supply is necessary. (i.e. permitting rules for thermal energy storage in the subsoil or in case of use of own biogenic waste clarifications are needed regarding the legislation and regulations in the area of waste, permitted emissions and fertilizers).
- The commitment from all Green Deal parties is a prerequisite for the successful completion of a Green Deal. A number of projects were not completed because it was not clear to all parties what their exact roles and responsibilities were.

The heat infrastructure is often costly. The decision is often made based on the availability of a local heat source and existing infrastructure in combination with the outcome of a feasibility study including a cost-benefit analysis. While large scale heat networks can allow a large number of consumers to have access to heat that has been produced from a number of sustainable sources, a number of Green Deals analysed in this study indicate that small scale projects (e.g. residual heat projects) are often more feasible on the short term. This brings up the importance of mapping potential heat sources as well as possible consumers in order to set long term heat strategies. Matching heat sources and heat consumers and thereby taking into account the right temperature levels is essential in setting long term heat strategies and defining the business cases.

Contents

1 Introduction

At ECN part of TNO the knowledge project 'Sustainable Heat' investigates ways to accelerate the deployment of sustainable heat in industry, the built environment and horticulture. The main aim is to contribute to a CO_2 neutral energy system in the Netherlands by 2050. As part of the knowledge project this report assesses past and ongoing Green Deals that are relevant to sustainable heat. The assessment aims to:

- Contribute to knowledge development about the characteristics of various sustainable heat options, obstacles to their realization and linkages between the sectors.
- Provide insight into possibilities, limitations and dilemmas in choices regarding the introduction of sustainable heat and sustainable fuels.

Green Deals are agreements between the national government and other parties (such as companies, civil society organizations and local authorities) to realize a sustainable and green economy in the Netherlands. Through Green Deals, the national government aims to give space to innovative, sustainable initiatives from society by removing the bottlenecks in the laws and regulations, create new markets, provide useful information and ensure optimal partnerships (Rijksoverheid, 2018).

Energy Deals are a subgroup of Green Deals focusing on both energy savings and sustainable energy. In the Energy Deals, there is a lot of cooperation with industry, the agricultural sector and SMEs. This concerns cooperation with individual companies but also cooperation projects with branches and/or chains. The Green Deals with individual companies are mainly focused on solving technical or financial bottlenecks. A number of other Deals mainly seek to create preconditions, for instance financially and/or organisationally to realize energy projects (Greendeals/Energie in Beeld 2011-2015, 2018).

Since the start in 2011 more than 200 Green Deals[1] have been signed. Screening of these deals resulted in 36 Energy Deals that are related to the heat sector. This report includes the assessment results of 30 Green Deals that are considered most relevant. The remaining 6 Deals[2] are considered less relevant to the heat sector and the ambitions of this study. They are, therefore, not included in this study.

Besides Green Deals there are other sustainable heat projects in the Netherlands, either ongoing or completed, that can be considered as example projects. A number

[1] An overview of the deals and final reports are obtained from the Green Deal site (Green Deals, 2018)

[2] The remaining green deals are GD002, focusing on biomass streams to maximise the value of biomass through valorisation of proteins from residual flows and producing chemical building blocks. GD016, supports the E-decentraal association representing decentralised energy initiatives and contributes to their professionalisation. Energy Nederlands (GD059) ,representative of almost all energy companies focuses on a number of topics ranging from electric cars to co-firing and CCS related topics. Another Deal, GD 163, focuses on CO_2 supply for greenhouse cultivation in North Holland. GD205 Invetsea relates to development of expert centre for biomass gasification in Alkmaar. Through the collaboration, the parties want to create maximum synergy for innovation, education and entrepreneurship and strengthen the position of biomass gasification technology. GD124 looks into the hydrogen symbiosis. It mainly focuses on the transport of H_2 and its use in the industry as feedstock.

of these projects focus on technologies that were not part of the studied Green Deals, for instance heat pumps. These projects are not assessed in this study. Instead, an overview of available information sources is provided in Appendix A.

This report consists of 4 chapters. Chapter 2 presents an overview of the Green Deals related to sustainable heat. In this chapter Green Deals are grouped as relevant to industry and horticulture, built environment and projects at provincial level. Chapter 3 explains the success factors and main challenges these projects have faced. Finally, chapter 4 presents the conclusions and lessons learned from these deals. An inventory of example projects is presented in Appendix A.

2 Assessment of Green Deals

2.1 Introduction

The focus of this assessment lies on extracting useful information from the Green Deals regarding supply of sustainable heat, related laws and regulations, and the barriers and challenges. Figure 1 illustrates the regions where the selected Green Deals are located. The Green Deals that are set up by umbrella organizations covering the whole country, for instance by Unie van Waterschappen focusing on wastewater plants in the Netherlands, are represented by 'no specific location' in the figure.

As explained in the introduction, 30 Green Deals are identified as relevant to sustainable heat. An overview of these projects is given in Tables 1-3.

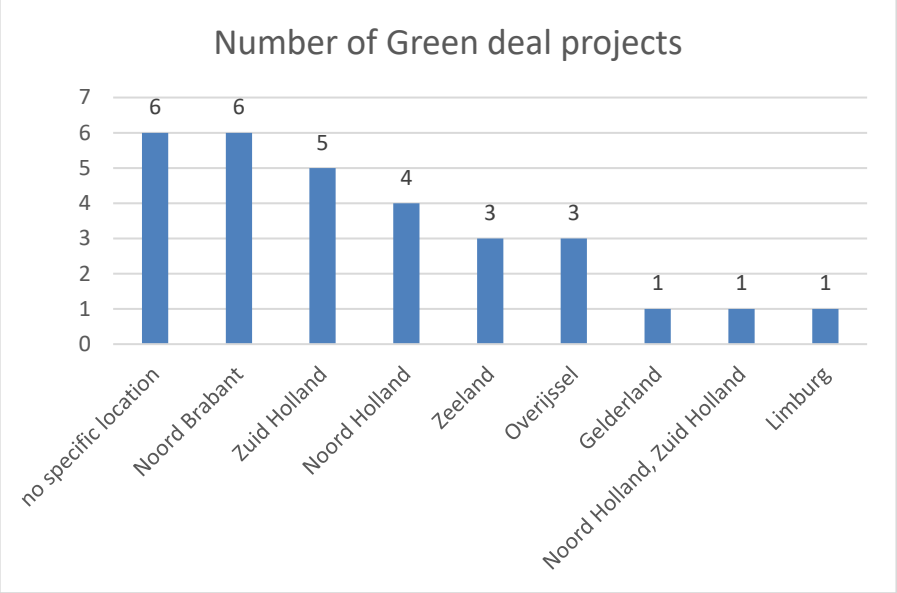

Figure 1: Provinces where the Green Deals related to sustainable heat are/have been located

There is a large diversity in Green Deals with regard to sectors involved, technologies and applied heat sources. Most frequent renewable heat sources in Green Deals are bioenergy and geothermal. Heat can either be exchanged between parties in the same sector, or exchanged between different sectors. A large number of the Green Deals look into the possibilities to utilise residual heat, entailing the heat released during electricity generation, industrial processes or waste incineration that cannot be used or recovered by the company. This is also referred to as 'waste heat[3]'. If this heat is efficiently used by another party, this is called residual heat exchange (RVO, 2015). Green Deals focusing on the exchange of residual heat, also when the origin is fossil, is also included in this study[4].

[3] In the Renewable Energy Directive Proposal (COM/2016/0767 final/2) 'waste heat or cold' means heat or cold which is generated as by-product in industrial or power generation. installations and which would be dissipated unused in air or water without access to a district heating or cooling system

[4] The REDII proposal includes the possibility of exploiting waste heat as an additional flexibility for Member States to reach their obligation under articles 15, 23 and 24.

In terms of heat supply, which can be alternatively expressed as natural gas savings expressed in petajoules (PJ), most of the Green Deal projects can be considered small scale. This is typically the case with individual point sources of residual heat from local (industrial) companies (<<1PJ). Green Deals can go as small as a company that ferments its own organic waste into biogas and supplies it to local consumers, or an ice-skating rink that is looking for ways to supply waste heat from its cooling installations to neighbouring buildings. Occasionally, large scale heat networks with tens of thousands of connected dwellings, represent heat supply of about 1PJ (for instance the heat network in Purmerend which has more than 60,000 connected dwellings). The planned large scale heat network in Zuid Holland ("Warmterotonde") would supply >20 PJ of heat to consumers in the region. Still, compared to the total heat demand in the Netherlands these are small amounts. The final energy use in the Netherlands is about 1,100 PJ in 2016 out of which 5.5% or 61 PJ is renewable (CBS, 2017).

Large scale heat networks, for example in Nijmegen, Amsterdam and in Zuid-Holland have been realised, and there are high ambitions for expansion (for instance in Amsterdam where the ambition is to connect 100,000 dwellings to the heat network by 2030). Large scale heat networks can have a big impact (>10%) on sustainable heat supply in the Netherlands (EY, 2016).

2.2 Grouping Green Deals by sector

While it is very difficult to define a strict categorization we grouped the Green Deals based on the main sector they consider supplying heat to: industry & horticulture or the residential sector. Green Deals at provincial level consider supplying sustainable heat to both industry and residential sector and they mainly focus on expansion of heat networks. We, therefore, placed them in a separate category. The sole purpose of this categorisation is to ease presentation of the wide diversity of Green Deals.

2.3 Green Deals - Industry & Horticulture

A wide range of industrial players has been involved in these Green Deals. Five of them focus on the horticulture sector, mainly greenhouses, and aim to contribute to the decarbonisation of this sector. Four of the Green Deals are initiated by associations representing certain industrial segments (e.g. the textile service sector, the Dutch Packaging & Pallet Industry Association etc.). Other Green Deals concern one or a few industrial players that aim to produce and/or supply sustainable heat to its processes.

Below section addresses some of the Green Deals whereas the full overview is presented in Table 1.

In 2016, agriculture and horticulture comprised around 11% of the total heat demand in the Netherlands (in absolute terms 111 PJ (ECN MONIT, 2017)). The main ways for heat production considered in the Green Deals are using waste streams for energy, geothermal, utilisation of residual heat and replacing gas fired boilers and CHP with green gas fired ones.

- Green Deal The "Groene Poort" (**GD007**) was a partnership between one greenhouse horticultural enterprise and five Zeeland farmers. The project

envisaged production and the use of green gas, CO_2 and water from fermentation of vegetable residual material. One of the biggest stumbling blocks for the entrepreneurs united in De Groene Poort was to obtain financing for their project. This deal made progress in the first phase, however in the end the financial close was not made by the entrepreneur, since conditions with regard to (equity) capital investments were not considered appropriate.

- De Meerlanden and SGN project (**GD010**) was aimed at, among other things, post-composting of organic materials with high temperature storage (HTS) and the wood boiler to supply renewable energy and heat to almost 15 hectares of greenhouse horticulture. This Green Deal was not realized. It was not clear to all parties what actions were promised and requested. Due to the absence of a permit De Meerlanden was forced to opt for another project implementation, for an aquifer thermal storage (ATES).
- Koppert Cress, a company concerned with seeding of plants, set up a Green Deal (**GD026**) to conduct a pilot project about low temperature heat-cold storage at a higher temperature (40^{o}C) that results in an annual energy saving of 1,8 million m^3 of gas. A trial license was issued by the province of South Holland for a pilot phase of five years. There was a pre-condition to monitor the effects with regard to impacts of high temperature on the biochemical processes in the soil and on the quality of the water and human health.

The greenhouse horticulture sector has been very active over the last years in identifying and exploiting locations for geothermal energy. In fact, 10 of the current 12 geothermal wells were initiated by gardeners (PBL, 2017). Two Green Deals, **GD165** and **GD017**, focus on heat supply through geothermal energy to the horticulture sector.

- Triassic layer research drilling Westland (**GD165**) investigates the use of geothermal energy from the Triassic layer. This earth layer is located about 4 km below the earth's surface. The temperature of the water from this earth layer is approximately 140^{o}C. According to the Westland energy scan, the entire Westland municipality currently uses around 30 PJ of heat annually. Utilization of the Triassic layer can provide more than 80% of the heating requirement, the remaining part comes from the lower chalk layer. On May 10, 2017, after many years of preparation, the start signal was given for a very deep geothermal drilling in the Westland. This is the first time that the Netherlands has drilled at a depth of 4 km for extracting geothermal energy. On May 31st 2018, the production test of the second well (production well) of the Trias Westland doublet took place. The test went well and confirmed that the reservoir is suitable. On this basis, a heat network can be installed with a capacity of 17 - 21 MWth. In concrete terms, this means that at least 26 greenhouse horticulture companies (with a maximum of 32 firms) could be connected to this source (Trias Westland, 2018).
- Geo Power Oudcamp, a cluster of 8 greenhouse horticulture companies, set up a Green Deal (**GD017**) that aimed to supply deep geothermal energy to greenhouse horticulture and a new housing estate to be built in the neighbourhood. The deep drilling has not been realised due to lack of sufficient knowledge about deep subsurface. However, the preconditions for unlocking deep geothermal heat were created. The exploration and production license in the Mining Act was adjusted and the government broadened the guarantee. This also allowed other deep geothermal projects to make use of RNES (National EZ geothermal subsidy scheme (Dutch name: “De regeling Risico's dekken voor aardwarmte”) to cover risks for geothermal heat.

- Another project (**GD217**) focusing on deep geothermal to supply high temperature heat to process industry is the Green Deal Ultra-Deep Geothermal (UDG) that was signed in 2017. The parties are working together to increase knowledge about and for UDG energy in the Netherlands and to make it applicable for the purpose of making high-temperature heat supply more sustainable.

Several industry associations have been involved in the Green Deals to decarbonise their energy demand. Some examples are given below:

- The association that represents rubber crushers and sorting companies (that jointly work up more than 70% of Dutch construction, renovation and demolition waste and industrial dry waste valuable raw materials), aimed to initiate a gasification plant to process the sorted waste and supply heat to 4,000 houses to be built in the municipality Veldhoven as part of the Green Deal (**GD006**). This project was not financially feasible.
- The Dutch Packaging & Pallet Industry Association (Dutch: EPV) is a sector association that represents producers, traders and repairers of wooden packaging. The industry uses a lot of energy[5] to heat the drying installations for pallets and wooden packaging in particular. The aim was to remove obstacles related to the use of own company residual wood for energy generation. This deal (**GD067**) was re-evaluated and considered to be in conflict with the policy focusing on reuse and recycling. It was terminated in 2014.
- The textile service sector sets its ambitions to save 35% of its energy in the coming 3 years. The sector's total energy consumption is stated to be 2 PJ. On average, three quarters of this demand relates to heat. To achieve this goal, and as part of the Routekaart Textielservice 2030, the sector initiated a Green Deal in 2011 (**GD136**). In total 5 projects were included in this deal. Among these projects, one focused on the application of 15 solar collectors and/or solar PV systems at 15 companies. The drying process using direct solar energy was part of the deal.
- De Unie van Waterschappen, the association of water bodies in the Netherlands, started a Green Deal in 2011 (**GD057**) with the aim to realize 12 large scale energy factories (that can produce green gas, sustainable heat and electricity). In the long term, they aim to build all 350 wastewater treatment installations into 'energy factories'. This Green Deal has been very successful. A new deal (**GD195**) has also been initiated, which not only focuses on production of electricity, heat and green gas but also includes sample projects for instance related to extraction of heat and cold from surface water (project number 10 and 11).

Next to the Green Deals initiated through associations, there were a few with a focus on certain industries. The realization of heat supply as a result of these deals appears to be unsuccessful.

[5] An average production site consumes 100,000 to 200,000 m^3 of gas on an annual basis.

Table 1 Green Deals that are most relevant to heat supply in Industry and horticulture

Green Deal Name/Number	Sector(s) involved	Parties involved	Heat technology	Main focus/type of Green Deal	Start year	Status	Results
Energy sustainability of greenhouse horticulture (GD007)	Horticulture	De Groene Poort (a partnership between a greenhouse horticulture company and five Zeeland farmers), Government: Ministry of Economic Affairs, Agriculture & Innovation and Ministry of Infrastructure & Environment	Replaces natural gas used in gas-fired boilers and gas-fired CHP units with green gas	Production and the use of green gas, CO_2 and water from fermentation of vegetable residual material	2011	Finished February 2014	This deal made progress in the first phase, but in the end the financial close was not made by the entrepreneur, since conditions with regard to (equity) capital investments were not considered appropriate.
De Meerlanden and SGN (GD010)		De Meerlanden and Stallingsbedrijf Glastuinbouw Nederland (SGN). Central government: Ministry of Economic Affairs, Agriculture & Innovation and Ministry of Infrastructure & Environment.	Residual heat from post-composting ATES. Wood-fired boiler plant for peak energy demand	Post-composting of organic materials with high temperature storage (HTS) and the wood boiler to supply renewable energy and heat to almost 15 hectares of greenhouse horticulture.	2011	Intended end date January 2013, but stopped early	Stopped early. This Green Deal shows that commitment from all Green Deal parties is required to be successful.
Koppert Cress (GD026)		Koppert Cress BV, Government: Ministry of Economic Affairs, Agriculture & Innovation, Ministry of Infrastructure & Environment.	Low temperature soil heat-cold storage (residual heat)	Conduct a pilot project about low temperature heat-cold storage at a higher temperature (40°C)	2011	Completed July 2015	The trial license was issued by the province of South Holland for the pilot phase of five years.
Triassic layer research drilling Westland (GD165)		Municipality of Westland, Westland Infra, Koninklijke Coöperatieve Bloemenveiling FloraHolland, HVC, National government	Deep Geothermal	Investigates the use of geothermal energy from the triassic layer	2014	In progress	On May 10, 2017, the starting signal was given for a very deep geothermal drilling in the Westland. This is the first time that the Netherlands has drilled at a depth of 4 km for extracting geothermal energy.
Geo Power Oudcamp e.a. (GD017)		Consortium Flora Holland, HVC en WestlandInfra en Geo Power Oudcamp	Deep geothermal	Supply geothermal energy to greenhouse horticulture(100-	2011	Finalised	The deep geothermal drilling has not been realised because of insufficient geological knowledge.

Green Deal Name/Number	Sector(s) involved	Parties involved	Heat technology	Main focus/type of Green Deal	Start year	Status	Results
				120 ha) and a new housing estate.			
Ultra-deep Geothermal (UDG) (GD217)	Process industry and horticulture	Ministry for Economic Affairs, Ministry of Infrastructure and Environment, EBN, TNO, consortiumparties	Deep Geothermal	Supply high temperature heat to process industry	2017	In progress	The parties are working together to increase knowledge about and for UDG energy in the Netherlands and to make it applicable for the purpose of making the high-temperature heat supply more sustainable.
Energy saving waste treatment (GD006)	Rubber crushers and sorting companies	Branch organisation breken en sorteren (consist of rubber crushers and sorting companies (including Dutch construction, renovation and demolishing waste and dry industrial waste), companies Baetsen Recycling BV and ARN Recycling and the Central government	Heat from gasification of sorting waste (partly organic)	Initiate a gasification plant to burn the sorted wastes and supply heat to 4,000 houses to be built in the municipality Veldhoven	2011	Finalised, but not realised	This project was not financially feasible.
Residual heat utilization (GD043)	Metallisation, coating and colouring industry	Vacumetal B.V. and BreedofBuilds. Central government: Ministry of Economic Affairs, Agriculture & Innovation and Ministry of Infrastructure & Environment	Residual heat transport including a heat exchanger	Meet part of Vacuumetal process heat demand from the residual heat that can be supplied from the companies in the area. The focus has been identifying potential suppliers and consumers of residential heat.	2011	Finalised	It was not possible to realize the residual heat project in the short term. However, provisions have been made in technical installation to link residual heat from third parties at a later date.
Useful application of residual wood (GD067)	Packaging and pallet industry	Pallet Kisten fabirek (PKF), Dutch Ambala and pallet industry association (EPV), Wood platform in Holland (PHN) and the central government	Wood burners , residual wood	Useful application of residual wood.	2011	Finalised October 2014	The deal was terminated due to the policy focus on circular economy.
Textile service industry energy efficiency (GD136)	Textile industry	Federation textielbeheer Nederland on behalf of many textile companies	Solar collectors (application of hot water buffers); WKK with water recycling (the	Realization of 5 projects aimed at energy savings of 35% in the textile service sector. The projects are part of roadmap Textile Service 2030.	2012	Finished	No detailed info concerning the progress on heat collectors. Application of solar energy leads to savings but payback times are long (>10 years)

Green Deal Name/Number	Sector(s) involved	Parties involved	Heat technology	Main focus/type of Green Deal	Start year	Status	Results
		and the Central government	renewable source is not mentioned)				
Unie van Waterschappen (GD057)	Wastewater treatment plants	Uni van Watterschappen, Central Government	Sewage sludge biogas -WKK and boilers	Realize 12 large scale energy Fabrieken (factories) (that can produce green gas, sustainable heat and electricity)	2011	Completed	Was very successful, 8 energy factories have been realized at the time, and this number is increasing rapidly.
Sustainable heat from biomass (GD027)	Mushroom company	Mushroom producer 't Voske and the government	Biomass incineration	Combusting its mushroom leftovers (champost) and use a share of produced heat in its energy-intensive mushroom growing processes.	2011	Finished in 2015	The incineration was installed at the completion of this deal. At that time, there were still a number of technical problems to be resolved.
Bio Energy Centrale (BEC) Essent (GD014)	Energy sector and industry	Essent, Central government, local industries (such as Gansenwinkel)	Biomass combustion, use of residual heat	Reopening of Essent's existing combustion plant and supply of heat (40 MW_{th}) to neighbouring industries in Cuijk.	2011	Finished	The power plant currently only produces renewable electricity (no heat).
Heat utilization and desulfurization (GD036)	Shell Chemie in Moerdijk	"Shell Nederland B.V. Central government: Ministry of Economic Affairs, Agriculture & Innovation and Ministry of Infrastructure & Environment."	CHP installation and utilisation of residual heat to the neighbouring companies	Installation of a CHP installation (70 MW_e) and possibility to use externally supplied steam to the CHP at Shell Chemie in Moerdijk.	2011	Completed	This Green Deal does not consider any renewable heat production.
Groen Gas Nederland (GD033)	Energy sector, and ECN	Gasunie, GasTerra, Eneco, Essent, Eon, Alliander, Enexis, Stedin and ECN, Wide support from other market parties and central government	Green gas production via anaerobic digestion and gasification	Green Gas Netherlands Foundation is a temporary project organization in which all experiential knowledge in the field of green gas is bundled. It is committed to accelerating the actual production of green gas installations and the realization of projects. The set targets from this organisation are as follows. • Increase raw biogas production to 1,5-2 billion m^3 in 2025 and 3 billion m^3 in 2030. • 3 billion m^3 in 2030 (fermentation and gasification).	2011	Completed in 2015	Through this Green Deal, the industry, the renewable gas sector, knowledge institutes and the government are working together to develop a bio-based economy and to increase the contribution of renewable gas in the energy mix. Characteristic of the application of biomass in this Green Deal is 'multiple valuation'. The Green Gas Netherlands Foundation now represents 125 companies and organizations in the biogas sector.

Green Deal Name/Number	Sector(s) involved	Parties involved	Heat technology	Main focus/type of Green Deal	Start year	Status	Results
Rotterdam Climate Initiative (GD056)	Industry	Rotterdam Climate Initiative / Municipality of Rotterdam, DCMR (environmental service). Central government: Ministry of Economic Affairs, Agriculture & Innovation, Ministry of Infrastructure & the Environment and Ministry of the Interior & Kingdom Relations.	Heat network (exchange of residual heat between companies)	Exchange industrial residual energy (via a steam pipe). Construction of a steam pipeline that saves in 2013 approximately 20,000 tons of CO_2, with view on 400,000 tons of savings in 2017.	2011	Finished, but projects continue	This project was not realised during the Green Deal period, because of issues among the parties involved at the time. All projects continued after completion of the Green Deal.

2.4 Green Deals - Built environment

Table 2 lists Green Deals that are considered in the category 'Built environment'. It can be observed that most of the projects relate to the expansion and heat sources of (existing) heat networks. It is remarkable that there are no Green Deals related to heat pumps. Many parties are involved in the planning, preparation, construction, and sustainability of heat networks. Conversely, in case of adoption of heat pumps in the built environment the initiative/incentive more often lies with individual parties (some references to heat pump projects are included in Appendix A).

Below bullet points address some of the green deals. The full overview can be found in Table 2.

- **GD120** concerns the sustainability of the heat network in Purmerend. In 2015, the main heat source of the heat network was changed from gas-fired boiler to a biomass heat plant. This means that more than 80% of the heat supply is now coming from renewable sources (with only a small share supplied by two gas-fired back up boilers and heat buffers) (SVP, 2018). The biomass is collected from regular maintenance of the forests owned by Staatsbosbeheer. The completion of this Green Deal contributed to the sustainability of heat supply in Purmerend. Currently more than 60,000 dwellings (75% of the dwellings in Purmerend) are supplied by the heat network. In 2014-2015 almost 1 PJ of heat was supplied.
- In Gelderland, there are currently two large scale heat networks supplying heat from waste-to-energy plants to consumers. In 2014 the networks in Arnhem and Duiven-Westvoort were connected (ECN, 2017). The other heat network is located in Nijmegen. The heating network in Nijmegen was opened in 2015 as a result of **GD130**. More than 3,700 homes in the Waalsprong were connected to this network by then. This heat network has potential for expansion. The aim was to ultimately supply 14,000 homes with residual heat. When the deal ended the ambition was to connect 22,000 homes or even 30,000 by 2030. There have been further investigations on whether the heating network can be connected to the Arnhem network. Partly due to the development of the Nijmegen heating network and the northern connection, an expansion of the heating network to 70,000 homes could be possible in the region in the long term.
- The municipality of Amsterdam was involved in a Green Deal with waste-to-energy company AEB (Afval Energie Bedrijf) Amsterdam. One of the objectives was to expand the heat network in order to be able to utilise heat from the waste-to-energy plant (**GD046**). Back in 2011, the goal was to connect 4,000 home equivalents per year to the heating network leading to 50-80% CO_2 reduction per residential connection. The distribution network had grown from 680 connections in 2009 to almost 10,000 connections in 2015 and supplied 0.6 PJ heat (ECN, 2017). The municipality of Amsterdam still has a large ambition to make the city's heat supply more sustainable, by means of expanding the heat networks and coupling residual and sustainable heat sources. Westpoort Warmte is a collaboration between Nuon Warmte and AEB Amsterdam. The joint venture supplies residual heat from AEB to homes and businesses in Amsterdam West port, Nieuw-West, Houthaven and Noord. In 2016, Westpoort Warmte had more than 22,000 connected home equivalents. This number is expected to rise to over 60,000 in 2030 (AEB, 2016).

- The development of the AEB heat network has to be seen in the light of the regional ongoing developments related to heat networks located in the metropolitan region Amsterdam - Zuid Holland. The aim of the Green Deal (**GD192**) is to promote the demand for collective sustainable heat and cold. In the metropolitan areas of Rotterdam and Amsterdam, the utilisation of residual heat to provide homes is the focus of attention. In addition, there are ongoing efforts to make the heat sources more sustainable. The densely populated areas offer opportunities to expand existing heating networks and build new ones.

  The parties focus on four themes:
  - Focus on the customer. Parties develop new market propositions.
  - Increasing the financing possibilities of projects.
  - Connecting parties. By, among other things, mapping out supply and demand.
  - Increasing awareness, knowledge and innovative strength.
- In Brabant, the Green Deal (**GD201**) focuses on the attractiveness of geothermal investments. This Green Deal started in 2016 and is ongoing. By joining forces in five projects and sharing knowledge and expertise, the parties want to achieve economies of scale. These projects go by the name 'Geothermie Brabant B.V.'. The projects will provide in total 20,000 homes, 3 production companies and several greenhouse growers with heat. This is expected to result in a CO_2 saving of 135,000 tons. Step by step, Tilburg-Noord (heat supply to industry) and then Lieshout (heat supply to Bavaria), Helmond (heat supply to the existing district heating network and greenhouse horticulture company Van Gog), Asten/Someren (heat supply to glass and horticulture) and Amernet (heat supply to the existing heating network Amercentrale) will be provided with geothermal heat. Parties in this Green Deal have the following goals:
  - Realize economies of scale through the bundling of five geothermal projects;
  - Improving funding for geothermal projects;
  - Gaining knowledge in the field of technical implementation, spatial integration, exploitation and supervision of geothermal projects;
  - Monitor the applicability and effects of geothermal energy on the subsoil.
- In Hengelo a transport pipeline for industrial waste heat was connected to the existing heat network (**GD202**). The company AkzoNobel has approximately 3 PJ of low temperature waste heat available, of which 0.5 PJ can be used in the short term. To use this heat, the heat network in Hengelo is connected to AkzoNobel via a 'backbone', which is extended to the HTSP Campus. As a result, the Hengelo Heat Network realises CO_2 savings of 2,500 tonnes per year with a potential growth to 5,000 tonnes or more, comparable to the energy consumption of 1,550 to 3,100 households.
  What is special is that the heat that AkzoNobel delivers has a temperature of about 40 degrees Celsius. Therefore, a low-temperature heat network is chosen for the Hengelo Heat Network; decentralized heat (temperature) upgrade installations are installed. A description of the roles for each of the stakeholders is given in the Green Deal summary document.

Table 2: List of Green Deals most relevant to heat supply in the built environment

Green Deal Name/Number	Sector(s) involved	Parties involved	Heat Technology/Heat resource	Main focus/type of Green Deal	Start year	Status	Results
Natural gas-free neighborhoods (GD212)	Built environment	31 municipalities, 5 network operators, IPO, NBNL, VNG, National government See complete overview here:	Various	The parties will accelerate the development of gas-free neighbourhoods and provide input for adjusting the conditions regarding: – legislation; – financing constructions; – responsibilities and powers; – planning and direction of adjustments; – public support and ownership for the intended changes	2017	In progress (End date 31 Dec 2018)	Ongoing
Geothermal Brabant; joining forces and knowledge development (GD201)	Built environment (but also Horticulture, Industry, Energy sector)	- Municipality of Tilburg - Municipality of Helmond - Municipality of Breda - Someren Municipality - Province of North Brabant - Brabant Water - Energy Fund Brabant - GeoMEC - Agristo - Bavaria - Ennatuurlijk - Vlisco - Van Gog - Woonpartners - Citizens' initiative Helmond - CDER - Government	Geothermal, Heat networks	By joining forces in five projects and sharing knowledge and expertise, the parties want to achieve economies of scale. The projects bear the name 'Geothermie Brabant B.V.' Together the projects will provide 20,000 homes, 3 production companies and several greenhouse growers with warmth. Usually, initiatives in this area are private, which makes it difficult to get financing and it is difficult to bring both the level of knowledge and the economic potential to a higher level. The joining of forces should, among other things, lead to improved financinal support for geothermal projects, because the yield varies per project; the risk is spread by bundling.	2016	In progress (End date: 31 December 2024)	Ongoing

Green Deal Name/Number	Sector(s) involved	Parties involved	Heat Technology/Heat resource	Main focus/type of Green Deal	Start year	Status	Results
Sustainable heat Deventer Keizerslanden (GD089)	Built environment	Essent NV (part of RWE), municipality of Deventer, Housing Corporation Ieder 1	Biomass/biogas combustion CHP	It concerns realising a sustainable heat network for the district (around 1000 houses). Essent (the heating network operator) investigates a boiler house to produce heat and electricity. Essent plans to use biogas and woody biomass as feedstock. In the future, they intend to connect the boiler house to the biogas hub and use regionally produced biogas.	2012	Finished January 2015	This Green Deal has long been finished. At the end of the deal the conditions needed to make the heat network more sustainable have been investigated.
District heating 2.0 (GD120)	Built environment	District heating Purmerend (SVP), Staatsbosbeheer, municipality of Purmerend, province of Noord Holland and the Ministry of Economic Affairs, Agriculture and Innovation	Biomass-heat plant	Making the heat production for Purmerend's district heating network more sustainable by using a biomass-heat plant using biomass (turned into woodchips) collected from the forests owned by Staatsbosbeheer	2012	Completed May 2015	Completed, about 75% of the dwellings in Purmerend is now supplied with heat from the biomass heat plant.
Promote demand for sustainable heat and cold in metropolitan region Amsterdam and South Holland (GD192)	Built environment	Province of North Holland; Municipality Amsterdam; AEB Amsterdam; Stichting Economic Board Amsterdam; Province of South-Holland; Central government	Residual heat use	Promote demand for sustainable heat and cold: – Focus on the customer. Parties develop new market propositions. – Increasing the finance possibilities of projects. – Connecting parties. By, among other things, mapping out supply and demand. – Increasing awareness, knowledge and innovative strength. Because of this they want to strengthen the image.	2015	In progress	Ongoing
Municipality of Amsterdam (GD046)	Built environment (also ICT, Transport, Energy sector)	City of Amsterdam, Foundation Green IT Region Amsterdam, platform Amsterdam Smart City, Westpoort Warmte. Government: Ministry of Economic Affairs, Agriculture & Innovation, Ministry of Infrastructure & the Environment	Waste heat from the waste incinerator of AEB, Heat network (amongst the various projects)	Various sustainability projects are mentioned, one of which is the connection of more dwellings to the AEB heat network.	2011	Completed May 2015	The current heat network of AEB is already much larger than the 4,000 dwelling equivalents as mentioned in the Green Deal description, which is caused by follow up developments after the Green Deal was completed.

Green Deal Name/Number	Sector(s) involved	Parties involved	Heat Technology/Heat resource	Main focus/type of Green Deal	Start year	Status	Results
		and Ministry of the Interior & Kingdom Relations					
Bio-CHP and residual heat utilisation (GD023)	Built environment	Jaap Eden Ice rinks in Amsterdam East, Eneco, consultancy firm Deerns, housing corporations De Key and Rochdale and the municipality of Amsterdam (District East and project bureau Zuidoostlob). Central government: Ministry of Economic Affairs, Agriculture & Innovation, Ministry of Infrastructure & the Environment and Ministry of the Interior & Kingdom Relations	Residual heat from ice-skating rinks	Construction of a heat infrastructure to supply heat from the ice rinks to nearby housing corporations	2011	Finished, project not realised	Five different concepts for the technical installations were examined in a feasibility study. The resulting business case analysis was not considered attractive enough so the residual heat project was not realized.
Nijmegen (GD130)	Built environment, Energy and waste sector	Municipality Nijmegen, Alliander, Waste-to-energy plant ARN, Nuon Heat, Province of Gelderland	Waste-to-energy, Heat network	Expand an existing heat network and use sustainable heat	2012	Completed March 2015	More than 3,700 dwelling are already connected to the network, there is an ambition to connect 14,000 dwellings.
Hengelo heat network: 'backbone' and HTSP campus (GD202)	Built environment, Industry	-Province of Overijssel -Municipality of Hengelo -Alliander -AkzoNobel -HTSP -Fudura -National government	Low temperature residual heat	The company AkzoNobel has approximately 3 PJ of sustainable low temperature heat, of which 0.5 PJ can be used in the short term. To use this heat, the heat network in Hengelo is connected to AKZO / Nobel via a 'backbone', which is extended to the HTSP Campus.	2016	In progress (End date: 31 December 2018)	Realised.

2.5 Green Deal - Provinces

Table 3 presents the Green Deals at the provincial level. These Green Deals often have a lot of general sustainability targets. Residual and sustainable heat supply through heat networks is an important aspect in achieving these targets.

The summary below address some of the Green Deals. The full overview is presented in Table 3.

- The Green Deal Province of Limburg (**GD051**) consists of seven projects that contribute to the future sustainability of Limburg. Two projects are directly related to the heat sector. One of them focuses on residual and sustainable heat supply to 30,000 homes and businesses by means of constructing an infrastructure network, so called “Het Groene Net”. The second one is the residual heat network Maastricht. This project is continuing and the heat networks are being realized after some delays. Selected partners pulled out of the project and new partners had to be found.
- The Green Deal with the Province of South-Holland (**GD055**) had very wide-range ambitions. An important aim was to provide extra impetus to the sustainability of the heat and cold supply in the province. The objectives were to define strategies for making heat supply more sustainable, realise a new heat network and increase the sustainability of existing heat networks by use of residual heat and geothermal heat. The ambition for sustainable heat in the southern Randstad was set to 20 PJ in 2020. The feasibility study has shown that the residual heat and geothermal potential in this region is substantial. The yearly heat cooled down in the Rotterdam harbour is mentioned to be around 12% of the annual gas consumption of the Netherlands. With residual heat and geothermal potential the southern Randstad can have a 'heat supply (‘warmte voorraad’) of 40 to 60 PJ. This is equal to 50-75% of the heat demand in the southern Randstad (Verkennend onderzoek warmterotonde, 2015).
- Heat sector related activities in the Province of Overijssel (**GD053**) Green Deal consisted of: i) expansion of geothermal heat supply in the horticultural area Koekoekspolder from 4,5 MW_{th} to above 5 MW_{th} by connecting new companies and cooling the water back to 20^{o}C, and ii) the heating network in Enschede and the heat supply in Grolschveste to be connected to the residual heat connection in Twente. The drilling in the Koekoekspolder has been successful and plans were being made for more geothermal projects in the area. In addition, a waste company (Twence) successfully provides residual heat to Enschede and to Akzo, which in turn provides low temperature residual heat to the heat network of Hengelo. These projects were completed after the finalization of the Green Deal period. This deal can be a national example of ‘heat cascading’ by constructing a low-temperature heating network that uses industrial (sustainable) residual heat. The Hengelo heat network is connected via a 'backbone' to HTSP campus (see **GD202)**.
- In the Province of Zeeland (**GD054**) the aim of the Green Deal was to utilize residual heat from industry and transport it to other industrial consumers via heat networks. Moreover, a pilot on mobile heat utilisation in which heat is transported by tanker vehicle from supplier to customer was investigated. It was not feasible to connect all companies on a large scale or to use the residual heat for homes. However, smaller scale connections appeared feasible. Within this deal the

national government investigated whether and how CO_2 rights can be set off for projects where a link is made between an ETS company and a non-ETS company and where the savings takes place at the non-ETS company.

- Finally, Deals Pilot Regions (**GD206**) was initiated in 2016. As a result of this deal the programme Regional Energy Strategies has been initiated. This program included 5 pilot regions. Next to that two other regions received support within this program. The goal of the learning network is that regions can watch each other, exchange experiences and develop energy strategies themselves. For each region an energy strategy about the current and 2050 energy demand and renewable energy supply is presented (Regional energy transition, 2018).

Table 3: List of Green Deals most relevant to heat supply within provinces

Green Deal name/Number	Sector(s) involved	Parties involved	Heat Technology	Main focus/type of Green Deal	Start year	Status	Results
Deal Pilots Regional Energy strategy (GD206)	Region Friesland, Noord Veluwe, Midden Holland, Drechtstede, West Brabant, Hart vn Brabant, Region Eindhoven	Association of Dutch Municipalities (VNG), The Interprovincial Consultations (IPO), the Union of Water Boards (UvW), Central government	No specific info	Develop and supervise regional energy strategies with concrete projects in the short term and to define longer term visions	2016	Ongoing (End datum mentioned as 1 October 2017)	For each region an energy strategy about the current and 2050 energy demand and renewable energy supply is presented.
Province of Limburg (GD051)	Province of Limburg, companies in the region	Province of Limburg and several municipalities and companies, including the Chemelot business parks (Sittard-Geleen) and De Beitel (Heerlen), engineering firm Imtech and the Healthcare real estate sector. Government: Ministry of Economic Affairs, Agriculture & Innovation, Ministry of Infrastructure & the Environment and the Ministry of the Interior and Kingdom Relations.	Heat networks, Residual heat	Constructing an infrastructure network, so called “Het Groene Net’ and another Residual heat network Maastricht	2011	In progress	Ongoing project. The heat networks are still being realised after some delays.
Province of Overijssel (GD053)	Province of Overijssel, companies in the region	Province of Overijssel, many companies and the government	Geothermal (deep)	Expansion of geothermal heat supply in horticultural area Koekoekspolder by connecting new companies and cooling the water	2011	Finished in 2015	These projects were completed after the completion of the Green Deal period.
Province of Zeeland (GD054)	Province of Zeeland and Industries	Province of Zeeland, Zeeland Seaports. Central government: Ministry of Economic Affairs, Agriculture & Innovation and Ministry of Infrastructure & Environment.	Heat networks (residual heat coupling)	Utilize residual heat from industry and transport it to other industrial consumers via heat networks. Next to that a pilot on mobile heat utilisation, in which heat is transported by tanker vehicle from supplier to customer was investigated.	2011	Finished January 2016	It appears not feasible to connect all companies on a large scale or to use the residual heat for homes. What is quite possible is to connect companies on a small scale in order to use each other's residual heat. with the business cases that were most promising.
Province of South-Holland (GD055)	Municipalities, energy companies, banks and greenhouse horticulture sector	E.ON Benelux Holding BV, Eneco Holding NV, Flora Holland, Gemeente Delft, Gemeente Pijnacker-Nootdorp, Gemeente Zoetermeer, HVC Groep, LTO Nederland, NV Nuon Energy, OCAP CO2 BV, Platform Geothermie, Provincie Zuid-Holland, RCI Rotterdam Climate Initiative, Stadsgewest Haaglanden, Warmtebedrijf Eneco Delft, Warmtebedrijf Rotterdam	Residual heat and geothermal	Define strategies for making heat supply more sustainable, realise a new heat network and increase the sustainability of existing heat networks by use of residual heat and geothermal heat.	2011	Finalised in 2013	A feasibility study defining strategies was prepared.

3 Main challenges and the success factors

The assessed cases highlight a number of aspects that may make the Green Deal a success or cause delays in the process and may eventually result in abandoning the project. These can be summarised as follows:

- Heat source availability, distance to the demand centres and the existence of the necessary infrastructure
- Financial feasibility (business case)
- Bottlenecks related to regulations and legislations
- Knowledge (e.g. technical, infrastructure, geological etc.)
- Good partnership and commitment.

The availability of heat sources near demand centres and availability of the necessary infrastructure is key for successful implementation of projects. In case of the Purmerend heat network, biomass from nearby forests was available for use in a biomass heating plant. A heat network (previously with heat from a natural gas fired installation) was also present. For the existing heat networks in Amsterdam and Nijmegen a waste incinerator was available as steady heat source.

A large number of projects focus on application of residual heat, which in many cases requires complex and costly heat infrastructure. These projects were mostly not financially feasible and therefore were not implemented in the short term (e.g. in Limburg and Zeeland). The business case improves when heat producers and consumers are densely clustered together. Connecting companies on a small scale, using each other's residual heat, has been proven to be more feasible on the short term. **GD053**, expansion of geothermal heat supply in the horticulture area and **GD202,** connection the heat network in Hengelo to AKZO/Nobel, are good examples of this. **GD054**, the province of Zeeland, also acknowledges connecting companies on a small scale to use each other’s residual heat as the most promising business case.

Initial research and feasibility studies are often (partially) financed by the government. The government also brings actors together with financial parties. However, financing a project can be challenging. In some cases new solutions were investigated, for instance in Brabant jointly investing in geothermal wells to realise economies of scale and to spread the related risks was looked into (**GD201**). The availability of governmental subsidies certainly plays an important role in making the business cases more attractive. For instance, the Green Deal focusing on wastewater treatment plants to produce energy has been very successful (partly) thanks to SDE+ subsidy.

In some cases existing regulations and legislations can hamper the development and deployment of sustainable heat. For instance, the current obligation to connect new buildings to the gas grid has been highlighted as an obstacle in the Green Deal with the province of Limburg (**GD051**). Starting mid-2018, this obligation will not be in place anymore; home owners will have possibilities to opt for alternative heating options. Another regulatory obstacle relates to the difficulties in obtaining different sorts of licensing and permits. Examples are as follows:

- A permit is required for higher temperature (underground) storage (HTS) above 30ºC. Within the current regulations and the design decision Soil Energy Systems

for temporal storage of hot water in aquifers in the subsurface to 500 m deep, the maximum temperature is 25°C. Due to the absence of a permit for an ATES De Meerlanden Green Deal (**GD010**) was forced to opt for a different project. Kopper Kress Green Deal also had to adapt their project design and consider two extra steps.

- In case of using own company biogenic waste (i.e. champost in **GD027**) - to produce energy - clarifications were needed regarding the legislation and regulations in the area of waste, permitted emissions and fertilizers. The packaging and pallet industry also highlighted the environmental permits to burn their own residual wood as a burden in **GD067**.
- Another interesting example relates to the CO_2 rights. Clarifications were needed on how CO_2 rights can be set off for projects where the heat is supplied from a company under the ETS to a non-ETS company.

As for deep geothermal drilling, the absence of sufficient geological knowledge has resulted in abandoning projects. Thanks to some of the geothermal related Green Deals parties are working together to increase knowledge about deep geothermal energy in the Netherlands.

- In the Green Deal Geo Oudcamp (**GD017**) eight horticulture companies have initiated a geothermal project. In 2016 the drilling was not realised due to insufficient knowledge about the deep surface. Currently the geothermal heat project is in the realization phase. The drilling site has been constructed and the drilling tower will be built in June 2018. Once the derrick has been built up the two wells will be drilled, after which the above-ground installations and heat network can be constructed.
- The Green Deal about ultra-deep geothermal (**GD217**) pointed out there is possibly insufficient flow and temperatures at these depths. Geological risk is based on the unfamiliarity with the underground deeper than 4,000 meters. Also, higher temperature and pressure regimes occur at these depths (currently unknown). These conditions are expected to require innovations in a.o. well design, stimulation concepts and measurement and monitoring programs.

Finally, a good partnership and commitment of all parties are important prerequisites for a successful project. It has to be clear to all parties what their roles and responsibilities are and this needs to be communicated (e.g. **GD010**). The government can take a guiding role in this.

4 Conclusions and lessons learned

This assessment highlights the large diversity of Green Deal projects with regard to sectors involved, technologies and heat sources used. In most of the projects multiple sectors are involved and heat can either be exchanged among parties in the same sector, or exchanged among different sectors. Sectors, here, refer to industry, horticulture and the built environment. The main heat sources/fuels included in the Green Deals are green gas, biogas (e.g. from fermentation of biogenic residues from own processes), use of biomass and/or waste streams in CHP/power plants or heat installations, (deep) geothermal, aquifer thermal storage (ATES), and use of residual heat from industrial processes.

Green Deals are also diverse when it comes to the main objectives. A number of projects focus on knowledge building on certain technologies by bundling expertise on a certain technology (e.g. geothermal, biomass gasification, or aquifer heat storage). Other projects investigate business cases through feasibility studies, and in some cases implement them. Other projects look for ways to improve the financing.

Given the very diverse nature of Green Deals it is not possible to draw concrete conclusions and lessons learned for sustainable heat supply in the Netherlands in general. Nevertheless, this study finds the main determinants to the successful implementation of a Green Deal, which can be summed up as follows:

- The feasibility of business cases is determined by three main factors: resource availability, distance to the demand centres and the existence of the necessary infrastructure. Whether a project can be successful or not depends on the local circumstances.
- Sufficient technical knowledge and knowledge about infrastructure (e.g. heat transport and residual heat infrastructure) is essential to implement sustainable heat projects. Sufficient geological knowledge about the (deep) subsurface is required in case of geothermal projects otherwise this could become a barrier for implementation.
- Finding (improved) ways of financing and the availability of governmental subsidies play an important role in making the business case more attractive.
- Clarity on legislation and/or regulations and ease of permit regulation when it comes to small scale renewable heat generation and supply is necessary. For example, permit regulation for thermal energy storage in the subsoil. Or, in case of use of own biogenic waste, clarifications are needed regarding the legislation and regulations in the area of waste, emission allowances and fertilizers.
- Generation and supply of sustainable heat to consumers can be very challenging. A number of projects were not completed because it was not sufficiently clear to all parties what their exact roles and responsibilities were. The commitment from all Green Deal parties is a prerequisite for the successful completion of a Green Deal.

The heat infrastructure is often costly. The decision is often made based on the availability of a local heat source and existing infrastructure in combination with the outcome of a feasibility study including a cost-benefit analysis. While large scale heat networks can allow a large number of consumers to have access to heat that has been produced from a number of sustainable sources, a number of Green Deals analysed in this study indicate that small scale projects (e.g. residual heat projects)

are often more feasible on the short term. This brings up the importance of mapping potential heat sources as well as possible consumers in order to set long term heat strategies. Matching heat sources and heat consumers and thereby taking into account the right temperature levels is necessary for determining long term heat strategies and defining the business cases.

5 Bibliography

AEB. (2016). *AEB*. Retrieved from http://www.aebamsterdam.nl/over-aeb/nieuws/2016/amsterdam-zet-in-op-warmtenetten/

CBS. (2017). *Hernieuwbare Energie in Nederland.*

ECN. (2017). *Monitoring Warmte 2015.*

ECN MONIT (2017). *National Energy Outlook database.*

EY. (2016). *Rapport RVO Onderzoek - Institutionele Belemmeringen Lage Temperatuur.* Retrieved from https://topsectorenergie.nl/sites/default/files/uploads/Systeemintegratie/Rapport%20deelstudie%20institutionele%20belemmeringen%20%20Lage%20temperatuurwarmte%20(EY).pdf

Green Deals. (2018). *Green Deal site (Green Deal texts, summarizing documents and final reports)*. Retrieved from https://www.greendeals.nl/green-deals

Greendeals/Energie in Beeld 2011-2015. (2018). *Greendeals/Energie in Beeld 2011-2015*. Retrieved from Greendeals/Energie in Beeld 2011-2015: http://www.greendeals.nl/wp-content/uploads/2015/06/89461_Energie_NED.pdf

PBL. (2017). *Verkenning van klimaatdoelen van lange termijnbeelden naar korte termijn actie.* Retrieved from www.pbl.nl/sites/default/files/cms/publicaties/pbl-2017-verkenning-van-klimaatdoelen-van-lange-termijnbeelden-naar-korte-termijn-actie-2966.pdf

Resultaten verkennend onderzoek warmterotonde. (2015). *Verkennend onderzoek warmterotonde cluster west.* Retrieved from https://www.greendeals.nl/wp-content/uploads/2015/04/Resultaten-verkennend-onderzoek-warmterotonde-cluster-west.pdf

Rijksoverheid. (2018). *Green deal aanpak*. Retrieved from Green deal aanpak: https://www.rijksoverheid.nl/onderwerpen/duurzame-economie/green-deal

RVO. (2015). *Overzicht duurzame energietechnieken en restwarmteuitwisseling voor de industrie.* Retrieved from https://www.rvo.nl/sites/default/files/2016/03/140220-01%20RVO_Overzicht%20DEenRW_04.pdf

SVP. (2018). *Stadsverwarming Purmerend*. Retrieved from www.stadsverwarmingpurmerend.nl

Trias Westland. (2018). *Tweede productietest bevestigt: uitstekend reservoir*. Retrieved from https://www.triaswestland.nl/nieuws/tweede-productietest-bevestigt-uitstekend-reservoir.

Appendix A: Sample projects

In this appendix an inventory of selected sample projects related to sustainable heat is provided. This overview is limited to a quick scan of available information sources. The inventory is shown in Table 4. It contains projects that are both finished and ongoing.

The project ‘Green well Westland’ is an example of a successful geothermal project. After some initial technical difficulties a geothermal well with a capacity of 10MW_{th} was realized. The extracted geothermal heat is already applied at 8 horticulture companies. Due to the successful course of the project, the connection of a number of additional horticultural businesses will be investigated.

The list also includes projects about heat pumps. An example is a new heat pump on the roof at high school Piter Jelles, located in Leeuwarden. Previously, the heating was provided by two central heating boilers. A feasibility study showed that heat supply by a heat pump was the best solution in order to save a substantial amount of natural gas (50,000 m^3 per year). The investment was large to overcome at first but the board took this risk. It was estimated that the investment will be recouped in about five years. An important condition for the success of this project was the presence of concrete core activation in the building, which makes the building suitable for a heat pump.

More examples of heat pump projects can also be found in the Heat pump status report (2014). See chapter 8: Sample projects Heat pumps and heat and cold storage.

Table 4: List of sample projects

Project name	Sector(s) involved	Heat source(s)/technology	URL(s)
Heat Roundabout Zuid-Holland	All sectors	Various	https://warmopweg.nl/warmterotonde/ https://www.portofrotterdam.com/nl/havenkrant/havenkrant-editie-30/warmterotonde
Bio-energy plant now also supplies steam	Industry	Steam/Bio-energy plant	https://www.rvo.nl/actueel/praktijkverhalen/bio-energiecentrale-levert-nu-ook-stoom
Steam grid Delfzijl provides steam and heat	Industry	Residual heat/Steam/waste incinerator	https://www.rvo.nl/actueel/praktijkverhalen/stoomgrid-delfzijl-voorziet-stoom-en-warmte
Sample projects heat pumps in the industry	Industry	Industrial heat pump projects	https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/duurzame-energie-opwekken/nationaal-expertisecentrum-warmte/warmtepompen-industrie
Sample projects residual heat industry	Industry & built environment	Residual heat	https://www.rvo.nl/sites/default/files/bijlagen/Voorbeeldprojecten%20Restwarmte.pdf
Residual heat from Akzo warms homes and businesses	Industry & built environment	Residual heat	http://www.installatienet.nl/restwarmte-akzonobel-verwarmt-huizen-en-bedrijven-hengelo/
The “Green Network” (Het Groene Net)	Industry & built environment	Residual heat	http://www.hetgroenenet.nl/
Heating network Nijmegen	Industry & built environment	Residual heat/waste incinerator	http://co2-reductierapporten.nuon.com/nijmegen/waar-wordt-warmte-geleverd
Heat network Arnhem and Duiven Westervoort	Industry & built environment	Residual heat/waste incinerator	http://co2-reductierapporten.nuon.com/arnhem-duiven-en-westervoort/mijn-co2-besparing
AEB heat network in Amsterdam	Industry & built environment	Residual heat	http://www.aebamsterdam.nl/over-aeb/nieuws/2016/amsterdam-zet-in-op-warmtenetten/
Sample projects residual heat	Industry & built environment	Various, mostly residual heat projects	https://www.rvo.nl/sites/default/files/bijlagen/Voorbeeldprojecten%20Restwarmte.pdf
Biomass heat network Purmerend (Green Deal 120)	Built environment	Bio-energy plant	https://www.stadsverwarmingpurmerend.nl/over-warmte/

Project name	Sector(s) involved	Heat source(s)/technology	URL(s)
Delft wants to link the heating network to geothermal energy	Built environment	Geothermal	https://www.rvo.nl/actueel/nieuws/delft-wil-warmtenet-koppelen-aan-aardwarmte
Housing corporation combines hybrid heat pump with green gas	Built environment	Green gas	https://groengas.nl/nieuws/woningcorporatie-combineert-hybride-warmtepomp-met-groen-gas/
Boilers replaced by heat pump at De Brêge / De Dyk	Built environment	Heat pump	https://www.greendealscholen.nl/praktijkervaringen/piter-jelles-vervangt-cv-door-warmtepomp http://www.hij5.nl/tag/de-dyk/
Sample projects heat pumps and heat and cold storage	Built environment	Heat pump/ATES projects	https://www.rvo.nl/sites/default/files/2014/11/Definitief_Statusrapportage%20Warmtepompen.pdf
Camping village de Zandstuve invests heavily in sustainability	Built environment	Heat pumps and solar collectors	https://www.rvo.nl/actueel/praktijkverhalen/kampeerdorp-de-zandstuve-investeert-fors-duurzaamheid
Amsterdam student association closes gas tap	Built environment	Heat pumps	https://www.duurzaamgebouwd.nl/projecten/20170522-amsterdamse-studentenvereniging-sluit-gaskraan
The Edge Amsterdam (head office of Deloitte / AKD) - energy-neutral	Built environment	ATES	https://www.breeam.nl/projecten/edge-amsterdam-0
Zeeland Seaports	Horticulture	Residual heat	https://www.zeelandseaports.nl/nl/het-havenbedrijf/projecten-en-samenwerking/glastuinbouw.htm
Green Well Westland	Horticulture	Geothermal	https://www.rvo.nl/subsidies-regelingen/projecten/green-well-westland https://www.rvo.nl/sites/default/files/rvo_website_content/SE/GreenwellWest/OpenbareindrapportGreenWellWestland.pdf
Greenhouse horticulture supplies geothermal energy to homes	Horticulture	Geothermal	https://www.rvo.nl/actueel/praktijkverhalen/glastuinbouw-levert-aardwarmte-aan-woningen