Interreg North-West Europe D2Grids

European Regional Development Fund

WORK PACKAGE: WPLT

DELIVERABLE NUMBER: DEL.1.3

PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN 7 FOLLOWER REGIONS

EAST MIDLANDS

DOCUMENT STATUS: FIRST DRAFT

October 24th, 2022

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Data sources:

Report done by: Nordic Energy

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1. Introduction

Activities in the Long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories ("follower regions"). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. The regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology is carried in this deliverable for each of the 7 follower regions defined for this project, namely: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project, has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

UK Context

"The UK was the first major economy to create a legally binding target to bring greenhouse gas emissions to net zero by 2050. This target was set considering the latest scientific evidence and was recommended by the Climate Change Committee (CCC), the UK's independent climate advisory body. The net zero target also responds to the overwhelming public support for acting on climate change. In recent surveys of the UK public, 80% of participants expressed concern about climate change."

UK National Policy References

- HM Government, Industrial Strategy
- HM Government, The Clean Growth Strategy: Leading the way to a low carbon future
- Ten Point Plan for a Green Industrial Revolution (2020)
- Net Zero Strategy – Build Back Greener (2021).
- Energy Security Bill (including provision for Heat Network Zoning)

Key policies:

- An ambition that by 2035, no new gas boilers will be sold.
- A new £450 million three-year Boiler Upgrade Scheme will see households offered
- grants of up to £5,000 for low-carbon heating systems so they cost the same as a gas boiler now.
- A new £60 million Heat Pump Ready programme that will provide funding for pioneering heat pump technologies and will support the government's target of 600,000 installations a year by 2028.
- Delivering cheaper electricity by rebalancing of policy costs from electricity bills to gas bills this decade
- Further funding for the Social Housing Decarbonisation Scheme and Home Upgrade Grants, investing £1.75 billion. Additional funding of £1.425 billion for Public Sector Decarbonisation, with the aim of reducing emissions from public sector buildings by 75% by 2037.

- Launching a Hydrogen Village trial to inform a decision on the role of hydrogen in the heating system by 2026

Heat networks – policy statement

"Under the £338 million Heat Network Transformation Programme, we will launch the £270 million Green Heat Network Fund to grow the market for low carbon heat networks. We will also pass new legislation to regulate the sector for consumers, give heat networks the statutory powers they need to build, and regulate the carbon emissions of projects from the early 2030s. We will also deliver new heat networks zones in England by 2025 where heat networks are the default solution for decarbonising heating. Finally, we will work with industry to increase the capacity and capability of the UK supply chain to support the sector to reach its growth potential and look to improve performance of legacy networks through the Heat Network Efficiency Scheme." P145

Heat Pumps – policy statement

"We will grow the UK heat pump market to support 600,000 installations per year by 2028. As part of this, and working with industry to do so, we will aim for cost parity between heat pumps and gas boilers by 2030 with significant cost reductions of at least 25-50% by 2025. To achieve this, we will introduce a range of new policies to support heat pump deployment, including a new £450 million Boiler Upgrade Scheme over 2022/23 to 2024/25 with grants of £5,000 for an air source heat pump." P145

2. Characterising the region

East Midlands Region – UK

The East Midlands is one of nine designated regions of England (see map below). It consists of the counties of:

- Derbyshire
- Leicstershire
- Nottinghamshire
- Lincolnshire
- Rutland
- Northamptonshire

Figure 1. East Midlands Region

The Region includes the major cities of;

- Nottingham
- Derby
- Leicester
- Mansfield
- Northampton
- Lincoln

There is **no** East Midlands Region governing organisation.

Local government is provided by elected Councils. Larger cities are usually 'Unitary Authorities' meaning that they provide a single layer of local government, answerable directly to Parliament. Other areas typically consist of County Councils under which are District Councils, a double tier in which both have decision-making powers.

Local Enterprise Partnerships

Alongside elected Councils are Local Enterprise Partnerships. These are private sector run and have responsibility for regional economic development for a number of local councils; they are not elected but decision-making bodies include representation from elected Councillors.

The five LEPs in the East Midlands area are;

- D2N2 - Derby and Derbyshire, Nottingham and Nottinghamshire
- GLLEP – Greater Lincolnshire
- LLEP – Leicester and Leicestershire
- SEMLEP – South East Midlands
- GCGP – Greater Cambridge and Greater Peterborough

The Sheffield City Region LEP used to include parts of the East Midlands but a boundary change has resulted in these areas moving to D2N2.

UK LEP Regions

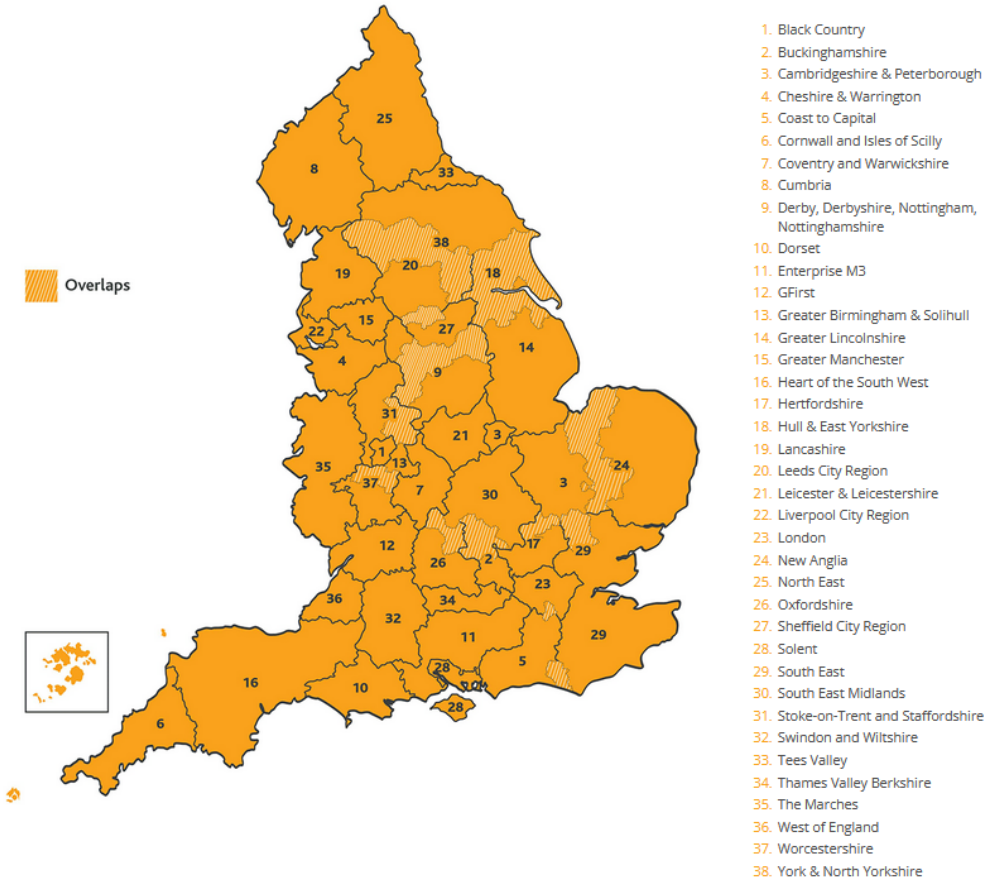

Figure 2. UK Local Enterprise Partnership (LEP) Regions

D2N2 LEP

D2N2 is the largest LEP area in the East Midlands Region and the fourth largest in England outside London. Encompassing Derby, Derbyshire, Nottingham and Nottinghamshire, it has a population of around 2.2 million and GVA of around £46 billion.

Economic scale and productivity

D2N2's total GVA is around £46 billion. This is equivalent to around £21,250 per capita – roughly 80% of the UK's per capita GVA figure. Across D2N2, GVA per head of population is strongest in Derby and Nottingham, where it is (in both cases) above the national average, reflecting both cities' functions as major centres of economic activity.

Productivity in D2N2 is about 12% below that of the UK overall, at around £28.60 per hour worked. This is broadly comparable with neighbouring LEP areas: the productivity deficit is a regional challenge, not just one for D2N2.

Reflecting its scale, the area is diverse, including the major urban centres of Nottingham and Derby (and their associated stock of commercial, educational and public sector assets), a number of significant sub-regional centres and areas of deep rurality and high environmental quality, including the Peak District National Park.

It enjoys generally good strategic connectivity via the Midland Mainline (rail) and the M1, A1 and A50, as well as via East Midlands and Doncaster Sheffield airports located just beyond its boundaries. Connectivity will be further improved following the completion of the High Speed 2 rail line (HS2) after 2030

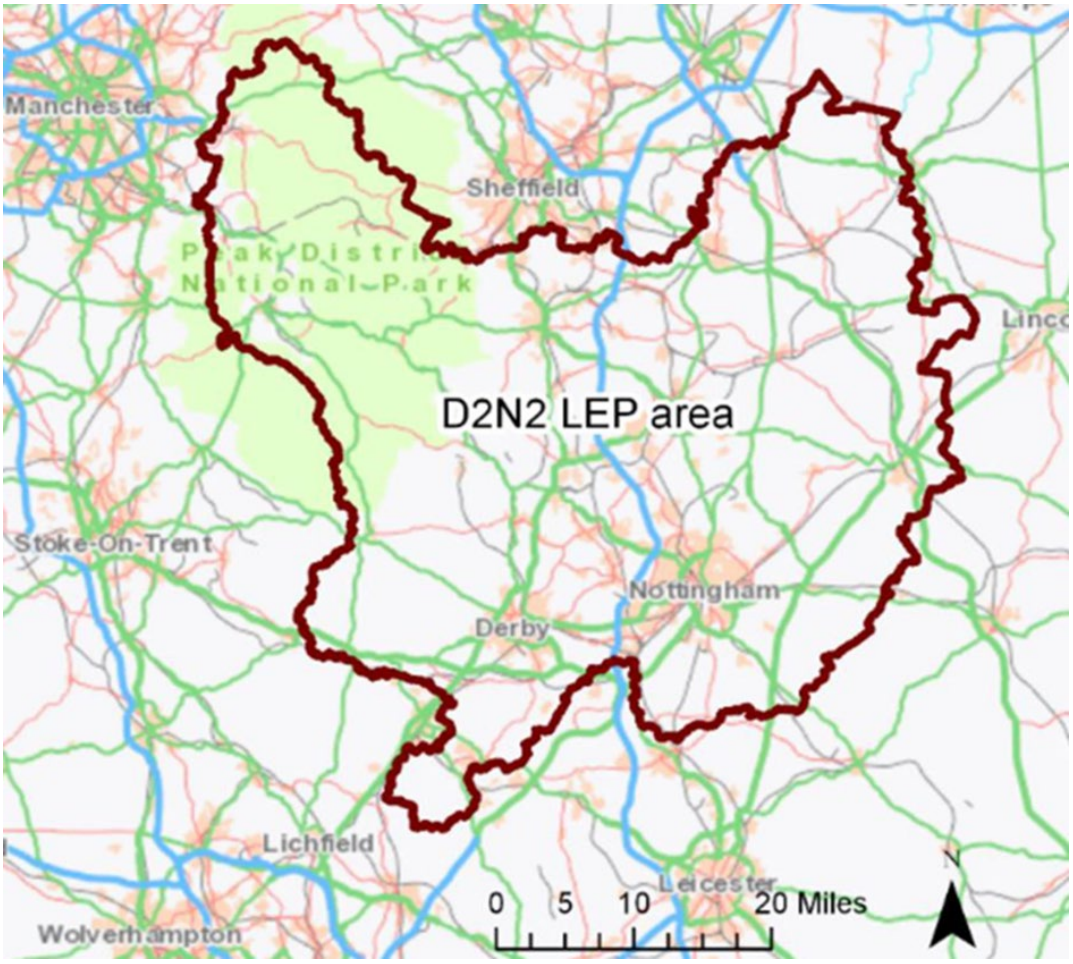

Figure 3. D2N2 LEP Region

Net Zero Hubs

In 2010 the UK government created a further layer by designating 5 'Energy Hubs' across the UK. More recently the Hubs have been renamed 'Net Zero Hubs' to reflect a broadening of their remit - to support and address critical net zero transition issues.

The East Midlands Region largely, but not completely, lies within the Midlands Energy Hub. The D2N2 LEP is within the Midlands Energy Hub.

The lack of precise alignment between the political and economic organisational layers can be an obstacle to the development of infrastructure projects.

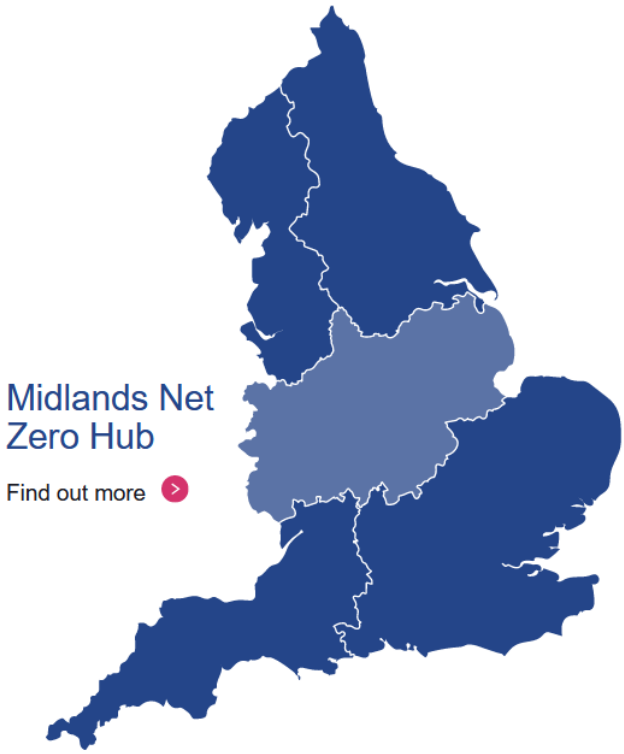

Figure 4. Midlands Net Zero Hub Region

To understand the opportunity for 5GDHC in the East Midlands we have developed an interactive model built on building level data and information such as energy consumption, EPC certificates and fuel types. This will be made available to public organisations and investors to assist in their technical and commercial evaluation of potential 5GDHC projects.

Geography

Most of the East Midlands region is relatively flat. The only higher ground is the South Pennine hills to the west.

Major rivers, that could provide significant 5GDHC opportunities are:

- Trent
- Nene
- Soar
- Welland

Much of the East Midlands region is situated above one of the UK's principle aquifers – map source – British Geological Survey (BGS) See below.

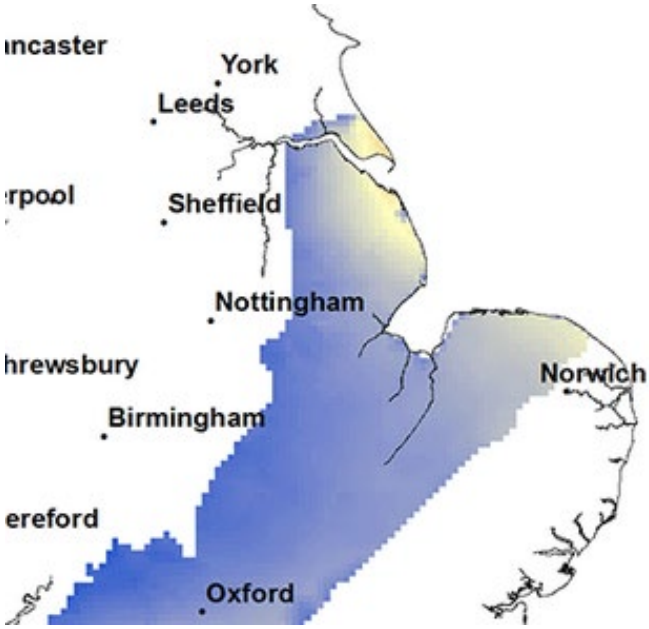

Figure 5. Aquifer below East Midlands Region

3. Analysis

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

The predominant heating fuel used in the UK is Natural Gas. Over 70% of the domestic, industry and service sectors are heated in this way. Electric Heating (both direct and heat pumps), non-gas fuels such as oil, solid fuel, bio-energy and waste make up the remaining 30%.

Remote areas are least likely to have a gas connection. Domestic connections in these areas make up the majority of the UK non-gas heating market.

Heat networks are estimated to deliver approximately 2% of overall heat demand nationally with expectation that this will rise to 20% by 2050. The East Midlands region is predominantly served by mains gas, historically this has been difficult to displace due to its low cost. Figure 6 shows the percentage of domestic buildings using particular heat sources in the East Midlands.

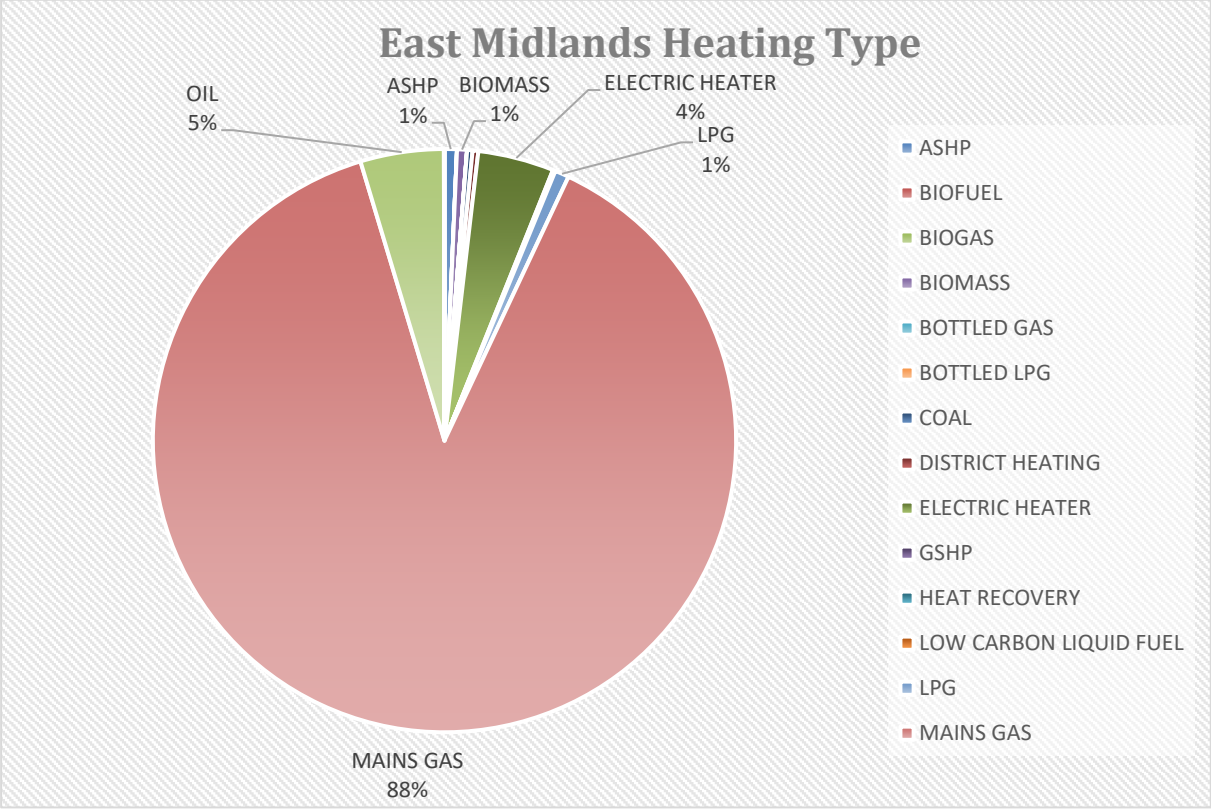

Figure 6. Heating Sources – East Midlands Buildings

3.1.2. Main Suppliers of energy for heating in the East Midlands

National Grid logo	The National grid is a public utility that is responsible for the transmission mains of both gas and electrical networks. It primarily deals with large scale power and gas transportation
Cadent	Responsible for smaller scale distribution of gas.
FCC	Operates erf that supplies heat to EM largest heat network
NCC	Operates the largest heat network in the UK, suppling ~5000 domestic dwellings and 100 commercial entities.
Western Power	Electricity distributed network operator, provides electrical infrastructure for electrical heating
Resellers	A Number of resellers who purchase electricity and gas for resale on the open market

3.1.3. Legal Framework

The Gas act 1989 (as amended) and the Electricity Act 1989 (as amended) prohibit certain activities unless the undertaking party are licensed, unless they are license exempt (which is typically bound by class acts) or, in the instance of the gas act, eligible for exception to the prohibition of licensed activities.

There are a set of licensed activities and industry codes that suppliers will need to sign up and adhere to.

For gas the following apply:

- Transmission
- Interconnector
- Shipper

- Supplier

For electricity the following apply

- Transmissions
- Offshore Transmission
- Interconnector
- Distribution
- Generation
- Supply

Heat networks are currently only regulated via the Heat Metering and Billing Regulations and health and safety legislation.

While heat networks remain largely unregulated in comparison with electricity and gas networks, the Competition and Markets Authority have advised that regulation should be introduced. This is currently in development – see details in section 4.1.5.

3.1.4. Competition in the market

Following the liberalisation of energy markets, customers remained with their regional supplier for electrictity and national supplier for gas. The intention was that customers would switch to save money and a competitive market would form.

Six major suppliers consolidated the market and switching fell below desired outcomes. The Competition and Markets Authority launched an investigation in 2014 and concluded that many customers were being charged on 'default' tariffs and therefore paying more than they should. The 'overcharging' was assessed to be in region of £1.4 Billion. This led to market reforms that improved tariff arrangements and delivered more value to consumers. A 'safeguard tariff cap' was introduced to prevent high 'default' tariffs.

The exit from Covid combined with Russia's invasion of Ukraine has led to a dramatic increase in wholesale gas prices. This has removed any competition in the electrical and gas markets as the UK government 'price cap' now delays the passing-on of new market pricing to domestic consumers. For the time being, switching tariffs would be disadvantageous for the consumer.

Heat networks are not covered by the government price cap and so networks that rely on gas have the potential to be considerably more expensive. In contrast, non-gas networks are currently in a favourable market position. For example, Nottingham's district heating network which primary fuel type is waste, is now able to deliver superb value energy to its customers.

3.1.5. Developments in heating policy and market contexts

The UK government created the Heat Network Development Unit (HNDU) to galvanise and support heat network growth. This scheme has enabled local authorities to spend approximately £30m on heat network project developments. into local authorities.

The funding is for feasibility studies and/or detailed project development that paves the way for construction financial support from the Green Heat Network Fund.

The Competition and Markets Authority has conducted an assessment of heat network operational practices in the UK and judged that the vast majority are typically charging consumers a fair market price. Those deemed to be overcharging were judged to be operating a poorly performing.

The UK has developed a code of practice for heat networks (CP1) to try to prevent poor operational practice. The Competition and Markets Authority recommended the sector should be regulated in line with other utility providers.

The Heat Network Market Framework is being developed to regulate heat networks with the primary goals of enabling sector growth whilst providing protections to consumers. The framework finished its consultation in February 2022.

In a major strategy development, the UK government has introduced legislation establishing heat network zones across the UK by 2025. Under the right technical, environmental and commercial conditions, this will mandate the connection of all buildings (except for individual homes) within designated zones to local heat networks and thereby significantly reduce the commercial risks currently faced by heat network developers.

3.2. Position of district heating

1.1.1. Regulation of district heating providers and 5GDHC

Heat networks in the England have only delivered heat to a small proportion of English dwellings. The heat network market remained unregulated until the introduction of the Heat Networks (Metering and Billing) Legislation in 2014. Its aims were to drive energy efficiency and reduce carbon emissions via a 3 stage process:

1. Heat Network Operators submit notifications of heat supply from their network to customers
2. Installation of Metering devices
3. Billing based on consumption

More legislation is expected to follow through the zoning programme and market framework. This regulation will also cover 5GDHC networks.

1.1.1. Ownership and operation of district heating systems

Heat networks within the UK are driven forward by a project sponsor and project operator. The relationship between them is governed by contractual and funding structures. The five most comment structures are:

- **3rd Party ESCo** – The project sponsor enters into an energy services agreement with a 3rd Party who will deliver the Heat network through an Energy Service Company (ESCo)
- **Concession** – The project sponsor forms a concencession agreement with a 3rd Party ESCo to deliver the Heat Network
- **Project Sponsor ESCo** – The Project Sponsor establishes a wholly owned ESCo to deliver the heat network
- **Joint Venture ESCo** – The Project Sponsor jointly establishes an ESCo with a Joint venture partner to deliver the heat network
- **In-House Delivery** – The Project Sponsor develops the heat network without establishing a stand-alone delivery vehicle. This is the operating model for the Nottingham District Heating Network.

1.1.2. Regulation of the price setting

The price setting for heat networks is not currently regulated. The Competition and Markets Authority has indicated that heat networks currently deliver fair value for the vast majority of consumers. Heat networks' pricing is largely competitive when considered holistically, that is beyond the price per kWh.

Following the rise in gas prices largely caused by the war in Ukraine, customers supplied by district heating networks run by gas have experienced very high price rises in 2022 as they are not protected by the UK price cap.

3.2.1. Role of building owners and building occupants

In the UK, building owners are responsible for infrastructure and costs associated with utility provision, including district heating. The tenant or occupier is typically responsible for paying for the energy used during its occupation. This can make

district heating rollout challenging because the interests of owners and tenants are not necessarily aligned. Value needs to be added to both parties which can be particularly challenging in retrofit situations.

Local authorities are able to impose planning rules for new developments that favour of low carbon systems including district heating. Many local authorities are reluctant to force connection as it could be seen as a deterrent for certain developers who then may take their capital and development prospects to a different local authority. The planned heat network zoning legislation will mandate connection which should resolve this question.

Part L building regulations set out standards for building fabric and efficiency. These standards are progressively being strengthened. With improved energy efficiency, buildings can run their heating systems at lower operating temperatures which improves opportunities for developing 5GDHC networks.

3.2.2. Financing and subsidies

Financing heat networks in the East Midlands has been challenging historically due to the low-cost counterfactual of gas. New schemes would typically need to achieve hurdle rates of 6% for public investment and 12% for private systems.

The government Green Heat Network Fund supports commercialisation and capital investment to uplift IRR's to investible propositions. The main goal of the fund is to act as a lever for private investment.

Figure 7. gives a summary of financing options that could be explored

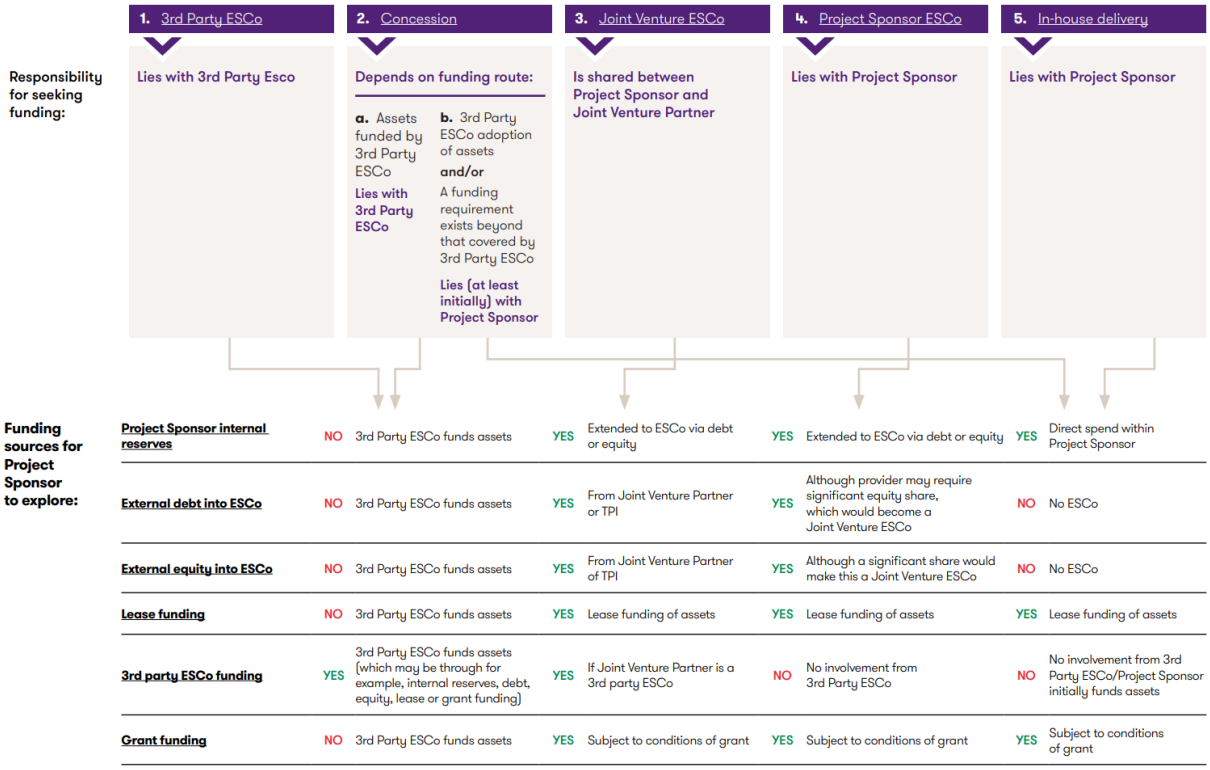

Figure 7. Financing Options

3.3. Available Energy Sources

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the

highest ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low grade sources would be in order to make a decent 5GDHC business case. At the time of writing, D.T1.1.4 has not been finalized.

Depending on the region and the country, there are different energy sources and storages. This can mostly be attributed to the different topography and available natural resources. For the development of 5GDHC it is relevant to know the different energy sources and storages. This allows planning from which source energy is to be drawn or whether another grid variant/generation such as 4GDHC is more advantageous. The main focus is on renewable energies. However, the potential of fossil fuels is also considered.

The number of heat networks in the East Midlands region is small. The major cities such as Leicester and Nottingham have heat networks, but the penetration is still small compared with other European countries. Natural Gas is the most common heat source for heat networks in the UK.

Electricity generating assets have significant potential to be able supply heat to heat networks. The figure below shows key electrical generation assets within the East Midlands.

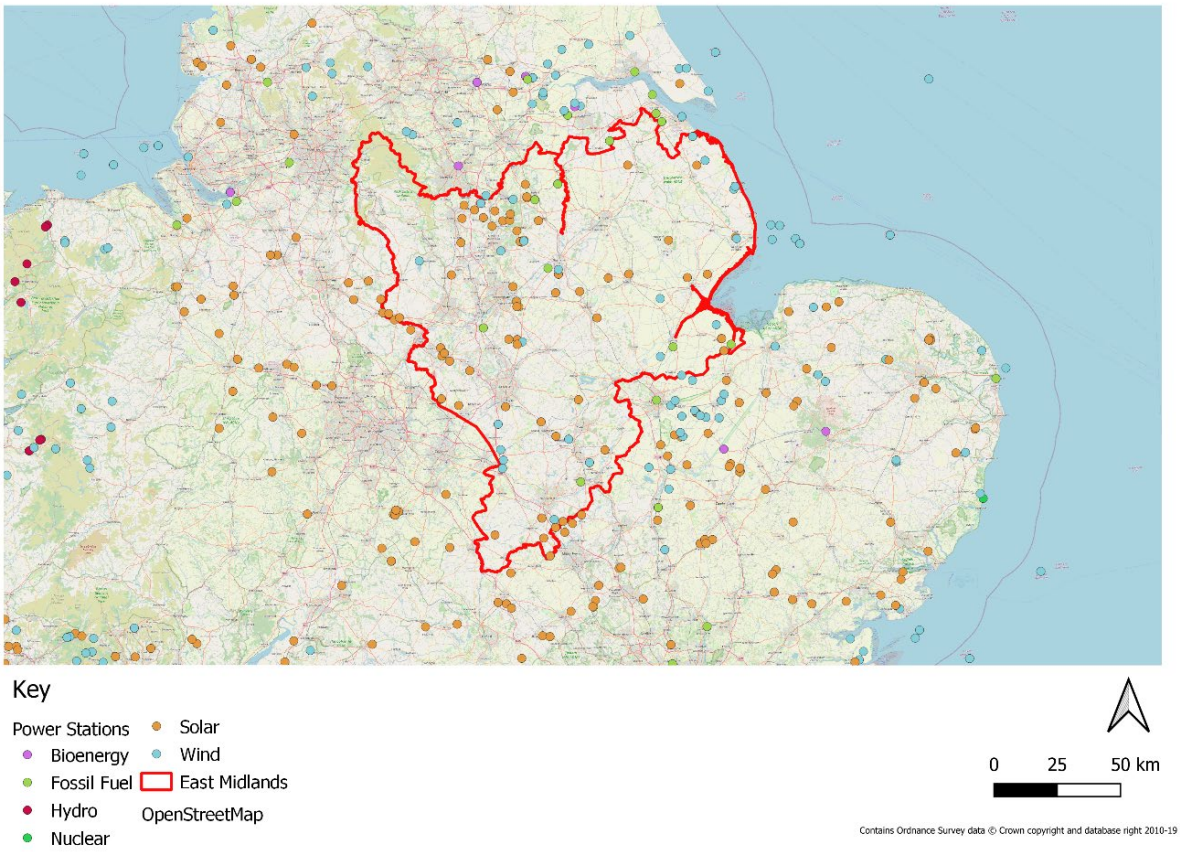

Figure 8. Electricity Generation Assets – East Midlands

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

One of the core principles of 5GDHC is to facilitate energy exchanges between local buildings. For instance, if one building is producing heat for its own consumption, it automatically also creates cold which ideally could be supplied to another nearby building.

Analysing the potential of such energy exchange is, however, not currently possible on a regional scale because the detailed energy consumption data, for different time periods is not available. The potential for energy exchange also depends on the design of the network and the type of users involved. Ideally, a good mix of consumers should be present, so that their energy flows and needs are complementary.

Nordic Energy has published an online tool that enables the detailed assessment of energy exchange potential. The model covers almost all buildings within the East Midlands and presents information via an interactive map enabling users to better understand the buildings and their energy demand. It therefore also enables users to identify the area-based potential for 5GDHC.

The regional demand opportunities are presented in the following diagram for the East Midlands.

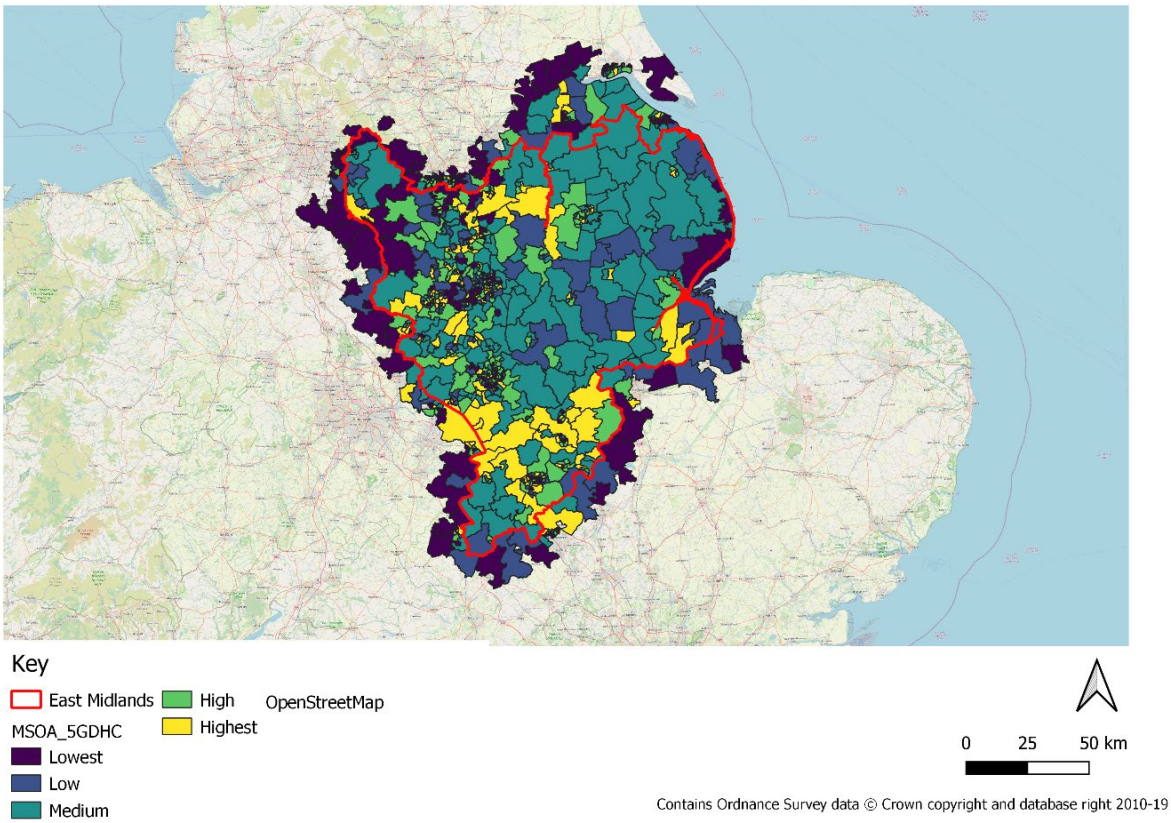

Figure 9. Comparative 5GDHC potential in the East Midlands (demand led)

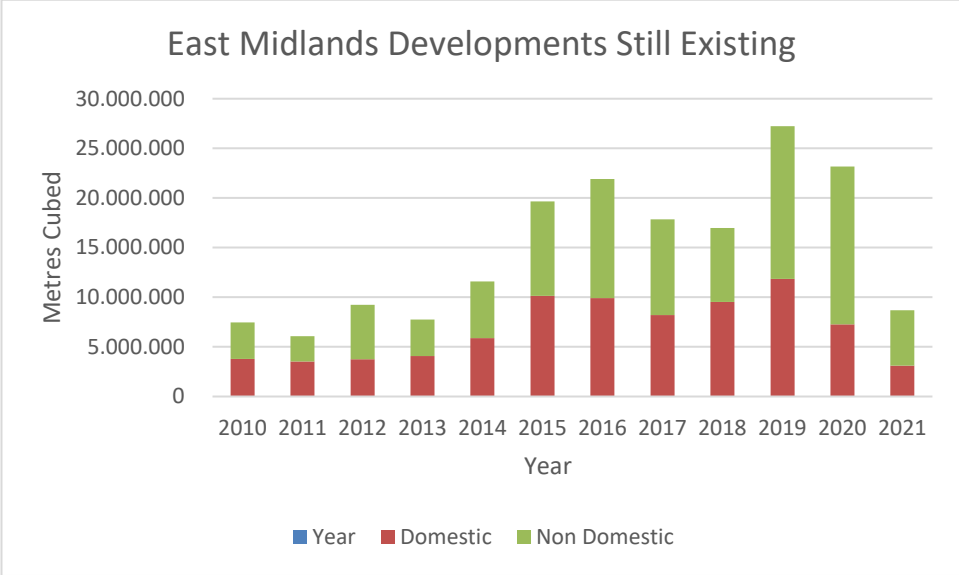

Figure 10. New Build developments in the East Midlands

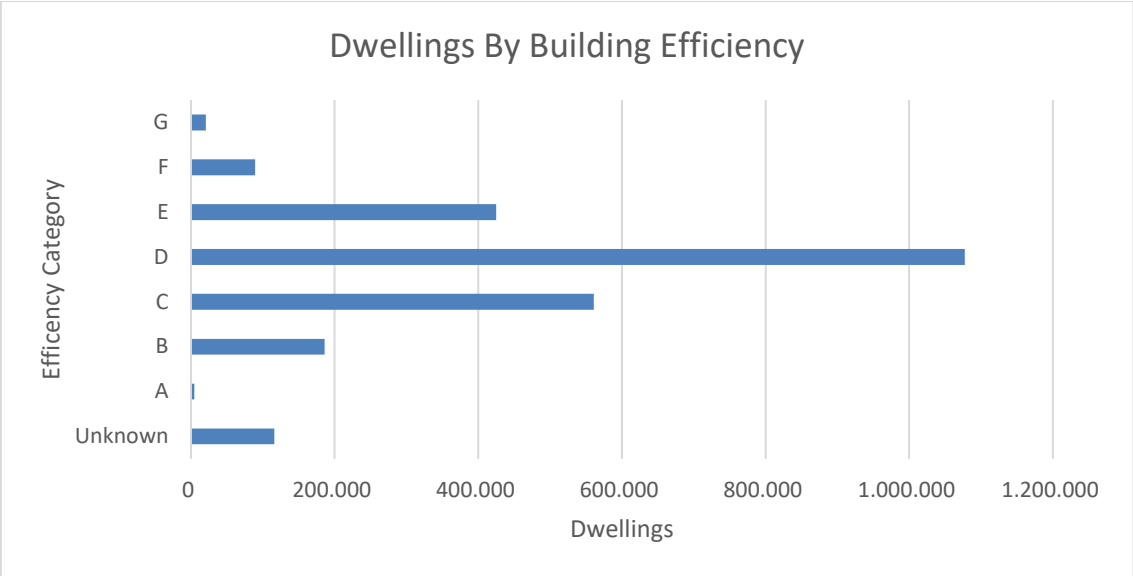

Figure 11. Current energy efficiency of building stock within the East Midlands.

The challenge of connecting existing buildings to 5GDHC networks is achieving good commercial returns given the efficiency improvements needed when heat is supplied at lower temperatures. Weather optimisation goes some way to improve this but until the gap between gas and electricity prices increases the commercial outlook remains challenging.

3.3.2. Ambient thermal sources from soil, water, air, and low temperature solar heat & low grade thermal storage possibilities

(Bertermann et al., 2015) analysed the pan-European very shallow geothermal energy potentials. Very Shallow Geothermal Potential, both BTES and ATES, is basically solar heat that is stored in the shallow underground (up to 10 metre depth).

The map below shows there are some areas with a very high heat conductivity potential in the East Midlands. Nevertheless, in some of these areas there are also limitations or restrictions for the implementation of shallow geothermal energy (see stripes in the background). Such limitations are caused, for instance, by protected zones, unsuitable soil types (Histosols, Cryosols, Leptosols, Gleysols, Planosols) or soil slopes >15°C.

Heat conductivity is expressed in Watts per meter*Kelvin. Red zones are 'highly suitable' and orange zones are 'very suitable'. Yellow zones are 'suitable', which is still better than the blue zones which are 'limited suitable' or 'less suitable'. For the East Midlands it shows that there are significant areas of opportunity for shallow geothermal energy.

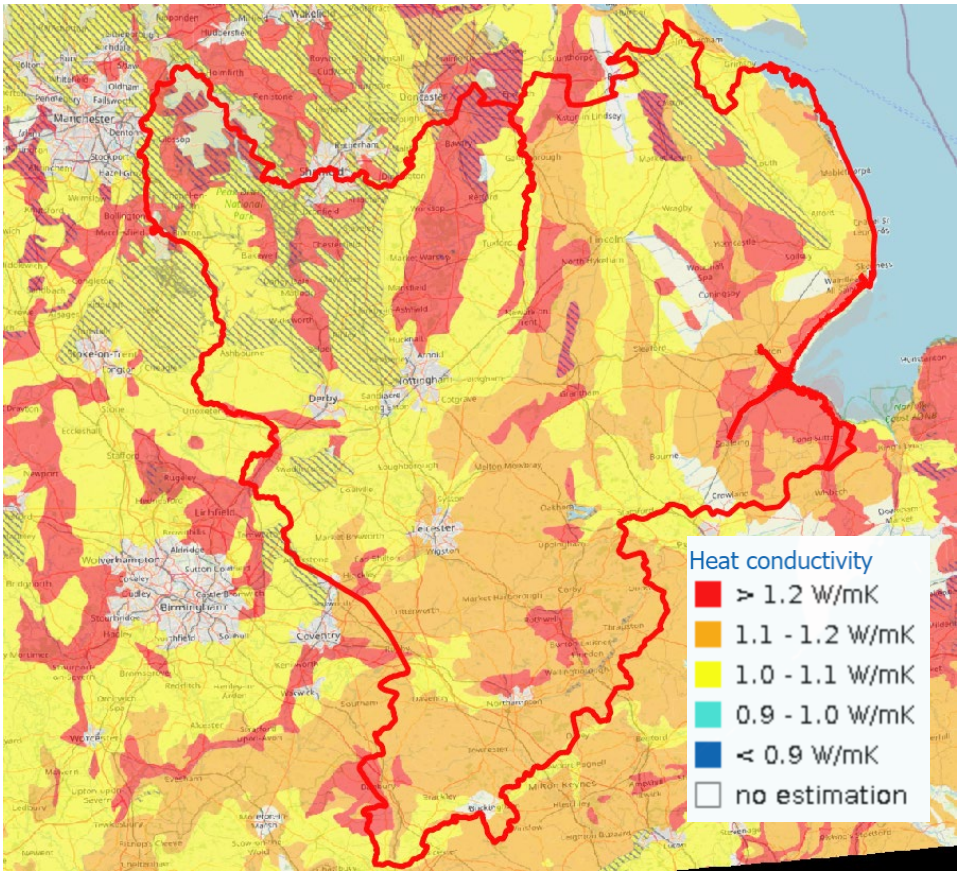

Figure 12. ThermoMap East Midlands (Red Border East Midlands)

Mine Energy

Minewater is another strong potential heat source in the East Midlands. The region has a significant history of coal mining in the areas represented by the Coal Authority's map below, numbered, 8,9,10 and 11.

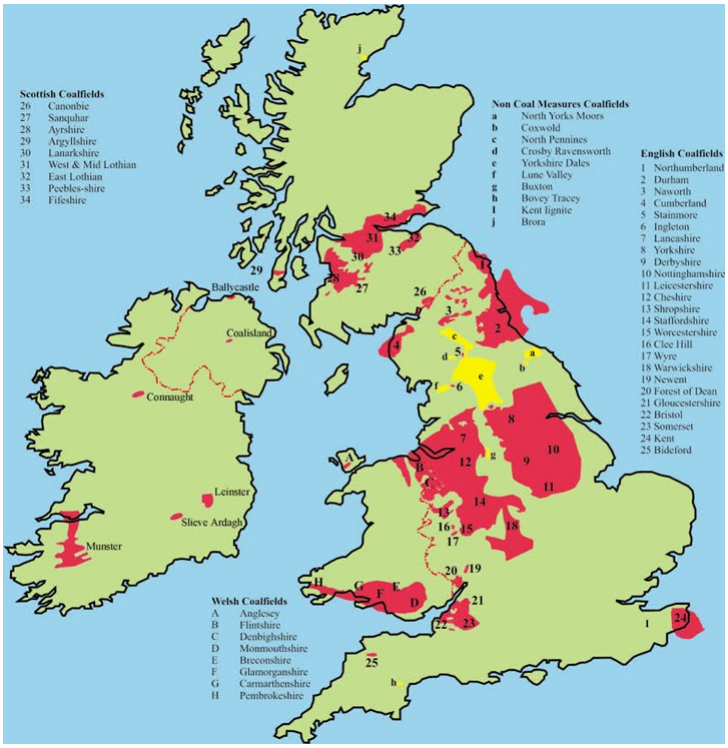

Figure 13. Coal Reserves in the UK

Since the mines closed, the Coal Authority has been managing legacy issues emanating from them such as preventing eruptions of mine water to the surface that would pollute water supplies.

The Coal Authority are also supporting projects that use the warm water that has filled the former coal seams to provide low temperature heat for district heating networks. The potential for mine energy in the East Midlands has not been fully explored due to the cost associated with procuring this information from the Coal Authority. The data is available to view on a non-commercial basis here (https://mapapps2.bgs.ac.uk/coalauthority/home.html).

Advantages of Mine Energy projects include:

- Substantial network of mine workings in a large area of the East Midlands
- Many Mine Workings in the East Midlands readily accessible via boreholes – between 100m and 300m below surface e.g. around Nottingham
- Potential storage opportunity, particularly in any mine shafts that have not been filled up after closure of the mine
- Most mine workings are close to population centres and therefore heating/cooling demands
- Most mine workings are also close to industrial sites and therefore can be integrated with heat recovery projects from industry

Former mining areas have lower than average economic and social/health indicators

- Job density below average
- Unemployment well above average
- Business activity well below average
- Ill-health double the level of South East England

Ref "The State of the Coalfields" – Foden, Forthergill and Gore, 2014 – Sheffield Hallam University

Therefore another advantage of mine energy schemes is the economic and social/health uplift that they bring to former mining communities that have strong cultural identities.

Mine energy as a heat source is still in its infancy. A number of innovative mine energy projects are underway which will help understand the mine water delivery potential in the UK. Some of the mine energy opportunities and issues are identified below;

- Data for geothermal energy assessments is not readily accessible
- There is a shortage of geothermal energy experts in the UK
- Mine energy projects are most suited to serving new build housing that is energy efficient
- Older housing needs energy efficiency retrofit measures to be undertaken prior to 5GDHC connection
- Low grade storage is becoming more utilised as technology develops but take up is low

Ambient Heat Sources and Heat Pumps

Over the past 3 years there has been a near 100% rise in the sales of heat pumps in the UK (35,000 in 2019 to 67,000 in 2021) as the demand for the technology increases. The domestic 'Renewable Heat Incentive' (RHI) has been a major policy driver in the rollout of heat pumps, although that scheme has now closed. The scheme supported 6,134 Air source heat pumps and 1,065 Ground source heat pumps since its inception in the East Midlands.

The Boiler Upgrade scheme is the new policy driver to support homeowners in their move to greener technologies, including heat pumps. This provides a grant of £5,000 towards replacement of a gas boiler with an air source heat pump and £6,000 for ground or water source heat pump.

Geothermal storage systems, both BTES and ATES, are increasingly being progressed in the UK but it is not yet widely established. The East Midlands region is suitable for both An assessment of the geology and soil, such as provided by the British Geological Survey (semi-public organisation) is necessary for these applications.

3.3.3. Higher temperature renewable sources like geothermal, solar heat

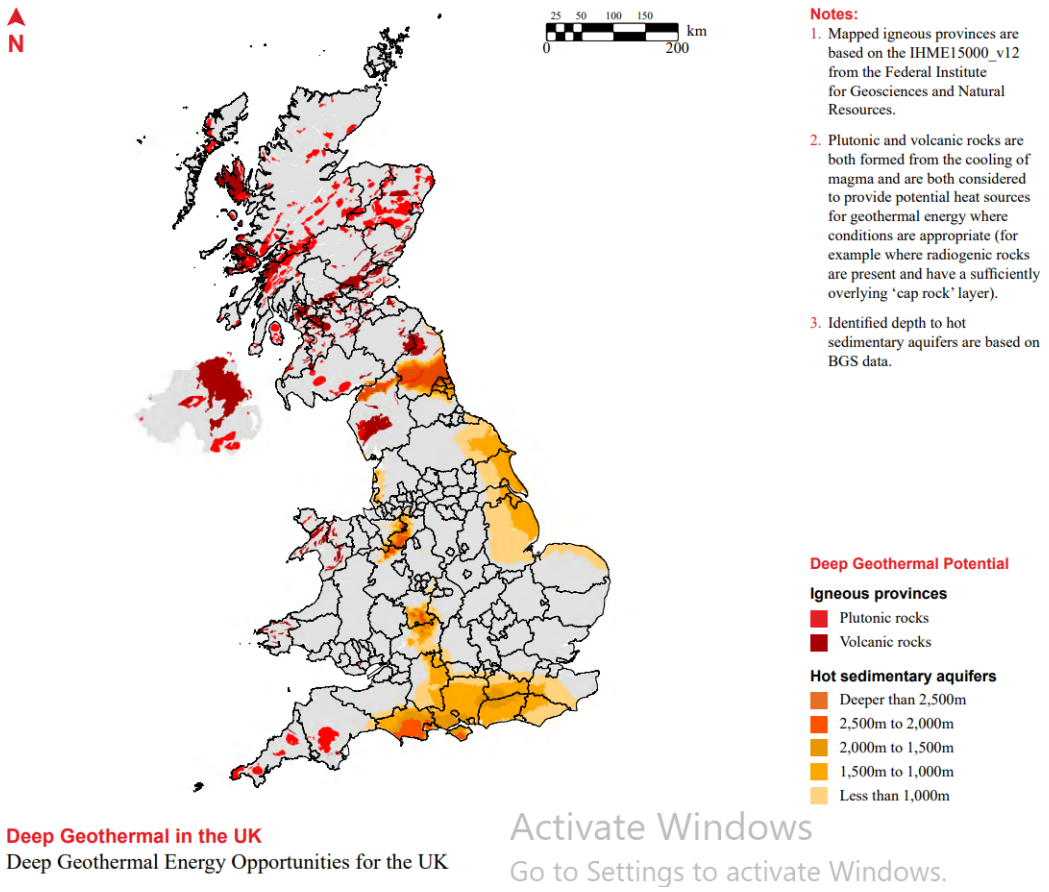

Figure 14. Deep Geothermal Energy Opportunities in the UK
Source : https://www.r-e-a.net/wp-content/uploads/2021/05/Deep-Geothermal-Energy-Opportunities-for-the-UK.pdf

A recent study by ARUP and REA has explored the potential for Deep Geothermal in the UK. The UK has only recently deployed its first deep geothermal project located in Cornwall. The united downs project produces temperatures of 188C at its 5km base. The project budget is £30M and made possible through the European Regional Development Fund.

Deep geothermal is in its infancy within the UK, with government support growth is expected to accelerate a number of projects. From current knowledge the East Midlands opportunity is there but limited when compared to other regions in the UK

Solar Heat

The vast majority of large solar projects in the UK are PV rather than heat. This is because the commercial case historically has favoured electrical production owing to the high price of electricity and the low price of gas. Small scale solar thermal typically covers around 40-60% of the household hot water consumption over a year.

3.3.4. Higher temperature industrial waste heat, otherwise rejected in the environment

Waste heat is the energy that is generated through processes which is not put into any practical use and is lost, through waste or dumping into the environment. Waste heat recovery technologies can be deployed to recover this valuable energy source and reduce the overall energy consumption. Excess recovered heat can be transported through district heating networks to consumers.

Below is map providing a broad estimate of waste heat availability across the UK.

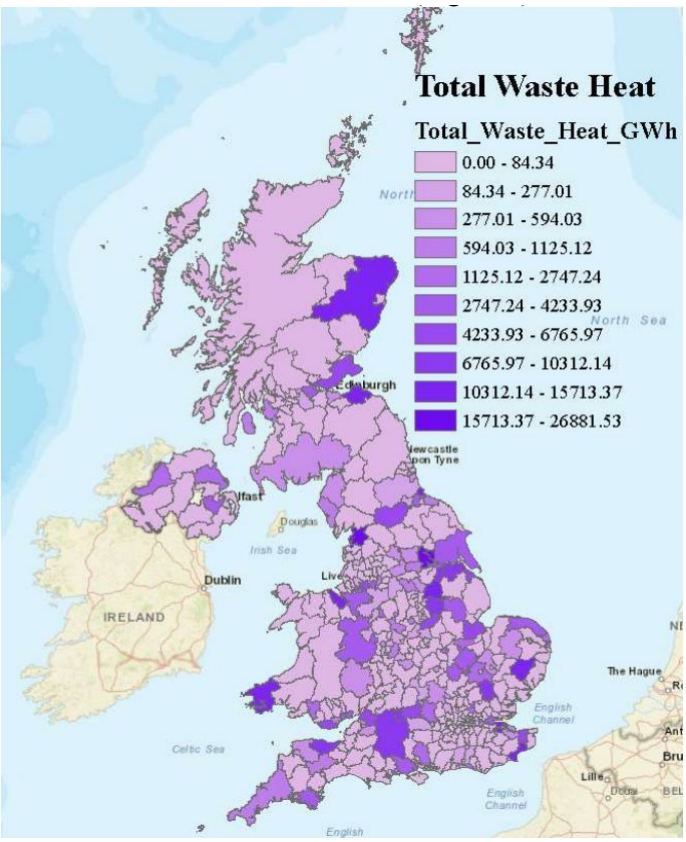

Figure 15. Distribution of estimated total waste heat in the UK (source : *Waste Heat Mapping: A UK Study* - *http://www.mygridgb.co.uk/waste-heat-map/*)

The potential for recovering waste heat in the East Midlands is significant. Across the UK, industrial waste heat has been estimated to be 391,000 GWh. However, UK industry has been tended to focus on improving processes as a means of improving productivity and efficiency rather than optimising resource management such as heat recovery. Progress, therefore in harvesting waste heat to then supply into heat networks has been limited.

3.3.5. Renewable electricity from local sources like wind, sun

The UK has seen an unprecedented rollout of solar and wind energy over recent years with a particular emphasis on off-shore wind, a significant proportion of which is near the East Midlands coastline. The Energy Security Bill, introduced to parliament in July 2022, reinforces the prioritisation of local renewable energy generation, the impact of which can be seen in the diagram and map below.

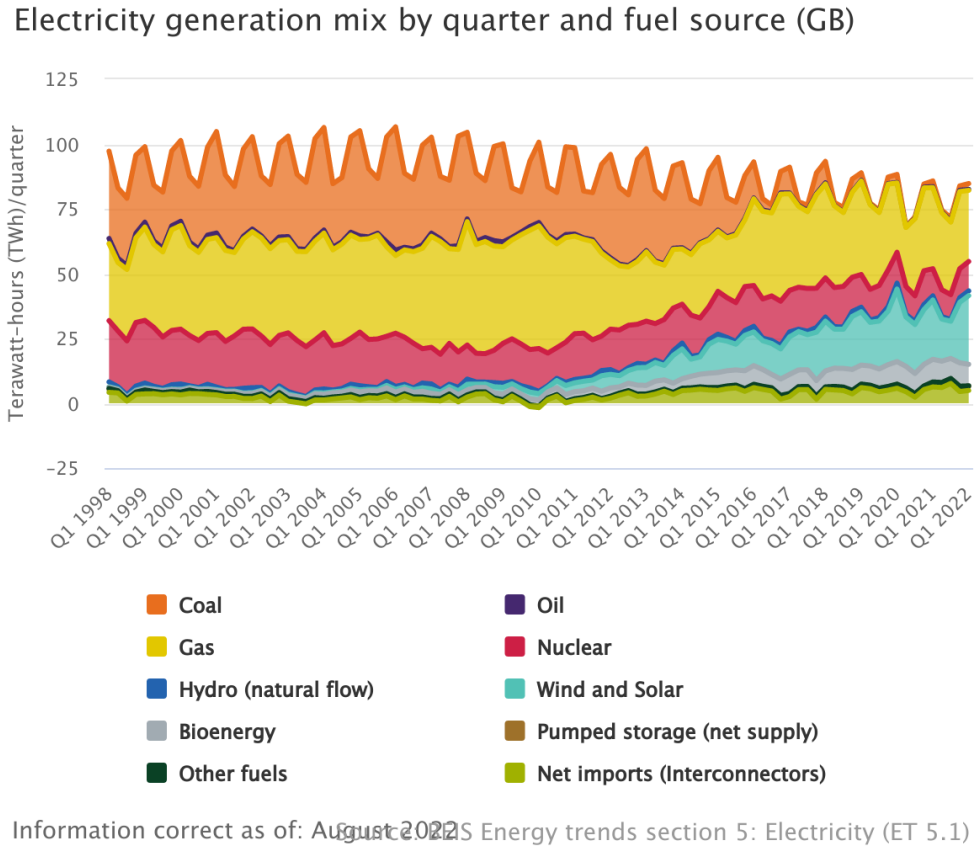

Figure 16. Electricity Generation mix by quarter and fuel source

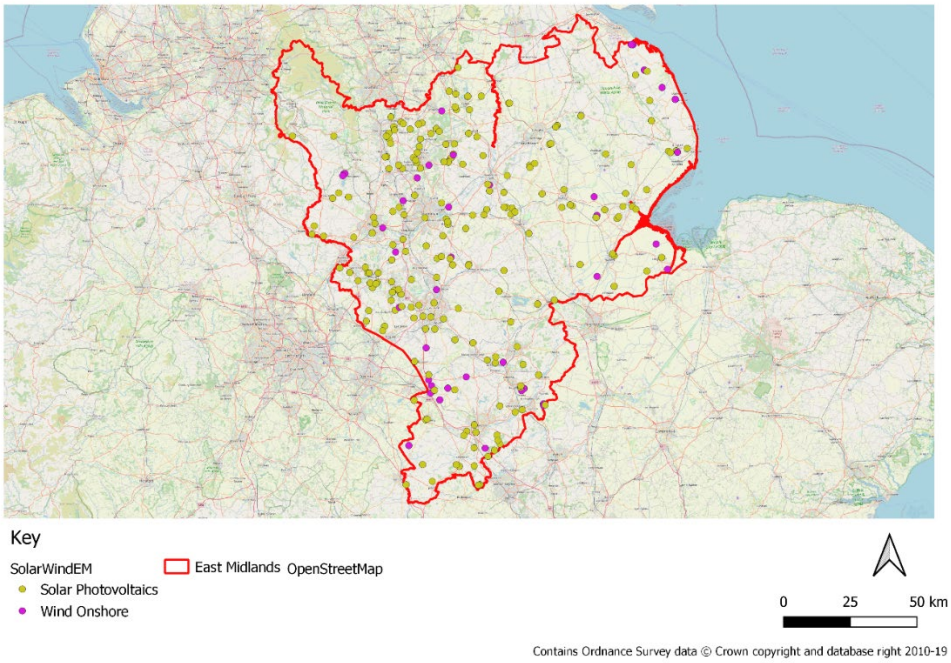

Figure 17. Solar and Wind Installations over 150 kW in East Midlands

Solar and wind installations (both operation and under construction) over 150kW in the East Midlands (*DBEIS Renewable energy planning database monthly extract*)

The East Midlands solar and on-shore wind electricity output is currently 2.5GW (2GW Solar, and 0.5GW Wind).

The off-shore wind electricity output is shown on the map below

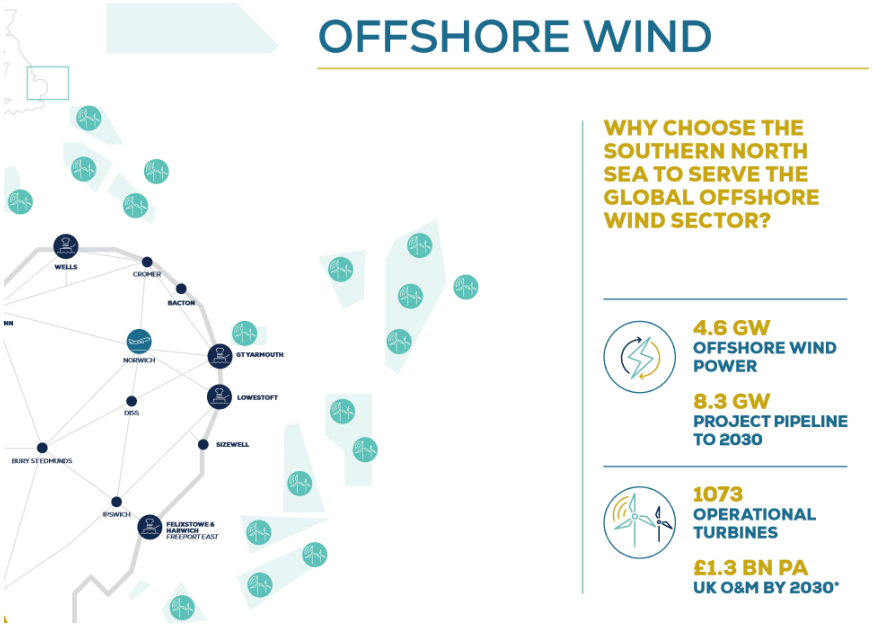

Figure 18. Norfolk and Suffolk All Energy Industry Council

3.3.6. Electricity use at times of renewable overproduction, e.g. when spot price is low

The electricity grid is evolving with the increased rollout of renewable energy and other factors such as the electrification of transport. Electricity is generated, transported, delivered and used continuously in real-time, and supply must always match demand as electricity cannot be stored at scale yet.

Although the generation, transportation, delivery and usage of electricity is continuous, for the purposes of determining consumption and organising payments, it is measured in half hour chunks called 'settlement periods'.

The electricity grid Balancing Mechanism uses the Electrical Supply Operators Primary Tool to balance supply and demand in settlement periods. If the electricity grid predicts there will be a difference between the amounts of electricity produced and consumed they may accept a 'bid' or 'offer' ('spot price') to increase or decrease, generation or consumption.

This creates pricing optimisation opportunities. Octupus energy, for example, offers 'Agile Tariff's that fluctuate according to market conditions in each settlement period. Other pricing mechanisms enable users of all scales to take part in low spot price trading if they have the flexibility to do so.

The graph below demonstrates the variation in potential future electricity demand in the East Midlands over a 24 hour period.

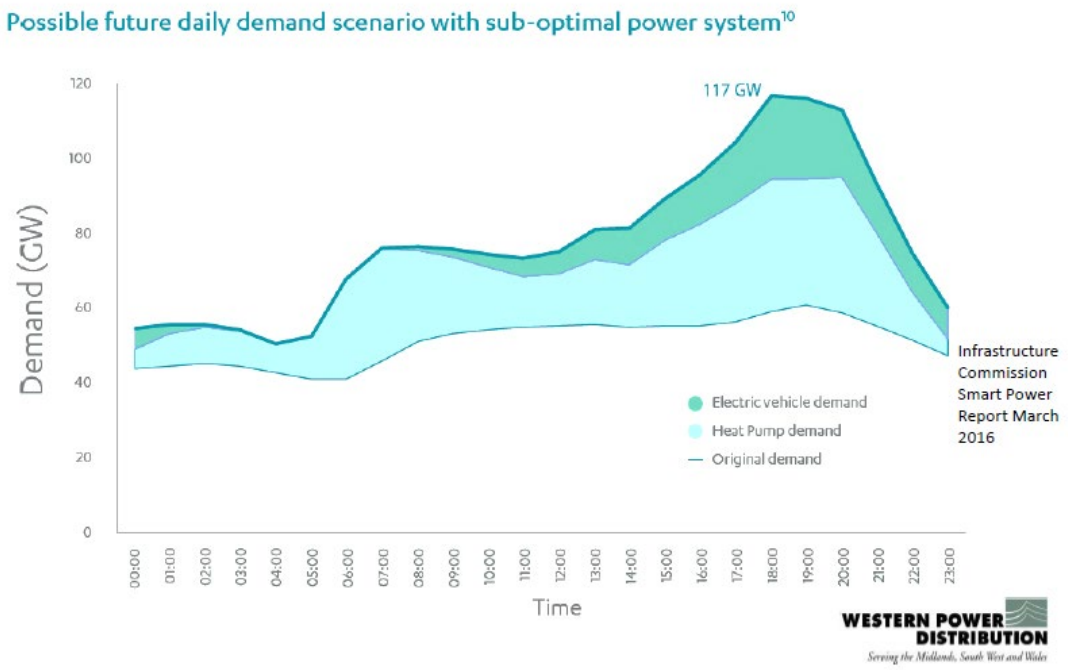

Figure 19. Potential future electricity demand over 24 hour period in East Midlands

The graph above also demonstrates the challenge from a changing demand profile with the introduction of heat pumps and electric vehicles. 5GDHC has a strong opportunity to support these demand challenges on aging electrical infrastructure with its ability to absorb electricity at specific times using the flexibility of its assets and operation.

3.3.7. High temperature heat from burning biofuels, biogas, biomass

In the East Midlands, 13,000 domestic properties use biomass as their primary source of heating, which constitutes approximately 0.5% of all domestic buildings. These are typically in rural areas. Biomass systems are becoming more financially appealing given the rise in wholesale gas and electricity prices. Biomass can be sourced from many different areas and provide market resilient heating. To address air quality issues, legislation imposes strict standards on the type of fuel which can be burned.

The table below gives an overview of the biomass technologies that operate with a generation capacity of over 150kWe in the East Midlands.

Technology	No CHP Installed Capacity (MWe)	No CHP Number	Yes CHP Installed Capacity (MWe)	Yes CHP Number	Total Installed Capacity (MWe)	Total Number
Anaerobic Digestion	17.4	7	20.5	10	37.9	17

Biomass (dedicated)	34.8	3	64.4	7	99.2	10
Grand Total	**52.2**	**10**	**84.9**	**17**	**137.1**	**27**

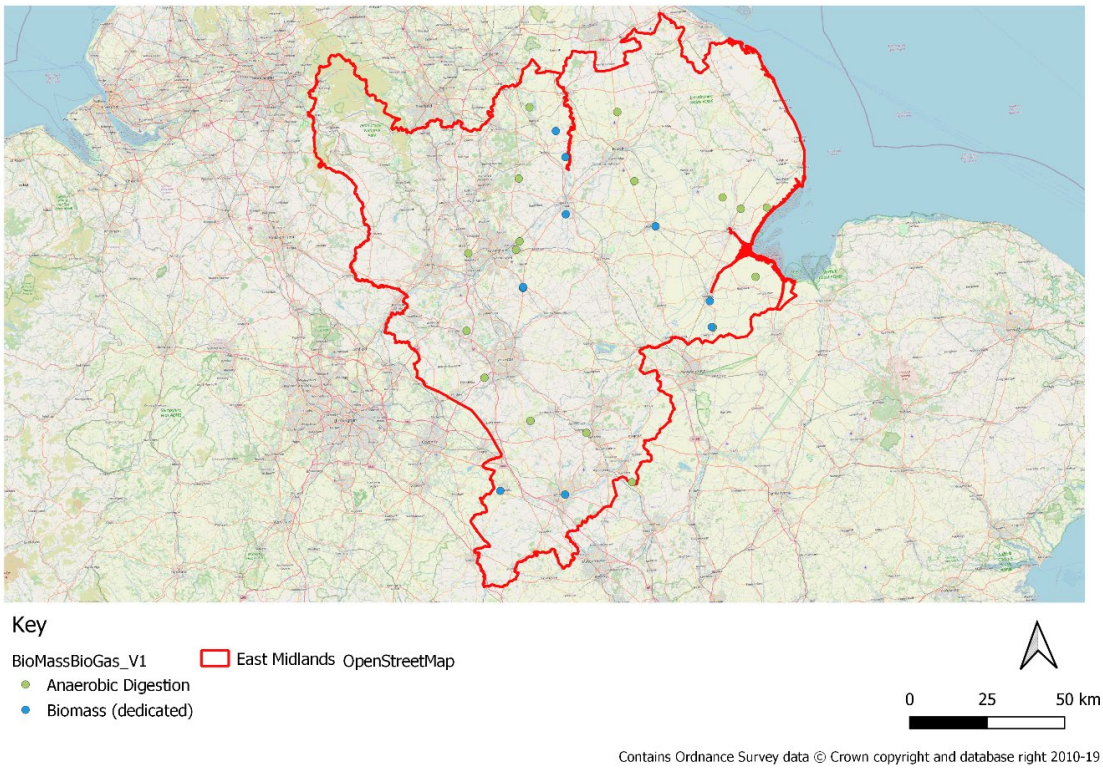

Figure 20. Sources of High Temperature Heat from Burning Bio Fuels – East Midlands

3.3.8. High temperature heat from burning fossil fuels

Coal

There are three coal-fired power stations still in operation in the UK, two of these stations are within the East Midlands region, 'West Burton A' and 'Ratcliffe on Soar'. Both of these power stations can generate 2GW but are scheduled to be decommissioned in the coming years. The timeframe is currently uncertain given the energy security issues the UK government is currently grappling with. Radcliffe on Soar currently operates as a 'peaker' plant to address periods of very high demand on the national grid.

Gas

There are five active gas-fired power stations within the East Midlands;

- West Burton B with a capacity of 1.33 GW
- Corby with a capacity of 0.41GW
- Cottam Development Centre with a capacity of 0.45GW
- Spalding with a capacity of 0.95GW
- Staythorpe C with a capacity of 1.77GW

On the domestic level its estimated that 88% of all homes and businesses in the East Midlands use Natural gas as a primary means of heating and hot water. There are drivers and support schemes to encourage residents to move and switch to a non-fossil based heating system.

4. SWOT analysis

Analyse SWOT	
Strengths	**Weaknesses**
- Heat network growth is being supported by government investment and policy - Private investment market is well developed in the UK - Market for non-fossil fuel based heating is substantial as most heating is currently from fossil fuel sources - Anticipated high level of house building growth - Technical regulations in the building industry becoming more advantageous – higher standards - Region has multiple sources of low temperature heat e.g. mine water, sea, waste water, aquifers, canals and rivers - Proven capability to develop renewable energy programmmes such as off-shore wind roll-out	- Gas network dominates heat supply in the East Midlands, creating a major obstacle for alternative heat suppliers - Heat offtakers expect to have control of their own heating infrastructure – gas boiler + radiators - District Heating is relatively new to a lot of customers/developers – resistance to change - High capital upfront costs - High Proportion of older buildings that are energy inefficient and difficult to connect to low temperature networks - Lack of sample projects as examples
Opportunities	**Threats**
- Government is supporting heat network growth with legislation such as Heat Network Zoning and funding such as HNDU and Green Heat Network Fund - Essential building fabric improvements aligns with 5GDHC needs - Proven inter-seasonal storage technologies ATES and BTES have high potential but currently under-developed - Opportunities for waste heat recovery growth, thereby strengthening security of energy supplies and improving revenues for industry - Using return temperatures on existing and new higher temperature networks could help facilitate 5GDHC - Expected introduction of regulation enabling DH to carry same utility rights as electricity and gas. - Good synergy with growing renewable electricity infrastructure – particularly off-shore wind	- UK heat market dominated by gas supplied by an operator with a monopoly - Poor UK economic conditions reducing investment appetite – government and private sector - High cost of UK electricity - heating costs rising beyond the means of customers - Adoption of the technology without ensuring a balance of heating and cooling - Future construction of 'passive' buildings that have limited heating and cooling needs

5. Regional vision

5.1. High potential areas and potential pilot sites

To develop a 5GDHC vision for the East Midlands, Nordic Energy has developed an Interactive Model which facilitates greater understanding of potential locations for 5GDHC.

The Interactive Model provides unprecedented detail regarding the current East Midlands building stock, circa 2.8million buildings. Data, largely comprising real (as opposed to modelled) data, provides the substance behind a 3D map covering the whole of the East Midlands region. Viewers can zoom in from a map of the whole region down to individual buildings. Hovering the mouse cursor over a building results in a pop-up box containing key information about the building such as its age, sources of energy, energy consumption and EPC certificate.

Two screenshots from Nordic Energy's interactive model are below, which can be accessed through their website (www.nordic.energy)

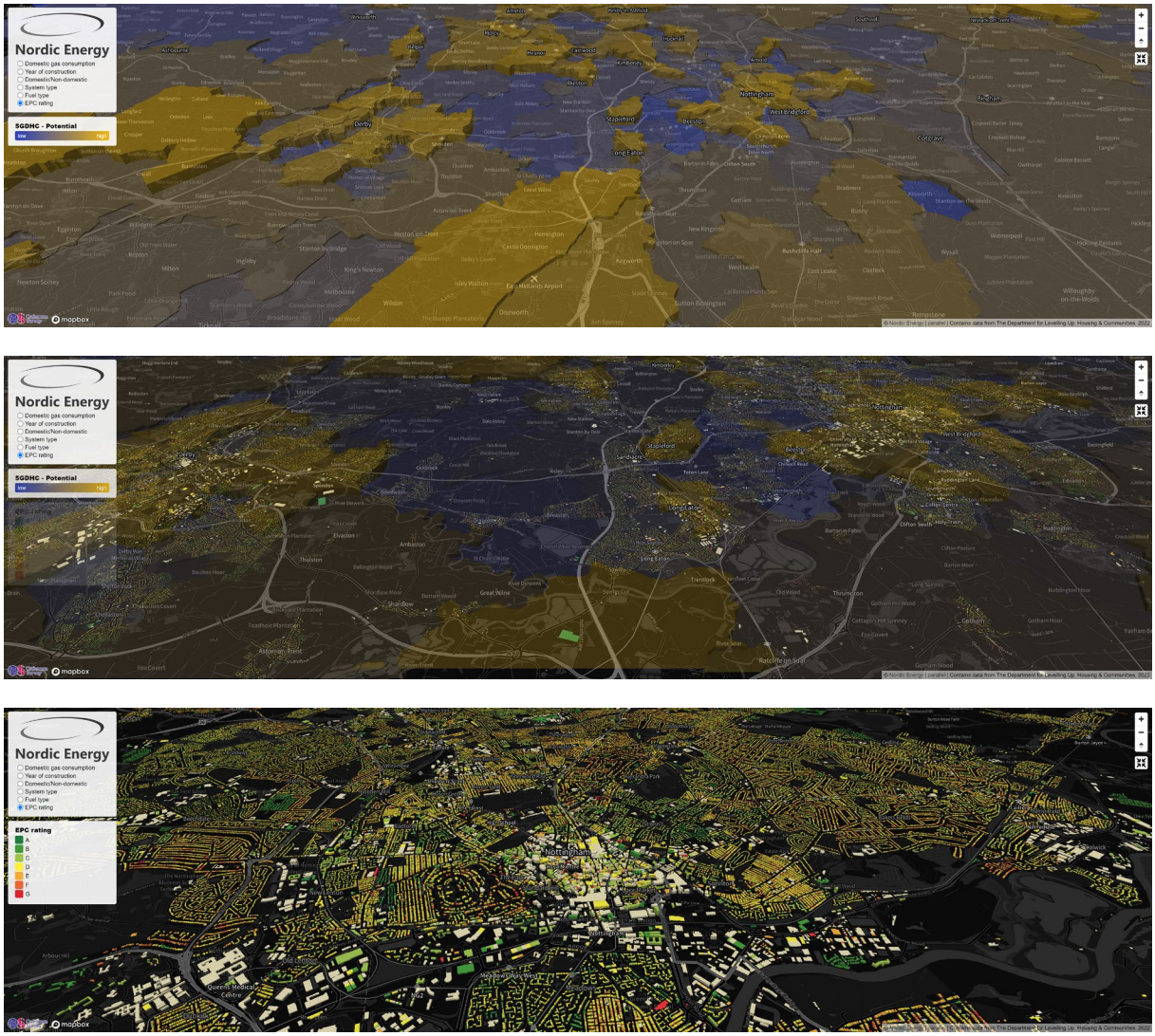

Figure 21. Screenshots of the interactive Model

DH networks are usually enabled by local authorities which can make it difficult to tie this in with a regional strategy and vision as the approach is very patchwork. BEIS has formed 'Net Zero Hubs' to help facilitate these regional developments.

Nordic Energy is in the process of sharing the Interactive Model with the Midlands Net Zero Hub (covering a similar area to the East Midlands) with a view to assisting the identification of optimal 5GDHC opportunities.

6. References

See notes through the text

Interreg North-West Europe D2Grids

European Regional Development Fund

WORK PACKAGE: WPLT

DELIVERABLE NUMBER: DEL.1.3

PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN 7 FOLLOWER REGIONS

July, 2021

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Abbreviations

EPB	EnergiePrestatie en Binnenklimaat
EPC	energieprestatiecertificaat
DH(C)	District heating (and cooling)
5GDHC	5th generation DHC
DER	Distributed Energy Resources
NECP	National Energy and Climate Plan
VITO	Vlaamse Instelling Technologisch Onderzoek
VILT	Vlaamse Infocentrum land- en tuinbouw
FEBEG	Federatie van de Belgische Elektriciteits- en gasbedrijven
VBO	Verbond van Belgische Ondernemingen
ODE	Organisatie voor Duurzame Energie
VREG	Vlaamse Regulator van de Elektriciteits- en Gasmarkt
TWh	TerraWatt Hour
CREG	Commission for Electricity and Gas Regulation
SME	Small and medium-sized enterprises
VEA	Vlaams Energie- en Klimaatagentschap
POM	Provinciale Ontwikkelingsmaatschappij
KMO	kleine of middelgrote onderneming
EU	European Union
ETS	Emission Trading System
Mton	Million ton
CO2-eq/year	Carbondioxide equivalents per year
CHP	Combined heat and power
SERV	Sociaal-economische Raad van Vlaanderen
VLAREM	Vlaams Reglement betreffende de Milieuvergunning
VCRO	Flemish Codex Spatial Planning
BTES	Borehole Thermal Energy Storage
ATES	Aquifer Thermal Energy Storage
PJ	Picojoule
MW	Mega Watt
GWh	Giga Watt hour
MWh	Mega Watt hour
MWh/a	Mega Watt hour per year
KWO	Koude- en warmteopslag
R&D	Research & Development
GDP	Gross Domestic Product
VME	Vereniging mede-eigenaars

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1. Introduction

Activities in the long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories ("follower regions"). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. This document provides a regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology in one of the 7 follower regions defined for this project, namely: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project, has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers, and opportunities of 5GDHC for each of the follower regions. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

2. Characterising the region

In this report, the entire follower region of Flanders is being analysed.

Political environment - It is important to understand that Flanders is part of Belgium, which has a complex institutional organization. In total, Belgium consists of three regions (Flanders, Wallonia and Brussels-Capital region), three language communities (Flemish Community, French Community, German-speaking Community) and a federal government. Each of them has its own responsibilities and government. The result of this is that, about some topics, there are overlapping responsibilities. For instance, about energy and climate, each region and the federal government has its own responsibilities. Consequently, energy policy in Wallonia and Flanders differs from each other, and there are certain regulations which are not decided by the Flemish Government but by the Federal government. The political climate in Flanders (and Belgium as a whole) is therefore very unstable, which creates a lot of uncertainty about legislation and continuation of legislation.

Energy usage and climate ambitions - Flanders is highly relying on gas for its heating purposes. District heating only takes up a very small place in Flanders. Fossil fuels are therefore widely spread in Flanders. While all EU Member States are increasing their levels of renewable energy production and energy efficiency, it should be noted that the Flemish climate policy plan for 2030 is not very ambitious in the sense that it only aims to reduce greenhouse gas emissions by 35% (compared to 2005) while Europe is setting this goal at a reduction level of 50-55%.

Energy-efficiency of buildings - The build environment in Flanders shows evidence of older, low energy-performing buildings. Nevertheless, Flanders is a very densely populated region which makes it suitable for collective systems such as DHC grids. As most buildings are not very energy-efficient, heat demand is quite high. This could be a good match with the many sources of high temperature residual heat that can be found in the region, although this is not necessarily a good match for 5GDHC grids.

3. Analysis

In what follows, a more detailed analysis of Flanders is given. Specifically, we zoom in on the heating context, on the position of District Heating and on the type of energy sources and storage available in Flanders.

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

Currently dominant heating technology in the region

Belgium (and therefore Flanders as well) has a history of gas usage. By 1850, each middle-large city in Belgium already possessed its own gas factory. Starting from 1932, a long-distance gas network was developed which was expanded throughout the year. Today, the total network length is about 4,000 km. This network size has in part been reached since the government was pushing access to natural gas for heating. For Flanders, for instance, the energy decree mentioned until the end of 2016 that by 2020 99% of all buildings in urban regions and 95% of all buildings in rural regions should have access to a gas connection. (MINARAAD, 2017) Belgium is not producing natural gas but is quite well located as it takes up a central position in the transport of natural gas through Europe.

However, changes are needed as Belgium's gas network consists of two parts. One part serves high-calorific gas, and one part serves low-calorific gas. The low-caloric gas is exported from the Groningen field in the Netherlands, which will be phased out starting from 2024 (potentially even earlier) (De Cleene, 2018). Currently, Belgium is importing about one third of its gas consumption from the Netherlands. If Belgium wants to continue using gas, it will need to adapt the part of the gas network which is now adapted to the low-caloric gas of the Netherlands. In addition, all domestic appliances and pressure regulators will require check-ups and possible upgrades (Van Horenbeek, 2017). Synergrid, the federation of transmission- and distribution grid operators for energy, started making the transformation from low-caloric to high-caloric gas networks with an indicative planning from 2018-2029 (FEBEG, 2016). The conversion affects about 1.6 million private customers and commercial entities (Gaschanges.be, 2021). The additional investments in the gas network raise the question whether this upgrade is a good investment as some countries are already phasing out gas in line with climate targets. The European Commission calls for a climate-neutral Europe by 2050 (European Commission, 2021). In addition, the transition to other energy-efficient energy technologies could bring along a lower demand for gas, leading to the issue of 'stranded costs' as the costs of the network are fixed and to be depreciated over longer time periods (VBO, 2017).

Apart from gas, oil is also used frequently by Flemish households. In total, about 90% of households in Flanders uses either gas or oil to heat up their houses. (ODE, 2019b)

District heating in the current heating regime

Given its gas history, district heating is only taking up a very small proportion of the heat consumption. There is also no national approach towards DHC. This is in part explained by the fact that the Belgian Federal State consists of three regions (the Flemish Region, the Walloon Region, and the Brussels Capital Region) which each have specific competences for their territory. Energy is in part a federal responsibility, but also a regional responsibility. About district heating, more initiatives can therefore be found on a regional level instead of on a national level.

For Flanders, in April 2019, there were a total number of 56 district heating grids. The VREG categorizes them in four categories (VREG, 2020b):

- 6 networks are small networks with less than 100 (mostly residential) consumers;
- 18 networks are larger networks with more than 100 (mostly residential) consumers;
- 25 networks mostly contain small commercial or public buildings (such as hospitals, schools…);
- 7 networks mostly contain industrial consumers.

Especially when looking at the total heat delivered within these networks, it becomes clear that district heating in Flanders mostly serves heat delivery to non-residential consumers (more than 2/3th of the heat in district heating grids). In total, in 2019, 316,5 GWh (VREG, 2020b) heat was delivered to district heating grids in Flanders. Compared to countries like Sweden and Denmark, this is not a lot. Compared to gas, in 2017, the total measured gas demand of Belgian end consumers was about 182 TWh (FPS Economy, 2019).

Figure 1 - VREG map district heating networks Flanders (Webinar warmtenetten 15 juni 2020 (VREG, 2020c))

Main actors in the current heating regime

Gas market

General actors	
VREG	Since December 2001, VREG is the independent authority that regulates and controls the Flemish energy market. They were founded in part to facilitate the liberalization of the Flemish electricity- and gas market. Their tasks, responsibility, working and management are dictated in Chapter I, title III, of the Energy Decree (Energiedecreet). Specifically, for gas (and electricity), VREG sets up technical rules that distribution operators need to follow when operating their grids, they approve grid tariffs and determine the grid tariff methodology, they control the market and grant supply permits to suppliers, they monitor the market, advice policy makers… (VREG, 2021)
CREG	The CREG is the federal, independent organization responsible for the regulation of the electricity and gas market in Belgium. The CREG is also responsible for setting social maximum prices. This is not the responsibility of regional regulators (such as the VREG for Flanders).
FEBEG	FEBEG is a Belgian employer federation that represents producers of electricity, and importers and suppliers of electricity and gas. With regard to gas, they are therefore only concerned with the import and supply of gas. They represent large industrial companies (33 members) who employ about 7.700 employees. (FEBEG, 2021b)
Input, transport, distribution, supply	
Input stakeholders	Gas is imported in Belgium either through underground or underseas pipelines, or per ship through the gas terminal in Zeebrugge.
Fluxys	Fluxys is operating about 4.000 km of high-pressure gas transmission grids in Belgium. It is a fully independent gas infrastructure group with headquarters in Belgium.
Distribution System Operators	Fluxys (transmission grid) transports gas to 17 Distribution system operators who operate a total of 70.000 km of low-pressure gas grids. Formerly they were intercommunal companies. The distribution system operators ensure

	consumer connection to the grid, they ensure the gas of the dedicated gas supplier is supplied to the consumer and they are responsible for meter measurements.
Gas suppliers	There are 20 gas suppliers who supply gas on the low-pressure gas grid. Suppliers need to have a supply permit to be allowed to supply gas. This permit proves they have sufficient technical and financial means to supply gas. The supplier is responsible for all commercial services and is responsible for invoices.
BALANSYS	As from the first of June 2020, the Luxembourg gas transmission system operator (CREOS Luxembourg) and the Belgian TSO Fluxys Belgium worked together to integrate their national markets. BALANSYS as a joint venture manages the commercial balancing of this integrated market.
(sub-)Consumers	
Large industrial end-users	In Belgium, about 200 large industrial end-users are directly connected to the gas transmission grid. In addition, 19 CHPs are connected to the gas transmission grid. Gas supply of industrial consumers connect to the transport network can be interrupted.
Power stations	A total of 18 power stations are connected to the gas transmission grid. Power generation from gas has declined mainly due to the closure of CCGT's. However, with the (partly) nuclear exit, it is to be expected that the gas demand by power stations might increase again.
Households	About 2,9 million households in Belgium are supplied by the low-pressure gas grid. Together with the SMEs, they are supplied by 20 gas suppliers. Gas consumption in Belgium is quite seasonal due to the large size and importance of the household group in the gas demand. Gas demand for this group is highly temperature dependent as they use it for space and water heating.
SMEs	About 100.000 SMEs are supplied through the low-pressure gas grid.

District heating

General actors	
VREG	VREG (VREG, 2021) is the independent authority of the Flemish energy market of today and tomorrow. Originally, their mission was to regulate and monitor the Flemish electricity and gas markets, but in the revised Energy Decree of 2019, they also become responsible for specific tasks regarding district heating and cooling grids. Such tasks include informing consumers of DHC grids (prices, conditions), controlling service delivery by heat- and cold suppliers to residential consumers, controlling reliability of DHC grids, arbitrating between consumers and heat/cold suppliers in case of discussions, controlling the implementation of the energy decree, provisioning of studies and statistics to the minister, controlling on the technical regulations, sanctioning in case of not following regulation…
VEA	Het Vlaamse Energieagentschap is the Flemish Energy Agency and is responsible for the implementation of a sustainable energy policy. Its role is to stimulate rational and sustainable energy consumption and production. Its focus is mostly on policy preparation, - implementation, awareness creation, reinforcement, policy evaluation…
Heat Network Flanders (Warmtenetwerk Vlaanderen)	Originally, Heat Network is a Dutch non-profit foundation. Heat Network Flanders is a department for Flanders of this foundation. The Foundation organizes in the Flemish region active discussions with stakeholders involved in district heating and cooling grids in Flanders. As of 2019, Heat Network Flanders has over 70 members, mostly residual heat generators, grid operators, operators of district heating and cooling grids, knowledge

	centers, consultancy companies, suppliers… The foundation also provides up to date information regarding the current regulation, market development, financial support measurements… They organize study days and an annual conference. (ODE, 2021)
DH operators, financiers, heat producers	
Cooperatives	In Flanders, some cooperatives (Beauvent, Zonnige Kempen, Ecopower…) are investing in and operating DH grids.
Energy suppliers	In Gent, Luminus is operating the city district heating grid. One of its electricity plants is linked to the DH grid through which residual heat from the plant is distributed to different buildings in the city.
Public grid utility company	Fluvius is the Flemish utility company that builds and operates electricity and gas grids. Fluvius is also operating/building some district heating grids in Flanders (Antwerpen Nieuw Zuid, Mol and Dessel, Turnhout-Niefhout, Roeselare-Hooglede, Kuurne-Harelbeke…) and is looking for other locations in the future.
Provinces, cities, municipalities	Many cities and municipalities are stepping up to develop or support DH in their region. Examples are the city of Leuven, Turnhout, Aalst, Antwerp, Gent, Roeselare… On top of that, provinces such as POM West-Vlaanderen are also taking up their responsibility in asking for (for instance) feasibility studies.
Waste treatment	ISVAG, IVAGO, IVBO, I.V.M., IVOO, MIROM, IOK, IMOG… are all waste treatment facilities. Many existing district heating grids are linked to waste treatment facilities or are considering district heating.
(sub-)Consumers	
VME	Collective buildings like appartements are obliged to have a VME (Vereniging van mede-eigenaars) or a syndicus who takes up collective tasks for the building. Often, collective buildings have some sort of collective heating installation for all inhabitants. With regard to district heating, in such case it is highly likely that the VME will be the contact point for the district heating operator.

Legal framework and operational context for these actors

Gas market Regulation

In April 1965, the "gas law" (Kruispuntbank Wetgeving, 1965), which regulates the transport of gas products through pipes (Federale overheid, 1965) in Belgium was developed. With the liberalisation of the energy markets, the EU set up some common rules regarding the transport, distribution, supply and storage of gas, the organisation of the gas sector, access to the market, obligations and the development of regulatory organisations who control the market. The European directives were transposed into the Belgian law of the 1th of June 2005 (Economie, KMO, Middenstand en Energie, 2005) and hereby changed the original gas law of the 12th of April 1965.

On top of this law, there is other regulation specifically regarding security and technical obligations of technical installations. Examples are:

- Royal Resolution (Koninklijk Besluit) of 19th of March 2017 regarding the security measures of the development and exploitation of installations for the transport of gas products and other by means of pipes. (ECONOMIE, KMO, MIDDENSTAND EN ENERGIE, 2017)
- Technical codes regarding design and construction, exploitation, risk analysis, management system for security

District heating Regulation

In Belgium, there is a division of competences between different regions (the Flemish Region, the Walloon Region and the Brussels Capital Region). As a result, there is no national policy with regard to DHC. Policies towards DHC and (renewable) energy policies are mostly regionalized and until recently, there was not really a clear framework for district heating. Only

since 2017, in Flanders, a heat- or cold network is defined in the Energy Decree as a set of interconnected pipes and the associated resources that are necessary for district heating or cooling, with the exclusion of networks on an industrial site (art. 1.1.3., 133/2°). District heating or cooling is defined in the Energy Decree as the distribution of thermal energy in the form of steam, hot water, or cooled liquids from a central production installation via a network that is connected to several buildings or locations, for heating or cooling of spaces or processes (art. 1.1.3., 113/1/1°).

Since April 1, 2019, the energy decree (Energiedecreet) has been amended to regulate the organization of the operation of heat and cold networks in the Flemish Region; and the energy executive order (Energiebesluit) has been adapted to regulate the organization of the operation of heat and cold networks and heat metering in the Flemish Region. This is mainly a response to the 2012/27 / EU directive of the European Commission on energy efficiency. Also, the decree regulating the role of the local advisory committee in the context of the right to minimum supply of electricity, gas and water (replacement decree 19 July 2013, art 3, I: 2 September 2013) and the supply of thermal energy (submitted decree on the 10th of March 2017, art. 2, I: 1 April 2019) adjusted so that it also became applicable for the supply of thermal energy (Flemish Government, 2019c). The same applies to the executive order of the Flemish Government regarding the composition and operation of the local advisory committee regarding the minimum supply of electricity, gas and water and the supply of thermal energy (submitted 1 February 2019, art. 1, implemented 1 April 2019). Note also that the requirements for heat meters are already laid down in the Royal Decree on measuring instruments (April 15, 2016). Finally, the VREG published on the 2nd of June 2020 an advice regarding changes needed due to Art. 9-11bis and appendix VIIbis of the Energy-efficiency directive of 2018/2002 and in the regulatory framework for heating, cooling and hot water supply through heat networks or through central production installations ("collective heating"). In this advice, the VREG is also highlighting potential changes needed in some of the current articles in the energy executive order (Energiebesluit) as they do not always have the desired impact. The advice is also giving suggestions for further, more transparent, and accurate calculations of individual heat consumption and the division of costs of thermal or hot water consumption. (VREG, 2020a)

A more detailed explanation of the most relevant heat regulations for Flanders can be found below:

- **The Energy Decree (Energiedecreet)** of the 8th of May 2009, which contains since March 2017 a framework regarding the organization of the operation of heat and cooling networks in the Flemish region (Title IV/1). (Vlaamse Overheid, 2009) It now explains what a DH or DC grid is, how residential consumers can be protected, what the role of a DH operator is (operation, development, measurements, communication on tariffs), and what the role of the heat supplier is (supply, invoice, social energy measurements, complaints management). It also details the tasks that the VREG receives. That is, the VREG is responsible to inform people about district heating, the buildup knowledge, to keep an overview over all networks and to advice regarding for instance the transposition of the energy efficiency directive. Finally, it also dictates specific technical obligations, among which heat metering. The framework is in implementation since April 2019. (Vlaamse Overheid, 2017)
- **The Energy Executive Order ("Energiebesluit")** of the 19th of November 2010, which was amended on the 1st of February 2019 regarding the regulation of the role of the local advisory commission in the framework of the right on minimum delivery of electricity, gas, and water and the delivery of thermal energy. (Vlaamse Overheid, 2017) The framework is in implementation since April 2019. The Executive Order is setting social energy measures, information obligations for suppliers, and other tasks of the DHC operators (such as reporting obligations).
- The rules regarding central heat meters (Energiesparen.be, 2021b) are mentioned in the **Royal Order of 15th of April 2016** (Federale overheidsdienst economie, K.M.O., middenstand en energie, 2016) regarding measurement instruments. It discusses the minimal requirements of such meters. In December 2016 (Vlaamse Regering, 2016), these new rules were also accepted by the Flemish Government and published in het Belgisch Staatsblad on the 23rd of January 2017.

Other District Heating Regulations

A recent study of (Loth, 2020) gave a very detailed overview of all regulations in Flanders that have an influence on district heating implementation. For a more detailed analysis we therefore refer to their study. For this report, we will give a concise overview of regulations that indirectly influence the possibilities to implement 5GDHC.

Flemish political vision and climate context:

- **Climate ambitions:** Flanders agreed to reduce its emissions to help reaching the European climate goals. However, Flanders (and Belgium in general) is not ambitious. Flanders' goal is to reduce their emissions of non-ETS (Emission Trading System) sectors by 2050 with 85% compared to 2005 (so not 100% compared to many other countries). In addition, to reach this target, Flanders is not on track as it acknowledges that it should do more efforts to achieve climate targets by 2050. Between 2005 and 2017, non-ETS emissions in Flanders decreased on average with 0,2 Mton CO2-eq/year. Yet, to achieve a reduction of 85% by 2050, an average reduction of minimum 1,1 Mton CO2-eq/year is needed. (Vlaamse Regering, 2019b)
- **Flemish coalition agreement:** The Flemish Government aims to achieve a long-term target by 2050 for housing renovation of (on average) 100 kWh/m². To do so, from 2021 onwards, new oil boilers cannot be installed anymore for new buildings and for serious renovations. Gas connections are for large new parcels or for large apartment buildings only allowed for collective heating via CHPs or in combination with renewable energy systems as main heating source. (Vlaamse Regering, 2019a)
  The Flemish government will prolong support for CHPs for 10 years. The current certificates for heat power savings will only gradually be reduced (with 30% by 2025) in line with evolutions of gas/electricity changes and other support mechanisms.
  Regarding renewable energy production, the Flemish Government has 2 important working points. One is focusing on electricity production, the second is focusing in making heat greener. In this framework, they will work out a heat plan and support local municipalities. They will also provide support for new deep geothermal projects.

Heat vision

In 2015, all Belgian regions and the Federal government agreed upon a division of the Belgian climate targets regarding renewable energy by 2020. To achieve the regional objectives, new measurements need to be taken and for heating more ambition was needed. With the new targets, 9.197 GWh green heat needs to be produced by 2020. Yet, with the existing policy measurements, Flanders would only produce 8.765 GWh. Therefore, in June 2017, the Flemish Government approved the **Heat Plan 2020** (Warmteplan 2020 (Vlaamse Regering, 2017b) to determine additional measurement in the short run to achieve the green heat targets.

In the longer run, the National energy- and climate plan 2021-2030 (Federale overheid, 2019), gives a continuous important role to district heating in Flanders. In the period 2017-2020, a yearly growth of 250 GWh/year in DH was planned and the plan is to continue this growth until 2030. This would imply that by 2030, 4000 GWh of heat is delivered by DH grids (compared to 600 GWh in 2017). The heat provided in DH grids consists for approximately 50% out of renewable energy sources in 2020 (in 2017, this was about 37%). Most of this heat is produced through geothermal energy (mostly deep, see further in the discussion on deep geothermal energy), heat pumps, biomass incineration and solar boilers. District heating is seen as a tool to further promote heat distribution of these renewable energy sources. In the following years, the goal is to reevaluate the call green heat, the EPB-regulation and the legislative framework to ensure there are sufficient incentives for green heat.

For 2025, and even 2030, a **new heat plan** is being developed to further increase green heat production. In the Flemish climate plan (Federale overheid, 2019), it is explicitly stated that it will almost always be more cost efficient to obtain impact on climate targets by having more green heat than through green power.

Nevertheless, for a good "heat vision", it is necessary that more concrete "spatial" plans are set up such as local heat plans by cities or municipalities. As can be seen in the next topic on spatial planning, this is currently not the case.

Spatial vision and/or development

Currently, no clear spatial vision regarding heating is present in Flanders. Yet, the actions documented below should lead to a more concrete heat vision in the short run.

In November 2016, the Flemish government sets up a "white book" for the **spatial development of Flanders** (Vlaamse Regering, 2017a). The document makes specific reference to district heating. Specifically, it mentions that 1) residual energy demand needs to be filled in by means of energy sources such as CHPs, heat pumps and/or DHC grids, and that the necessary space needs to be foreseen for these technologies; 2) energy exchange needs to be organized spatially by

bringing together functions in buildings, building blocks, areas, industrial sites…; 3) energy infrastructure needs to be bundled where possible, for instance by foreseeing underground pipe- and cable lanes; 4) the Flemish spatial policy is also largely focusing on seaports as these are important for Flanders. These ports have a large potential for residual heat which is acknowledge in the document. In general, to increase energy efficiency, the supply of residual heat through a district heating grid should be encouraged. 5) To increase energy efficiency, it is also important to look at existing areas, whereas currently, heat networks are mostly developed in newly build areas. Specifically, further goals should be to examine in the short run the possibilities for district heating. Concrete actions indicated in the document state that local governments will receive more means to further develop DHC grids, some strategic heat projects (such as energielandschappen 2.0 with the province of East-Flanders, feasibility study for DH in Limburg) and reinforcements of the seaports.
For the government period 2019-2024, **heat zone plans** (warmtezoneringsplannen) are being prepared based on data on energy consumption and -production, based on the availability of new or residual heat sources, based on the possibility to develop DHC grids, and based on the possibility of new decentral (and preferably renewable) heat production… (Federale overheid, 2019) This will help citizens and companies to make proper investment decisions. As indicated by the "stroomgroep", heat zone plans should for instance only encourage heat pumps in regions where no district heating will be developed (Stroomgroep hernieuwbare energie: groene stroom en warmte, 2019).
In line with this, the SERV also indicated in its vision document of 2019 that it is important to properly synchronize different measurements. That is, for instance in zones where district heating is/will be developed, to adapt the level of renovations of buildings to infrastructure plans. (SERV, 2019)

Finally, with regard to spatial planning, there are some instruments that are used to plan, control or restrict new infrastructural investments.

- The **Flemish Codex Spatial Planning (VCRO)**: this Codex regulates the use of the topsoil. It states whether certain functions are compatible with the planning destination. This is governed through the usage of Permit Requirements. Only under certain conditions, such a permit is not allowed. For instance, in case of "usual underground constructions", the installation/infrastructure is exempted from the permits. DHC grids are, however, not perceived as being "usual underground constructions". Similar rules apply to the necessity of having environmental permits for the construction of both above ground and underground structures. (Loth, 2020) The VLAREM environmental permit for instance put specific requirements on the application of geothermal projects. Geothermal projects are also subject to the so-called VLAREL regulations. The **VLAREM-rules** dictate that for certain permit applications, a cost benefit analysis needs to be performed to examine the usage of CHPs or residual heat (via district heating).
- **Regulations of other infrastructure companies** such as Water, Railways, Roads, Bridges… can also pose serious limitations to whether a DHC grid can be installed.
- The **Energy Executive Order** is stating that it is obliged to perform a feasibility study for new larger buildings (>1000 m²) to see whether alternative energy systems are feasible and cost-effective. In this context it is also required to check the connection to a heat network. The study is required for a zone of 500 meters from the designated locations on the Flemish heat map. (Loth, 2020)
- **Soil Decree, Vlarebo, Waste policy, Groundwater decree**: when making use of groundwater or the soil, it is necessary to ensure environmental quality standards are maintained.

Other regulations impacting District Heating

- The **EPB sets rules and regulations**, which determine how energy efficient buildings should be, are not favorable for DHC grids. Within the EPB-methodology, specific attention is given to heat delivery, but also to the generation of energy. As such, EPB is having an influence on the type of heating and generation technologies that are used. Specifically, when DHC grids do not make use of renewable energy sources, EPB is punishing the system. Nevertheless, in a lot of cases, DHC grids start with non-renewable energy sources to evolve later to more renewable sources. Furthermore, DHC grids are punished for heat losses that they have through the piping system and for the electricity usage of circulating warm water in the grid.

Current organization of heating markets

Gas market

The Belgian gas market is split up in 3 regions (Flanders, Brussels, and Wallonia). Since the liberalisation of the energy market (gas and electricity), transmission, distribution and supply of gas are split up between different actors. These actors and their roles are discussed in the table above. Before the liberalization of the gas market, the entire market was managed by Distrigaz. The European Directive 2003/55/EG of the 26th of June 2003 was transposed into the Belgian law of the first of June 2005 who changed the original gas law of the 12th of April 1965. Originally, the gas sector was fully vertically integrated ("bundled"), implying that production, input, transport, distribution and supply of gas were taken up by one actor. Since January 2007, transport and distribution of gas are disconnected (unbundled) from all other activities in Belgium (in Flanders, this is already the case since June 2003). This led to more competition in the sector. Gas suppliers can buy gas through gas producers directly, or on the gas stock market. (FEBEG, 2021a) As such, only the transport and distribution of gas remain a monopolistic activity where no competition is possible. All other activities are liberalized and open to all (qualified) actors.

District heating

Flemish regulation does not require unbundling and one party is allowed to take up multiple roles. In addition, no permits are required to execute the role of heat supplier or operator. It is therefore sufficient if the roles are clearly determined in the contractual agreements of the DH grids in Flanders. As such, everybody can take up these roles if they follow the obligations stipulated by law.

- Specifically, for Flanders, this implies that, currently, many stakeholders take up multiple roles at the same time. As such, there is no pure unbundling in Flanders. In most cases operation of the heat grid and supply of heat is done by the same party. This was the case for 49 of the 56 DH networks that we registered by the VREG in April 2019 (see Table 1 in the report of (VREG, 2020b)). This is in part also caused by the fact that district heating grids in Flanders are only of limited size.
- In case a district heating grid is supplying collective residential buildings (apartments), in most cases two heat suppliers exist. The first heat supplier supplies heat to the building and has a contract with the VME. Afterwards, the VME supplies the end-users behind the building meter. Recently, in line with the European Directive on Energy-efficiency, it is regulated by law what the rules are for the division of such heat costs between different end-users in the same building. This is leading to additional obligations for the VME who is seen as a heat supplier. In addition, VREG is indicating that it is in such schemes not clear who is responsible for which part of the network as there is no clear definition of where the DH grid stops. This is important for responsibility regarding maintenance of the grid, but also when it comes to consumers who are not paying their invoices.
- Finally, there are some rare cases where multiple heat network operators and heat suppliers are acting on one network (Bocholt (DH Bocholt – DH Scholen van Morgen Bocholt) and in Roeselare (DH MIROM –DH St.-Idesbald, Subnet Het Laere)). As indicated, juridically, this is allowed, but VREG indicates in it heat network report of 2020 that it is important to question whether (for Flanders) this is an efficient organizational model as it complicates, for instance, transparency in cost division (VREG, 2020b).

On top of this analysis of a possible distinction between distribution and supply, the Interreg HeatNet NEW project notices that within Flanders, depending on the heat source, there is a separation between heat production and distribution. Specifically, in case of industrial waste heat delivery to a residential neighborhood, or in the case of a geothermal source which is connected to a district heating grid, the heat producer is not operating the grid itself. (Interreg North-West Europe HeatNet NWE, 2019)

With regard to third party access, Art. 4/1.1.5. states that the Flemish Government can set obligations with regard to service provision to heat- or cold suppliers who have access to the grid. In this regard, they refer to potential obligations regarding the timing of delivery of measurement data, connection information… Third-party access is therefore allowed, but not facilitated.

Finally, even though the current heat market is freely organized, it should be pointed out that the Flemish Government in its coalition agreement 2019-2024 indicated that it is important to examine how the development and exploitation of district heating can be organized in an efficient way. (Vlaamse Regering, 2019a) Warmtenetwerk Vlaanderen is worried about this statement as it might open doors to allow for a monopoly in the development and exploitation of heat networks in Flanders. Previously, Fluvius, already aimed to convince municipalities to give them the right to exploit heat networks in their municipality. (Warmtenetwerk Vlaanderen, 2020)

3.1.2. Developments in heating policy and market contexts

These issues have been addressed in the previous section.

Current developments in the legal system and market organization

As there have been recent changes in the legislation with regard to DHC grids, there are currently no concrete plans for further development of the legal system and/or market organization.

Expected developments in terms of energy transition policy or market transformations to accommodate green energy

Keeping in mind the European ambitions, it goes without saying that Flanders will move towards a greener region with more attention to renewable energy. However, today, developments in renewable energy are often not facilitated. While "plans" and "climate targets" are present, such plans are often vague and limitedly concrete, which often creates challenges to reach climate targets. Furthermore, some of the plans mentioned, are not always executed (such as the heat ambassador which was proposed (see further)).

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

As DH in Flanders is very specific and unique from region to region, the legislative framework remains very open. A lot of technical obligations are not regulated in the first district heating framework. The legislative framework is, however, clearly defining market roles and responsibilities. These roles can be taken up and combined by different actors. Everybody can take up these roles if they follow the obligations indicated in the framework. The VREG is responsible for supervising whether the legislation is followed properly, and for controlling whether heat and cold suppliers have an appropriate service delivery.

Specifically, the Energy Decree ("Energiedecreet") is stipulating the role of the DH operator and heat supplier.

- DH operator (operation, development, measurements, communication on tariffs),
- Heat supplier (supply, invoice, social energy measurements, complaints management).

Regarding technical aspects, as discussed earlier, the energy decree is discussing technical aspects of metering.

3.2.2. Ownership and operation of district heating systems

As explained earlier, the market for DH is very open in Flanders. DH grids can be owned and operated by any party. In Flanders both private as public parties are playing their role regarding DH grids.

About property rights, there are, however, a couple of regulations to take into account when a DHC-grid is installed on municipal lands. These are in more detail discussed by (Loth, 2020). First of all, there is a distinction based on whether the initiator of the installation of a DHC-grid is a private party or the government is. In case it is a private party, the same rules apply as for the installation of telecom cables. That is, the initiator needs to get easements on the public domain owned by the government. In case the government is the initiator, a concession is required for public works in the utility sector. Such concession can involve various sub-assignments (design, construction, operation…). (Loth, 2020) In case a DHC-grids passes over private property, business agreements must be made with each landowner. Acquiring the rights to go over the different private plots has proven to be very complicated in practise (Loth, 2020).

Specifically, when it comes to specific heat sources, such as geothermal heat, ownership of the heat sources also needs to be examined. Generally, it can be said that in case the geothermal heat is positioned above 400-500 meter, then the owner of the geothermal heat is the owner of the property on the surface. In case that the geothermal heat is situated deeper, than the heat is property of the Flemish Government. (Loth, 2020)

3.2.3. Regulation of price setting

Since January 2020, the federal government sets a social heat tariff for vulnerable customers connected to a district heating grid (Dierick, 2019). There is no other heat price regulation in Flanders (nor in Belgium) regarding district heating. Heat suppliers are free to set their own tariffs. Nevertheless, there seems to be a "Dutch" influence in the sense that one often refers to the NMDA-idea. Stakeholders generally tend to compare with tariffs for alternative fuels. Nevertheless, as heat is supplied at different pressures and temperatures, it is harder to compare.

About tariff setting when there is third party access, the energy decree, Title IV/1, Chapter I, section III, Art. 4/1.1.3. states that when "the grid operator does not act as a supplier of thermal energy, he defines the tariffs and conditions through which a third party who wants to deliver thermal energy can get access to the grid". Section IV defines public service obligations that the district heat- or cold grid operators have.

3.2.4. Role of building owners and building occupants

Deciding the heat source of the building

In case of single-family buildings, the decision for the heat source is most often taken by the building owner. In cases where such single-family buildings are developed during a larger real estate project where a full region is being developed, it might occur that the project developer chooses the heat source. In the latter case, local municipalities might also have their say in case they already developed a vision on heat zones.

In the future, heat zone plans will be developed by the local governments / municipalities and the decisive influence on the heat source choice will not remain solely with the building owner.

In case of multi-family buildings, Flemish buildings are obliged to have a VME (Vereniging mede-eigenaars) who represents all building owners. It is the VME who takes decisions regarding changes in the heating system, although the owners still have voting rights. A minimum majority of owners needs to agree before a decision is taken.

Investments and energy bill

As indicated in the section on market organization, the energy bill is paid by the end user. However, it is possible that in case of multi-family buildings, the VME or another third party has a contract with the heat supplier. In that case, the VME pays the heat supplier, and charges the end-consumer afterwards to retrieve the money.

Investments are in the end also paid by the end-user. Nevertheless, pre-financing might be done by the VME, by a project developer, or by a cooperation.

3.2.5. Financing and subsidies

Localized subsidy or grant mechanisms available

D.T2.1.2 will discuss options for financing in more detail. For Flanders, only the most relevant financing mechanisms are summed up below.

Since December 2013, Flanders has a yearly call for green heat, residual heat and district heating (e.g., call "green heat"). Most of the budget of this call goes to district heating and residual heat projects. For instance, for 2020, the budget for the call was approximately 10 million euros, of which about 70% goes to DHC projects (Energiesparen.be, 2021a).

In the National climate plan, Flanders is highlighting a number of financing tools it aims to continue for the following years:

- About 1,1 billion euro per year are reserved for green energy certificates for renewable energy production
- Cheap or rent-free loans are given for specific target groups (55 million euro/year)
- Distribution system operators are given subsidies for solar boilers (4 million/year), for heat pumps (3 million/year), and for heat pump boilers (1,8 million/year).
- …

In addition, there are other specific subsidies for green heat such as (Agentschap Innoveren & Ondernemen, 2021):

- Heat power certificates (warmtekrachtcertificaten)
- Ecologiepremie+
- Strategische ecologiesteun

3.3. Available energy sources and storage

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the

highest-ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low-grade sources would be to make a decent 5GDHC business case.

In what follows, we go through the preference scale of D2Grids and examine the existing situation of energy sources, together with possible planned changes to existing sources and planned additions to these sources. Some side notes need to be considered when going through the ranking below. First of all, at the time of writing, D.T1.1.4 has not been finalized, therefore the ranking is conditional. Secondly, it is likely that not for all energy forms in the ranking, data are available on a local or regional level. Finally, the time horizon for this study are projects that are being developed in the period 2022-2025, with a lifespan of approximately 30 years. In case projections of energy sources in the future are available, a distinction will be made between the existing situation and the planned changes to these sources.

Even though the number of heat networks is still small in Flanders, a wide variety of heat sources are already used today. This can be seen on the figure below. Biomass and gas are the most used heat sources in Flanders.

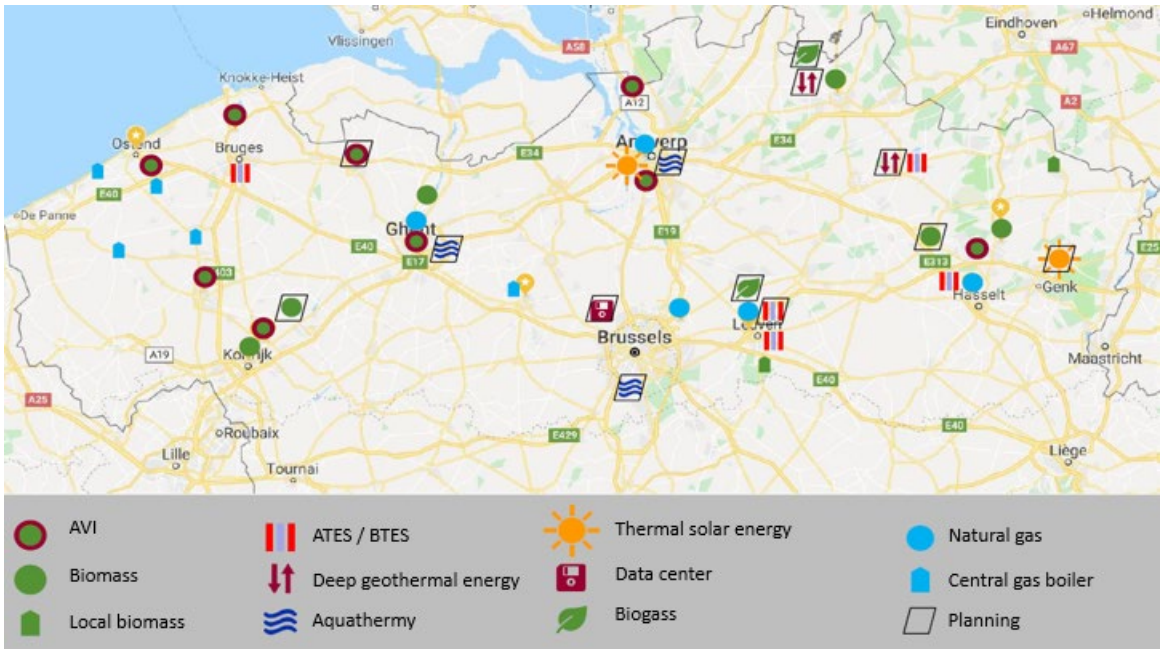


Figure 2 – Current heat sources used in DH grids in Flanders (presentation Warmtenetwerk Vlaanderen on the launch event of FlexHarvester, 2020)

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

The core idea behind 5GDHC is to facilitate energy exchanges between local buildings. For instance, if one building is producing heat for its own consumption, it automatically also creates cold which ideally could be supplied to a nearby building. Ideally, as much local energy should be reused to minimize any possible type of energy losses. Analyzing the potential of these types of energy exchange is, however, not possible on a regional scale. It highly depends upon the project, and detailed buildings consumption and production data, for different time periods, are needed. Its potential highly depends on the design of the network and the type of users involved. Ideally, a good mix of consumers should be present, so that their energy flows and needs are complementary.

Making all building data available to evaluate beforehand such potential, might be a possible action point to take up in the action plan. It is important that all demand and supply profiles can be compared, as this might provide incentives for complementary sectors to join the new site.

3.3.2. Ambient thermal sources from soil, water, air, and low temperature solar heat & low grade thermal storage possibilities

Another potential energy source highly suited for 5GDHC grids are lower temperature, renewable heat sources from soil, water, air, and sun.

(Bertermann et al., 2015) analyzed the pan-European very shallow geothermal energy potentials. Very Shallow Geothermal Potential is basically solar heat that is stored in the shallow underground (up to 10-meter depth) (both BTES and ATES). The figure below (Figure 3) illustrates that for Belgium, there are quite some areas with a very high heat conductivity potential. Nevertheless, in some of these areas there are also limitations or restrictions for the implementation of shallow geothermal energy (see stripes in the background). Such limitations are caused, for instance, by protected zones, unsuitable soil types (Histosols, Cryosols, Leptosols, Gleysols, Planosols) or soil slopes >15°C. In Figure 3, heat conductivity is expressed in Watts per meter*Kelvin. Red zones are 'highly suitable' and orange zones are 'very suitable'. Yellow zones, which take up the majority of Belgium, are 'suitable', which is still better than the blue zones with are 'limited suitable' or 'less suitable'. For Belgium it shows that in most regions there are suitable options for shallow geothermal energy.

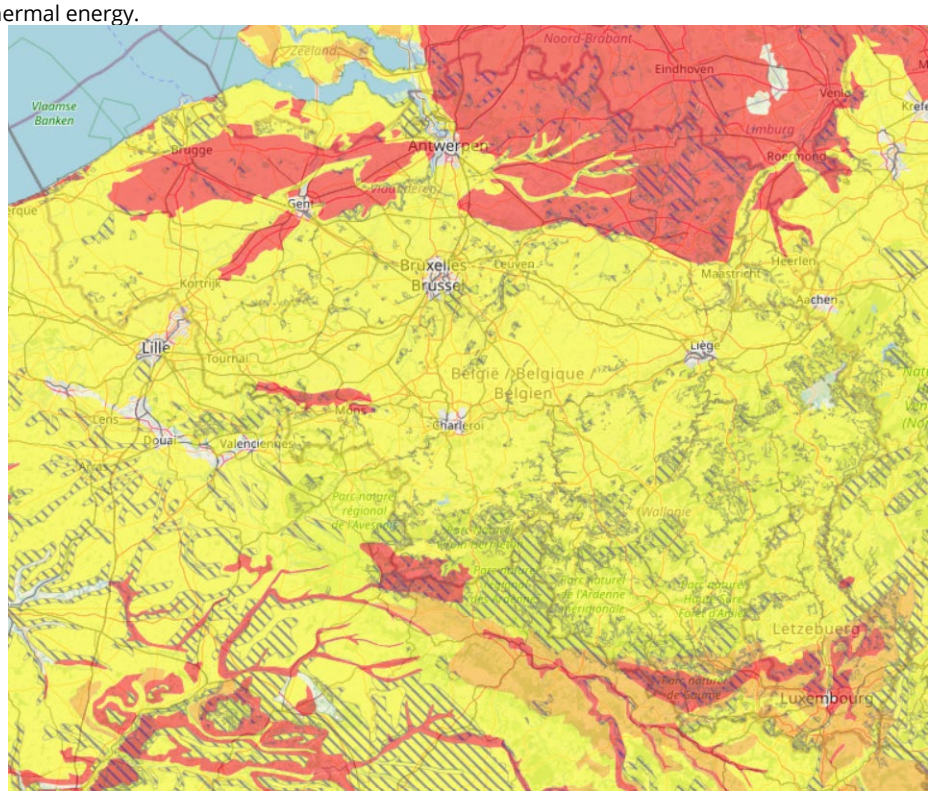


Figure 3 - Printscreen TermoMap Belgium (Heat conductivity legend: red (>1,2 W/mK), orange (1,1-1,2 W/mK), yellow (1,0-1,1 W/mK), light blue (0,9-1,0 W/mK), dark blue (<0,9 W/mK), stripes in the background: limited usage area).

When comparing the potential for shallow geothermal energy with its current implementation in Flanders, it appears that there remains a lot of unused potential. In Flanders, only 0.43% of the total gross consumption of heating and cooling in 2018 was delivered through heat pump applications. Of all the green heat, 8% comes from heat pumps (Statistiek Vlaanderen, 2020a). In total, in 2019, there were in the whole of Belgium 337.397 heat pumps. Only 15.804 of these were ground source heat pumps. All the rest were aerothermal heat pumps. For the foreseeable future, it also seems that the growth trend continues in favor of aerothermal heat pumps. Most heat pump installations in Belgium remain air-air heat pumps (94.380 in 2019). In 2019, there were only 2.595 geothermal (ground source) heat pumps. The latter is, however, a significant increase compared to 2018, where there were 1.872 geothermal (ground source) heat pumps. (Eurobserv-er, 2021)

Heat pumps in Belgium are therefore increasing their market share but remain only a very small portion of the heating and cooling production. Solar boilers as well only take up a small proportion of the heat generation. Currently, solar boilers produce about 0,89 PJ in Flanders (on a total of 33,11 PJ green heat). This is less than 3% of the total green heat. (Vlaamse Overheid, Departement Omgeving, 2020)

In Table 1, the expected growth in total green heat can be seen for 2030. Heat pumps will double their efforts. Yet, both solar boilers and heat pumps remain limited in size. By 2030, together, they would generate about 18% of the green heat in Flanders.

Table 1 - Targets for usage of renewable energy for heating and cooling in Flanders with regard to heat pumps and solar boilers (data from Milieurapport (2020) (Vlaamse Overheid, Departement Omgeving, 2020))

PJ	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Goal 2020	Goal 2030
Heat pump (boilers)	0,22	0,26	0,31	0,39	0,49	0,6	0,72	0,83	0,94	1,08	1,24	1,64	2,2	5,24
Solar boilers	0,11	0,17	0,19	0,22	0,25	0,29	0,45	0,5	0,55	0,6	0,63	0,65	0,89	1,03
Total green heat target	33,11	33,11	33,11	33,11	33,11	33,11	33,11	33,11	33,11	33,11	33,11	33,11	33,11	34,88

Furthermore, as discussed by (Loth, 2020), in Flanders there are also options for aquathermia. Aquathermia can be done in open waters or in municipal sewer systems (that is riothermia). In case open water are used for cooling water, a cooling water fee for the usage of river water needs to be paid per m³ of water. In case of riothermia, it depends from one local situation to another to see whether it is possible and allowed.

Low grade thermal storage possibilities (such as flooded underground infrastructure, and natural and artificial aquifers)

When looking at geothermal storage applications, as can be seen in Figure 4, a first distinction is made based on the temperature that needs to be reached. Higher temperatures can only be reached in the deeper underground and are part of the discussion in the next section. This section focusses on lower temperature applications.

When it comes to thermal storage systems, making use of shallow geothermal energy (50-150 meter approximately), offering both heating and cooling, the number of applications has been rising throughout the years. Depending on the application and geological characteristics, both BTES (closed system making use of a borehole - BEO) and ATES (open source system, making use of aquifers - KWO) are used. To see whether the soil is appropriate for such applications, it is necessary to have an overview of locations that have suitable ground layers from which water can be pumped up (often limestone and sandy underground).

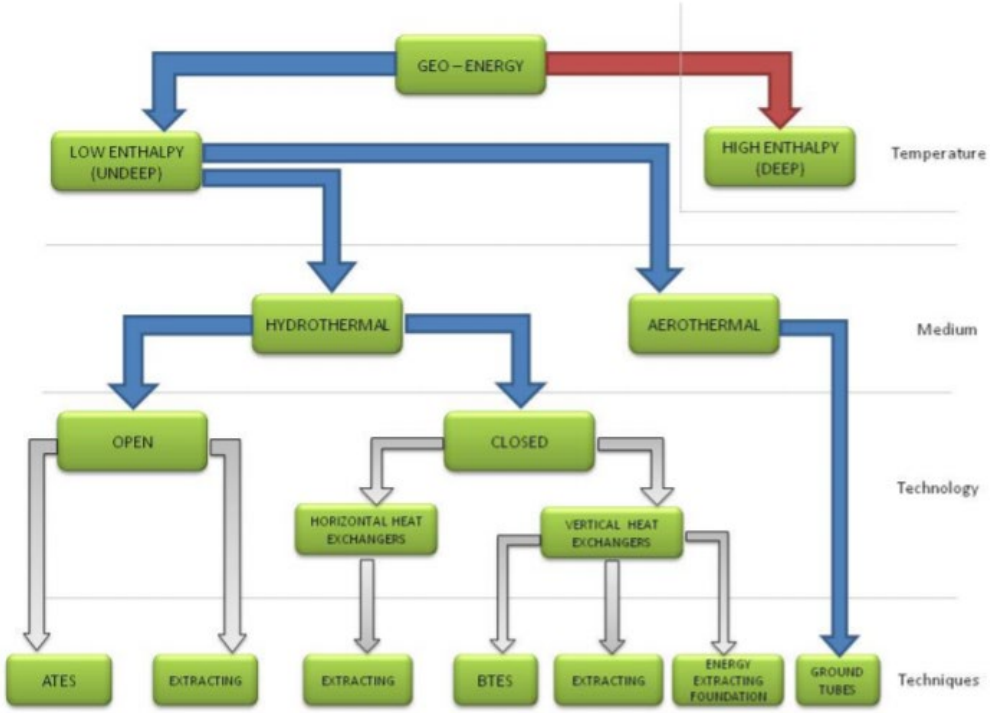


Figure 4 - Overview of geothermal energy sources (source: VITO beknopte wegwijzer, geothermie in België (De Boever et al., 2012))

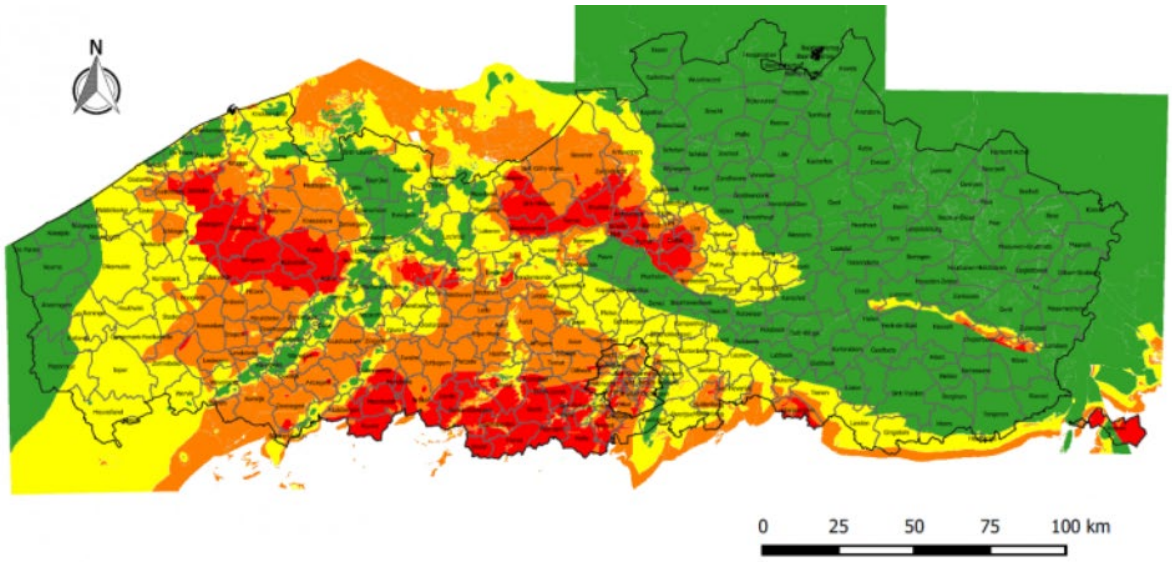


Figure 5 - Potential for ATES in Flanders (source (LATENT, 2021))
* red- ATES is not possible (T<50m²/day)
* orange-ATES might be possible (50 m²/day =< T < 125m²/day), a site-specific study is necessary
* yellow-ATES is probably possible (125 m²/day =< T < 250 m²/day)
* green-ATES has a high potential (T>= 250m²/day)

For shallow geothermal systems that make use of open aquifer systems (ATES), it appears that the North-East and the East part of Flanders is suitable (see Figure 5). In other regions, such as the West and the South of Flanders (Gent, Brugge,

Oostend), which have a sub-ground that contains more clay, BTES systems which are not dependent on natural aquifers would be an alternative. (De Boever et al., 2012)

The company Terra Energy indicates on her website, that they have over 150 ATES and BTES projects spread out over Belgium. Some of their projects are summarized on their website (TerraEnergy, 2021). ATES and BTES systems allow for both heating and cooling in buildings, and they provide seasonal thermal energy storage. Ground sourced heat pumps are used in winter to extract the heat from the soil.

Finally, Belgium has a mining history, and could therefore also make use of underground flooded mining infrastructure. While most mines were in the Walloon region, in the Kempen in Flanders, in the province of Limburg (Beringen, Zolder, Genk, Maasmechelen) had a number of mines (belgischesteenkoolmijnen.be, 2021). In Genk, in the mines of Winterslag and Waterschei, in the past the thought was raised to use the water from the flooded mines to provide heating to new residential areas in the area. However, until now, such plans have never been pursued (Lemmens, 2018).

3.3.3. Higher temperature renewable sources like geothermal, solar heat

Deep geothermal energy in Flanders is still very limited and estimations regarding the potential of deep geothermal energy in Flanders are therefore mostly theoretical. Currently, it is hard to find an interesting business case for deep geothermal projects and Flanders is therefore mostly working with pilot projects to gain further insights in the geothermal potential of the region. Specifically, within Belgium, a large part of Antwerp, Henegouwen and Limburg consists of aquifers in the deeper underground with an appropriate temperature for space heating. In the Belgian underground, temperature increases approximately 30°C per kilometer (starting temperature is approximately 10°C at the surface). As such, to reach a minimum temperature of 25°C, it is necessary to drill at least 500 meters deep.

Vranckx et al. (2015) developed an optimization model for geothermal energy in the EFRO-project GEOTHERMIE2020 and indicated on the map below the maximal potential of thermal energy in the different North-Eastern Flemish regions. The study indicated that these results are with a certainty of 50%.

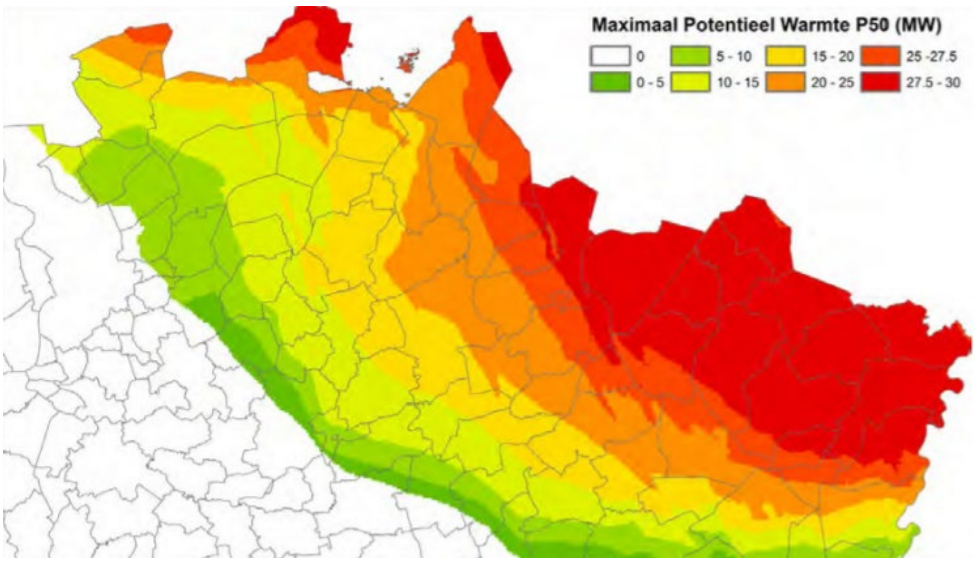


Figure 6 - Geothermal potential Flanders (expressed in MW capacity and with a 50% certainty) - source Vranckx et al. (2015) (Broothaers et al., 2017)

In Flanders, there are 2 pilot projects on geothermal energy: the Balmatt-site in Mol, and Janssen Parmaceutica N.V. in Beerse. Nevertheless, the government is assuming that by 2030, there will be about 12 installations with deep drilling between 500 and 3,500 meters, connected to a district heating grid. However, this estimation will be adapted based on the evaluation of two running geothermal projects. (Broothaers et al., 2017)

Table 2 - projected green heat production per technology in the national energy and climate plan (Federale overheid, 2019)

Generation (GWh)	2020	2025	2030
Solar	193	233	287
Heat pumps	610	905	1,455
Geothermal energy	**95**	**345**	**594**
Biomass residential households	3,850	2,900	1,950
Biomass other	3,841	4,621	5,401
Total	**8,589**	**9,122**	**9,688**

With regard to high temperature solar heat, the energy company AZTEQ (AZTEQ, 2018), located in EnergyVille (Thor Park Genk) is installing the first pilot installations for solar mirrors in Ostend, Genk and Antwerp (concentrated Solar Power). Such solar mirrors produce green heat at temperatures up to 400°C. This heat can be used by industrial and large companies. The technology has not been implemented previously in Flanders (nor in Belgium). The Flemish Government offered 819.000 euros in subsidies to the project. In total, the three installations will produce 1.390 MWh additional green heat per year. In Ostend, the heat will be used for the chemical company Proviron (which needs heat at a temperature of 180°C). In Antwerp, the heat is used in a company in the port (ADPO from Kallo). They need heat at a temperature of about 140°C for the storage of liquids. The third installation is used at the science park of Thor Park where the heat is used for experiments (in the laboratories) regarding ORC-installations. Potentially, the heat would also be used for heating the DHC grid that will be installed in the future.

3.3.4. Higher temperature industrial waste heat, otherwise rejected in the environment

Regarding industrial waste heat, in 2015, a study was performed by VITO that made waste heat from different industries in Flanders. The study indicated that spread out over Flanders, but mostly in the neighbourhood of the Port of Antwerp, there are numerous suppliers of waste heat. The following maps (Figure 7 and Figure 8) indicate waste heat below and above 120°C (medium and high temperature waste heat).

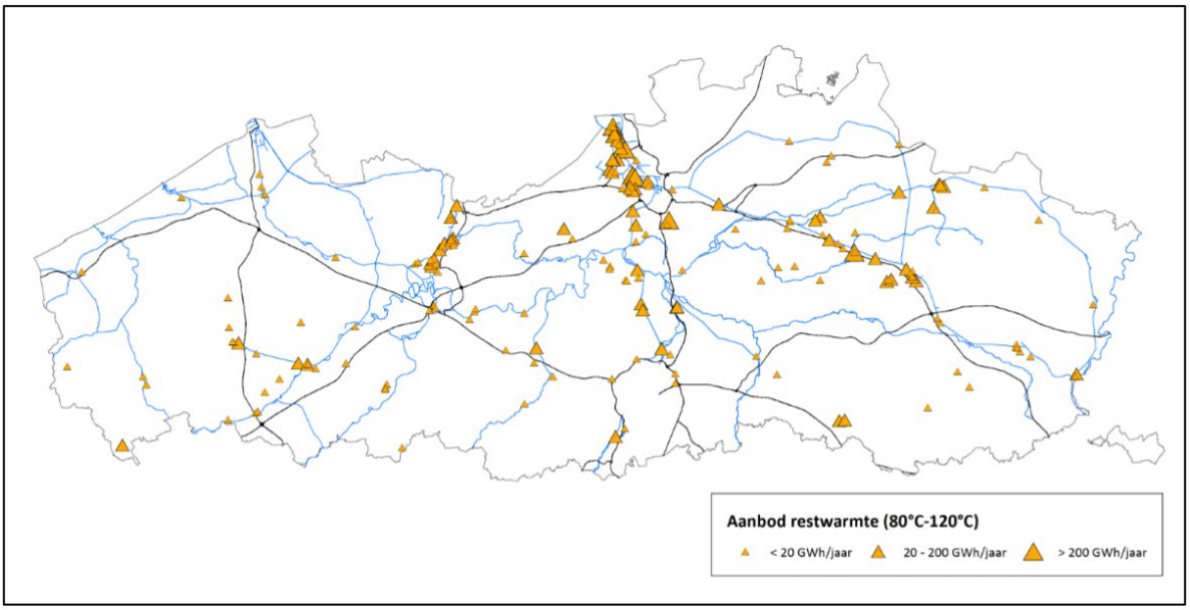


Figure 7 - Availability of residual heat <120°C from large industry, in 2012 (GWh/year) (source: (Renders et al., 2015))

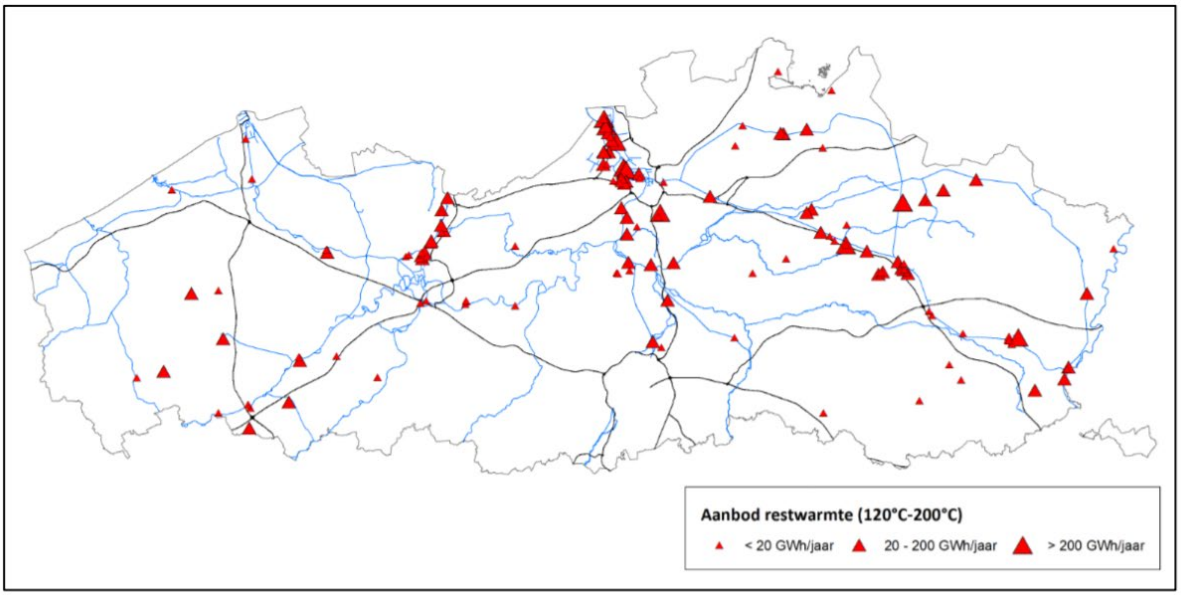


Figure 8 - Availability of residual heat 120-200°C from large industry, in 2012 (GWh/year) (source: (Renders et al., 2015))

Table 3 - Heat demand and residual heat per industrial sub-sector in Flanders in 2012 (source: (Renders et al., 2015))

	Heat demand (GWh)	Supply residual heat (<120°C GWh)	Supply residual heat (120-200°C)
Refinery	17300	900	900
Iron and steel	4300	0	4300
Non-ferro	1500	200	800
Chemistry	33600	4900	4900
Minerals	2100	600	1400
Food	5600	500	0

The table above shows the results of the industrial sub-sectors in Flanders that offer the most residual heat in Flanders. It should be noted that the amount of residual heat indicated in the table, is not necessarily heat that can be supplied externally, as some of the waste heat will be used through the companies internally. The study also showed that there are large differences between the different supply opportunities of the different companies. Individual potential supply of waste heat can vary from 0 TWh to about 3,5 TWh. In total, about 23 of the 384 companies offer 73% of the total residual heat in the industry in Flanders. (Renders et al., 2015)

For Flanders, the study analyzed which regions were suited for DH grids, based on the assumption that residual heat was transported to the neighboring areas. In that case, the following map was obtained. An important assumption when making this map was that there was government support for sharing waste heat. In case this support is not available, the number of district heating grids with a positive profitability decreases with about 50%.

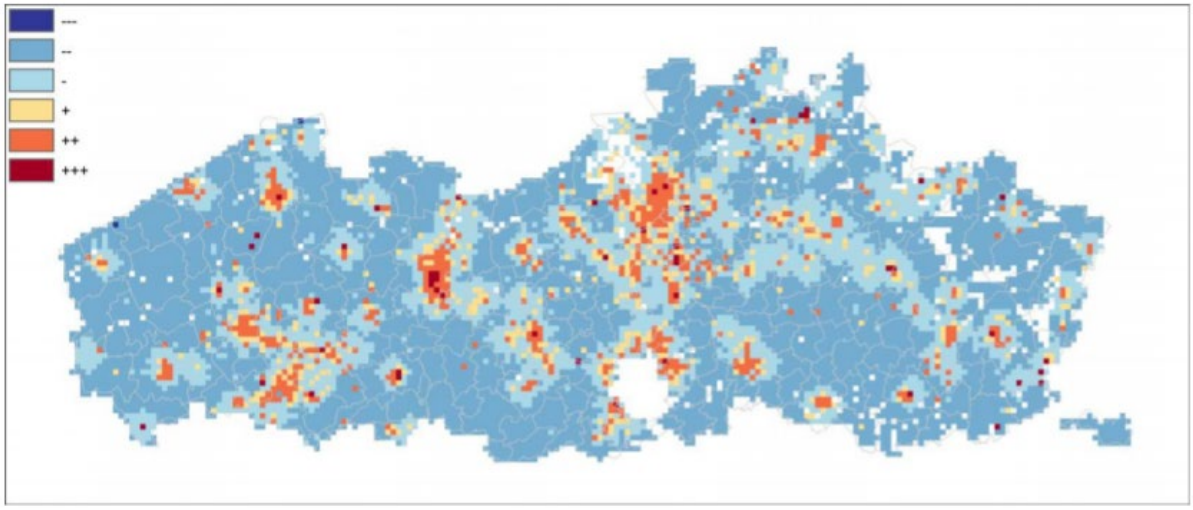


Figure 9 - Benefits of a DH grid (incl. investment support) if residual heat is transported to nearby cells (source: (Renders et al., 2015)

Most likely, the map above gives an overview of regions where 5GDHC grids are not suited due to the fact that in these regions higher temperature sources and demands are available. Furthermore, (Loth, 2020) emphasized that for proper planning, a map of higher resolution is necessary. In this regard, the "Pan-European thermal atlas" could be more useful, but, even there it remains necessary to get access to local data on heat sources and demand. Such open source data are, however, not always available.

3.3.5. Renewable electricity from local sources like wind, sun

Where possible, 5GDHC aims to make use of local renewable electricity sources to use local electricity to drive heat pumps in the system. As such, it is important to also analyse which regions have a lot of local electricity to place 5GDHC more in their proximity.

For Flanders, however, it seems that 5GDHC should not look at existing installations to determine the position of their grids. First, there is currently not yet a lot of renewable energy in Flanders. From 2005 to 2018, the proportion of renewable energy in the total Flemish gross energy consumption increased from 1,9% to 6,9%. These numbers take into account the usage of renewable energy sources for green electricity, heating, cooling, and transportation (such as biofuels). Looking only at green electricity, in 2018 the gross green electricity production was about 8.525 GWh (which is about 14,2% of the gross Flemish electricity consumption). Nevertheless, it should be pointed out that in Flanders, a large proportion of green electricity is produced through bioenergy. As can be seen on the graph below (Figure 10), over the last decade, there has been a significant increase in renewable energy from solar and wind.

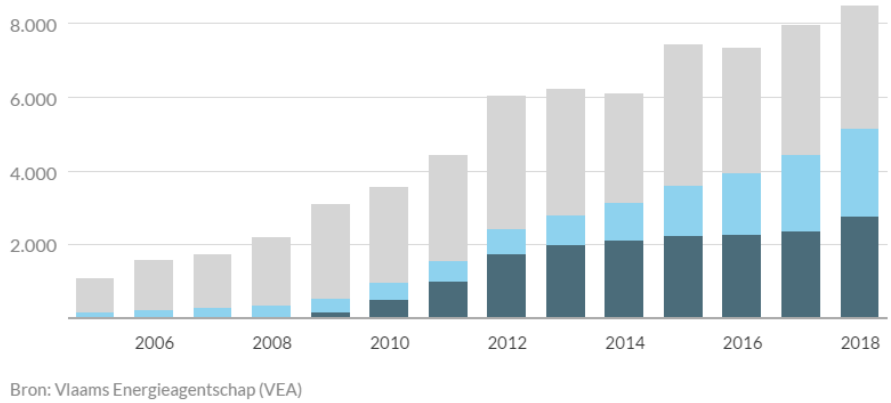


Figure 10 - Green electricity production (GWh) per renewable energy source for the Flemish Region (source: (Statistiek Vlaanderen, 2020a))

*Dark blue: solar energy
*Light blue: wind energy
*Grey: bio energy

Secondly, even if a lot of solar energy is available at a specific building, it should be pointed out that in a lot of cases this energy might be dimensioned to the own consumption of the building, and there might not always be a lot of additional energy available.

As such, it is important to look at areas where there is still a lot of potential to install solar installations. In order to look in more detail at solar energy options on a local level, Flanders has a solar map that estimates what the potential of solar energy (both solar panels and/or solar boilers) is on Flemish roofs (2,5 million roofs approximately). The map combines weather data of the KMI, together with building data on surface and orientation of the roof. For each roof in Flanders, it is estimated the potential for solar energy per roof. On this website https://www.energiesparen.be/zonnekaart, the reader can find an elaborate list of all Flemish municipalities, their potential capacity for solar energy, the number of existing solar installations and the capacity that is currently installed. In Table 4, only the top 20 municipalities are ranked (of a total of 308 municipalities). In total, the average Flemish utilization rate of solar installations compared to their potential, is only 4,4%. As such, there is still a lot of unutilized potential in Flanders.

In addition, for 5GDHC it is also interesting to look at the local solar production in center cities (centrumsteden) in Flanders. As indicated on the map with the potential for DH grids, these cities might not be the best place for 5GDH as there is a lot of high temperature heat available. However, also from a perspective of available solar energy, it seems that these cities are not frontrunners with regard to solar energy (see Table 5).

Table 4 - ranking top 20 municipalities with solar installations on building roofs (source: (energiesparen.be, 2021))

Ranking in Flanders	Municipality	Province	Potential capacity (in MW)*	Corrected installed capacity (in MW)**	Utilization factor (in%)*	Number of installations	Number /1000 inhabitants	capacity/ inhabitant (in W)
1	Dilsen-Stokkem	Limburg	191,98	20,10	10,5%	1557	76,66	989,47
2	Opglabbeek	Limburg	134,22	13,99	10,4%	1118	108,35	1356,06
3	Wijnegem	Antwerpen	75,13	7,73	10,3%	395	40,89	800,11
4	Heusden-Zolder	Limburg	229,71	22,99	10,0%	2445	73,74	835,23
5	Lommel	Limburg	331,59	29,12	8,8%	2861	84,16	944,93
6	Hechtel-Eksel	Limburg	92,70	7,41	8,0%	1226	99,87	603,53
7	Niel	Antwerpen	45,00	3,57	7,9%	378	36,93	348,49
8	Nieuwerkerken	Limburg	75,03	5,92	7,9%	625	90,04	852,80
9	Diepenbeek	Limburg	142,71	10,92	7,7%	1776	93,05	572,10
10	Kinrooi	Limburg	134,74	10,26	7,6%	1278	104,10	835,76
11	Temse	Oost-Vlaanderen	235,76	17,72	7,5%	1611	54,58	638,75
12	Meerhout	Antwerpen	85,68	6,38	7,4%	886	86,39	622,26
13	Lummen	Limburg	163,74	12,17	7,4%	1341	91,46	830,23
14	Boom	Antwerpen	102,80	7,59	7,4%	414	23,27	426,65
15	Geel	Antwerpen	359,21	26,18	7,3%	2983	75,40	661,77
16	As	Limburg	48,12	3,49	7,2%	644	78,44	424,83
17	Neerpelt	Limburg	119,42	8,61	7,2%	1490	86,99	502,63
18	Bekkevoort	Vlaams-Brabant	76,68	5,52	7,2%	469	76,46	900,66
19	Dessel	Antwerpen	91,68	6,54	7,1%	878	92,16	686,38
20	Houthalen-Helchteren	Limburg	248,65	17,66	7,1%	2092	68,36	577,09

*On roof parts where the measure solar radiation is larger than 1000 kWh/m²/j

**Data from the DSOs until 31/03/2018, reduced with the capacity of known ground installations of a minimum of 750 kW

Table 5 - ranking cities in Flanders with solar installations on building roofs (energiesparen.be, 2021)

Ranking in Flanders	Municipality	Province	Potential capacity (in MW)*	Corrected installed capacity (in MW)**	Utilization factor (in%)*	Number of installations	Number /1000 inhabitants	capacity/ inhabitant (in W)
35	Genk	Limburg	602,18	39,26	6,5%	2847	43,15	595,02
74	Hasselt	Limburg	532,06	29,33	5,5%	4099	53,15	380,33
88	Turnhout	Antwerpen	320,42	16,65	5,2%	1489	34,26	382,95
109	Sint-Niklaas	Oost-Vlaanderen	576,14	27,58	4,8%	3423	45,02	362,82
112	Herentals	Antwerpen	262,46	12,39	4,7%	1387	49,89	445,66
135	Aalst	Oost-Vlaanderen	609,46	26,89	4,4%	3865	45,55	316,87
160	Roeselare	West-Vlaanderen	700,92	28,89	4,1%	3704	60,07	480,68
174	Brugge	West-Vlaanderen	944,40	36,84	3,9%	4246	35,93	311,68
189	Kortrijk	West-Vlaanderen	692,37	25,66	3,7%	3666	48,40	338,87
195	Gent	Oost-Vlaanderen	1.747,62	63,65	3,6%	6848	26,43	245,66
220	Mechelen	Antwerpen	484,58	16,49	3,4%	2325	27,14	192,48
247	Oostende	West-Vlaanderen	427,43	13,22	3,1%	2048	28,85	186,18
248	Leuven	Vlaams-Brabant	504,95	15,53	3,1%	2935	29,26	154,84
260	Antwerpen	Antwerpen	2.290,09	66,01	2,9%	5460	10,49	126,83

*On roof parts where the measure solar radiation is larger than 1000 kWh/m²/j

**Data from the DSOs until 31/03/2018, reduced with the capacity of known ground installations of a minimum of 750 kW

Specifically, for wind, the map below show that wind is mostly interesting in the West side of Flanders. As a result, as can be seen in Figure 11, most of the wind turbines can be found in that region.

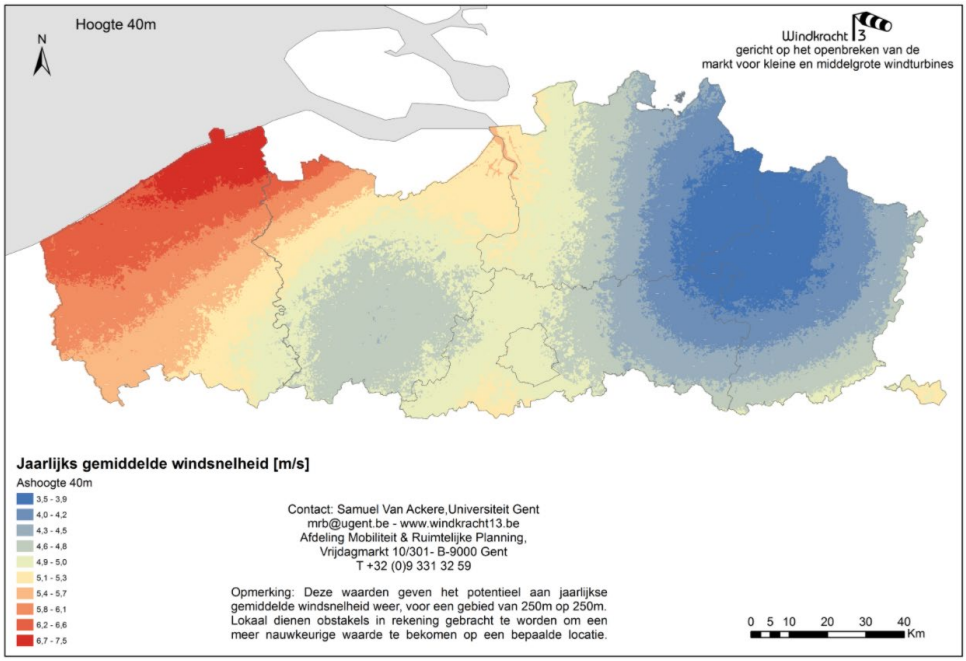


Figure 11 - Wind map Flanders (source (Van Ackere, 2015))

In 2015, in Flanders there were 295 large wind turbines, together having a capacity of 690 MW. On the map below, the yellow dots show all wind turbines in 2015 which received a building permit at the time. The green dots are the wind turbines who are already constructed in 2015. End of 2016, the Flemish Government accepted the draft of the wind plan "windkracht 2020" which indicated that by 2020 280 new wind turbines needed to be installed in Flanders. They would aim to focus a lot on the ports of Antwerp, Gent, Ostend and Zeebrugge. In 2019, the total amount of wind energy in Flanders was 1.278 MW (about 543 wind turbines). On the website of ODE, a full list of all large wind turbines in Flanders can be found (ODE, 2019a). In 2020, up on writing of this section, 26 additional wind turbines were installed in Flanders.

Currently, most of the wind turbines can be found in the West side of Flanders (which is in line with the wind map) (see Table 6). Note that Flemish Brabant does not have a lot of wind turbines. This is caused due to restrictions of the nearby airport of for instance Zaventem. (Clerix, 2015b)

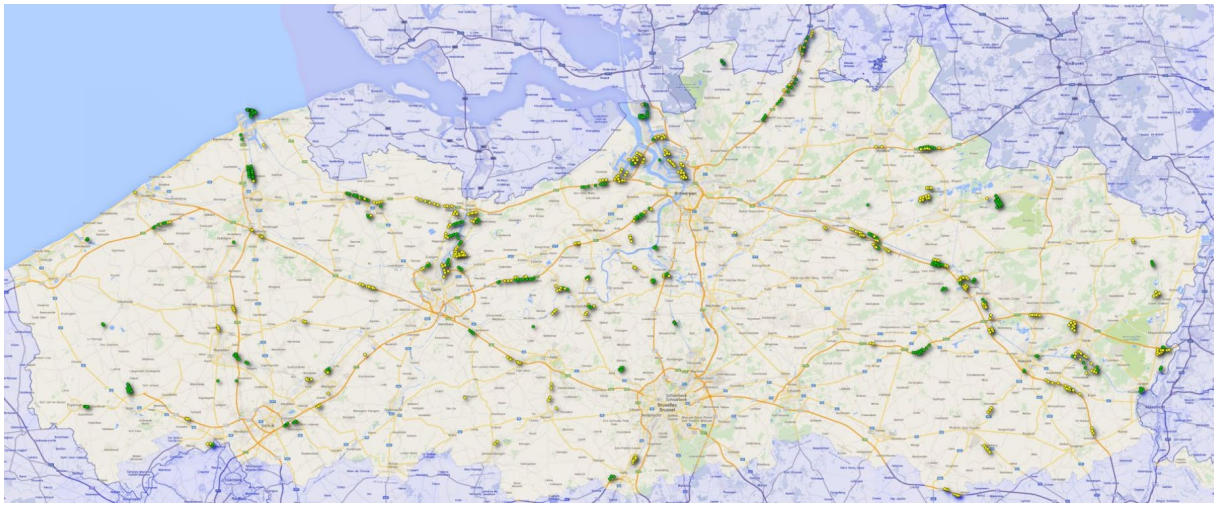


Figure 12 - Current (green) and future (yellow) wind turbines in Flanders 2015 (source: (Clerix, 2015a))

Most of the wind turbines in Flanders are build next to high and water ways, followed by wind turbines in industrial areas or in ports. Such wind turbines are therefore more often located in areas that are less suited for 5GDHC. With the windplan, the goal will be to have more small and medium-large wind turbines for, for instance, SMEs and farms. The Flemish government aims to further facilitate regulation in this regard to make sure that procedures are easier. This might be an opportunity for 5GDHC as it gives options to invest in smaller scale wind energy next to the potential 5GDH grid (Clerix, 2015b; ODE, 2020; Team Duurzame Ontwikkeling Vlaamse Overheid, 2021; Tommelein, 2015).

Table 6 - Additional wind turbine capacity installed over the last year and total capacity installed (MW) (data until October 2020) (source: (energiesparen.be, 2020))

	2015	2016	2017	2018	2019	2020	Total capacity
Province Oost-Vlaanderen	82,5	28	94,25	36,82	36,9	22,85	**460,92**
Province Antwerpen	32,3	39,3	86,74	31,45	6,3	16,1	**351,00**
Province Limburg	62,4	20,2	26,8	14,6	8,7	19	**278,10**
Province West-Vlaanderen	19,3	15,9		8,05	11	3,6	**197,56**
Province Vlaams-Brabant	12	13,52	7,2	10,37			**63,69**
Total	**208,5**	**116,92**	**214,99**	**101,29**	**62,9**	**61,55**	**1351,27**

In case a more detailed overview is necessary for the reader, through the following website (https://www.energiesparen.be/energiekaart/cijfers), it is possible to get an overview of windturbines per municipality. The data are from October 2020 and are updated more frequently. However, this overview as well only focuses on large windturbines.

3.3.6. Electricity use at times of renewable overproduction, e.g. when spot price is low

For now, this is only relevant in areas with known overproduction, like the north of the Netherlands (overproduction of PV) and the north of Germany (wind).

3.3.7. Electricity mix from the external grid

With regard to the national electricity mix, the TSO (Elia) reported the statistics below. In 2018, some nuclear power plants were out of service, which explains the high dependency on imported electricity during that year. Compared to 2018, however, 2019 saw a significant increase in off-shore (and on-shore) wind energy. As a result, in 2019, Belgium exported

more electricity than it imported. In total 1,8 TWh was exported (which is 2,1% of the electricity mix). In the graphs below (Figure 13), it can also be seen that there is an increased usage of gas power plants for electricity.

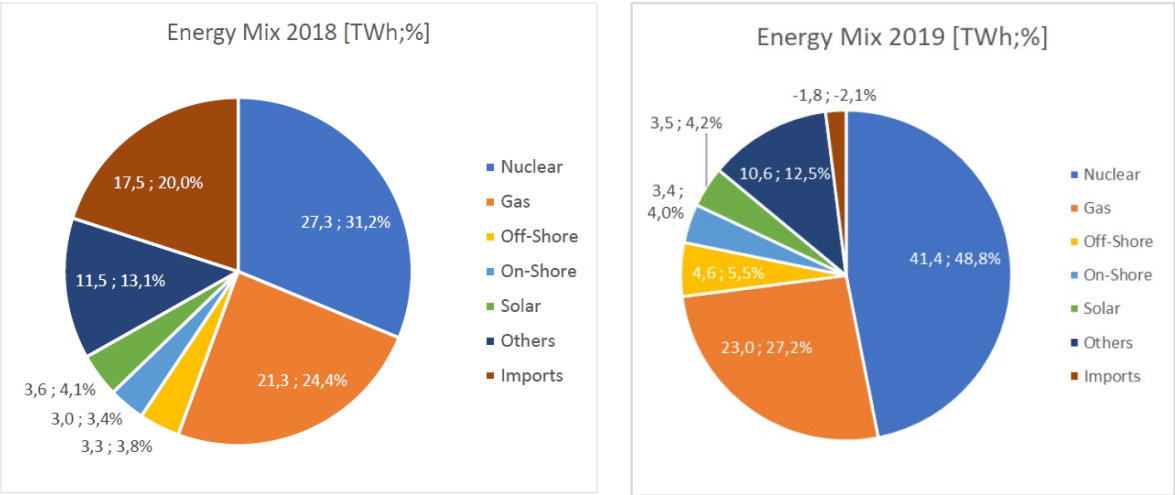


Figure 13 - Energy Mix Belgium 2018-2019 (Elia, 2020)

3.3.8. High temperature heat from burning biofuels, biogas, biomass

Table 7 gives an overview of all projected green heat production sources in the NECP (National Energy and Climate Plan). In this section, the focus is on biomass which, compared to the other technologies, takes up the largest part of the green heat production in Flanders. With regard to biomass and biogas, a distinction is made between households, and larger installations. Some households heat their houses with wood stoves. Yet, it is assumed that the usage of these energy sources will decrease over time (the target is to decrease their consumption with 50%). Instead, there will be a shift to more central heating installations via (small) district heating grids.

For waste incineration, an important shift is foreseen from green power to green heat through district heating grids. In addition, waste is assumed to reduce by 25% within 2030 due to better waste management. As such, heating capacity needs to have the highest energetic efficiency. It is assumed that larger and more central installations will become more efficient and will further find their way in the Flemish energy landscape (Vlaamse Overheid, Departement Omgeving, 2020).

Table 7 - projected green heat production per technology in the national energy and climate plan (Federale overheid, 2019)

Generation (GWh)	2020	2025	2030
Solar	193	233	287
Heat pumps	610	905	1,455
Geothermal energy	95	345	594
Biomass residential households	3,850	2,900	1,950
Biomass other	3,841	4,621	5,401
Total	**8,589**	**9,122**	**9,688**

Even though there are quite some biomass installations in Flanders, data about them can only partially be found and focus mostly on their electric potential. As far as we know, there are no public data on the thermal capacity of biomass or biogas installations in Flanders. The 2017 VITO study 'potentieel biomassa 2030' (Kreps et al., 2017) gives an overview of biomass and biogas installations in 2017. This study was also used for the projections given in the earlier table.

With respect to biogas, according to VILT (VILT, 2018), biogas is responsible for 10,6% of all green electricity in Flanders, and 12,9% of all green heat.

3.3.9. High temperature heat from burning fossil fuels

Residential households in Belgium mostly use fossil fuels for heating their buildings. Data of 2016 showed that natural gas and gas oil were the most commonly used energy sources for households in Flanders.

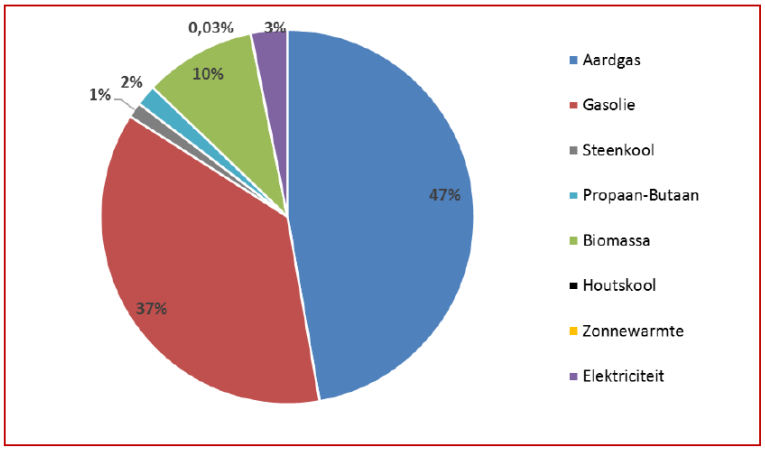


Figure 14 - Energy consumption for heating of households in 2017 (based on data of 2016 by the Gezinsbudgetenquête) (source: (FOD Economie, K.M.O., Middenstand en Energie, 2019))

In 2016, 88% of the Flemish households were using natural gas and oil for their heating. This can be derived from the table below

Table 8 - main heating source households (year 2016) (source: (Stroomversnelling - Werkgroep Hernieuwbare energie, 2017))

	Natural gas	Oil	Wood	Electricity	LPG	Charcoal	Heat pump	District heating
% households	63,2	25,2	1,7	7,2	1,0	1,0	0,8	0,2
Number of households	1.736.300	691.200	45.700	197.800	27.500	27.500	22.000	5.500
Consumption 2016 (TWh)	25,3	17,9	4,0	2,4	0,6	0,5	0,2	0,1

4. SWOT analysis

Given the information gathered above on the market and on availability of energy resources, an analysis of the strengths, weaknesses, opportunities and threats when implementing 5GDHC in the region can be made. The SWOT analysis will help to interpret the information given earlier and will as such help to understand which locations in Flanders might be better suited for 5GDHC.

4.1. Strengths

In what follow, strengths of the Flemish region, that give 5GDHC an advantage over other projects and technologies, are discussed.

4.1.1. Flexible regulatory framework with options for different types of systems

In theory, Flanders is not having juridical barriers for DHC grids, of any generation. Different types of business models, organizational structures and collaboration between numerous stakeholders are allowed. This gives opportunities to flexibly test new concepts, ideas and organizational models.

4.1.2. (Government) Resources for research and development and interest to adopt state-of-the-art/novel concepts in DH

As 5GDHC still needs to be further developed, it is important that there are sufficient resources for research and development. In this regard, the Flemish region is scoring well compared to other (European regions). In 2018, the Flemish Region spend almost 8 billion euros on R&D, which is about 2,92% of the GDP. Most of the resources go to companies (about 70% of the resources).

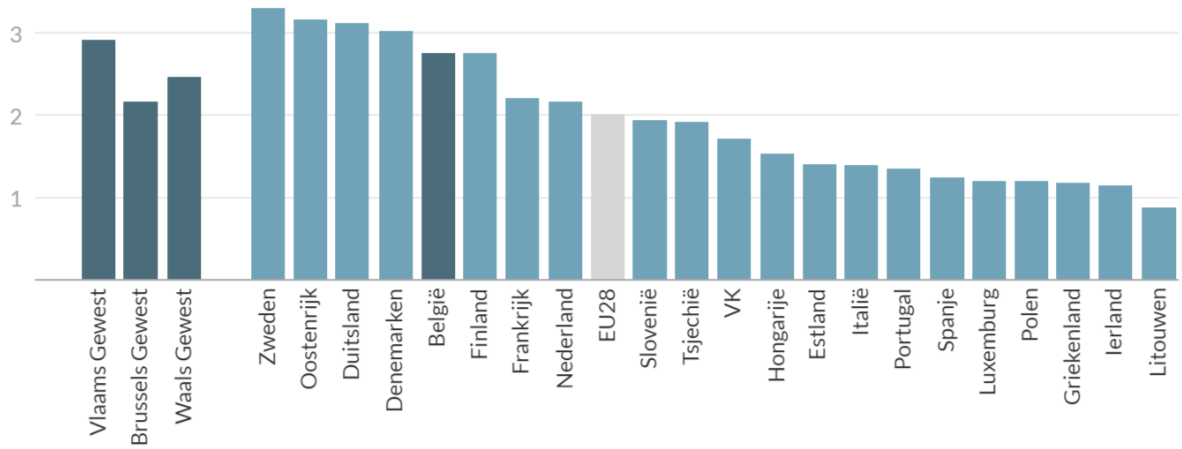


Figure 15 - R&D resources in % of GDP (data for 2017) (source: (Statistiek Vlaanderen, 2020b))

Specifically, with regard to R&D, Flanders is home of EnergyVille, a research institute and technology provider on advanced district heating innovation (That is: using low-grade sources for low-grade demand, match supply-demand).

On a somewhat subjective note (this should be tested with some field questionnaires), Flanders seems to have a willingness to adopt state-of-the-art/novel concepts in district heating. This is supported by the expertise of DH engineering companies.

4.1.3. Densely populated area

Flanders is a densely populated area. As such, it is better qualified to comply with one of the 5 principles of 5GDHC: "Local sources as a priority". This helps to decrease or even avoid energy losses during transport.

4.2. Weaknesses

4.2.1. Strong presence of gas (distribution networks)

Flanders has a history of gas usage. Gas distribution networks are rolled-out in most of Flanders. Replacing such networks, which have an existing infrastructure, with an entirely new infrastructure is not easy.

4.2.2. DH grids are still rare in Flanders and end-consumers are not familiar with them

Gas is widely spread out in Flanders and is therefore the dominant heating source. Switching to DH grids when existing infrastructure is already in place goes slowly. As a result, people are not yet familiar with DH grids and there is a possible reluctance to change. Stakeholders might also not always be well-informed about the benefits of DH grids. As DH grids are developed over multiple years, it is important that all stakeholders are well-informed so that earlier decisions do not undermine DH grid opportunities.

Furthermore, DH grids have to compete with the existing liberalized gas and electricity markets in Flanders where customers have more freedom in switching between suppliers. In that sense, DH is a real monopolistic market which might scare consumers.

4.2.3. Lacks cost efficiency in the short and middle term

In Flanders, innovative energy systems based on renewable energy sources need to compete with traditional fossil fuel systems. The later are heavily under-priced in Flanders as most taxes are charged on electricity instead of on fossil fuels. There are no emission taxes. As a result, business cases for DHC grids in Flanders are low, and given the long-term investment character of DH grids, it takes a long time before a DH developer gains back his investment. This is especially the case for 5GDHC as this requires higher investment costs.

For 5GDHC it is also important that production of renewable energy is incentivized sufficiently. In January 2021, net metering for solar panels in Flanders came to an ending. This will increase electricity costs. Starting from 2022, a capacity tariff for grid tariffs will be introduced.

From an end-user perspective, it also seems that there are only limited subsidies (for instance for connecting to a DH grid).

4.2.4. High availability of high temperature residual heat

As became evident from the analysis in section 4.3, Flanders possesses numerous high temperature heat sources. As indicated, a significant amount of such sources is located in the neighbourhood of densely populated areas. While this is definitely a strength for 3GDH grids, it is not entirely clear whether this is beneficial for 5GDHC. Depending on the context, 5GDHC grids can also use high temperature residual heat, but this needs to be examined locally. In any case, higher temperature heat is more beneficial for 3GDH than for lower generations.

4.2.5. High demand for high temperatures at residential buildings

Almost 60% of the Flemish houses are older than 50 years old. Most of these houses are not renovated and have a very low energy performance. The average EPC-score in Flanders is about 350 (on a scale to 700).

	One family building		Apartment	
	#	%	#	%
<1945	610.762	28,7%	19.435	15,2%
1946-1970	565.290	26,6%	34.091	26,6%
1971-1991	516.447	24,3%	26.824	21,0%
1992-2011	357.435	16,8%	34.997	27,3%
>2011	78.838	3,7%	10.206	8,0%
Unknown	264	0,0%	2.430	1,9%
Total	**2.129.036**		**127.983**	

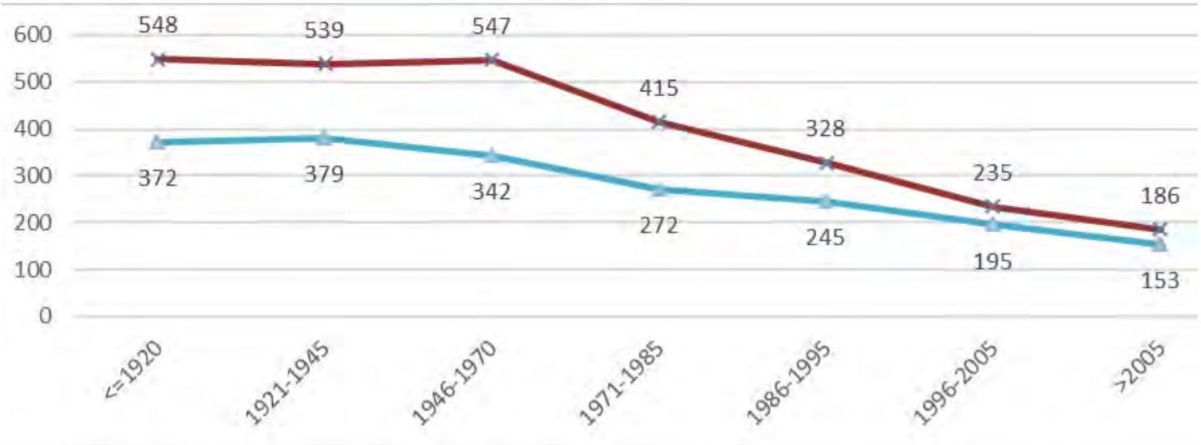


Figure 16 - EPC correlated by building year in Flanders (red: individual family house, blue: apartment) source: VEA (Vermeiren, 2020)

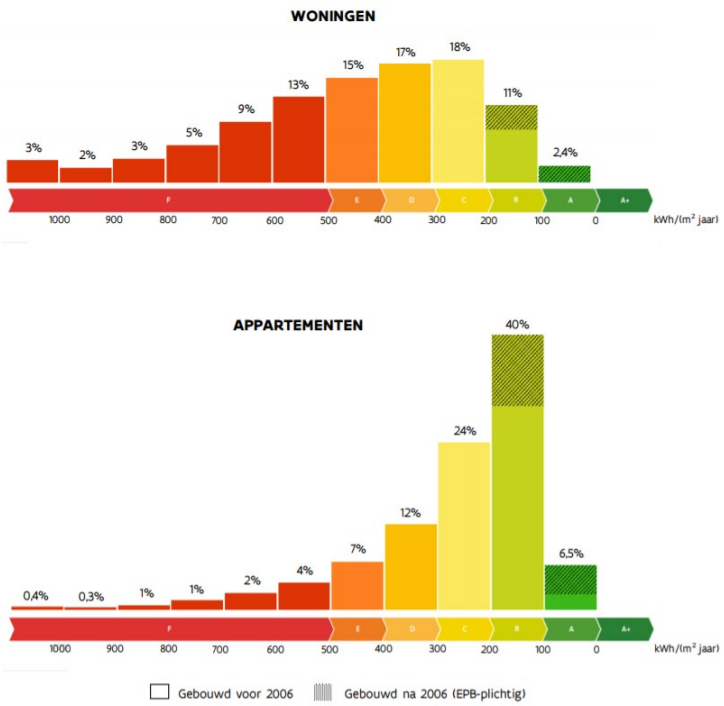


Figure 17 - EPC value single family buildings ("woningen") and apartments ("appartementen") (source: (Vlaamse Regering, 2020))

The goal is to decrease the EPC-value for Flanders with 75% by 2050, and thus to achieve a label A (EPC-value of maximally 100). Currently in Flanders, only approximately 3,5% of the houses and apartments reaches this target. In the group of the single-family buildings, about 35% of the buildings as an F label. For apartments, this is less than 9%. It therefore seems that most of the building stock in Flanders is not ready for lower temperature DH grids.

4.2.6. Local governments not yet sufficiently enhanced

The Flemish Government recognizes that it is important that local governments (cities, municipalities) are involved in the development of DHC grids. DHC grids are local concepts and public local involvement is important. However, it seems that not all municipalities are well aware of all the different possibilities. The Flemish Government therefore proposed to set up a network of local governments with regional workshops so that they can learn from each other (Vlaamse Regering, 2017b). A guidance book to start the development of DHC grids is also developed. Furthermore, there were ideas to set up the concept of a 'warmtemakelaar' (heat ambassador) that will assist local governments. However, while it is correct that support for local governments is useful and needed, in practise it is not well developed in Flanders. As far as we know, there is only a heat ambassador in Kortrijk. As such, local governments are often not well equipped to help with the roll-out of DHC grids.

4.2.7. Lack of open source data

As indicated, to plan DH grids, it is important that there is access to data to match demand and supply. For 5GDHC grids this is even more important as they make use of more local resources. Such local data are often, however, not available in Flanders or they are time-consuming to achieve. This makes planning of such grids more complicated.

4.2.8. Lack of focus on cooling options when planning DH-networks

When planning DH grids, stakeholders are easily focusing on the heating part of the grid, and are not necessarily considering the cooling strategy. The same goes for heat plans and heat visions that are set up in Flanders. 5GDHC is considering both heating and cooling, and to reach a full roll-out, it is necessary to value cooling as much as heating.

4.2.9. Lack of coordination among various stakeholders and possible partners in DHC

Previous actions taken by other stakeholders (replacement/installation of sewage system, drinking water installation, optical fiber network; roadworks;...) can create options to install immediately other infrastructural improvements in a specific location. However, often, coordination of such district renovations is not taken place and actions are taken separately/individually from other stakeholders. This is especially for 5GDHC grids a weak point, as such grids are highly linked to other systems. 5GDHC grids aim to improve efficiency of the total system and their success therefore also depends on other features of the local environment or related smart grid infrastructures (electricity grid, district heating grid, cooling grids, gas grids, and other infrastructure).

4.2.10. Lack of two-sided interaction between heat networks and other energy carriers

These days, heat networks are sometimes already linked to electricity networks to provide ancillary services to the electricity grid. However, a real interaction is still missing as this is mostly a one-sided interaction and often there are still other energy carriers such as (gas/oil...) involved.

4.2.11. Lack of huge seasonal storage

As indicated, Flanders has some options for seasonal storage, but the question is whether the existing systems are large enough for 5GDHC. In most cases, 5GDHC grids require a huge seasonal storage due to the unbalance in the heat and cold demand. However, in practise, this might not always be feasible in Flanders. Further examination based on more local data is needed to verify this.

4.2.12. Low heat density in rural areas

Although there is a highly populated area in Flanders, in rural parts of Flanders, there is a relatively low heat density in a lot of areas.

4.3. Threats

4.3.1. No fixed organisational models

The flexible regulatory framework can both be a strength and a weakness of the Flemish region. As there are currently not that many DH grids, stakeholders always have to look from scratch to see how they will organize DH grids. Especially in the case of 5GDHC grids, where there is a possibility that there are even more stakeholders involved, this might complicate doing business together.

Furthermore, as many stakeholders don't have experience with these systems, procedures might take longer than in the case of traditional systems. For instance, in case of public procurement, cities do not always seem to have the knowledge to write out tenders (while they do have to obey public procurement legislation) (Interreg North-West Europe HeatNet NWE, 2019).

4.3.2. No clear energy policy vision and incoherence and discontinuity in policy measures

Belgium does not have a clear energy policy. In theory, climate targets are available, but how these should be reached is not worked out in detail. In addition, the measures that will be taken are conservative in the sense that policymakers do not have the courage to shift taxes from electricity to fossil fuels.

Furthermore, there is a lot of uncertainty, as regulation easily changes with different government formations. As a result, there is an incoherence and discontinuity in policy measures to support and incentivize renewable energy technologies (an example is the recent stop in net metering for renewable energy such as PV). Also, there are many different policy levels and regulations with inconsistencies between them.

4.3.3. Energy performance regulation does not look at system perspective

Specifically, for heating, EPB-legislation (Energie Prestatie & Binnenklimaat – Energy performance and Indoor climate) is not in favour of DH. DH is punished for its heat losses as EPB mostly looks at technologies from an individual perspective and not from a system perspective. In addition, the use of electricity to circulate warm water in DH is punished. Compared to other generation DHC grids, 5GDHC grids have a benefit in Flanders as they have a higher energy efficiency of heat production and DER (Distributed Energy Resources) due to lower supply and return temperatures. They also have lower heat losses in the distribution grid. Nevertheless, EPB is still punishing system with high electricity usage. And 5GDHC grids still rely on for instance pumps to deliver heat and cold in the system.

4.3.4. Gas lock-in and gas network operator monopoly

Gas networks are widely spread out in Flanders. In addition, the gas network operator, Fluvius, would like to gain a monopoly on the development of district heating in Flanders. Most probably, this would not be beneficial for the development of district heating grids in Flanders as Fluvius would compete with its own gas networks against district heating grids.

4.3.5. Green heat call in favour of projects with low costs compared to the CO2-emission reduction

Flanders provides subsidies for investments in green heat, residual heat and biomethane. However, such subsidies are less interesting for 5GDHC than for lower generations of DHC grids. Specifically, the green call is ranking projects based on the ratio emission savings versus investment cost. As such, the call is in favor of lower cost projects. Nevertheless, subsidies should be given to innovative projects that are still in a learning phase due to which they have higher costs. 5GDHC grids have higher investment costs and therefore less likely to receive funding.

4.4. Opportunities

4.4.1. Lack of DH networks

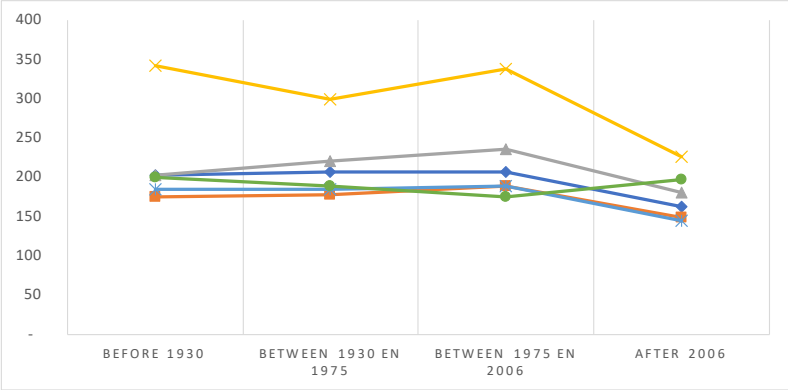
Currently in Flanders, there is only a very limited amount of DH grids. This is actually an opportunity specifically for 5GDHC as it is hard or limitedly feasible to upgrade 3GDH to 5GDHC grids. As a result, in Flanders, one can move directly to 5GDHC grids.

4.4.2. Decreasing heating demand (through thermal insulation, passive houses, active houses, etc.)

While a large part of the current heating environment is not yet ready for 5GDHC in Flanders, the goal is in the long run to have better energy performing buildings. As it takes a long time to build out DH grids, there are opportunities to start developing those regions which are more ambitious regarding becoming more energy efficient.

4.4.3. Lower heat demand and higher climate ambitions in non-housing buildings

For commercial buildings (offices, schools, hospitals…) Flanders is more ambitious and aims to have an emission free building park by 2050. These buildings currently already have better EPC values than household buildings. The figure below (Figure 17) gives an overview per sector in kWh/m²). It shows that heat demand in these buildings is lower. In addition, commercial buildings also require more cooling than housing buildings. This is an important aspect for 5GDHC.



		Before 1930	Between 1930 en 1975	Between 1975 en 2006	After 2006
Other social and personal services	EPC number	202	207	207	163
	#buildings	3.406	3.432	2.399	597
Health care and social services	EPC number	175	178	189	149
	#buildings	1.607	2.058	1.817	454
Shops	EPC number	202	221	235	180
	#buildings	6.743	6.816	4.562	1.103
Hotels and restaurants	EPC number	342	299	337	226
	#buildings	6.586	4.115	1.488	297
Offices and administration	EPC number	185	185	189	144
	#buildings	7.860	8.946	8.133	2.289
Education	EPC number	200	188	175	197
	#buildings	714	762	308	68
Total	**EPC number**	**230**	**215**	**214**	**161**
	#buildings	**26.916**	**26.129**	**18.707**	**4.808**

Figure 18 - Evolution EPC in non-housing buildings per sector and per building period (figure translated from …) (source: (Vlaamse Regering, 2020))

4.4.4. Import stop of low caloric gas from the Netherlands to Belgium

Normally, the fact that a large part of the gas grid will not be suited anymore to supply gas, should be an opportunity to switch in those areas to alternative, and more renewable heating systems. However, it seems that Belgium is turning an opportunity in a threat by rolling out a plan to replace all low-caloric gas connections with high-caloric gas. This implies replacement at transmission infrastructure, distribution networks and in household appliances. Nevertheless, this report continues to highlight this fact as an opportunity as the project to replace all low-caloric system takes about 10 years. There are therefore still plenty of opportunities to change the plan.

Furthermore, Flanders already decided that gas network operators are not required anymore to provide a gas grid to all houses. Originally, the legislation stated that 95% of all homes in rural areas, and 99% of the houses in urban areas needed to be connected to the gas network.

4.4.5. Climate targets

In theory, climate targets should be an opportunity for any type of renewable energy technology. This also counts for Flanders, even though as indicated under weaknesses, Flanders is progressing slowly towards these targets and Flanders is not having a high ambition level regarding climate goals. Nevertheless, to achieve climate targets, Flanders has worked out (or is working out) some plans (such as the heat plan, the wind plan, the solar plan, the spatial vision plans…). These plans could (or should) lead to a better energy policy vision.

4.4.6. One third of the Belgian climate target can be filled in with green heat

In Flanders, more than half of the gross final energy consumption consists of heat demand. Green heat has the potential to fill in one third of the climate targets (Vlaamse Regering, 2017b). Regions are aware of this and try to integrate green and residual heat in spatial plans. For instance, in the spatial planning of Flanders (Beleidsplan Ruimte Vlaanderen – BRV), different measures are examined to integrate heat on different levels and to search for synergies. "Het Renovatiepact" is one concrete way in which the Flemish Government further aims to stimulate synergies. It aims to tackle the challenge of integrating green heat in existing buildings.

With regard to the integration of different energy sources (heat, power, gas), the European directive on renewable energy expects that the potential of district heating grids with regard to providing balancing and other system services is examined. Different aspects are being examined:

- Electrification of heat demand through the integration of electrical heat pumps in DH grids and buildings for temperatures below 90°C. This will allow to switch between green power and green heat.
- Making CHPs more flexible by foreseeing thermal energy storage and technical components that allow production to easily start or stop.
- Focussing more on hybrid DH grids, which are grids that make use of different energy sources.
- Combining more DH grids with heat storage.
- Making electricity demand more flexible by making use of industrial cooling (data centres, cold storage…), electrical cooling in office buildings in combination with thermal storage…

4.4.7. Thor Park (Genk) is a living lab with possibilities to create a 4-5GDHC

As will be indicated in the roadmap, Thor Park Genk is an SME site which is readily available and interested in a 5GDHC grid. Thor Park is the home of EnergyVille, which is conducting significant research in low temperature DHC grids. This could further boost knowledge and expertise on DHC grids in Flanders.

4.4.8. High potential of low temperature heat in cities

Cities contain many sources of low temperature residual heat. This can come from datacentres, sewage water (plants), metro stations, tunnels, office buildings… It should be examined to which extent these can be integrated in a low temperature DHC grid.

4.4.9. Natural seasonal storage

It could be an opportunity to use seasonal storage like ATES, BTES and old mines. ATES is possible in the Campina region (Part of province of Antwerp and Limburg), BTES is almost everywhere possible in Flanders. Nevertheless, as indicated previously, it should also be examined whether the size of such systems is sufficient as it seems that opinions differ in this regard.

4.4.10. Cascading

As there is a lot of high temperature residual heat in Flanders, it could be interesting to use that heat in 3-4 GDH grids that need to supply higher temperature demand. The heat in the return pipes could then be used as an input for 5GDHC grid.

5. Regional vision

The regional vision addresses which barriers need to be addressed first and which opportunities should be taken when rolling out 5GDHC in the region. The vision includes a roadmap describing how much thermal demand (in MWh and/or floor area) could be fulfilled between the end of D2Grids and 2030, including likely locations where implementation can start.

5.1. High potential areas and potential pilot sites

The above analysis of Flanders shows that it is hard to clearly identify concrete potential pilot sites for Flanders for 5GDHC. Instead, a more general appointment of Flanders is given below based on the insights of the previous analysis.

One of the most important key aspects of 5GDHC is the reuse of thermal energy. As indicated, such reuse is only possible when a good mix of end-users, who are complementary to each other with regard to their consumption and production profiles, is present. However, for Flanders, it is hard to find public data on production and consumption profiles of different buildings. As such, it is hard to determine which regions are ideal with respect to plausible energy exchanges. This is an analysis that can only be done when a specific site has been selected, and after consultation of the different buildings.

With regard to energy generation and availability, within Flanders, it seems that there are quite some regions with high-temperature energy sources. Such sources are often situated in densely populated areas such as cities. With regard to energy demand, it seems that many Flemish buildings are badly insulated and therefore require high temperature heat sources. As such, regions with a supply of residual high temperature heat, in combination with high heat demand, are more likely to be suited for lower generation DH grids.

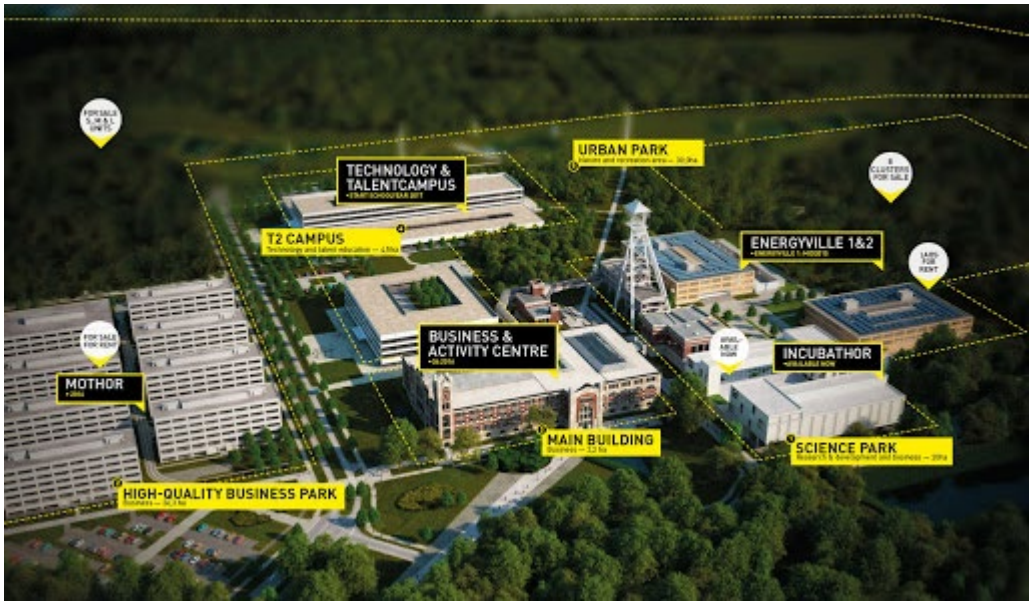
Interesting locations for 5GDHC grids in Flanders are therefore slightly more rural or suburban regions, which are further away from residual (high-temperature) heat sources. In these regions, 5GDHC grid developers need to look for low-temperature heat demanding buildings. Specifically, the previous analysis indicated that more commercial buildings have higher climate ambitions in the short run, and are often better insulated. As such, commercial sites, and/or modern highly insulated new-build residential housing areas, are more likely to be suited for 5GDHC grids in Flanders.

When looking at energy sources available in the above described regions, it seems that mining regions such as Genk, could be interesting, especially with regard to utilizing thermal energy from the flooded mines. However, it is important that some vision is created in this regard as for instance in Thor Park (Genk), a concentrated Solar Power installation is being build and this high temperature heat would potentially be used for the DHC grid that one aims to implement there.

5.2. Roadmap

The roadmap systematically shows the steps to take to implement 5GDHC in the follower region, based on the analysis made for this deliverable.

For 2022 the roadmap assumes Thor Park (Genk) is the first pilot site to roll-out 5GDHC in Flanders. Thor Park houses the restored mine building, the IncubaThor office building, the T2 Campus training centre and the buildings of EnergyVille, the collaboration between KU Leuven, VITO, imec and UHasselt for research into sustainable energy solutions. In 2020, Thor Park became the first regulatory sandbox in Flanders and it is allowed to exchange energy between different buildings on the site. It works on three key pillars. First of all, its aim is to better integrate and exchange (renewable) energy locally. Secondly, the researchers want to experiment with an innovative thermal network to optimally integrate renewable sources. For example, the consumption of the heat pumps can be adjusted to peaks in solar and wind energy to simultaneously produce, store and then efficiently deploy heat and cold where necessary. Thirdly, the park aims to implement innovate DH (direct current) networks and connections.



Currently, Thor Park has 5 buildings, of which 4 are planned to be part of the 5GDHC. The buildings that will be part of the grid are summarized below.

Table 9 - Thor Park 2022

Building	m²	Function	Total heating demand (MWh)	Total cooling demand (MWh)	Side note
Incubathor	+/- 5.400 m²	Mostly offices	279	150	
Thor Central	+/- 11.000 m²	Different functions	300	240	Currently an additional +/- 11.000 m² is not used
EnergyVille 1	+/- 10.000 m²	Labs and offices	300	300	
EnergyVille 2	+/- 5.000 m²	Labs and offices	225	225	Total building is larger than EnergyVille 1, but is not completely in use yet.
Total	**31.400 m²**		**1.104**	**915**	

For 2032, we assume that the existing Thor Park is expanded with 8 additional buildings. When assuming that those buildings are similar to the building of EnergyVille1, the results below are obtained.

Table 10 - Assumed Thor Park 2032

Building	m²	Function	Total heating demand (MWh)	Total cooling demand (MWh)	Side note
Thor park 2022	+/- 42.400 m²	Offices, labs, varia	1.479	1.230	EnergyVille2 and Thor Central completely in use
8 additional lots	+/- 80.000 m²	Offices, labs, varia	2.400	2.400	8 additional lots with similar characteristics as EnergyVille 1
Total	**122.400 m²**		**3.879**	**3.630**	

Assuming a linear growth, we assume that Thor Park in 2027 will have 4 additional lots filled in. This would result in the following characteristics for Thor Park.

Table 11 - Assumed Thor Park 2027

Building	m²	Function	Total heating demand (MWh)	Total cooling demand (MWh)	Side note
Thor park 2022	+/- 42.400 m²	Offices, labs, varia	1.479	1.230	EnergyVille2 and Thor Central completely in use
4 additional lots	+/- 40.000 m²	Offices, labs, varia	1.200	1.200	4 additional lots with similar characteristics as EnergyVille 1
Total	**82.400 m²**		**2.679**	**2.430**	

It is reasonable to assume that by 2032 there will be a second pilot site. However, currently, no concrete site is envisioned yet.

		2022	2027	2032
PROPOSED 5GDHC ROLL-OUT	Floor area [m²]	31.400 m²	82.400 m²	122.400 m²
	Energy [MWh/a]	6,43 MWh/a	6,20 MWh/a	6,13 MWh/a

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Interreg North-West Europe D2Grids

European Regional Development Fund

WORK PACKAGE: WPLT

DELIVERABLE NUMBER: DEL.1.3

PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN NORTH-EAST FRANCE

July, 2021

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Data sources:

Report done by: BRGM

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Abbreviations

5GDHC	5th Generation District Heating and Cooling
5GDHCN	5th Generation District Heating and Cooling Network
ADEME	Agence de la transition écologique (Agency for Ecological Transition)
APUR	Atelier parisien d'urbanisme (Paris Urbanism Agency)
BRGM	Bureau de Recherches Géologiques et Minières
BSS	Banque de données du sous-sol
COP	Coefficient of performance
DHN	District heating network
DHW	Domestic hot water
EMS	Strasbourg Eurometropolis
GPM	Greater-Paris Metropolis
IRIS	Ilots regroupés pour l'information statistique
MGP	Metropolis of Greater-Paris
OM	Orleans Metropolis
PCAET	Territorial Climate Energy Plan
PCAEM	Metropolitan Climate Energy Plan
RTE	Réseau de Transport d'Électricité
SEM	Strasbourg Eurometropolis
SOeS	Service d'Observation et des Statistiques
SRADDET	Regional sustainable planning and development scheme and equality of territories

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1. Introduction

Activities in the long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories ("follower regions"). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. The regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology is carried in this deliverable for each of the 7 follower regions defined for this project, namely: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

2. Characterising the region

The analyse focuses on three dense urban areas of the Interreg NWE that are Orleans Metropolis ("Centre Val-de-Loire" region), Greater-Paris Metropolis ("Ile de France" region) and Strasbourg Eurometropolis ("Grand-Est" region) (Figure 1). Those locations were chosen as the "followers regions" in North-East France for different reasons detailed hereafter.

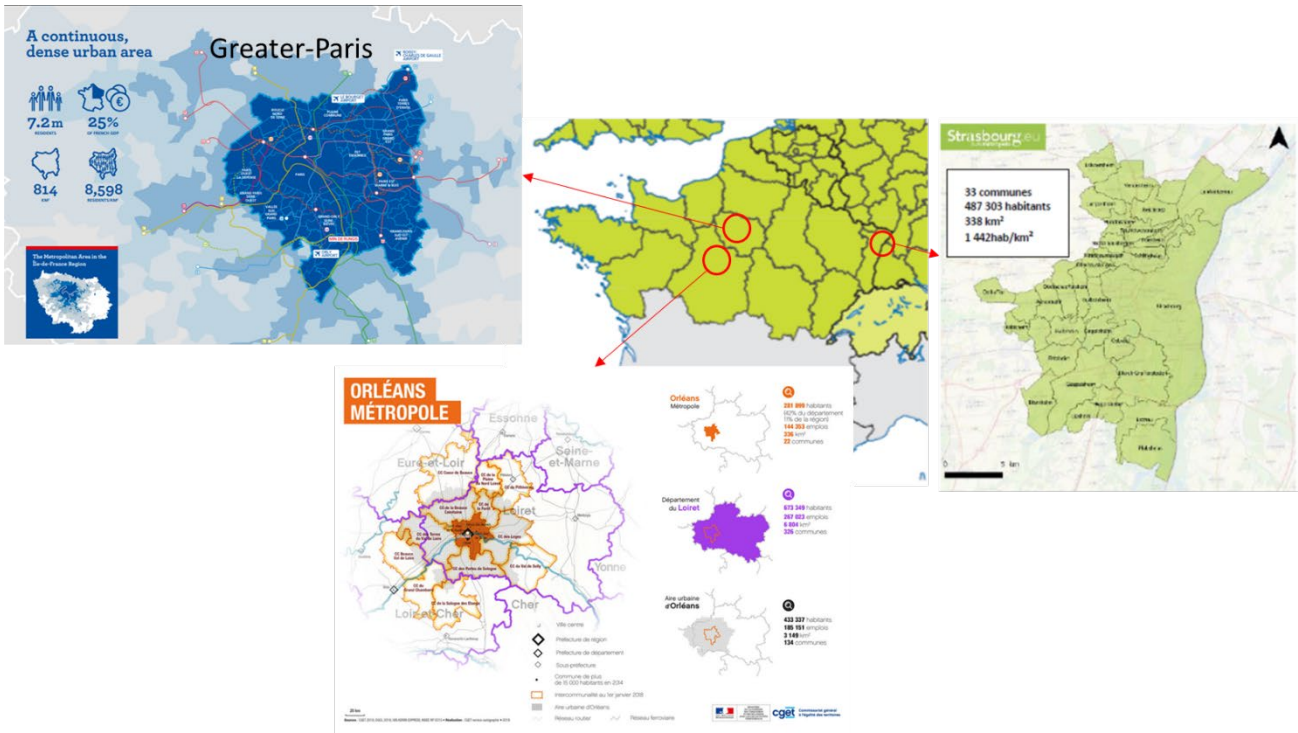


Figure 1. Localization of the three urban areas of interest for "follower region" in North-East France

2.1. Orleans Metropolis (OM)

Orleans Metropolis (Figure 2) is in the Loiret department (45) and the Centre-Val de Loire region (around 100 km southwest of Paris). It is composed of 22 municipalities with a population of 286 000 inhabitants on a geographic area of 334 km^2 (*i.e.*, 856 hab/km^2 in 2017). In November 2019, the metropolitan Council adopted its Territorial Climate Air Energy Plan (PCAET), which aims at reducing global energy consumption by 12%, increasing the share of renewable energy production by 50% and reducing GHG emissions by 17% within 2025. The long-term objective fixed by the PCAET (within 2050) is to become a positive energy territory and reach energy sobriety and efficiency in addition to cover 100% and more of energy demand by local renewable energy sources. Among the objectives stated to increase the share of renewable energy production, Orleans Metropolis foresees the extension of existing biomass heating network for collective use, the connection of 22 000 housing to geothermal energy (a hundred building connected in 2012) and 15 000 housing to solar thermal energy (*i.e.*, 37 000 m² of panel for only 500 m² in 2012) and the reuse of waste heat over industrial sites for heating purposes.

The BRGM scientific and technical centre and headquarter are in Orleans Metropolis and has facilitated knowledge exchanges and discussions with personnel in charge of the application of the PCAET in the metropolitan area. The BRGM signed a convention in December 2019 with Orleans Metropolis to accompany them in the implementation of a territory geothermal energy development plan to meet the objectives of the PCAET. Indeed, the Horizon 2030-2050 planning and Master Plan for the heating networks of the PCAET adopted foresee 65 000 additional dwellings to be connected using geothermal energy based heating networks. One task of the convention, conducted in 2020, intended to study how

geothermal energy, both shallow and deep, could be deployed in the area accounting for the geological and hydrogeological context and the energy demands. The results of this study will be the baseline for defining potential areas for 5GDHC roll-out in the territory.

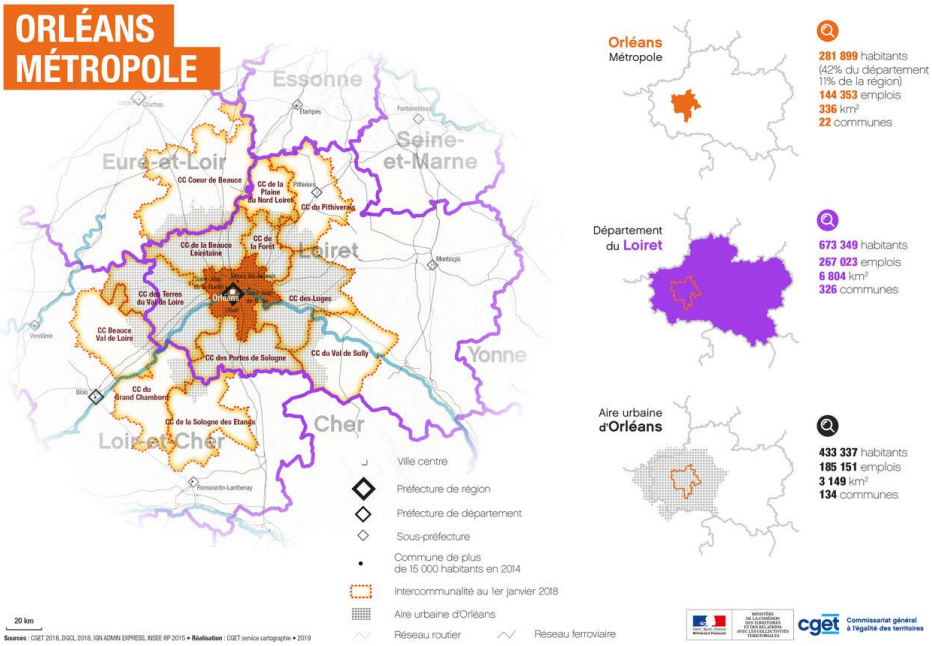


Figure 2. Orleans Metropolis location and population (figures from Insee 2015). Source CGET

2.2. Greater-Paris Metropolis (GPM)

Metropolis of Greater-Paris ("Métropole du Grand-Paris" or MGP) is a dense urban inter-municipal association, which includes the city of Paris (Ile-de-France) and 130 municipalities in the departments of Hauts-de-Seine, Seine-Saint-Denis, Val-de-Marne, Essonne, and Val d'Oise (Figure 3). The MGP has 7.2 million inhabitants on a geographic area of 814 km^2 with about 8600 hab/km^2 (figures from 2016). In November 2018, the MGP Council adopted its Metropolitan Climate Air Energy Plan (PCAEM), a strategic document aiming at achieving carbon neutrality by 2050 and accelerating the energy transition. Within 2050, the MGP foreseen a 100% low-carbon built stock and an energy mix consisting of 60% renewable and recuperated energy, 30% of which should be locally produced. To achieve this ambition, one of the priorities is to draw up a metropolitan energy master plan to strengthen energy demand management, develop local production of renewable and recovery energy and coordinate the development of electricity, gas, heating and cooling distribution networks.

In this context, the Metropolis of Greater-Paris brought together ADEME, APUR and BRGM to support the energy transition and the development of renewable energies (photovoltaic, methanation, geothermal, etc.). The project started in 2020 and proposed a global approach to establish a renewable energy master plan, including the identification of potential resources and energy demand, the development of urban planning and the technical and operational constraints for renewable energy deployment. Concerning the mobilisation of subsurface resources, the MGP wishes to be able to develop shallow geothermal energy projects in favourable sectors of its territory given the considerable resources available to meet the objectives of the PCAEM. The results of this study will be the baseline for defining potential areas for 5GDHC roll-out.

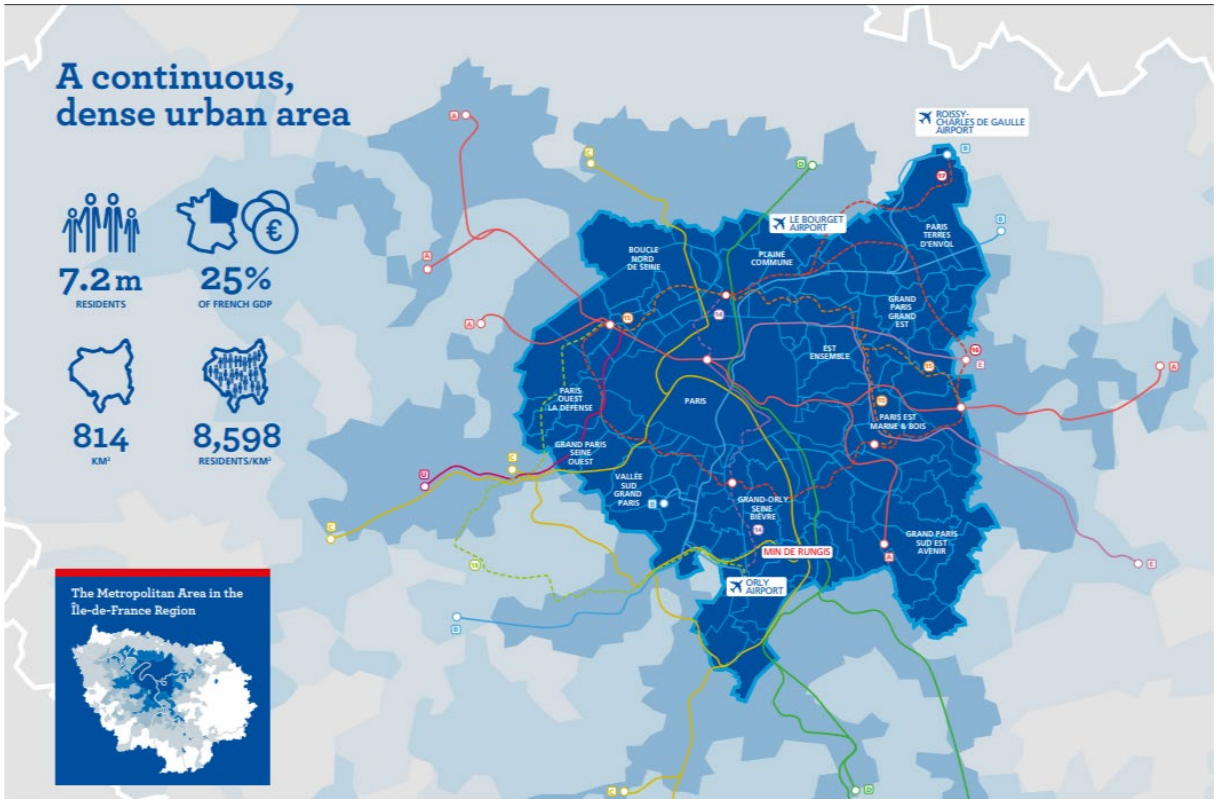


Figure 3. Greater-Paris Metropolis and its 11 territories (figures from 2016)

2.3. Strasbourg Eurometropolis (SEM)

Strasbourg Eurometropolis (Figure 4) is located in Grand-Est Region along the German border and is composed of 33 municipalities with a population of 487 303 inhabitants on a geographic area of 338 km^2 (*i.e.*, 1442 hab/km^2 in 2019). 60% of the population of the metropolis is concentrated in Strasbourg and the population of the metropolis represents one quarter of the total population in Alsace. At the end of 2016, the Eurometropolis of Strasbourg has stimulated a reflection on his territory around an air-energy-climate strategy, which was the basis for building its Territorial Climate Air Energy Plan (PCAET). The 2030 climate plan aims at reducing global energy consumption by 30 % (55% in 2050), attaining 40% (100% in 2050) of renewable energy production in final energy consumption and reducing GHG emissions by 40% (90% in 2050). The long-term objective fixed by the PCAET (within 2050) is to become a positive energy territory and reach energy sobriety and efficiency in addition to cover 100% and more of energy demand by local renewable energy sources.

Different studies have been conducted by BRGM on the Rhine alluvial aquifer. The alluvial deposits of the Rhine are the seat of a powerful aquifer (up to 150 m thickness). It is one of the largest alluvial aquifers in France and Europe. This water resource is easily accessible from the surface and generally has high productivity and ambient temperature (about 12°C in areas not impacted by heat pumps). In 2014, 617 shallow geothermal production or reinjection wells have been listed by ONAP (Observatory of the Rhine aquifer). This renewable huge resource associated to a high energy density with the objectives of the Eurometropolis to create 3000 new residential buildings per year and renovate 5000 old residential buildings per year make it a good candidate for evaluating the possibility of 5GDHC development.

Figure 4. Strasbourg Eurometropoplis municipalities and population (figures from 2019)

3. Analysis

3.1. Heating regime

The different heating regimes and actors involved are summarized Table 1 below for the three metropolitan areas. Sections 3.1.1 to 3.1.3 describe for each metropolis more in detail the current heating technologies/sources and current energy consumption and production.

Table 1. Main heating regimes and actors

Targeted follower regions	Dominant heating technology	Main actors in the current heating regime	Legal framework of actors operation
Orleans Metropolis (Centre-Val de Loire region)	-RES : biomass (wood base) -Non RES : natural gas	DALKIA and ENGIE Solutions	Public service delegation contract
Greater-Paris Metropolis (Ile de France region)	-RES: intermediate and deep geothermal energy -Non RES: natural gas and electricity	DALKIA, ENGIE, Groupe CORIANCE, IDEX Energies Réseaux	Public service delegation contract or direct management
Strasbourg Eurometropolis (Grand-Est region)	-RES : biomass (wood base) -Non RES : petroleum fuels and natural gas	R-CUA ("Réseaux de Chaleur Urbains d'Alsace"), Strasbourg Energie, Electricité de Strasbourg (ES)	Public service delegation contract and also some private networks

3.1.1. Orleans Metropolis

For the edition of the 2019 PCAET, Orleans Metropolis in association with Lig'Air carried a global overview of energy demand and consumption over the Metropolis area. They evaluated the global electricity and heat consumption over the territory to 5 987 GWh for the year 2012 with the repartition among sectors as illustrated in Figure 5. The amount of greenhouse gas emission was evaluated at 1 154 $kt_{eq}CO_2$ in 2012 with a majority of coming from road transportation (33 %), tertiary sector (24 %), residential sector (24 %) and industries (16 %).

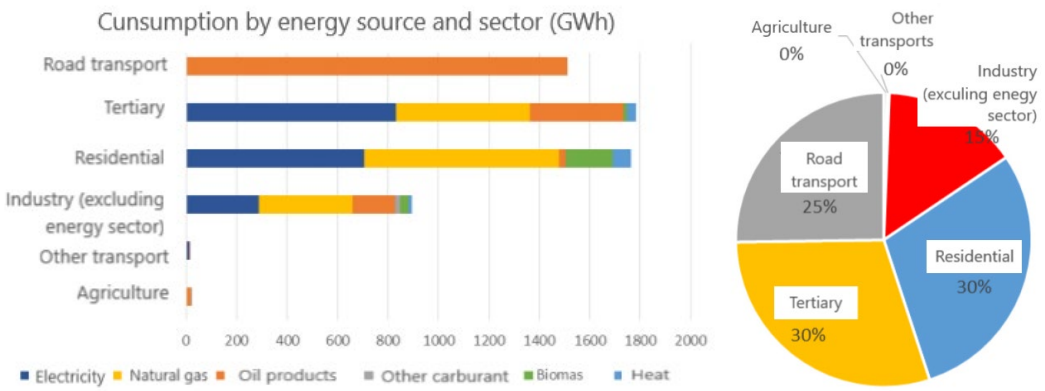


Figure 5. Distribution of energy consumption in GWh (electricity and heat) by energy sources and by sector (%) in Orleans Metropolis in 2012 technology (source: Orleans Métropole - Rapport de diagnostic énergétique)

The current dominant heating technology for residential sector in the Metropolis area is natural gas as it represents 1 300 GWh and 49 % of total heating consumption. Natural gas is also the principal source for heating in the industrial sector (374 GWh consumption representing 41% of total heat consumption for this sector). In the case of tertiary sector, electricity seems to be the main source for heating as the consumption is estimated to 831 GWh, which represents 46% of total heat consumption for this sector. Oil base products are the main heating technology used in the agriculture sector with 16,3 GWh estimated in 2012 which represents 73% of heating consumption in this sector. The elements provided here have been estimated by Lig'Air during the 2012 study.[1]

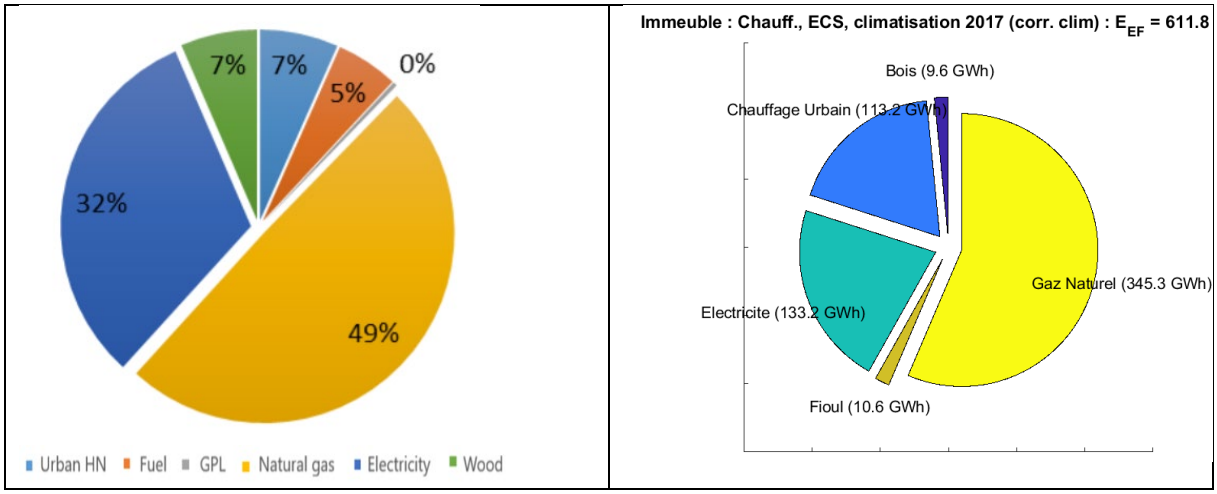


Figure 6. Distribution of heating energy consumption by energy source for residential sector technology (left, source: Orleans Métropole - *Rapport de diagnostic énergétique & INSEE 2013*) and in 2017 according to the recent study and figures from ARTELYS (right)

Biomass is the first renewable heating source over Orleans Metropolis as it represents about 265 GWh per year and provides heat to 30 000 equivalent housing units. Two biomass cogeneration plants are in Orleans, one in the centre and one south of the Loire River and a third plant is located in Fleury-les-Aubrais, north of the Metropolis (Figure 7). All plants are managed under a public service delegation contract. Details about each plant is given here below:

- Heating plant south of Orleans[2]: the network is mainly supplied by a biomass cogeneration plant (68 %) and is managed by SOCOS (subsidiary of Dalkia) under a public service delegation contract. Commissioned in 2012, the plant delivers 15 000 equivalent residential units and supply heat notably to the BRGM (indeed, BRGM and other research centres are located right next to the plant). Total heat production is estimated to 149 GWh in 2019 according to ADEME[3]. Backup supply is ensured by a gas boiler. Electricity production is estimated to 44 GWh.
- Heating plant north of Orleans[4]: the heating network is mainly supplied by a biomass cogeneration plant (81 %) and is managed by SODC (subsidiary of ENGIE Solutions) under a public service delegation contract. Commissioned in 2015, the plant delivers 12 000 equivalent residential units for a total heat production of 90 GWh in 2018 according to SODC. Electricity production is estimated to 68 GWh.
- Heating plant of Fleury-les-Aubrais[5]: the heating network is mainly supplied by a biomass plant (63 %) and is managed by SOFLEC (subsidiary of Dalkia) under a public service delegation contract. Commissioned in 2015, the plant delivers 3 000 equivalent housing units and produced 26 GWh of heat in 2019 (according to ADEME). Backup supply is provided by a fuel and gas boiler. Electricity production is estimated to 6.8 GWh.

[1] https://www.orleans-metropole.fr/fileadmin/orleans/MEDIA/document/environnement/plan-climat/1_Diagnostic.pdf
[2] https://carto.viaseva.org/public/viaseva/building/#panel/building/v/building_id/4501C
[3] https://centre.ademe.fr/sites/default/files/annuaire-complet-reseaux-chaleur-centre-val-loire.pdf
[4] https://carto.viaseva.org/public/viaseva/building/#panel/building/v/building_id/4503C
[5] https://carto.viaseva.org/public/viaseva/building/#panel/building/v/building_id/4505C

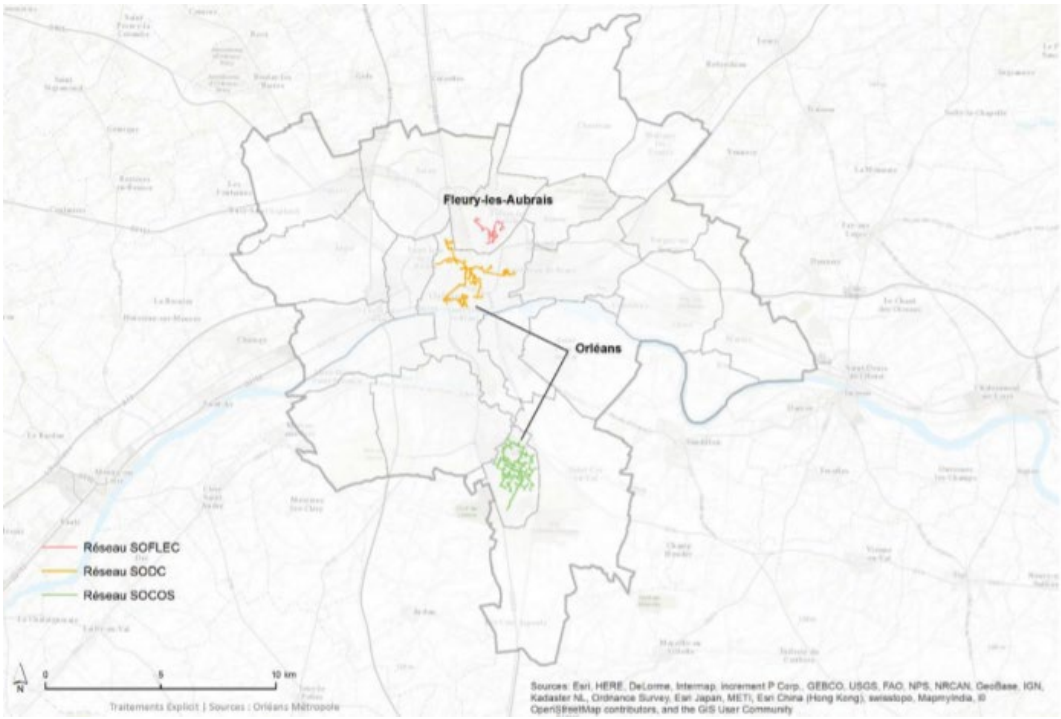


Figure 7. Location and extension of the three DHN in Orleans Metropolis

The global production of energy (heat and electricity) from renewable sources was evaluated between 235 and 443 GWh, *i.e.*, 5 to 8% of global consumption in 2012 by Lig'Air as detailed here below and in Figure 8:

- 433 GWh electricity and heat (collective and individual) by cogeneration are produced by wood base combustible
- 32 GWh of electricity is produced by the recycling plant of Saran (waste to energy plant)
- 2.8 Gwh of electricity is produced by photovoltaic panel (653 stations recorded to the grid)
- 2,1 GWh of heat is produced by solar thermal station
- Over 120 geothermal operations have been recorded in the area (shallow probe and doublet)

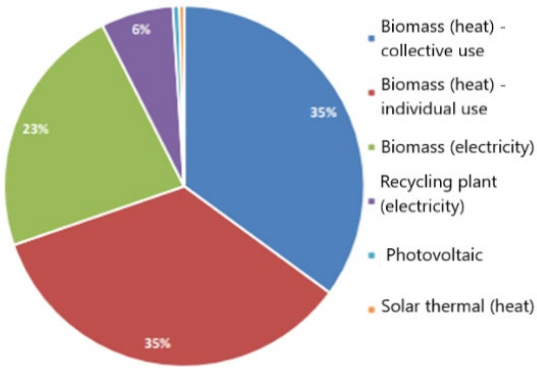


Figure 8. Distribution of renewable energy source consumed in the territory of Orleans Metropolis by technology in 2012 (source: Orleans Métropole - Rapport de diagnostic énergétique) and for multi-unit buildings

During the 2020 study regarding geothermal energy development carried out within the convention between BRGM and Orleans Metropolis, ARTELYS provided information of heating, domestic hot water and cooling consumptions corrected for thermal energy climatic variation at the IRIS mesh level for residential and tertiary sectors (Figure 9, Figure 10). This unit is a statistic information block unit being of inhabitation (with usually 1800 to 5000 inhabitants), activity or mix types, with 117 IRIS on the territory. Agriculture and industrial sectors have been considered in the study as deprived of thermal energy needs.

In 2019-2020 BRGM has carried out an estimation of how shallow geothermal energy may contribute to the thermal energy mix of the Agglomeration. This analysis crossed energy consumption with underground data, taking into account regulation constraints. The use of the IRIS raised a difficulty since a finer spatial analysis of the consumptions was expected to estimate the shallow geothermal energy contribution at the building level. The energy data was crossed with the ground occupancy urbanism geodatabase built by Orleans Metropolis to better localize the energy distribution (cf. Figure 11). In every IRIS, the distribution of the consumption in residential areas assumes that the energy density on “multi-unit buildings” is twice the density of “mixt urban tissue”, which is twice the density of “detached house”, while the energy consumption of the tertiary sectors is distributed according to the surface.

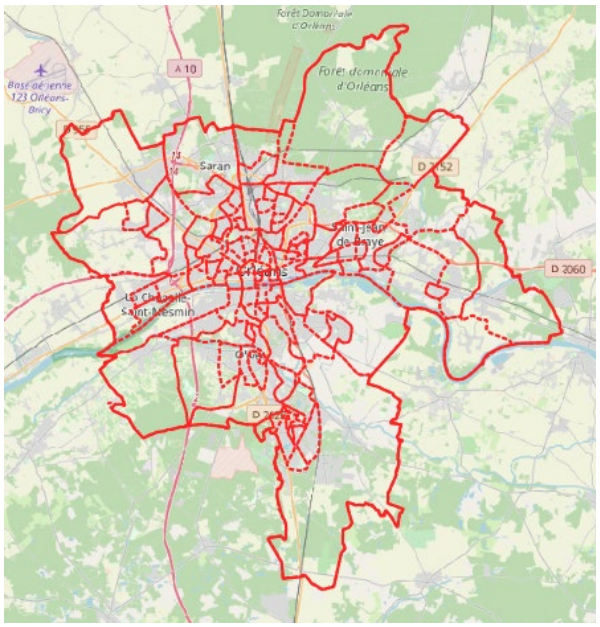


Figure 9. IRIS on Orleans Metropolis

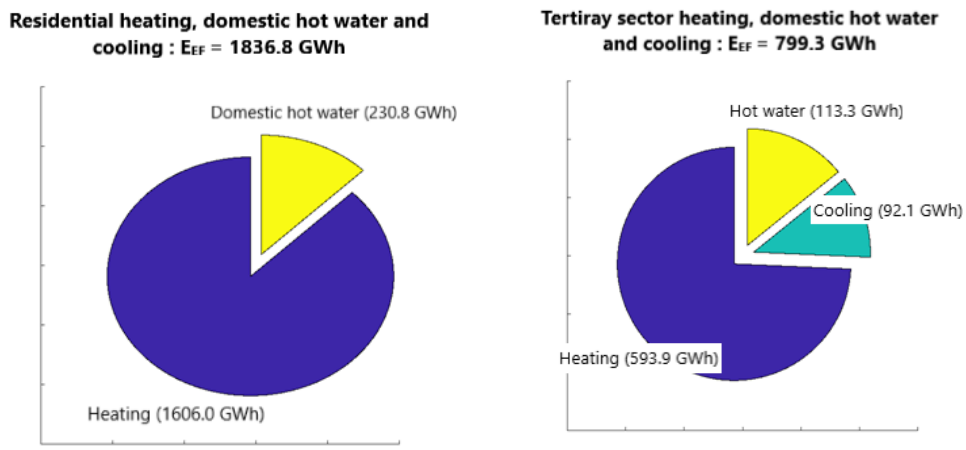


Figure 10. Thermal energy consumption by sector (Tertiary sector on the right and residential on the left) and by typology (heating, hot water and cooling) using climatic correction

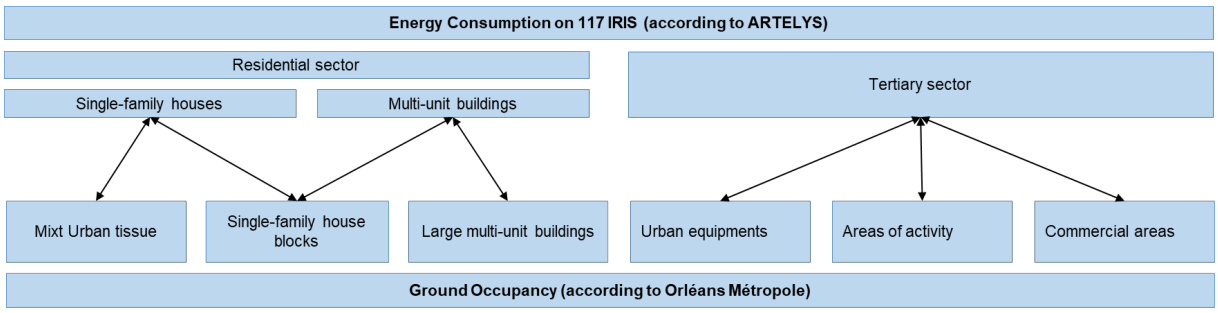


Figure 11. Methodology used for crossing energy data with ground occupancy data

Crossing the ground occupancy with the energy data resulted in 536 zones, i.e., the less than 117 × 6 = 702 zones since not every type of occupancy appears in every IRIS. The results depend upon the weights used to compare the energy consumption of every zone. It can be pointed out that the cooling accounts for only 4 % of the total thermal energy demand (including heating, cooling and DHW), and there is no zone where the cooling requirement is estimated to be higher than the heating and DHW demands (cf. Figure 12). At this stage, the research of zones with balanced requirements of heating and cooling do not seem to be a driver for 5th generation grids.

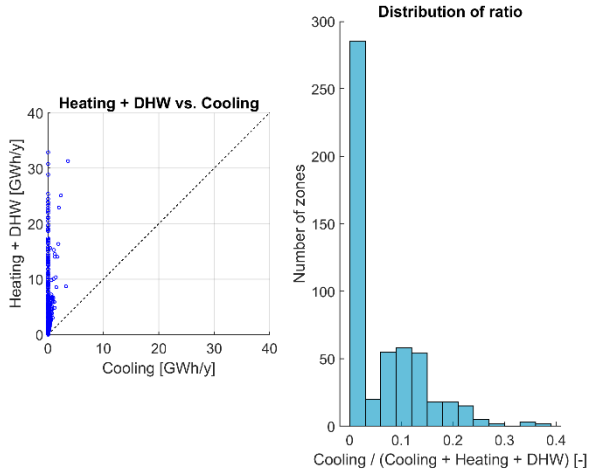


Figure 12 : Heating vs. Cooling for the 536 zones (left). Distribution of the share of cooling in the total thermal needs (right)

3.1.2. Greater-Paris Metropolis

For the edition of the PCAEM in the 2018, a global diagnosis was edited at the level of the Greater Paris territory using 2012 surveys. The global energy consumption in 2012 is estimated to 91 TWh, which represents 56% of the Ile-de-France region (excluding the transportation sector that represents for the whole region 98 TWh/yr of energy consumption). Only 12% of energy consumed comes from renewable and recoverable sources.

The residential sector represents more than half of energy consumption in the metropolitan area with 48 TWh/yr (53%), the tertiary sector consumption is estimated to 34.5 TWh/yr (i.e., 38% of total consumption) and industries represents 8.2 TWh/yr (i.e., 9% of total consumption). The distribution between sources by sector is given in Figure 13. Natural gas and electricity represent a major part of final energy consumption for all sectors (excluding transport). Heating represents the majority of total energy consumption in the GPM (about 60% for residential sector) as illustrated over Figure 14. Between 2005 and 2012, final energy consumption has been reduced by 7% over the metropolitan area across all sectors and concerns all energy sources. However, the reduction more significant for oil products consumption (-34%) and natural gas consumption (-7%).

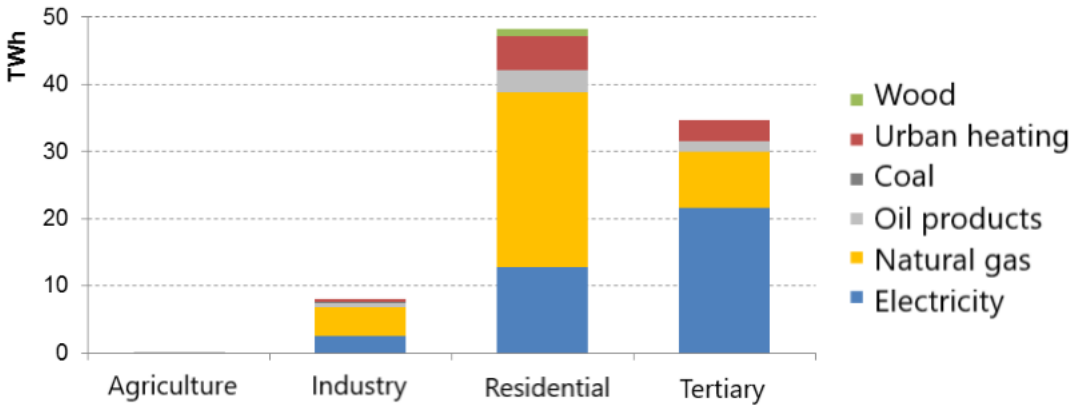


Figure 13. Energy consumption for the Greater-Paris metropolitan area in 2012 by energy source and by sector (source: ROSE 2012)

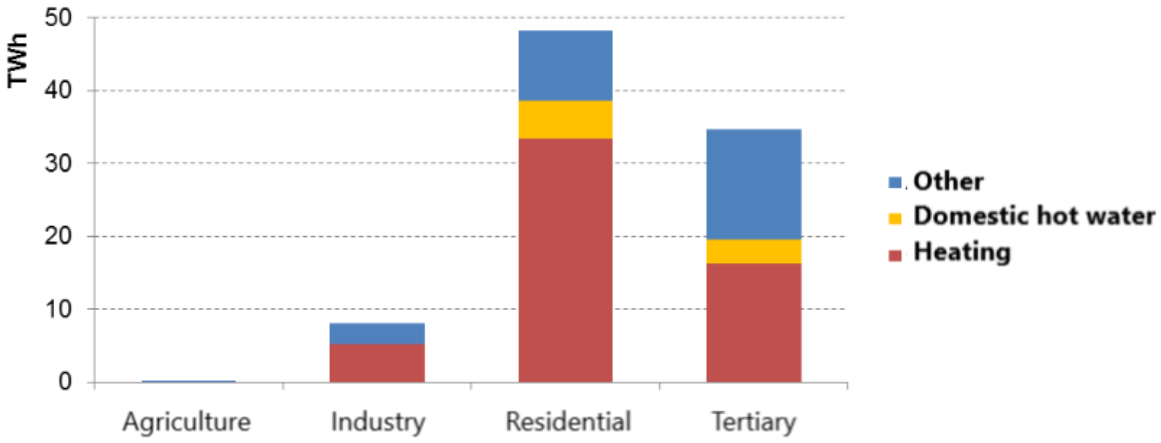


Figure 14. Final energy consumption for the Greater Paris metropolitan area in 2012 by usage and by sector (source: ROSE 2012)

Focusing on the residential sector, in 2012 the metropolitan territory gathers 3.5 million housing over about 210 million m² of floor space of which 90% correspond to primary residences. The energy consumption is estimated to 48 TWh in 2012 thus representing around 53% of regional energy consumption excluding transportation. Natural gas and electricity are the main energy sources used over the metropolitan area for heating. Natural gas is mostly used for heating, and to a lesser extend domestic hot water and cooking and is responsible of 60% of greenhouse gas emissions in the territory. The distribution of housing typology is relatively heterogeneous in the different sectors of the metropolis. Indeed, individual houses are almost inexistent in Paris while they represent 20% of accommodations in the outskirt of Paris and 13% over the whole metropolitan area. Collective housing (out of social housing, company, and offices) remains the great majority of dwelling over all the territory (51% in the GPM, 68% in Paris and 42% in the municipalities directly in the outskirt of Paris) and social housing represent 22% of accommodations in the metropolitan area and 15% in Paris. In 2014, heating of the residential sector over the GPM is individual for 57% and 41% are equipped with collective heating systems. Among the individual heating, 33% is produced using electricity, 23% using natural gas and 1% using fuel. Among the collective heating systems, 17% are connected to urban heating network, 18% are produced by gas boiler systems and 5% to fuel boiler systems. 8.6 TWh of heat is consumed through urban network in 2015 (source APUR). Six cooling networks are listed over the GPM representing around 700 GWh of cold delivered each year in the GPM networks.

Tertiary sector energy consumption is estimate to 34.5 TWh in 2012 representing 38% of energy consumption at regional level. Electricity is a main source of energy consumed (62%) before natural gas (about 25%). In 2007, the number of square meters occupied by tertiary building (public and private) in the region Ile-de-France is estimated to 217 million m². Offices and commercial area are the principal consumer of energy of the metropolitan area for the tertiary sector.

Over the metropolitan area, only 12% of energy consumed comes from renewable and recoverable energy sources and only 4% of total energy consumption comes from local renewable energy sources (Figure 15). Indeed, renewable electricity production estimated to 6785 GWh/yr (source: RET 2016, RTE 2012 and ROSE 2012) is provided mainly by national grid and extraterritorial productions (hydraulic, wind, solar, etc.) and to a minor extend using local production (photovoltaic, cogeneration from waste to energy plant). Renewable and recoverable heat represents 5% of total energy demand of the territory with 3 TWh being distributed through urban heating network in 2012 and 1.2 TWh produced for direct use. Most of heat production comes from household waste to energy plant (74%), from deep geothermal resource exploitation (21%) and wood-fired heating or biomass (6%). Direct renewable heat used comes from biomass energy combustion, collective and industrial boilers (99%) and solar thermal panels to a minor extend (1%). Geothermal energy represents thus the first local renewable heating resource in the GPM and waste-to-energy represent the first recoverable heating source. Biomass cannot be considered as local since wood consumed by boilers is produced outside of the metropolitan area and even outside the French territory. Renewable cooling network is estimated to 384 GWh according to ROSE 2012 study (i.e., more than 50% of cold distributed is renewable).

The objectives fixes in the PCAEM voted in 2018 intends to increase within 2050 the share of local renewable energy up to 30% and bring the share of renewable heating in the network from 34% to 100% (Figure 15).

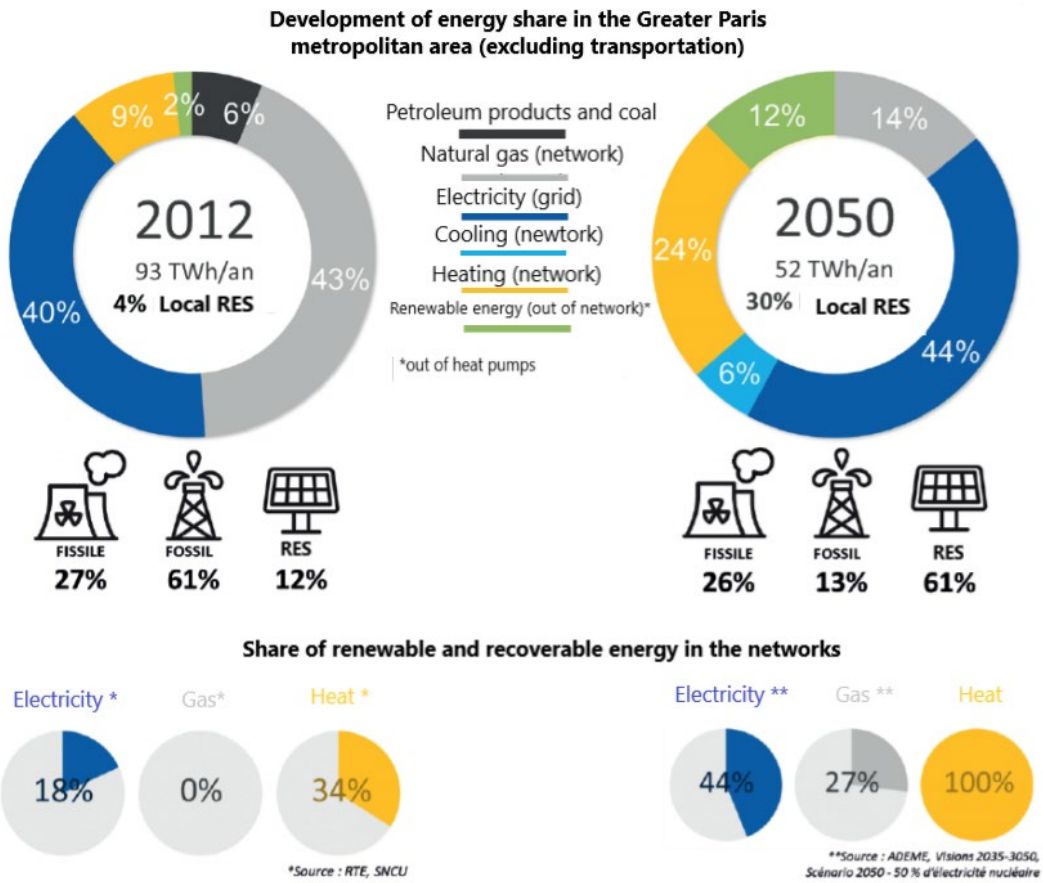


Figure 15. Share of renewable energy in the mix of Greater Paris metropolitan area in 2012 (left) and development forseen within 2050 (right) (source : PCAEM MGP 2018, ADEME, RTE, SNCU. Translated in english)

3.1.3. Strasbourg Eurometropolis

The energy consumption is evaluated to 12,5 TWh in 2017 (34,6 MWh/resident) and is distributed throughout the territory in balanced way between the residential (30%), the tertiary (25%), the industrial sector (21%) and road transport (23%). Fossil fuels (oil products and natural gas) are the main type of energy consumed in the EMS territory, representing 60% of the total energy consumption of the territory (Figure 16).

The residential sector (nearly 223,000 primary residences in 2015 according to the INSEE) is the main source of energy consumption with 3.8 TWh, i.e., 30% of the EMS's total energy consumption. Nearly three quarters of this consumption is for the heating of buildings, which is itself covered for nearly half by the combustion of natural gas, a major emitter of greenhouse gases (Figure 17). The tertiary sector and transport (mainly road) consume approximately 3.2 and 2.8 TWh respectively, i.e., 25% and 22% of the energy consumption of the EMS. Oil products that emit large quantities of greenhouse gases, are the main type of energy consumed by road transport (92% of energy consumption). On the other hand, electricity dominates the energy mix in the tertiary sector, at 52%. The industrial sector accounts for approximately 20% of the energy consumption of the EMS, i.e., a consumption of around 2.5 TWh, 62% of which is covered by the combustion of natural gas (Figure 17).

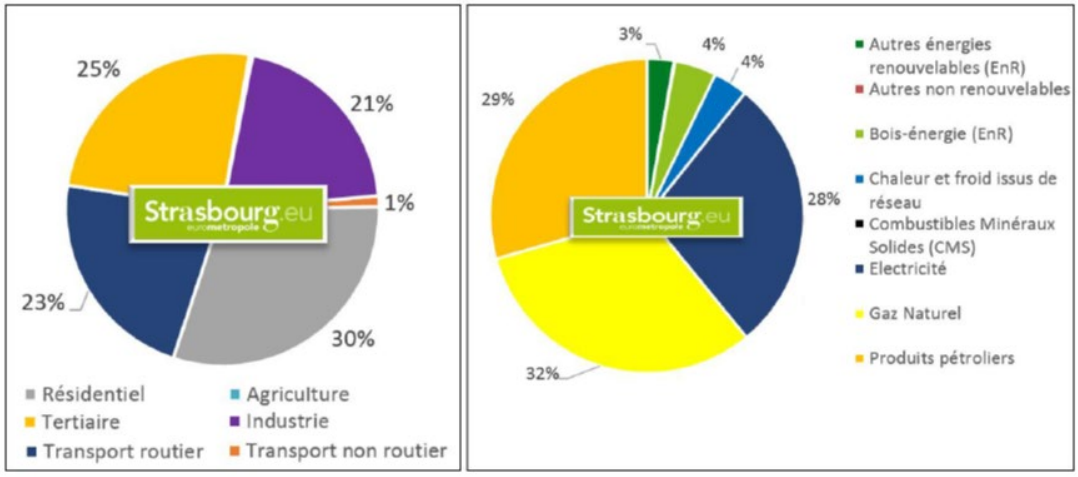


Figure 16. Distribution of final energy consumption adjusted for annual temperature variations (left) and by energy sources (right) (source: Invent'Air V2019 - ATMO Grand Est)

Left: grey: residential, yellow: tertiary, dark blue: road transport, purple: industry, orange: other transport.
Right: dark green: other renewable sources, light green: wood-energy, light blue: DHC networks, dark blue: electricity, yellow: natural gas and orange: oil products

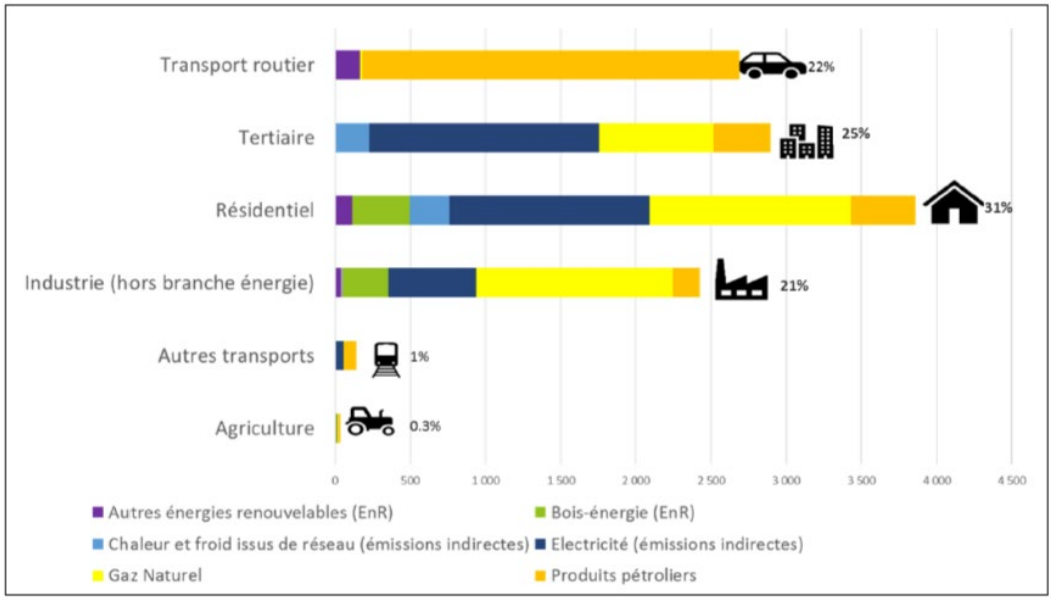


Figure 17. Distribution of final energy consumption by sector in 2017 (source: Invent'Air V2019 - ATMO Grand Est)

From top to bottom: road transport, tertiary sector, residential sector, industry, other transports and agriculture
Purple: other renewable sources, green: wood-energy, light blue: DHC networks, dark blue: electricity, yellow: natural gas, orange: oil products

The renewable energy consumption is estimated at 1 776 GWh in 2017 (Figure 18). It covers 14.2% of the territory's final energy consumption adjusted for climate variations, all sectors combined. The most consumed energy is hydroelectricity accounting for 45% of the total RE consumption in the EMS, followed by wood energy with 33%. The others RE are biofuels (10%), aerothermal and geothermal heat pumps which account respectively for 4% and 2% of the consumption, biogas (2%) and thermal solar (1%).

The total renewable energy production is estimated at 1 498 GWh in 2017 (Figure 19). The distribution of local RE production is dominated at 53% by hydroelectric production with the "Port du Rhin" power station in Strasbourg which produces around 800 GWh of electricity each year (791 GWh in 2017). The wood-energy production represents 541 GWh in 2017 (36% of total RE production) and comes from a departmental or regional deposit. The other RE (11%) are shared between aerothermal HP (4,4%), biogas (2,9%), geothermal HP (2,4%), thermal solar (1,1%) and PV solar (0,2%).

However, the local mix could be significantly expanded by 2020, to reach 20-25% (estimates by the Eurometropolis of Strasbourg) by integrating new deep geothermal sites, the biomass plant in the Port, the development of photovoltaic projects, heat pumps, etc.

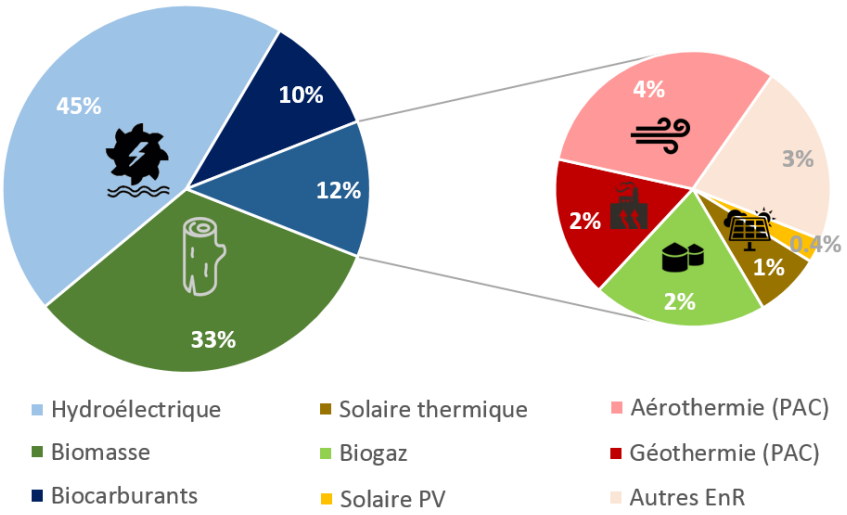


Figure 18. Distribution of renewable energy consumption by sources (source: ATMO Grand Est V2019)

Light blue: hydroelectric, green: biomass, dark blue: biofuels
Pink: aerothermal, red: geothermal, light green: biogas, brown: thermal solar, yellow: PV solar, light pink: other RES

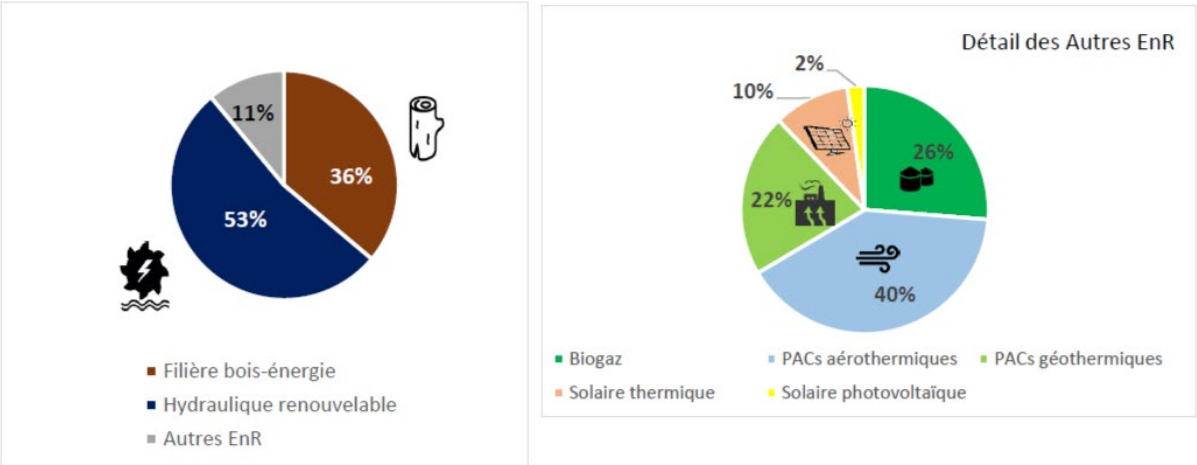


Figure 19. Distribution of renewable energy production by sources (source: ATMO Grand Est V2019)

Dark blue: hydroelectricity, brown: wood-energy 36%), gray: other RE (%)
Light blue: aerothermal HP, drak green: biogas, light green: geothermal HP, orange: thermal solar, yellow: PV solar

The heating networks have been developed in the territory of Strasbourg since the 1960s. They have the advantage to distribute centralized renewable energies. Biomass represents the main heat source to date, geothermal energy, and industrial heat recovery in the future. The EMS oversees 4 public heating networks in the area (Elsau, Esplanade, Hautepierre and Wacken, see location in Figure 22). A network is in project in the municipality of Illkirch-Graffenstaden for a commissioning in 2023 (south of the EMS). Also 25 private heating networks and collective boiler are inventoried, to date, on the territory. The diagnosis of the Hautepierre, Elsau and Esplanade heating networks was carried out as part of the "Schéma Directeur des Réseaux de Chaleur (SDRC)" of 2016-2017. The overall rate of renewable energy in the networks is slightly above 15%. The future developments aim to increase the part of RE in the networks with the objective of:

- 65% of RE in Hautepierre DHN (0% in 2018), and with an energy production of 200 GWh in 2027 (133 GWh in 2017);
- 65% of RE in Elsau and Esplanade DHN (55% for both networks in 2018), and with an energy production of 350 GWh in 2050 (260 GWh in 2018);
- >87 % of RE in Wacken DHN (7 MW biomass plus surplus of heat from industrials).

Figure 20 shows the total heating consumption and development plan of DHN in the Eurometropolis. The objective pursued regarding the heating networks is, on the one hand, to increase the share of energy distributed by the networks to at least 1,093 GWh in 2030 (i.e., the equivalent of 109,000 housing units supplied) and, on the other hand, to increase the share of RE to at least 75% in 2030 through the extension and the creation of new networks and their connection to renewable sources. This development should make it possible the heating networks to deliver 29% of the heat consumed on the territory in 2030, against 12% in 2018.

4 areas of development have been identified to achieve these objectives:

- To densify existing networks and strongly expand their concessive perimeter (see Figure 22);
- To develop networks in high-energy density areas;
- To create new heating networks: heating network of Illkirch (south of the EMS), which is mainly powered by deep geothermal energy, and of the north of the urban area, supplied by the geothermal site of Vendenheim. However, currently these projects are stopped because of u=induced seismicity. A private heating network is also being set up in the Port Autonomous sector from Strasbourg which will be based on the recovery of waste energy;
- To experiment new solutions for the 2020 period to 2030, such as the use of solar thermal energy in a network, of short-term and inter-seasonal storage, as well as "smart-grid" technologies to optimise real time management from the networks.

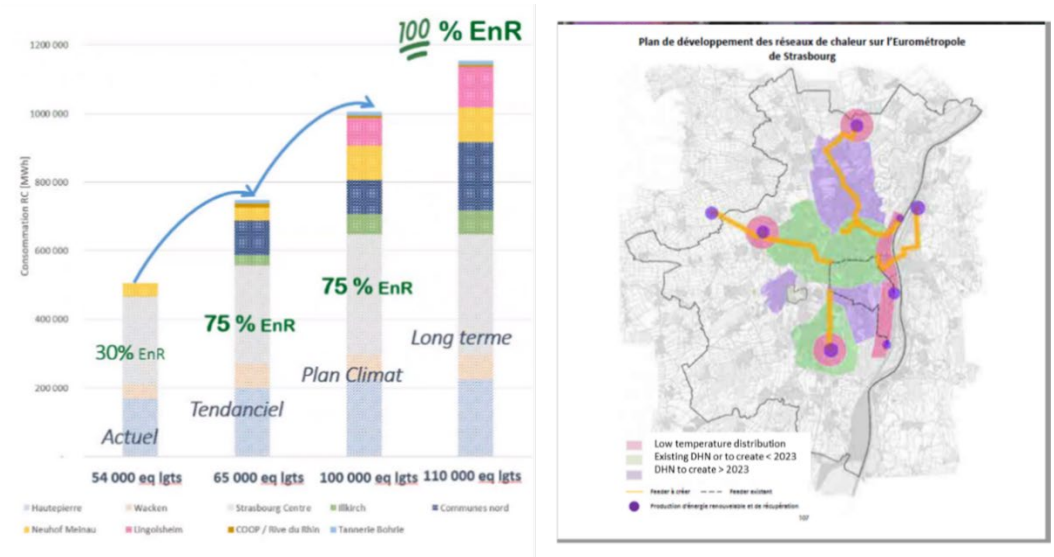


Figure 20. Energy consumption (MWh) in district heating networks with equivalent dwellings (left) and future DHN development plan (right) (source: EMS, Stratégie Réseaux de chaleur, 7 janvier 2021)

The objective fixed in the PCAET is to decrease the overall energy consumption by 32% in 2030 (in comparison to 2017) and by 55% in 2050 with an objective of 5700 GWh with 100% renewable energy sources (Figure 21). In this scenario, electricity is the major energy source in all the most consuming sectors with 50% produced by local sources. Biogas occupies an important part of the mix and supplies in particular the residential sector for heating needs and transport. Geothermal, wood and waste heat sources are the major components for residential and industrial sectors. Part of the potential for recovery of waste heat is used in a closed loop in the industrial sector. The "Other RE" category includes hydrogen with a significant part of which is used in the transport sector.

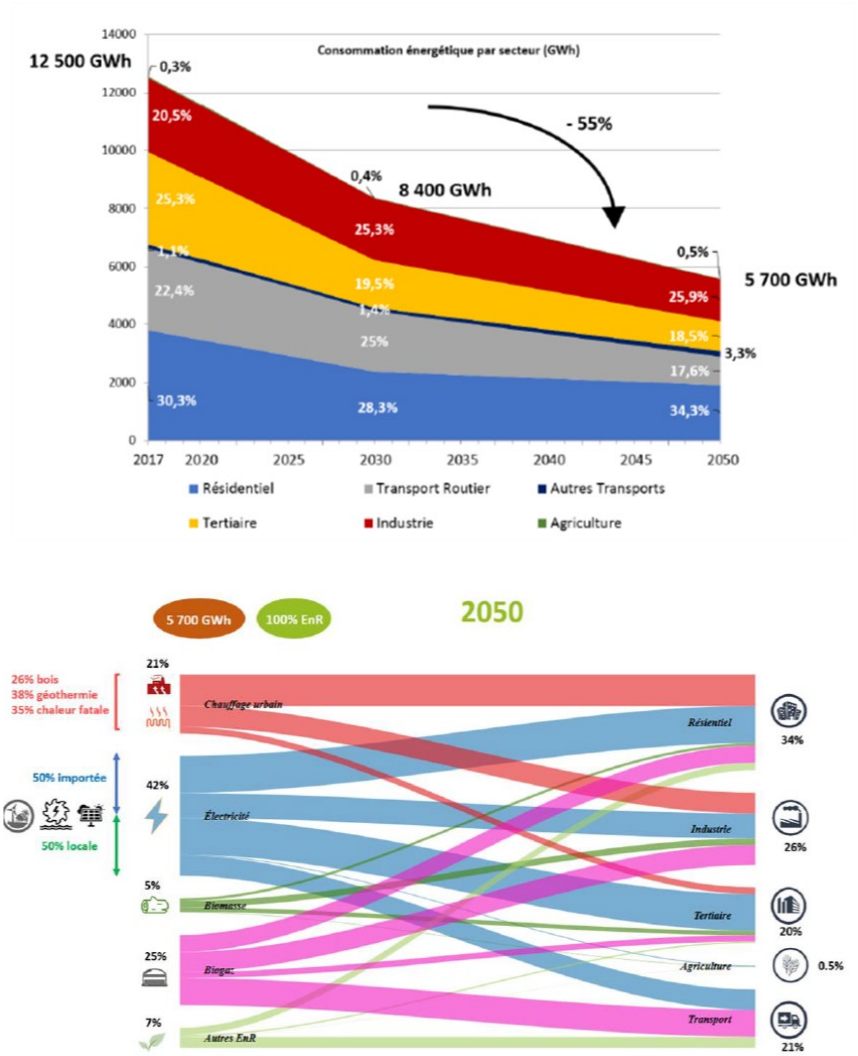


Figure 21. Evolution of the energy consumption in 2030 and 2050 (above) and energy mix targeted in 2050 (below) (source: "Synthèse des Schémas Directeurs des Energies", décembre 2019)

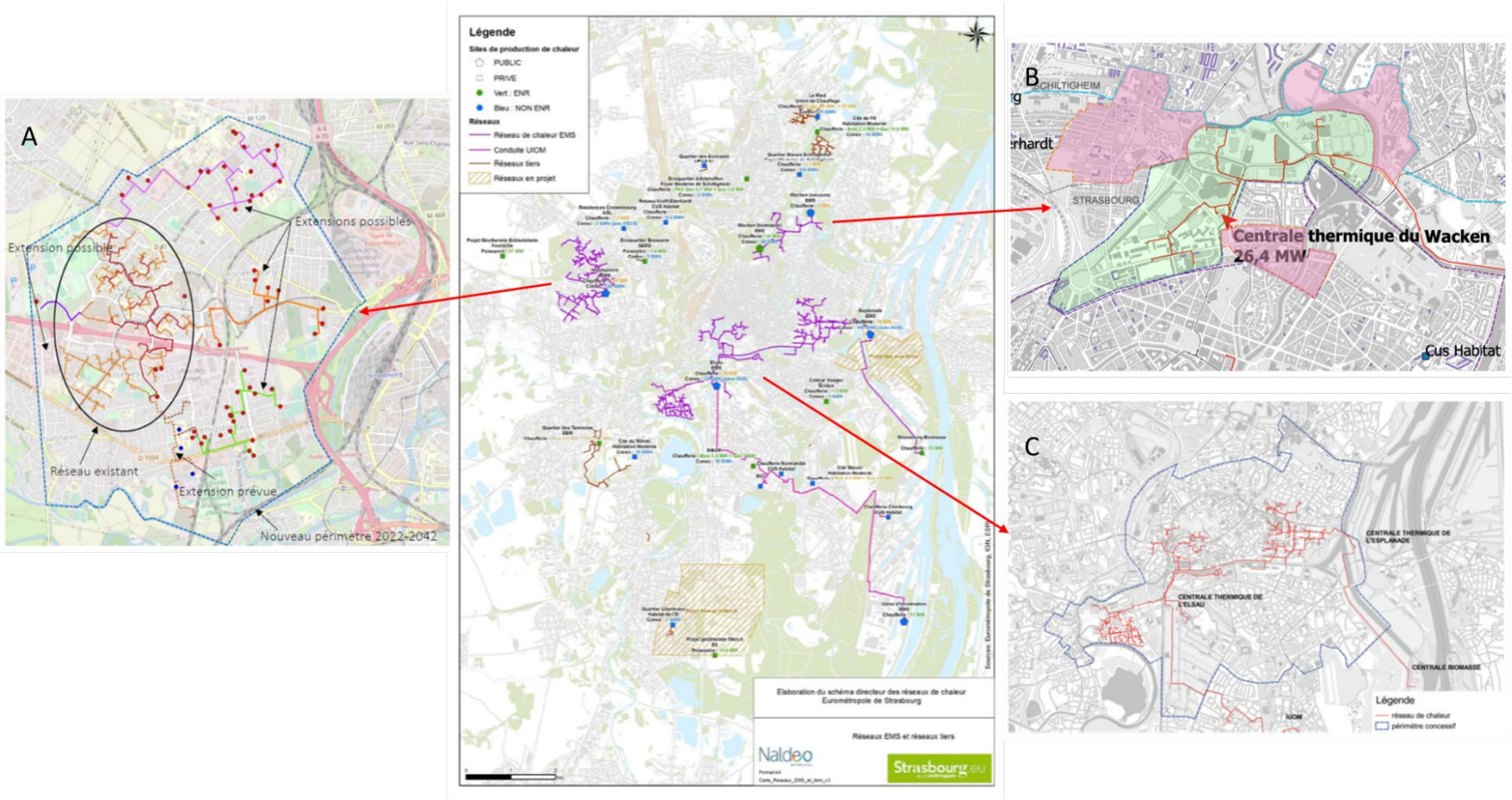


Figure 22. Location of the main district heating networks in EMS territory and possible future connections (source: "Schéma Directeur des Réseaux de Chaleur de Strasbourg", 2017)
A: Hautepierre DHN
B: Wacken DHN
C: Elsau and Esplanade DHN

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

The classification of a heating or cooling network is the procedure that allows a local authority to make connection to existing or planned networks compulsory in certain areas for new building installations.

This territorial energy planning tool offers local authorities the possibility of better controlling the development of renewable heating and cooling on their territory, improves visibility for the implementation of renewable heat network projects and contributes to the improvement of practices, particularly through enhanced consultation. Such a classification also makes it possible, in conjunction with other planning tools, to achieve the development of RES and GHG emission reduction objectives.

From a financial point of view, imposing the connection also makes it possible to have a slightly greater visibility on the use of the service and therefore on its financial balance.

Articles L712-1 to L712-5 of the Energy Code and the Order of 22 December 2012 define the conditions and procedure to be followed for the classification of the network. 3 conditions must be met for a network to be classified:

- the network is supplied with 50% or more by renewable and/or recovered energy (RE&R),
- the quantities of energy delivered per delivery point are metered,
- the financial balance of the operation during the amortisation period of the installations is ensured.

It should be noted that the status of the network (public or private) has no impact on the classification possibilities.

The classification decision refers to a zoning that defines so-called "priority development" zones. Within these zones, the connection of new or substantially renovated buildings is mandatory under penalty of a fine when the heating, air conditioning or hot water production capacity exceeds 30 kW.

3.2.2. Ownership and operation of district heating systems

There are two possibilities of district heating management for public heating networks:

Public service delegation (or “DSP” in French) is a management method frequently used for public services. It corresponds in the French jurisdiction to all contracts by which a legal person governed by public law subject to the general code of local authorities entrusts the management of a public service for which it is responsible to an economic operator whose remuneration is substantially linked to the operating result of the service.

The local authority can also decide to directly manage the public service (cost-plus contract management or direct management, “régie” in French) which is the case of certain district heating network operated in the Paris area. In Orleans Metropolis and Strasbourg Eurometropolis, the district heating networks are under public service delegation contracts. In Strasbourg Eurometropolis there are also some private and landlord networks.

3.2.3. Regulation of price-setting

The law has established the principle that billing must include a share for fixed costs and a variable share reflecting the cost of the quantities of heat recorded. However, the respective proportions of the fixed ("R2") and variable ("R1") terms are not regulated, which may lead to tariffs that are not very attractive given the importance of fixed investment costs. The Grenelle law aimed to remedy this lack of incentive for new user behaviour, by providing for a new rule whereby subscribers to a heating network can request a readjustment of the subscribed power after carrying out renovation work. This will allow them to obtain a reduction in the flat rate ("R2") of their bill. Similarly, tenants of low-rent housing are entitled to a reduction in their charges corresponding to at least 25% of the energy savings made when the owner-user of the network carries out work leading to such energy savings.

3.2.4. Role of building owners and building occupants

Deciding the heat source of the building

As mentioned in 4.2.1, the cases where buildings are subjected to the connection to an existing or planned network are the following:

● case n°1: construction of a new building (if the building permit application was submitted after the classification decision);

● case n°2: new part or extension of an existing building exceeding 150m² or 30% of the existing surface area;

● case n°3: renovation of a building, energy performance improvement work on a building or part of a building subject to articles R131-25 and R131-26 of the "Code de la construction et de l'habitation". In accordance with these articles, the work concerned are those that comply with all the following 3 conditions:

- building of more than 1000m² (except for the following buildings: buildings that do not use energy to regulate their indoor temperature; temporary buildings (duration less than or equal to 2 years); agricultural, craft and industrial buildings (except for residential premises) and requiring a small amount of energy for heating, DHW or cooling; places of worship; historical monuments,

- work on either the envelope and installations (heating, DHW, cooling, ventilation, lighting) or on the shell alone,

- estimated amount of energy performance improvement works greater than 25% of the value of the building.

● case n°4: replacement of the heating/cooling installation in a building or an industrial heating/cooling installation if the capacity is greater than 30 kW.
If the project corresponds to one of these four cases and is located within a priority development area of a classified heating network (information available from the local authority), connection is compulsory, unless an exemption is granted.

Investments and energy bill

The investment is covered by the collectivity and thanks to specific financial aids (see §4.2.5).

The different expenditure items of a heating network are

- the purchase of fuel to produce heat (wood, gas, fuel) or the purchase of heat directly from a third party (waste heat, district heating network, etc.);
- operating and maintenance costs of the network, which cover the personnel required to operate the central heating plants, electricity to run the distribution network auxiliaries, replacement of faulty parts, etc;
- depreciation of initial investments (surface and sud-surface installations).

Depending on how the heating network is managed (public authority, public service contract), its manager may also make a profit on the sale of heat. The bill sent to subscribers by the network manager logically covers all the above expenses. A particularity of heating networks is that the subscriber is not necessarily the final user but rather the building manager (lessors, co-ownerships, public authorities, etc.). There is generally no individual metering per dwelling: metering is done by substation, for the whole building or a group of buildings. The cost of the heat is then distributed to the occupants, according to a calculation and not a measurement.

3.2.5. Financing and subsidies

Localized subsidy or grant mechanisms available

At national level, the Renewable Heat Fund ("Fonds de Chaleur") is a financial aid for geothermal installations producing renewable heat or cold in the collective housing, the tertiary sector, the industry, and the agriculture. Initially dedicated only to renewable heat, the fund was enlarged also to renewable cold in 2018 and recently to low temperature DHC system (5-

30 °C). The fund enables geothermal facilities to be economically competitive compared to conventional energy-using facilities. In the case of low temperature DHC grids (like 5GDHC), are eligible the resource recovery (geothermal wells, borehole thermal exchanger…), the heating and cooling grid, the decentralized heat pumps. Aid from the Heat Fund allocated to geothermal energy DHC projects (creation or extension) is conditioned by the fact that the buildings are supplied at least by 50% of RES. In addition, some technical criteria of the DHC must be met as the length of the network (minimum of 200 m), the energy supply from RES (minimum of 200 MWh/y), the global COP of the installation (COP>3).

At local level, Orleans Metropolis has presented 33 actions following 6 strategic focuses to lead its ambition regarding carbon emissions and overall energy consumption reducing in addition to the development of renewable energy in its territory. The global budget of the metropolis is 23,4 M€ among which 19 M€ are directly related to investments. 18 additional jobs are intended to be created to lead the action plan proposed under the PCAET voted in 2019. The actions foreseen are for example in the geothermal energy domain the improvement of knowledge and development of the branch (action n°10[6]) through the edition of shallow and deep geothermal resource maps over the territory to improve the understanding of subsurface and identify areas of potential development.

3.3. Available energy sources and storage

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the highest ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low grade sources would be in order to make a decent 5GDHC business case. At the time of writing, D.T1.1.4 has not been finalized.

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

N.a. at this scale

3.3.2. Low temperature renewable sources (from soil, water, geothermal, solar heat)

Orleans Metropolis

The geothermal potential of the area was first estimated in 2007 and was then updated in 2017. The studies have provided an overview at regional level (Centre Val de Loire) of the favourability of open loop systems given underground information gathered and have shown a very good potential over Orleans metropolitan area as shown in Figure 23.

Orleans Metropolis has listed 120 shallow geothermal operations in 2012. A review carried out in 2019 reported over 154 operations on the metropolitan area, however this figure might be underestimated as some operations are not yet registered in the database of the underground (BSS). Among those 154, 78 operations have been identified has producing from shallow aquifer, the rest of operations is not clearly identified has open or closed loop. A broader referencing project of shallow geothermal operations is in progress to identify in more detail and more exhaustively the number of operations in France.

[6] https://www.orleans-metropole.fr/fileadmin/orleans/MEDIA/document/environnement/plan-climat/4_Plan_d_actions.pdf

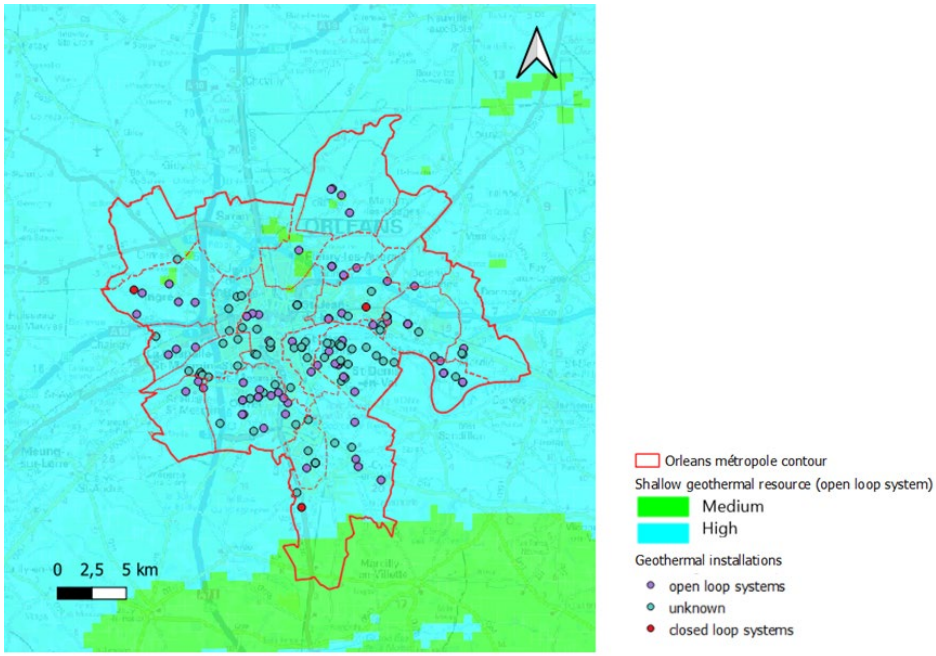


Figure 23. Geothermal potential for open loop systems in Orleans metropolitan area estimated in 2017 (Source: report BRGM/RP-66591-FR)

In 2020, a complete study has been carried out at Orleans Metropolis scale to refine the geothermal potential on shallow aquifers (open loop systems) or by using geothermal borehole exchangers (closed loop systems). The main target for shallow geothermal operations are the Beauce limestones composed by the Pithiviers and Etampes limestones (Figure 24). The depth varies between 10 and 30 m according the sector for the Pithiviers unit and between 30 to 40 m for the Etampes unit (Figure 25). The analysis of pumping tests give transmissivity between 3.10^{-3} and 3.10^{-1} m^2/s with an average of 9.10^{-2} m^2/s. High values of transmissivity can be the results of the presence of karst in Beauce limestones (especially values above 0.1 m^2/s). The hydraulic conductivity was estimated between $1,2.10^{-3}$ and 4.10^{-3} with a median of $1,4.10^{-3}$ m/s. The hydraulic gradient varies between 0,075% in lower-water hydraulic regime and 0,135% in higher-water regime. The temperature of the Beauce limestones is estimated about 13°C.

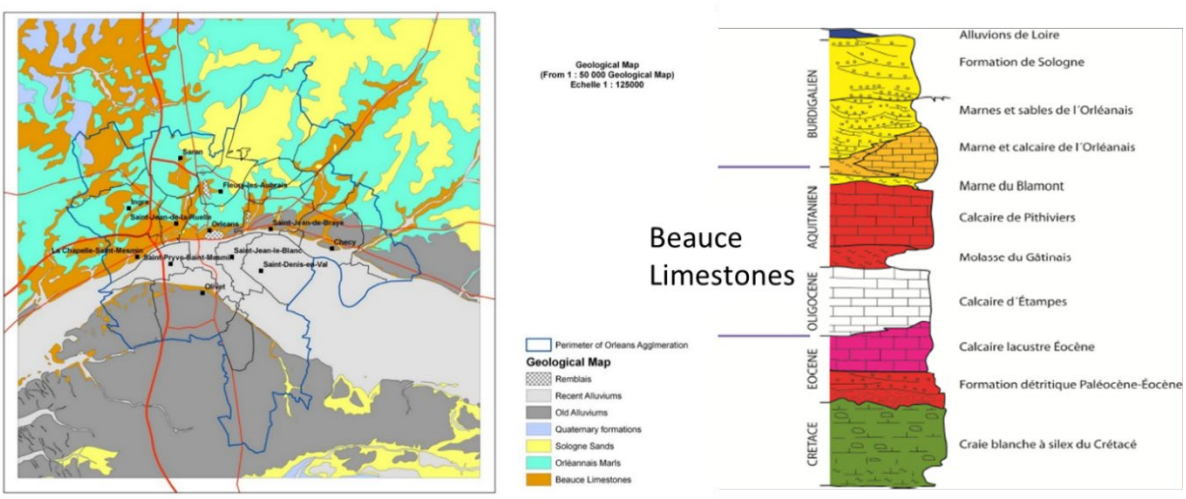


Figure 24. Geological map at Orleans Metropolis and hydrogeological units (Source: report BRGM/RP-70449-FR)

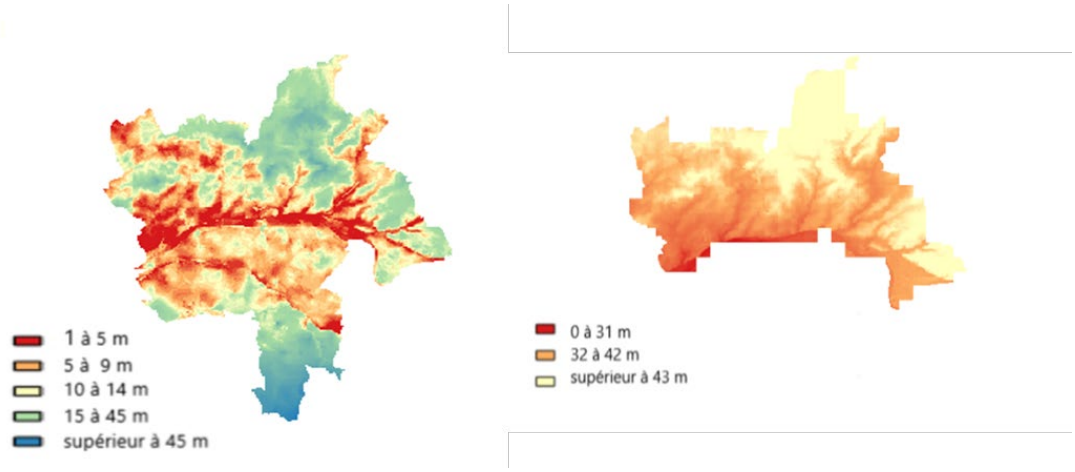


Figure 25. Depth of the Beauce limestones at Orleans metropolis (left: Pithiviers limestones, right: Etampes limestones) (Source: report BRGM/RP-70449-FR)

The methodology used to evaluate the shallow geothermal potential was based on hydrothermal simulations and on an algorithm which was developed in order to estimate the maximum theoretical coverage rate per open loop systems (doublets) for both aquifers (Pithiviers and Etampes limestones). The fraction of energy covered increases iteration after iteration as the doublets are positioned. For Pithiviers limestone, it represents around 27% (Figure 26), i.e., 723 GWh out of the 2607 GWh per year required. For Etampes limestones it represents about 38% (992 GWh).

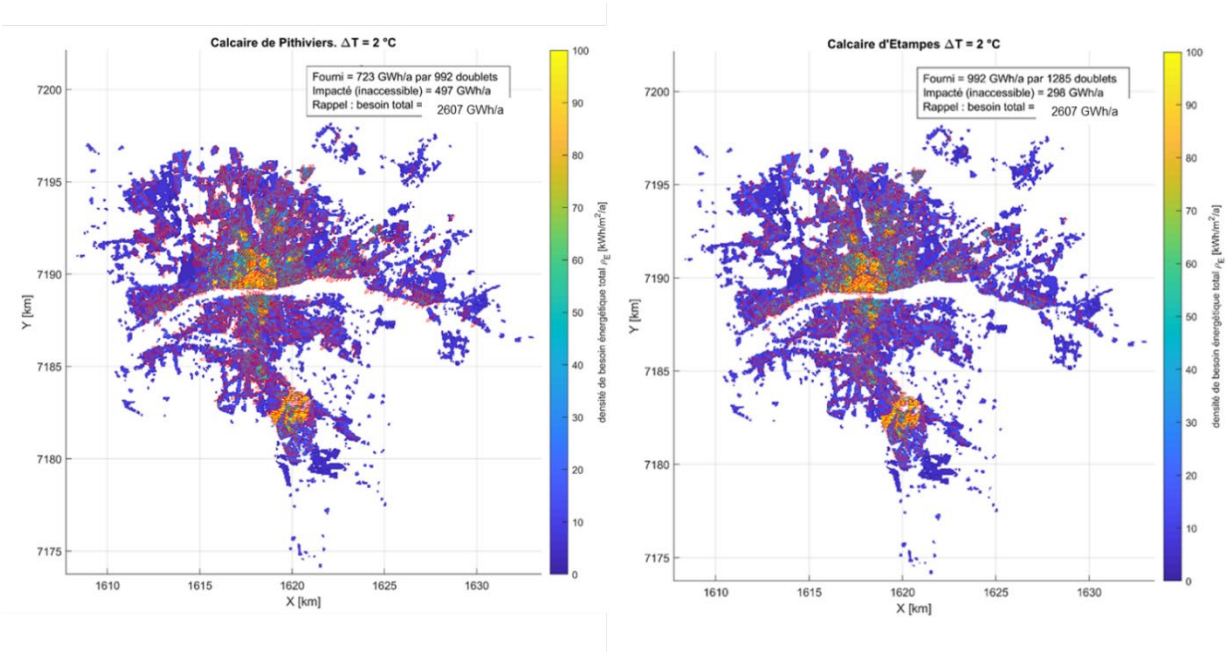


Figure 26. Maps of the shallow geothermal potential using open loop systems (left: Pithiviers limestones, right: Etampes limestones) (Source: report BRGM/RP-70449-FR)

Greater Paris Metropolis

The geothermal potential of the area was first estimated in 2005. The study has provided an overview at regional level (Ile de France) of the favourability of open loop systems given underground information gathered and has shown a good potential over the metropolitan area as shown in Figure 27. A 2020 study in partnership between the Greater Paris Metropolis and the BRGM has permitted to assess the potential for open loop and closed loop systems over the metropolitan area in more detail than the previous study.

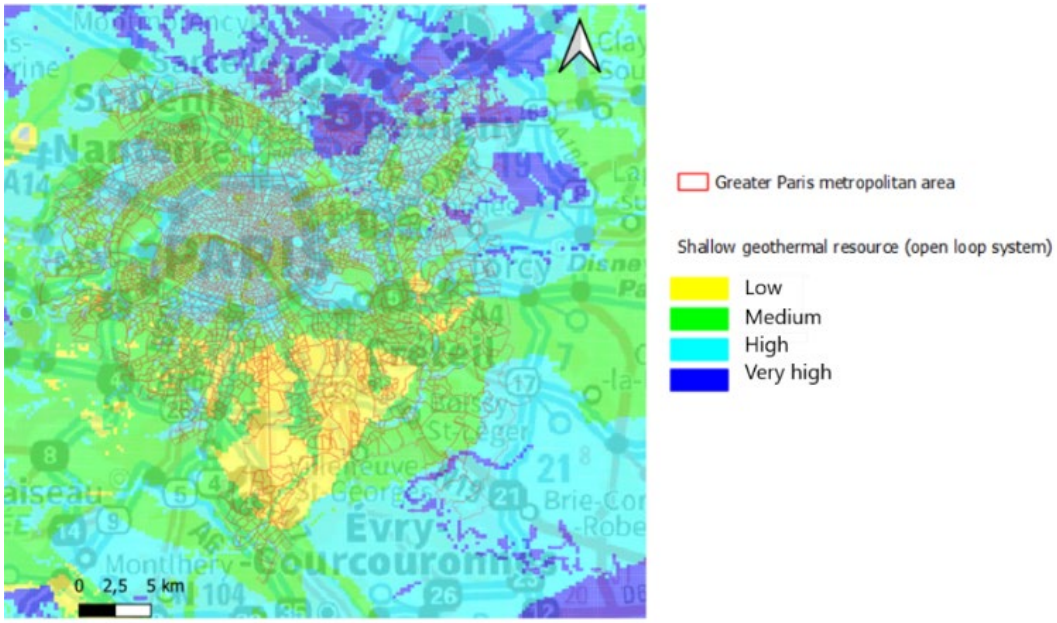


Figure 27. Geothermal potential for open loop systems in Greater Paris metropolitan area estimated in 2005 (Source: report BRGM/RP-53306-FR)

A study in partnership between the Greater Paris Metropolis and the BRGM to assess the potential for open loop and closed loop systems over the metropolitan area has been launched in 2020 is currently underway. An inventory of shallow installations over the area has permitted to identify 593 shallow geothermal wells in the GPM in January 2021, among which 272 are vertical probes and 321 are targeting aquifers below the MGP.

Three main aquifers are currently targeted by open loop systems: the Lutetian aquifer, the Ypresian aquifer and the Craie aquifer (chalk). Figure 28 presents the stratigraphic column of the MGP underground and highlights the position of the main aquifer formations along this column.

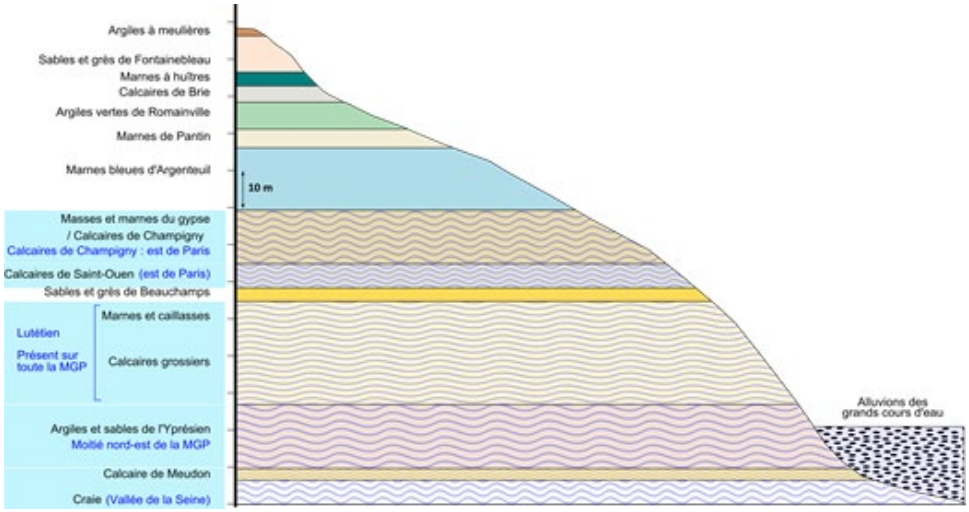
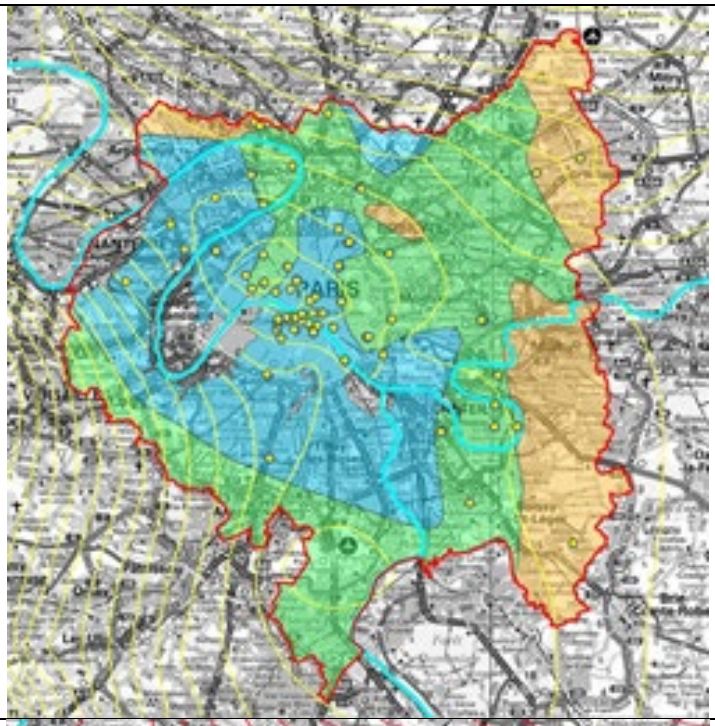
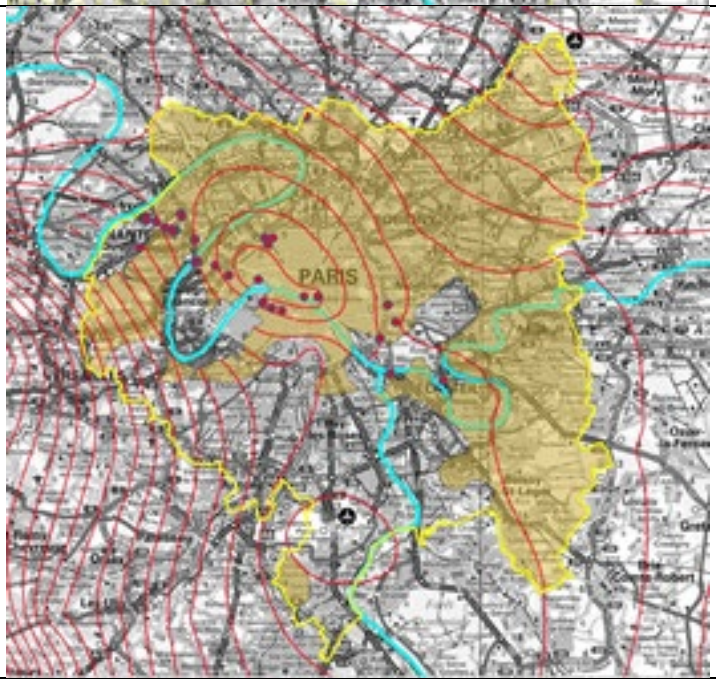


Figure 28. Stratigraphic column of geological formation below Paris metropolis and aquifer environment (blue highlight)

The first aquifer encountered in the underground corresponds to the Lutetian aquifer, which is composed of coarse limestones, marls and loose stones. 166 geothermal wells are currently operating in this aquifer according to BRGM inventory (dating from January 2021). This aquifer covers almost all the territory of the metropolis and the piezometers available indicate a depression at the centre of the metropolis (i.e., above Paris). The transmissivity of the aquifer, which indicated its exploitability, ranges from 10^{-2} m²/s and 10^{-4} m²/s depending on the location (cf. Figure 29, illustration on the left).

The second aquifer encountered corresponds to the Ypresian sands. 71 geothermal wells are currently operating in this aquifer according to BRGM inventory (dating from January 2021). Besides having less geothermal operations to this date in comparison to the Lutetian aquifer, the extractible flow rates can be significant in the Ypresian formation as the transmissivity is more important (based on the few wells available, transmissivity ranges between 10^{-2} m²/s and 10^{-3} m²/s (cf. Figure 29). This aquifer is thus interesting for new geothermal operations over the MGP. Outside of the areas identified in Figure 29, the proportion of clays in the aquifer is more important and the aquifer becomes less productive.

The third aquifer encountered in the underground of the MGP corresponds to the chalk aquifer (named Craie aquifer). 85 geothermal wells are currently operating in this aquifer according to BRGM inventory (dating from January 2021). No piezometric measurements are available over this formation. The exploitability of the aquifer has been classified according to the presence or absence of tertiary overlying formation (cf. Figure 29, central illustration). The risk of low productivity is higher when the aquifer is under the Tertiary formation and the exploitability area in the MGP corresponds to area where the formation is close to being outcropped (I.e., under the alluvial formations).

Lutetian aquifer Transmissivity: blue : between 1.10^{-2} m²/s and 9.10^{-2} m²/s green : between 1.10^{-3} m²/s and 9.10^{-3} m²/s orange : between 1.10^{-4} m²/s and 9.10^{-4} m²/s	
Ypresian aquifer Transmissivity of the aquifer between 1.10^{-2} m²/s and 1.10^{-3} m²/s (yellow)	

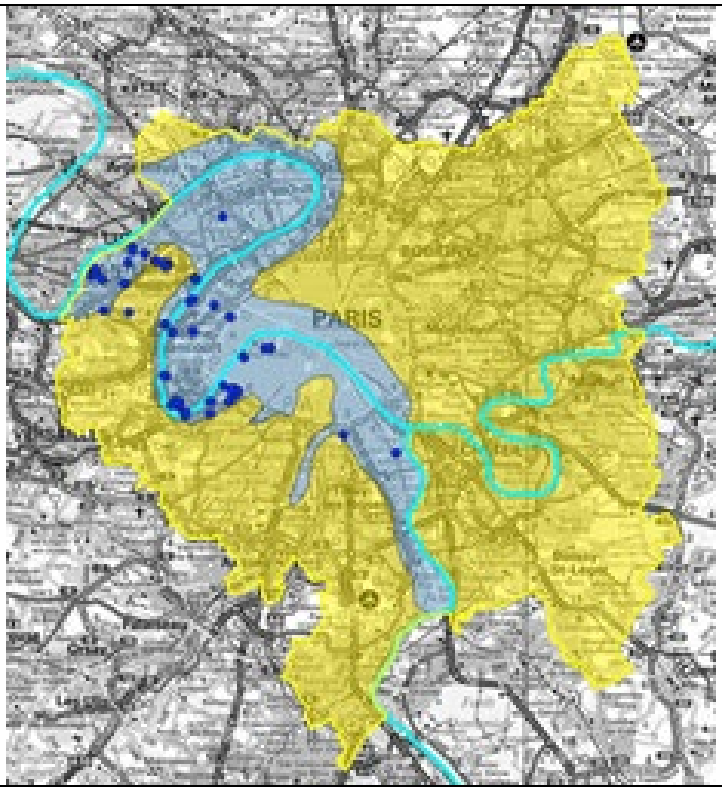
Craie aquifer Blue area: good exploitability (overlying formation has limited thickness) Yellow area: risk of low exploitability (Tertiary formations overlying the Craie aquifer)	

Figure 29. Illustration of transmissivity distribution in each aquifer considered for shallow geothermal energy production over the Greater Paris Metropolis (top: Lutetian aquifer, centre: Ypresien aquifer, bottom: Craie aquifer) along with the location of geothermal wells operating and piezometric map (BRGM)

The shallow geothermal potential using probes of the GPM is estimated to 6.1 TWh by APUR and the potential using aquifer base resource is estimated to 17.9 TWh (BRGM 2005 study). Potential for cold production using shallow geothermal source using heat pumps and open loop systems is estimated to 1.1 TWh per year over the metropolitan area. Hydrothermal potential for cold production in the Seine River (freecooling) is also possible over the MGP. The evaluation has not been carried out so far but operation such as le cooling network of Climespace have proven the possible use of this renewable energy source.

Strasbourg Eurometropolis

The metropolis of Strasbourg is characterised by the shallow Rhine alluvial aquifer. The alluvial deposits of the Rhine are the seat of a powerful aquifer (up to 150 m thickness) at the location of the EMS (Figure 30). The Rhine aquifer is already largely exploited for heating and cooling needs at the location of the Eurometropolis. A study in 2016 has evaluated the impact of the different shallow geothermal wells on the natural temperature distribution of the Rhine alluvial aquifer (Figure 31).

This alluvial aquifer is always recharge by the Rhine whatever the hydrogeological situation. The hydraulic conductivity of the alluvial deposits are in average 10^{-3} m/s and decrease with depth. The flow direction is oriented SSW-NNE (Figure 32) with a hydraulic gradient about 0,1%. The alluvial deposits cover the Oligocene marls which constitute the impermeable substratum of the aquifer. The depth of the alluvial aquifer can vary from 1 to 30 meters according to the sectors.

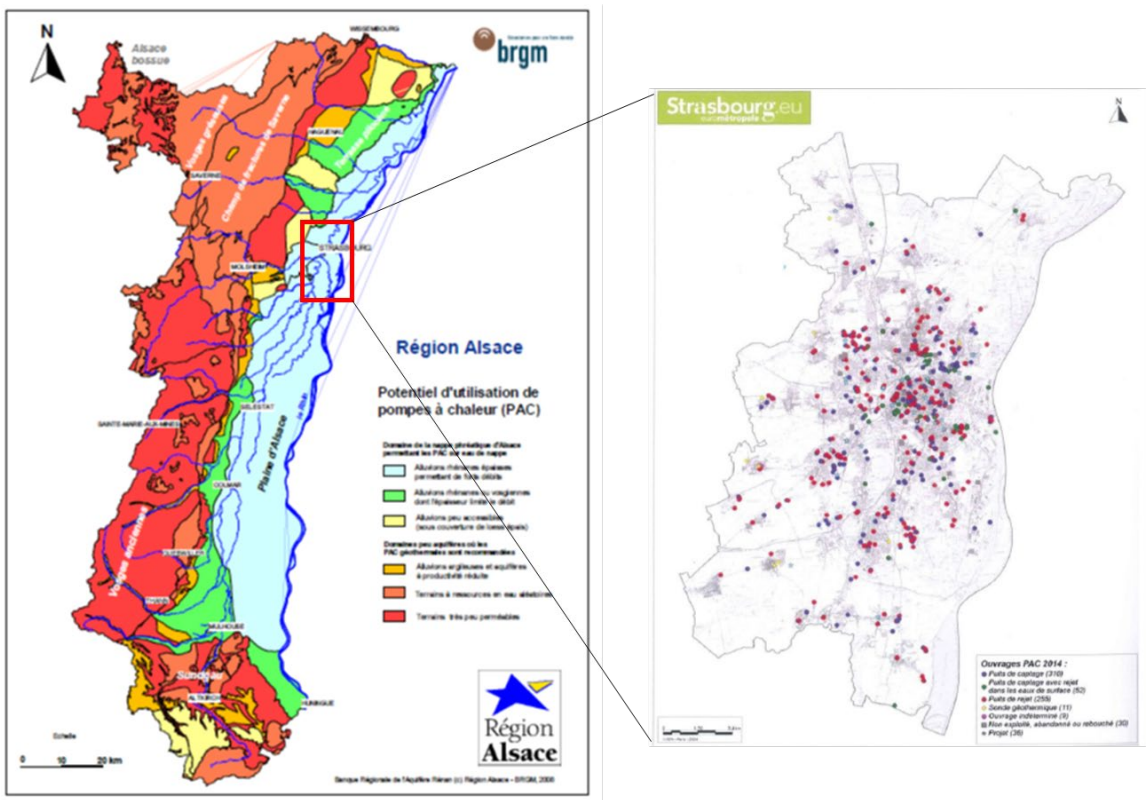


Figure 30. Shallow geothermal potential using heat pumps in Alsace (blue: alluvial Rhine aquifer allowing high flow rates) and location of shallow production and injection wells in the EMS (sources: reports BRGM/RP-59978-FR and BRGM/RP-65094-FR)

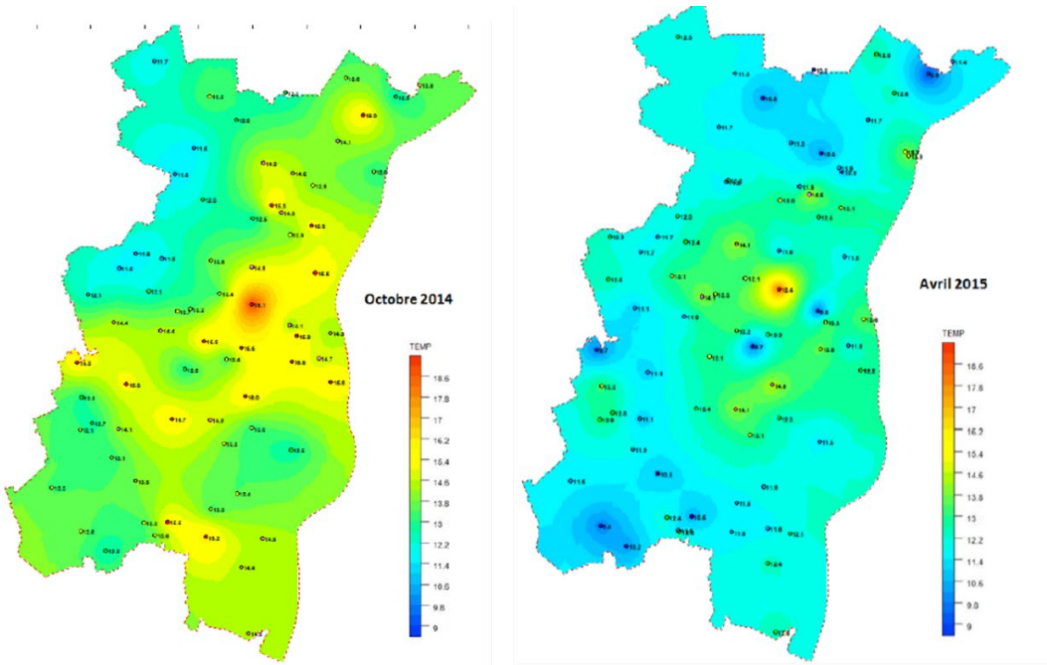


Figure 31. Temperature measurement of the Rhine alluvial aquifer (3 m below aquifer roof) after summer period (October 2014, left) and winter period (April 2015, right) (source: report BRGM/RP-65094-FR)

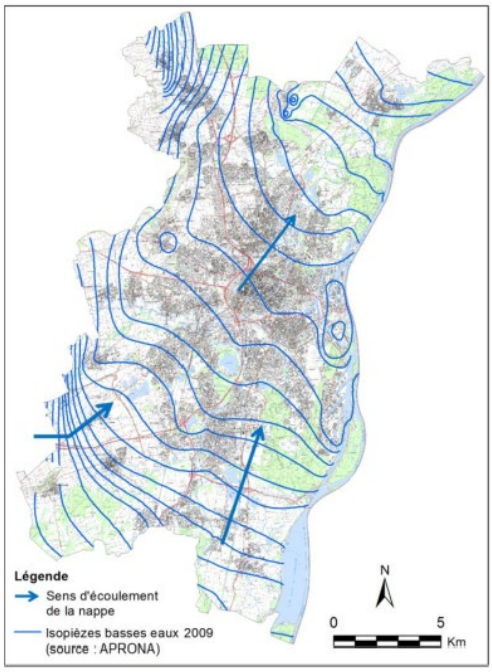


Figure 32. Main direction of flow of the Rhine alluvial aquifer at the EMS scale (source: report BRGM/RP-65094-FR)

3.3.3. Higher temperature renewable sources like geothermal, solar heat

Geothermal potential

The Greater-Paris Metropolis has a high potential for deep geothermal energy because of the presence of favourable geological units like the Dogger limestone aquifer (Jurassic age, between 1500-2000 m deep and 60 to 80°C) which is exploited for district heating in Ile-de-France region since the 1980's. About 50 operations are currently operating in the Paris area and provide an estimate of 1500 GWh in 2019. Others geothermal resources are the intermediate Albian and Neocomian sandstones units (Cretaceous age, between 800 and 1000 m deep, 30 to 40°C) or the deeper Triassic sandstone unit (2500-3000 m deep, 80-100°C). The Albian-Neocomian units, currently exploited by 6 operations (of which Paris Saclay geothermal doublets), are however facing technical reinjection issues linked to the nature of the geological formation that must be yet overcome.

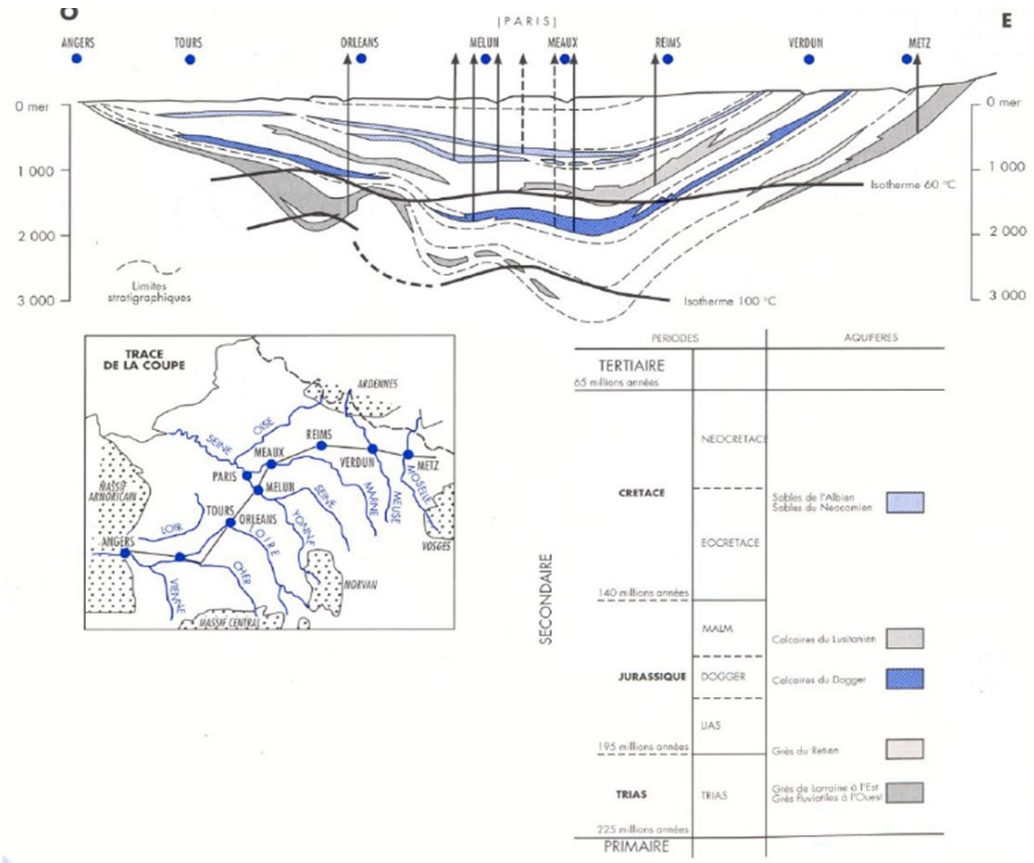


Figure 33. Geothermal deep resources in the Paris Basin

Those geological units (Cretaceaous, Jurassic and Trias age) are also present under the Orleans Metropolis but with lower depth and thus lower temperatures and potentially different hydrogeological characteristics. Only one doublet has targeted the Trias formation in Orleans Metropolis in the 80's (Melleray) but was operating for a short time because of technical issues. The study carried out by BRGM in 2020 enabled to better define the geometry and depth of the Dogger and Triassic units under Orleans Metropolis by using the interpretation of existing 2D seismic data and information of former hydrocarbon and geothermal wells. A geological model was build integrating all the data and has permitted to do a first assessment of the geothermal potential by considering the calculation of the heat in place (Figure 34). Those maps show that the highest potential considering heat in place for the Dogger aquifer is in the North of the Metropolis and for the Triassic aquifer, the highest potential is located in the southeast of the Metropolis. The Sennely fault, which crosses the metropolis area in the northeast with an orientation N-N-W S-S-E, has an impact notably on the Triassic depth in the southeast of the modelled area where the highest potentials are located along the fault line.

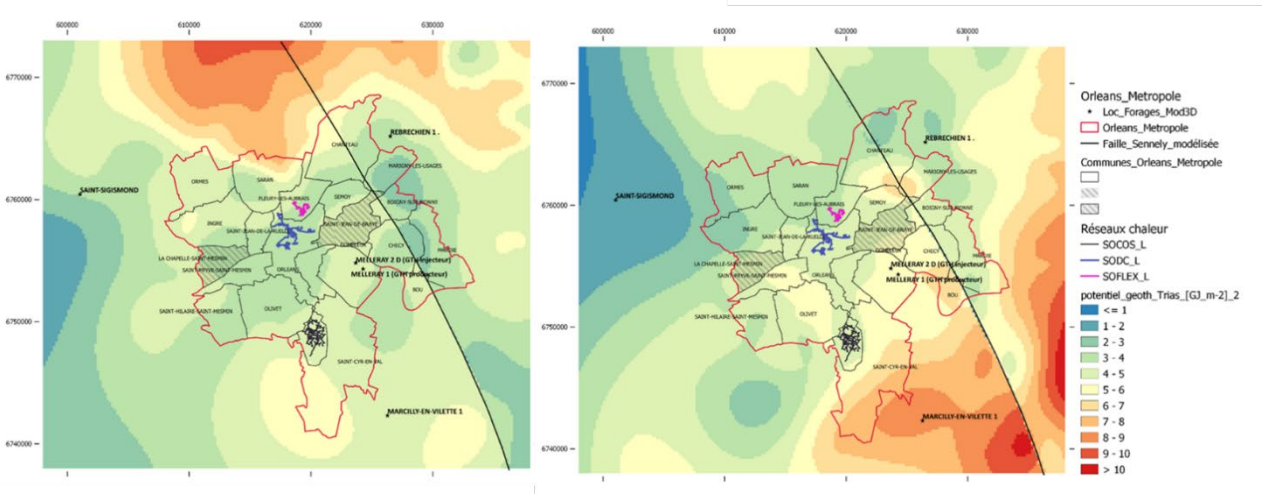


Figure 34. Assessment of the Dogger and Trias geothermal potential in Orleans Metropolis (GJ/m2) (source: report BRGM/RP-70363-FR)

Deep geothermal energy is also present in the Eurometropolis of Strasbourg with projects (Vendenheim, Illkirch) targeting the fractured granite basement below triassic sedimentary layers in the Rhine graben for cogeneration (electricity and heat production). Nevertheless, those projects were stopped in December 2020 because of induced seismicity during well development and testing. Low temperature geothermal energy in sedimentary layers (Buntsandstein) remains however an opportunity for district heating networks (Figure 35).

Two other deep geothermal heating and/or power plans are currently in operation in the north of Alsace (outside the territory of Strasbourg Eurometropolis): the Soultz-sous-Forêts deep geothermal power plant which produces electricity (12000 MWh/y) and the deep geothermal heating plant in Rittershoffen which supplies 25% of the heating needs of the Roquette factory (190000 MWh/y).

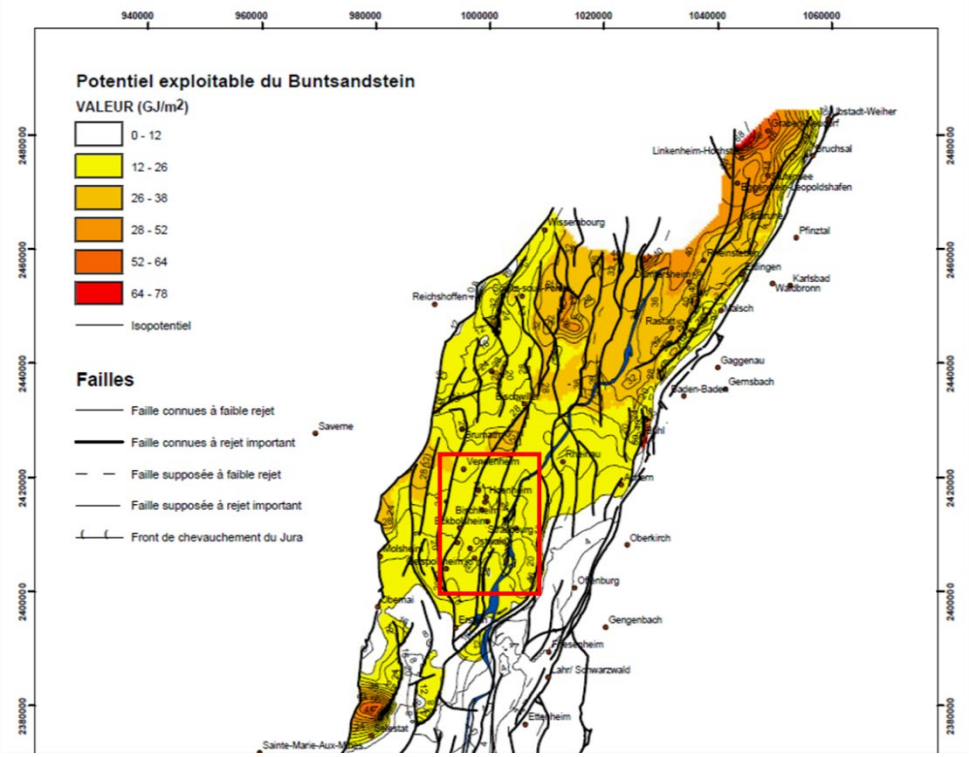


Figure 35. Geothermal potential of the Buntsandstein (GJ/m2) at the Eurometropolis (source: report BRGM/RP-56626-FR

Solar thermal development potential

The Metropolis of Orleans has one thermal solar plant providing 2.1 GWh a year (in 2014 according to PACET). Orleans Metropolis has considered the potential distribution between thermal and photovoltaic to identify both potential over its territory according to NégaWatt hypothesis that foresee a high roll-out of solar thermal panels over the French territory. They estimated the total roof surface available for thermal and photovoltaic panels deployment to 5 320 535 m² in its territory and given certain hypothesis, they estimated the potential production by thermal solar panels to 150 GWh by installing 510 000 m² of solar thermal panels which could cover 69% of residential hot water needs over the metropolitan area.

The Greater Paris metropolitan area had in 2012 a production of heat by thermal solar sources of 13 GWh. Over the area, the APUR (Parisien Urbanism bureau) has estimate the potential for development of solar thermal heat production around 2.3 TWh/yr for the residential sector (considering a 30% efficiency). However, the dynamic of this market is declining despite public support (guarantee fund "*fonds chaleur*", regulation, etc.). An important work of communication towards consumers and greater public support are required to increase the share of solar thermal in the energy mix of the GPM.

The Eurometropolis of Strasbourg has a high solar potential. The EMS has developed a tool, the "solar cadastre", to estimate the solar potential of the roofs and to be accompanied in the project for the installation of solar thermal or photovoltaic panels. Social landlords, companies, local authorities, associations and co-ownerships can in particular be eligible for grants through the Climaxion programme for the "Grand-Est" Region. In 2016, the Eurometropolis of Strasbourg had 39,000 m² of thermal solar panels installed on the territory. With an estimated production of 16 GWh/year, i.e., less than 3% of the domestic hot water demand. Despite the strengths and maturity of the technology, the solar thermal sector has been slowing down since 2012. This can be explained by the low prices of fossil fuels (especially natural gas) and competing technological solutions such as heat pumps. The objective is to cover by 2030 at least 240,000 m² of solar panels.

3.3.4. Lower and higher temperature industrial waste heat, otherwise rejected in the environment

At national scale, a study from ADEME (French Agency of Environment and Energy Management) in 2017, has estimated the industrial waste heat of 109,5 TWh (Figure 36) and the waste heat from incineration plants, water treatment plants and data centers of 8,4 TWh (Figure 37).

At regional scale, the « Grand-Est » region, represents the higher industrial waste heat potential with 17 660 GWh. The Centre-Val de Loire and Ile de France regions have a smaller industrial waste heat potential with respectively 4440 GWh and 4420 GWh. The study also showed that a large part of the waste heat potential is below 100°C with 8610 GWh (i.e., 49%) for region "Grand-Est", 2660 GWh (i.e 60%) for region "Centre-val de Loire" and 2180 GWh (i.e 49%).

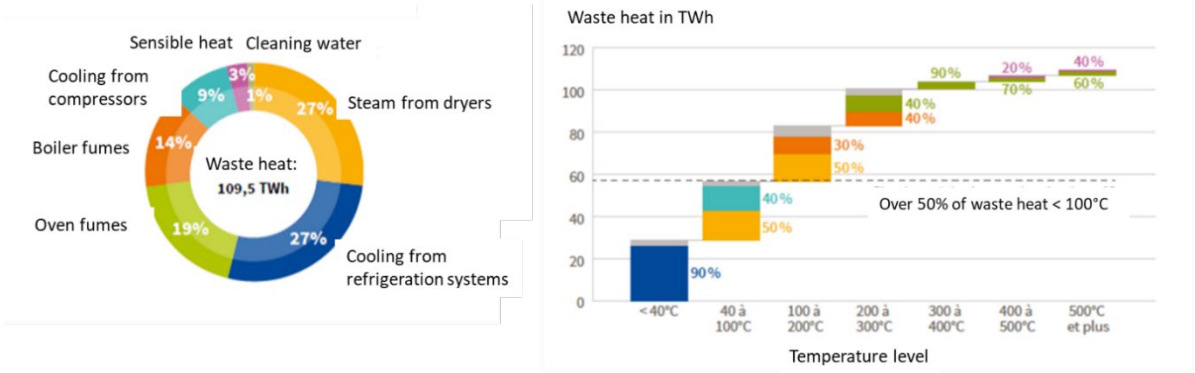


Figure 36. Distribution of industrial waste heat at national level (source: report ADEME on waste heat production, 2017)

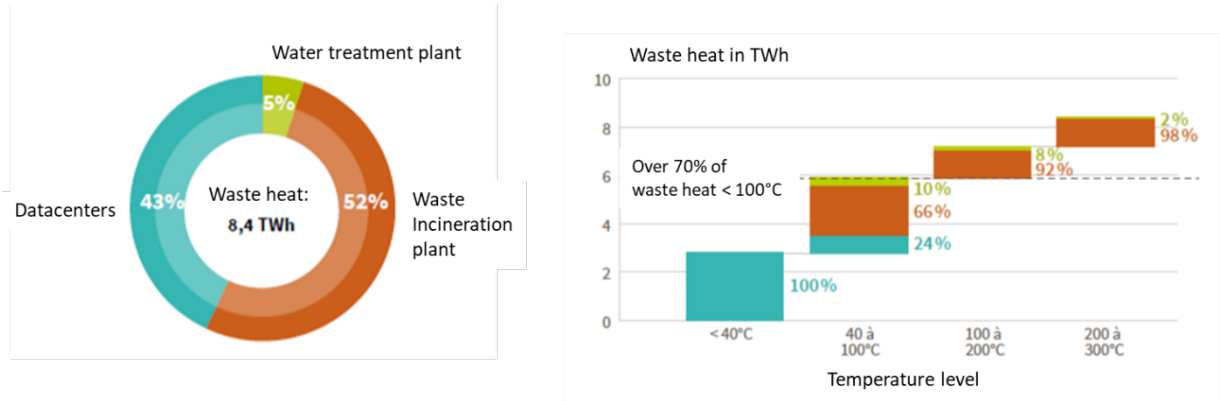


Figure 37. Distribution of waste heat from water treatment plants, waste incineration plants and datacenters at national level (source: report ADEME on waste heat production, 2017)

16.7 TWh of waste heat (> 60°C) was identified near an existing heating network, i.e., more than 70% of the energy delivered in 2013 by heating networks in France. The potential of waste heat with temperature higher than 60°C and in the vicinity of existing district heating networks (DHN) was estimated at regional scale (Figure 38). In « Grand-Est » region, it represents 2260 GWh of which 30% with temperature level between 60 and 90°C. In « Ile-de-France » region, the potential of waste heat is estimated 1690 GWh (37% with temperatures between 60 and 90°C) and in « Centre-Val de Loire » region it is estimated 370 GWh (32% with temperatures between 60 and 90°C).

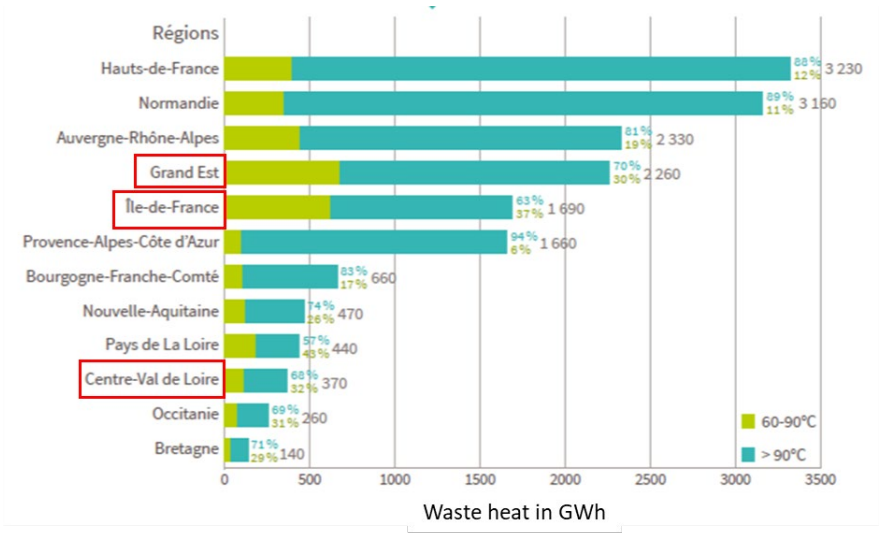


Figure 38. Distribution of waste heat (>60°C) in vicinity of DHN at regional scale (source: report ADEME on waste heat production, 2017)

Orleans Metropolis

Over the metropolitan area of Orleans (Centre-Val de Loire region), the waste heat potential is estimated to more than 150 GWh with 93 GWh of high temperature and 57 GWh of low temperature (no indication of the temperature level of the sources where given in the PCAET document). An industry in Saint-Jean-de-la-Ruelle, located west of the metropolitan area gathers most of waste heat production with 81 GWh (THERMOR PACIFIC, specialised in heater construction, heat pumps for pools etc.). This industrial company represents 54% of total waste heat production and 87% of high temperature potential. The low temperature potential is in particular interesting for the concept of 5GDHC networks. This analysis only concerns industries with waste heat potential higher than 1 GWh. The among of excess heat produced over the territory is identified by municipalities in Table 2 here below.

Table 2. Summary of waste energy resource of high and low temperature by municipalities (source: Orleans Métropole - Rapport de diagnostic énergétique)

Municipality	High temperature potential (GWh)	Low temperature potential (GWh)	Industries producing waste energy
La-Chapelle-Saint-Mesmin	2,1	16	Duralex (production of tempered glass tableware) & Maingourd (cannery)
Orleans	3,8	9,6	
Ormes	1,2		
Saint-Jean-de-Braye	1,6		
Saint-Jean-de-la-Ruelle	81,2		Thermor Pacific (radiator and heat pump factory)
Fleury-les-Aubrais		24,5	Tardival (abattoir)
Saint-Cyr-en-Val		6,9	
Saran		Not estimated	UTOM (waste treatment plant)

Greater Paris Metropolis

Heat valorisation and consumption in district heating network from waste-to-energy plant represents 2.2 TWh in 2012 in the metropolitan area (source: PCAEM 2018). The potential of waste-to-energy heat production development is relatively limited and is foreseen to increase by 0.1 or 0.2 TWh within 2050.

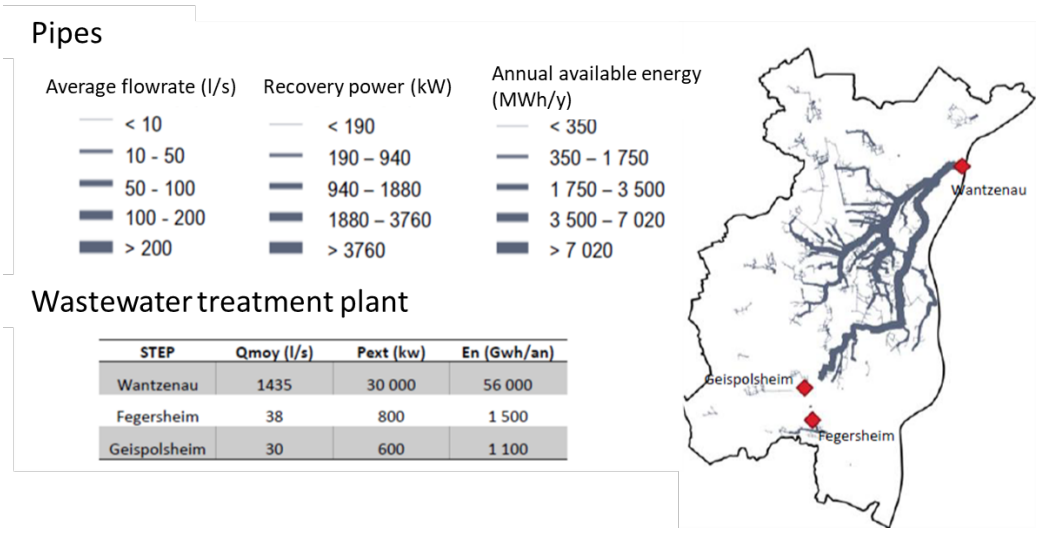
In the Greater Paris metropolitan area the potential of heat production from waste energy using resources from data centers, waste water treatment plants and industries was estimated to respectively of 206 GWh, 14 GWh and 77 GWh (source: PCAEM 2018 and ADEME 2017). A Data Center in Seine et Marne department, Val of Europe will supply the district heating network up to 600,000 m² of offices and prevent the emission of 5,400 tons of CO2eq per year.

Strasbourg Eurometropolis

In Strasbourg metropolitan area, solutions of waste heat recovery are already operational or emerging:

- The waste heat recovery in the residence on Waldhorn of the eco-district of the Kronenbourg Brewery since 2018;
- Recovery of fatal energy from the BSW (Badische Stahlwerke) steelworks in Kehl, supplying the Esplanade heating network with some 45 GWh per year of heat that could thus cross the Rhine;
- Energy recovery project (150GWh) underway at 3 industries in the Autonomous Port, supported by the company RCUA
- Project to recover waste heat from the Heineken brewery in Schiltigheim (10 GWh), as part of the development of the "Communes Nord" heating network;
- Arlanxeo plant (La Wantzenau): recovery potential of fatal energy (50GWh/year) from the condensate return, currently disposed of in the sewer.

The objective is to mobilise all potential sources, that is to say any installation releasing large quantities of heat from industrial sites, electrical production, storage of computer data, waste incineration and wastewater treatment. For the latter, a first evaluation of the heat recovery potential of wastewater has been studied at the EMS scale. Figure 39 shows the location of the three wastewater treatment plants in the EMS with their yearly energy production and the heat capacity and available energy from the different pipes. This source of waste energy could benefit to different potential users in the vicinity of the pipes with temperature ranging between 7 to 17°C by using decentralized heat pumps.



STEP	Qmoy (l/s)	Pext (kw)	En (Gwh/an)
Wantzenau	1435	30 000	56 000
Fegersheim	38	800	1 500
Geispolsheim	30	600	1 100

Figure 39. First assessment of wastewater heat recovery (source: "Etude sur le potentiel de récuperation d'énergie des eaux usées d'un territoire urbain – Application Eurométropole de Strasbourg", Antea-Group, 17 juin 2020)

3.3.5. Renewable electricity from local sources like wind, sun

Orleans Metropolis

Current photovoltaic production is estimated to 2.81 GWh (figures from SOeS survey in December 2015) with 653 installations connected to the grid. To identify the development potential of solar based power production, Orleans Metropolis assessed the amount of un-occupied zones in the area (out of agriculture zones, out of commercial zone, open land, un-forested etc.). According to their findings, 171 zones covering 450 ha have been identified as potential zones for solar photovoltaic plant development (ground surface installation, Figure 40) and considering the hypothesis of installation of panels of 150 Wc power and 1 581 mm x 809 mm, the total installed power capacity could represent up to 165 MW. Given those hypotheses and the local sunlight, the potential solar production over all of the 450 ha ground surface available could represent around 170 GWh. Photovoltaic panel potential, through exploitation of roof surface available in Orleans Metropolis has been estimated to 537 GWh by installing around 4.8 million m² of photovoltaic cells. This power production potential represents 64% of residential sector electric consumption and 27% of total electric consumption over the territory.

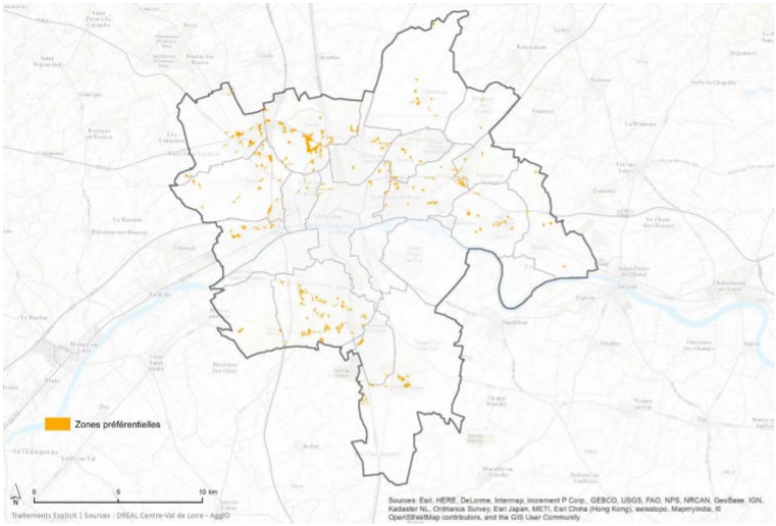


Figure 40. Potential zones for solar plant development in Orleans Metropolis

No development inside the Metropolis is foreseen for wind energy production.

Currently, hydroelectric power is ensured by several dams over the Loire river out of the metropolitan area. A first fluvial hydrokinetic power station was tested in 2014 in Orleans for a nominal power of 40 kW. Despite the success, the development of such technology is not yet foreseen within the metropolitan area. A potential for renewable electricity production exists however through more classic fluvial energy with hydroelectric power plants. Indeed, along the river Loire and Loiret, 25 dams or water impoundment have been listed in the territory. Using those structures for electricity production has been estimated by the Metropolis to around 500 MWh per year

Greater Paris Metropolis

In 2016 according to RTE, the metropolitan area had 3303 photovoltaic installations for 20 GWh. Another local source of electricity production is waste-to-energy plants, which produced 274 GWh in 2016 according to RTE.

The production of local electricity in the Greater Paris metropolitan area is thus very limited for now. Wind and hydraulic resources are absent of the territory but the Regional Climate Air and Energy plan of 2012 defined along with the APUR foresees great development of local renewable electricity thanks to great increase at regional level notably of photovoltaic panel total capacity up to 9550 GWh in 2050 and around 3700 GWh produced within the metropolitan area. The distribution of photovoltaic electricity production between residential sector and tertiary or industries is respectively of 1.2 TWh and 2.5 TWh (15% efficiency). The development of photovoltaic at the level of the GPM remains limited compared to the whole

region because of difficulties to develop their installation in dense urban areas. The share of electricity produced by waste-to-energy plants is foreseen to decrease from 274 GWh in 2012 to 136 GWh/yr.

Strasbourg Eurometropolis

The specific electricity[7] consumption in the territory amounts to 1872 GWh in 2017 with 69% of non-renewable electricity, 22% of local renewable electricity and 9% non-local renewable electricity. In 2050, the objective is to reduce by 40% the electricity consumption (1127 GWh) with half of the specific electricity consumption covered by domestically produced renewable electricity and the other half imported renewable electricity. Local renewable energy production is largely provided by hydraulic power. A smaller part is provided by photovoltaic solar energy and even by cogeneration through biogas combustion.

3.3.6. Electricity use at times of renewable overproduction, e.g. when spot price is low

For now, this is only relevant in areas with known overproduction, like the north of the Netherlands (overproduction of PV) and the north of Germany (wind).

3.3.7. Electricity mix from the external grid

Orleans Metropolis

Three biomass cogeneration plants ensure local electricity production along with a waste-to-energy plant and to lesser extent photovoltaic panels. The remaining electricity is produced in great majority with nuclear power from four different plants (the nearest is located in Dampierre-en-Burly, at 45 km Est of the metropolis) and from wind power.

Greater Paris Metropolis

The electricity distributed over national grid within the GPM is produced at 80% from six nuclear plants (Paluel, Penly, Nogent, Dampierre, Belleville and Saint-Laurent) and to a lesser extent from fossil fuel, hydraulic dams and wind farms outside of the territory. 95% of electricity consumed by the GPM originates from outside its territory. The part produced using nuclear power is estimated in 2012 by RTE to 26.2 TWh and the part of electricity produced by fossil fuel is estimated around 2.9 TWh. 6.4 TWh of electricity injected in the grid is produced using renewable energy sources (outside of GPM such as hydraulic, wind, solar plant etc.).

Another local and non-renewable energy source used in the GPM is the thermal power plant using a fossil fuel heat source. Electricity production using this source is estimated to 1.2 TWh in 2012.

Strasbourg Eurometropolis

The other important source of electricity is the nuclear plan from Fessenheim (south of Strasbourg Eurometropolis) which has produced more than 8 TWh/y until its decommissioning in June 2020.

3.3.8. High temperature heat from burning biofuels, biogas, biomass

[7] specific electricity refers to electricity used for services that can only be provided by electricity (thus excluding electricity for heating, mobility or certain industrial processes)

Orleans Metropolis

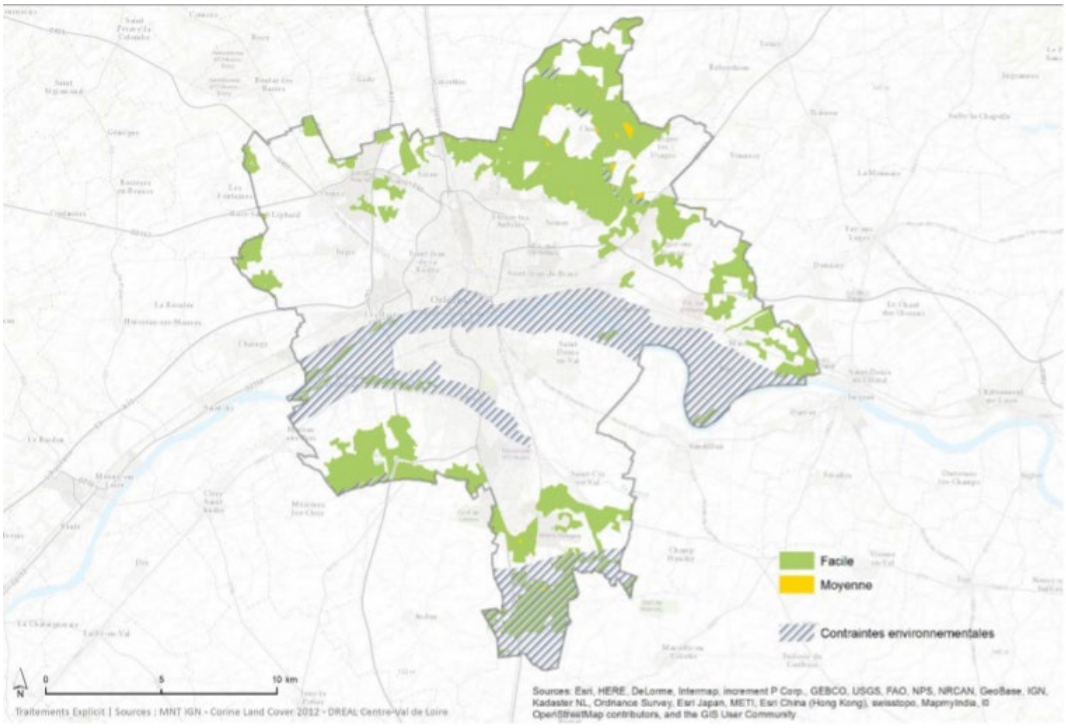


Figure 41. Location of forest areas and their potential of exploitable (easy in green, medium in yellow and under environmental constrain in hatched grey) inside the Metropolis of Orleans (source: Orleans Metropole - *Rapport de diagnostic énergétique*)

Biomass represents the first heating source over the Orleans metropolis with 167 GWh produced in 2016 for collective use and 171 GWh for individual use in 2013 over 3 biomass plants. The production potential associated with easily exploitable forests is estimated at around 80 GWh minimum, considering environmental constraints as an obstacle to operation, and to 96 GWh approximately, assuming they are not a problem (see areas identified in Figure 41). This potential therefore represents between 3.6% and 4.3% of the current heat needs (heating and domestic hot water needs of the residential sector, estimated to 2 194 GWh in 2019).

Methanation using wastes from food industry, agriculture, waste from water treatment plant and collective waste products or catering has been evaluated to 133 GWh (PCAET 2019), which represent 10% of current gas consumption from the residential sector. The principal source is agriculture (40% of total deposit) followed by mud from water treatment plants and wastes from food service industry and agro-industry.

Greater Paris Metropolis

Biomass heating production in the Metropolitan area is estimated to 177 GWH/yr in 2012 according to RTE for the heat injected in urban networks. Individual use of wood base energy for heating is estimated to 1.1 TWh and 21 GWh for collective or individual use (out of urban networks) according to RTE in 2012.

The estimated development potential for biomass out of networks is 1.1 TWh for domestic use and 517 GWh for collective and industrial biomass. The potential for biomass heat production through urban network is estimated to 7.4 TWh. Biogas from methanation represent a potential of heat production of 1.2 TWh over the metropolitan area (source: GRDF). Indeed, in the MGP, the estimated amount of bio-waste is around 1 360 000 tonnes per year. The waste come from households (38%), restaurant industry (37%), green waste (9%), from store and market (7%) and food industry (7%).

Strasbourg Eurometropolis

Wood based biomass largely supplies public as well as private facilities. It must be implemented within the limit of the sustainable management of forest areas and develop the use of other sources of biomass (agricultural waste, granules, other bio-waste, etc.). The use of wood energy for private individuals also deserves the same attention, hence the Fund "Air-Wood" action to encourage the renewal of the park and good practices.

The biomass power plant in Strasbourg supplies the Esplanade's heating network (112000 MWh/y representing 70% of the heating needs of the network) and produces electricity that is fed into the grid (70000 MWh/y).

The production of biomethane from the waste water treatment plant (La Wantzenau) or from bio-waste has a capacity in 2020 of approximately 40 GWh/year. The objective is to multiply this biogas production by a factor of 2 on the horizon of 2030 by relying on the specific collection of fermentable households wastes (generalised collection of bio-waste, etc.). The ambitions are limited by the potential for local bio-waste production, but the modalities to support external production of the territory will be studied.

3.3.9. High temperature heat from burning fossil fuels

Orleans Metropolis

Fossil energy represent 54% of energy consumption for heating in the residential sector (1.4 TWh in 2012), 60% of consumption in the industry sector (0.5 TWh in 2012), 50% of consumption in the tertiary sector (0.9 TWh in 2012) and 81% in the agriculture sector (17.9 GWh in 2012). The petroleum products consumption has already decrease of -13% between 2008 and 2012 and is foreseen to decrease all the more in the coming years and same goes for gas consumption (-10% between 2008 and 2012).

Greater Paris Metropolis

The gas networks in the GPM consummed 39.4 TWh in 2012 according to ADEME in great majority for heating purpose and to a lesser extend domestic hot water and cooking. Carbon based energy sources used in urban heating network in the MGP represent over 60% of sources providing heat. Energy sources consist of coal (1.2 TWh consumed in 2012), fuel (620 gWh consumed in 2012) and natural gas (3.6 TWh consumed in 2012). For the contribution of fossil energy source in heating outside of urban heating network represents more than 80% of sources with 5.6 TWh of petroleum products being used for heating and 97 GWh of coal. The consumption of carbon-based sources is far ahead of domestic biomass and solar thermal sources.

The objective of PCAEM plans voted by the GPM is to reduce drastically the contribution of carbon-based energy within 2050.

Strasbourg Eurometropolis

Nearly 60% of the energy consumed on the territory is of fossil origin (oil, natural gas). The objective of the EMS is to reduce the energy consumption by 2 in 2050 with 0% fossil energy.

4. SWOT analysis

Table 3 below summarizes the SWOT analysis for the three metropolis regarding the possibility of implementing 5GDHC networks in their territory.

Table 3. SWOT analysis

Diagnosis	
Strengths	**Weaknesses**
• The presence of shallow geothermal sources (Beauce limestones in OM, Rhine alluvial aquifer in SEM, Lutetian, Ypresian and Craie aquifers in GPM) with relatively homogeneous hydraulic characteristics at the scale of the metropolis and opportunity to develop operations (closed and open loop systems) almost everywhere in the territories with high performances; • Shallow geothermal energy production is a mature technology, already developed in the different metropolis. Nota: "Entry ticket" for an aquifer doublet may be high, but marginal investment costs are very low, which makes it worth for thermal powers above c.a. 200 to 300 kW; • From the administrative and regulatory points of a view, 5GDHCN are regarded as "classical" 3GDHN or cooling DHN by the thermal regulation (RT2012 and RE2020) and by the French administrations in charge of Energy and Climate (DGEC) and Housing and Urbanism (DHUP). This implies that the well-defined "classification" procedures applies too if the network provides at least 50% of renewable & recuperation thermal energy (which is the case for 5GDHCN), leading to an obligation to connect buildings to the DHCN (if technically and economically feasible) and a discounted VAT; • Development of 5GDHC allows low temperature DHN roll out (compared to current networks available in the different metropolis operating at high temperature); • Budget has been made available for the development of renewable energy and execution of territorial energy plans (PCAET) in the different metropolis (e.g in Orleans metropolis, the budget allocated to the implementation of energy strategic plan is 23.4M€ of which 19 M€ is investments in actions to be taken before 2022. The total amount of the local investment aid in the GPM is 68.5M€); • Research and development opportunities for 5GDHCN are facilitated in Orléans Metropolis as the BRGM scientific and technical center is located in Orléans and provides advice to the metropolis in geothermal energy development opportunities & possibilities and also to industrials and companies based in Orléans. More broadly, the Orléans technical center of the BRGM along with its local agencies in Paris and Strasbourg provide guidance to public and private actors willing to develop projects.	• Limitation related to decision making and opportunity to promote 5GDHC and use of shallow geothermal energy compared to other renewable energy which operate at high temperature (biomass, waste plant, deep geothermal); • The investment costs and thus cost efficiency for 5GDHC are difficult to assess at early stage of feasibility assessment and more specifically in comparison to competitivity with other DHCN already implemented; • High initial investment required for shallow geothermal projects even though grant mechanisms allow the technology to be competitive in relation to other renewable energy (shallow geothermal systems have a return on investment around 10 years in average according to AFPG); • Operational risks related to drilling the underground and potential issues encountered when operating shallow geothermal aquifer (corrosion, geochemical deposit, limited flow rates, etc.) or drilling borehole heat exchangers (suited methods to grout boreholes in kartsts shall be used). Those risks are however mitigated thanks to best practices developed through the years and qualification of professionals involved in projects; • No balanced needs between cooling and heating (for example in OM the referenced cooling needs represents only 4% of the total estimated thermal needs i.e., heating, cooling and domestic hot water). Compliance of buildings and houses with low temperature is not identified in all the areas of the three metropolises; • Limited to no application of 5GDHCN in the territory means that the metropolis and the end-users are not familiar with the technology. The investment to develop such network will be to first get the stakeholders familiar with the technology, how it works, its advantages and where it could be developed in the city, at which cost before engaging in feasibility studies or development projects.
Trends	
Opportunities	**Threats**
• Urbanization of vast areas (for example 2025 5.7 km² must be urbanized "from scratch" in Orléans metropolis). The 5GDHCN infrastructure can be planned and built along the other networks (road telecommunications, etc.) to save construction costs; relevant heating and cooling emitters can be selected ahead of the construction. The 5GDHCN modular nature ensures it can start little and grow. New residential and economical areas may be interconnected if excess heat is produced from offices (for cooling) or industrial areas (although Orléans is not an industrial city, rather a logistics hub / tertiary city). Those areas will also present globally decreasing heating demand thanks to thermal insulation, passive housing which are all the more relevant with 5GDHCN principles; • Little competition with other use of underground resources (especially drinking water) that would prevent the use of shallow geothermal energy. In addition, geothermal operation uses the technology of doublet (production and reinjection wells) which prevent from depleting the resource; • Administrative process facilitated by law for shallow geothermal operations (<200 m). Simplified declaration (according to decree n° 2015-15 of 8 January 2015) applies on the whole territory, as long as criteria such as a peak power below 500 kW, etc. are fulfilled. If not fulfilled, then an instruction procedure applies, leading to a 6 to12 month instruction period by relevant regional authority (DREAL, DRIEAT). It does not seem to be a blocking point if anticipated, can be rolled out simultaneously of the urbanism planification; • Shallow aquifers experience a stable temperature throughout the year (around 10 to 16 °C), enabling the production of "free" geo-cooling. The potential for low temperature heat and cooling in the city is high. The aquifers can be used as seasonal storage system to balance the demand; • The past heat waves (locally > 40°C reached in 2018) raised the awareness that cooling is or will be needed in summer, even for housings and especially for tertiary buildings (offices, hospitals, schools, shops, etc.); • A limited number of district heating networks in Orléans metropolis and Strasbourg Euro Metropolis are operating with high temperature. Several new sectors are currently under development and present lower temperature needs; • The three metropolis are looking to reduce their energy consumption, increase the share of renewable heat and electricity production and to go towards energetic sobriety. All those objectives' fixes in the energy plans are compliant with 5GDHCN principles.	• Extensions of the 3GDHN operating at a high level of temperature (> 70 °C) not compatible with 5GDHCN; • In zones to urbanize for economical purposes, companies may prefer to retain control on their thermal production needs; • New residential buildings will have very high insulation and little thermal need requirements, this may not justify the infrastructure cost of 5GDHCN. Property developers tends to keep the investment costs has low as possible, and future owners appreciate to retain control on their thermal production needs too. However, cooling provided by 5GDHCN may be a work-around.

5. Regional vision

The regional vision addresses which barriers need to be addressed first and which opportunities should be taken when rolling out 5GDHC in the region. The vision includes a roadmap describing how much thermal demand (in MWh and/or floor area) could be fulfilled between the end of D2Grids and 2030, including likely locations where implementation can start.

5.1. High potential areas and potential pilot sites

5.1.1. Orleans Metropolis

Thanks to the data available at Orleans Metropolis, a first assessment of areas of interest for 5GDHC roll-out is proposed here-after. In a second step (deliverable LT1.4 on local action plan), a preliminary feasibility study will be done on a potential pilot site (Parc de la Saussaye, South of Orleans Metropolis) in agreement with Orleans Metropolis stakeholders.

According to the Metropolis land occupancy database, 97.4 km² (29 % of the 334.3 km² Metropolis) is currently referenced to as "built areas" for residential or tertiary purposes. Note that the surfaces mentioned here do not refer to the ground or floor surfaces of the buildings, but to the surfaces categorized as built areas, and include parking, private gardens, small roads, etc. Orleans Metropolis is experiencing fast urban growth, 123 zones have been identified to be urbanized (or transformed if already built) between 2018 and 2050, which represents 15.4 km², including 11.6 km² of non-built areas, making up respectively 16 % and 12 % of the currently built surface. We have focused our analysis on these sectors, since we believe that the Metropolis awareness of the sectors to be urbanized or transformed is a key factor to the emergence of 5GDHC networks. Note that little information is available on the zones to be urbanized: only the shape, usage (residential or economical) and deadline (in almost cases) are known. It is worth noting that 7.96 km² must be urbanized by 2025, especially in "virgin" (not already built) areas for economical purposes (3.41 km²) or residential purposes (2.26 km²) (cf. Figure 42).

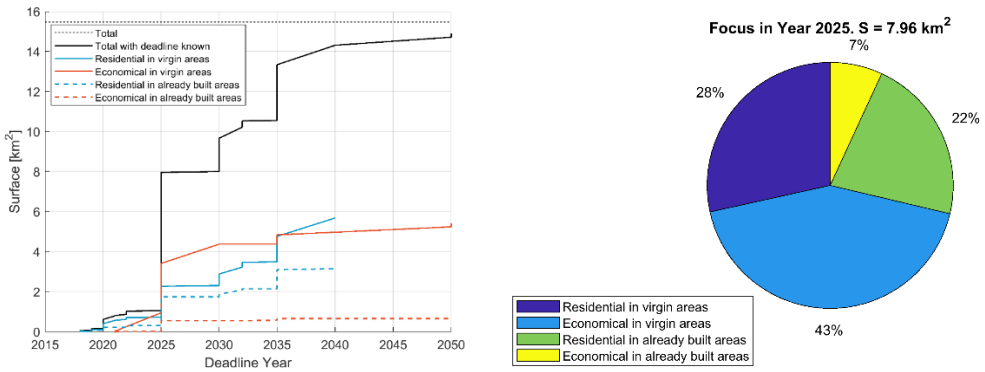


Figure 42 : Cumulated surface of the zones to be urbanized or re-urbanized as a function of the deadline (left). Special focus on deadline 2025 (right)

The 3.90 km² (=15.4 - 11.6 km²) of area to be transformed are mainly covered with "urban mixt tissue" (43% of the surface) and "areas of activity" (27%). However, the energy consumption could barely be estimated on those areas, since it is only known on the higher IRIS level.

As pointed out in section 4.1 ("Heating regime") the research of zones with balanced requirements of heating and cooling do not seem to be a driver for the 5th generation grids, since the referenced cooling needs represents only 4% of the total estimated thermal needs (i.e., heating, cooling, domestic hot water). However, the groundwater resource is abundant and has been extensively used to feed Ground-Source Heat Pumps (78 operations have been identified according to the BSS database managed by BRGM as producing geothermal energy from shallow aquifers), though not connected to 5GDHC networks so far. Geothermal energy from shallow aquifers and/or Borehole Heat Exchangers seem to be a driver for the

5th generation district heating and cooling network (5GDHCN) deployment in Orleans. Starting from the identified 11.6 km² areas to be built, 5GDHCN "killers" where successively applied so that to finally estimate the share of this surface that may be coupled to 5GDHCN. "Killers" are understood as factors that will prevail any operator to develop any 5GDHC network. The identified killers are "3th generation District Heating Networks", "regulation constraints" and "insufficient room for shallow geothermal doublet". Throughout the analysis, a specific focus is made on economical and residential areas in "virgin" areas.

Three (3th generation) District Heating Networks are present on the Metropolis. In France, DHN are usually operated so that the temperature returning to the DHN plant is above 55 °C or even 60 °C to avoid any Legionella development. These temperatures are barely compatible with ground-source heat pumps. Massive investments have been made in the past decade to connect DHN to biomass units ensuring that level of temperature, so it is not realistic they will switch to 5GDHC operating close to ambient temperature, even though it would be capable to deliver cooling. Further, we assume that any operator having the opportunity to connect to a 5GDHCN would do, either on their own initiative or through regulatory binding measures. If we assume a critical distance of 200 m between the boundaries of the zone and the closest 3GDHN, still 113 zones (= 123-10) would not connect to a 3GDHN (see Figure 43). Changing the value of this parameter do not affect the conclusion significantly, with e.g. 99 zones still too far away from 3GDHN if one assumes a critical distance of 500 m. Applying the 200-m criteria results in excluding 2.4 km² of zones to be urbanized, but only 0.5 km² of virgin, non-built areas. In other words, 3GDHN are not a serious obstacle to the development of 5GDHCN especially in zones to be developed.

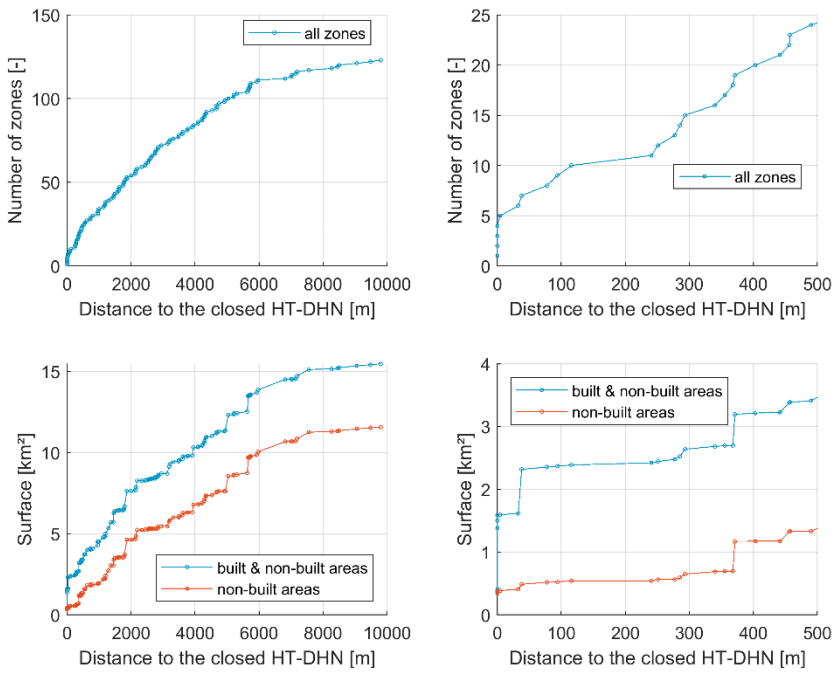


Figure 43 : Zones to be urbanized or re-urbanized: Distance from the zone boundary to the closest 3G-DHN

From a regulative point of view, the perimeters of protection for drinking water withdrawals are the only regulation constraint. However, the impact of the perimeters of protection is very limited, since they impact only 5 % (about 0.7 km²) of the areas to be urbanized or re-urbanized (see Figure 44). Only 6 to 7 areas see more than half of the surface impacted by the protection perimeters. Besides, about 70% of the zones can shelter a 200 m long straight line (see Figure 45). This distance is thought to be long enough to consider a doublet with sufficient distance between injection and extraction wells, though the required distance will strongly be dependent upon the underground water flow and local hydraulic characteristics.

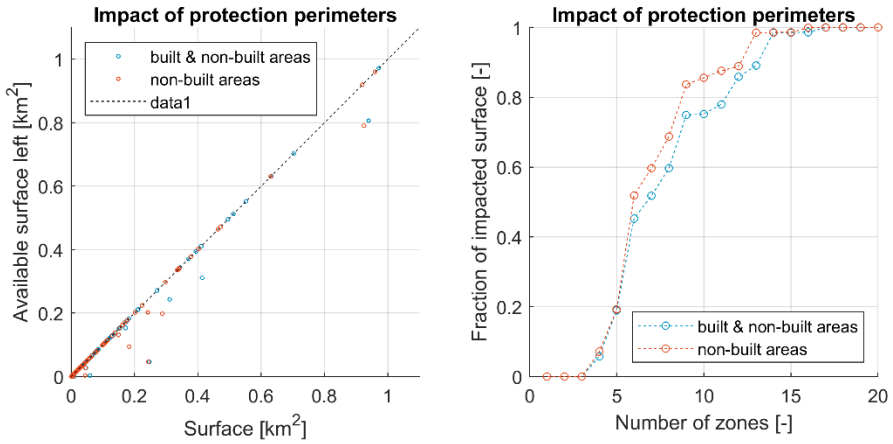


Figure 44 : Zones to be urbanized or re-urbanized: Surfaces impacted by the protection perimeters

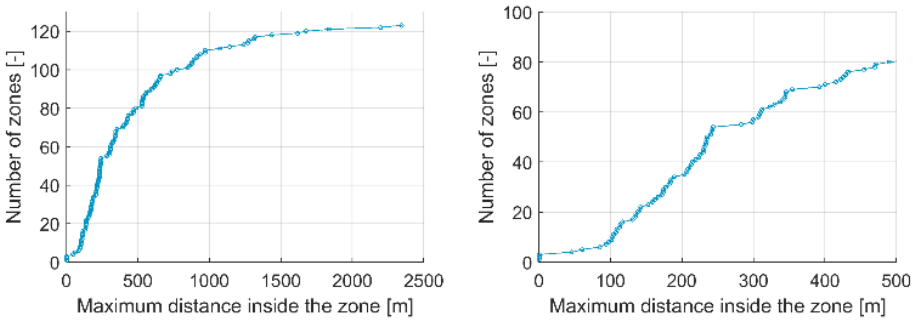


Figure 45 : Zones to be urbanized or re-urbanized: Maximum distance inside each zone for the implantation of doublets once the protection perimeters have been subtracted

Three sources of waste heat at low temperature have been identified on the area on the Metropolis (see section 4.3.4), and could be an interesting opportunity for 5GDHC. However, there is a geographical mismatch between the zones to urbanize and these waste heat produce. For only 2 zones the distance from the zone boundaries to the waste heat location are below 500 m (cf. Figure 46). Waste heat at low temperature do not seem to be an appropriate option for 5GDHC in Orleans Metropolis.

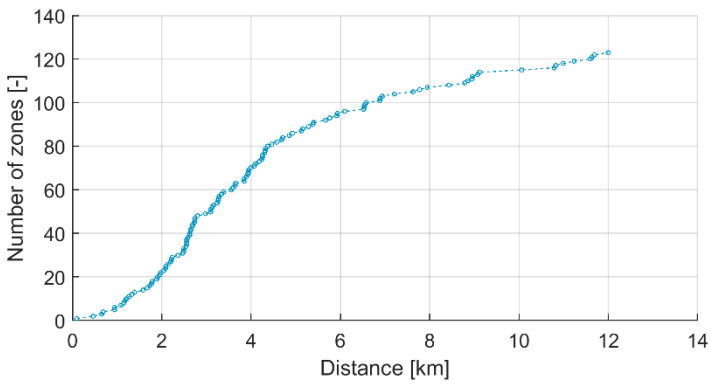


Figure 46 : For every zone to urbanize or re-urbanize, distance between the zone and the closet waste heat producer at a low temperature level

Figure 47 and Figure 48 summarize the total surface left of zones to urbanize or re-urbanized that could fit 5GDHC systems. 60% of the zones to be urbanized by 2025 (4.8 km²) could be connected to 5DGHN.

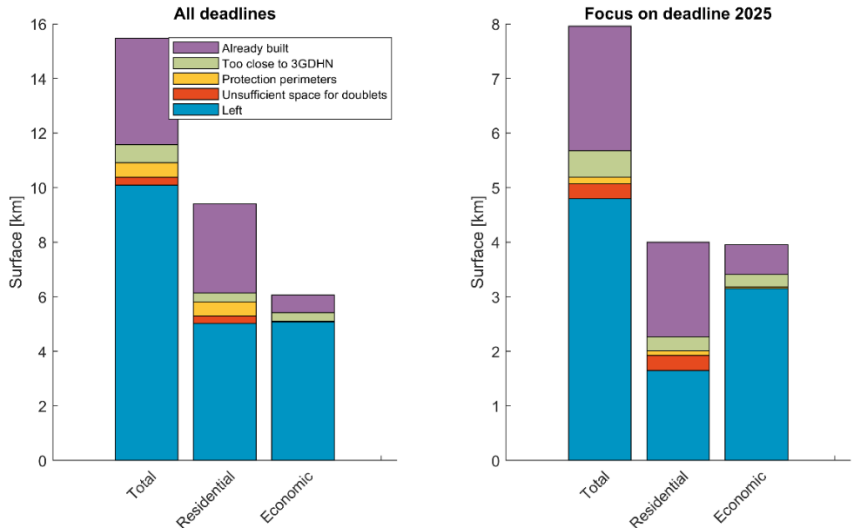


Figure 47 : Surface of zones to urbanized or re-urbanized left for connection to 5GDHC once already built areas, proximity to 3GDHN, protection perimeters for drinkable water wells and insufficient space for doublet has been subtracted

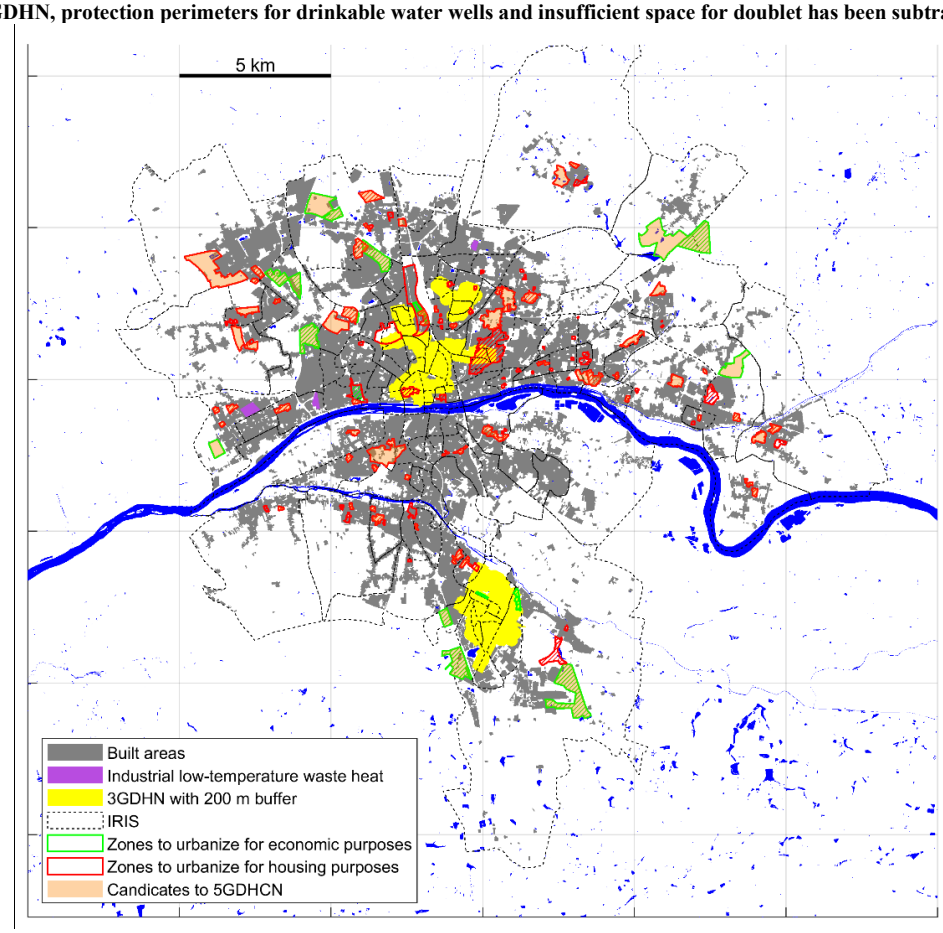


Figure 48. Potential areas for 5GDHC development in Orleans Metropolis. Hatched polygons accounts for zones to urbanize before 2025. Candidates (colored in orange on the map) to 5GDHCN have room for doublets, are 200 m far away from any 3GDHN, are outside protection perimeters of drinking water wells, and have at least 50% of surface to be developed from scratch.

5.1.2. Strasbourg Eurometropolis

As we had no detailed data on the surface to be urbanized and typology of buildings like in Orleans Metropolis, we evaluated the global residential heating needs and tertiary heating and cooling needs based on the data from the CEREMA (http://reseaux-chaleur.cerema.fr/cartographie-des-besoins-de-chaleur-par-secteur-france). We then considered that a certain percentage of heating and cooling could be covered by the development of 5GDHC networks without defining specific areas. In the case of Strasbourg Eurometropolis a more specific prefeasibility study and appointment will be make in DLT.1.4 as for Orleans Metropolis.

The cartography from the CEREMA (Centre for studies and expertise on risks, environment, mobility and development) provides at 100 m grid spacing:

- the heating needs for the residential and tertiary sectors for different usages (heating, DHW, cooking, others) and building typologies (houses, apartments, year of construction for the residential sector and offices, administrative and commercial buildings, community houses, etc.. for the tertiary sector);
- the cooling needs only for the tertiary sector.

Figure 49 and Figure 50 represent for Strasbourg Eurometropolis the repartition of the heating and cooling demands for meshes of 100 x 100 m^2. Figure 49 give the total heating and cooling demand on the metropolis area. Those figures show that the residential sector represent the larger part of the heating needs and that the cooling demands only a small part of the global needs. The tertiary sector seems to be the more adapted to 5GDHC future development, as there is in most cases a need of heating and cooling (even if unbalanced) which is not the case for the residential sector. Nevertheless, as mentioned in the SWOT analysis, this will most likely be developed in the coming years due to the increase in outdoor temperatures.

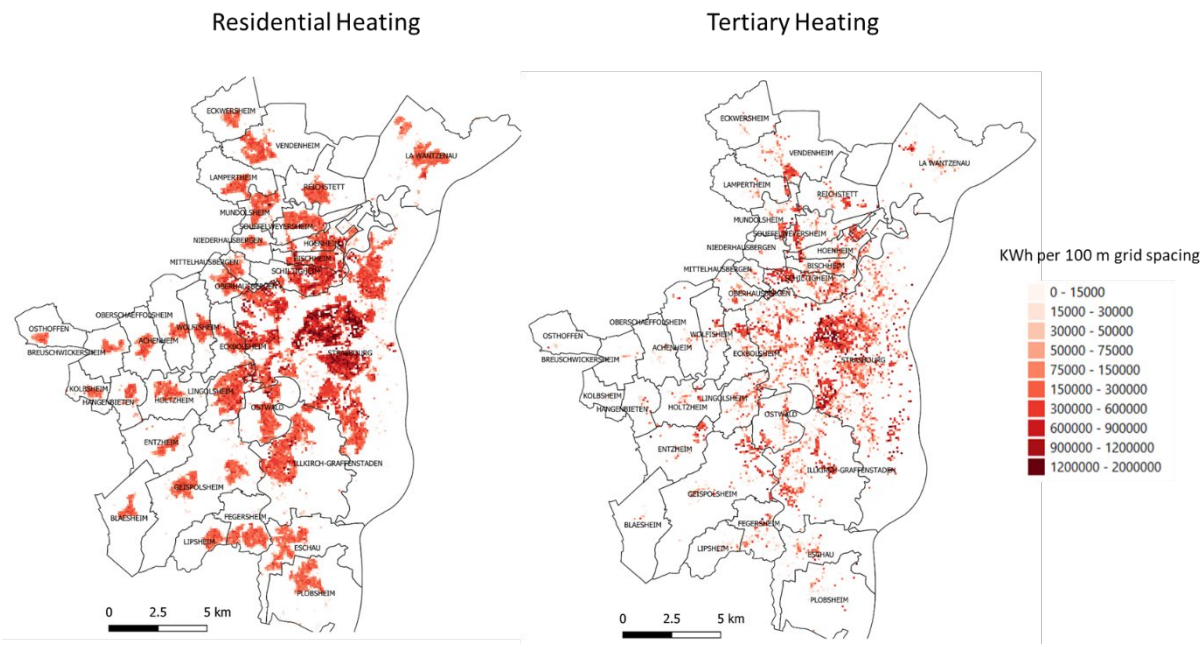


Figure 49. Residential (left) and Tertiary (right) heating needs in Strasbourg Eurometropolis (Source: CEREMA, 2020)

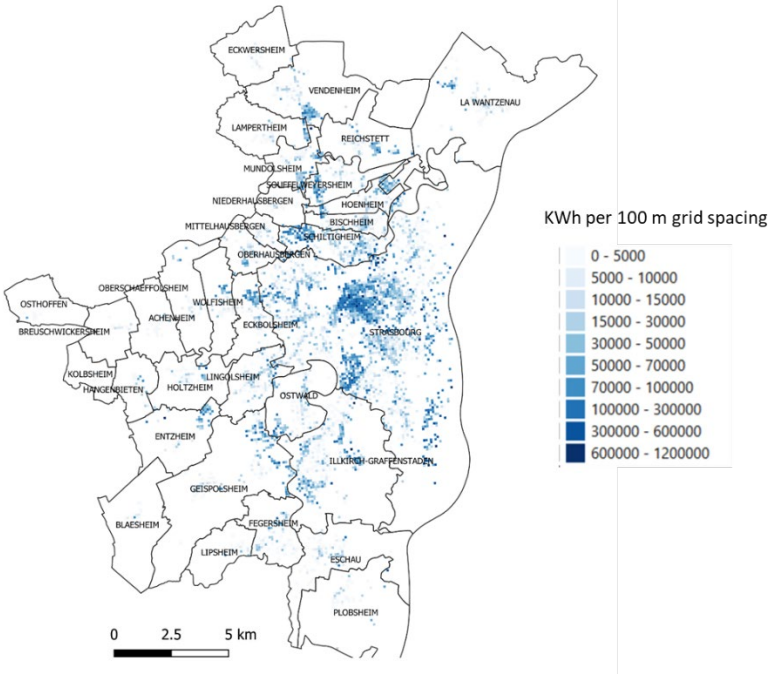


Figure 50. Tertiary cooling needs in Strasbourg Eurometropolis (Source: CEREMA, 2020)

Table 4. Evaluation of the global heating and cooling demands at the metropolis scale and part that could be fed by 5GDHCN

	Strasbourg Eurometropolis	Greater Paris Metropolis
Residential heating needs (TWh/y)	2.48	27.84
Tertiary heating needs (TWh/y)	1.51	22.24
Tertiary cooling needs (TWh/y)	0.2	5.06
Part of heating/cooling that could be covered by 5GDHCN (TWh/y)	0.12-0.2	0.77-1.54

5.1.3. Greater Paris Metropolis

Greater Paris Metropolis faces the same limitation as Strasbourg Metropolis, the CEREMA data at a scale 100 × 100 m was used as for Strasbourg Metropolis (cf. Figure 51 a-c). There is no cell were the cooling need would exceed the heating need: the cooling from the tertiary sector never exceeds 25% of the total heating requirement (cf. Figure 51 d).

APUR ("Atelier Parisien d'Urbanisme") is an association where 29 partners share prospective multi-scale study place. It documents, analyzes and imagines the urban and societal evolutions concerning Paris, the territories and the Greater Paris Metropolis (https://www.apur.org/fr). APUR has so far identified 1300 zones inside the MGP whose urbanism should be reorganized (so-called "secteurs opérationnels"), covering 225 km^2, i.e., 28% of the MGP area. The total surface of floor mentioned in the data made available by APUR so far covers 42.3 km^2 (see Figure 52). Assuming a conservative approach that 5 to 10 % of these surfaces can be connected to 5GDHNC, the total surface of building floor connected to 5GDHNC can be in the range 2.1 to 4.2 × 10^6 m^2. No projection on the energy consumption of these modified areas is available. However, assuming they cover 28% of the MGP area, and that the current energy consumption is 55.1 TWh/y (see Table 4 above), then a target of 0.77 TWh/y (= 0.28 × 55.1 × 0.05) to 1.54 TWh/y (= 0.28 × 55.1 × 0.10) can be set.

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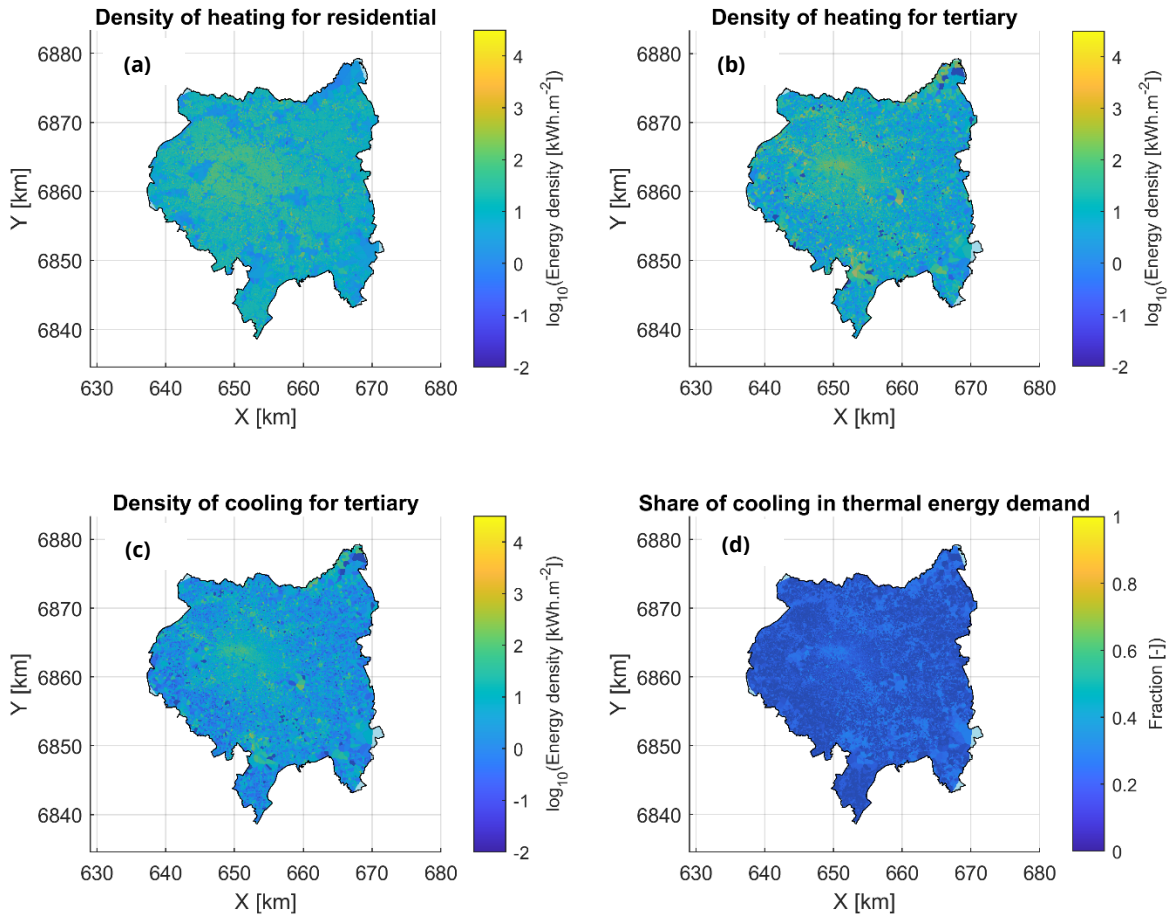

Figure 51. Greater Paris Metropolis : (a)-(c) : Needs for heating in housings (a), in tertiary sector (b) and cooling in tertiary sector (c) ; (d) : share of cooling for tertiary sector in the thermal energy demand (i.e., sum heating and cooling) (Source: CEREMA, 2020). Data are represented at 100 m x 100 m pixels.

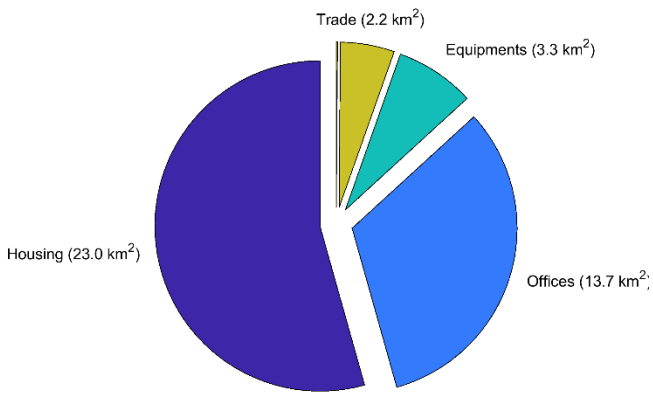

Figure 52 : Repartition of the type of surfaces of floor in the zones covered by the APUR.

5.2. Roadmap

Based on the analysis of the three regions and contacts with local actors, the roadmap in the framework of D2Grids assumes that two potential pilot sites will assess 5GDHC networks in North-East France.

The first potential pilot will be assessed in South of Orleans Metropolis "Parc de la Saussaye" which is a business park with several SMEs that will be extended by 30 additional hectares with the arrival of new SMEs (the type and needs of the enterprises is not yet defined). A datacentre will probably also be created. As there was no reflection on energy supply yet (gas pipeline nearby), the project represent an opportunity to study the possibility of rolling out 5GDHC network with low temperature and with shallow geothermal source.

A second pilot site (not defined at this stage) is also in discussion in Strasbourg Eurometropolis where the Heads of Renewable Energies and Heat Networks are interesting by the 5GDHC concept and are currently seeing with their operational urban planners if a new project in development could comply with 5GDHC technology.

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Interreg North-West Europe D2Grids

European Regional Development Fund

WORK PACKAGE: WPLT

DELIVERABLE NUMBER: DEL.1.3

TEMPLATE PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN 7 FOLLOWER REGIONS

October, 2022

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1. Introduction

Activities in the Long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories ("follower regions"). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. This document provides a regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology in one of the 7 follower regions defined for this project, namely: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project, has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

Useful Resources

1)Rapport biannuel de l'institut luxembourgeois de régulation sur le système d'étiquetage années 2017-2012 (général sources)

2) PLAN NATIONAL INTÉGRÉ EN MATIÈRE D'ÉNERGIE ET DE CLIMAT DU LUXEMBOURG POUR LA PÉRIODE 2021-2030 (figures and général sources)

3) Bewertung des Potenzials für den Einsatz der hocheffizienten KWK und der effizienten Fernwärme- und Fernkälteversorgung ,(figures and général sources)

4) https://eau.gouvernement.lu/fr/ressources-en-eau/eaux-souterraines/ Figures

2. Characterising the region

2.1. Luxembourg:

Luxembourg is a small country, but with some specificities. We can therefore have a global vision of the territory. Luxembourg is based on a schistic foundation against the background of the Parisian basin. Luxembourg had 645,397 inhabitants on 1 January 2022, with a population density of 250 inhabitants per km². The country covers an area of 2,586 km². Luxembourg is an essentially rural country, especially in the north and east of the country. The most urban part is in the west and south of the country. 51% of its population live in rural areas, while less than one in five (18%) live in cities, and less than one in three (31%) live in "intermediate zones". Luxembourg thus has the most rural population in the EU. Economic and urban development is mainly located in the south-western area. There are some urban development projects in the north (Wiltz) and in the north (Diekirch).

The population of Luxembourg is growing every year. The government's ambition is to have 1 million inhabitants by 2050. The increase in the number of inhabitants is mainly concentrated around the existing cities through the creation of new districts often located on former industrial wasteland. These neighbourhoods could all benefit from 5th generation heat network technologies.

In the early 19th and 20th centuries, two industries were the main providers of work: iron and slate mining. These mining areas could develop heat networks based on the D2Grids concept. The iron ore mines are in the south of the country (Minett territory), along the French border. They are adjacent to and connected to the mines in the north of Lorraine (see BRGM report on this deliverable). The slate mines are located along the Belgian border, in the Martelange region. (Slate mine museum). All the slate mines are flooded. On the other hand, the iron mines are either totally or partially flooded, or are dry. Some of them are still used as an industrial water reserve by Arcelor Mittal, so a case-by-case study is needed. There is no up-to-date map of the iron and slate mines in Luxembourg. These are documents dating from the 1980s at the latest, linked to the end of their exploitation.

In the west and north of the country, there are slate mines in the neighbouring towns of Martelange and Asselborm. These mines are flooded, the volume of water is very large but we lack any estimation of the capacity, the temperature is regularly 12° C. This mine will be used to develop a grid in Martelange (Belguim) and Rombach in Luxembourg and perhaps Asselborn, but at this moment there is no project concerning this area.

For the south of the country, each iron ore mine must be studied on a case-by-case basis according to the projects that could be developed near it. Some technical and legal issues have no known precedent, for example, can a sunken mine in France (near the border) be exploited to supply a Luxembourg district? However, there is potential in Differdange, Esch sur Alzette, and Dudelange. A more detailed study should confirm the exact potential. There is no real identified potential for geothermal energy, but research is underway. This research concerns deep geothermal energy, at a depth of more than 1000 metres. The concept is to study the possibility of heating water to around 30°C and reinjecting the surplus heat in summer. This deep geothermal project is associated with the 'Neischmeltz' project at Fond du Logement in the southern city of Dudelange. The Fond du Logement is currently waiting for the drilling permit.

The creation of natural storage using small groundwater tables is almost impossible in view of the environmental laws in force on the territory at the moment to protect the aquifer.

This Luxembourg territory along with Lorraine Iron basin in region “Grand Est” could think in a cross-border way for the development of D2Gids technology. On other way to support the D2grids development in Luxemburg is to work with a geothermal infrastructure.

2.2. Lorraine Iron basin in region "Grand-Est"

The Lorraine Iron basin (Figure 5) is located in the east part of France below the Luxembourg border in the region "Grand-Est". It covers an area of about 430 km^2. The iron Basin is composed of three main basins: South basin (137 km^2), Central basin (126 km^2) and North basin (97 km^2) and eight smaller reservoirs (< 20 km^2). Mines were exploited until 1994 for the Central basin, until 1995 for the South basin and until 2005 for the North basin. The cessation of mining activities and pumping resulted in the progressive flooding of the mine workings (galleries and collapsed levels) and the creation of artificial reservoirs. Mining reservoirs are considered to be hydraulically independent, *i.e.* they do not exchange water with neighbouring mining reservoirs. This hydraulic independence of the reservoirs may result from the history of mining, which has left in some places blank areas of work between two reservoirs; the geological configuration of the exploited land (major fault); or the installation of underground dams in the mine workings before flooding to redirect flood waters to the chosen overflow points. A monitoring network has gradually been set up since 1993 and includes currently 41 points of water survey (flowrates, temperatures, chemical analyses).

BRGM has been commissioned in 2017 to study the geothermal potential of the Lorraine iron basin by the Environment and Energy Management Agency ("Agence de l'Environnement et de la Maitrise de l'Energie", ADEME) and the Lorraine Regional Council (now the region "Grand-Est"). Knowledge of its potential is indeed limited, yet the main flooded mining reservoirs in the basin constitute a reserve of almost 500 million m^3 of underground water, which could represent a major shallow geothermal source opportunity for heating and cooling purposes. The study was part of a geothermal development approach for the Lorrain iron basin, 25 years after the end of dewatering in the mines. This study allowed to define the different mining typology (mining voids, porous media), depth of mining reservoir, depth of water level, water temperature and location of urban areas. This work will help to define opportunities for developing 5GDHC networks in the region with the development of new potential activities in former mining region.

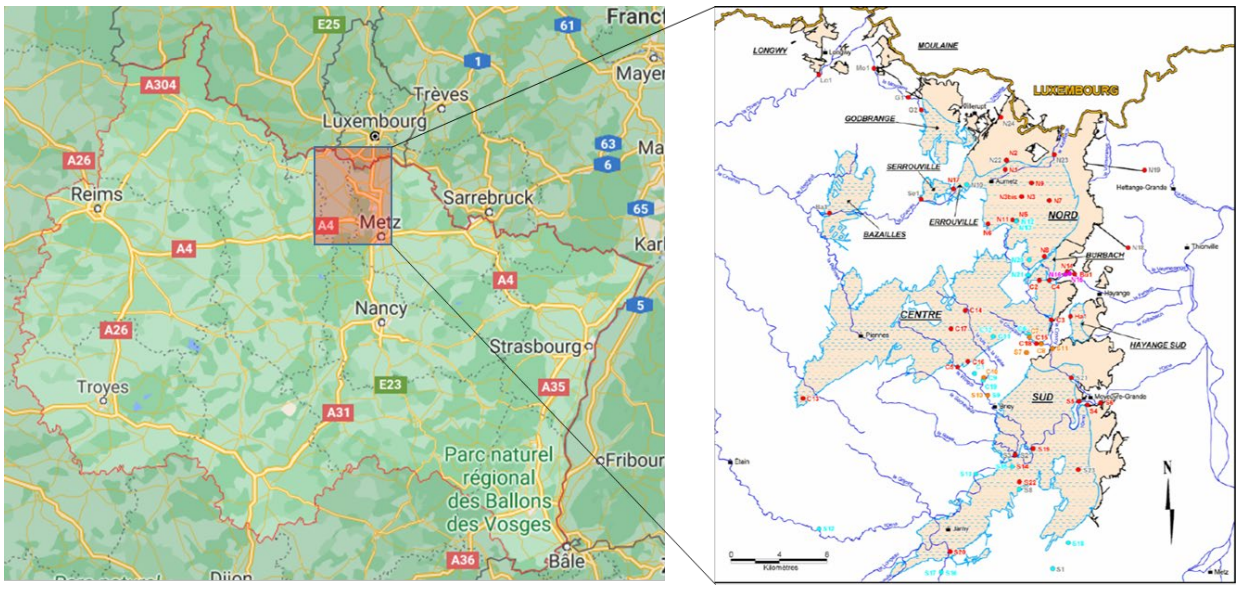

Figure 1. Localization of the Lorrain Iron Basin and main reservoirs (North, Central and South) at the Luxembourg border in "Grand-Est" region (source: report BRGM/RP-67079-FR

3. Analysis

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

The main source of heating is still individual heating in gas, fuel and wood. The gas network extends around urban and suburban centres. Individual gas heating is in the towns and peri-urban villages. In the rural part, heating is mainly with oil and wood. A detailed heat demand analysis for all municipalities in Luxembourg can be found in Figure 2. From 2022, a new law requires the installation of heat pumps in new homes.

In the seven municipalities with a floor area ratio of more than 0.1, there are large areas with a heat density and heat sales of more than 10 GWh per year. In addition, there are other municipalities that have a low floor area ratio, but still have relevant areas from the heat demand analysis. Figure 37 shows the results regarding the distribution of heat demand and identifies the areas that fulfil the previously defined conditions. The map also shows which areas in the individual municipalities are eliminated for economic development through heat networks due to the decline in heat demand (marked in blue).

The largest heat demand of over 700 GWh is in the municipality of Luxembourg City, followed by Esch-sur-Alzette. In total, the heat demand that can be tapped by heat grids in the seven municipalities that meet the potential limits amounts to about 1,606 GWh in 2012, which drops to 1,170 GWh by 2030. This corresponds to a share of 5 % of the heat demand of the building sector in 2030. The data just comes from an analysis of the needs of a heat network but does not include a heat-cold network approach which by selling cold can make the network more profitable.

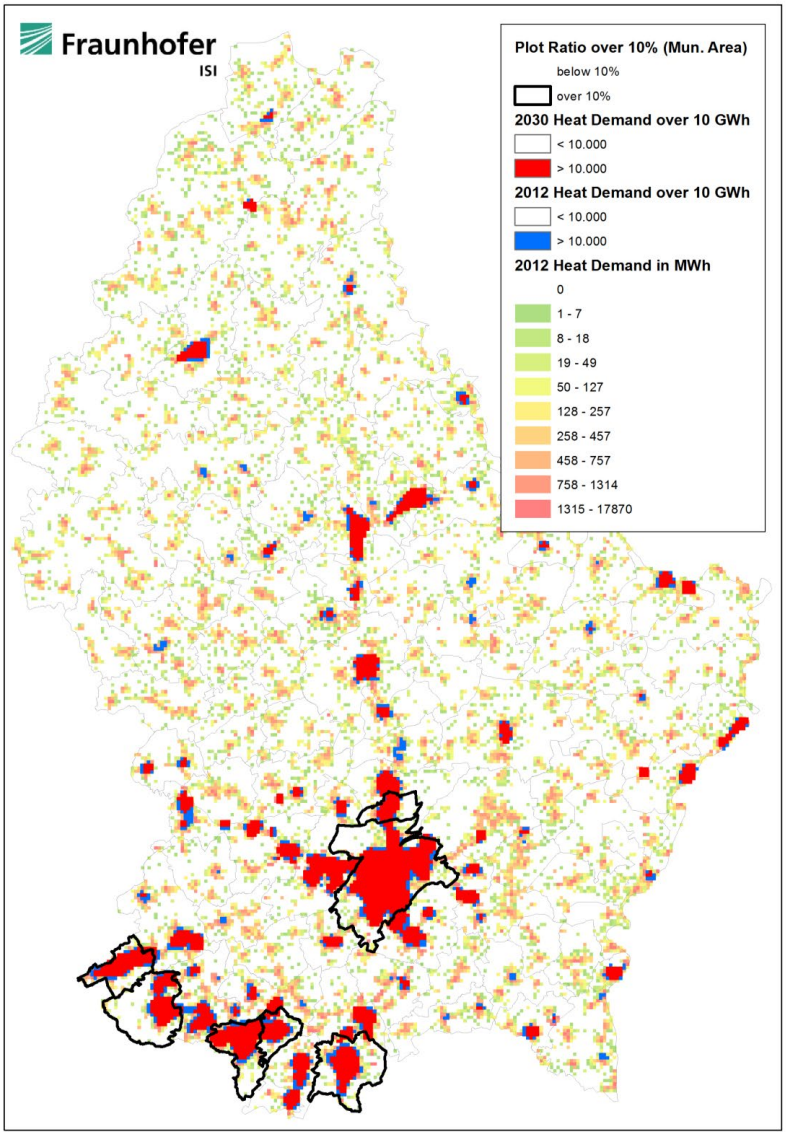

Figure 2: Heat demand analysis for Luxemburg municipalities(Assessment of the potential for the use of high-efficiency cogeneration and efficient district heating and cooling. Report of the Ministry of Economy Luxembourg 2016)

Currently dominant heating technology in the region

The current dominant technology is the high temperature heat network (first and second generation) with heat generators with gas. Today, the heat produced is of renewable origin, biogas, wood. These networks operate mainly according to the cogeneration principle, with water at a temperature of about 350°C. The water is then converted into electricity. This water is fed into a turbine to produce electricity and then fed into the heat network. The government has set up a major subsidy programme to replace existing oil-fired boilers with biomass boilers. These networks have been developed on the principle of cogeneration, with an economic viability based on the sale of both heat and electricity. They help the national production of electricity as the country does not have its own power plant. Until 2015, the design of heat networks was linked to electricity production. In addition to this system, other networks recover industrial residual heat for steel factory or wood panel production.

The analysis of existing heat networks (Figure 3) shows that the majority of Heating Network, are located in municipalities with an economic potential for heat networks. Most of the are located in the metropolitan area of Luxembourg-City and adjacent areas. However, smaller heat networks can also be found in rural areas.

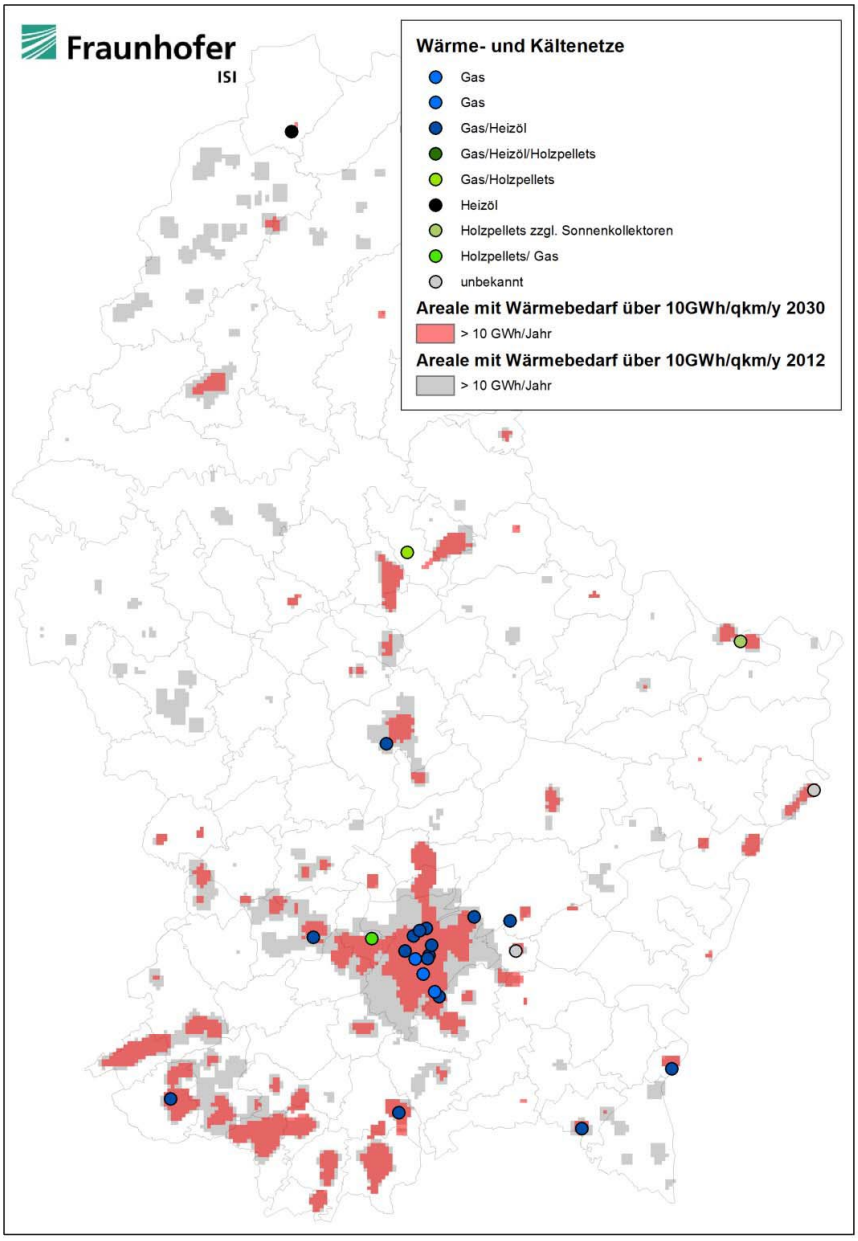

Figure 3: Analysis of existing heat networks Assessment of the potential for the use of high-efficiency cogeneration and efficient district heating and cooling. Report of the Ministry of Economy Luxembourg 2016)

District heating in the current heating regime

District heating (heating network) is mainly developed in the country's cities. They are mainly present in the districts built since the 1980s. Some networks are present in the villages but these are mainly for the heating of communal buildings and houses in the surrounding area.

The areas built before 1990 are mainly heated by individual gas heaters. Today all new districts use a heating network, but there is still no lime-cold network installed in Luxembourg. This is due to the culture of heat networks based on cogeneration.

Main actors in the current heating regime

At national level, there are two main actors. The most important one is LUXENERGY. LUXENERGY is a private company created on 1990. The first company in Luxembourg dedicated on urban grids heating. Their activity is mainly concentrated in Luxembourg city, but they also manage a number of new district heating networks throughout the country. They mainly develop cogeneration networks. They manage about thirty networks of all sizes (from a few communal buildings to an urban district). They employ about one hundred people.

The second most important player is SUDCAL, a public company with capital from the cities of Esch sur Alzette, Sanem and the Luxembourg state. SUDCAL is more specialised in the management of residual heat from industry, here it is ARCELOR MITTAL. It manages the heating network in the cities of Sanem and Esch sur Alzette. SUDGAS also supplies gas. A third operator is developing, EnergiePark Reiden, which operates small networks in rural areas. Some of these networks are managed in a cooperative form like Beckerich or Diekirch municipality, but they are still quite rare.

We have only one national gas and electric provider CREOS.

Legal framework and operational context for these actors

There is no legal framework for heat networks or hot-cold networks in Luxembourg.

There is a "natural" geographical distribution with SUDCAL working on the cities of Esch sur Alzette and Sanem, LUXENERGIE in the rest of the country.

Developers have the choice to use the most optimal network for their real estate project. This leaves a very open perspective for the use of 5th generation networks.

However, there are a number of environmental laws that may impact on 5th generation networks, such as the ban on drilling on groundwater. For example, there is no law governing deep geothermal energy in Luxembourg. With the development of this type of network, there will be constraints, not yet identified, which will have to be lifted on a case-by-case basis.

Current organization of heating markets

In Luxembourg, the market is too small to have a real competition. Heat networks are usually local projects supported by national subsidies. As mentioned above, Luxembourg is a small market divided up as follows:

- In the south of the country, SUDCAL works in the towns of Esch sur Alzette and Sanem.
- LUXENERGIE is located in Luxemborug and in a number of other cities (about ten)
- ENERGIE PARK REINDEN, is a player that develops mainly in small rural networks.

To date, there are no foreign players on the national territory, due to the low economic interest.

3.1.2. Developments in heating policy and market contexts

Current developments in the legal system and market organization

There is no specific law for hot and cold greads However, two laws can help to set up this type of network, the law promulgated on 3 February 2021, allows the establishment of energy communities in Luxembourg, which was very difficult or impossible before. These communities will help the development of 5g networks in the new districts. A second law,

promulgated on 7 April 2022, increases the subsidies for the installation of heat pumps and renewable energy production systems.

Expected developments in terms of energy transition policy or market transformations to accommodate green energy

Luxembourg will introduce more and more green energy into the heat networks. The government also wants to make use of all the residual heat identified on the territory, as is already done in Esch sur Alzette with Arcélor. The state also wishes to support local investment in these networks by encouraging the setting up of energy cooperatives.

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

There is no national law governing heat networks. There is support for heat networks that include renewable energy. However, these are too small to influence the economic model of the network. The integration of renewable energy depends on the willingness of the developers and the energy viability of the network. Therefore, no particular regulation exists at the moment to regulate district heating providers or 5GDHC.

3.2.2. Ownership and operation of district heating systems

The ownership of the networks is communal, either they are operated directly by the communes or unions in the form of a public service, or they are managed in the form of a public service delegation by private operators.

3.2.3. Regulation of price setting

As of today, there is no price regulation. There is a free price, set at the cost of operating the network.

3.2.4. Role of building owners and building occupants

Deciding the heat source of the building

In the context of a new district, it is the development programme that requires the connection to the heating network if one is planned. In the case of a programme in an already built-up area, if there is no municipal obligation, it is the builder who chooses the heating system, depending on the price of the heat.

Investments and energy bill

There are at least two models:

- The one where the municipality pays the investment, which operates or leases the network to a farmer. The investment is included in the cost of the heat charged. The price is indexed either to the cost of living or to the cost of fuel oil or to some other systematic index.
- The other model is that the investment in the heat network is included in the purchase of the property, the bill then only includes the part of the network management and the cost of the heat. The network is often not managed cooperatively in this case.

3.2.5. Financing and subsidies

Localized subsidy or grant mechanisms are available

There is no specific aid programme planned. Each project is studied on a case-by-case basis and receives funding according to its innovative character.

3.3. Available energy sources and storage

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the highest ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low grade sources would be in order to make a decent 5GDHC business case. At the time of writing, D.T1.1.4 has not been finalized.

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

As it was previously explained, to this date, there is no such projects in Luxembourg. For the moment there are also no identified leads, The development of 5th generation heat networks will be the first application of this technique in Luxembourg.

3.3.2. Ambient thermal sources from soil, water, air, and low temperature solar heat

[1] analyzed the pan-European very shallow geothermal energy potentials.

Flooded underground infrastructure

For flooded underground infrastructure, there is an identifiable potential in the west of the country, the Grumelange sector, around the slate mines. However, it is important to beware of this rural area, due to the problems linked to housing density for the deployment of a heating network. The low density of the settlement significantly increases the amortisation of the network in relation to its operating cost, as less energy is consumed per linear metre of grids compared to an urban environment.

In the south, there are iron mines, many of which are under-dried because they were exploited on the hillside. However, some of them are flooded and are located near the French border. They are located near large cities such as Differdange, Sanem and Esch sur Alzette. There is a potential development possibilities on these territories. Moreover, it should be noted that this would be done mainly in old districts as they are the closest to the mines. However, this will require greater investment than in new districts, as the infrastructure work is more extensive. Roads have to be demolished to lay the networks.

Aquifers

In Luxembourg, it is regulated by law, that the use of natural aquifers is prohibited for anything other than drinking water. However, it would be possible to use artificial aquifers for thermal energy storage, but at the moment there is none in Luxembourg.

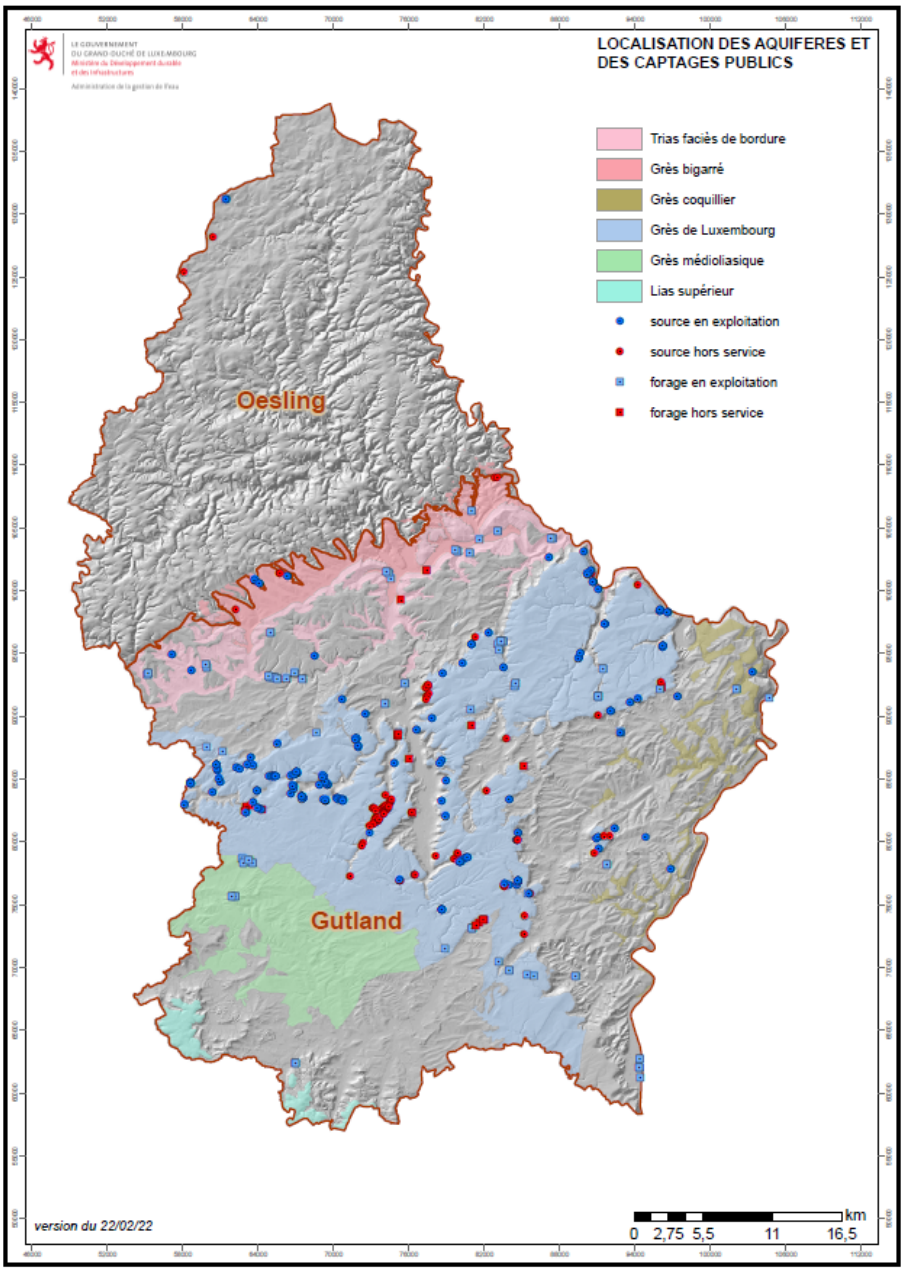

Figure 4. Location of aquifers in Luxemburg

Solar thermal development potential:

All new grids installations in Luxembourg are designed with a solar installation. For practical reasons, more and more photovoltaic panels are used and hot water is produced with the electricity. However, there are installations that include thermal panels for additional thermal production.

3.3.3. Higher temperature industrial waste heat, otherwise rejected in the environment

There are not many large industrial companies in Luxembourg that can produce 100° C of waste heat. Currently there are two identified industries, steel production on the Arcelor Mittal sites and the Kronospan site in Sanem equipped with 2 wood cogeneration plants. The waste heat from the Arcelor Mittal factory in Esch sur Alzette is used by the Sudcal network to heat the new Belval district.

3.3.4. Renewable electricity from local sources like wind, sun

The part of renewable electricity from local sources is about 11.9%. Solar energy is always included in the design of new projects.

3.3.5. Electricity use at times of renewable overproduction, e.g. when spot price is low

The share of renewable energy production is too low to have excess production to manage. In 2017, Luxembourg's energy consumption was dominated by the need for oil products. In addition, energy needs were also covered by natural gas, electricity and biomass (see Figure 5).

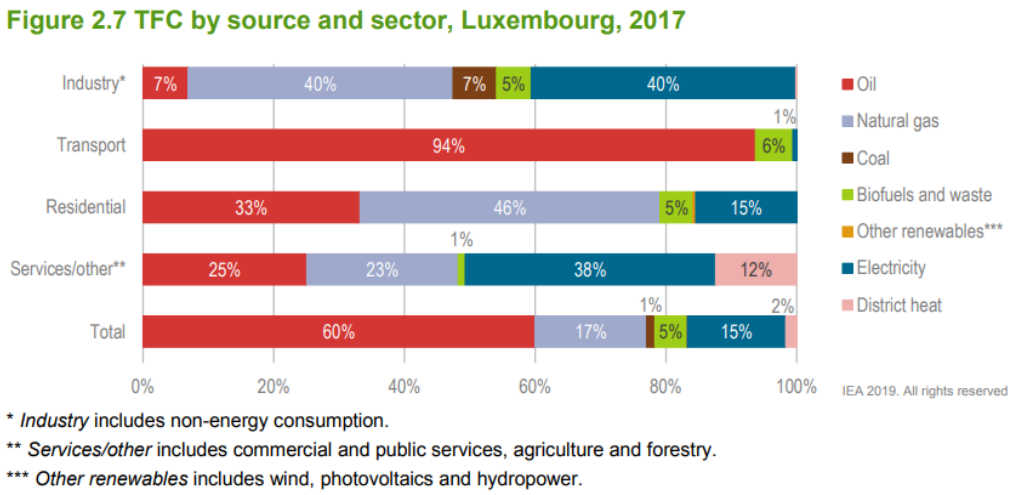

Figure 5. Total final consumption by source an sector.
Source: IEA (2019b), World Energy Balances 2019, www.iea.org/statistics.

Currently, the government has engaged a strong support policy for photovoltaics (subsidy, obligation of photovoltaic installation on new industrial buildings...) Wood is mainly present in heat networks. The main wood consuming installation is an urban installation, it is the installation of the plateau du Kircberg.

3.3.6. Electricity mix from the external grid

Bioenergy was the main source for electricity generation in Luxembourg in 2021, accounting for 27.3 percent of total power production. Closely following, wind energy made up 24.5 percent of the country's power mix. That year, over 80 percent of Luxembourg's electricity production was derived from renewable sources.

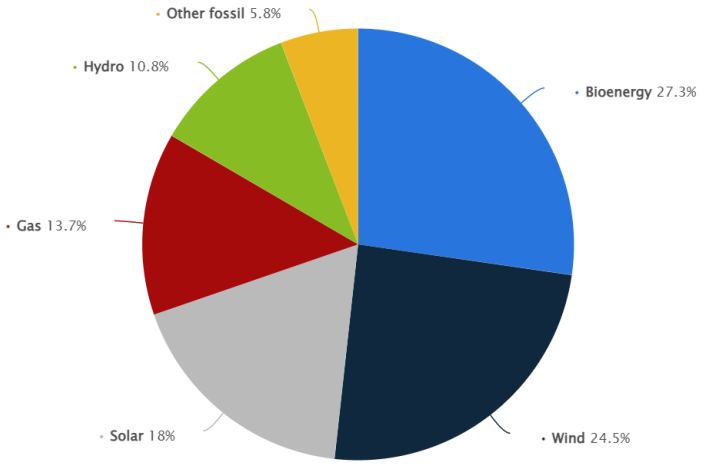

Figure 6. Distribution of electricity generation in Luxembourg in 2021, by source. www.statista.com

3.3.7. High temperature heat from burning biofuels, biogas, biomass

The percentage of biomass for the grids is around 5%, especially in small rural heat networks, for example in Beckerich. As a result of technological developments, there should no longer be any biogas-fuelled heat networks, as biogas is now fed directly into the gas network. The main player are Luxenrgie and Energiepark Reiden.

3.3.8. High temperature heat from burning fossil fuels

Luxembourg has an efficient gas network, the heating grids that do not use renewable energies run on gas. There are also grids which are based on the residual heat of companies with a complement of gas. The main players are Sudcal and Luxenergie.

4. SWOT analysis

Given the data gathered above, an analysis of the strengths, weaknesses, opportunities and threats of implementing 5GDHC in the region can be made.

SWOT Analysis	
Strengths	**Weaknesses**
- As a small country, we can adapt laws quickly to support a new method of development or technology. - Good knowledge of the needs at the level of urban areas and of the availabilities such as the residual heat of the companies. - Many new districts under construction, which can use the technology, (introduction). -Very good technical regulations in the building industry. Because they only build triple A buildings (heating requirement of 22 Kw/m² per year), but these buildings have a cooling requirement, which results in a hot-cold demand that is balanced and favors 5th generation networks.	- Little knowledge of the technologyof D2grids - Few cities with sufficient urban density for 5th generation networks - Companies not open to change, we need to change the way we technically manage buildings and how we install fluid systems - No possibility of using aquifer
Opportunities	**Threats**
- Innovative young companies, because they are more capable of integrating new technology and open to innovative construction methods. - Financing facility for the development of new grids, Luxembourg is one of the leading green financial centres. It is easier to find investors interested in green technologies. - Development of technology for artificial seasonal storage	- Difficulty of developing this type of network in old neighborho ods, This type of neighbourhood is the most important at national level. Adapting D2grids technology to this type of housing would increase its development potential - As there is little natural storage capacity, it is necessary to develop the technology without this system (artificial storage...)

5. Regional vision

Barriers: Identifying and sensitizing the relevant actors (Public real estate funds, private promoters, municipalities) in a way, that accessing the project planning could be done in time. Often the planning is engaged fixing already construction, economical or deadline limits.

Opportunities: There is a real existing potential via urbanization projects on brownfield sites in the south, and north of Luxembourg, new quarter projects of the growing city of Luxembourg. Beside this, refitting existing quarters with or without existing DH will be a big issue in the next years. Existing DHs are mainly based on Gas CHPs which will no more replaced and where alternative heat production forms have to be found.

5.1. High potential areas and potential pilot sites

Potential 5GDHC-network sites were investigated for the region of Luxembourg based specific requirements for the successful implementation of this technology. Therefore, either areas with a high density of development (existing or to be planned) or the reversion of brownfield sites were considered. In the region of Luxembourg, this applies for the following areas (Figure 7):

High density of development	Reversion of brownfield sites
Wiltz	Entire South region (Esch-sur-Alzette, Dudelange, Differdange, ...).
Nordstad	
Entire Alzette valley from the city of Mersch to the city of Luxembourg	
Agglomeration of the city of Luxembourg	
Entire South region (Esch-sur-Alzette, Dudelange, Differdange, ...).	

In the described areas, potential 5GDHC sites were identified and are marked on the map (Figure 7) as blue crosses. The location of the 2 LAPs is highlighted with a red cross.

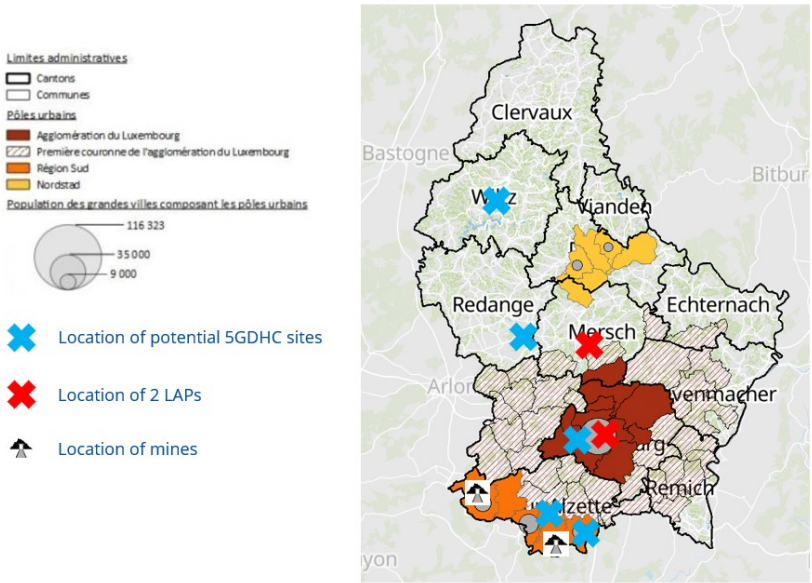

Figure 7: Potential 5GDHC sites in Luxembourg.

In Wiltz, it is a new district of about one hundred dwellings. There will be no seasonal storage capacity, but there will be a strong integration of photovoltaic energy.

The first LAP is in Mersch. This project consists of a new quarter of about 1.000 dwellings as well as some commerce buildings. The LAP envisaged Energy stations equipped with hybrid heat pumps in combination with residual heat from the buildings supply heat to grid. Seasonal storage concepts as well as the integration of photovoltaic energy were analysed, allowing a strong amount of sector coupling in the area (Power-to-heat).

The second LAP lies in the agglomeration of Luxembourg. For this district, there is a water table underneath, but drilling is prohibited. The LAP envisaged to combine the recovery of residual heat from administrative buildings and the production of photovoltaic energy. It is a 500-unit housing estate with about 3.000 dwellings. Also, a second potential 5GDHC site has been identified in the agglomeration of Luxembourg. In this new quarter, a zero-emission concept with high ecological and innovative standards is targeted.

In Dudelange, the project covers 10 ha and includes 1500 dwellings. The project includes deep geothermal energy (1200 meters) and photovoltaic energy production. To date, we do not know if it will be possible to reinject the surplus heat in summer into the well. This project should work on the principle of energy community.

No potential sites were identified for the refitting of larger quarters until now, bit the current energy crisis will certainly create a demand in the next months.

5.2. Roadmap

Based on the assumption that the respective project promoters take the decision to apply the concepts, the following theoretical roadmap can be derived:

		2022	2027	2032
PROPOSED 5GDHC ROLL-OUT	Floor area [m2]	0	320.000	95.475
	Energy [MWh/a]	0	12.500	5.133
	Part of regional total [%]	0	71	29

6. References

1) PLAN NATIONAL INTÉGRÉ EN MATIÈRE D'ÉNERGIE ET DE CLIMAT DU LUXEMBOURG POUR LA PÉRIODE 2021-2030
2) Bewertung des Potenzials für den Einsatz der hocheffizienten KWK und der effizienten Fernwärme- und Fernkälteversorgung
3 https://eau.gouvernement.lu/fr/ressources-en-eau/eaux-souterraines/

Regional Vision Parkstad Limburg

Opportunities for 5th generation district heating and cooling

CE Delft

Committed to the Environment

Interreg North-West Europe D2Grids

Regional Vision Parkstad Limburg

Opportunities for 5th generation district heating and cooling

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Delft, CE Delft, November 2022

Publication code: 22.220182.162

Client: Mijnwater B.V.
Your reference: MW100247

Publications of CE Delft are available from www.cedelft.eu

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Content

Summary

D2GRIDS is an Interreg North-West Europe project dedicated to increasing the share of renewable energy used for heating and cooling by accelerating the rollout of 5th generation district heating and cooling networks (5GDHC) in Europe. 5GDHC is an innovative, demand-driven form of district heating, operating at low temperatures. The D2GRIDS project has seven follower regions, as defined in the application form:
Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). Mijnwater, a supplier of heating and cooling via a 5GDHC network in Parkstad Limburg in the Netherlands, is the lead partner of the D2GRIDS project. Each follower region will prepare a regional vision, describing its aspirations for contributing to the rollout of 5GDHC.

This vision describes the aspirations of Parkstad Limburg on how the region can contribute to the rollout of 5GDHC. The objective of the regional vision is to identify the most suitable potential regions for implementing 5GDHC.

Potential of implementing 5GDHC in Parkstad Limburg

Deciding on the regions where 5GDHC technology can be implemented is not straightforward. Many factors must be taken into account that play conflicting roles in determining where the technology is most suitable. These include financial, technical, spatial and social factors. A multi-criteria analysis was therefore used to resolve this multi-faceted problem. The multi-criteria analysis assesses all neighbourhoods in Parkstad Limburg to determine which neighbourhoods are most suitable for implementing 5GDHC technology.
Two regions have been selected based on the multi-criteria analysis; one in the proximity of the existing Mijnwater district heating and one further away from existing district heating. The selected regions are the Heerlen Centrum district, consisting of four neighbourhoods in the centre of Heerlen, and two neighbourhoods in Kerkrade (Rolduckerveld and Holz).
A local action plan will be prepared for these two regions.

Strengths and weaknesses

A SWOT analysis is conducted for 5GDHC in Parkstad Limburg. The region's greatest strength is its experience with 5GDHC by Mijnwater. In addition, national and local plans for energy transition provide a good basis for identifying areas where it is feasible to implement district heating networks. The growing demand for cooling in the built environment in the Netherlands is another technical advantage for the implementation of 5GDHC.

The main weaknesses of the region are bureaucracy and achieving the participation needed for collective heating systems. We have identified the most important threats as the imbalance between heating and cooling demand and financial feasibility due to high investment costs. On the other hand, high energy prices due to the current energy crisis in Europe provide an opportunity for the implementation of 5GDHC.

Contextual information on 5GDHC in the Netherlands and Parkstad Limburg

For the implementation of 5GDHC technology in the Netherlands, particularly in Parkstad Limburg, we have compiled relevant contextual information.

The heating market in the Netherlands is rapidly changing due to energy transition (or gas phase-out), as we switch from fossil fuels to renewable energy. In the Netherlands, the most likely alternatives to conventional gas-fired boilers are hybrid heat pumps using renewable gas, all-electric heat pumps and collective district heating such as 5GDHC.
In the context of the energy transition, the government is providing various subsidy schemes for investments in insulation, heat pumps and district heating, which can also be used for 5GDHC. Although energy tariffs for district heating are strictly regulated in the Netherlands, there are no specific tariff regulations for 5GDHC.

Parkstad Limburg has several potential heating sources. The most promising sources are waste heat, solar thermal energy on repurposed agricultural land and the exchange of heat flows from different types of buildings. Furthermore, ground-coupled heat exchangers are allowed in most of Parkstad Limburg.

The region: Parkstad Limburg

This regional vision focusses on the Parkstad Limburg region. The Parkstad region is an administrative collaboration between seven municipalities in the province of Limburg, in the south of the Netherlands. The seven municipalities are Beekdaelen, Brunssum, Heerlen, Kerkrade, Landgraaf, Simpelveld and Voerendaal. Parkstad Limburg has 256,000 inhabitants and 126,000 households. It has a very high-population density of roughly 1,000 inhabitants per km^2. Most of the land in Parkstad Limburg is zoned for buildings and agriculture.
The western part of Parkstad is mainly covered by agricultural land, while urban areas predominate in the eastern part.

As is the case elsewhere in the Netherlands, most of the buildings in Parkstad Limburg are heated using natural gas-fired boilers. Some buildings are connected to the district heating network of Mijnwater. Mijnwater currently operates a 5GDHC network in Heerlen and Brunssum.

1 Introduction

The D2GRIDS is an Interreg North-West Europe project which aims to increase the share of renewable energy used for heating and cooling, through accelerating the rolling out of 5th generation urban heating and cooling networks (5GDHC) in Europe. 5GDHC is an innovative form of district heating which is characterised by the following principles:

- ultra-low temperatures close to end-user needs allowing the use of low-grade renewable heating sources;
- demand-driven temperature based on smart control, and decentralised installations enabling heating and cooling exchange between end-consumers thanks to a closed loop;
- integrated heat and power networks to reduce power peaks (Mijnwater, ongoing-c).

The D2GRIDS project has seven follower regions as defined in the application form: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK) and involves five pilot sites in Bochum (DE), Brunssum (NL), Glasgow (UK), Nottingham (UK) and Paris-Saclay (FR). Mijnwater, a supplier of heating and cooling via 5GDHC in Parkstad Limburg in the Netherland, is the lead partner of the D2GRIDS project.

Within the D2GRIDS project the long-term work package aims to sustain roll out D2GRIDS outputs to a wide variety of target groups, including policy makers, financial investors, professionals, SMEs[1] and other companies in the DHC industry, as well as to new territories ('follower regions'). In this work package each follower region prepares a regional vision. This vision describes ambitions of each of the follower regions on how the region can contribute towards the goal of rolling out 5GDHC. To inform this regional vision, a preliminary feasibility assessment is conducted first. The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within five years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. Mijnwater and the Open University asked CE Delft to perform the pre-feasibility assessment. This document contains the results in the form of the regional vision for Parkstad Limburg.

Reading guide

Chapter 2 describes Parkstad Limburg. It gives a general description of the region as well as more detailed insight in the types of buildings and the current heating technologies. **Chapter 3** gives an overview of the Dutch heating markets and the developments in the Dutch energy transition in the built environment. **Chapter 4** examines the position of district heating in the Netherlands. It describes the regulatory framework, the stakeholders involved and the financing and subsidies. The available energy sources and storage are outlined in **Chapter 5.** This all comes together in the SWOT analysis in **Chapter 6**. A multi-criteria analysis shows which neighbourhoods are most suitable for 5GDHC in **Chapter 7**. This leads to the selection of two regions for the local action plans in **Chapter 8.**

[1] Small Medium Enterprise.

2 The region: Parkstad Limburg

2.1 Characterisation of the region

This regional vision focuses on the region Parkstad Limburg. The Parkstad region is an administrative collaboration between seven municipalities in the province Limburg, in the south of the Netherlands (see Figure 1). The seven municipalities are Beekdaelen, Brunssum, Heerlen, Kerkrade, Landgraaf, Simpelveld and Voerendaal.
The Parkstad region had 256,000 inhabitants and 126,000 households in 2021.
It has a very high-population density of roughly 1,000 inhabitants per km^2 (CBS, 2021).

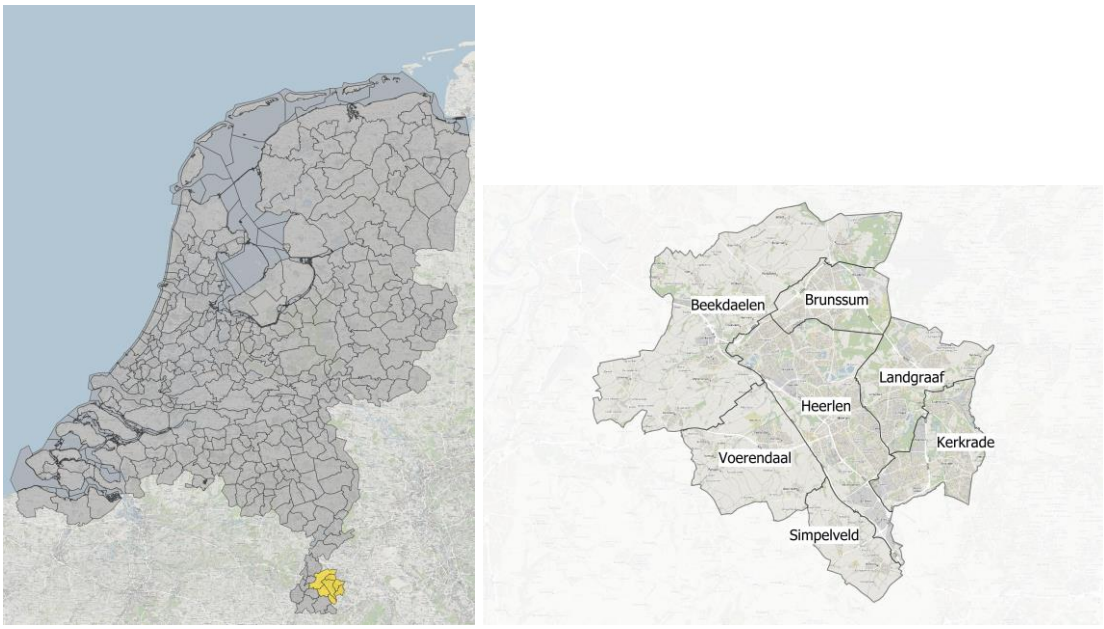
Table 1 - An overview of the population in Parkstad Limburg and the Netherlands in 2021

	Parkstad Limburg	The Netherlands
Population (2021)	256,318	17,475,415
Number of households (2021)	126,263	8,043,443
Area	235 km^2	33,671 km^2
Population density	1,093/km^2	519/km^2
Average income per resident with income	€ 29,300	€ 33,300

Provinces, municipalities, districts and neighbourhoods

The Netherlands is divided in geographical regions on several scales (CBS, 2022a).
The largest division scale are the provinces. There are twelve provinces in the Netherlands. The provinces have administrative power over subjects such as spatial planning, transport, agriculture and nature and landscape. Within the provinces are the municipalities. Figure 1 on the left shows the 345 municipalities in the Netherlands. The municipalities are the third administrative layer in the Netherlands (after the national government and the provinces). Municipalities are responsible for a wide variety of public services, such as land-use planning, public housing, management and maintenance of local roads, waste management and social security. They are also responsible for a large part of the execution of the Energy transition. Within the municipalities there are districts ('wijken'), and within the districts there are neighbourhoods ('buurten'). There is no definition of the size of a neighbourhood. On average about 600 households live in a neighbourhood, however in some neighbourhoods there are 13,000 households and in some there are none. A district typically consists of two to fifteen neighbourhoods.

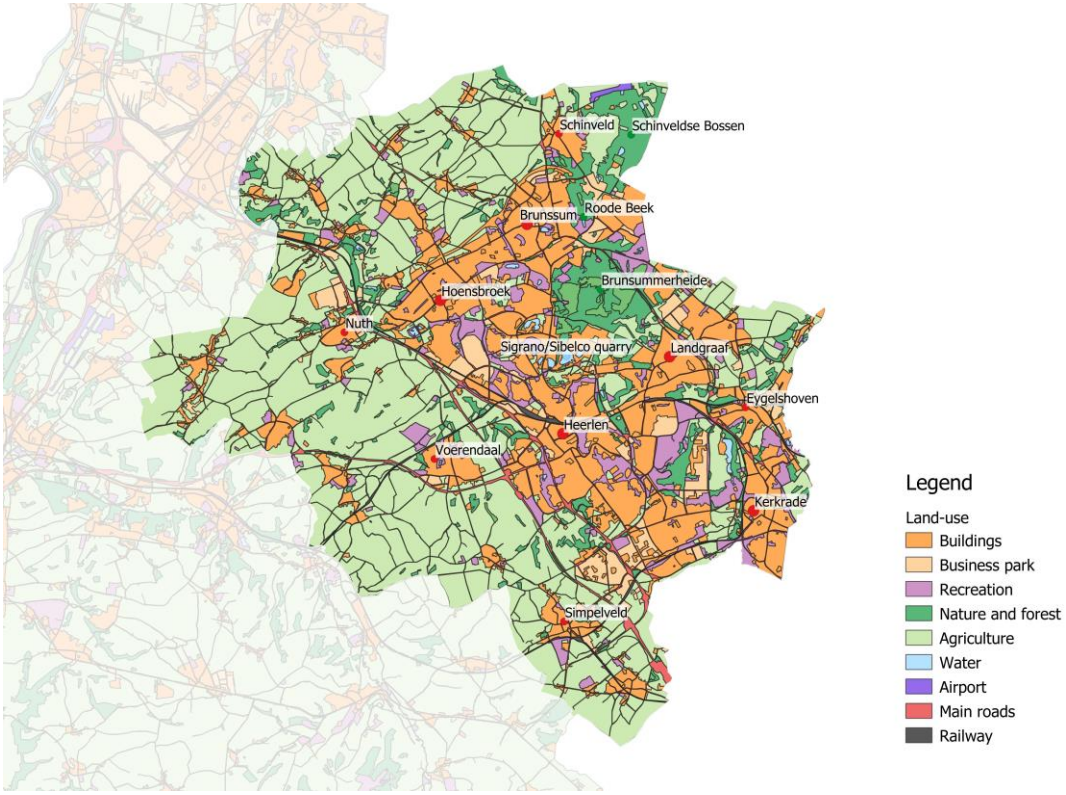
Figure 1 – Left: The municipalities of the Netherlands. The municipalities in yellow are the municipalities in the Parkstad region. Right: The seven municipalities of the Parkstad region



Landscape

Figure 2 shows the land-use of Parkstad Limburg. Most of the land-use is for buildings and for agricultural use. The western part of Parkstad is mainly agriculture, while the eastern part has more cities and villages. The largest cities (Heerlen, Kerkrade, Landgraaf, Brunssum and Hoensbroek) are fused together. There are some nature reserves: the Brunsummmerheide, Roode beek and Schinveldse bos. Limburg, and especially the south of Limburg, is hillier than the rest of the Netherlands.

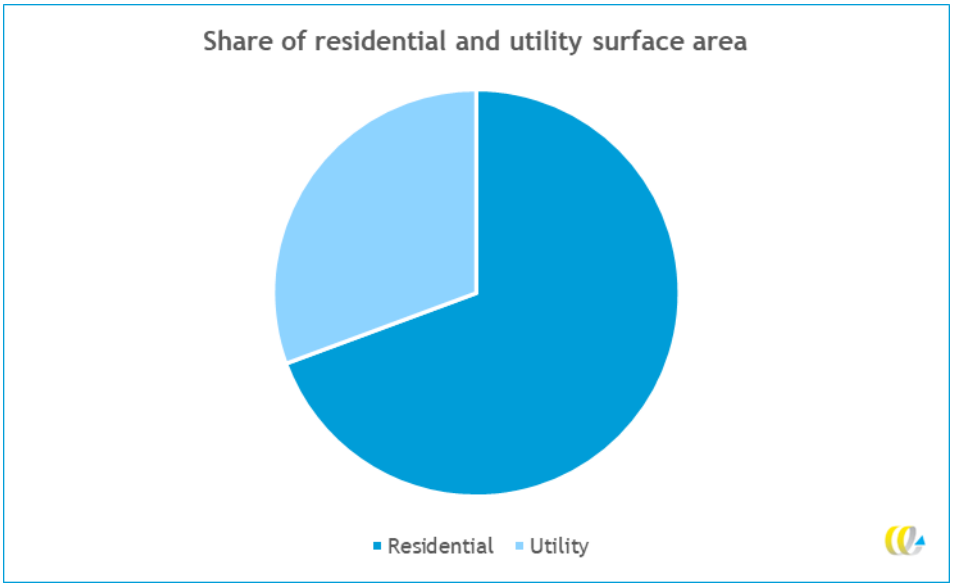
Figure 2 – Land-use in Parkstad Limburg



2.2 The built environment in Parkstad

In 2020 there were almost 130,000 dwellings and over 13,000 utility buildings in Parkstad Limburg. Utility buildings are all non-residential buildings such as schools, offices, hospitals et cetera. Figure 3 shows that roughly two third of the building surface area is residential.

Figure 3 - Share of residential and utility surface area in Parkstad Limburg (Kadaster, ongoing-b)



Dwellings

The average surface area of a dwelling in Parkstad Limburg is 130 m^2. This is larger than the average Dutch home, which has an average surface area of 120 m^2 (CBS, 2022b). Figure 4 shows the distribution of dwelling types in Parkstad Limburg. Almost half of the dwellings are terraced houses (mid-terrace and end of terrace), about 30% are stacked dwellings and almost a fourth of dwellings are detached or semi-detached. In general, the detached and semi-detached houses have the larges surface area, and the stacked dwellings have the smallest surface area.

Figure 5 shows the distribution of dwellings over six categories of building years. Dwellings built in the same period have roughly the same building characteristics. For example, most dwellings built before 1945 are often poorly insulated and lack cavity walls, which makes insulation challenging, while dwellings built after 1945 do have a cavity wall which can be insulated.
Figure 5 shows that the number of dwellings is fairly evenly distributed over the different periods.

Figure 4 - Distribution of dwelling types in Parkstad Limburg (Kadaster, ongoing-b)

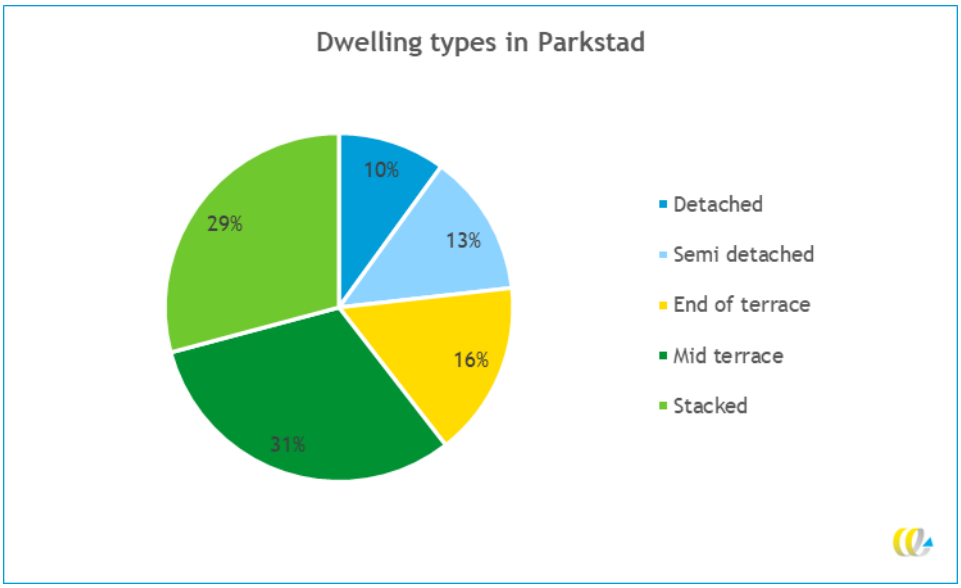
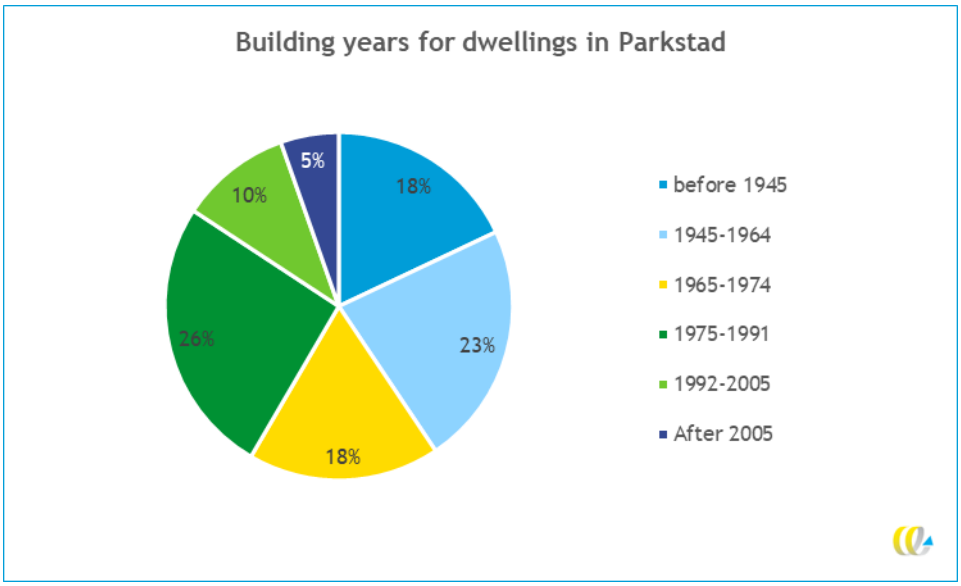
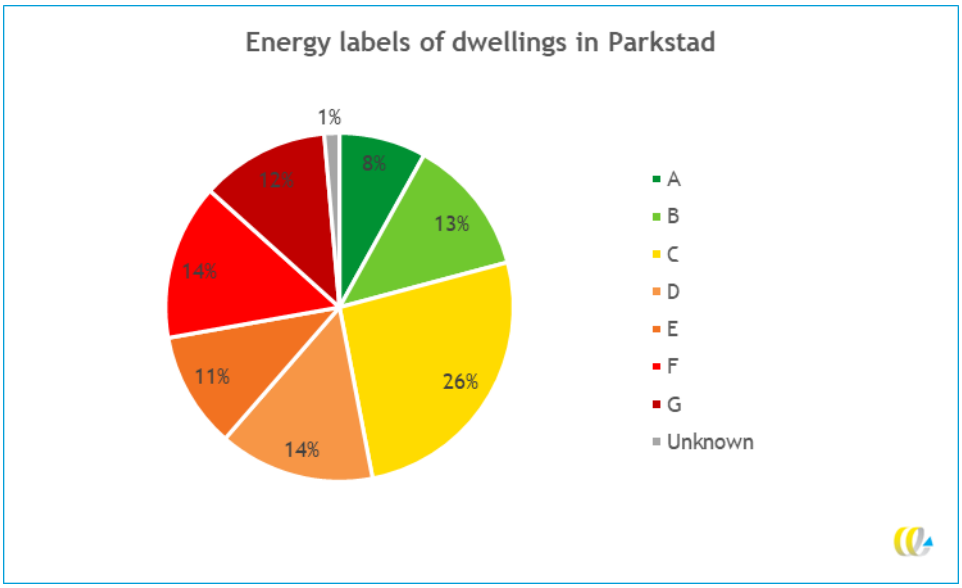


Figure 5 - Distribution of dwellings over six building year periods (Kadaster, ongoing-a)



The energy performance of dwellings is indicated with a letter from A++++ to G (A being the best and G being the worst). The energy label is based on the fossil energy use in kWh/m^2/yr. Energy labels are required for all homes that are being built, sold or rented. As of January 2020, approximately 50% of homes in the Netherlands had an energy label, of which almost 40% have the best-performing label A or B (Rijksoverheid, 2020). As all newly built homes have energy labels, the national share of well-insulated homes is expected to be lower.

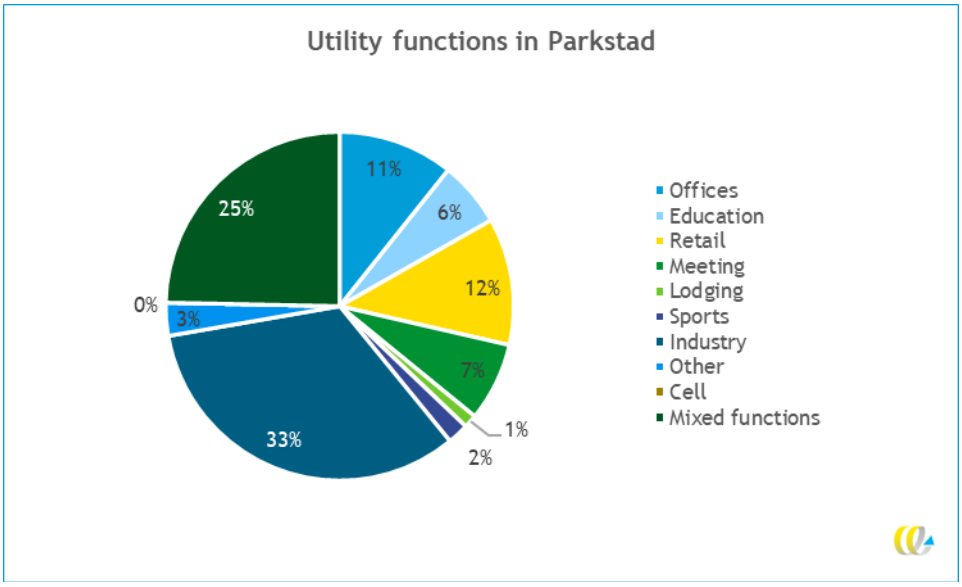
Figure 6 - Energy labels of dwellings in Parkstad Limbug. Labels A to A++++ are in the A category



Utility

Figure 7 shows the utility functions and their share in Parkstad Limburg. Common utility functions such as offices, education, retail and meeting seem to have a relatively small share. However, there are many buildings with these functions, but their surface area is not as large as the industry buildings. About 25% of utility has mixed functions, this can be a mix of industry and offices for example.

Figure 7 - Utility in Parkstad Limburg by function. The share of a utility function is based on the surface area of buildings with this function



2.3 Current dominant heating technology

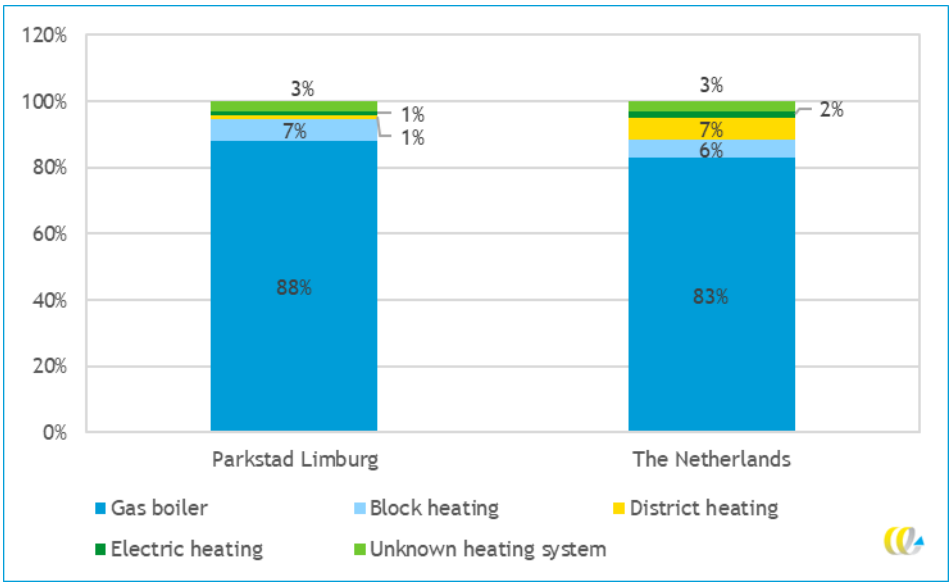
Most buildings are heated using natural gas

Natural gas is the most important energy carrier in the Dutch heating system. Most buildings use gas boilers for heating, and district heating systems are primarily powered using natural gas. This dependency on natural gas is attributable to the presence of a very large natural gas field in the north of the Netherlands. The country's energy system has developed around natural gas since its discovery in the 1960s.

Figure 8 shows the main heating technologies for dwellings in Parkstad and in the Netherlands. It is clear from this figure that in Parkstad, like in all of the Netherlands, the gas boiler is by far the technology most often used in dwellings. In Parkstad only 1% of the dwellings was heated with district heating in 2020. The average home in Parkstad Limburg uses 1,222 m^3 of gas per year (CBS, 2020).

It is not known how many homes have a cooling system, but estimations lie between 2 and 11% of homes. The general expectancy is that the number of homes with a cooling system will increase, but by how much is very uncertain (W/E Adviseurs, 2018).

Figure 8 - Main heating technology for dwellings in Parkstad Limburg and in the Netherlands in 2020. Block heating and district heating in the Netherlands are primarily powered by natural gas (CBS, 2022d)



District heating in Parkstad

Some regions in Parkstad Limburg already have district heating. Mijnwater has a 5th generation district heating and cooling (5GDHC) network in Heerlen and Brunssum.
The Oranje Nassau Mine is the main heating source in the network in Heerlen.
The city office and the APG datacentre are supporting heating sources (Warmtenetwerk, 2022). Another heating company, Ennatuurlijk, exploits a small high-temperature district heating network in the centre of Heerlen (Warmtenetwerk, 2022).

2.4 Regional visions of municipalities in Parkstad

All Dutch municipalities have drawn up regional visions[2] for the heating transition. In a regional vision the municipalities describe where they are going to start with the heating transition in their municipality (see the following frame for more information about the regional visions). For the potential of 5GDHC in Parkstad it is important to know the plans of the municipalities. Upscaling 5GDHC will be more successful when local governments are on board with the plans. It is desired to incorporate the municipalities' regional visions within the plans for Mijnwater.

The Dutch Climate Agreement states that all municipalities in the Netherlands have to a regional vision. The deadline for these vision documents was the end of 2021. In the regional vision the municipalities give direction to their approach of insulating buildings and the natural gas phase-out in the built environment. They have to make a timeline for the gas phase-out in their municipality. The Dutch Climate Agreement says that a regional vision should at least contain:

- the number of dwellings and other buildings that will be insulated or heated without natural gas by 2030;
- the promising alternative heating technologies;
- the heating alternative with lowest national costs (PAW, lopend).

Conclusions of regional visions in Parkstad

The seven regional visions for the municipalities in the Parkstad region use the same template and the same method. They use the results of the 'Startanalyse'[3] for the analysis on national costs[4] for the promising alternative heating solutions, which are

- an all-electric heat pump;
- district heating with a high-, mid- or low-temperature sources;
- boilers on renewable gas.

Besides national costs, the regional vision uses several criteria to determine the most suitable neighbourhoods to start with the gas phase-out:

- support from inhabitants and the presence of citizen initiatives make a neighbourhood more suitable;
- a large share of housing association property makes a neighbourhood more suitable;
- a large share of government buildings makes a neighbourhood more suitable;
- homogeneity makes a neighbourhood more suitable;
- neighbourhoods with a large share of monumental buildings are less suitable;
- the possibility to combine the gas phase-out with other infrastructure maintenance[5] makes a neighbourhood more suitable.

The regional visions do not give the results of this criteria analysis. Also, none of the municipalities in Parkstad Limburg have appointed neighbourhoods that will be heated without natural gas in the near future. They state in the regional visions that the analysis they have done so far is not detailed enough to make definite choices for districts and neighbourhoods.

[2] Transitievisie Warmte (TVW) in Dutch.

[3] The Startanalyse is an analysis done by the Netherlands Environmental Assessment Agency (PBL). In the analysis they have calculated the national costs for five natural gas-free heating strategies for each neighbourhood in the Netherlands. For three scenarios the Startanlyse indicates the heating strategy with lowest costs for each neighbourhood. For more information see https://themasites.pbl.nl/leidraad-warmte/2020/#.

[4] National costs for a heating system are all costs associated with that heating system, independent of who has to pay for it. National costs also include costs that are socialised, such as electricity and gas infrastructure costs.

[5] In Dutch this is often referred to as '*koppelkansen*'.

3 The Dutch heating market and energy transition

This chapter describes the Dutch heating market and the developments in it. The heating market is rapidly changing due to the energy transition, where we move from fossil fuels to renewable energy. We describe the main stakeholders and their roles in the process. This chapter also describes the most important policies in the energy transition.

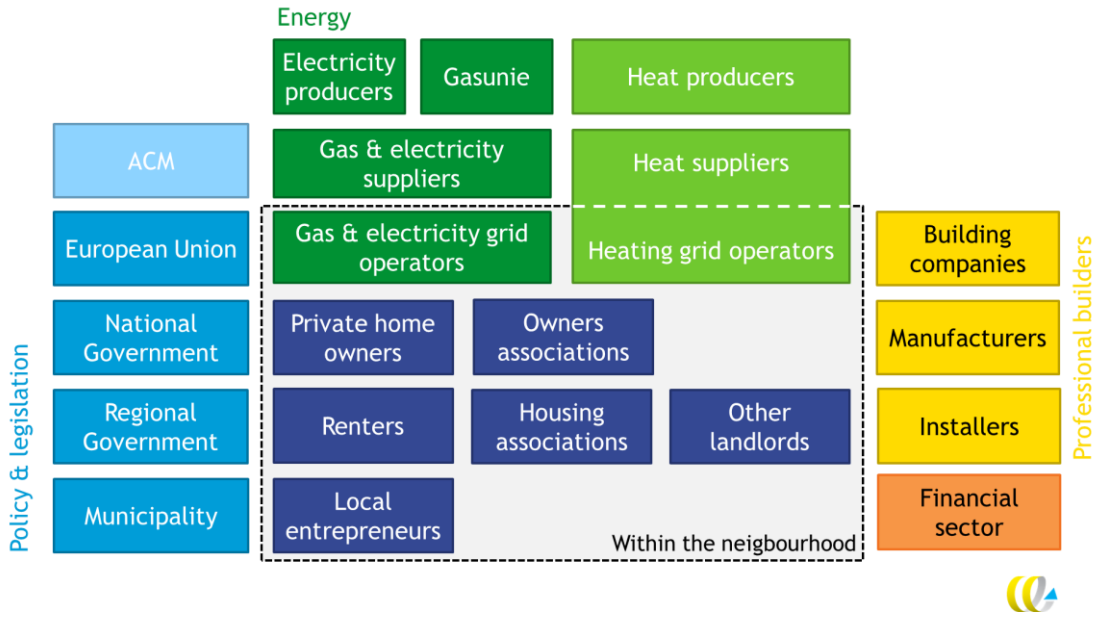
3.1 Main actors in the current heating regime

Figure 9 provides an overview of the main actors in the heating market in the Netherlands. Central in the heating market are the citizens with buildings that need to be heated (shown in blue in Figure 9).

The energy sector is shown at the top (in green). Grid operator companies and energy supply companies are separate entities. The Dutch Energy Act regulates the responsibilities and permitted activities of grid operators as they have a monopoly in their region. National and local governments legislate, subsidise and oversee the heating market, as shown on the left. The Authority for Consumers and Markets (ACM) ensures fair competition between businesses and protects consumer interests. ACM regulates energy tariffs.

The professional builders, shown on the right, are involved when physical changes need to be made. They are especially relevant in the energy transition. Builders are rarely part of the debate on energy transition, but many buildings will have to be renovated and infrastructure will have to be changed to make it happen. The capacity of builders is, however, limited and the current shortage of building materials limits the pace of the transition. Finally, the figure shows the financial sector, which is essential to finance the transition.

Figure 9 - Overview of main actors in the Dutch heating market



3.2 Policy measures for the energy transition

Several policy measures can be identified that significantly contributed to progress in the gas phase-out. Broadly speaking there are five categories of measures:

- regulation: minimum energy requirements for new construction and, to a lesser extent, existing buildings;
- pricing: taxation of energy use;
- district-oriented approach with municipalities taking the lead;
- voluntary and binding agreements with housing associations;
- incentivisation of consumers through positive price signals, such as subsidies and loans.

Regulation: Requirements for new construction

Since July 2018, all new construction has to be built without a gas connection (Ministerie van BZK & Ministerie EZK, 2018). This was enacted by a change in the Gas Act (‘*Gaswet*’). While electricity and gas grid operators were previously obliged to connect all consumers to the grid, in 2018 gas DSOs (Distribution System Operators) were prohibited from connecting new construction, with some exceptions (Ministerie van BZK & Ministerie EZK, 2018).
In 2019, 70-80% of new homes were built without a gas connection; in 2020, this was 87% (Netbeheer Nederland, 2021).

Since January 2021, all new construction must meet the NZEB (Nearly Zero Energy Buildings) requirements. These requirements were legislated through the European Energy Performance of Buildings Directive (EPBD). The NZEB requirements define strict maximum values for energy demand and primary fossil energy consumption, as well as a minimum percentage of renewable energy use. The exact values vary, based on the type of building and its compactness. The exact requirements were defined in partnership with the construction industry.

Regulation: Energy performance of buildings

A system of applying energy labels to buildings has been used in the EU since 2002. These labels, ranging from G (worst-performing) to A (best-performing) indicate how energy efficient buildings are. Attributes such as fossil energy use and renewable energy production are also attributes used in determining the label of a building.

All existing office buildings in the Netherlands are required to have energy label C by 2023, which translates into a maximum total energy use of 225 kWh/m^2 (20.9 kWh/ft^2) per year. Furthermore, a predecessor of the Climate Agreement states the portfolio of homes owned by housing associations should have an average energy label B by 2021. This is considered to be sufficient for heating with an all-electric heat pump. This means a portion of these homes will be sufficiently insulated for gas-free heating ('gas-free-ready'), but others will still need additional insulation.

Existing privately-owned homes currently have no energy performance requirements. There are, however, guidelines which inform homeowners which insulation level is regarded to be futureproof in switching away from natural gas. These levels were developed in 2021 in a follow-up to the Climate Agreement and are referred to as the 'Insulation Standard'. The recommended insulation levels should ensure that heating with a temperature of 50°C is possible in homes built after 1945 and 70°C in homes built before 1945. While these guidelines are currently only a communication instrument, the introduction of more binding instruments is under consideration (Ministerie van BZK, 2021)

Pricing: Energy tax

The Dutch energy taxation rates are used as an instrument to incentivise energy savings. Gas and electricity have separate tax rates and both taxation systems have five tax brackets based on the amount of energy users consume. Low-volume consumers (households and low-volume commercial customers) pay higher rates than high-volume users, such as industry and horticulture.

In the Climate Agreement, it was decided to increase the rate for gas incrementally between 2020 and 2026 by € 0.10 per m^3 (€ 3.00 per MMBTU) in total, while decreasing the tax on electricity (Rijksoverheid, 2019) by € 0.05 per kWh. For an average household, this results in a € 124 increase in gas taxes and a € 137 reduction in electricity taxes annually by 2026. In this way, households and businesses are incentivised to move away from natural gas.

District-oriented approach with municipalities taking the lead

The phase-out of natural gas in existing buildings is built around what is called a district-oriented approach. In this approach, municipalities take the lead in the heating transition.

Programme for Natural Gas-Free Districts

A national programme (PAW, Programme for Natural Gas-Free Districts) was created in 2018 to support the first districts that make the transition towards natural gas-free heating. Through this programme, municipalities can apply for additional funds to support the transition. Additionally, municipalities can apply their general instruments, i.e., provide

funds themselves, receive extra funds from the national government or issue loans with favourable conditions for energy efficiency measures.

Besides a funding scheme, the PAW has played a key role in gaining experience for coordinating large-scale building renovations. In this way, practical barriers to going gas-free (such as legal, financial, organisational, capacity-related issues) are identified, lessons learned can be shared and signalled to the national government. The evaluation of the scheme concludes that municipalities did learn a lot about the complexity of the task, which they will take with them in future projects (KWINK & Rebel, 2020). The evaluation identified several improvement points for the learning aspect of the programme. In the future, regional governments will provide more support to smaller municipalities to ensure higher success rates.

Local heating plans

As described in Section 2.4, municipalities are obliged to develop a vision of the local heating transition[6]. In this document, the municipalities, together with stakeholders such as district heating companies, housing corporations and utility companies, develop an indicative time path for realising alternative (natural gas-free) heating, neighbourhood by neighbourhood. For those neighbourhoods where the gas phase-out will take place before 2030, the municipalities indicate the most suitable alternative to gas. From the beginning of 2020 onwards, each municipality was obliged to prepare and submit such a plan before January 1st, 2022.

After these local heating visions, municipalities are obliged to develop individual neighbourhood execution plans[7], in which they commit to a timeline and heating technology. Citizen participation is widely regarded as an important part of the execution plans.

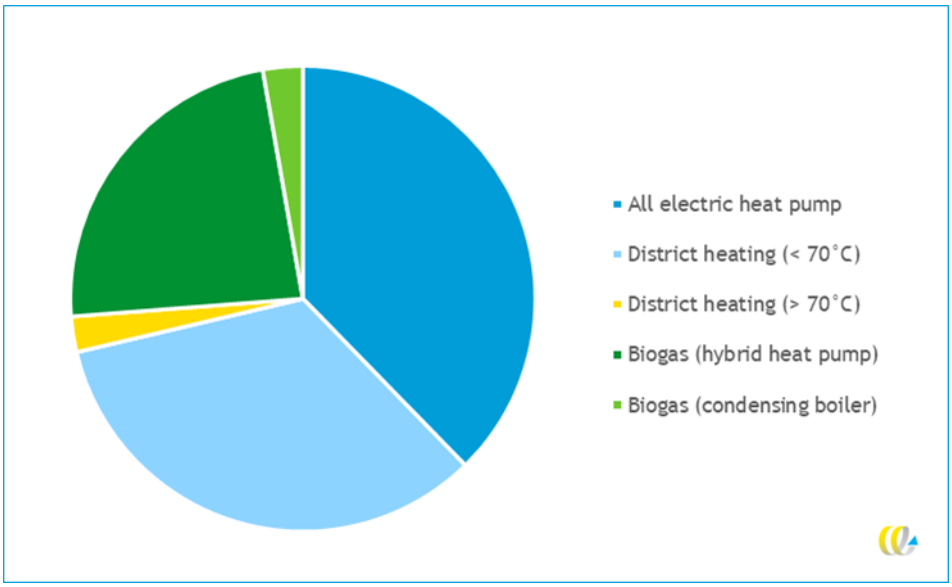
In both the local heating visions and the neighbourhood execution plans, the technical alternatives must be based on the lowest cost (according to the affordability principle). Different parties, including the Netherlands Environmental Assessment Agency (PBL), have developed projections of lowest-cost scenarios based on modelling of the built environment.

The calculations of PBL result in a natural gas-free technique with the lowest total cost for each neighbourhood (an area with on average around 600 houses). Figure 10 shows the distribution of techniques for all buildings in the Netherlands according to the lowest-cost scenario modelling.

[6] Transitievisie Warmte (TVW) in Dutch.

[7] Wijkuitvoeringsplannen (WUP) in Dutch.

Figure 10 - The results of the lowest cost scenario bases modelling of the built environment by PBL; shares of heating techniques for buildings



Incentivisation of consumers: subsidies and loans

Several subsidy schemes and loans exist to stimulate the energy transition in the Netherlands. The most important subsidies for the energy transition in the built environment are described below.

The **Energy Savings loan** is a loan with relatively low interests that can be used to finance energy saving measures. This loan is only for homeowners that also live in that house.
Stimulating Natural gas-free Rental Homes (SAH) scheme (RVO, ongoing-c). Housing associations and other landlords may receive a subsidy of a maximum of € 5,000 per rental house for the connection to an external heating network. The subsidy covers the adjustments in the dwellings to be able to connect to the district heating and the connection costs to the heating network.
Investment subsidy for sustainable energy (RVO, ongoing-a**)** is a subsidy that homeowners can get for insulation measures, the investment in a heat pump, the investment in a solar boiler and the connection to district heating.
Stimulating Sustainable Energy Production and Climate Transition Scheme (RVO, ongoing-b) is a subsidy scheme for the large-scale production of renewable energy.
The **Energy investment Allowance (EIA)** is a fiscal advantage for entrepreneurs when they invest in energy-efficient technologies and sustainable energy (RVO, 2022).
The **Environmental investment deduction (MIA)** and **Arbitrary depreciation of environmental investments (Vamil**) are fiscal advantages for entrepreneurs that invest in environmentally-friendly technology (RVO, 2021).

3.3 Recent developments

The Dutch Climate Agreement has been in effect since 2019, and in the past two years a diverse set of policy measures (as described in the previous section) have been implemented. The progress so far does not indicate that the 2030-goals for the built environment will be met. Additional measures will therefore be necessary. The new Dutch cabinet presented a coalition agreement on December 15th, 2021 (VVD et al., 2021). This agreement proposes additional policy interventions that aim to increase the pace of emission reductions in the sector. The suggested interventions are especially relevant since they aim to address some key problematic areas that currently represent important barriers. These barriers specifically are cost, lack of skilled staff and not enough focus on insulation and hybrid heat pumps.

The coalition agreement suggests the following additional policy measures:

1. Organising large-scale insulation efforts through a 'national insulation programme'.
2. Requiring and incentivising renters and private homeowners who live in poorly insulated houses to insulate.
3. Requiring heating installation suppliers to install an increasing number of (hybrid) heat pumps when replacing existing condensation boilers. From 2026 consumers that replace their gas boiler have to change to a more sustainable alternative, such as a hybrid heat pump or an all-electric heat pump (Rijksoverheid, 2022).
4. Requiring energy companies to blend green gas with natural gas to a minimum percentage.
5. Creation of an educational programme that aims to increase the availability of technical staff.
6. Creation of a large fund that provides subsidies for insulation, (hybrid) heat pumps, district heating and other interventions.
7. Subsidising currently unprofitable district heating network business cases.

Although not yet part of official government policy, the addition of these measures to existing policy will likely accelerate the move away from natural gas heating and towards a sustainable built environment.

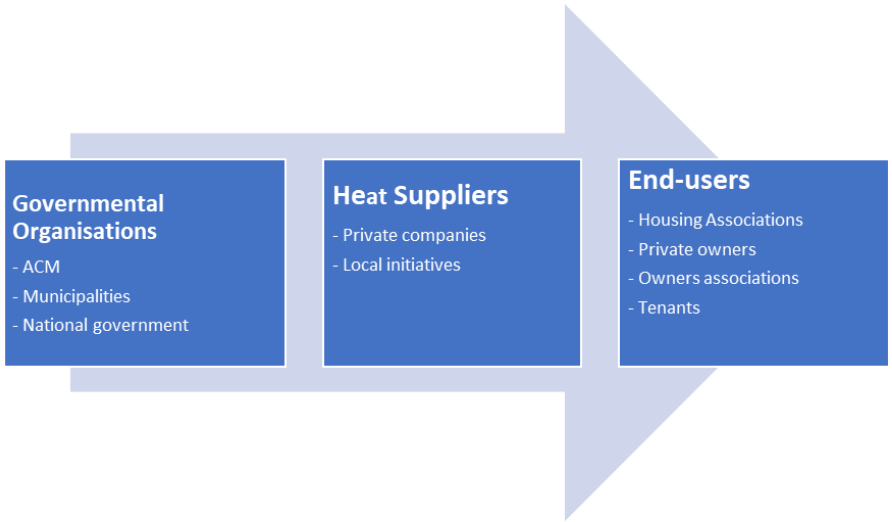
4 District heating in the Netherlands

In this section, the district heating technology is further studied in the context of the Netherlands. This analysis forms a framework for the implementation of 5th generation district heating and cooling (5GDHC) networks as they are in development. First, the value chain is presented with all stakeholders and their roles. It follows an analysis of the regulatory framework and existing price regulations for the district heating networks. Finally, financing and subsidy possibilities are listed that are available in the Netherlands for district heating specifically.

4.1 Stakeholders for district heating

The value chain of district heating in the Netherlands is shown in Figure 11.
There are three main players in the market, namely governmental bodies, heat suppliers and the end users.

Figure 11 - The value chain of district heating in the Netherlands



Governmental Organisations

Based on the plans and targets of the national government, municipalities prepare the heating transition and local action plans in which they pinpoint the suitable neighbourhoods to build a heating network. The new Dutch Heat Act ('Warmtewet 2') provides municipalities with the authority to set local rules for implementing the transition from natural gas to sustainable alternatives. According to the new law, the municipality can designate certain districts where an energy supply with sustainable energy becomes available to replace natural gas.

Municipalities can play four different roles in the implementation of district heating (DWA, 2020). Firstly, a municipality can become the owner and operator of the district heating network. In this case, the financial flows are running through the municipal budget. Secondly, a municipality forms a consortium and looks for partners to develop and operate the district heating. In this case, the municipality (co-)finances and/or provides guarantees to the market entity. The third option is that a municipality grants a concession to a third party for the development and operation of the heat supply and hereby grants guarantees to the concessionaire. Finally, if there is enough demand from building owners to connect to the district heating network, the municipality can function as a facilitator and helps the heat supplier to start delivering heat.

In the Netherlands, the Authority for Consumers & Markets (ACM) [8] regulates the energy market and thus the district heating market, see also Section 3.1 and 4.2.

Heating suppliers

According to the registry of ACM, as of September 2022, there are 35 licensed heat suppliers in the Netherlands. These are private companies and/or public private partnerships.

Local initiatives, such as those of owners associations or energy corporations, can also deliver heat without a licence obligation. According to the local energy monitor 2021, there are 87 local district heating initiatives in the Netherlands, 62 of which are actively working either on a feasibility study or on the realisation of a collective heating project. The rest of the local collective heating projects are no longer active after having worked on the policymaking or have completed a feasibility study with a negative conclusion (Hier opgewekt, 2021).

End-users

In the Netherlands, four types of end-users are identified in the built environment that are connected to the district heating network:
- housing Associations;
- private owners;
- owners associations;
- tenants.

The most significant role for the end-users is that they decide if they would like to connect to the heating network and they pay for the heat they use from the district heating network. Different from electricity and gas markets, small-scale users are not yet able to select their district heating supplier.

The current Heat Act aims to protect small-scale consumers by tariff regulation (maximum permitted rates), rules on connection and disconnection, compensation in case of failures etc. Since 1 July 2019, the Heat Act no longer applies to customers who receive heat from their landlord or by an owners association. The reason for this is that tenants and members of owners associations are also protected under the Civil Code.

The decision whether to connect a building to a heating network or make use of a different heating source for the building lies with the building owner.

[8] ACM is an independent regulator which protects the rights of both consumers and businesses by competition oversight, sector-specific regulation of several sectors, and enforcement of consumer protection laws. More information about ACM: The Netherlands Authority for Consumers and Markets

4.2 Regulatory Framework

The Dutch Heat Act assigns ACM for issuing licenses to district heating providers for small businesses up to 100 kW capacity. Providers which deliver at least more than 10,000 GJ heat per year to 10 consumers simultaneously are required to apply for a license at ACM.[9] After the revision of the Heat Act in 2019, lessors and homeowner associations are excluded from this obligation.[10]

ACM evaluates the district heating providers with regard to the set-up of a working administrative organisation and internal/external audits. The organisation is assessed on the following aspects[11]:

- conformity with laws and regulations;
- responsibility of every director/manager/employee at an energy supplier to act with integrity;
- controlling business processes (including risk management);
- segregation of duties for internal audits;
- information and relational check of purchase and sales figures,
- control of information, capacity and delivery;
- control of information, registers;
- security

As can be seen, the provider is assessed based on the audit procedures inside and outside the organisation, registers of client agreements and purchase/sales figures, procedures for complaints next to the processes for management of risks regarding the delivery and the purchase of heat.

4.2.1 District heating tariffs

ACM sets tariff caps for the heat suppliers based on the Not-More-Than-Else principle. Accordingly, the households that are connected to the district heating networks do not pay more than the households with conventional gas boilers.

The heating rate consists of a variable, i.e., usage-related part, and a fixed, i.e., usage-independent, part. The consumers pay the variable rate for the heat they use and this tariff cap for this rate is directly linked to gas prices. There is also a maximum price for connection, disconnection, rental of a delivery set and measuring consumption. When a house is connected to a heating network, there are five different cost components, namely:

- once-off connection costs;
- fixed costs (standing charge);
- rent delivery set;
- measurement costs;
- cost for the heat (GJ).

The rates for these cost components are (partly) regulated in the Heat Act and set by the Netherlands Authority for Consumers and Markets (ACM). The Heat Act was introduced to protect consumers against excessive prices for heating and hot water, unacceptable malfunctions and non-transparent suppliers.

The law states exactly how the variable rate must be calculated, and it is based on the gas prices that the ten largest gas suppliers charge on average. The price includes the tax on

[9] ACM: Ik wil warmte leveren. Wat moet ik doen? (only in Dutch)
[10] ACM: Revised Dutch Heat Act in effect
[11] ACM: Toelichting op het aanvraagformulier voor warmte (Only in Dutch)

gas and the Sustainable Energy Storage (ODE) in the rate. So, in the end the consumers of the district heating networks pay no more than what a consumer pays for gas, a central heating boiler and the standing charge for gas. The costs are those of an average household (incl. 21% VAT)

The New Dutch Heat Act ('Warmtewet 2'), which is expected to take effect before the end of 2022, changes the way how the heating rates are determined. The heating rates will no longer be dependent on the gas prices but depend on the costs incurred by a heat supplier to realise the heating network and keep it in operation. This will be implemented in three phases.

In the first phase, the gas price reference will still be used and corrected by the costs of the district heating network and a reasonable return rate. In this phase, the heat suppliers will keep track of their costs until enough information is available for Phase 2, which is estimated to take 3-5 years. In the second phase, the gas price reference is released, and ACM regulates the tariffs entirely based on costs. A periodic cost-based correction can be made on this. ACM's insight into the costs will become increasingly clear in this phase.
In the third phase, ACM uses a benchmark method that determines the permitted income of the heat suppliers. This phase will commence at a time to be determined by the minister. Within the three phases of the Heat Act, ACM is developing a better monitoring tool to gain insight into the costs of heating networks within individual plots.

No specific tariff regulations for 5GDHC

In the Netherlands, there is no specific regulation for the 5GDHC networks neither in the current Heat Act nor in the upcoming new Heat Act. Especially the heat discharge to the network by users would require a special arrangement for the operation of the heating network and the price determinations.

For cooling, tariffs are regulated in the Heat Act only in the case where it is used from a source to balance the heating load, for example from a ground water energy storage system (ATES). Small consumers pay only a standing charge whereas utility users often pay an amount per used amount (GJ or kWh) of cold. In the case of a cooling network with only a cooling source, it is also possible to pay per GJ for homes. The maximum standing charge for cold for small users of ATES systems has been set in 2020 at € 236.80 per year including VAT. The standing charge for large users depends on the capacity of the connection.
The GJ rate for large users varies per cooling network between € 11 and 21 excluding VAT (Vattenfall and Eneco, 2020 respectively) (TKI Urban Energy, lopend).

4.2.2 Ownership

In principle, there are three possible scenarios regarding the ownership of the district heating networks. Either private companies, local governments or private-public partnerships own and operate the district heating networks. This is determined case by case depending on the size of the district heating project and the risks associated with the development and operation of the network.
If there are uncertainties about the heating demand and the number of buildings that will be connected to the heating network, then the risks are too high for a commercial company to step in alone. This means then the municipality either takes up the ownership alone or it joins forces with a private party to form an entity ('entiteit' in Dutch) for developing and operating the heating network. See Section 4.1 for the roles that municipalities can play in this process.

Licenses are granted to operators of the district heating also when they do not have the economic or legal ownership of the heating network(s). With the introduction of the New Dutch Heat Act ('Warmtewet 2'), the Dutch Climate and Energy Minister is planning to transfer the ownership of the district heating networks from private companies to the public hands.[12] This means a drastic change to the current market in the Netherlands, as most heating networks are currently in the hands of heating companies.

4.3 Financing and subsidies

Section 3.2 already described the most important subsidies for the energy transition in the Netherlands. The subsidies that are relevant for district heating for both consumers and providers of heat are:

- SAH: Stimulating Natural gas-free Rental Homes. Housing associations and other landlords may receive a subsidy of a maximum of € 5,000 per rental house for the connection to an external heating network.
- ISDE: Investment subsidy for sustainable energy. Homeowners can get € 3,325 subsidy for the connection to district heating.
- SDE++: Stimulating Sustainable Energy Production and Climate Transition Scheme. This subsidy scheme is for the heat suppliers who will generate renewable or low-CO_2 heat, for example by renewable biomass, deep/shallow geothermal, solar thermal energy, residual heat, etc.

[12] Warmtenetwerk : Minister Jetten wil eigendom warmtenetten van privaat naar publiek

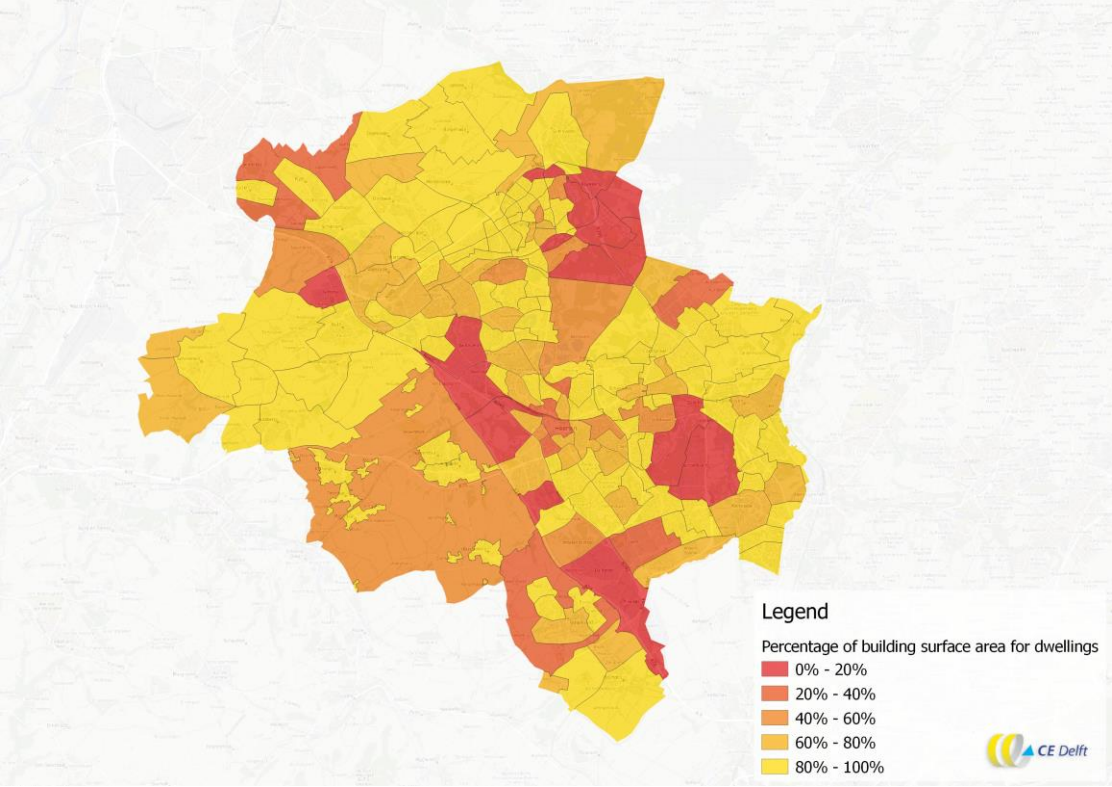
5 Energy sources and storage

Energy sources and storage are an essential part for 5th generation district heating and cooling (5GDHC). This chapter describes the availability of several types of energy sources and storage. As part of the work in D2Grids, a preference scale of energy sources has been developed. The structure of this chapter reflects this ranking, with the highest ranking forms of energy mentioned first.

5.1 Reuse of thermal energy

The reuse of thermal energy by the exchange of heating and cooling demand is already realised in the Mijnwater district heating in Heerlen. In 2020 about 350 dwellings and nine large office building were connected to the Mijnwater district heating (Mijnwater, ongoing-b). Figure 12 shows the percentage of building surface area that are dwellings for each neighbourhood in Parkstad Limburg. The yellow neighbourhoods are neighbourhoods with mostly dwellings in it, the red neighbourhoods are mostly business parks and the orange neighbourhoods are mixed. The reuse of thermal energy by exchange between heating and cooling demands functions best when there is a mix between dwellings and utility buildings. The orange neighbourhoods or the yellow and red neighbourhoods that are adjacent each other are best suited for the reuse of thermal use.

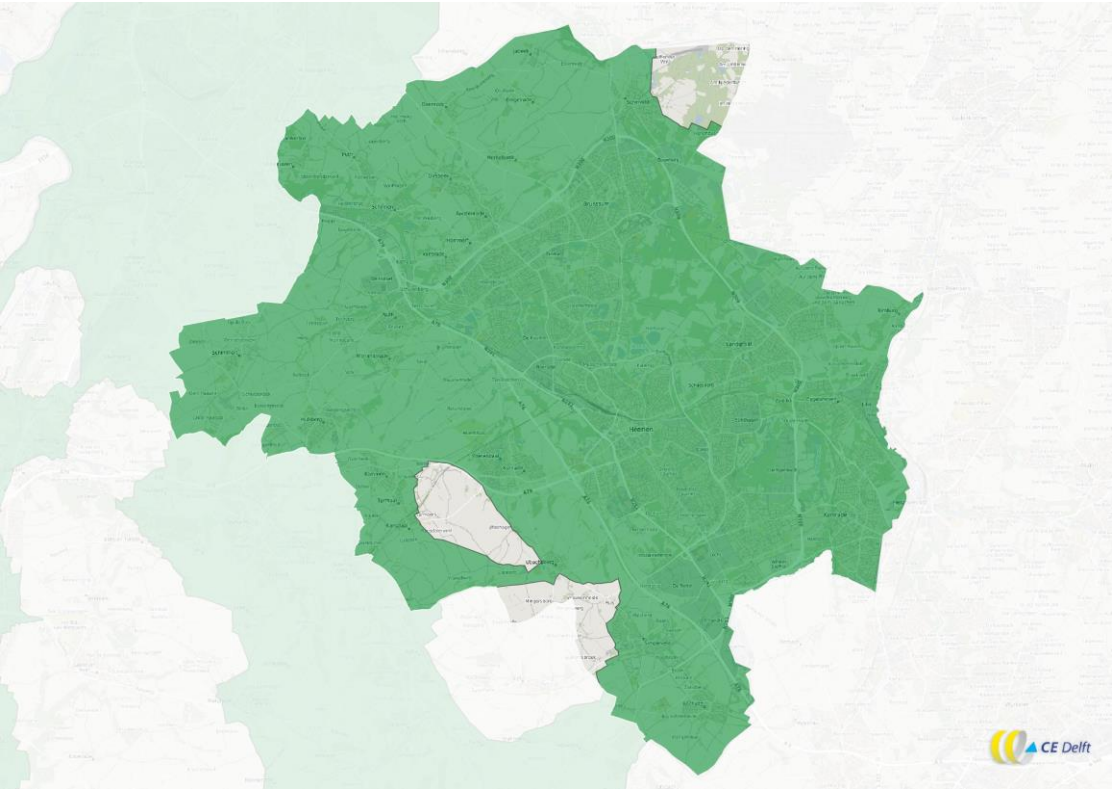
Figure 12 – The percentage of building surface area that are dwellings for each neighbourhood in Parkstad Limburg



Source: Analysis by CE Delft based on (Kadaster, ongoing-a).

The heating and cooling demand of buildings will never be exactly in balance. Because of this, storage is needed such as ATES. In some regions in the Netherlands this are not allowed, for example due to interference with drinking water. Figure 13 shows that these systems are allowed in most of Parkstad Limburg. The regions where this kind of storage is not allowed, are less suitable for exchange of heating and cooling demand.

Figure 13 – The green area shows where ground-coupled heat exchangers are allowed in Parkstad Limburg

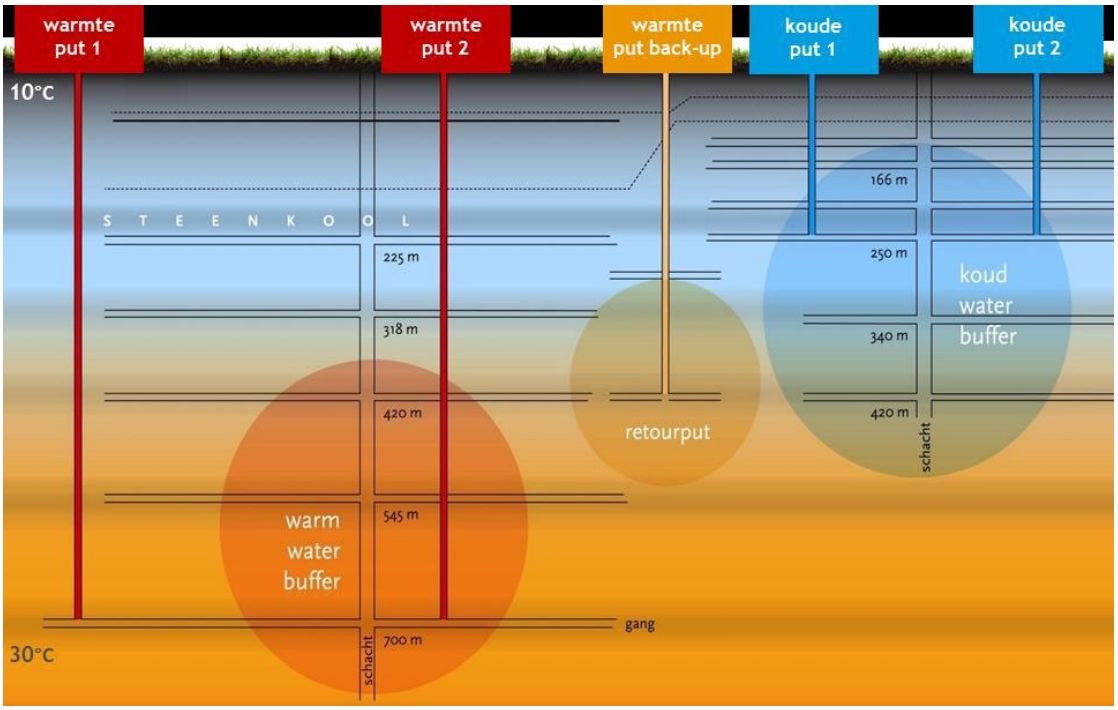


5.2 Ambient thermal sources and higher temperature renewable sources

A flooded mine as thermal storage

The Mijnwater district heating uses a former mine, the Oranje Nassau mine, as a heating and cooling source as well as thermal storage. This is called mine thermal energy storage or MTES. When the mine closed, its corridors filled with water with groundwater that is heated by the earth. The further down the mine, the hotter the water is. Wells were drilled, to subtract heat from the water in the mine. There are two wells at 700 meters below the surface, where the water has a temperature of 28°C and two wells at 250 meters below the surface, where the water has a temperature of 16°C. These wells serve as sources for heating and cooling. A 5th well is drilled to be used as buffer for storage and reuse of thermal energy (CE Delft, 2018). Figure 14 gives a schematic overview of the use of the Oranje Nassau mine for Mijnwater. Innovation has made it possible to use the Mijnwater concept with other storage options (such as ATES) when there is no mine that can be used (Mijnwater, ongoing-b).

Figure 14 - A schematic overview of the use of the Oranje Nassau mine for Mijnwater (CE Delft, 2018)

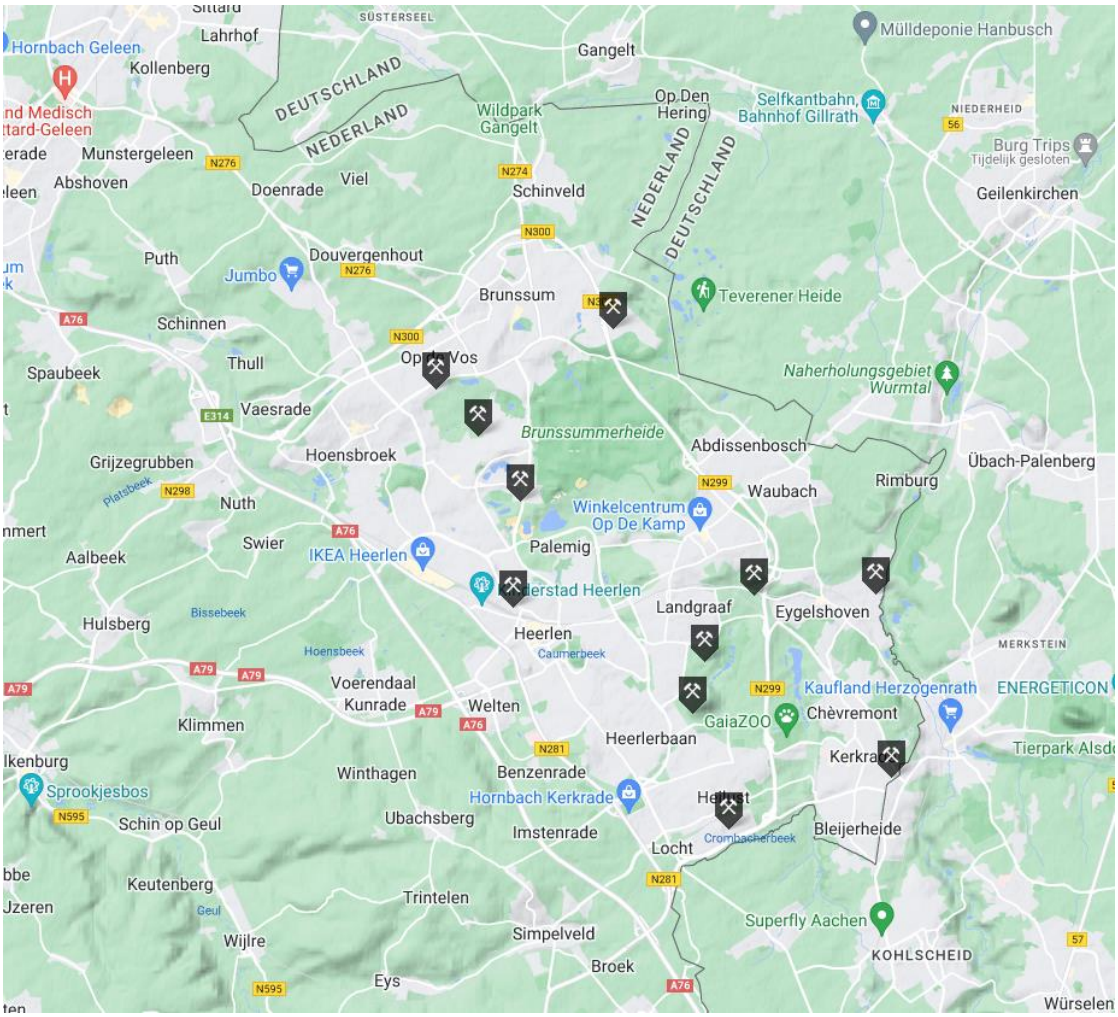


There are eleven former mines in Parkstad Limburg, four in Heerlen, four in Kerkrade, one in Landgraaf, one in Brunssum and one in Hoensbroek (municipality Heerlen). They can be seen in Figure 15. One former mine in Heerlen is already being used as a thermal source and storage. It can be researched whether the other former mines are also suitable for this. As far as we know, besides the Oranje Nassau Mine, there has been no research into the suitability of mines in Limburg to function as thermal source and storage.

A requirement for MTES is large mine water volume (Kallesøe & Vangkilde-Pedersen, 2019). Most of the mines in Limburg are flooded (Projectgroep GS-ZL, 2016). Most of the shafts are filled (for example with concrete) and closed off. The mine corridors are not filled or closed off, however some may have collapsed (PBL, 2021).

In order to determine whether a mine is suitable for MTES, the location of mine corridors should be determined, and it should be researched if there is a location where the drilling of wells is possible.

Figure 15 – The location of eleven former mines in Parkstad Limburg

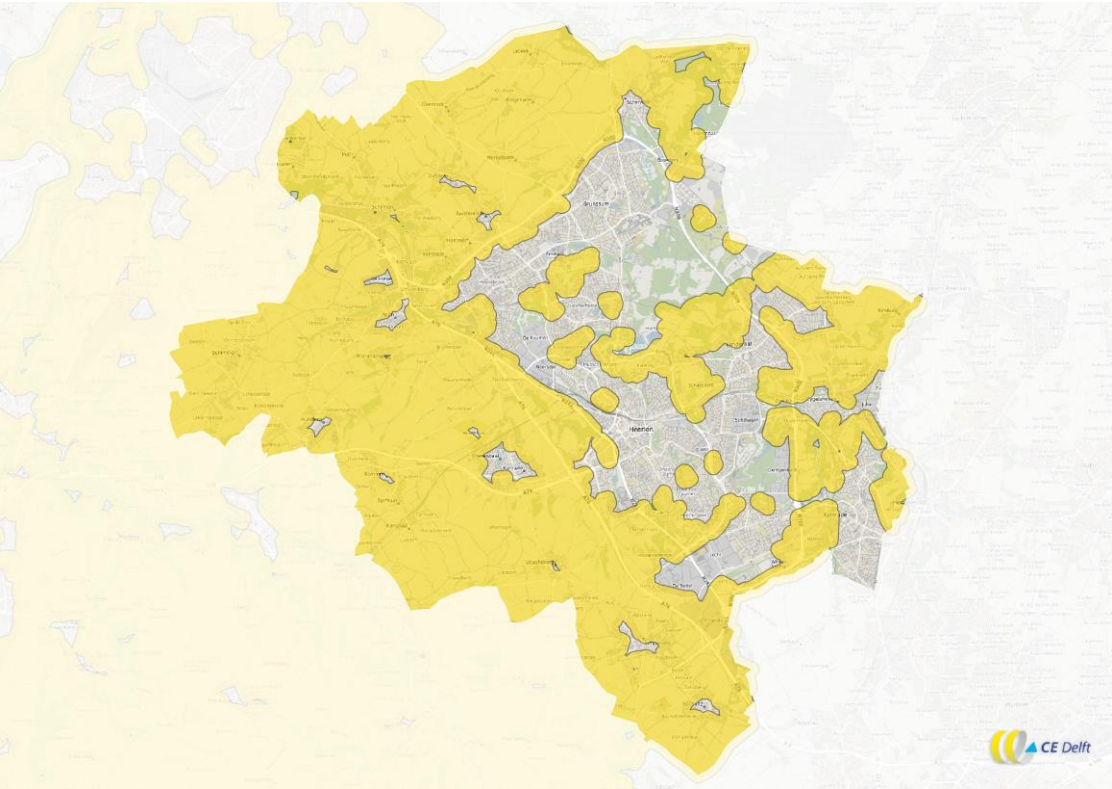


Source: (DeMijnen, 2022).

Solar thermal energy is possible in Parkstad

There are no large-scale solar thermal installations in Parkstad Limburg. Figure 16 shows the areas (in yellow) that could potentially be suitable for solar thermal energy. An area is appointed to be suitable for solar thermal energy if it currently is used for agriculture and if the surface area is larger than 5,000 m^2 (0.5 ha). We did not take into account the ownership of the land. This map gives an indication where solar thermal energy might be possible. The average potential for solar thermal energy is 0.5 GJ per m2 land (CE Delft, 2020).

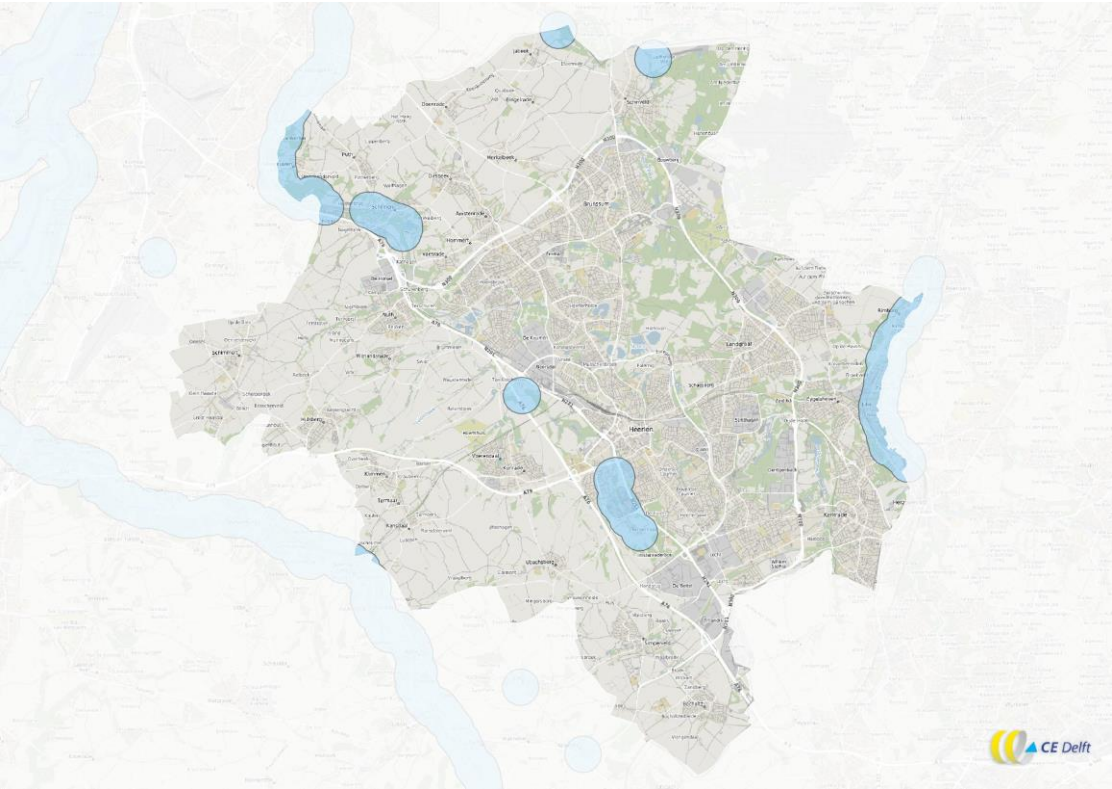
Figure 16 – Potential area's for solar thermal energy. This potential does not take into account the ownership of land



Limited potential for aqua thermal energy

There are a few waters in Parkstad Limburg that could potentially be used for aqua thermal energy from surface water. Figure 17 shows the regions, in blue, where aqua thermal energy could potentially be used. The surface waters with potential are obtained from the Startanalyse[13]. We have assumed that aqua thermal energy could be used within 500 meters from these waters. Currently there are no projects using thermal energy from surface water in Limburg. The average potential for solar thermal energy is 0.5 GJ per m^2 land (CE Delft, 2020).

Figure 17 – The blue area's indicate where aqua thermal energy is a possibility



No geothermal energy in Parkstad

The Warmteatlas, a database with potential for heating sources in the Netherlands, shows that there is no known potential for low-temperature or high-temperature geothermal energy in Parkstad Limburg (RVO, ongoing-d). In 2021 the potential for geothermal energy is researched by TNO within the SCAN research program.

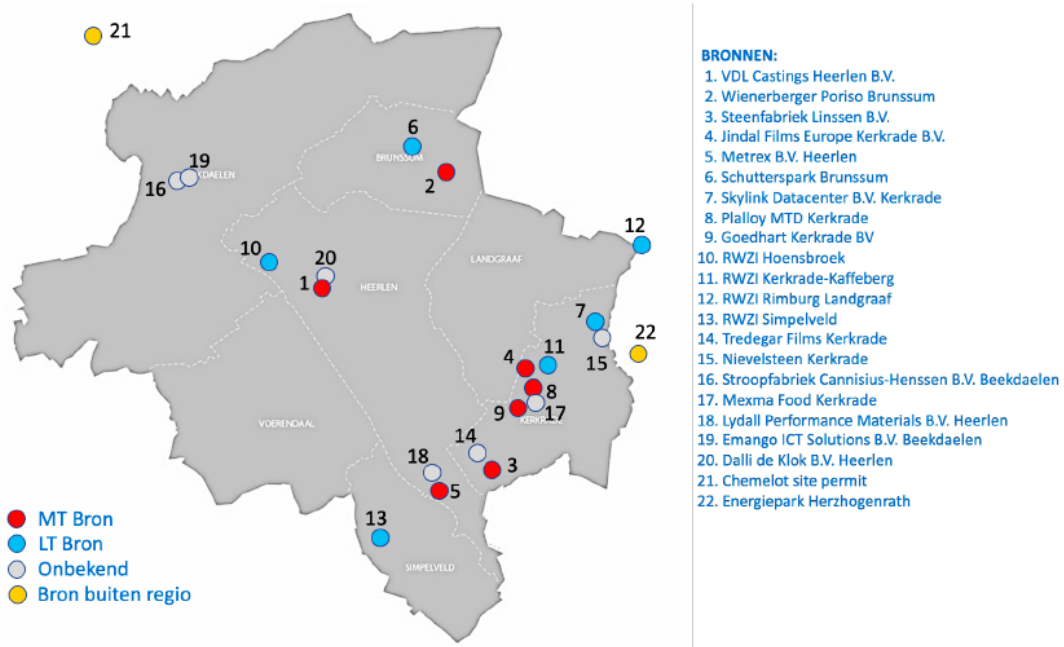
[13] The Startanalyse is an analysis done by the Netherlands Environmental Assessment Agency (PBL). In the analysis they have calculated the national costs for five natural gas-free heating strategies for each neighbourhood in the Netherlands. For three scenarios the Startanalyse indicates the heating strategy with lowest costs for each neighbourhood. For more information see Startanalyse aardgasvrije buurten, versie 2020.

5.3 Higher temperature industrial waste heat

In the Parkstad region there are twenty possible waste heating sources. Figure 18 show these sources and their location. There are two large sources just outside of the Parkstad region: Chemelot (nr. 21) in Sittard-Geleen and Energy Park Herzogenrath, just of the border next to Landgraaf and Kerkrade (nr. 22). The industrial waste heat from Chemelot is already used for district heating outside of Parkstad Limburg (Het Groene Net, Ongoing).

For most of the waste heating sources in Parkstad it is not yet known whether they can really be used as sources in district heating. However some sources are already used in district heating or there are concrete plans to use them. The industrial waste heat from Chemelot is already used for district heating outside of Parkstad Limburg (Het Groene Net, Ongoing). Mijnwater has plans to make a cluster where VLD castings Heerlen B.V. (source nr. 1) can exchange thermal energy with a swimming pool (Mijnwater, ongoing-a).

Figure 18 – Potential waste heating sources in or close to Parkstad Limburg. The red sources are mid temperature sources, the blue sources are low-temperature sources and the yellow sources are sources that are outside Parkstad Limburg



Source: (Gemeente Heerlen, 2021).

5.4 Renewable electricity

In the Dutch Climate Agreement ('Klimaatakkoord') it has been agreed to research where and how renewable electricity production can be realised. For this research the Netherlands has been divided over 30 energy regions. For each of these regions a regional energy vision ('Regionale Energie Strategie') has been drawn up. Parkstad is part of the vision for Zuid-Limburg. In Table 2 the existing, planned and ambitioned production resulting from this vision is set out. The solar rooftop systems consist of systems of at least 15 kW.

Table 2 - Local renewable electricity production in Parkstad (RES Zuid Limburg, 2021)

Source	Existing (GWh)	Planned (GWh)	Additional ambition (GWh)
Wind	2	0	128
Solar - rooftop	18	27	139
Solar - land	6	26	158
Total	**26**	**53**	**425**

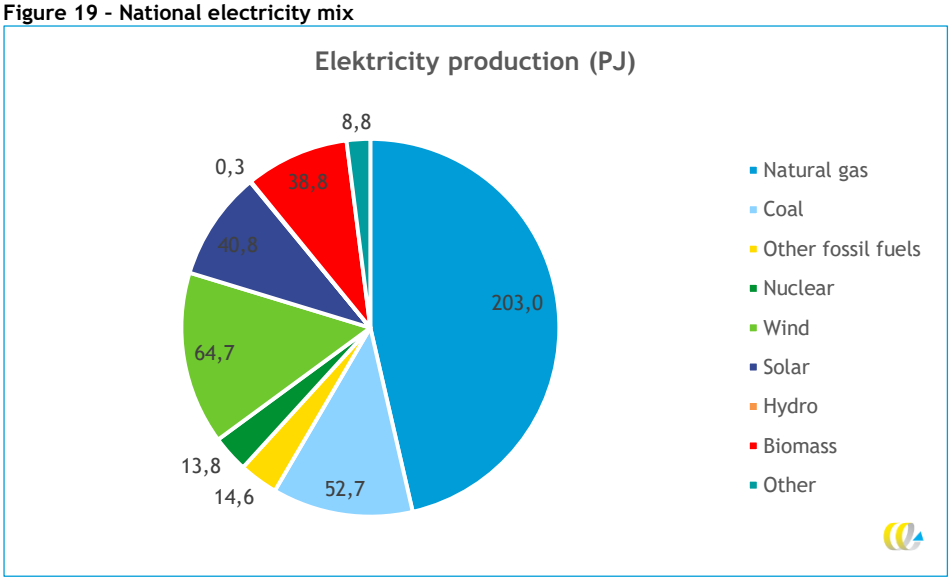
5.5 Electricity use at times of renewable overproduction

Currently there is no known overproduction of electricity from renewable sources in the Parkstad region.

5.6 Electricity mix from the external grid

The national electricity mix for 2021 is shown in Figure 19. Almost half the electricity production is from natural gas. In total 62% of the electricity production is from fossil fuels. A quarter of the electricity production is from wind and solar.

Figure 19 - National electricity mix



Source: (CBS, 2022c).

5.7 High-temperature heating from burning biofuels, biogas, biomass

The Parkstad region has no potential to produce biofuels or biogas. There is potential for biomass. According to Palet 3.0 (Parkstad Limburg et al., 2016) the potential for biomass is 415 TJ.

5.8 High-temperature heating from burning fossil fuels

As Section 2.3 describes, a lot of buildings in the Netherlands are heated using natural gas. In the transition to heating without fossil fuels, natural gas will still play a role until it can be totally replaced by renewable energy sources.

6 SWOT analysis

For the implementation of the 5th generation district heating and cooling (5GDHC) technology, we perform a SWOT analysis.

6.1 Strengths

Experience with 5GDHC (Mijnwater) and District Heating

Regarding the implementation of 5GDHC technology, the most important strength is the experience with the technology itself in Parkstad region. In 2013, the municipality of Heerlen built the first 5GDHC network in Europe using mine water system to store heat and cold. It was initiated as a 4DHC and later by the introduction of a system to exchange heat and cold between customers, it has been turned into a 5GDHC system.

Currently, more than 350 homes (in Heerlerheide and Maankwartier) and nine large office buildings are connected to the network. The company is rolling out its network throughout the city (including the centre pipeline through the heart of Heerlen, including a connection to the new city office) and is a supplier for renovation projects of various housing associations in Heerlen and Brunssum.

Gas phase-out in the Netherlands

As indicated earlier, the national government has set a target to make all dwellings in the Netherlands gas-free by 2050. For this purpose, municipalities have set up heating transition vision documents in which they define the pathways towards a natural gas-free municipality in 2050.

In this framework, available heating sources in the Netherlands have been investigated and inventoried as part of the techno-economic feasibility studies for sustainable heating opportunities at neighbourhood level. This constitutes a good basis for spotting areas where district heating networks are feasible to implement. For 5GDHC technology, this could be an initial step to find out where a heating network can be implemented.

Next to that, in the Netherlands there are currently 64 living labs as part of the Natural Gas-free Neighbourhoods Program (PAW) and through these living labs, practical know-how is built as to how to implement different heating options. Eighteen of these living labs work actively on a heating network and this forms a knowledge basis, not only technical but also organisational knowledge for implementation, for the implementation of 5GDHC networks.

Existing skills and Infrastructure

Thanks to Mijnwater project in the region, there is considerable experts that are actively working on 5GDHC technology. As mentioned above, there are several initiatives in the Netherlands in which the expertise and know-how on district heating networks build up. Therefore, the existing level of knowledge and skills in the Netherlands is an important advantage for rolling out the 5GDHC technology.

The data infrastructure in the Netherlands provides a wide opportunity to investigate the possibilities for the implementation of 5GDHC. The cadastre register includes all relevant data about the building stock. Besides potential energy sources are well registered in databases such as Warmteatlas (RVO, ongoing-d)

Growth of cooling demand

The demand for coolth in the built environment is expected to increase in the Netherlands due to a number of factors:
- average temperature increase due to climate change;
- better insulated buildings;
- heat island effect in the urban environment;
- aging population;
- stricter requirements for comfort in buildings.

6.2 Weaknesses

Bureaucracy

The realisation of a heating network takes several years and it is often a complex process with several stakeholders (DWA, 2020):
- permit applications for the construction and realisation of the heating source;
- apply for grants such as SDE++ for sustainable heating sources;
- communication with residents and other stakeholders;
- consultation and coordination with the grid operator about excavation work to lay the pipes;
- connecting homes and buildings and minimise nuisance as much as possible;
- supervision of the realisation process and work to be performed by the contractor.

Participation

Participation is an important aspect for energy transition in general and also for the implementation of 5GDHC technology. Although a large group of Dutch people is positive about making the gas-free, less than 10% is prepared to take action themselves in the short term. The majority indicate that they prefer to wait for plans from the municipality, the landlord or the VVE (Stichting Warmtenetwerk & DNE Resarch, 2020). This means it will be difficult for stakeholders to start a district heating project because of high risks and uncertainties.

Moreover, the fact that consumer price of the heat from district heating is still coupled to the gas prices makes the connection to a district heating network less interesting for end-users. Although this is going to change in time, the prices will not be totally independent of gas prices in short term.

6.3 Threats

Balance between heating and cooling demand

The main challenge for the implementation of 5GDHC technology, different from a conventional district heating network, is the balance between heating and cooling demand. Especially, in the existing building stock, the fact that the energy demand is mainly for heating and that the cooling demand is minimal is a threat to the functioning of the 5GDHC system.
As an example, the performance of an ATES system is also dependent on the balance between heat and cold demand. In the Netherlands, the performance is guaranteed by regular checks by the province. The permit requires the supplier to submit a report on the performance of the ATES system and the level of soil quality to the province every year. Every five years the supplier is required to submit a more detailed evaluation report. If the results in these reports do not comply with the permit, the province will impose sanctions. These sanctions range from warning letters and fines to even stopping your TES system or revoking the permit.

Initial Investment Costs and Financial Feasibility

The investment costs for the realisation of the district heating networks is already high. This pushes municipalities to take ownership of the district heating projects and cooperate with market parties to realise the projects. For 5GDHC technology, however, investment costs are even higher considering the infrastructure required for cooling and advanced systems for the communication between different users.

6.4 Opportunities

Rolling out existing district heating networks, such as the one of Mijnwater, is the first opportunity that the region has in term of 5GDHC implementation. Especially the new building projects, which have a more balanced heating and cooling demand, are especially interesting for the implementation of 5GDHC networks.

The energy crisis in Europe has been a driving force for the acceleration of gas-free policies and programmes. Due to high energy prices, Netherlands paying the highest price for gas in Europe, and geopolitical risks associated with natural gas, district heating networks become more interesting for policy makers as well as for citizens in the Netherlands.

7 Multi-criteria analysis

The decision on the neighbourhoods where the 5th generation district heating and cooling (5GDHC) technology can be implemented is not straightforward. One needs to take into account many aspects that play a conflicting role in determining where the technology is suitable. It includes financial, technical and social aspects. Therefore, a multi-criteria analysis is the best option to solve this problem with many facets. Criteria for suitable neighbourhoods

In the multi-criteria analysis we rate all the neighbourhoods in Parkstad Limburg to determine the most suitable neighbourhoods for implementing 5GDHC. In the analysis each criterion has a weighing factor; the higher the weight, the more influence the criteria has in the total score for a neighbourhood. The criteria on which the neighbourhoods are rated are listed and explained in this section.

7.1 Criteria for the multi criteria analysis

An overview of all criteria can and their weights can be found in Table 3. Weighing factors are determined by CE Delft taking in consideration input from experts from Mijnwater and the Open University. The criteria that are weighed by two are considered to be more important for determining the most suitable neighbourhoods for 5GDHC.

Table 3 - Overview of criteria, the method for scoring and their weight

Criterion	Explanation	Method of scoring	Weight
Number of dwellings	Minimal number of dwellings necessary for implementing 5GDHC	Less than 50 dwellings are filtered out. Between 50 & 100 dwellings score -1.	2
Room for investment in 5GDHC	High costs for the alternatives provide a room for investments in 5GDHC	Highest 30% score 1. Next 30% score 0.5.	2
Ratio total costs to insulation costs	Higher energy costs give an opportunity for 5GDHC to be more economically viable than alternatives	Highest 30% score 1. Next 30% score 0.5.	1
Exchange heating and cooling	A balance in heating and cooling demand is needed for optimum performance of 5GDHC (mix of functions)	A cooling to heating demand ratio of more than 15% score 1. Two or more buildings with continuous cooling demand score 1.	2
Infrastructure costs	Lower infrastructure costs for district heating makes a neighbourhood more suitable for 5GDHC	20% with lowest infrastructure costs score 1, next 20% score 0.5. 20% with shortest infrastructure per dwelling score 1, next 20% score 0.5.	1
Proximity of existing district heating	Connecting to an existing district heating network is easier than building a new one	Mijnwater backbone in neighbourhood score 1.	1
Urban density	High-urban density favours district heating	Urban density 1 and 2 score 1. Urban density 3 score 0.5.	1
Heating source available	Usually there is more heating than cooling demand in the Netherlands, a heating source can provide this extra demand	A heating source available in neighbourhood score 1.	2
Social housing	Higher percentage of dwellings owned by social housing corporations	> 75% is social housing score 1. > 50% is social housing score 0.5.	1

Criterion	Explanation	Method of scoring	Weight
	provides higher potential to connect a large number of dwellings to 5GDHC		
Infrastructure replacement	If gas infrastructure is replaced before 2024 the neighbourhood is less suitable to start with a gas-free heating option	Neighbourhoods where more than 30% of gas infrastructure will be replaced before 2024 get a score of -1, when this is between 20% and 30% they get a score of -0.5.	1
Heat Island	5GDHC does not increase heat island effect, therefore it is interesting for districts with higher risk of heat island effect	More than 1.4°C score 1. Between 1°C and 1.4°C score 0.5.	1

Number of dwellings

District heating is a collective heating system, multiple buildings are connected to a network that distributes hot water for heating of buildings. Larger-scale implementations are favourable for district heating, in terms of costs as well as performance. This applies even more to 5GDHC. A minimum number of buildings that can exchange heating and cooling is needed to ensure high performance of the system. Because of this, in selecting the most suitable neighbourhoods for 5GDCH, we filter out all neighbourhoods that have few dwellings based on the following rule:

All neighbourhoods with less than 50 dwellings are filtered out completely, neighbourhoods with 50 to 100 dwellings get a score of -1.

Room for investment in 5GDHC

One of the criteria is the room for investment in 5GDHC. This is determined by the costs for alternative heating solutions, where we look at the alternatives for 5GDHC. The higher the costs for the alternatives, the more opportunity for 5GDHC to be an economically more favourable option. In other words, we find out the neighbourhoods where alternative heating options are relatively expensive and therefore provide room for investing in 5GDHC. We look at the total costs for the heating of a dwelling over 30 years and call this the room for investment. This includes the investments for installation and insulation but also the maintenance costs and energy costs for 30 years.

In our analysis, we take three options in consideration for heating dwellings: a gas-fired individual heating system, a gas-free individual system and a gas-free collective system. The gas-free collective system in this study is 5GDHC. The individual systems are the alternatives. For the costs we assume that for heating a dwelling wit a gas-fired individual option, the first fifteen years a conventional gas boiler is used and the next fifteen years a hybrid heat pump is used. The gas will be a mix of natural gas and green gas. The percentage green gas increases linearly from 0% in 2020 to 20% in 2030 and from 20% 2030 to 100% in 2050. For these heating systems insulation is not required, so they are not taken into the costs for this alternative.
The gas-free individual option is an all-electric heat pump. This option takes into account the advised insulation levels which are determined by Dutch specialists based on the Climate Agreement, called the insulation standard (see Section 3.2). For the alternative with gas, energy costs are the most important factor in the costs. For the gas-free alternative, investments in the heating installation and insulation play a larger role.
An overview of the two situations that we calculate costs for can be seen in Table 4.

Table 4 - Overview of reference situations where the costs are calculated for, to determine the room for investment in 5GDHC

Alternative to 5GDHC	Heating system	Insulation
Situation with gas	Condensation boiler for 15 years and hybrid heat pump for 15 years	No extra insulation
Gas-free situation	All-electric heat pump for 30 years	Insulation that is required for low-temperature heating

Using our CEKER model[14], we calculate the total costs over 30 years for two alternative options as explained above. As a result, we find the neighbourhoods with the highest room for investment.

The 30% of neighbourhoods with the highest room for investments get a score of 1. The next 30% get a score of 0.5 and the rest gets zero score.

Ratio total costs to insulation costs

Besides the total costs for alternative heating systems, we also take in consideration what elements the costs are for. Investments in insulation are needed in the gas-free reference, but they may also be necessary for 5GDHC. When most of the costs are needed for insulation, there is less room for investment in 5GDHC. While higher energy costs give an opportunity for 5GDHC to be more economically viable than alternatives. The ratio total costs to insulation gives an indication whether most costs are needed for insulation. A high ratio total costs to insulation is favourable for 5GDHC.

The 30% of neighbourhoods with the highest ratio total costs to insulation get a score of 1. The next 30% get a score of 0.5 and the rest gets zero score.

Potential for exchange between heating and cooling supply and demand

A key component of 5GDHC is the exchange of heating and cooling supply and demand. For each neighbourhood we have estimated a heating and cooling demand based on the type of buildings in that neighbourhood. Therefore, for our multi-criteria analysis, we look at the ratio between the total cooling and heating demand in each neighbourhood.

Neighbourhoods with a cooling to heating demand ratio of more than 15% get a score of 1. The rest gets zero score.

In general the heating demand and cooling demand are not simultaneous, most buildings have a cooling demand in summer and a heating demand in winter. However some buildings, such as datacentres or supermarkets, also have a cooling demand in winter. We have gathered the locations of these buildings with a continuous cooling demand. In neighbourhoods with these buildings, it is more likely to realise a balance between heating and cooling in the network.

Neighbourhoods with two or more buildings with a continuous cooling demand within a radius of 500 meter get a score of 1. The rest gets zero score.

[14] CEKER is a fast and flexible calculation model, developed by CE Delft, that calculates the costs for end users of sustainable heat options. The model works on housing level, neighbourhood level, municipal level and central government level. More information: CEKER Kosten voor Eindgebruikers Rekenmodel (Available only in Dutch).

Infrastructure costs

With our CEGOIA[15] model we can calculate the costs for district heating infrastructure in a neighbourhood. The costs include the investments in the pipelines, heat transfer stations, substations and costs for extra systems to meet peak demand. The costs that we calculate are not the same as for 5GDHC, but they can give an indication of where the infrastructure costs for 5GDHC will be high or low. We assume that neighbourhoods with lower infrastructure costs are more suitable for 5GDHC.

The 20% of neighbourhoods with the lowest infrastructure costs for high-temperature district heating get a score of 1. The next 20% get a score of 0.5 and the rest gets zero score.
The 20% of neighbourhoods with the shortest infrastructure length per dwelling equivalent get a score of 1. The next 20% get a score of 0.5 and the rest gets zero score.

Urban density

District heating generally is more interesting to implement in regions with high urban density. A large share of costs for district heating to the infrastructure and in neighbourhoods with high urban density these costs can be shared by many buildings and owners. Statistics Netherlands (CBS) gives every neighbourhood a score of 1 to 5 on urban density, where 1 is the highest density and 5 the lowest.

Neighbourhoods with urban density 1 or 2 get a score of 1, neighbourhoods with urban density 3 get a score of 0.5. The rest gets zero score.

Availability of heating sources

In the Netherlands, the heating demand in buildings is generally higher than the cooling demand. An external heating source to meet the extra heating demand can be beneficial for the balance in the 5GDHC. Although it is not a requirement, neighbourhoods where heat from an external heating source is available can be more suitable for 5GDHC. Public data from the Warmteatlas (RVO, ongoing-d), a database with potential heating sources in the Netherlands, is used to determine whether a heating source is available. In this case available means that there is a heating source, it is unknown whether the heat is already used, or the whether it is practically possible in that specific case to use the heat in district heating. The heating sources present in Parkstad Limburg are presented in Chapter 5.

Neighbourhoods get a score with a maximum of 1, based on the availability of heating sources in the neighbourhood.

[15] CEGOIA is an optimisation model with a web-based interactive interface, which is developed by CE Delft. The model finds the cost-optimal heating technology for each neighbourhood in the area of interest, for example a municipality, province or service area. More information: CEGOIA – Heat transition in the built environment.

Proximity of existing district heating

Mijnwater already has a backbone in Heerlen that is used for the current 5GDHC network. Adding more clusters to this backbone can be easier than building new infrastructure.

The neighbourhoods where this backbone goes through get a score of 1.

Social housing corporations

In terms of stakeholder management, connecting dwellings that are owned by a social housing corporation to district heating is usually easier than connecting a large number of privately-owned dwellings. In the case of social housing corporations, a contract with just one party ensures a large number of connections to the network.

Neighbourhoods where 75% or more of the dwellings are owned by a social housing corporation get a score of 1. When between 50 and 75% of dwellings are owned by a corporation the neighbourhood gets a score of 0.5. The rest gets zero score.

Infrastructure replacement planning

Enexis, the owner of energy infrastructure in Parkstad Limburg, has an infrastructure replacement planning. This planning indicates where the gas infrastructure will be replaced before 2024. Since it is not realistic to completely replace the gas infrastructure with 5GDHC before 2024, the neighbourhoods where a large part of gas infrastructure will be replaced are less desired to start with 5GDHC.

Neighbourhoods where more than 30% of gas infrastructure will be replaced before 2024 get a score of -1, when this is between 20% and 30% they get a score of -0.5.

Heat island effect

Heat islands are areas in urban regions that experience higher temperatures than outlying areas. Buildings, roads and other infrastructure absorb and re-emit more heat that natural landscapes, which increases the temperature in urban areas. Installations that emit heat, such as air conditioning or heat pumps that are used for cooling in summer, also contribute to the rise of temperature in cities. In areas with high risk for the heat island effect a system that does not contribute to the heat island effect, such as 5GDHC, can be a better alternative. The heat island effect is indicated with the difference in temperature between the urban areas and the surrounding rural areas.

Neighbourhoods where the heat island effect is more than 1.4 ºC get a score of 1, when the heat island effect is between 1°C and 1.4 °C get a score of 0.5.

7.2 Costs for alternative heating systems

The costs for the alternative heating systems give an indication where alternative heating options are relatively expensive and therefore provide room for investing in 5GDHC. In this section we go further into the costs for alternatives in the neighbourhoods in Parkstad Limburg. As explained in the previous section, two alternatives to 5GDHC are considered (see Table 4). One in which gas is used for heating and dwellings are not further insulated and another where only electricity is used for heating and the dwellings are insulated.

Costs for alternatives

The costs for the gas reference and the gas-free reference are calculated for each neighbourhood that contains dwellings in Parkstad Limburg. Considering all neighbourhoods in the region, the average total costs for heating a dwelling for 30 years is 121 k€ and 123 k€ respectively for the alternative with gas and the gas-free alternative, as shown in Figure 20.

As discussed in the previous section, the total costs of alternative heating systems over 30 years are defined as the room for investment for 5GDHC implementation.

Figure 20 - Average total costs for heating a dwelling for 30 years. The error bars indicate the standard deviation.

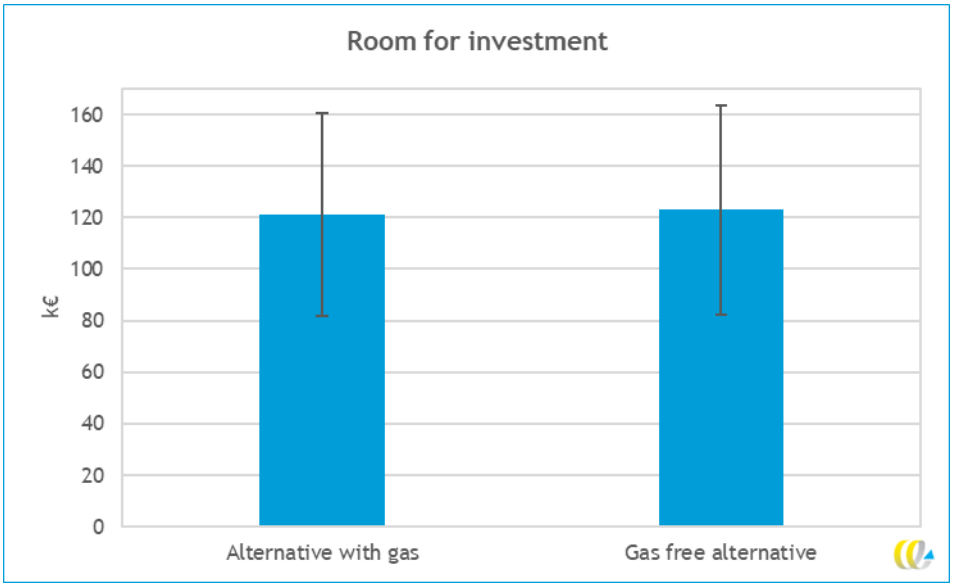
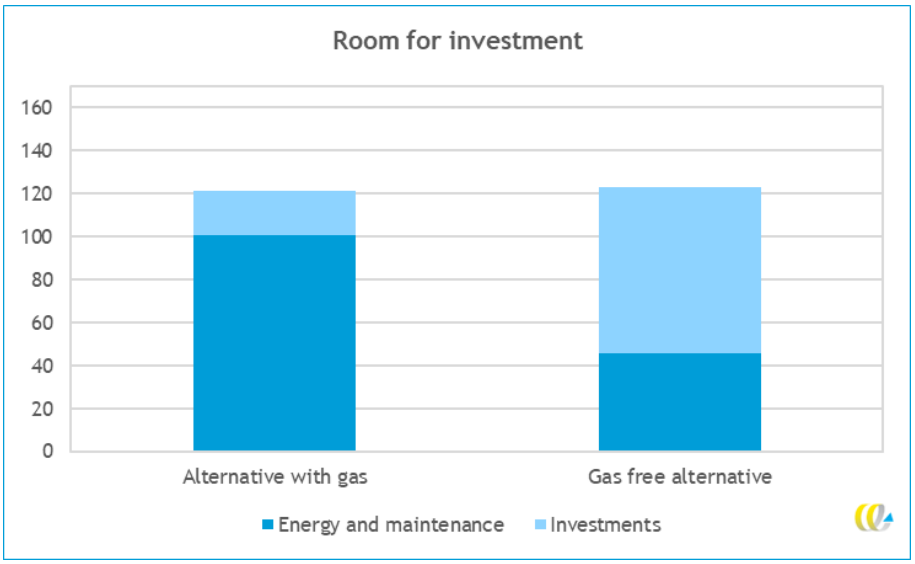


Figure 21 shows the share of operational costs (opex) consisting of energy costs and maintenance and investments (capex) in the heating installation and insulation in the total costs. It shows that the operational costs are the highest in the situation where gas is used, while in the gas-free situation the investments are the main part of the costs. For the alternative with gas, no further insulation of dwellings is needed. Because of this, the investment costs are just for the heating systems, however the energy costs are relatively high. In the gas-free reference the investments are almost four times higher, since a heat pump has higher costs compared to a condensation boiler and a hybrid heat pump. Also the insulation adds to the investment costs. Insulation however, lowers the energy use, and thus lowers energy costs.

Figure 21 - The room for investment split up in operational costs (energy and maintenance) and investment costs (capex)



Differences in costs between neighbourhoods

In the multi-criteria analysis each neighbourhood gets a score based on the total costs over 30 years for alternative heating options. The costs vary from neighbourhood to neighbourhood. Neighbourhoods with large and/or poorly insulated dwellings generally have higher costs per dwelling. Figure 22 shows for various bandwidths of the total costs, the number of neighbourhoods that lies within this range. There are few neighbourhoods with high costs up to around 500 k€ per dwelling. In the figure it can clearly be seen that these neighbourhoods are outliers. Most of the neighbourhoods have costs around 121 k€, i.e. the average cost. Figure 22 shows the costs for the alternative with gas. A similar distribution is seen for the gas-free alternative.

Figure 22 - Spread over neighbourhoods of costs for alternative heating solution in the gas reference. The numbers on the horizontal axis indicate the range for the room for investment.

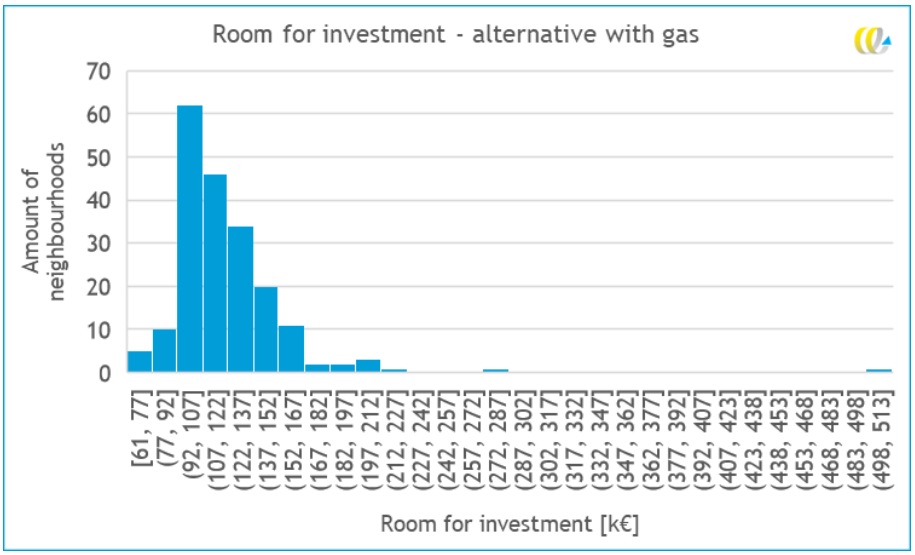
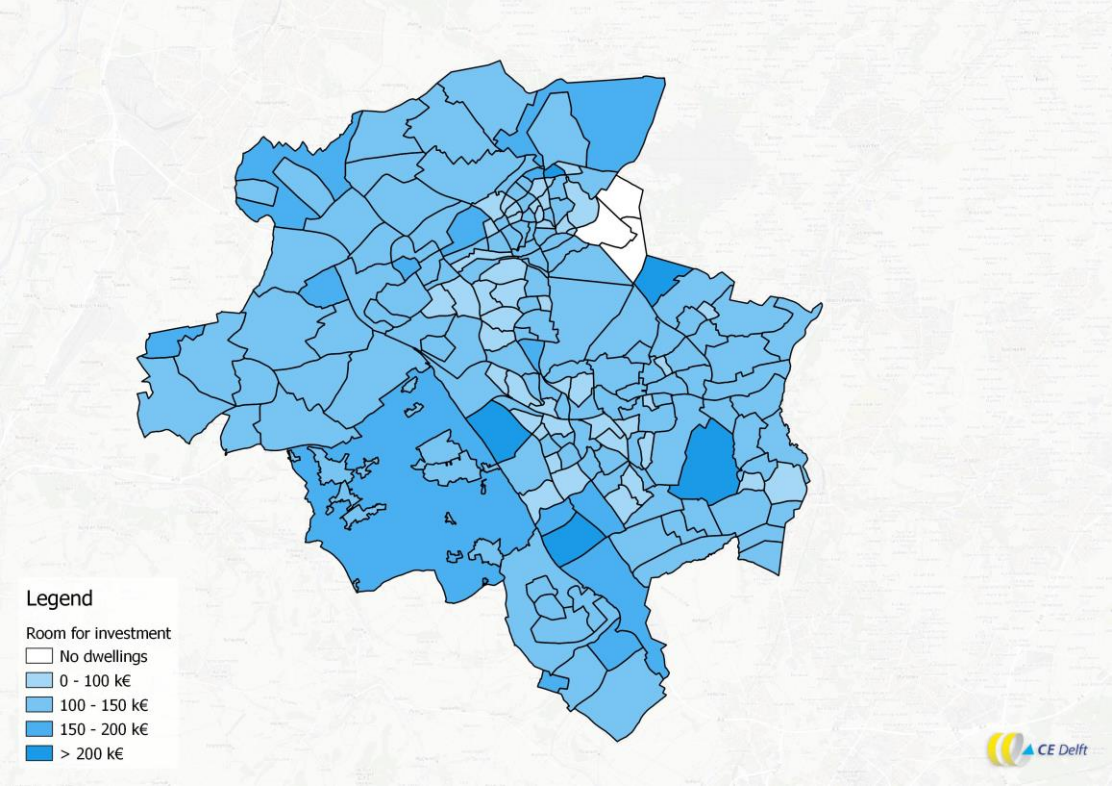


Figure 23 shows the neighbourhoods in Parkstad Limburg with the corresponding room for investment in the reference scenario with heating using gas. Each neighbourhood in the highest room for investment category is not necessarily suitable for 5GDHC. That is why it is important to also look at the other criteria described in Section 7.1.

Figure 23 – Room for investment per dwelling in the reference with gas for the neighbourhoods in Parkstad Limburg



Price scenarios

Investments in district heating infrastructure requires a long-term view. A district heating net that starts operating in 2025, is expected to be in use at least until 2055. The decennia in between also mark the period in which the bulk of the energy transition is expected to occur. The scale of the transition leads to considerable uncertainties. To account for uncertainties in future energy prices and building costs, we have defined three price scenarios:

1. Peak and recovery: after the current peak in energy prices, the prices recover to a level slightly above the price prediction from 2019.
2. Steady state high prices: the current peak results in long-term high energy prices.
3. Recovery with working shortage: this scenario involves fast recovery from the currently high energy prices, however because of a working shortage building costs remain high.

Table 5 shows the energy prices and increase in building costs for each scenario. In the appendix a further explanation of the scenarios can be found. We use the peak and recovery scenario as the base scenario. All results shown before are calculated using the parameters from the peak and recovery scenario.

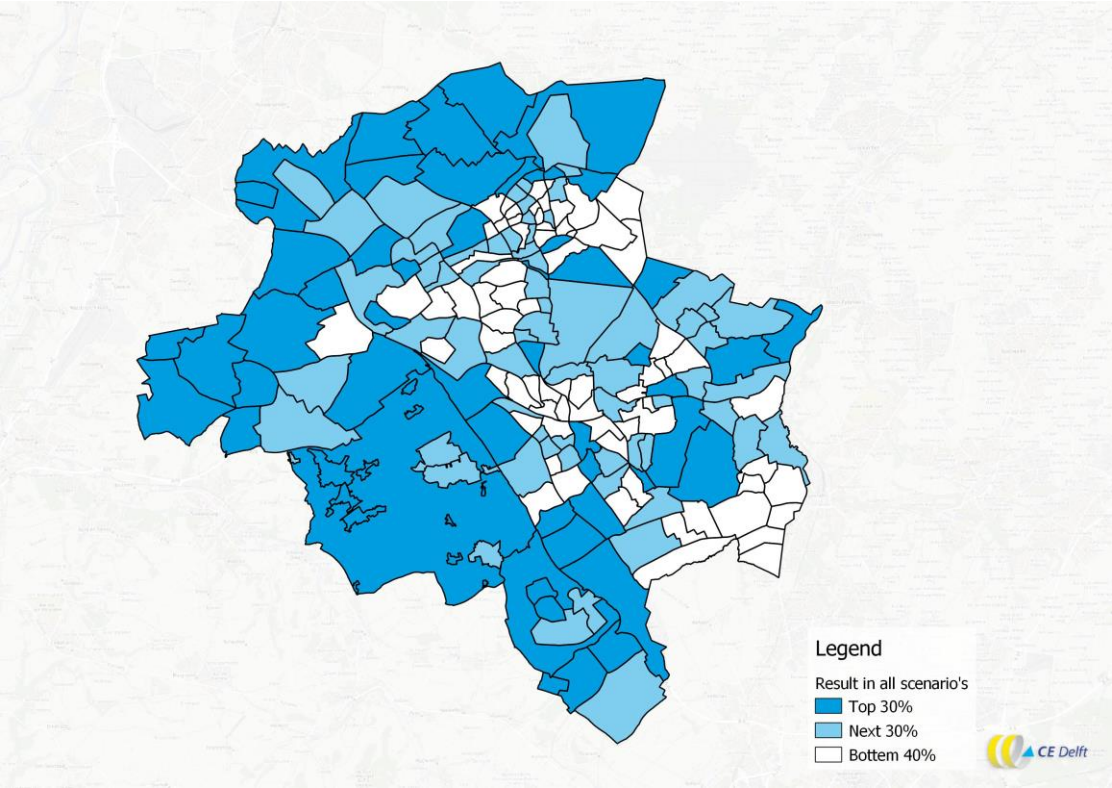
Table 5 - Overview of energy prices and increase in building costs for three scenarios

Scenario	Gas consumer price (€/m^3)	Electricity consumer price (€/kWh)	Increase in building costs (%)
Peak and recovery	1.78	0.31	12
Steady state high prices	2.31	0.34	22
Recovery with working shortage	1.25	0.28	17

Higher energy prices mostly impact the alternative with gas, since the main share of the costs is for energy and maintenance. The increase in building costs mainly affects the gas-free alternative, since the main share of the costs are for the installation and insulation. In general both alternatives will have higher costs in the steady state high prices scenario. In the recovery with working shortage, the energy prices are on the lower end, but the increase in building costs is higher than in the base scenario. In this scenario (recovery with working shortage) the costs for the alternative with as is relatively low, while the costs for the gas-free alternative will be of the same order as the costs in the base scenario.

When comparing the room for investment in three scenarios, it can be noted that most of the neighbourhoods that have a high room for investment in the peak and recovery scenario, also have a high room for investment in the other two scenarios. Figure 24 indicates which neighbourhoods have high room for investment in all scenarios. The dark blue neighbourhoods, 63 of the total 201 neighbourhoods in the region, are in the top 30% of the neighbourhoods with highest costs in all scenarios in the reference with gas or the gas-free reference (or both). These neighbourhoods are minimum affected by price, therefore they offer the highest financial room for investments in 5GDHC.

Figure 24 – The dark blue neighbourhoods have a high room for investment in all price scenarios. The light blue neighbourhoods have a bit lower, but still relatively high room for investment in all scenarios. The white neighbourhoods are not in the highest 60% room for investment limits in all scenarios



7.3 Results multi-criteria analysis

All neighbourhoods in Parkstad Limburg are rated on the criteria as described in Table 3. The maximum score possible for a neighbourhood is 12. None of the neighbourhoods receives this maximum score, the highest score is 8. This is achieved by the neighbourhood called Heerlen Centrum, it is the city centre of Heerlen. Figure 25 shows all neighbourhoods with their score in the multi-criteria analysis. Figure 26 shows the top 3 neighbourhoods. They are all located in the centre of Heerlen and close to the current Mijnwater district heating network.

Figure 25 – Neighbourhoods in Parkstad Limburg with their score in the multi-criteria analysis

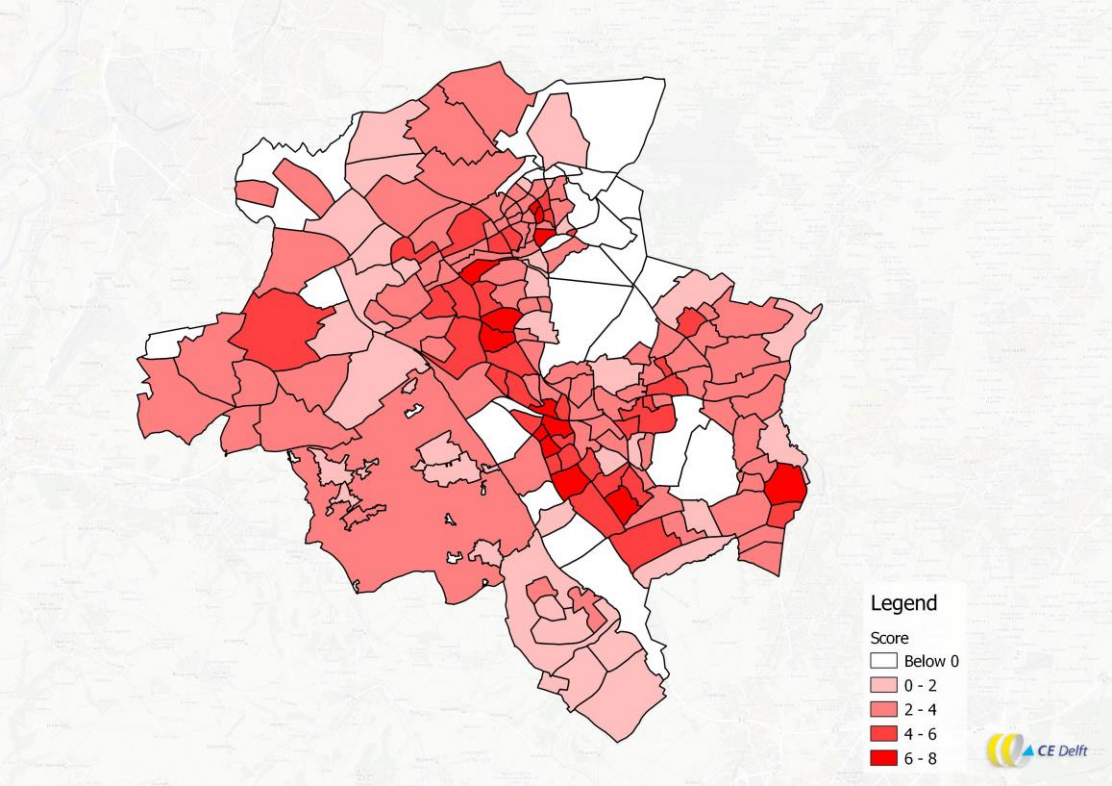
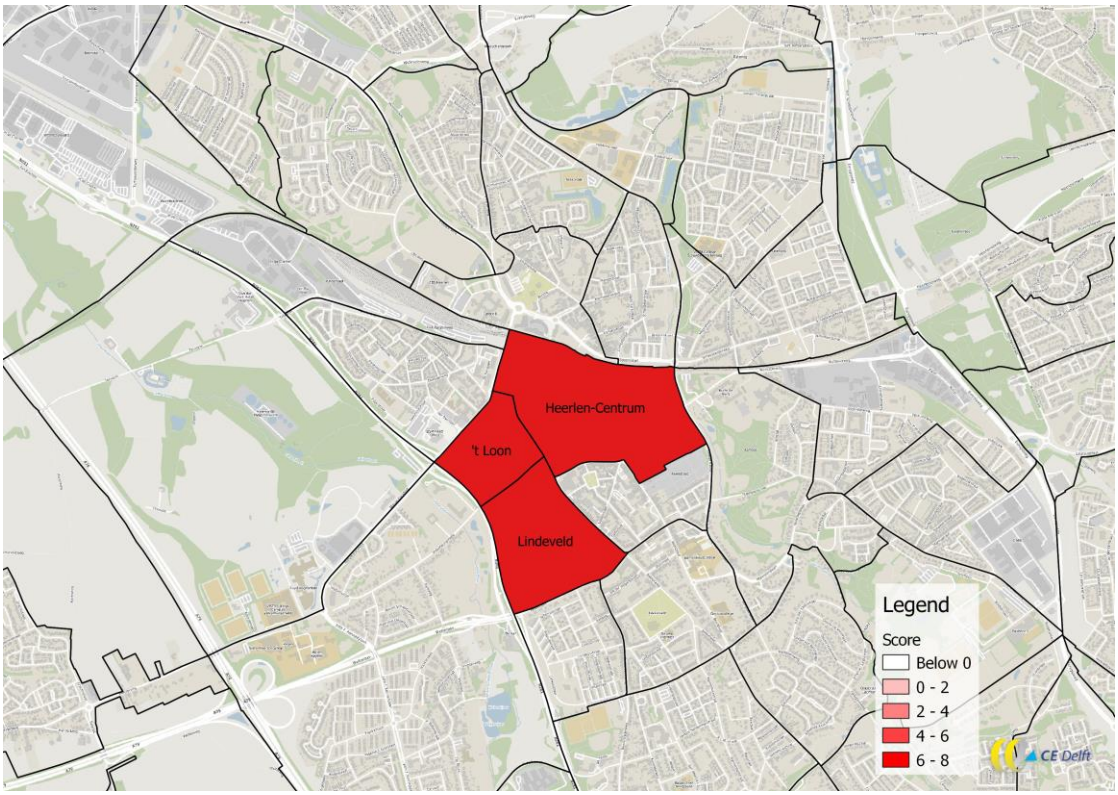


Figure 26 – The top 3 neighbourhoods from the multi-criteria analysis are all in the centre of Heerlen



8 Potential for 5GDHC in Parkstad

8.1 High potential neighbourhoods

The regional vision is an initial exploration of the potential for 5th generation district heating and cooling (5GDHC) in Parkstad Limburg. The regional vision identifies two regions that are promising for the implementation of 5GDHC. The next step is to take a closer look at these two regions and prepare a local action plan.
One of the criteria for the multi-criteria analysis (see Chapter 7) is the proximity to the existing Mijnwater network. It may also be of interest to explore regions further away from the existing Mijnwater network. For the local action plans, we have selected one region in the proximity of the Mijnwater network and one that is not in the proximity of the Mijnwater network.

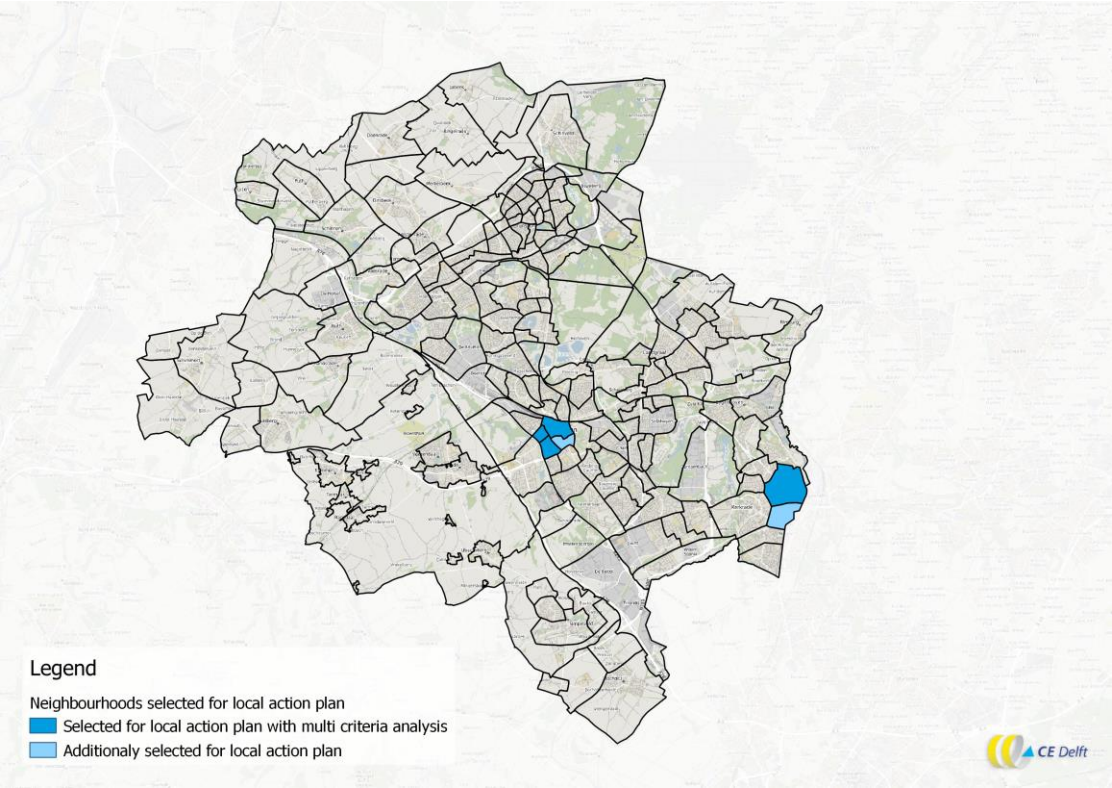
The Heerlen Centrum district

The top three neighbourhoods identified in the multi-criteria analysis are all in the same district ('wijk'): the Heerlen Centrum district. This district consists of four neighbourhoods. It makes sense to select the whole district to examine local action plans.

Neighbourhood not in the proximity of existing Mijnwater district heating

When selecting the region for the second local action plan, a neighbourhood with no existing Mijnwater district heating, we choose the neighbourhood with the highest score in the multi-criteria analysis that is not in Heerlen or Brunssum. This neighbourhood is Rolduckerveld in Kerkrade. This is a neighbourhood with a lot of multi-storey buildings, which makes it suitable for a collective heating option, such as 5GDHC. The neighbourhood just south of Rolduckerveld, called Holz, also scores relatively highly in the multi-criteria analysis. This neighbourhood will be included in the region for the local action plan.

Figure 27 - The two regions selected for the local action plans. One region is the Heerlen Centrum district, consisting of four neighbourhoods in the municipality of Heerlen. The other region consists of two neighbourhoods, Rolduckerveld and Holz, in the municipality of Kerkrade.



8.2 Roadmap

The two regions that we propose for implementation of 5GDHC are the Heerlen Centrum district consisting of four neighbourhoods and two neighbourhoods in Kerkrade. Table 6 gives an overview of the potential for 5GDHC in this area. For the Heerlen Centrum district this excludes the buildings that are currently connected to the heating network (estimated with use of a percentage).

Table 6 - Overview of the potential floor area and energy demand (after insulation) in the selected regions for the local action plan

Region	District Heerlen Centrum	Neighbourhoods Rolduckerveld and Holz
Number of dwellings	2,400	2,600
Number of utility objects	600	550
Total floor area dwellings (ha)	27	30
Total floor area utility (ha)	28	8
Total estimated heat demand (TJ/year)	160	100
Total estimated cold demand (TJ/year)	37	12

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A Price scenarios

District heating requires long-term view

Investments in district heating infrastructure requires a long-term view. A district heating net that starts operating in 2025, is expected to be in use at least until 2055. The decennia in between also mark the period in which the bulk of the energy transition is expected to occur. The scale of the transition leads to considerable uncertainties, among others in terms of future energy prices.

Future energy prices

Future energy prices are of considerable importance for many parties to make investment decisions. That is why different organisations seek to provide insights in future energy prices. We can distinguish two sets of data sources for future energy prices: one for short- and medium-term prices, and one for long-term energy prices. It is important to note that in both cases the energy prices are the *commodity* prices, paid by parties active on the wholesale market. End-consumers pay *consumer* prices, which are for energy comprised of commodity prices, distribution and transportation costs, taxes and levies, standing charges, and a certain markup. This also means that the difference between commodity and consumer prices is partly dependent on current and future policy decisions, such as CO_2 taxation for end-consumers. This memo concerns itself with insights in future commodity prices, leaving developments in other components of consumer prices out of scope.

Short- and medium-term energy prices

Short- and medium-term energy commodity prices are prices for up to the next three to five years. Insights in these energy prices are based on trading in so-called energy futures[16]. The data are accessible through platforms such as www.ICE.com. These short- and medium-term prices are thus expectations of the market itself. The last several months (the third quarter of 2022) the market has responded nervously to the news cycle, which has resulted in high volatility of prices. This volatility impacts both current prices, as well as prices in the medium-term (up to five years).

Long-term energy price forecasts

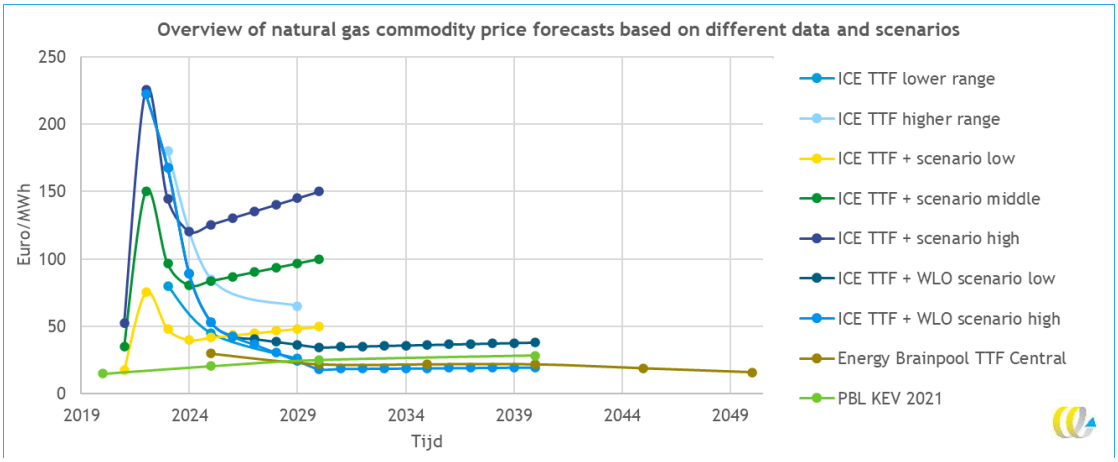
Long-term energy commodity price forecasts are made by research and knowledge institutes and organisations such as the International Energy Agency (IEA) and the Netherlands Environmental Assessment Agency (PBL). These forecasts are based on scenarios describing the future energy system and assumptions of future costs of exploitation of technologies within the system. The IEA World Outlook Scenarios are seen as one of the most important ones. Creating such scenarios and running the corresponding models requires considerable time. That is why such scenarios lag in their assumptions. The latest currently available IEA and PBL scenarios do not take the war in Ukraine, nor the energy crisis into account.

[16] Futures are contracts made by parties at a certain time, for the delivery of energy at a later point in time.

Insights through scenarios

Given the large uncertainties both short-term (volatility of markets) and long-term (difficult of future assumptions), scenarios are a broadly used method to gain insights in possible future outcomes. Figure 28 shows an overview of several scenarios for natural gas commodity prices based on different data sources and assumptions for both short- and medium-term, as well as long-term. In the figure three periods can be distinguished: the sharp short-term peak (around 2023), the highly uncertain medium-term period (2025-2029), and the long-term nearly constant price period (up to 2050). Prices in each period are a product of their underlying data. Short-term data reflect the current market nervosity. Long-term data reflect the pre-existing assumptions in long-term scenarios of institutions such as the IEA, and do not guarantee long-term low prices. The medium-term data are influenced by both short- and long-term data and therefore show the large range of uncertainty. Given the current knowledge, we believe it is this range of uncertainty that should be taken into account in scenarios.

Figure 28 - Overview of different data sources and scenarios for natural gas commodity prices up to 2050



TTF: Title Transfer Facility. WLO: Welvaart en Leefomgeving (Prosperity and Living Environment). PBL: Netherlands Environmental Assessment Agency. KEV: Klimaat- en energieverkenning (Climate and Energy Outlook).

Project scenarios

To account for the large existing uncertainties fuelled both by the current crises and the overall energy transition uncertainties, we advise to take a broad range of commodity prices into account in the scenarios. For natural gas we propose the range between 50 and 150 €/MWh. This corresponds with consumer prices between 1.25 and 2.31 €/m^3.
For electricity we propose the range between 50 and 100 €/MWh. This corresponds with consumer prices between 0.28 and 0.34 €/kWh. Within these ranges we define three scenarios, where we vary the energy prices and the increase in building costs since 2020:

- **peak and recovery**: after the current peak in energy prices, the prices recover to a level slightly above the price prediction from 2019;
- **steady state high prices**: the current peak results in long-term high energy prices;
- **recovery with working shortage**: this scenario involves fast recovery from the currently high energy prices, however because of a working shortage building costs remain high.

Table 7 shows the energy prices and increase in building costs for each scenario.

Table 7 – Overview of energy prices and increase in building costs for three scenarios

Scenario	Gas consumer price (€/m^3)	Electricity consumer price (€/kWh)	Increase in building costs (%)
Peak and recovery	1.78	0.31	12
Steady state high prices	2.31	0.34	22
Recovery with working shortage	1.25	0.28	17

Consumer prices for district heating are currently linked with natural gas prices. However, we expect that link to dissolve in the coming years, either through policy intervention or through technological changes. However, as the energy system is expected to become increasingly more interconnected, electricity and gas (methane and/or hydrogen) prices are expected to continue to be of importance for the competitiveness of district heating systems, and therefore for the investment decisions in district heating.

Interreg North-West Europe D2Grids

European Regional Development Fund

WORK PACKAGE: WPLT

DELIVERABLE NUMBER: DEL.1.3

PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN 7 FOLLOWER REGIONS

July, 2021

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Abbreviations

4GDHC	4th generation district heat and cold
5GDHC	5th generation district heat and cold
AGFW	Energieeffizienzverband für Wärme, Kälte und KWK e. V.
AVBFernwärmeV	Verordnung über Allgemeine Bedingungen für die Versorgung mit Fernwärme
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle (Federal Office of Economics and Export Control)
BAT	Best available technique
BDEW	Bundesverband für Energie- und Wasserwirtschaft (Federal Association for Energy and Water Management)
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy)
CHP	Combined heat and power
CO2	Carbon dioxide
DH	Direct heating
DHN	District heating network
EEWärmeG	Erneuerbare-Energien-Wärmegesetz (Renewable Energies Heat Act)
EnEG	Energieeinsparungsgesetz (Energy Conservation Act)
EnEV	Energieeinsparverordnung (Energy Saving Ordinance)
GEG	Gebäudeenergiegesetz (Building Energy Act)
GWh	Gigawatt hour
km	Kilometer
KWKG	Kraft-Wärme-Kopplungs-Gesetz (Combined Heat and Power Act)
LANUV	Landesamt für Natur, Umwelt und Verbraucherschutz (State Office for Nature, Environment and Consumer Protection)
MW	Megawatt
MWh	Megawatt hour
NRW	Nordrhein-Westfalen
TPA	Third party access
TWh	Terawatt hour

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1. Introduction

Activities in the Long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories ("follower regions"). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. The regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology is carried in this deliverable for each of the 7 follower regions defined for this project, namely: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project, has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

2. Characterising the region

The analysis will focus on the Ruhr area ("Ruhrgebiet"), a polycentric urban area in North Rhine-Westphalia ("NRW"). The Ruhr region takes its name from the river Ruhr, which runs along the southern edge of the region. The focus of the Ruhr region is on industry. As early as 1850, its coal mining and iron and steel industries made it one of the most important coal and steel regions in Europe.

North Rhine-Westphalia (NRW) is a German state in Western Germany. NRW is covering an area of 34 092 km^2, which makes it the fourth largest state in Germany. It has a population of 17.9 million making it the largest state by population and most densely populated state in Germany. NRW has always been Germany's powerhouse with the largest economy among the German states by GDP figures. Figure 1 displays the different regions in NRW. The Ruhr area is marked in grey.

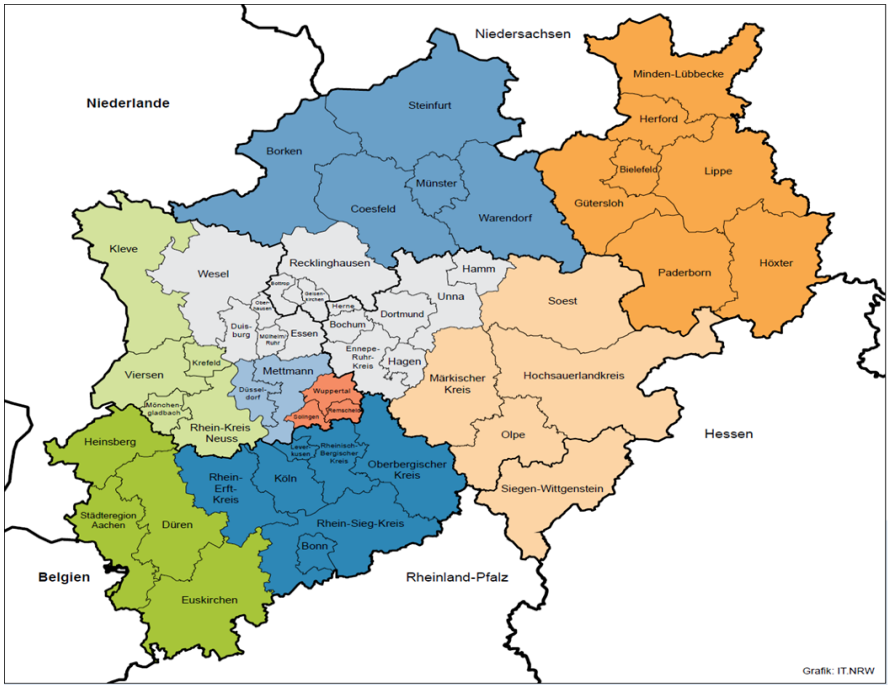

Figure 1: The Ruhr area in NRW [1]

The Ruhr area is located in NRW and accounts for about one third of the population. Today, 5.11 million inhabitants live in the Ruhr area, which covers an area of 4439 km^2 with 1152 hab/km^2. It is the sixth largest metropolitan region in Europe. Around 39.1 % of the area is used for residential areas and traffic, 58 % is covered by vegetation (including agriculture) and 2.9 % is covered by water [2]. The Ruhr area contains four rural districts and eleven cities, which are independently administrated on municipal level, although there exists the supracommunal "Regionalverband Ruhr" institution. The districts are Wesel, Recklinghausen, Unna and Ennepe-Ruhr-Kreis. The independent cities are Hamm, Dortmund, Hagen, Herne, Bochum, Gelsenkirchen, Essen, Bottrop, Oberhausen, Muhlheim an der Ruhr and Duisburg. The biggest city is Dortmund with 588 250 residents and the smallest municipality is Sonsbeck with 8763 residents. [3]. The Ruhr area does not have a typical centre but is spread out relatively even in terms of settlement structure.

The Ruhr area uses mainly gas, oil and district heating for its heating purposes. Even though the heat supply is mainly based on fossil fuels, the share of district heating is not insignificant. Europe's largest district heating network is located in the Ruhr area. This is a substantial aspect in the design of a sustainable energy supply system.

The Ruhr region has a comparatively low proportion of residential buildings with more than six residential units compared to other cities in Germany. The share of single- and two-family homes in the Ruhr area is higher than in the comparative

cities. Most buildings in the Ruhr area are older, low energy-performing buildings. The highest average energy consumption values have unrenovated residential buildings built before 1979. In the Ruhr area, the proportion of residential buildings built before 1979 is 73 percent. By comparison, 60% of residential buildings in Germany were built before 1979.

Three natural units intersect each other within the borders of the Ruhr area's topography: Westphalian Basin (North and East), Lower Rhine Plain (South), and Rhenish Mountains (West). The mean elevation level is low, that is, within the core area no higher natural elevations exist; the outer area features a few steeper elevation slopes such as outcrops or stream cutting erosions and some greater altitudes at the southern borders.

The Ruhr area is located within Europe's moderate climatic zone and is influenced by maritime climate sector. Thereby mild winter temperatures result. The historically averaged (1970 – 2015) monthly mean air temperatures lay between 3 °C in January to 19 °C in July, for Dusseldorf, a city not part of the investigation area, but connecting to it as its south-western border.

Figure 2: Map of the Ruhr area [3]

3. Analysis

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

Currently dominant heating technology in the region

In the following, district heating in NRW (since no separate data for Ruhr area is available) is examined in more detail due to the increased importance in this context. District heating is used in many sectors. In the industry it is used, for example, as process heat, whereas in households district heating is mainly used for space heating and hot water. It is interesting to consider the district heating consumption of the different sectors and the amount of district heating consumption in NRW. In addition, the heating systems of the apartments in NRW should be considered in order to know the current dominant heating technology.

In 2017 NRW had a heat consumption of 313.07[1] TWh. To determine the heat consumption of NRW, the heat share (55.62 %) of the end energy consumption of Germany was administered as a reference value. The heat share was applied to the end energy consumption of NRW in order to obtain an estimation of the heat consumption.

In NRW a total of 26.4 TWh district heat was consumed in 2017, of which 15 TWh was used by the industry, 8.7 TWh were used by households and 2.6 TWh in the commerce, trade, service sector. Thus, district heating accounted for 8.43 % of the heat consumption of NRW [4]. Germany had a total district heat consumption of 114.1 TWh in 2017. This means, that NRW accounts for 23.14 % of the total German district heating consumption. It is noticeable that in Germany the majority of district heating (51.5 TWh) is consumed by households, closely followed by the industry (47.8 TWh). In NRW, however, the industrial sector has the largest consumption of district heating with more than 50 %. This is not surprising, since NRW and especially the Ruhr area is an industrial stronghold that has a high energy consumption.

The Ruhr area had a district heating consumption of approximately 7.53 TWh in 2017. This was estimated with the values of NRW.

Bochum, a city in the Ruhr region, can be taken as another example. In 2019 the end use energy consumption in Bochum was supplied by the following energy sources: the leading source was gas with an amount of 2190 GWh, followed by district heating with an amount of 522 GWh and heating oil with an amount of 432 GWh. Heat pumps (9 GWh), electric heating (47 GWh) and renewable sources (e.g. biomass; 57 GWh) play a minor part in Bochum.

The BDEW (Bundesverband für Energie- und Wasserwirtschaft) has examined the heating behavior of Germans in a recent study. In NRW there are 8.7 million apartments that are heated with various heating systems. The leading technology/energy source is natural gas. It is used to power 3.5 million (40%) central heating systems, 1.2 million (14.3%) floor heating systems and some gas heat pumps and gas stoves. A total of 4.8 million apartments in NRW use natural gas, which corresponds to a share of 55.6 %. Throughout Germany, 48.2% (19.5 million) apartments use natural gas. Heating with oil takes second place. Around 2.1 million (23.9%) apartments in NRW are heated with oil central heating and only 61000 (0.7%) with oil stoves. This results in a total share of 24.5 %. In Germany the share is 25.6% (10.4 million). In NRW district heating ranks third with 0.8 million (9.1%) apartments. In Germany, a total of 5.6 million (13.9%) apartments are supplied with district heating. This means that around 14% of all apartments in Germany that are supplied with district heating are located in NRW. The remaining apartments are heated with “other energy sources” such as liquid gas, wood and electricity. [5]

[1] Own calculation

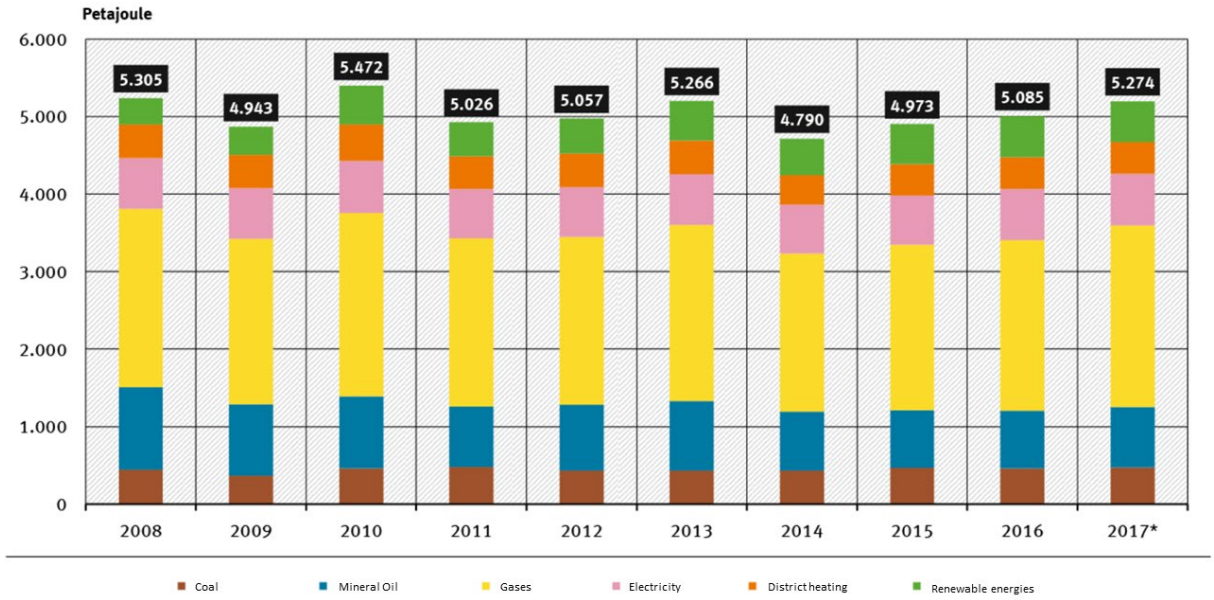

Figure 3: Heat consumption by energy source in Germany [6]

Figure 3 displays the heat consumption by energy source in Germany. The considered energy sources are coal (brown), mineral oil (blue), gas (yellow), electricity (pink), district heat (orange) and renewable energy (green). Each column represents one year. The share of district heat is a small but not unimportant part of the heat consumption and stayed at the same level over the past years. It also shows that gas is by far the most widely used energy source. In second place is the mineral oil. The distribution is similar to the energy sources that are used for heating in NRW.

According to AGFW (2018), NRW has 257 district heating grids that are operated with water. They have a length of 4981 km with an output of 9636 MW. Compared to Germany, this corresponds to 23.51 % (21184 km) of the nationwide district heating grid length and 19.30 % (49931 MW) of the nationwide district heating output. In addition, there are 9 steam powered district heating grids with a grid length of 102.4 km, which corresponds to a share of 18.55 % (551.9 km) of the nationwide steam powered grid, and an output of 860,8 MW, which corresponds to a share of 24.47 % (3532.4 MW) of the nationwide output. [8]

District heating is mainly generated by CHP and waste incineration plants, but also increasingly from decentralized heat sources such as industrial waste heat and renewable energies. Gas-fired and coal-fired power plants are of particular interest for CHP. However, the coal phase-out will take place by 2038 at the latest. Until then, alternatives must be used to supply district heating networks.

The district heating network (DHN) of the Ruhr area is one of the largest in Europe. It consists of five independents primary DHNs. They are furthermore separated in 25 secondary DHNs. The DHN delivers 6500 GWh per year with a maximum thermal power of 2300 MW. Feed and return flow temperatures vary. The primary networks of Fernwaermeversorgung Niederrhein GmbH and Steag operate at a maximum of 180 °C feed flow temperature, E.ON Nord and E.ON Sud (connected), Oberhausen, and Duisburg operate at a maximum of 130 °C. The secondary network only operates within the range of 100 °C to 110 °C, since it obtains the heat from the primary networks. The return flow temperatures are set between 60 °C and 70 °C. The following figure shows the district heating grid of the Ruhr area.

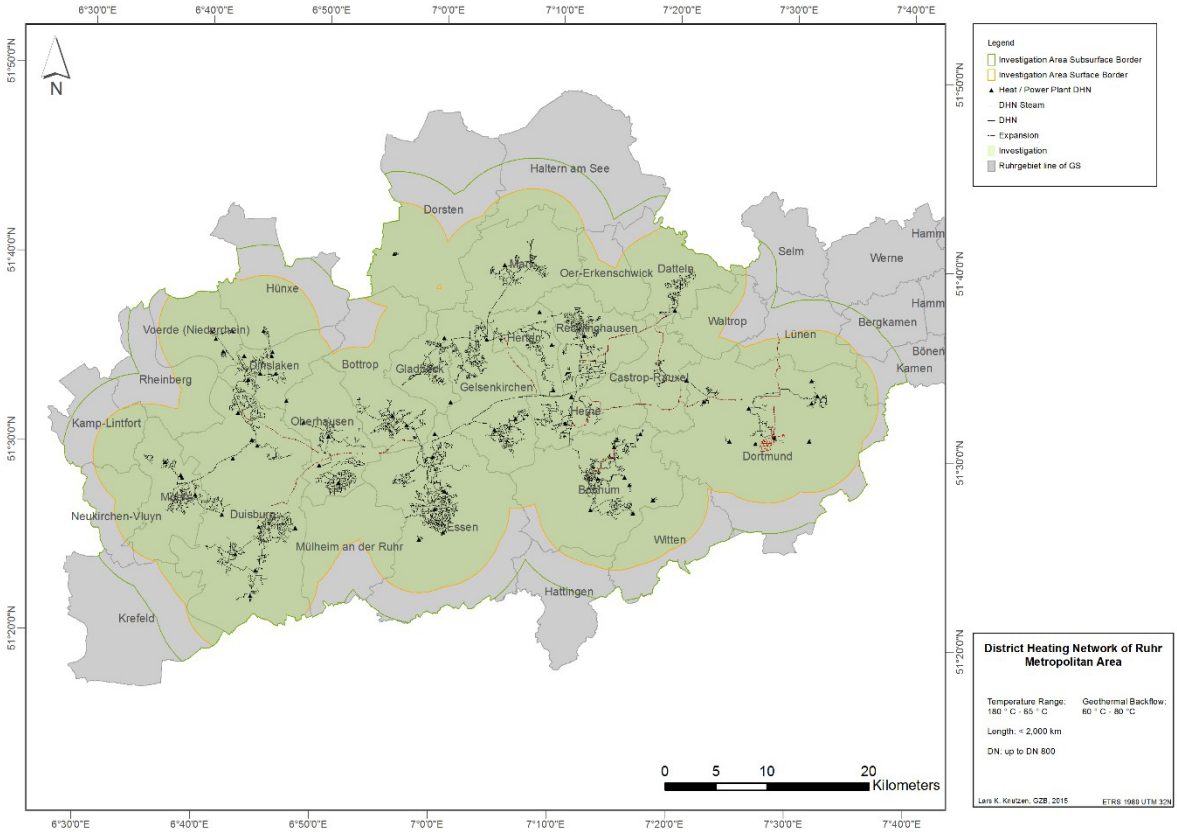

Figure 4: District heating grid of the Ruhr area [9]

District heating in the current heating regime

In order to achieve the goals of the planned heating transition by 2050, the proportion of conventional heating methods must decrease and be replaced by future-oriented methods. To this end, the expansion of combined heat and power (CHP) and district heating is being promoted. As already mentioned in 4.1.1, the share of district heating of the heat consumption in 2017 in NRW was around 8.43%. However, in 2015 the share of district heating of the final energy consumption was only 4.66 %.

The Ruhr area had a district heating consumption of approximately 7.53 TWh in 2017. This would mean that the Ruhr area accounts for about one third of the district heating consumption in NRW. This was estimated with the values of NRW.

Figure 6 displays the district heating consumption according to sectors and its share of the end energy consumption in NRW. Each column represents one year. The columns are divided into industry (light blue), household (dark blue) and commerce, trade, service– sector (light turquoise). The left y-axis indicates the amount of energy in TWh and refers to the bars. The right y-axis describes the share of district heating of the final energy consumption in percent and refers to the red line.

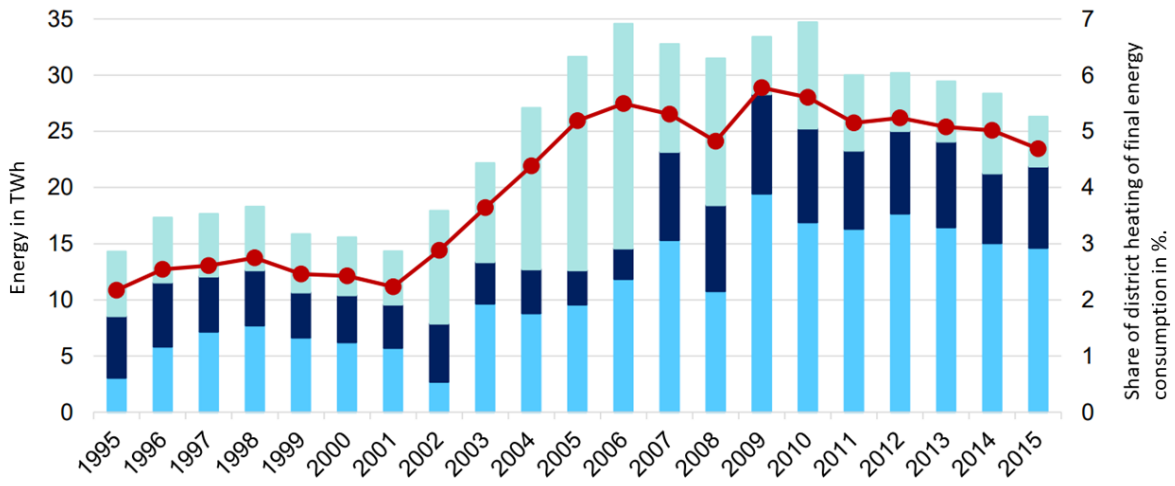

Figure 5: District heating consumption according to sectors and their share of end energy consumption in NRW [10]

Over the past 20 years, the share of district heating in the industry has grown from an initial 3.1 TWh/year to 14.6 TWh/year in 2015. The household sector also recorded an increase of 1.7 TWh in the same period (from 5,5 TWh to 7.2 TWh per year). Only for the commerce, trade, service-sector and other consumers did the district heat decrease from 5.8 TWh to 4.4 TWh per year. The total heat consumption from district heating grids in NRW increased by a factor of 1.8 during the period under review. Today the expansion of heating grids continues to be supported by laws and subsidies [10].

Main actors in the current heating regime

Natural gas is the second most important primary energy source in the German energy mix after mineral oil. In 2016, its share of primary energy consumption was 22.6 percent [11]. Most of the gas for energy supply in Germany is supplied to Germany from abroad. The gas network in Germany has a total length of 511 000 kilometres. In connection with the gas supply, companies operate in the areas of gas pipelines, distribution grid, storage and trade [12]. Gas trading is a big part of the heating market. The German gas market is characterized by a large number of market players organized under private law in the areas of gas networks, storage operation and trading. There are currently two market areas (NCG and Gaspool), each with a market area manager who ensures the efficient handling of gas network access and market operations [11].

There are currently 1050 gas suppliers and 16 gas transmission companies in Germany. Other players include distribution system operators, storage operators, and trading companies. The following figure shows important gas suppliers by gas sales in Germany in 2019. In 2019 the total gas sales amounted to 929 995 GWh. [13]

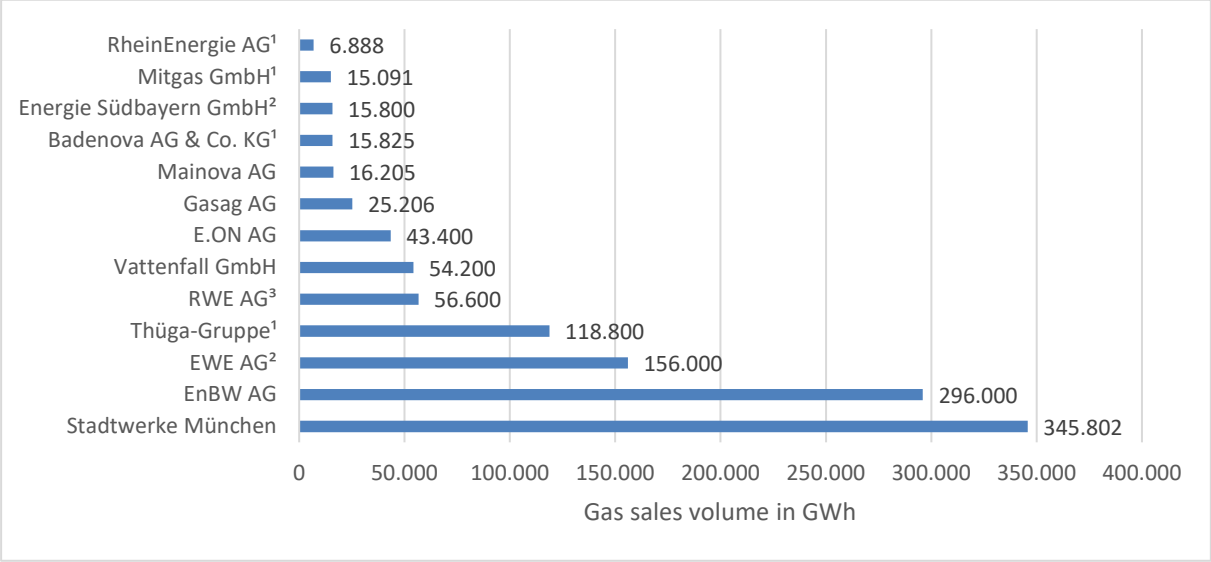

Figure 6: Important gas suppliers by gas sales in Germany in 2019 [13]

Stadtwerke München, EnBW AG, EWE AG and the Thüga Group have particularly high sales compared to the other companies. It should be noted that sales from Stadtwerke München include both natural gas and oil. The Thüga-Group consists of over 100 municipal utilities throughout Germany. Otherwise RWE AG, Vattenfall GmbH and E.ON AG play an important role in the gas market.

The district heating supply is dominated by large energy supply companies. However, municipal utilities are also often main actors. They act as producers, grid operators and traders at the same time. Thus, there are ten providers that control most of the district heating in the Ruhr area.

The main district heating operators in the Ruhr area are:

- DEW Dortmunder Energie- und Wasserversorgung GmbH
- ENNI Energie und Umwelt Niederrhein GmbH
- Uniper Wärme GmbH
- Energieversorgung Oberhausen AG
- Fernwärmeversorgung Herne GmbH
- Fernwärmeversorgung Niederrhein GmbH
- Hertener Stadtwerke
- Stadtwerke Bochum Gruppe (including FUW GmbH)
- Stadtwerke Duisburg GmbH
- STEAG Fernwärme GmbH

Legal framework and operational context for these actors

In the area of district heating, there is no regulated third-party access (TPA) in Germany. This is, among other things, due to the fact that district heating networks are self-contained local water- or steam-based supply systems where it is not readily possible to transfer the heat from external/third-party suppliers. District heating producers are usually also the owners and operators of district heating networks [14]. Additionally, there are several (unregulated) bilateral contracts between the owners/operators of district heating networks and heat suppliers (e.g. waste heat, waste incinerating plants). With regard to the design of district heating supply contracts, the Federal Ministry for Economic Affairs and Energy (BMWi) was authorized to design the general conditions for the supply of district heating of end customers. The BMWi has introduced such a regulation by decree of the AVBFernwärmeV [15]. For example, the AVBFernwärmeV stipulates that price change clauses may only be designed in such a way that they take account of both the cost development in the production and

supply of district heating by the company and the respective conditions on the heat market. They must identify the relevant calculation factors in full and in a generally comprehensible manner to ensure price transparency for the customer [16].

In addition, there is no restriction on who may build or operate a district heating network. This is very helpful for the future implementation of further D2Grids projects.

The heating market is strongly influenced by the requirements of various laws aimed at reducing energy consumption in the building sector.

The Energieeinsparungsgesetz (EnEG) was introduced with the aim to reduce energy consumption in the building sector. It enables the federal government to regulate the following aspects with respect to the heat domain (§1-§2a) [17]:

- Energy efficient thermal insulation in new buildings to reduce loss of energy (§1(1))
- New installations of energy-saving systems in buildings (concerning new installations of heating, room air technology, cooling and water supply systems, etc. specifically in the course of retrofitting) (§2(1))
- Building standards: Buildings with heating or cooling systems that are constructed after 31st December of 2020 have to meet criteria as "lowest energy buildings" ("Niedrigstenergiehaus") (§2a (1))

More regulations and standards set by the Federal Government are formulated in the Energieeinsparverordnung (EnEV). It states that buildings must comply with several minimum energy and heating performance standards and addresses technical aspects for example the replacement of oil and gas boilers, thermal insulation of ceilings and top floors or the application of energy performance certificates. [17]

Another law relevant for the domain was the Erneuerbare-Energien-Wärmegesetz (EEWärmeG), which was passed to increase the share of renewable energies for heating and cooling in the building sector to 14 % until 2020.

The Gebäudeenergiegesetz (GEG) has come into effect on 01.11.2020 and merged the EnEG, EnEV and EEWärmeG into one modern law. The GEG creates a uniform, coordinated set of regulations for the energy requirements for new buildings, for existing buildings and for the use of renewable energies to supply heating and cooling to buildings.

These laws encourage the use of district heating. On one hand, there is an obligation to exchange oil and gas boilers that are more than 30 years old. This gives an impetus to switch to a district heating connection instead of installing a new boiler. On the other hand, there are requirements for new buildings to use a minimum share of renewable energies. However, these requirements can be met through alternative measures. This includes connection to district heating grids that draw at least 50% of the heat from CHP systems.

Current organization of heating markets

The German gas market has been officially liberalized since 1998, but significant progress in liberalization is only measurable since 2007. For this purpose, network access has been significantly simplified and the number of market areas has been reduced in various steps from 19 to officially two [18]. The German gas market is currently divided into two market areas, each with separate H-gas and L-gas trading. The so-called entry-exit-model is used. With the amendment to the Gas Network Access Ordinance (Gasnetzzugangsverordnung) 2017, the transmission system operators were obliged to create a uniform Germany-wide market area from the two previous market areas NetConnect Germany and GASPOOL by April 2022 at the latest. [19]

In contrast to the gas market, there is no regulated TPA in the district heating market. There is kind of a monopoly structure since district heating grids are typically self-contained water or steam-based supply systems. This means that the district heating suppliers are usually the only providers within the respective network area. Thereby no direct competition exists, and customers cannot choose freely between different district heating providers. There is also no wholesale market for district heating. [20]. Traditionally, district heating suppliers are vertically integrated companies, i.e. they operate the heat distribution network and supply heat, mostly self-generated, to the customers connected to the network. They are therefore active in several markets: on the market for the transport of heat over the grid, on the other hand on the markets for the supply to industrial/commercial customers, large redistributors or household and small business customers [14].

3.1.2. Developments in heating policy and market contexts

Current developments in the legal system and market organization

The transition from the Energieeinsparungsgesetz (EnEG), the Energieeinsparungsverordnung (EnEV) and the Erneuerbare-Energien-Wärmegesetz (EEWärmeG) to the Gebäudeenergiegesetz (GEG) is currently taking place. The GEG implements the coalition agreement, the resolutions of the "Wohngipfel 2018" and the measures for the 2030 climate protection program with regard to energy saving law for buildings. A uniform coordinated set of rules has been created for the energy requirements for new buildings, for existing buildings and for the use of renewable energies for heating and cooling buildings [21].

The CO2 tax on gasoline, diesel, heating oil and gas has been in force in Germany since January 2021. Previously, only companies in certain sectors had to pay for CO2 emissions. These included, for example, airlines or industrial companies that produce a large amount of the greenhouse gas. With a uniform CO2 price, Germany aims to achieve its CO2 reduction targets. Thus, anyone offering goods or services that emit CO2 will have to pay this tax.

Germany will phase out coal-fired power generation by 2038 at the latest, and preferably as early as 2035. The first power plants will be taken off the grid in 2020, and by the end of 2022 only 30 gigawatts of today's 40 gigawatts of coal-fired power plant capacity (15 gigawatts each of hard coal and lignite) will still be in operation; by 2030 only 17 gigawatts (8 gigawatts hard coal and 9 gigawatts lignite) will remain.

However, there are support measures. Federal funding for efficient heating grids (heating grid systems 4.0) is handled by the "Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA)". This addresses innovative heating grid systems with a predominant share of renewable energies and waste heat. There are different funding modules. Feasibility studies can be supported with up to 60 % of the eligible expenditure. The implementation of a heating grid system 4.0 is subsidized with up to 50% of the eligible expenditure. However, this only applies to the construction of a new grid or the transformation of complete heating grid systems. Furthermore, it is possible that measures that aim to inform customers about the planned heating grid system are funded [22].

Expected developments in terms of energy transition policy or market transformations to accommodate green energy

The emissions in the heating sector remained the same between 2011 and 2017, because of the absence of a CO2 price. However, with CO2 certificates, incentives can be created to reduce CO2 emissions in a cost-effective manner using inexpensive technologies. This concept is already being used in the energy sector and industry, which enabled a reduction of 33.3 % respectively 31.0 % between 2005 and 2018 [23].

The CO2 pricing could be implemented in the form of a surcharge, based on the CO2 emissions, on the energy taxes of heating oil, natural gas, diesel and petrol. However, despite all the virulence of the current climate policy debate, it does not appear very likely that the building sector will be integrated into the European emissions trading soon [23].

From 2026 on, oil heating may not be installed at all or only as a hybrid system that integrates renewable energies. In addition, oil and gas boilers that are more than 30 years old must be replaced. A ban similar to that of oil heating is not foreseeable for gas heating. This can be attributed to the fact that the well-developed gas network would lose its usefulness.

In addition, there is a potential funding program by the Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie) called „funding for efficient heating networks" (Bundesförderung Effiziente Wärmenetze), which is expected to be passed in 2021. The Federal Association of Energy and Water Management (Bundesverband der Energie- und Wasserwirtschaft) is assuming that this funding program will be adopted in 2021 and that it will be of great importance for the implementation and advancement of the heating transition in Germany.

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

No regulatory body exists for DH in Germany to regulate a TPA. However, DH is affected by most of the laws ruling the energy sector, which have significantly evolved during the last decade. Some of these laws incentivize DH by supporting CHP, energy efficiency or renewable energy requirements in buildings. However, price setting as well as the design of contracts, on the other hand, are regulated by law (e.g. AVBFernwärmeV). Compliance with these requirements is monitored by the Cartel Office (at federal or regional level). In this respect, also compare the remarks in the heading "What is the legal framework and context these actors are operating in?" and section 4.2.3.

3.2.2. Ownership and operation of district heating systems

District heating suppliers are usually vertically integrated companies. Production, grids and sales are in one hand. The main actors are the large energy providers, grid operators and technology plant manufactures. In the DH and CHP technology field, it is hence mainly a few large plant-manufacturing companies (such as Siemens) who are driving innovations. In general, most DH plant and grid operators are partially publicly owned and partially private companies. [17]

The municipalities are key players in the heating transition, in particular because of their diverse connections to end-consumer-groups. Municipalities award concessions for heating grids and operate their own heating grids and power plants through the municipal utilities, sometimes in cooperation with citizens' cooperatives. Municipalities also create long-term climate protection concepts and energy plans and can use their own properties. [24]

In addition, district heating grids mainly run under public traffic routes and land owned by the respective municipality. To be able to lay district heating pipes and operate them, a district heating supplier is dependent on the respective municipality allowing the use of these areas.

3.2.3. Regulation of the price setting

District heating suppliers are usually vertically integrated companies. Generation, grids and sales are in one hand and determine acting in the grid islands. Thus, there is no competition and without regulation the prices could be "freely" determined by the providers [20]. However, the prices of the gas and oil providers play an important role. If the price for district heating is too high, the customer can change his heating technology. Therefore, district heating providers have to adapt to the prices of gas, oil and other influencing factors such as CO_2 emission allowances.

With regard to the design of district heating supply contracts, the Federal Ministry for Economic Affairs and Energy (BMWi) was authorized to design the general conditions for the supply of district heating. The BMWi has introduced such a regulation by decree of the AVBFernwärmeV. For example, the AVBFernwärmeV stipulates that price change clauses may only be designed in such a way that they take account of both the cost development in the production and supply of district heating by the company and the respective conditions on the heat market. They must identify the relevant calculation factors in full and in a generally comprehensible manner to ensure price transparency for the customer. Compliance with this ordinance (AVBFernwärmeV) and further requirements is monitored by the German Federal Cartel Office and the cartel offices at regional level.

3.2.4. Role of building owners and building occupants

Deciding the heat source of the building

In single-family buildings, the building owner decides about the heat source. There are laws that influence the type of heat source. For example, in new buildings, a certain percentage of the annual heat must be covered by renewable energy. Occasionally, it is a desire of the municipalities to promote district heating by introducing a so-called connection and use obligation. But in practice, municipalities nowadays introduce a connection and use obligation less and less frequently.

If several people own shares in the building, the parties must come to an agreement.

Investments and energy bill

The building owner pays for the investment. If it is an energy improvement, the owner is entitled to increase the annual rent of the occupants by 8 % of the costs.

The energy bill is paid by the end user.

3.2.5. Financing and subsidies

Localized subsidy or grant mechanisms available

In order to increase efficiency in the area of electricity and heat generation, the Federal Government supports the expansion of combined heat and power, in particular through the "Kraft-Wärme-Kopplungs-Gesetz" (KWKG). In addition to the electricity remuneration for CHP systems and the promotion of heat and cold storage, the KWKG provides funding for heating and cooling grids. A maximum of 20 million euros can be paid out per project, as long as the supply of consumers connected to the new or expanded heating grid is at least 75 percent from CHP heat. Alternatively, other heat mixes are also possible [25].

With the Market Incentive Program (MAP), the Federal Ministry for Economic Affairs and Energy (BMWi) offers subsidies for companies. Funding for the expansion or new construction of local heating networks is particularly interesting for large companies, provided that a certain proportion of heat distributed in the company is generated with renewable energies. Heating grids that are powered from renewable energies can receive a repayment subsidy of up to 1 million euros. If geothermal energy is used, this can even increase up to 1.5 million euros [26].

Municipalities can also benefit from the BMWi's market incentive program. The construction and expansion of heating grids are funded if they are powered by renewable energy. The term of the loan can be set variably up to 30 years, usually for up to 25 million euros per project. Up to 100 % of the eligible costs are financed [26].

See also description of funding programs under point 4.1.2. (Developments in heating policy and market contexts).

3.3. Available energy sources and storage

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the highest-ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low-grade sources would be in order to make a decent 5GDHC business case. At the time of writing, D.T1.1.4 has not been finalized.

Depending on the region and the country, there are different energy sources and storages. This can mostly be attributed to the different topography and available natural resources. For the development of 5GDHC it is relevant to know the different energy sources and storages. This allows planning from which source energy is to be drawn or whether another grid variant/generation such as 4GDHC is more advantageous. The focus is on renewable energies. However, the potential of fossil fuels is also considered.

The existing energy sources and storages in the Ruhr area can be estimated well. The reason for this are the diverse potential studies of the "State Office for Nature, Environment and Consumer Protection North Rhine-Westphalia" (Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)). Much of this information is entered in energy atlases and potential maps to provide easy access. For example, in the field of geothermal energy, the potential map of NRW can be accessed to check the productivity of geothermal probes. For the potential of mine water, the potential study "Warmes Grubenwasser" of the LANUV can be accessed. Furthermore, the use of old mine buildings as storage facilities is possible in the Ruhr area, which is an advantage over many other regions. As shown a lot of information is available via the NRW energy atlas.

This enables a summary of the energy sources and storages that are of interest for the implementation of 5GDHC. This is also particularly interesting for the implementation of further 5GDHC in the future. The list of the following subsections reflects the relevance of the forms of energy for 5GDHC, whereby the most important form of energy is mentioned first.

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

There is a great potential and a wide range of possible applications, but at the moment there are almost no figures or studies. There is only some minor talk about the advantages of the exchange between heating and cooling demands, which are represented in the following text.

Simultaneous cooling and heating is a requirement that often comes into play, particularly in larger commercial buildings, offices, shops and property construction. In one part of the building, heat must be dissipated (e.g. server room), while in another area, heating or hot water is required. An exchange between the superfluous and the required energy can take place here by means of appropriate systems.

Heating and cooling are also important issues in industry. More than 70 % of the final energy consumption in the industry is used for heating and cooling, the largest part of which is process heat. For this purpose, case studies were carried out in the research project "EnPro", which examined the use of heat pumps to shift heat and cold. The active cooling of industrial processes has received little attention as an efficiency potential so far. The BAT document on energy efficiency states that cooling should be combined with the use of heat, otherwise it would be wasteful. In all cases considered, the end and primary energy consumption and CO2 emissions are reduced. Therefore, the integration of a heat pump and thus the combined use of heat and cold leads to an increase in efficiency and a reduction in emissions [27].

3.3.2. Ambient thermal sources from soil, water, air, and low temperature solar heat

Warm mine water [28]

The closure of mines does not mean that the use of the underground mine tunnels and pits has to end. Mine water contains an energetic heat potential, which was investigated by the LANUV in a potential study.

It is possible to use the regional heat potential from warm mine water from former and still operating mining infrastructure in NRW. For this purpose, the LANUV limited the determination of the potential to areas in which the warm mine water occurs or is still accessible through an existing infrastructure. In NRW this concerns:

- The closed stone coal strip mines with
  - Drainage systems (pump stations)
  - Former mine shafts

Open systems have a mine water temperature of a maximum of 35 °C.

Table 1 shows the technical heating energy that can be obtained in the Ruhr area either by means of dewatering or sump measures or from mine shafts. The year 2035 was chosen as the reference year.

Table 1: Heating potential of mine water in the Ruhr area (2018) [29]

	Technical heating energy (MWh/a) (Reference year 2035)	
	Drainage	Mine shaft
Bochum	212424	1163.4
Bottrop	0	2728.7
Dortmund	0	3798.8
Duisburg	137510	412,3
Ennepe-Ruhr-Kreis	0	0
Essen	190253	3842.8
Gelsenkirchen	0	10614.1
Hagen	0	0
Hamm	0	4584.4
Herne	0	1539.1
Mühlheim an der Ruhr	0	0
Oberhausen	0	2742
Recklinghausen	0	26030.6
Unna	141564	10889
Wesel	729511	5575.2
Total	1411262	73920.4

Shallow geothermal energy [30]

Large amounts of energy are stored in the earth and new energy is constantly being produced. The use of geothermal energy in the upper 400 meters is called “shallow geothermal energy”.

NRW has a geothermal potential of 153.7 [TWh/year]. This is limited to shallow geothermal energy (up to 100 m) and geothermal probes. The heat requirement is 271.1 [TWh/year], which would allow a coverage of 56.7% by means of geothermal energy.

The graphic below shows the technically usable geothermal potential for each district.

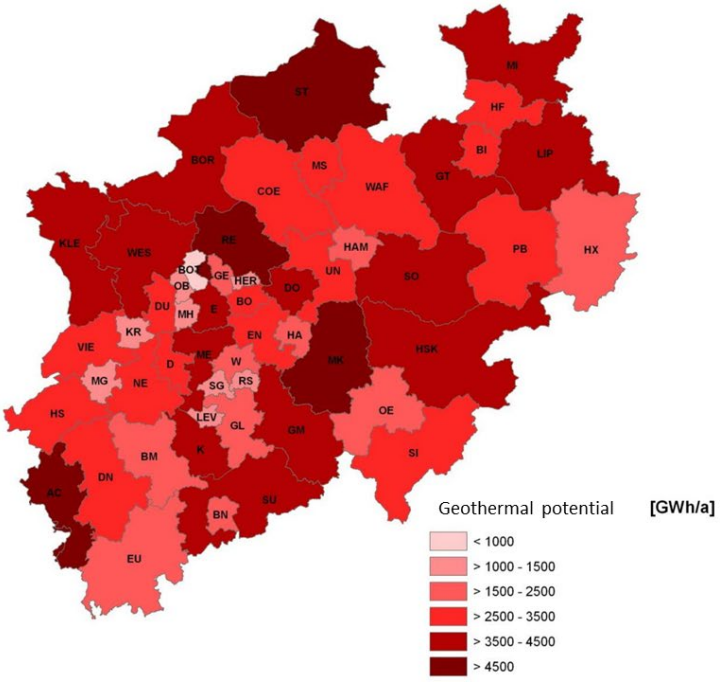

Figure 7: Potential of shallow geothermal energy in NRW (2015) [30]

The exact geothermal potentials in two scenarios of the Ruhr area are shown in Table 2.

Table 2: Geothermal potential of the districts and independent cities in the Ruhr area (2015) [29]

	Technical potential (GWh/a)	
	Scenario A	Scenario B
Bochum	2853.9	2806.3
Bottrop	918.3	851.4
Dortmund	3671.7	3602.4
Duisburg	3192.0	3062.2
Ennepe-Ruhr-Kreis	3470.0	3194.5
Essen	4248.1	4196.7
Gelsenkirchen	1775.3	1769.5
Hagen	1527.8	1485.9
Hamm	1631.5	1631.5
Herne	1128.6	1128.6
Mühlheim an der Ruhr	1312.5	1218.3
Oberhausen	1456.4	1456.4
Recklinghausen	5182.0	4958.8
Unna	3350.2	2980.2
Wesel	4252.6	3760.5
Total	39970.9	38103.2

Due to an inhomogeneous approval practice regarding the limitation of use in hydrogeological critical areas and water protection zones, two scenarios were considered: Scenario A with a depth limitation of 40 m and water as brine liquid and Scenario B with a complete exclusion of use.

The highest potential is in Recklinghausen with 5182.0 (GWh/a) and the lowest in Bottrop with 919.3 (GWh/a).

3.3.3. Higher temperature renewable sources like geothermal, solar heat

Deep geothermal energy

Deep geothermal energy is the use of geothermal energy at depths between 400-5000 meters. Compared to shallow geothermal energy, the temperatures are much higher.

Two geological aspects can be identified for deep geothermal development:

- Thickness >> 100 m
- Widespread over the Ruhr area.

The following figure shows the geothermal potential for the formation "Kulm / Kohlenkalk". The temperature of the potential is over 80° C.

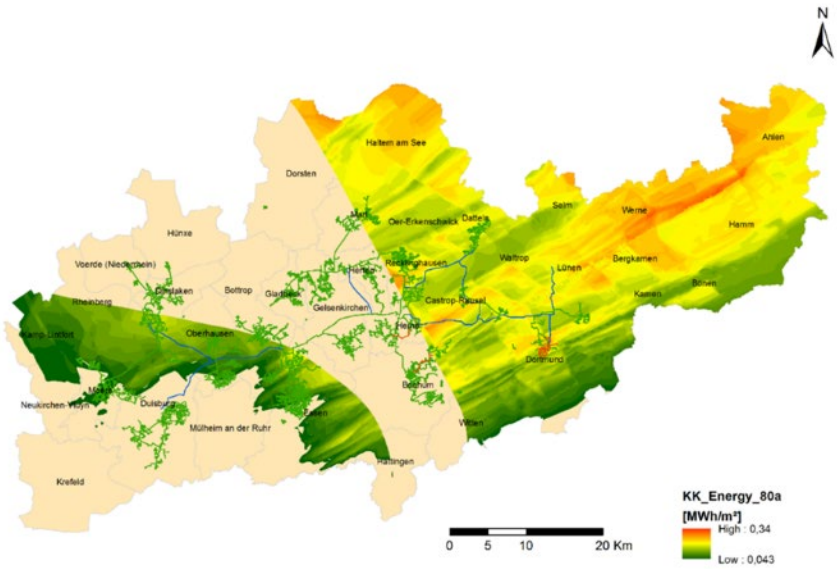

Figure 8: Geothermal potential of the formation "Kulm / Kohlenkalk" in NRW [9]

The geothermal potential for the mass limestone formation is shown in the figure below. The temperature of the potential is over 80° C.

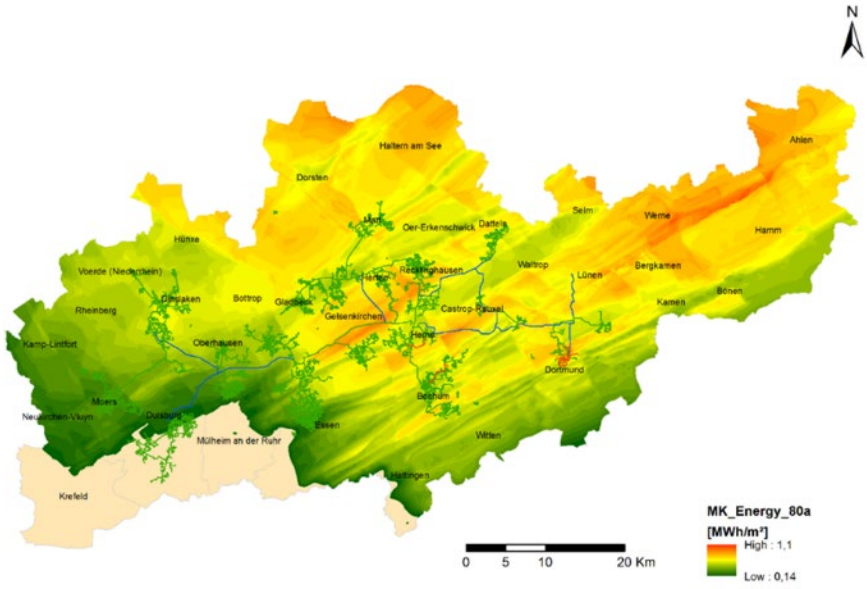

Figure 9: Geothermal potential of the formation "Massenkalk" in NRW [9]

Figure 10 and 11 show that the geothermal potential for the formation “Kulm / Kohlenkalk” as well as for the formation “Massenkalk” is the highest in the north of the Ruhr area and decreases more and more towards the south.

Solar thermal energy [31]

Solar thermal refers to the use of solar energy with the help of solar collectors for the provision of heating and hot water. In this way, the enormous energy potential of the sun can be used and fossil fuels and thus heating costs can be saved.

In 2016, more than 570 GWh of heat was generated with an area of about 1.5 km^2 of solar thermal collectors in NRW. Bochum has a solar thermal potential for heating water of > 50-100 (GWh/a).

In NRW, the theoretically producible amount of heat by means of solar thermal energy is 214.9 [TWh/year]. In the Ruhr area the production of 45.1 [TWh/year] of heat is theoretically possible. The annual growth rate in solar thermal energy has been at a relatively low and consistent level since 2010. The following figure provides an overview of the distribution of usable solar thermal energy potentials at the district level.

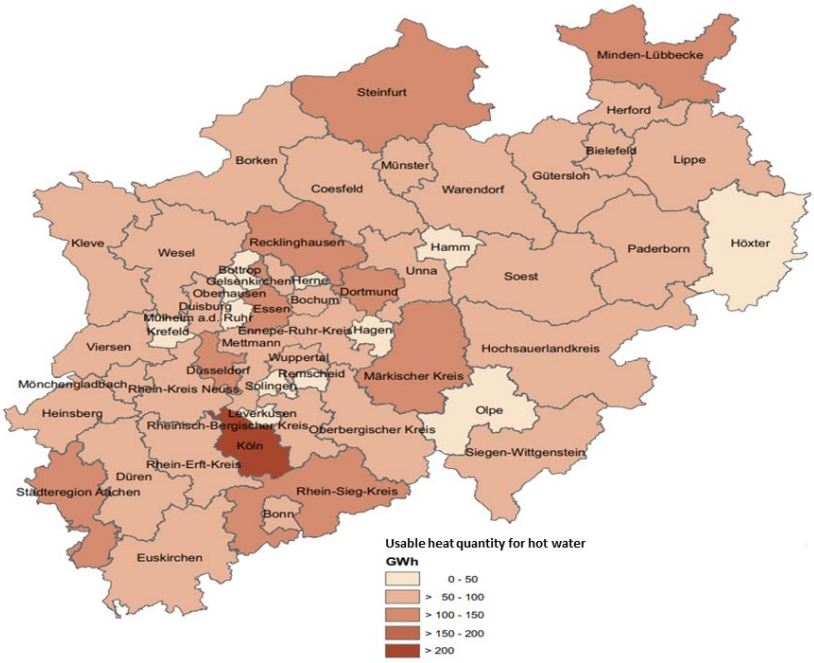

Figure 10: Solar thermal potential in NRW (2018) [32]

Table 3 shows the solar thermal potential of the districts and district-free cities in the Ruhr area. Essen has the highest potential with 138 (GWh/a) and Bottrop has the lowest potential with 24 [GWh/a].

Table 3: Solar thermal potential of the Ruhr area (2018) [29]

	Usable amount of heat for hot water processing (GWh/a)
Bochum	69
Bottrop	24
Dortmund	111
Duisburg	99
Ennepe-Ruhr-Kreis	89
Essen	138
Gelsenkirchen	53
Hagen	47
Hamm	39
Herne	35
Mühlheim an der Ruhr	33
Oberhausen	42
Recklinghausen	141
Unna	93
Wesel	99
Total	1112

3.3.4. Higher temperature industrial waste heat, otherwise rejected in the environment

In Germany, heat is the most important process energy for the industry. A secure energy supply is one of the most important location factors and decisive for the profitability of a company and the attractiveness of a region. More than one

third of the process energy used in industry is lost globally as waste heat. The reuse of waste heat is therefore a necessary step, both from an economic perspective and in terms of sustainability. [10]

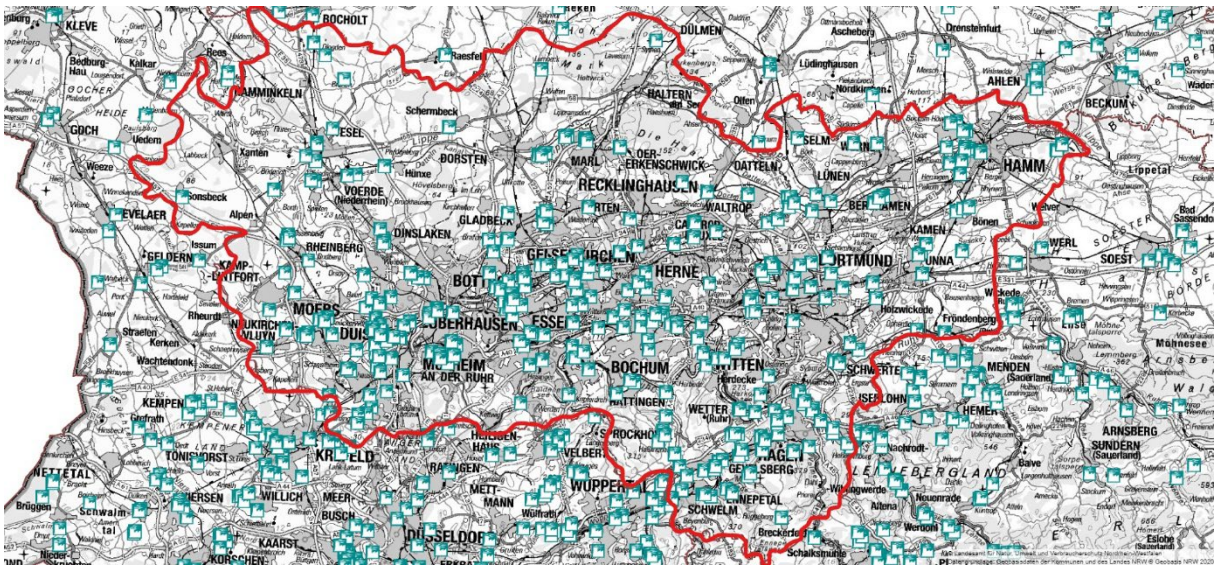

Figure 11: Locations of industrial companies with waste heat [33]

Figure 13 shows the locations of industrial companies that were classified as “potentially relevant for waste heat” in the industrial waste heat study in NRW. It can be recognized that a very large number of locations in the Ruhr area can deliver waste heat. The north-eastern part has a lower density of locations compared to the core or south of the Ruhr area.

In total there is a technically usable waste heat potential of approximately 44 – 48 [TWh/year] in NRW.

In figure 14, the Ruhr area is circled with a red line. The waste heat potentials of the industrial sites in the districts and district-free cities in NRW were aggregated in figure 14. Duisburg and the Rhein-Erft-Kreis represent the highest waste heat potentials with 2.1 [TWh/year] (18%) and 1.4 [TWh/year] (12%) at the county level. The lowest potential is in Remscheid. The following table shows the waste heat potential for the Ruhr area. [10]

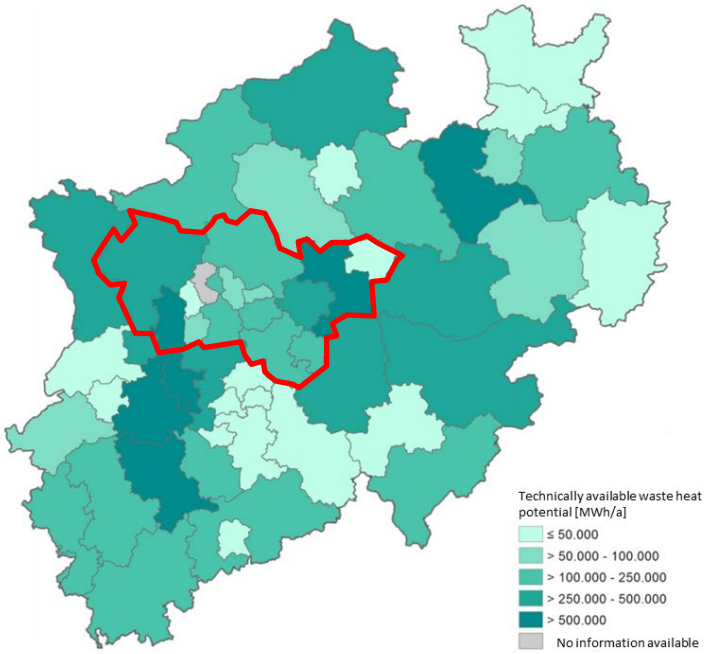

Figure 12: Potential of waste heat in NRW (2019) [10]

Table 4: Waste heat potential of the districts and independent cities in the Ruhr area (2019) [29]

	Technically available waste heat (GWh/a)
Bochum	134.1
Bottrop	0
Dortmund	313.7
Duisburg	2146.5
Ennepe-Ruhr-Kreis	107.9
Essen	158.8
Gelsenkirchen	99.3
Hagen	200.6
Hamm	14.2
Herne	51.5
Mühlheim an der Ruhr	75.9
Oberhausen	16.3
Recklinghausen	152.5
Unna	708.0
Wesel	267.4
Total	4446.7

3.3.5. Renewable electricity from local sources like wind, sun

Within the borders of NRW, 19774 GWh of electricity was generated by renewable energies (2017). 8855 GWh were generated by wind energy, 3556 GWh by photovoltaics (roof) and 6202 GWh by biomass. The rest was produced by other energy sources such as hydropower and mine, landfill and sewage gas. This represents 12.6% of the electricity generation. [34]

Exact values are not available for the Ruhr area.

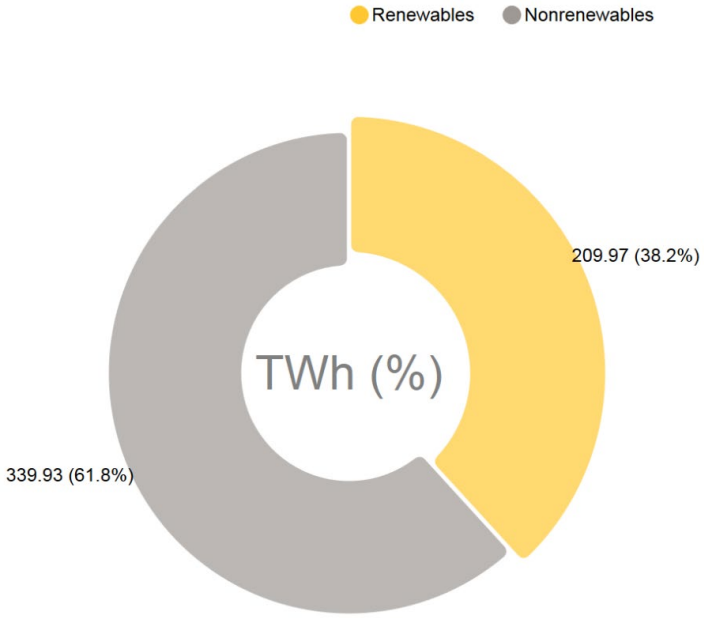

Figure 13: Total net electricity generation in Germany (2017) [35]

As can be seen in Figure 15, the share of renewable energy (yellow) in Germany in 2017 was 38.2 %. This means that the share of renewable energy sources in electricity generation in Germany is almost three times as high as in NRW. The reason for this is the high proportion of lignite used for electricity generation and the high population density in NRW. However, NRW has the potential to generate 46.7 GW_P with photovoltaic modules if all suitable roof surfaces in NRW are filled with modules. This could generate an annual electricity yield of 38.7 TWh. [31]

3.3.6. Electricity use at times of renewable overproduction, e.g. when spot price is low

For now, this is only relevant in areas with known overproduction, like the north of the Netherlands (overproduction of PV) and the north of Germany (wind).

3.3.7. Electricity mix from the external grid

Germany generated 515.56 TWh electricity in 2019 [35]. The electricity mix consists of:

- Nuclear: 71.09 TWh (13.8%)
- Brown coal: 102.18 TWh (19.7%)
- Hard coal: 48.69 TWh (9.4 %)
- Natural gas: 54.05 TWh (10.5 %)
- Renewables: 237.41 TWh (46.1 %)

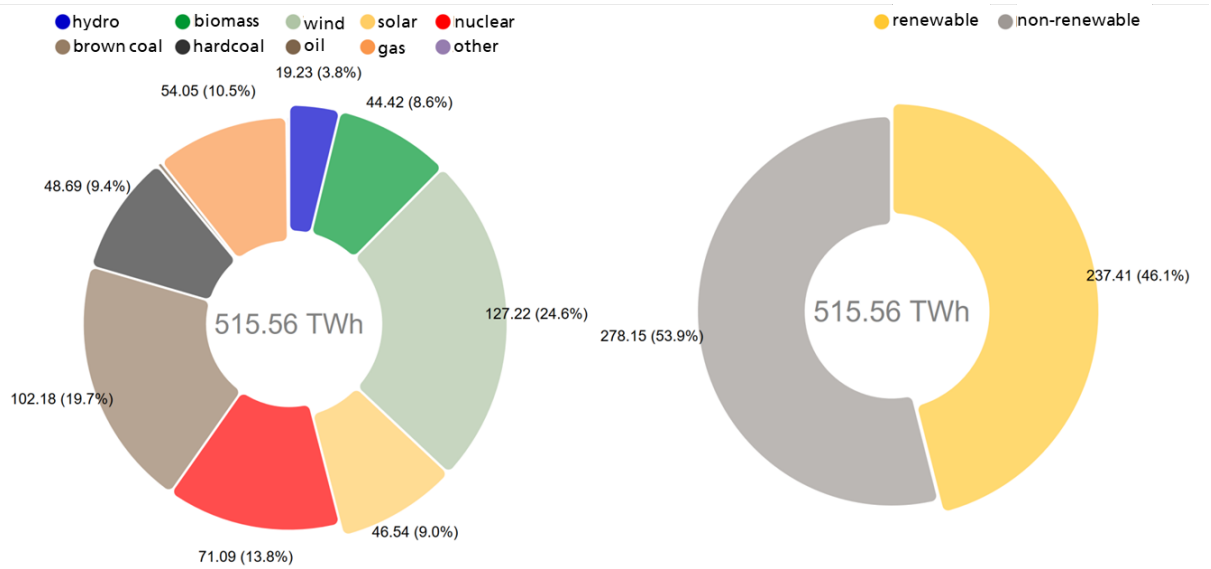

Figure 14: Net electricity generation in Germany in 2019 [35]

3.3.8. High temperature heat from burning biofuels, biogas, biomass

Figure 17 presents the biomass plants of the Ruhr area. It can be clearly seen that biomass plants are operating in the entire Ruhr area. There are over 100 biomass plants in total.

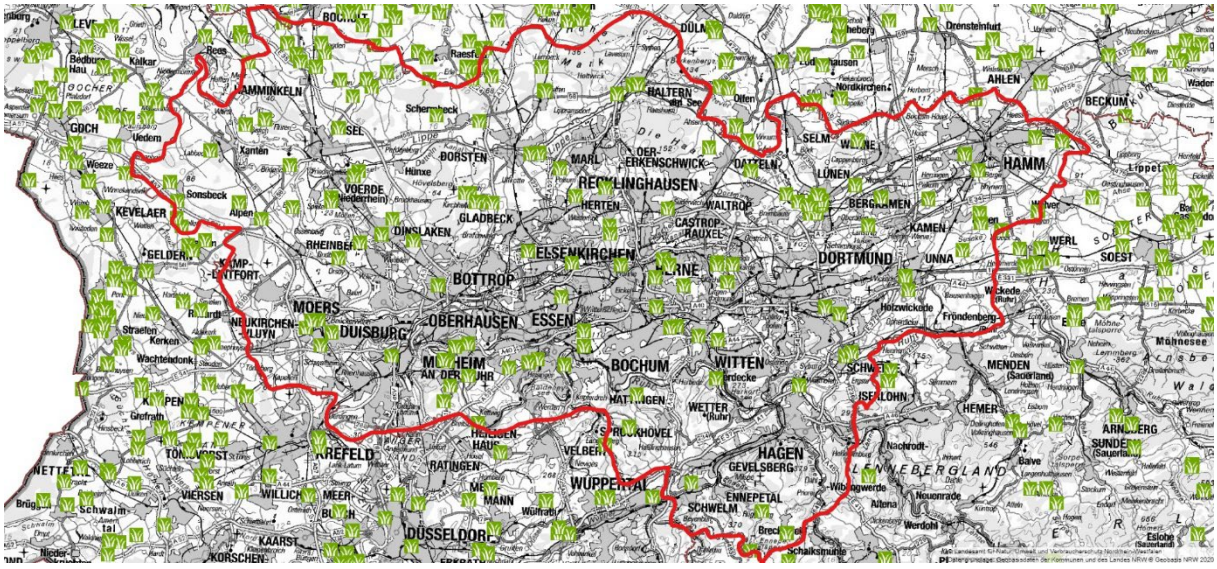

Figure 15: Biomass plants in the Ruhr area [34]

In addition, the potential of energy from biomass was researched. The minimum and maximum feasible potentials as well as the potentials of the NRW lead scenario were compared with the electricity and heat produced by biomass today. It shows that especially agriculture has the possibility of generating a large amount of heat with biomass [36].

Table 5: Potential of biomass of the sectors Landwirtschaft (agriculture), Forstwirtschaft (forestry) and Abfallwirtschaft (waste industry) in NRW (2014) [36]

Sector	Electricity [TWh/year]			Heat [TWh/year]			Already produced [TWh/year]	
	Minimal	Reference value	Maximal	Minimal	Reference value	Maximal	Electricity	Heat
Agriculture	2.60	4.65	9.57	11.36	12.00	15.64	1.41	1.75
Forestry	0.16	0.16	0.22	3.25	4.25	5.53	0.15	3.03
Waste Management	2.9	3.54	3.54	6.30	7.27	7.27	3.09	6.17
Sum	**5.66**	**8.35**	**13.33**	**20.91**	**23.52**	**28.44**	**4.65**	**10.94**

3.3.9. High temperature heat from burning fossil fuels

CHPs can generate mechanical energy and usable heat at the same time in a joint process. There are already some power plants in NRW that use combined heat and power [37]:

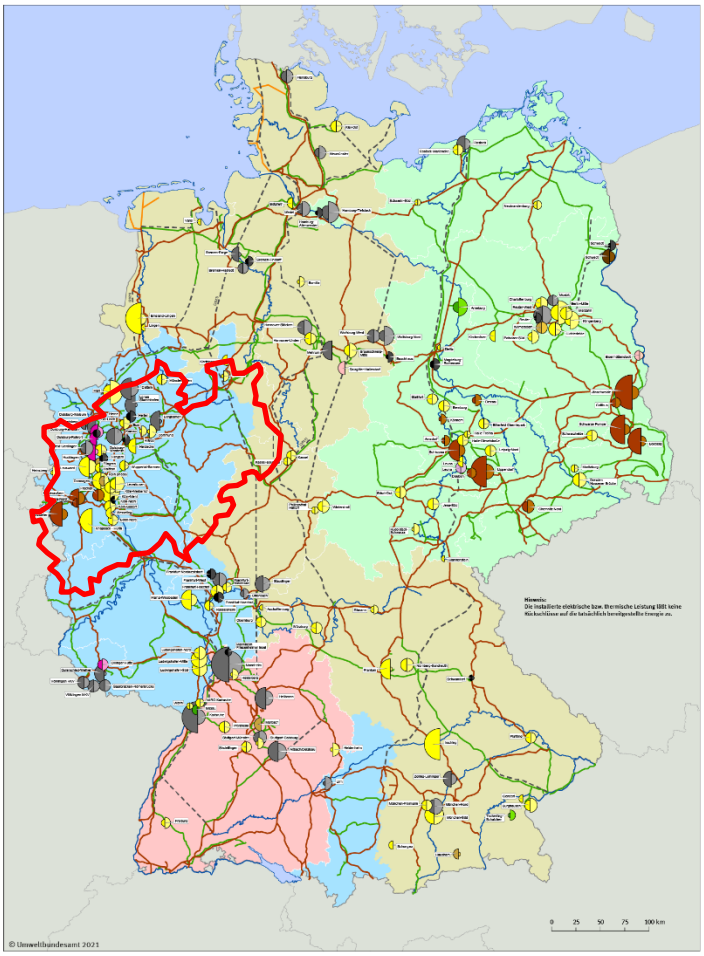

Figure 16: Power plants with CHP in Germany [38] (2020)

Figure 19 represents power plants with CHP in Germany, which have at least a capacity of 50 MW_{el} or 100 MW_{th}. NRW is located in the center of the west of Germany (red circled). It can be clearly seen that many power plants use CHP in NRW. Thus, there is a very good possibility to obtain heat from power plants in NRW. Overall, hard coal and gas plants are the most common. But there are also some lignite power plants, furnace plants power plants and waste power plants, which use CHP.

3.3.10. Low grade thermal storage possibilities

Low grade thermal storage is possible with flooded underground infrastructure, natural aquifers and artificial aquifers. But these storages aren't usable in every region. In the following the possibilities/potentials in the Ruhr area are considered.

There is the possibility of using the mine water in many mines in the Ruhr area to store heat. For the establishment of such underground thermal storage facilities, appropriate infrastructure measures must be carried out in the mine and suitable access and conveying systems must be developed. HEATSTORE is a project, which aims to accelerate the implementation of geothermal energy by promoting various types of underground heat storage facilities (UTES), providing a means to maximise geothermal heat production and addressing technical, economic, environmental, regulatory and political aspects, necessary to support the efficient and cost-effective use of UTES technologies in Europe.

Aquifer Thermal Energy Storage (ATES) is a suitable technique to supply buildings with large amounts of heating and cooling. ATES bridges the seasonal mismatch between the ambient temperature and the heating or cooling demand of a building. At the moment only four ATES exist in Germany. [39]

Borehole Thermal Energy Storage (BTES) use the underground rock to store heat. Geothermal probes are inserted up to 100 m deep into the ground in vertical or inclined boreholes. The heated water is led through these geothermal probes into the subsoil, where it heats the rock. Every shallow geothermal system can basically be used as a storage facility.

4. SWOT analysis

Given the information gathered above on the market and on availability of energy resources, an analysis of the strengths, weaknesses, opportunities and threats when implementing 5GDHC in the region can be made. The SWOT analysis will help to interpret the information given earlier and will as such help to understand which locations might be better suited for 5GDHC.

4.1. Strengths

4.1.1. Many unused mine structures

The Ruhr region has many disused mines and mine shafts. The existing warm mine water can be used as an energy source for 5GDHC. With its low temperature level of 13 °C - 35 °C it is perfectly suitable to supply low-temperature networks with temperatures of 50 °C.

4.1.2. Intercommunal cooperation

Intercommunal cooperation refers to the cooperation of municipalities, cities belonging to or independent of districts, as well as districts for the realization of common goals and tasks. Important task areas of intercommunal cooperation are in the field of spatial planning, technical infrastructure and environmental protection. 5GDHC is particularly dependent on other systems to function successfully. Through the joint implementation of such a project, the combination of the different systems can be secured.

4.1.3. High waste heat potential due to industrial structure

In Germany, heat is the most important process energy for the industry. Due to the dense industrial structure in the Ruhr area, there is a high production of waste heat. This waste heat potential can act as an energy source for 5GHDC. 4.4 TWh/year would be technically usable.

4.1.4. Densely populated area

With its 1152 inhabitants/km^2, the Ruhr region is one of the most densely populated areas in Europe. This plays into 5GHDC's cards, as many heat consumers live in a small area. This leads to reduced heat losses due to transport.

4.1.5. High potential for geothermal probes

In the Ruhr area, there is a high geothermal potential, especially for borehole heat exchangers. This is already being used by many private households and forms a good basis as an energy source for 5GDHC.

4.2. Weaknesses

4.2.1. Already existing high temperature district heating network

District heating networks already exist within the Ruhr area. However, these are operated with a high temperature level of 130 °C - 180 °C. This makes it impossible to combine the existing networks with 5GHDC. This means that certain areas cannot be developed for 5GDHC.

4.2.2. High proportion of old buildings

In the Ruhr region, 73 % of buildings were built before 1979. The energy demand of these buildings is correspondingly high because they are not well insulated. At the same time, the old radiators require very high flow temperatures. This contradicts the low flow temperature of 5GDHC.

4.2.3. Lack of sample projects as examples

Since this is a pilot project, there are no comparable projects from which information, improvements or assistance can be drawn. This is always a deterrent for stakeholders, as it means an uncertain investment.

4.2.4. Huge variety of independent district heating suppliers

Within the Ruhr region alone, there are 10 different district heating operators running their own networks. This means that the barrier to market entry is particularly high and it is difficult to find a firm foothold in the market. It will therefore be difficult to implement 5GHDC.

4.3. Threats

4.3.1. Waste heat will dissipate as a result of structural changes

The above-mentioned strength of the high potential of waste heat will decrease more and more in the future. This can be attributed to the coming structural changes due to climate targets. Industrial plants have to become more and more energy efficient and at the same time the operation of power plants will be discontinued. Waste heat currently functions as a good energy source, but it will become increasingly scarce in the coming decades.

4.3.2. Low prices for gas and no prospect of improvement

More than half of the apartments in NRW use natural gas. Due to the low gas prices, many building owners choose gas heating or do not consider switching to district heating. Moreover, there is no prospect of gas prices rising in the near future.

4.3.3. Future regulation of the district heating market

The district heating market is not currently regulated like the gas or electricity market. However, it is repeatedly stated that regulation of the district heating market is important and must come about. There are no firm plans for this, but there are various ideas ranging from network access regulation to regulation of the overall district heating price. Changes in the district heating market are therefore to be expected in the future.

4.4. Opportunities

4.4.1. Many different funding opportunities

There are many funding opportunities in the field of renewable energies. District heating is also supported, for example, by the BAFA's "Wärmenetze 4.0" (Heat networks 4.0) model or, in the future, by the Federal Ministry of Economics and Technology's "Bundesförderung effizienter Wärmenetze" (Federal funding for efficient heating networks) investment support program. At the same time, measures are promoted that lead to an increase in the energy efficiency of a building or the connection to a heating network. This promotes the use of district heating.

4.4.2. Pressure to act due to climate targets

The use of district heating will also become increasingly relevant in the future, as the climate targets set by Germany are to be met by 2030 and 2050. For example, the building sector is to emit only 70-72 million metric tons of CO2 equivalents

(direct emissions) by 2030 - a reduction of 66-67 percent compared with 1990. Major efforts are needed in the building sector to achieve this very ambitious target.

For this, classic heating technologies such as gas and oil must be left behind and climate-neutral methods such as district heating in combination with renewable energies must be resorted to. Here, 5GDHC in particular can play an important role, as it accesses environmental energy for heating.

4.4.3. Extensive experience with heat pumps

Germany has expertise in the use of heat pumps. Due to the legal regulations for new buildings, a certain proportion of the heat consumption must be covered by renewable energies. For this purpose, many people resort to heat pumps. In 2020 alone, 120000 heat pumps were installed, which corresponds to a growth of 40% compared to last year.

5. Regional vision

5.1. High potential areas and potential pilot sites

There is a great difficulty in determining concrete possible future project areas for the Ruhr area and deducing the corresponding potentials. There are no uniform or general area development plans for the Ruhr area. The huge variety of independent district heating suppliers in the Ruhr area is a challenging aspect in terms of a further roll-out of 5GDHC in the region. Nevertheless, as the previous chapters show, there are good conditions and potentials for a further roll-out of 5GDHC technology in the Ruhr area. In addition, it can be assumed that the successful completion of the pilot project in Bochum on the Mark 51° 7 site can serve as a model and inspiration with enormous radiance for further projects in the region. However, it should be pointed out once again that the authorities/competences of the Bochum project partners in order to stimulate and plan follow-up projects in other parts of the Ruhr area are severely limited.

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Interreg North-West Europe D2Grids

European Regional Development Fund

WORK PACKAGE: WPLT

DELIVERABLE NUMBER: DEL.1.3

TEMPLATE PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN 7 FOLLOWER REGIONS

July, 2022

SW Public
General

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Data sources:

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Contents

1. Introduction

Activities in the Long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories ("follower regions"). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. This document is a template for regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology in the 7 follower regions as defined in the application form: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project, has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. This document explains the method for conducting a preliminary feasibility assessment for 5GDHC in a region. It includes some generic sources and methods of calculation, but these need to be supplemented with region-specific sources to come to a reliable regional analysis. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

2. Characterising the region

In this report, the entire follower region of Scotland is being analysed. Very little implemented 5GDHC in Scotland to date, and as such this report will focus om how Scotland will look to integrate 5GDHC as a technology option for low carbon heat, through both legislative and practical elements.

Political environment

For Scotland, the Climate Change (Scotland) Act 2009 set a target renewable heat target for Scotland. Scotland's Energy Strategy, published in December 2017, set out the Scottish Government's vision for a flourishing, competitive energy sector, delivering secure, affordable, clean energy for Scotland's households, communities and businesses. Delivery of the Strategy is monitored via an Annual Energy Statement alongside the Annual Compendium of Scottish Energy Statistics (ACSES[1]). The Scottish government plan to publish a first review to the Energy strategy in Autumn 2022. The plan is to further refine the approach to heat de-carbonisation, ensuring a 'coherent whole-system view and further embedding our evolving policies within our wider approach to delivering on a just transition'.

Energy usage and climate ambitions

Scotland still relies heavily on gas for domestic heating purposes, with 80% of homes still utilising gas boilers. In 2020 Oil and Gas made up 78.4% of all Scottish energy consumption and 91% of heat demand.

The UK has set a Net-Zero carbon emissions target for 2050 in the UK (2045 in Scotland). In order to meet these targets meet Net Zero targets the UK need to convert 20,000 homes a week to low carbon heating.

Climate Change (Scotland) Act 2009 set a target renewable heat target for Scotland to reach equivalent of 11% of fuels (other than electricity) consumed for heat[2].

From a 2005-2007 baseline, Scottish Energy consumption was down by 13.1% in 2018. In 2019 24.6 % of Scottish households were classified as being in Fuel poverty, 12.4 % of which were classed as in extreme fuel poverty.

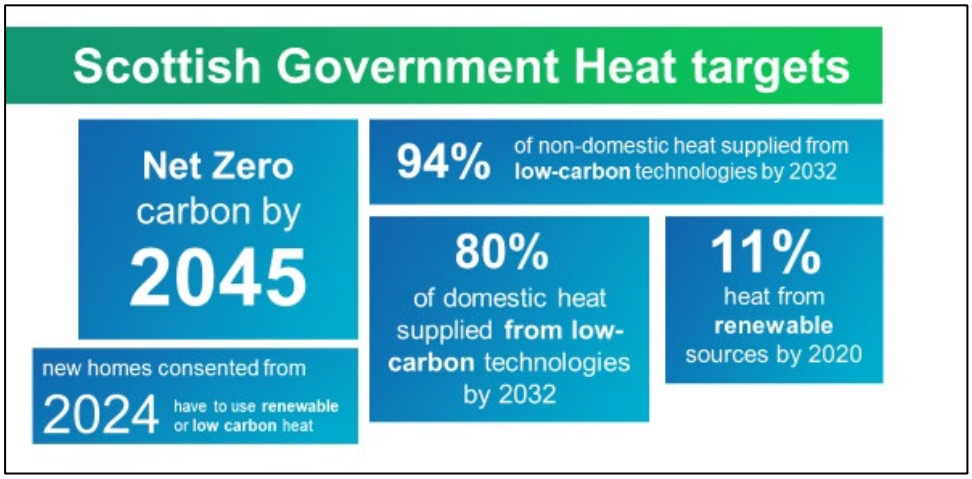

Figure 1. Scottish Government heat targets

[1] Annual Compendium of Scottish Energy Statistics 2020 (Scottish Government) ACSES+2020+-+December.pdf (www.gov.scot)
[2] The 2020 11% renewable heat target was set by the 2009 Renewable Heat Action Plan which was replaced by the 2015 Heat Policy Statement and the 2020 Routemap for Renewable Energy in Scotland. The 2021 Heat in Buildings Strategy replaces these earlier plans for the promotion of heat from renewable sources, and sets a provisional renewable heat target that will be reviewed in the 2022 Energy Strategy and Just Transition Plan.

Overall the annual compendium report 2020 found that Scottish energy consumption was down by 31.1% compared to 2018 (see fig 2 below)

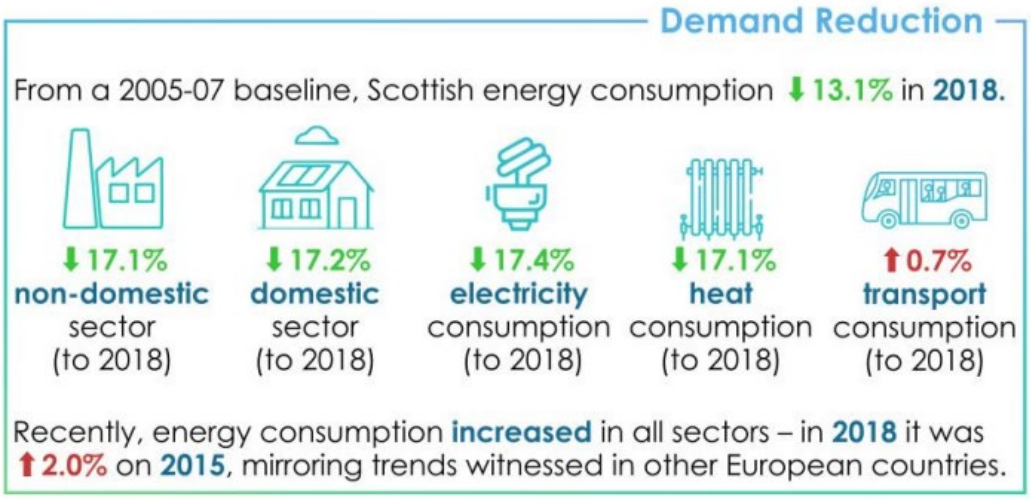

Figure 2. Energy demand reduction in Scotland [3]

There are only 2 implemented 5GDHC schemes in Scotland to date. Work so far has been to identify the opportunity for District heating generally (3GDH and 4GDH) and mapping to date has been on these rather than 5GDHC. In 2017 the Scottish Government introduced the concept of Local Heat and Energy Efficiency Strategy (LHEES), which set-out the long term plan for decarbonising heat in buildings across local authority areas. A pilot scheme has just been completed, with an evaluation report published in January 2022[4], the output of which will be taken forward for national rollout. The pilot scheme has resulted in detailed mapping of pilot regions and identification of heat network opportunities. Additionally, the pilot gives an understanding of energy efficiency and decarbonisation requirements for heating in pilot areas, and addresses the requirements for Funding, Skills development, external support requirements and partnership working in the delivery of low carbon heat in Scotland.

Energy-efficiency of buildings

The 2019 Scottish House Condition Survey found that Scotland's 2.5 million homes account for around 13% of the nation's total greenhouse gas emissions. Currently 55% of properties are still rated beneath the Energy performance Certificate (EPC rating) of C). To meet the 2045 net zero target, Scotland has committed to look at homes and buildings.

[3] Annual Compendium of Scottish Energy Statistics 2020
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[4] Local Heat and Energy Efficiency Strategy (LHEES) Pilot programme: Synthesis evaluation (Jan 2022) 5. Next steps - Local Heat and Energy Efficiency Strategy (LHEES) pilot programme: synthesis evaluation - gov.scot (www.gov.scot)

3. Analysis

In the next section gives a more detailed analysis of Scottish energy systems. Specifically, we look at the current heating context in Scotland, the current position of district heating, and at the type of energy sources and storage currently available in Scotland.

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

Currently dominant heating technology in the region

Currently in the UK, more than 80% of UK homes (24 million) still use natural gas. Heating is the UK's largest source of greenhouse gas emissions, and he widespread de-carbonisation of heat is challenging.

According to the 2019 Scottish House Condition Survey[5] Scotland's 2.5 million homes account for around **13%** of the nation's total greenhouse gas emissions. To meet the 2045 net zero target Scotland has committed to turn attention to the efficiency of homes and buildings. In 2019, 81% of Scottish homes used mains gas as their heating fuel. 2% of non-domestic buildings are on the lowest energy performance (EPC) band G, and around 50% of these properties are using Heating, ventilation, and **air conditioning** (HVAC)

The same survey revealed that just 278,000 Scottish households (around 11%) are heated using a renewable or low carbon system, and while the energy efficiency of Scotland's homes is improving, around 55% of properties are still rated below the recommended minimum Energy Performance Certificate (EPC) rating of 'C'

Renewable heat

The Scottish 'Annual compendium of Scottish energy Statistics reported that Scotland generated 5,205 GWh of renewable heat in 2019, a rise of 4,8% since 2019. This is equivalent of supplying 385,000 Scottish homes with gas for the year, and represents 6.5% all non- electrical heat demand.

District heating only takes up a very small place in Scotland to date. Progress towards the renewable heat target In 2020, for useful renewable heat produced in Scotland was equivalent to 6.4% of fuels (other than electricity) consumed for heat. This realized an increase from 6.2% in 2019. The majority of this heat came from biomass, contributing 70% of useful renewable heat. The next largest contribution was biomethane at 14%. Growth in renewable heat from 2019 to 2020 was limited by a 52GWh output reduction from large biomass sites due to changes in operation at a small number of sites. Whilst biomass and biomethane dominate renewable heat generation, there has been a steady growth in heat produced by heat pumps. Heat pumps saw the largest increase in number of installations and output with an additional 3,020 installations.

In 2020 the Energy Saving Trust published their renewable heat in Scotland report[6]. In 2020, 6.4% of non-electrical heat demand was met by renewable technologies which places Scotland a little over half-way towards the target of 11% by 2020. This represents an increase of 4.5 percentage points (up from 1.9%) since 2010 and an increase of 0.2 percentage points from 2019.

An estimated 5,008GWh of useful heat output was generated by renewable technologies in 2020, an increase of 2% (83GWh) from 4,925GWh in 2019 and more than triple the output generated in 2010 (1,667GWh). The increase in output between 2019 and 2020 was primarily from heat pumps (83GWh), medium sized biomass installations (32GWh) and biogas (19GWh).

[5] Scottish House condition survey 2019 Acknowledgements - Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)
[6] https://energysavingtrust.org.uk/report/renewable-heat-in-scotland-2020/#:~:text=Summary%20of%20key%20findings,target%20of%2011%25%20by%202020.

Overall growth has been limited by a 52GWh output reduction from large biomass sites due to changes in operation at a small number of these sites.

2.14GW of renewable heat capacity was operational in Scotland by the end of 2020, up from 2.06GW in 2019 and from 0.44GW in 2010.

District heating in the current heating regime

Heat Networks currently meet circa 2% of heat demand in the UK (Including Scotland), with natural gas as the primary fuel source. In Scotland, a national comprehensive assessment by BEIS1 found that economically viable heat networks could supply 28% of total heat demand. 5GDHC could make up a subsection of this heat supply, although the immaturity of the technology makes it difficult to make a specific assessment of the exact scale for its application.

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

As detailed in section 3 above the Scottish policy environment is generally very supportive of heat networks. Policy has enabled targeted financial support towards low carbon heat networks, however the Scottish regulatory landscape for district heating is very much still under development. New district heat networks will need to below carbon in order to attract government funding, however it is important to clarify that at present both legislative and funding positions relate to district heating generally and are not specifically targeted to support 5GDHC.

Regulation of heating networks in Scotland

The devolution of heat policy and heat network regulation across the UK is complex. In Scotland heat policy is devolved, but consumer protection is reserved to the UK Parliament. Unlike gas and electricity, heat networks do not currently have an official regulator in Great Britain. This means that while the supply of gas to a heat network is regulated, the supply of heat from the network to homes is not.

Regulation of heating networks in Scotland falls under several complimentary themes

The **HEAT NETWORKS (SCOTLAND ACT) 2021** sets out the first steps towards regulating heat networks in Scotland. It is intended to enable increased deployment of heat networks across the country. The definition of heat networks is very wide but would include 5GDHC in addition to 3G and 4G technologies. The legislation focusses on the Renewable sources of production and use of waste heat are relevant considerations for licensing and regulation of networks, but as yet, the legislation should be viewed as 'enabling legislation', with further detail to follow in Secondary legislation, which may not be fully rolled out until 2024.

Heat Network delivery plan

The Heat network Delivery plan was Issued March 2021 as a requirement of the Heat Networks act. It sets out a strategic level plan focused on the following;

- Sets out a programme for rolling out regulation
- Includes Heat network targets of targets for 2027 and 2030 (6twh)
- Describes the approach to buildings and developments to facilitate connections
- Sets out wider policy such as skills and fuel poverty
- Gives detail on Capital programme and funding

There is no specific provision within the plan for 5GDHC, and there are limited references to renewable heat networks. The plan does however confirm 90% non- domestic rates relief for heat networks using renewable heat generation until March 2024, but does not confirm any obvious substitute for the current Renewable heat incentive (RHI)

Policy environment is generally supportive but perhaps a lack of targeted support.

3.2.1. Ownership and operation of district heating systems

The devolution of heat policy and heat network regulation across the UK is complex. In Scotland heat policy is devolved, but consumer protection is reserved to the UK Parliament. In February 2022 The house of Commons published a research briefing on Heat networks and energy pricing [7]

Heat networks currently do not have an official regulator in Great Britain. The Office for Gas and Electricity Markets (Ofgem) regulates the supply of electricity and gas, but heat networks are not – at present - within its remit. This means that while the supply of gas to a heat network is regulated, the supply of heat from the heat network to homes is not. The Government has set out proposals to regulate heat networks, including appointing Ofgem as the regulator. It has said it will introduce legislation for this before the next general election.

3.2.1. Regulation of price setting

The Heat Network (Metering and Billing) Regulations 2014 require that where cost effective and technically feasible, heat network suppliers must provide individual meters to heat network customers, and provide them with bills based on the meter readings.

The energy price cap (also known as the Default Tariff Cap) sets a price limit on default tariffs for domestic supplies of electricity and gas. The cap rose by 54% on 1 April 2022, increasing the average annual domestic energy bill to around £2,000. It is forecast to rise by a further 30 to 50% in October 2022. Most heat network customers are not protected by the cap, since the supply of gas to heat networks is commonly classed as "non-domestic". This is because the heat network operator purchases gas and then converts this to heat, before selling the heat on to households, often on a commercial basis. Heat networks operated on a not-for-profit basis can be classed as domestic supply (and so covered by cap), under certain circumstances.

The impact of energy price rises on heat network customers Since late 2021 energy prices have risen substantially. Heat network operators who have renewed their commercial gas contracts since the autumn have seen large price increases, which they are passing onto customers. According to Heat Trust (a consumer protection scheme), consumers and landlords have reported heat network price rises of up to 700%. The Government has said that price rises on larger district heat networks are "broadly in line" with the energy price cap, but noted that larger increases have been seen on smaller communal heat networks. In response to the price rises, there have been calls in Parliament, and elsewhere, for the Government to introduce price protections for heat network customers.

In Proposals to regulate heat networks The British Government has said it wants "heat network consumer to have comparable levels of service and protection to those using electricity and gas".

Following the recommendations of the Competition and Market Authority's (CMA's) 2018 Heat Network Markets Study, the Government has developed proposals to regulate the heat networks sector. These include appointing Ofgem as the regulator, and granting it new powers to regulate heat network prices. Under the proposals the Government does not intend to introduce a price cap for heat networks currently, but it plans for the Secretary of State to have powers to introduce pricing regulation in the future. The Government has committed to introducing legislation to regulate heat networks during this Parliament.

[7] House of Commons Research briefing Heat Networks and Energy pricing April 2022 CBP-9528.pdf (parliament.uk)

3.2.2. Role of building owners and building occupants

Deciding the heat source of the building

Currently it is a decision of Domestic property owner to choose the heat source for their building.

However, through the Heat in buildings strategy published October 2022 the Scottish government sets out the regulatory approach that they will consult on in order to introduce regulations by 2025 to require owners to reduce demand for heat through energy efficiency improvements where feasible, and install a zero emissions heating supply, within the extent of our powers.

In the Energy Efficient Scotland Route Map 2018, the Scottish government set the prediction that regulations be phased in, starting with the largest buildings with the scope of the regulations increasing over time so that by 2045 all non-domestic buildings would be improved. A phased approach is likely to remain appropriate.

Public sector buildings

The Scottish government intend to set the example through commitment that the public sector needs to act more rapidly and in advance of the introduction of further regulations for new-build and existing non-domestic buildings. They are developing a set of phased targets, stating with easy targets in 2024, with the most difficult buildings like hospitals being decarbonised by 2038, and for all publicly-owned buildings to meet zero emission heating requirements, with a backstop of 2038.

They expect public sector leadership to include the early phase-out of all fossil fuel-based heating systems in the public estate at the earliest feasible dates.

Investments and energy bill

Currently domestic customers are expected to meet the cost of investment in low carbon technologies, though domestic customers are ow eligible to apply for funding under the £300 million Heat Network Fund described in section 4.2.4 below.

3.2.3. Financing and subsidies

Localized subsidy or grant mechanisms available

The **Scottish Government Heat Network Fund** was launched in February 2022. **£300 million** has been made available over the next parliamentary session to support the development and rollout of zero emission heat networks across Scotland.

The Government aim is to stimulate commercial interest, and investment in order to maximise Scotland's potential in the low carbon sector, whilst contributing to the positive progress on reducing Scotland's greenhouse gas emissions.

From April 2021 businesses in Scotland are eligible to claim a 50% relief on non-domestic their premises is being used for a district heating network, or mainly being used for a district heating network. This relief will be available until 2032. A 90% relief is available for district heating networks powered by renewables. This relief will be available until 31 March 2024.

3.3. Available energy sources and storage

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the highest-ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be

better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low grade sources would be in order to make a decent 5GDHC business case. At the time of writing, D.T1.1.4 has not been finalized.

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

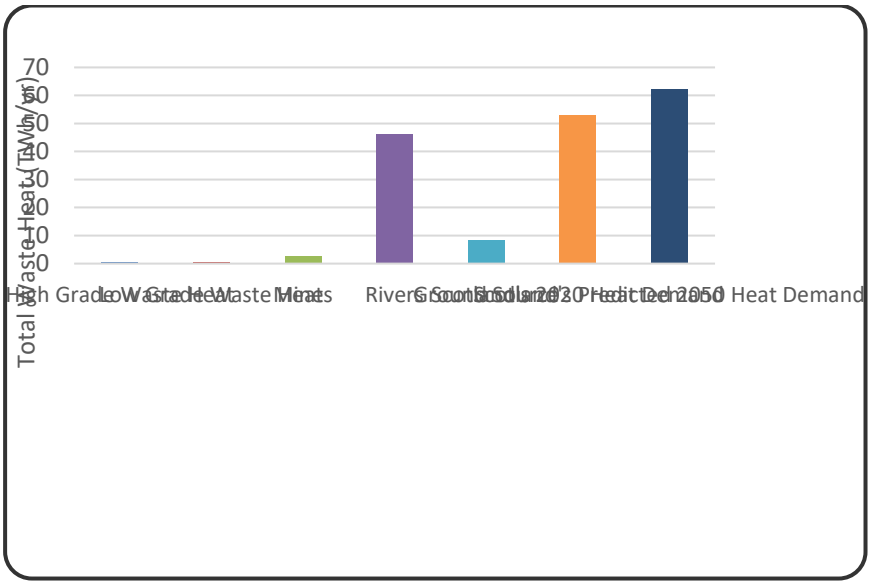
The core idea behind 5GDHC is to facilitate energy exchanges between local buildings. For instance, if one building is producing heat for its own consumption, it automatically also creates cold which ideally could be supplied to a nearby building. In Scotland there is little or no need for cooling in a domestic setting.

Ideally, as much local energy should be reused in order to minimize any possible type of energy losses. Analyzing the potential of these types of energy exchange is, however, not possible on a national scale. It highly depends upon the project, and detailed buildings consumption and production data, for different time periods, are needed. Its potential highly depends on the design of the network and the type of users involved. Ideally, when considering a new network, developers should engage and appoint a a good mix of consumers should be present, so that their energy flows and needs are complementary.

Making all building data available to local authorities during the LHEES could help in the consideration and development of viable 4GDHC networks in Scotland. action point to take up in the action plan. It is important that all demand and supply profiles can be compared, as this might provide incentives for complementary sectors to join the new site.

3.3.2. Ambient thermal sources from soil, water, air, and low temperature solar heat

Scotland has a wealth of ambient heat sources available for potential heat networks, such as soil, water air and sun. These have been quantified in fig 3 below.



Heat Source	Total Heat (GWh/yr)
Mines[1]	2,722
*Rivers[2]	46,312
*Ground Source[2]	30,272
High Grade Waste Heat[3]	665
Low Grade Waste Heat[3]	407

Figure 3. Ambient thermal sources in Scotland

Waste heat is available in Scotland and will further be discussed in section 4.1.1. below. However, using waste heat will only satisfy a small portion of Scotland's demand, we will need to utilize these ambient sources to be capable of fulfilling the rest of the heat demand, and as can be seen from the table, there is plenty of heat available to Scotland in various forms. In addition to these sources, there is also heat available from the ambient air that can be used in Air source heat pumps. A benefit of these natural, sources that some of them are seen as more reliable than waste heat in the long term, as they do not rely on the continued operation of another facility (e.g. a data centre) to provide heat. However, Scotland does have

some very reliable long term sources of lower grade waste heat which is suitable for 5GDHC, which should be considered carefully when assessing potential heat sources, especially when existing locally to the heat users.

3.3.3. Higher temperature industrial waste heat, otherwise rejected in the environment

Waste Heat Sources

When high grade heat is available in large quantities it is better utilised in 4GDH systems. 5GDHC systems are flexible to incorporating a wide range of heat sources into the network, including low grade waste heat, without having to upgrade it.

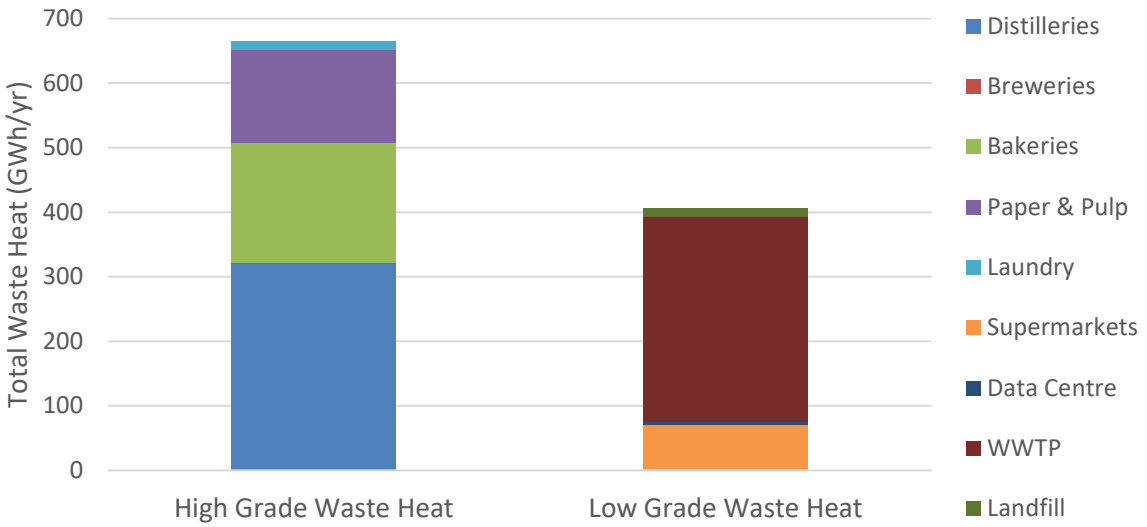


Figure 4. Waste heat sources in Scotland

Grade	Heat Source	Average Waste Heat Per Site (MWh/yr)	Total Waste Heat (MWh/yr)
High Grade Waste Heat (>50°C)	Distilleries	2,481	320,104
	Breweries	17	992
	Bakeries	2,562	187,040
	Paper & Pulp	23,901	143,405
	Laundry	1,631	13,341
Total High Grade Waste Heat			**664,882**
Low Grade Waste Heat (<50°C)	Super-markets	162	69,889
	Data centres	505	4,546
	WWTP	13,287	318,905
	Landfill	76	13,680
Total Low Grade Waste Heat			**407,020**

Source: "Potential sources of waste heat for heat networks in Scotland", ClimateXChange (2020)

Note: There are some uncertainties in these values and they should be used for indicative purposes only.

[2] estimated the technical potential of waste heat per EU country and the UK, per temperature level, per industrial sector. They found that waste heat of less than 100 °C was only available in the food and beverages industry. They calculated the fractions of the contribution of each of these industrial sectors towards the total national industrial waste heat for each European country.

Waste Water

The use of wastewater as heat source in Scotland is a reliable long term option for 5GDHC. Over 921 million litres of wastewater are produced daily in Scotland source of renewable heat energy that we are only just beginning to exploit. Scottish Water owns and operates over 31,000 miles of sewer network. These networks and WWTW (final effluent) present an enormous opportunity for 5GDHC, through extracting the heat form the wastewater as shown in fig 5 below

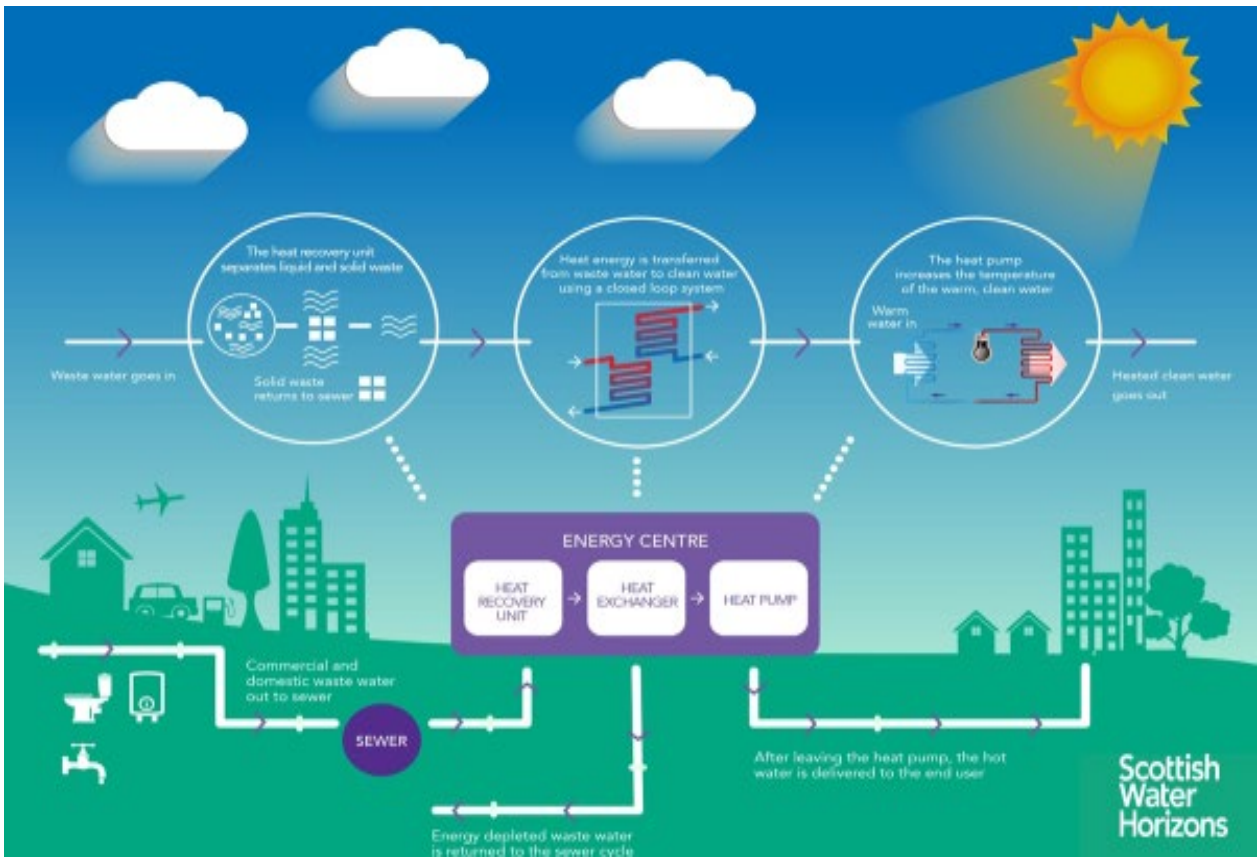


Figure 5. Wastewater extraction from waste water

Low grade thermal storage possibilities

Scotland does not yet have any DH networks that utilise large ambient thermal storage. However, there are many large mines which could be used for long term storage in ambient networks, suggesting a key capability gap that might support the 5GDHC market .

3.3.4. Higher temperature renewable sources like geothermal, solar heat

There are two classifications of geothermal heat, Shallow Geothermal and Deep geothermal. Fig 4 below shows the differences between the two.

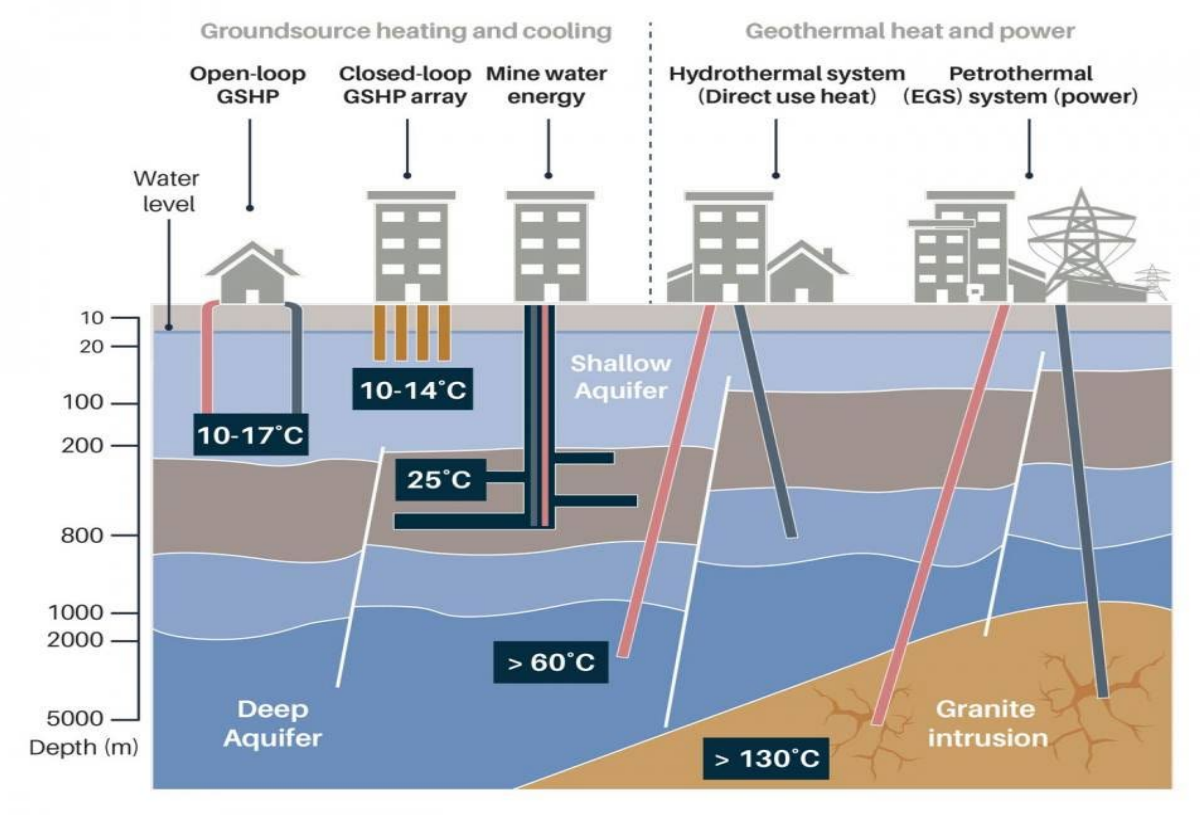


Figure 6. Shallow vs deep geothermal energy

The most common form of shallwo geothermal energy systems in Scotland provide heating through a ground source heat pump, as can be seen on the left hand side of the digram above . Up to 7.6 TWh of energy is available on an annual basis in Scoltand from this source.[8]

Deep geothermal

Scotland has geothemal sources in Deep hot sedimantary aquifers, Igneious granites and hydrocarbon wells.. These can be used or both heat and power through enhanced geothrermal systems. These can be seen in fig 7 below.

[8] McLoughlin, Nicola (12 July 2006) "Geothermal Heat in Scotland

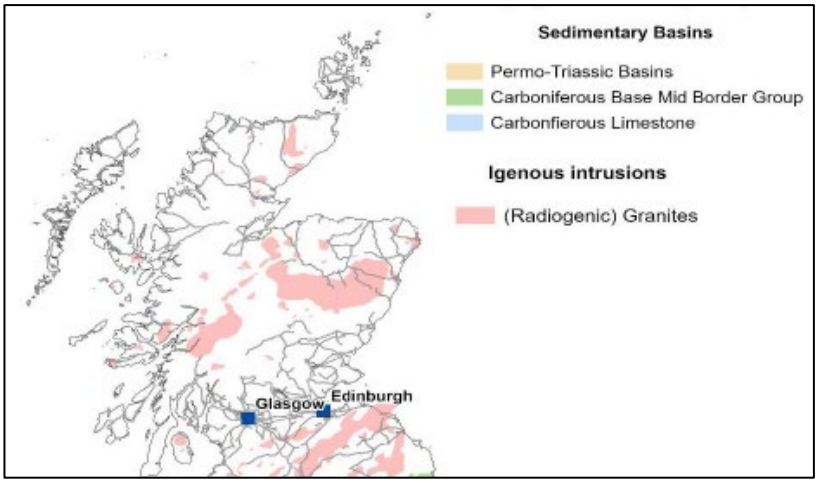


Figure 7. Scottish Deep Geothermal Stores

Areas of increased heat flow are associated batholith in the Eastern Highlands of Scotland. Mine-water geothermal systems are also being explored, utilising the consistent ambient temperature of the earth to raise the temperature of water for heating by circulating it through unused mine tunnel.

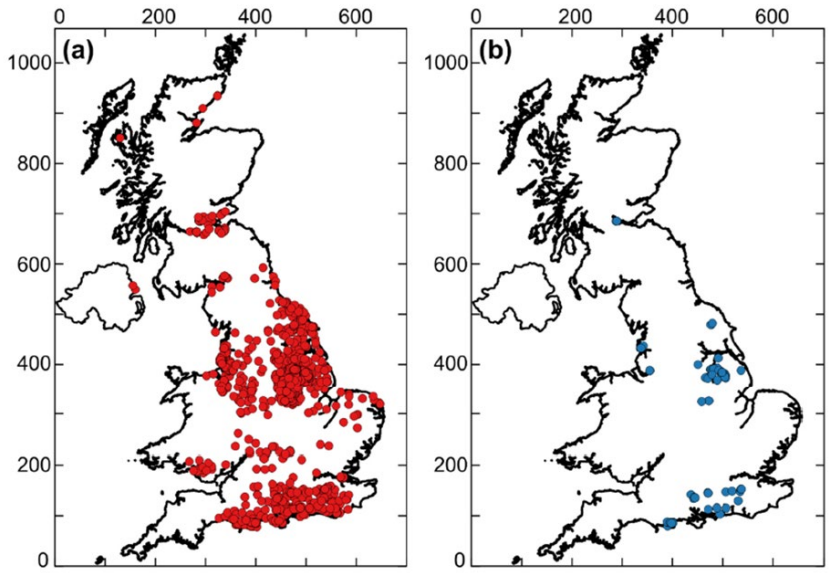


Figure 8. potential locations for deep geothermal in the UK

There are some concerns about the widespread use of geothermal as a heatsource, largely related to resource potential, regulation and economic barriers. There is also potential for geothermal energy production from decommissioned oil and gas fields.

3.3.1. Renewable electricity from local sources like wind, sun.

The Scottish government has a target to generate 100% of Scotland's own electricity demand by 2020. Scotland currently generates renewable electricity equivalent to 98% of its annual demand. 2020 was a record year for renewable electricity generation in Scotland with 31.8 TWh generated, 4.2% up on 2019. In 2020 had Scotland had 11.9GW of renewable electricity operational and 14 GW of projects consented in the pipeline, Scotland generated 30.5TWh of renewable electricity in 2019 73.1% was from wind. Renewables make up 54.9% of all electricity generated in Scotland in 2018 compared with just 28.9 % in England and Wales.

In 2019, the equivalent of 90.1% of gross electricity consumption (Gross electricity consumption refers to total electricity generation minus net exports) as from renewable sources, rising from 76.7% in 2018. Much of this increase is due to wind; in the 2019 there was an almost 1.0 GW increase in wind capacity, which contributed to approximately 3 TWh increase in electricity generation via wind.

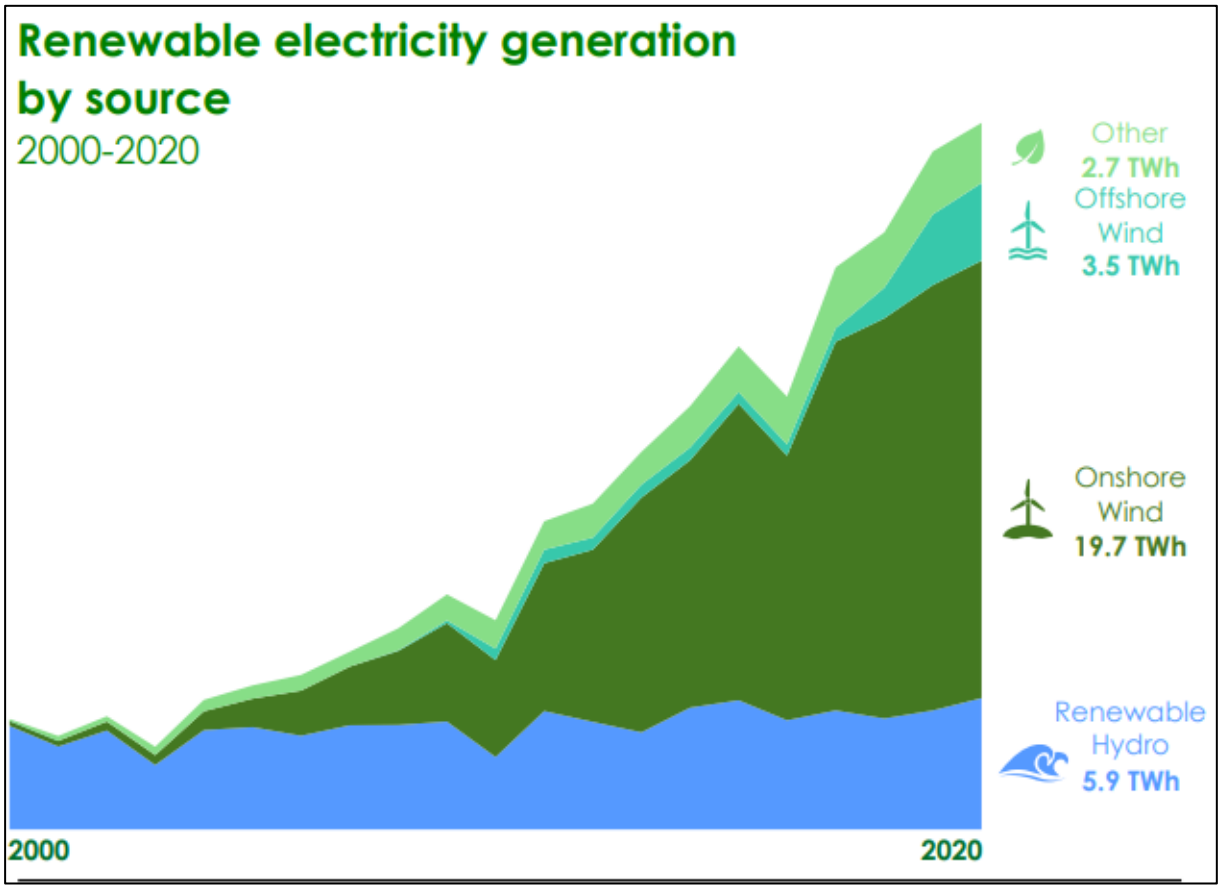


Figure 9. Renewable electricity generation in Scotland

3.3.2. Electricity use at times of renewable overproduction, e.g. when spot price is low

For now, this is only relevant in areas with known overproduction, like the north of the Netherlands (overproduction of PV) and the north of Germany (wind).

3.3.3. Electricity mix from the external grid

Most electricity in Scotland is carried through the national grid with Scotland's renewable mix thus contributing to the electricity production of Great Britain as a whole. Scotland has its own networks, run by SSE (Scottish eand Southern energy) and SP energy networks ((Scottish Power Energy Networks)

The table below shows the difference in energy mix between SSE when compared to the UK National grid.

SSE Generation Mix (relates to electricity supplied in the period April 2019 to March 2020)		
Electricity supplied has been sourced from the following fuels	Electricity supplied by SSE % of total	Average for UK (for comparison) % of total
Coal	0.0%	3.9%
Natural Gas	48.1%	39.4%
Nuclear	0.0%	16.6%
Renewable	51.9%	37.9%
Other	0.0%	2.2%
Total	100%	100%
Environmental impact	Electricity supplied by SSE	Average for UK
High-level radioactive waste g/kWh	0.0000	0.0012
Carbon Dioxide emissions g/kWh	178	198

3.3.1. High temperature heat from burning biofuels, biogas, biomass

Scotland utilizes a number of known technologies for the generation of heat from renewable sources. Fig 4 shows the current mix of renewable heat generation capacity in Scotland. 2,140 GW of renewable heat capacity was operational in Scotland by the end of 2020, up from 2.06 GW in 2019 and 0.44 GW in 2010. Biomass accounts for 81 per cent of the total capacity followed by heat pumps which account for 13 per cent of the total. Fig 5 details renewable heat output by technology in 2020. In total, 5,008

GWh of heat was produced from renewable sources; total renewable heat output has increased by 2 per cent from 2019.

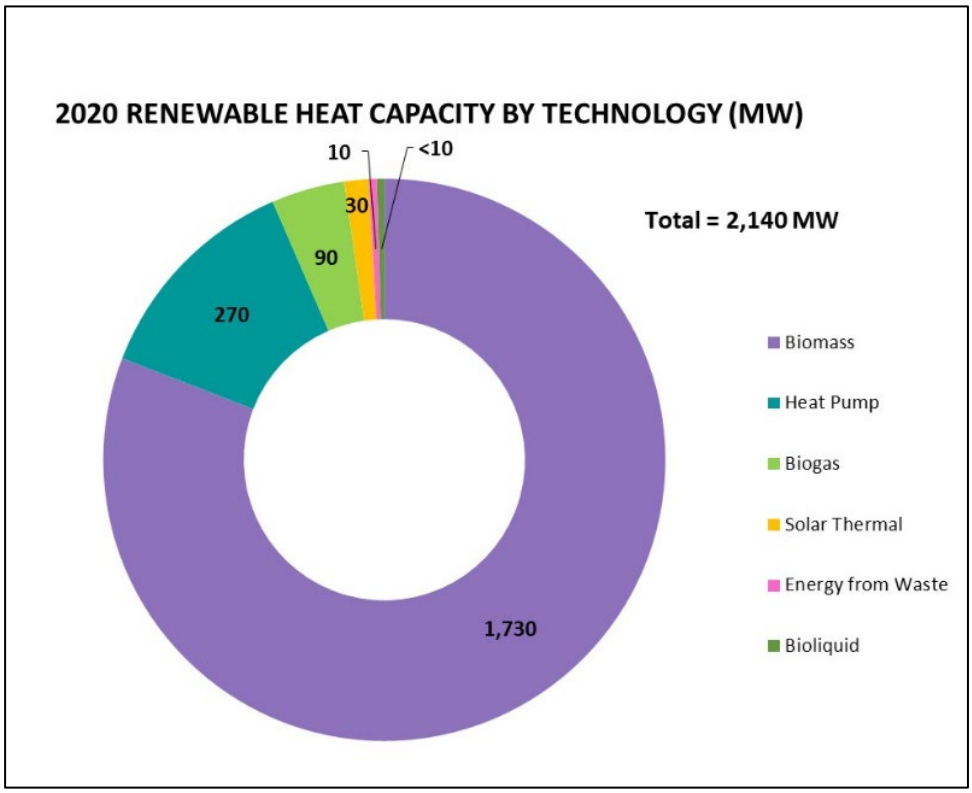


Figure 10. Scottish Renewable heat generation capacity in 2020

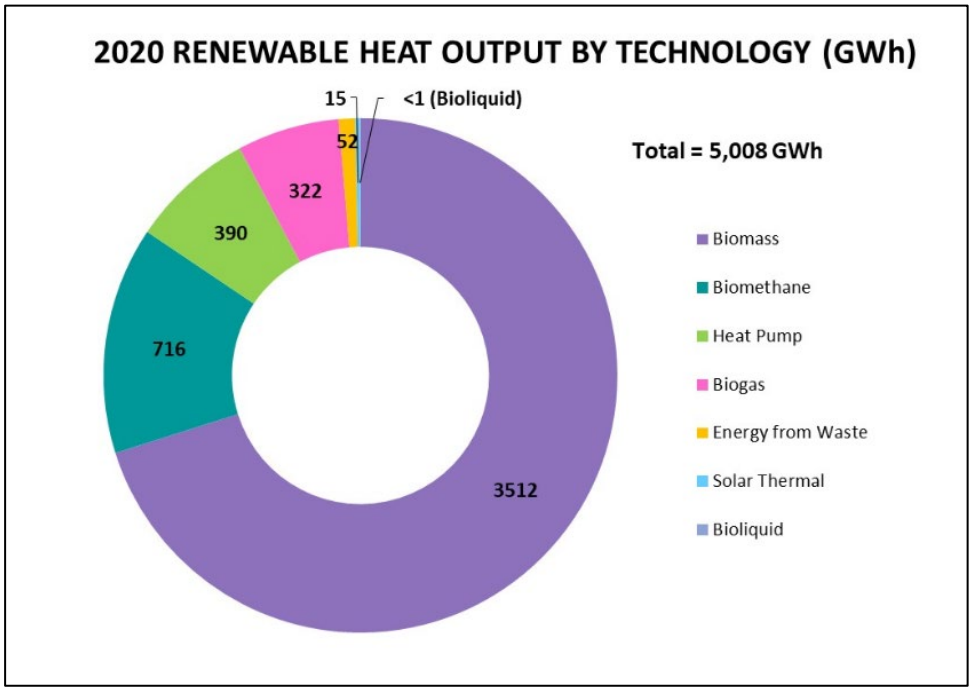


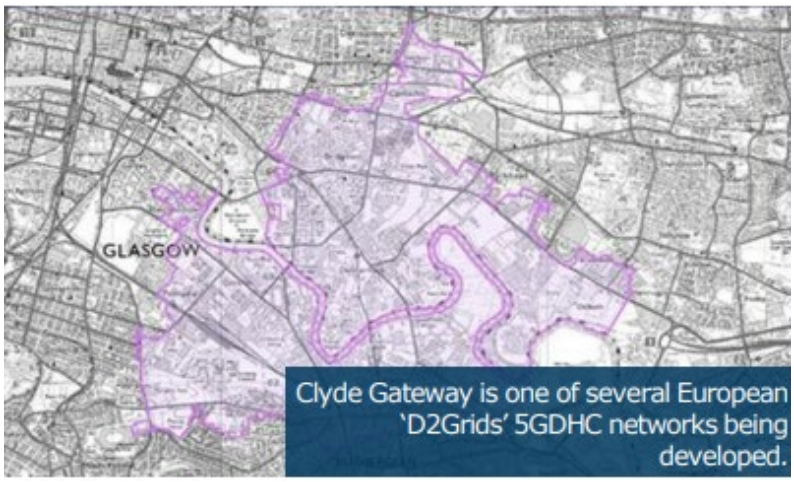
Figure 11. Renewable Heat output in Scotland 2020

3.4. Infrastructure, skills and capabilities in Scotland for 5GDHC

3.4.1. Existing projects

There are currently only two pilot projects for 5GDHC in Scotland, AMIDS, and Clyde Gateway.

Clyde Gateway represents "Scotland's largest and most ambitious regeneration programme" and is located in the east end of Glasgow. The regeneration programme will include two district heating networks, a traditional centralised network, and a 5GDHC network. The networks are being developed in partnership with Scottish Water Horizons. The 5GDHC network is one of five Interreg D2Grids pilot projects, which aims to set industry standards for 5GDHC. The 5th generation network will originally connect to 3 office buildings, with plans to increase this to 8 buildings in the future. The network will recover waste heat from the final effluent of a local waste water treatment works. It is due to be completed by early 2023.



Clyde Gateway is one of several European 'D2Grids' 5GDHC networks being developed.

The **"Advanced Manufacturing Innovation District Scotland" (AMIDS)** will be an internationally-recognised centre for advanced manufacturing – ideally placed in Scotland's industrial heartland." AMIDS is located in Paisley, Renfrewshire, and will have a 5th generation district heating network. Partners of the project include Renfrewshire Council, Scottish Water Horizons, Scottish Enterprise, Scottish Futures Trust and Zero Waste Scotland. The network will originally connect to two buildings; the National Manufacturing Institute Scotland (NMIS) and the Medicines Manufacturing Innovation Centre, with the capability to expand as more buildings are constructed in the district over the next 10 to 15 years. The network will recover waste heat from the final effluent of Scottish Water's Laighpark Waste Water Treatment Works through a heat exchanger. It is due to be completed by mid-2022.


AMIDS is located in Paisley, Renfrewshire and will recover waste heat from a wastewater treatment works. *Image: sdi.co.uk*

3.4.2. Main capabilities for implementing 5GDHC and retaining value in Scotland

In 2021 Scottish Enterprise commissioned a report to assess the potential for Scotland to be a leader in 5th Generation heating and cooling networks[9].

The Ramboll report provided an analysis of the 5GDHC Market and supply chain in Scotland, and aimed to set out the opportunities and challenges for Scotland in developing these networks through conducting desktop studies, expert and industry interviews, and analyzing the role of policy in enabling these networks to develop.

As we see from the pilot projects above, 5GDHC is not yet established in Scotland, and there is limited knowledge of 5GDHC in the industry and public domain, however Scotland does have some existing capability which would enable the implementation of 5GDHC, and the Scottish government have committed to support industry in the local manufacture of components of Heat networks, including those required specifically for 5GDHC.

Scotland has a thermal storage manufacturer, Sunamp, located in Scotland, is the only thermal storage manufacturer in the world to be awarded A Grade RAL Certification, the independent quality mark and the only global standard for Phase Change Material (PCM) and PCM products, confirming reliability and long life of Sunamp thermal batteries. These units allow the use of off peak electricity for storage of heat at the end user's property with 3x the density of a water tank.

In terms of pipework, 5GDHC utilizes the same uninsulated pipework as gas and water mains used in Scotland. As such Scotland has good experience, expertise and existing contractor capable of installing mains required for 5GDHC, however there are currently no manufacturers of uninsulated pipework in Scotland, which may cause issue with supply chain in a growing heat network market. Scotland has two existing heat pump manufacturers, however they are not currently producing technology suitable for 5GDHC, and additionally Scotland has a lack of heat pump installers. Upskilling in these areas is a key priority for the Scottish government.

Component manufacture and emerging markets.

The Scottish A 2022 report was commissioned by Scottish Enterprise, analyzed key components required for district heat network and existing supply chains, and he markets for these in Scotland, UK, Denmark and France[10]. The report investigated the part Scotland may play in contributing to the emerging District Heating market. The report considered both 4 and 5G networks, and found there was a strong market growth forecast for the key components, but particularly in the UK and France. The study concluded that within heat pumps, compressors and controls were identified as two of the components with the most potential for Scotland. For heat networks, it was controls and pre-Insulated steel pipes. These components were selected according to their value, existing expertise in Scotland, innovation potential, procurement difficulty, and potential for retrofits. and all show strong forecast market growth. Across all, where predicted growth rates were highest. This was found to be due to a combination of factors including macro trends towards decarbonisation and security of supply and local policy environments.

[9] Scottish Enterprise – Analysis of potential for Scotland to be a leader in 5th Generation Heating and cooling networks (Ramboll November 2021)
[10] Heat pumps and Heat networks assemblies and Key component analysis (Ramboll April 2022)

4. SWOT analysis

Given the information gathered above on the market and on availability of energy resources, an analysis of the strengths, weaknesses, opportunities and threats when implementing 5GDHC in the region can be made. The SWOT analysis will help to interpret the information given earlier and will as such help to understand which locations Scotland might be better suited for 5GDHC.

4.1. Strengths

In what follow, strengths of Scotland as a region, that could give 5GDHC an advantage over other projects and technologies, are discussed.

4.1.1. Existing skillset:

On a practical level, Scotland has existing skills which would support the implementation of 5GDHC Nationally. Incumbent gas and water networks all rely on the same trench digging and installation expertise for of HDPE Pipework which would also be required for 5GDHC in Scotland. Scotland also has a wealth of experienced boiler fitters which could be retrained to install heat pump technology. The Oil and has industry also utilises drilling techniques which would transfer well for deep geothermic drilling which is also present in Scotland as a potential heat source.

4.1.2. Scottish Legislative Policy and support

The legislative and government support for Heat networks gives a favorable environment for the implementation of 5GDHC in Scotland. Although currently Heat Networks in Scotland are well behind many European counterparts, the Scottish government has set some ambitious targets, supported with both a developing legislative framework and funding to push Scotland forwards quickly as a leader in Heat networks in 5GDH

4.2. Weaknesses

4.2.1. Energy demand suitability

Scotland does not currently utilise space cooling in many domestic and public building settings and, as such this does not lend itself naturally to the implementation of 5GDHC in these settings.

4.2.2. Technical issues

Currently in Scotland there is a large gap in understanding with regards to 5GDHC in the industrial supply chain, and public understanding of Heat networks. While the government is implementing policy and support to rectify these issues through funding, training, and policy development these policies are aligned more generally to district heating and not unique to 5GDHC. when compared with 4GDH 5GDHC has larger spatial requirements for the larger pipework, which could cause issue particularly in retrofitting to older infrastructure. Additionally, unlike with 4GDH, 5GDHC requires changes to electrical infrastructure on an individual building basis, where 4G requires this at a centralised energy centre only.

4.2.3. Financial modelling and viability.

Lack of previous exemplar projects make the timeline to deploy projects difficult to plan, and with no secure supply chain financial models are fairly difficult to predict accurately, to ascertain the financial viability of the project. Projects in Scotland today would not have been able to proceed without funding, and 5GDHC is unlikely to be financially competitive with other heat networks unless government schemes such as the recently introduced Heat network fund continue to support these projects.

4.3. Threats

A 5GDHC Business model is difficult to develop where cooling is not required. While not necessary, a network will be a lot more viable where both heating and cooling requirements are present within the anchor loads of the scheme.

Projects to date have realized a major threat to be in the complex nature of business and financing for 5GDHC. Alignment of planning, funding, and the onboarding of anchor load customers to enable the financial viability of a project is more difficult where individual premises need to adapt or design their electrical infrastructure on a building by building basis rather than with a large energy centre as found in both 3G and 45 DH systems .

4.4. Opportunities

There is recognized potential for the development of existing pilots, namely , the AMIDS and Clyde Gateway projects in Renfrewshire and Glasgow. Both projects were built to allow for future expansion when additional heat users and funding become available.

Use of existing resources:

Scotland has an array of natural and man made resources which lend themselves towards the implementation of district heat networks generally, as well as 5GDHC. Flooded Mines have the potential to provide thermal stores, and the wealth of rivers, coastline and recovered heat from the sewer provide readily available heat sources close to heat users which would enable development of new networks.

The Implementation of LHEES by local government, will be aided by the by the first National assessment of potential Heat Network zones in 2022, and findings will give will give the opportunity for local council areas to quickly build on the national information with local knowledge to develop local plans which should include consideration of 5GDHC as a longlist option for any plans going forward. As there is relatively little District heating developed in Scotland to date, the consideration for 5G should not be complicated by a need to connect to existing 3G and 4G systems.

Legislative and financial incentives such as the Heat network fund 2022 will encourage both public and private investment, and help to develop the market, thus driving down cost in the longer term (both in terms of infrastructure and unit cost of heat).

5. Regional vision

The regional vision addresses which barriers need to be addressed first and which opportunities should be taken when rolling out 5GDHC in the region. The vision includes a roadmap describing how much thermal demand (in MWh and/or floor area) could be fulfilled between the end of D2Grids and 2030, including likely locations where implementation can start.

5.1. High potential areas and potential pilot sites

The First National Assessment of Potential Heat Network Zones (FNA)[11] was completed for Scotland in 2021. The work undertook an analysis to identify areas that might be suited to heat network development from a heat demand density perspective. The focus of the work was to Identify potential zones through assessment of nationally available data on heat demand density, and provided and assessment using national datasets of the areas that are most suited to heat networks from a demand density perspective. The study gave heat demand data for identified zones,

The assessment and identification of potential zones was not specific to 5GDHC and the report acknowledges the requirements for further studies that incorporate local development plans, existing heat networks and sources of waste or surplus or low carbon heat. It is intended that the FNA study can be built upon by local authorities, and further work should incorporate assessments on economic viability, and detailed technical or stakeholder related aspects of project opportunities in identified zones. Further detailed assessment will also be required to understand if heat network projects within potential zones could offer heat to properties at a cost that is competitive against alternative options, and to consider 5GDHC in the longlist of options.

5.2. Roadmap

The FNA is framed by two key policy drivers discussed in section 4.2.1 above (the ongoing development of Local Heat and Energy Efficiency Strategies (LHEES) and the Heat Networks (Scotland) Act 2021 (the 2021 Act)). This work is aimed to support the development of policy and regulations, including informing the Heat Networks Delivery Plan (as detailed in the 2021 Act) and the local identification of potential zones for heat networks as part of LHEES, including 5GDHC. The work may also be used to support wider policy development.

Regarding LHEES, the local authority specific analysis provided by the FNA (and shared with local authorities as part of the LHEES National Assessment outputs) is intended to support local authorities to work towards their requirements within LHEES in regard to heat networks. The LHEES process includes local consideration of potential zones outputs, bringing in local knowledge to sense-check anchor loads and other factors such as local development plan sites, existing heat network connections within potential zones and other requirements as set out in the 2021 Act, refreshing the outputs as required. This work has also informed updates to the LHEES process, and these will feed-in to ongoing development of the LHEES methodology.

It is predicted that Scotland will have a cumulative expenditure of **£5.2BN** on heat networks from 2022 to 2030. Based on Scottish Government Targets to meet 2.6 TWh of renewable heat networks by 2027 and 6 TWh by 2030 there is a requirement for a multi-disciplinary approach. We will need to deliver a combination of government policy, packages of financial support and funding, and progression in technical and manufacturing capability. Additional targets to enable delivery will be set for 2035. These will be put to national consultation in early 2023.

[11] First national assessment of Potential Heat Network Zones Baseline and stringent assessment for Scotland using the LHEES Methodology (V03, August 2021) – Zero Waste

6. References

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