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

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Abbreviations

5GDHC	5^{th} Generation District Heating and Cooling
5GDHCN	5^{th} 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.

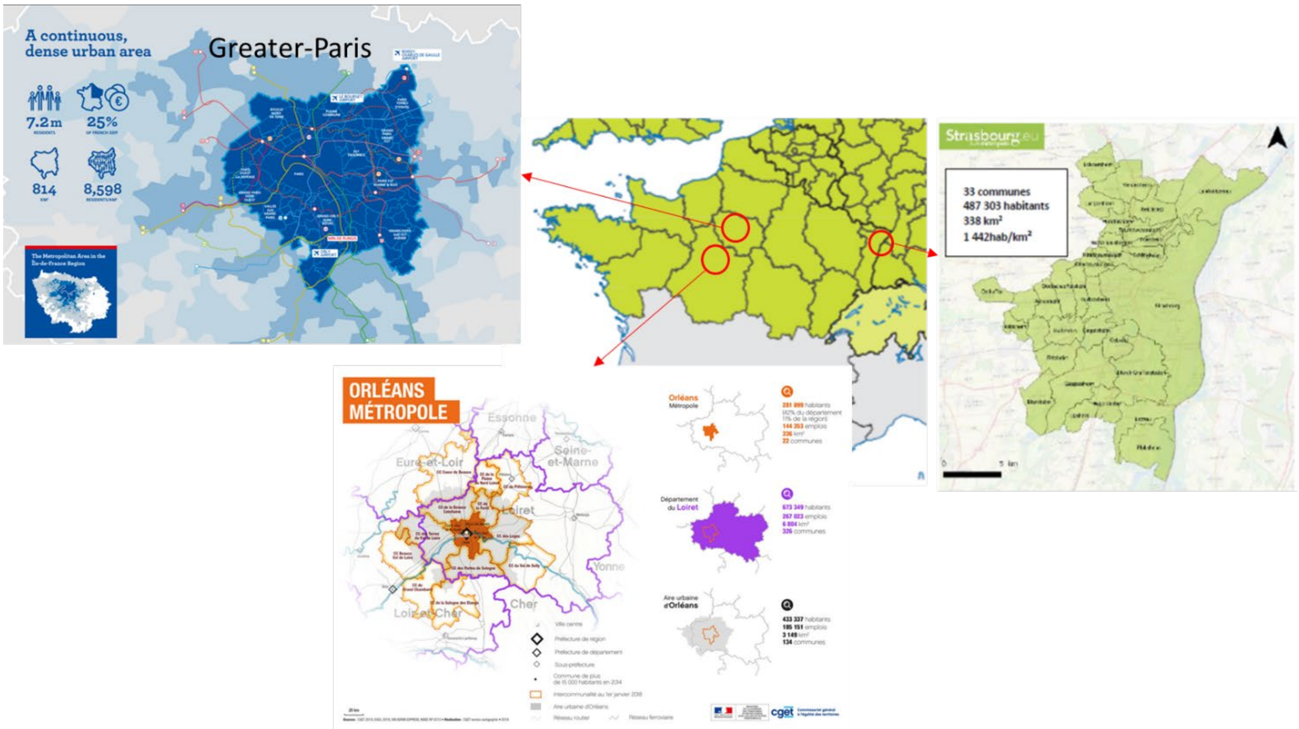

Figure 1. Localization of the three urban areas of interest for “follower region” in North-East France

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.

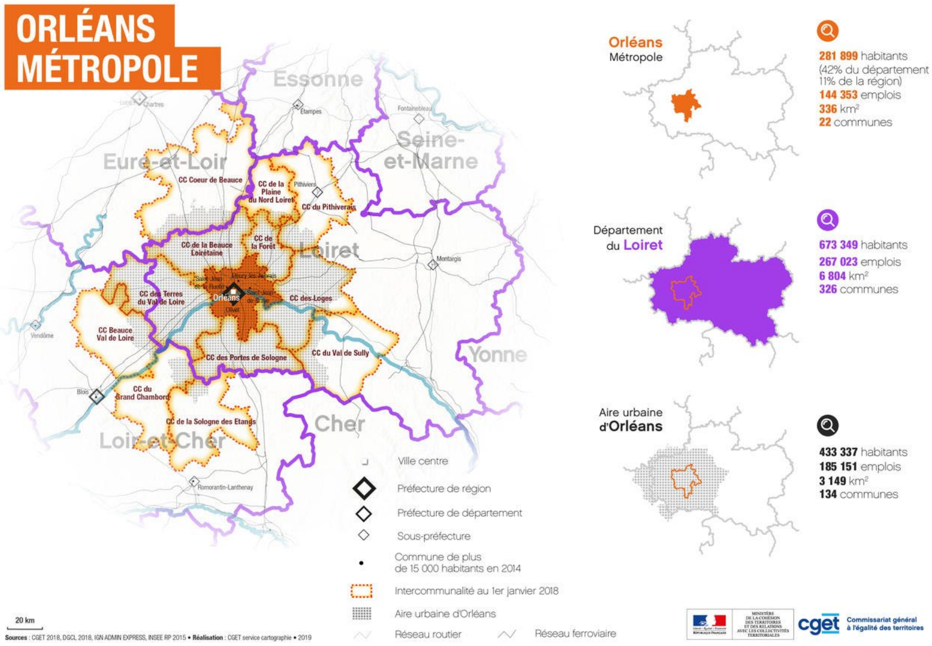

Figure 2. Orleans Metropolis location and population (figures from Insee 2015). Source CGET

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.

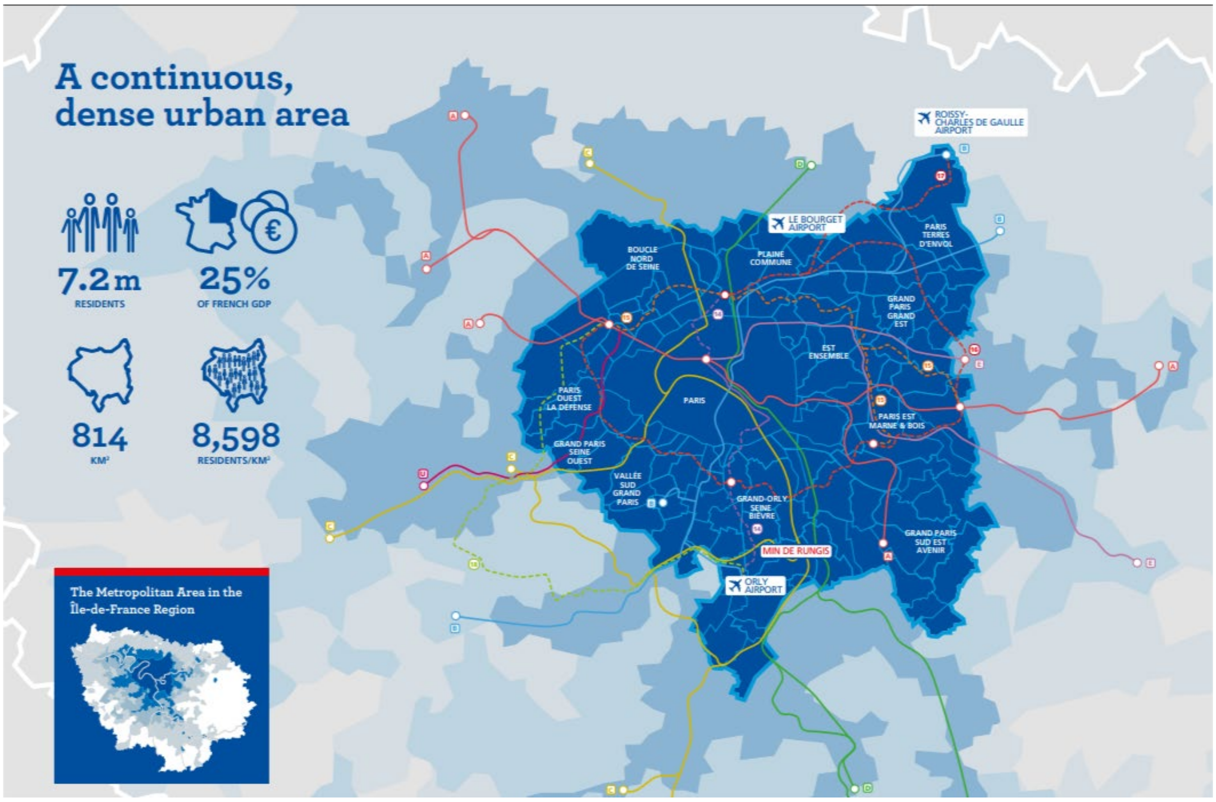

Figure 3. Greater-Paris Metropolis and its 11 territories (figures from 2016)

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 %).

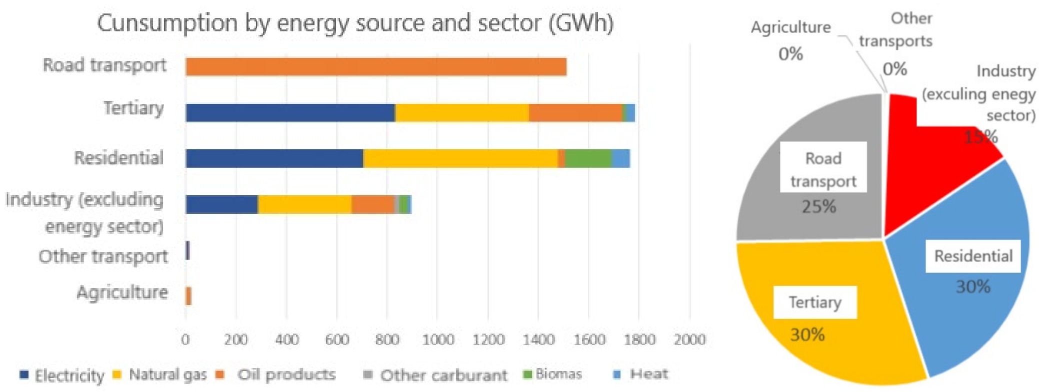

Figure 5. Distribution of energy consumption in GWh (electricity and heat) by energy sources and by sector (%) in Orleans Metropolis in 2012 technology (source: Orleans Métropole - Rapport de diagnostic énergétique)

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]

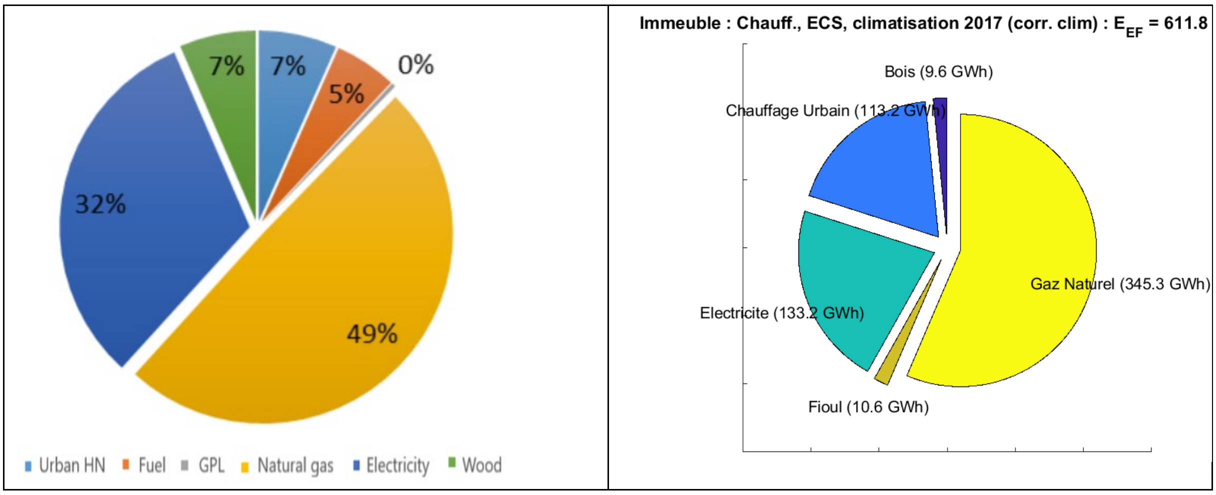

Figure 6. Distribution of heating energy consumption by energy source for residential sector technology (left, source: Orleans Métropole - *Rapport de diagnostic énergétique & INSEE 2013*) and in 2017 according to the recent study and figures from ARTELYS (right)

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
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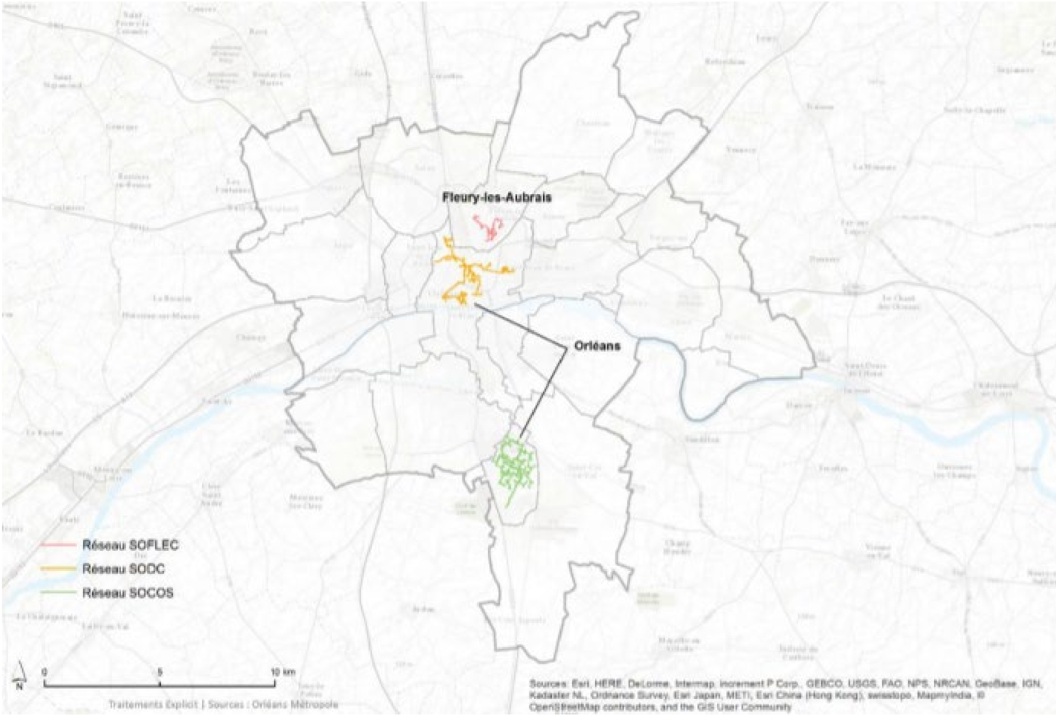


Figure 7. Location and extension of the three DHN in Orleans Metropolis

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)

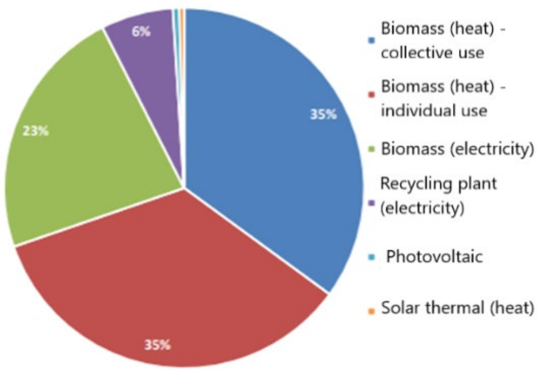


Figure 8. Distribution of renewable energy source consumed in the territory of Orleans Metropolis by technology in 2012 (source: Orleans Métropole - Rapport de diagnostic énergétique) and for multi-unit buildings

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.

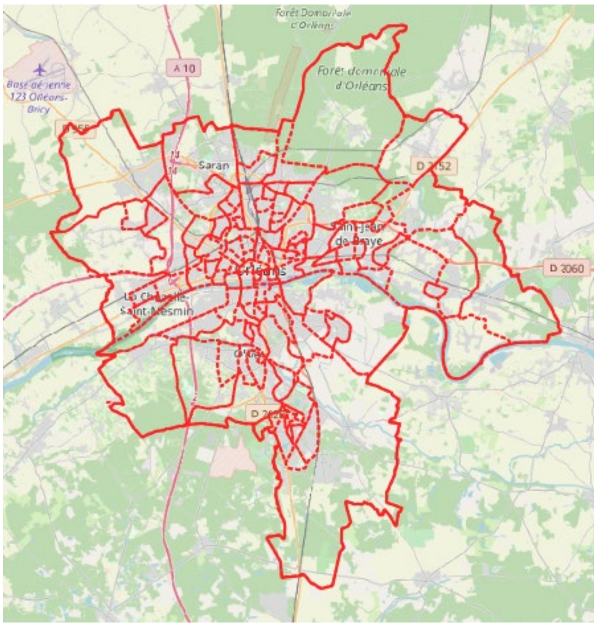


Figure 9. IRIS on Orleans Metropolis

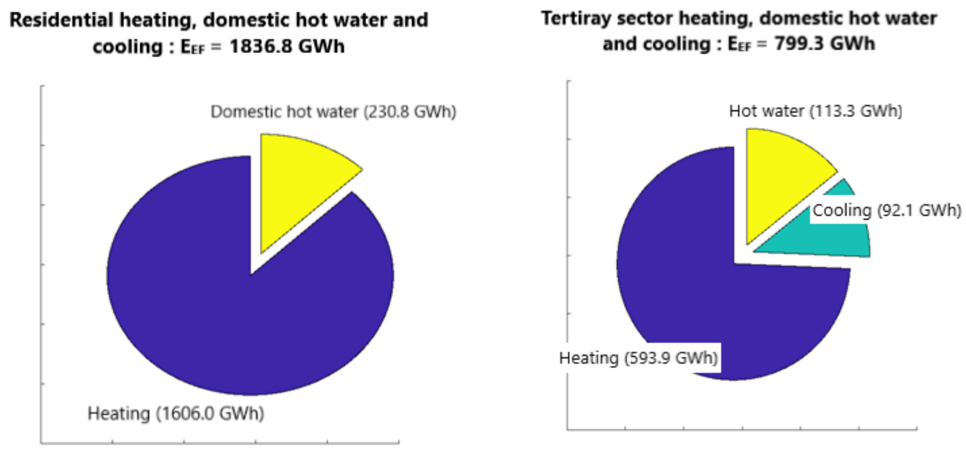


Figure 10. Thermal energy consumption by sector (Tertiary sector on the right and residential on the left) and by typology (heating, hot water and cooling) using climatic correction

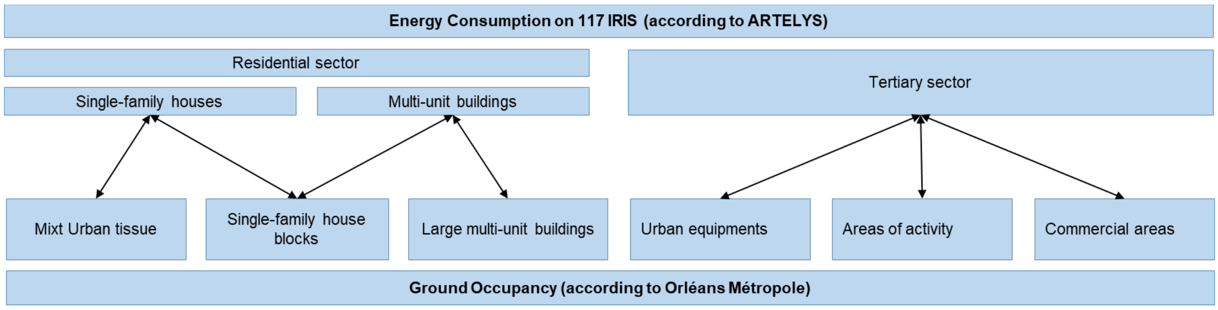


Figure 11. Methodology used for crossing energy data with ground occupancy data

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.

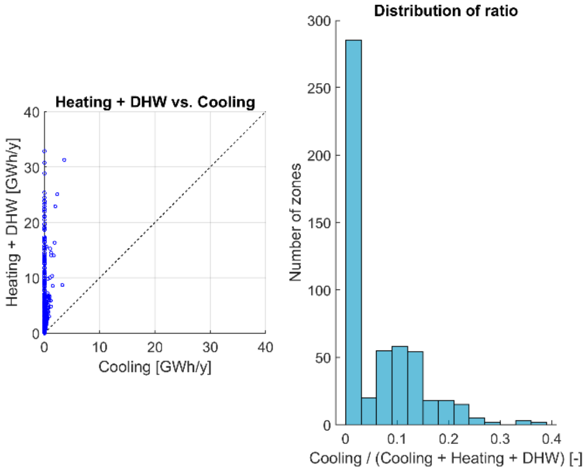


Figure 12 : Heating vs. Cooling for the 536 zones (left). Distribution of the share of cooling in the total thermal needs (right)

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%).

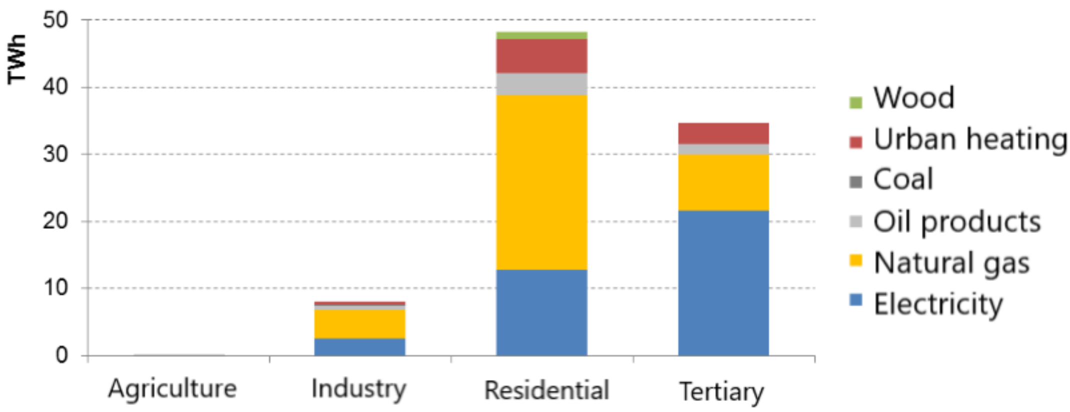


Figure 13. Energy consumption for the Greater-Paris metropolitan area in 2012 by energy source and by sector (source: ROSE 2012)

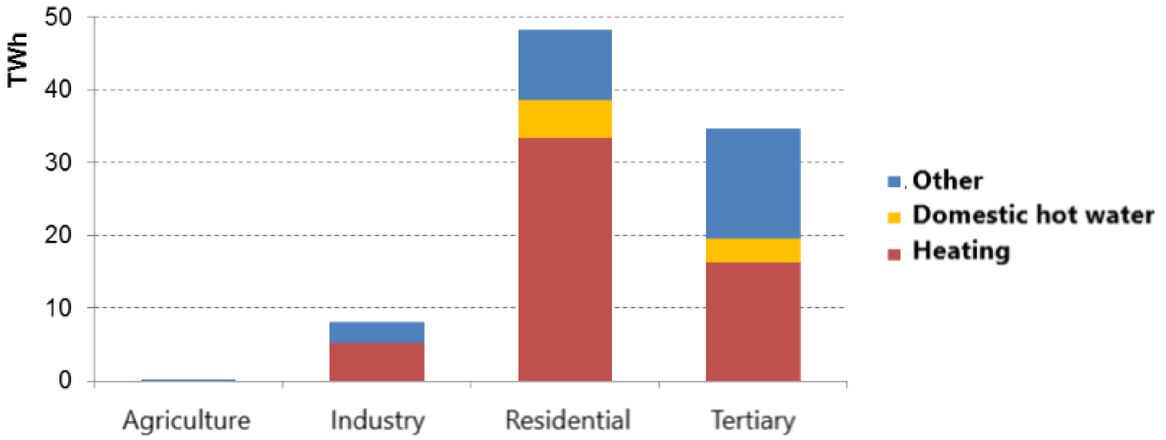


Figure 14. Final energy consumption for the Greater Paris metropolitan area in 2012 by usage and by sector (source: ROSE 2012)

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).

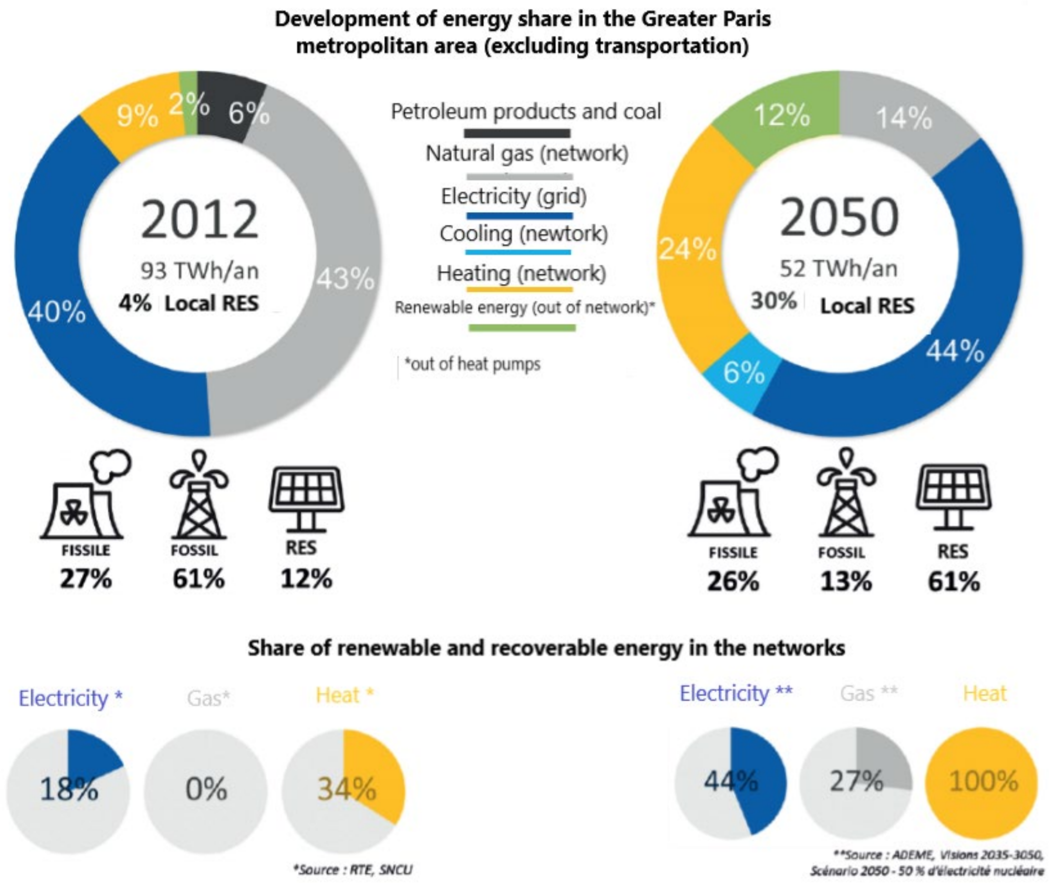


Figure 15. Share of renewable energy in the mix of Greater Paris metropolitan area in 2012 (left) and development forseen within 2050 (right) (source : PCAEM MGP 2018, ADEME, RTE, SNCU. Translated in english)

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).

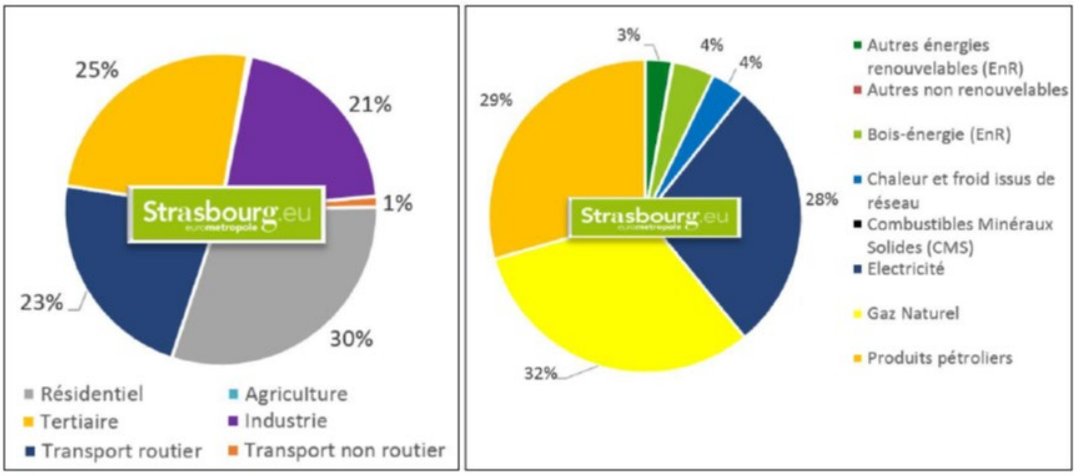


Figure 16. Distribution of final energy consumption adjusted for annual temperature variations (left) and by energy sources (right) (source: Invent'Air V2019 - ATMO Grand Est)

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

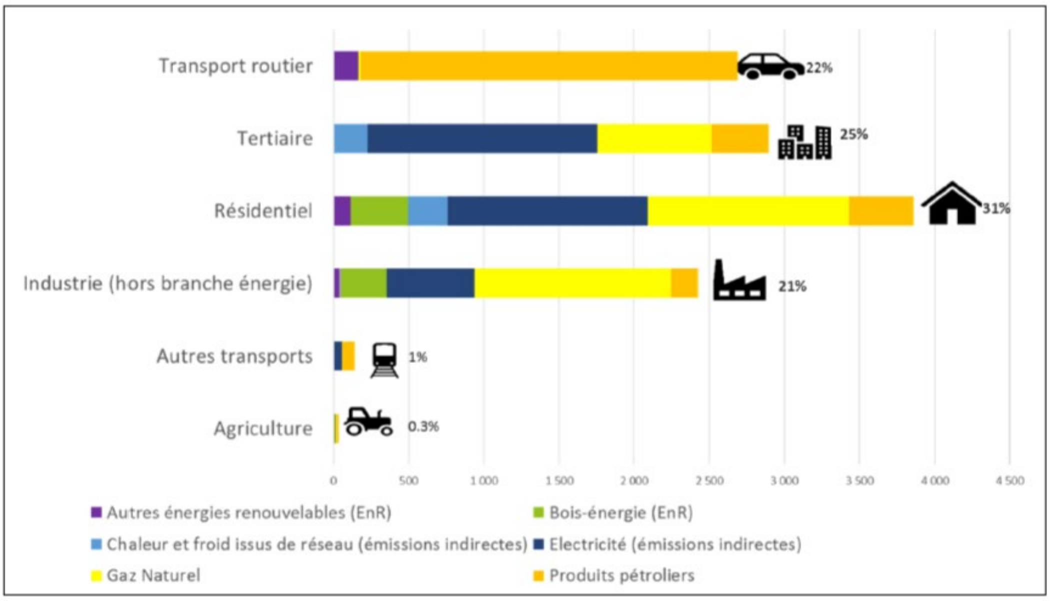


Figure 17. Distribution of final energy consumption by sector in 2017 (source: Invent'Air V2019 - ATMO Grand Est)

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.

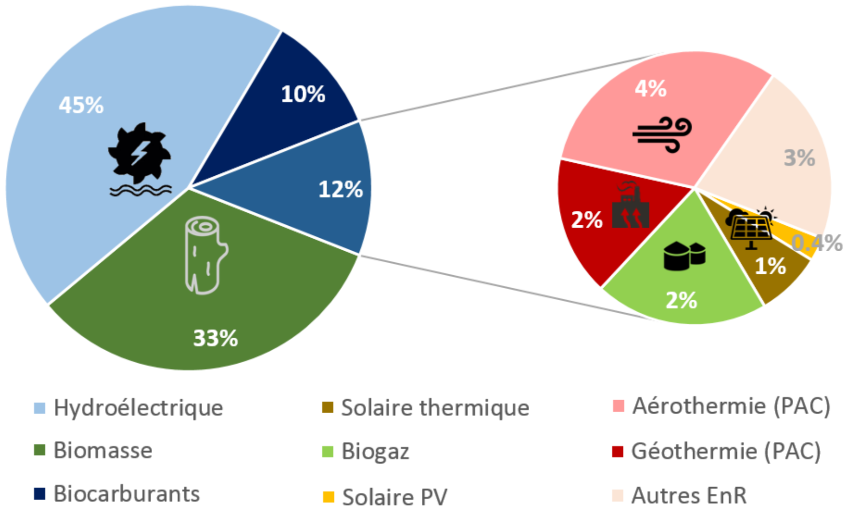


Figure 18. Distribution of renewable energy consumption by sources (source: ATMO Grand Est V2019)

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

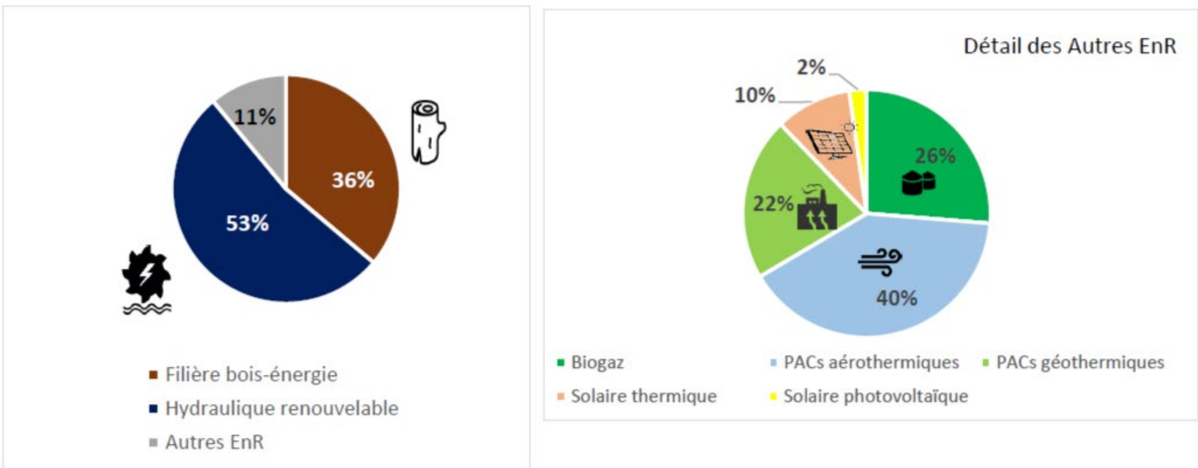


Figure 19. Distribution of renewable energy production by sources (source: ATMO Grand Est V2019)

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.

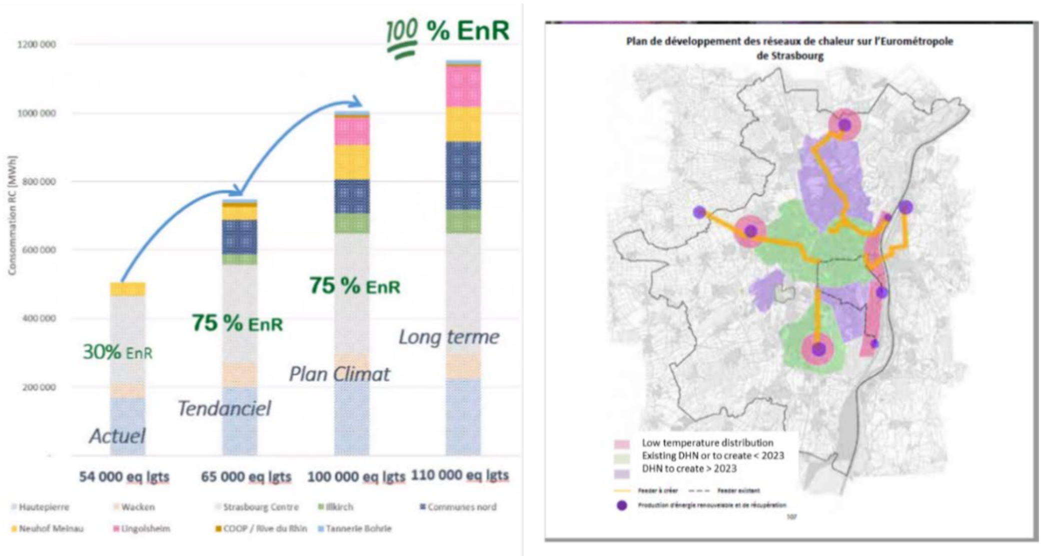


Figure 20. Energy consumption (MWh) in district heating networks with equivalent dwellings (left) and future DHN development plan (right) (source: EMS, Stratégie Réseaux de chaleur, 7 janvier 2021)

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.

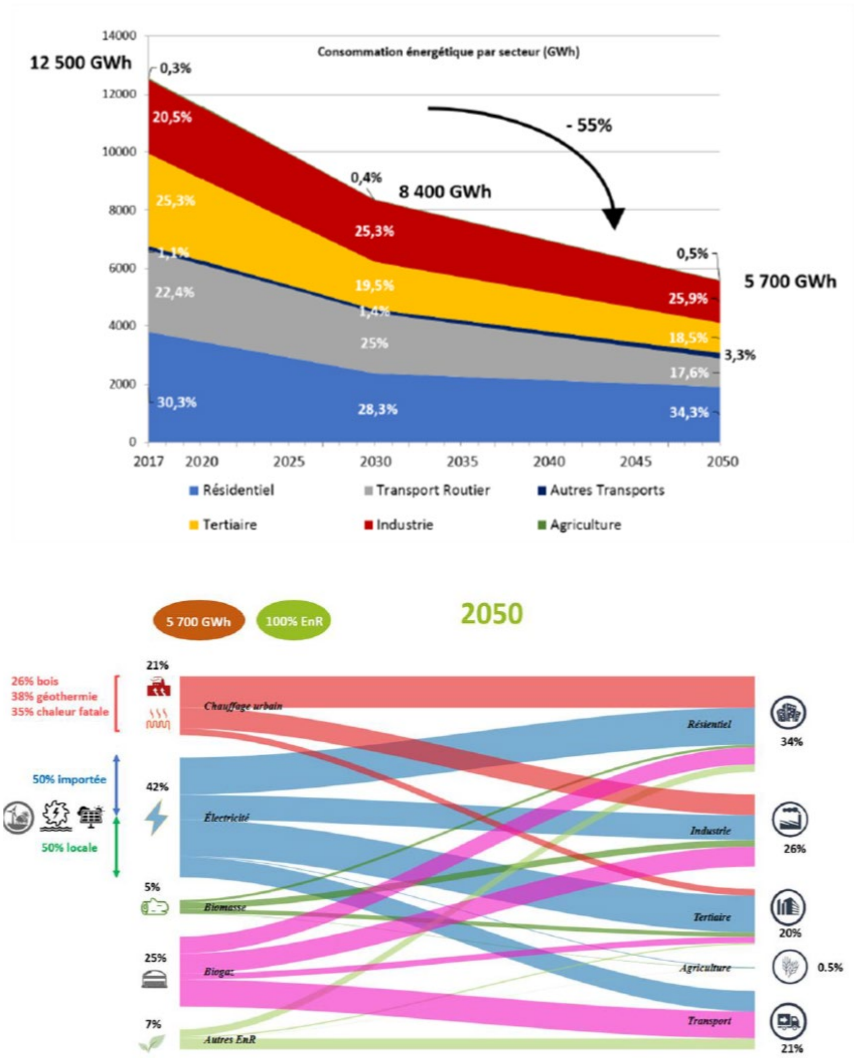


Figure 21. Evolution of the energy consumption in 2030 and 2050 (above) and energy mix targeted in 2050 (below) (source: "Synthèse des Schémas Directeurs des Energies", décembre 2019)

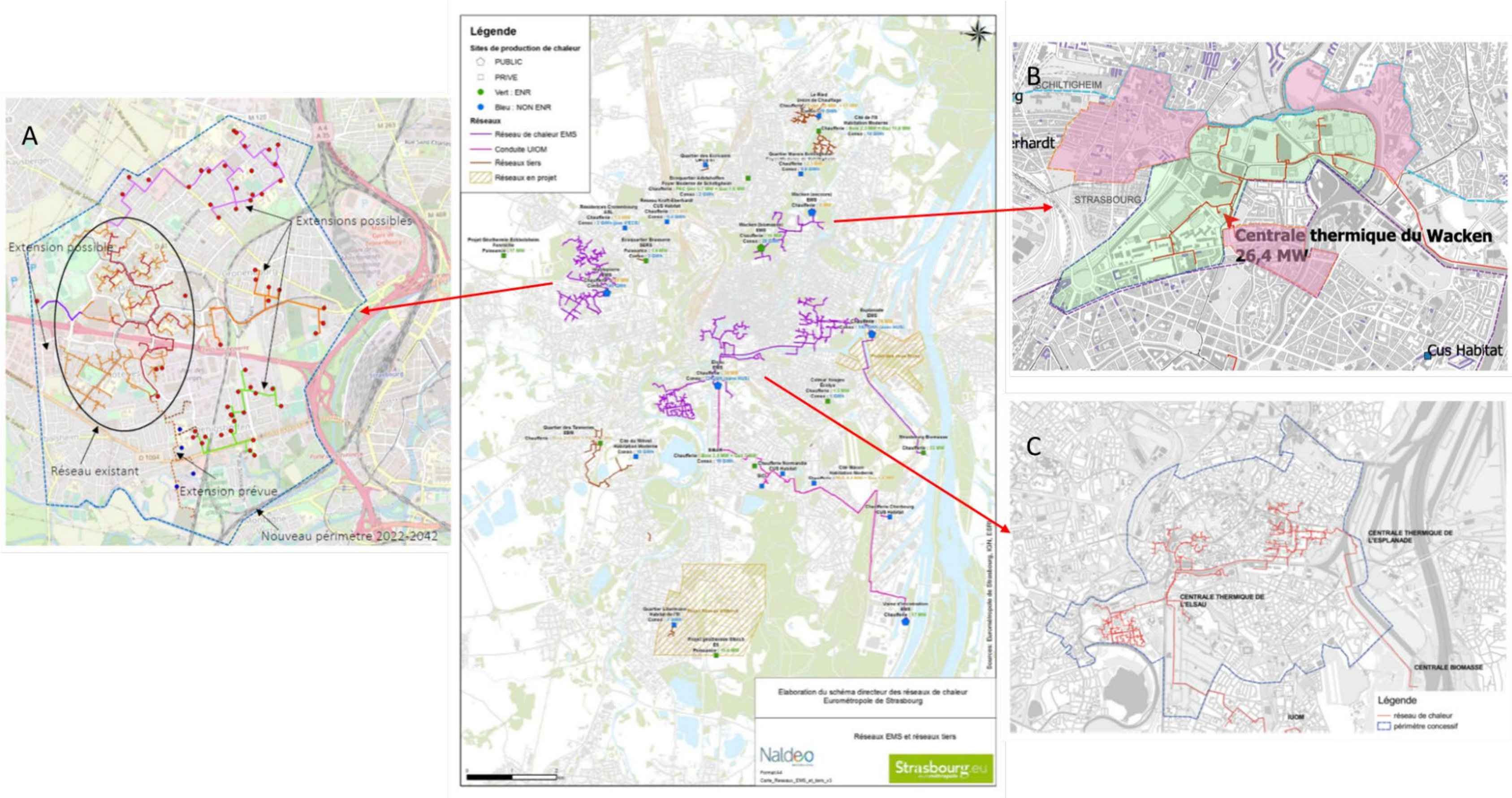


Figure 22. Location of the main district heating networks in EMS territory and possible future connections (source: "Schéma Directeur des Réseaux de Chaleur de Strasbourg", 2017)
A: Hautepierre DHN
B: Wacken DHN
C: Elsau and Esplanade DHN

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

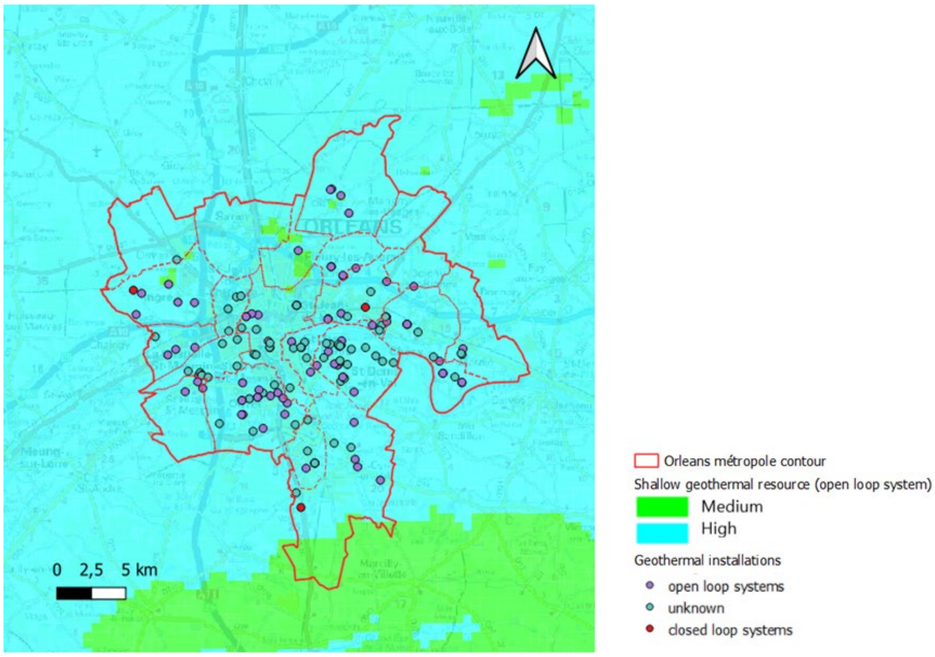


Figure 23. Geothermal potential for open loop systems in Orleans metropolitan area estimated in 2017 (Source: report BRGM/RP-66591-FR)

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.

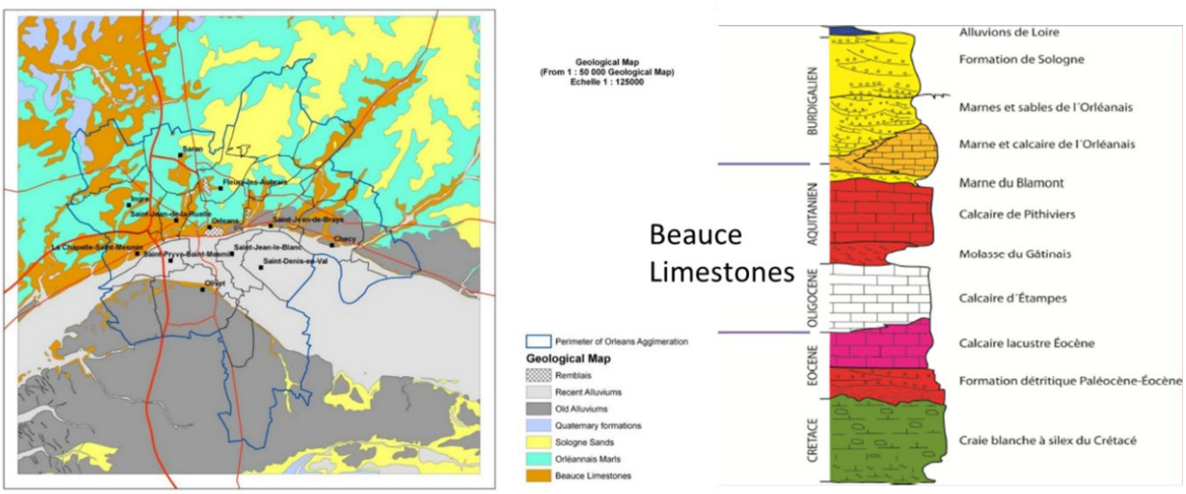


Figure 24. Geological map at Orleans Metropolis and hydrogeological units (Source: report BRGM/RP-70449-FR)

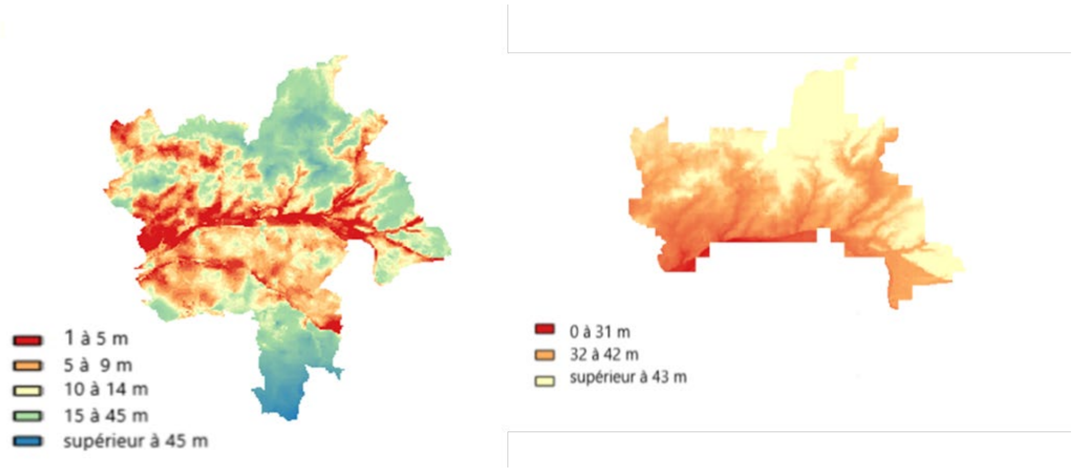


Figure 25. Depth of the Beauce limestones at Orleans metropolis (left: Pithiviers limestones, right: Etampes limestones) (Source: report BRGM/RP-70449-FR)

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).

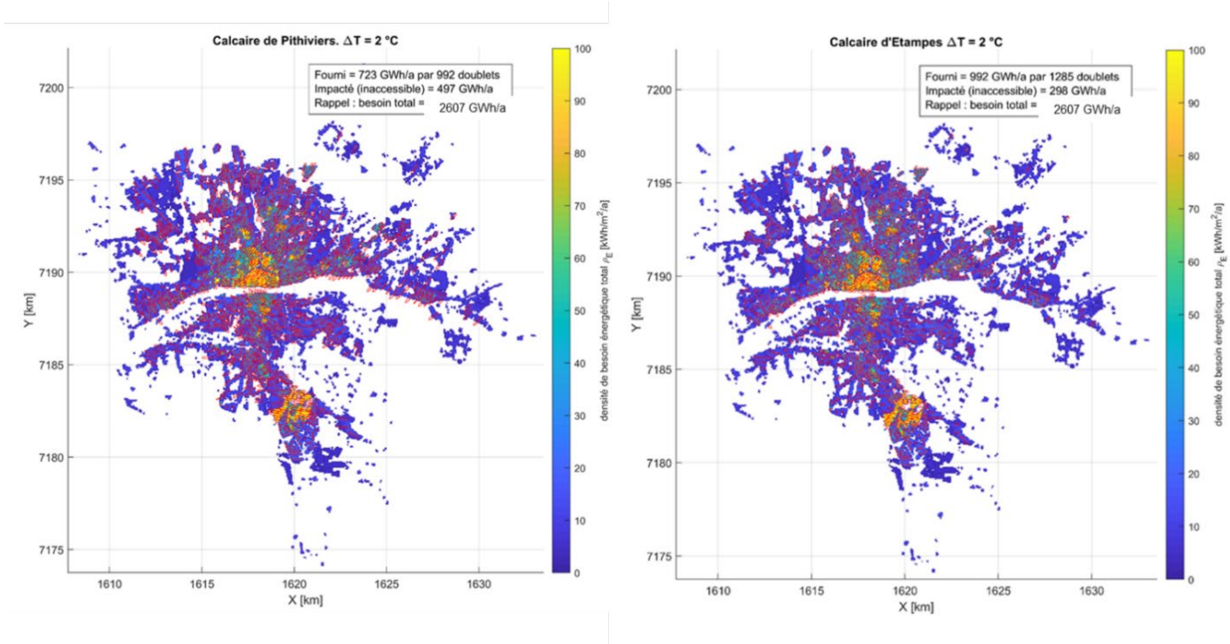


Figure 26. Maps of the shallow geothermal potential using open loop systems (left: Pithiviers limestones, right: Etampes limestones) (Source: report BRGM/RP-70449-FR)

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.

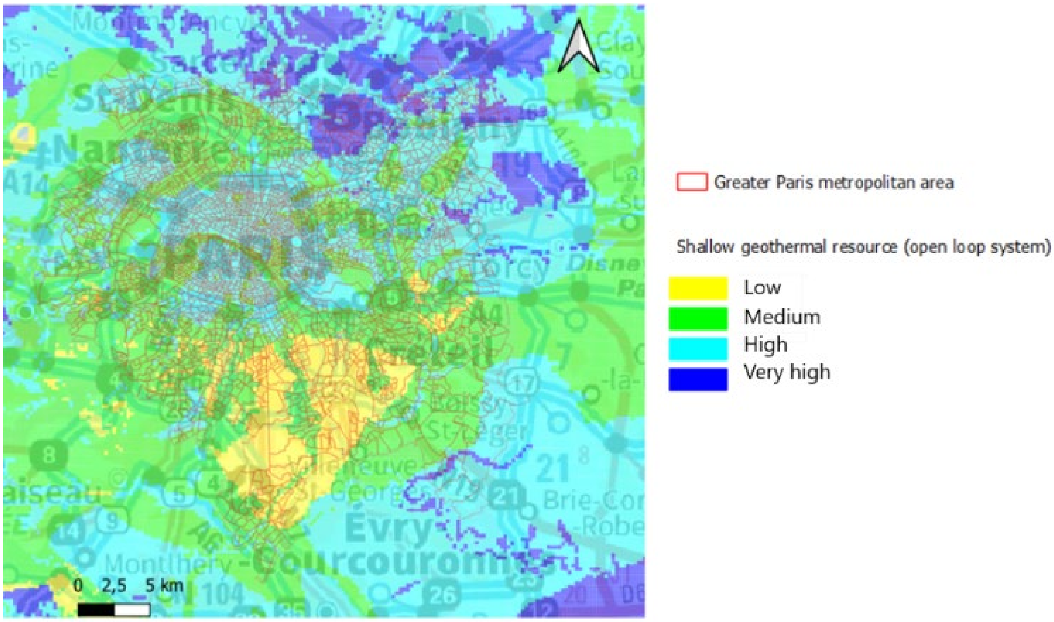


Figure 27. Geothermal potential for open loop systems in Greater Paris metropolitan area estimated in 2005 (Source: report BRGM/RP-53306-FR)

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.

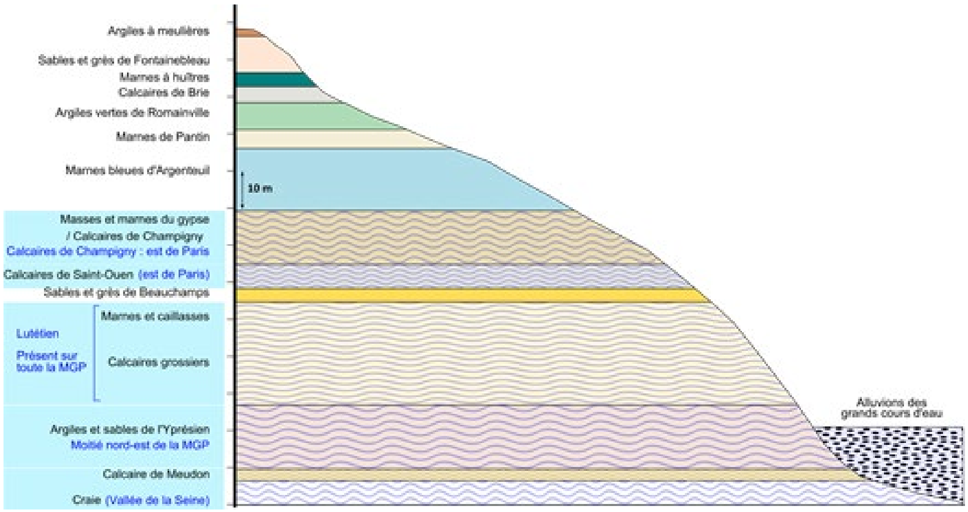
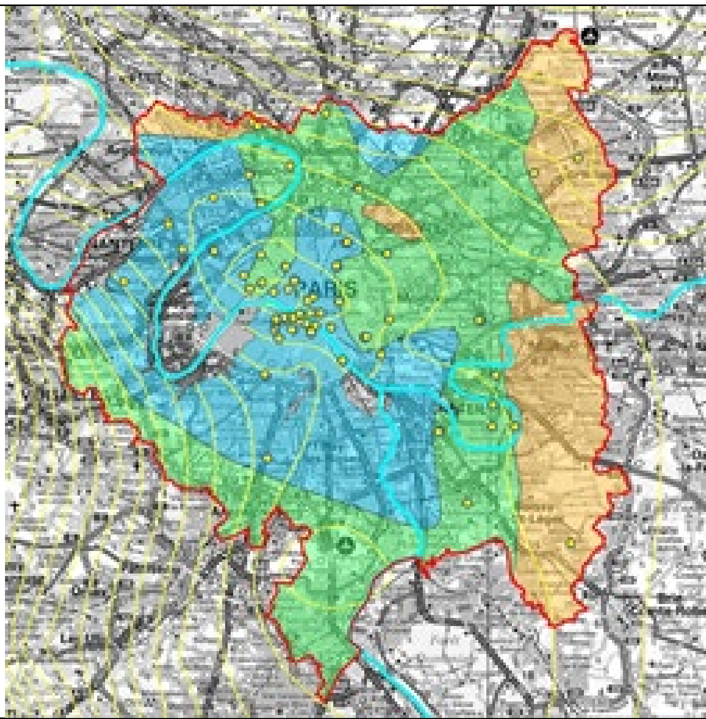
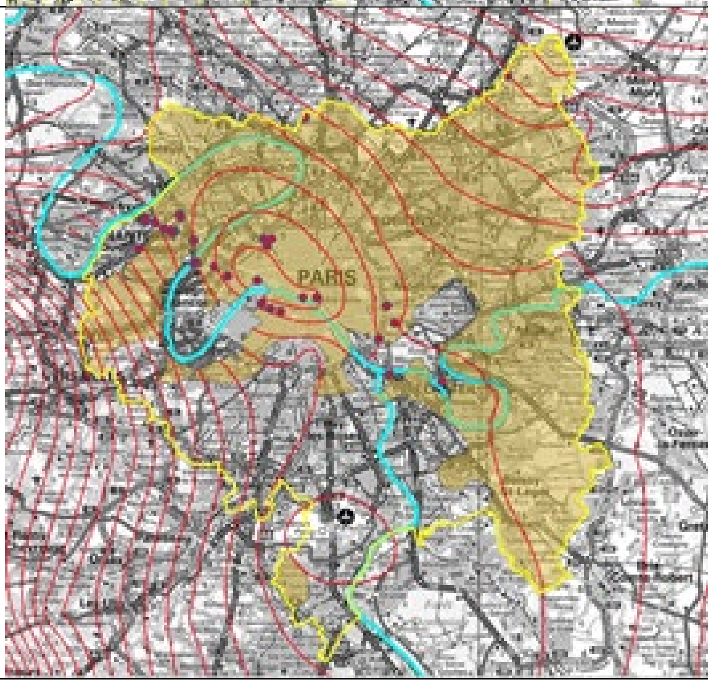


Figure 28. Stratigraphic column of geological formation below Paris metropolis and aquifer environment (blue highlight)

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)	

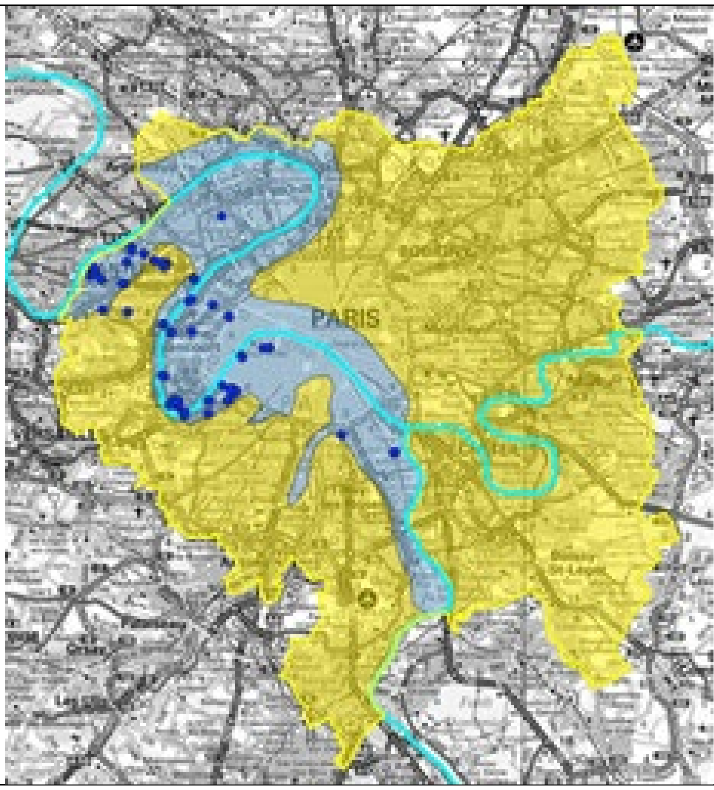
Craie aquifer Blue area: good exploitability (overlying formation has limited thickness) Yellow area: risk of low exploitability (Tertiary formations overlying the Craie aquifer)	

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.

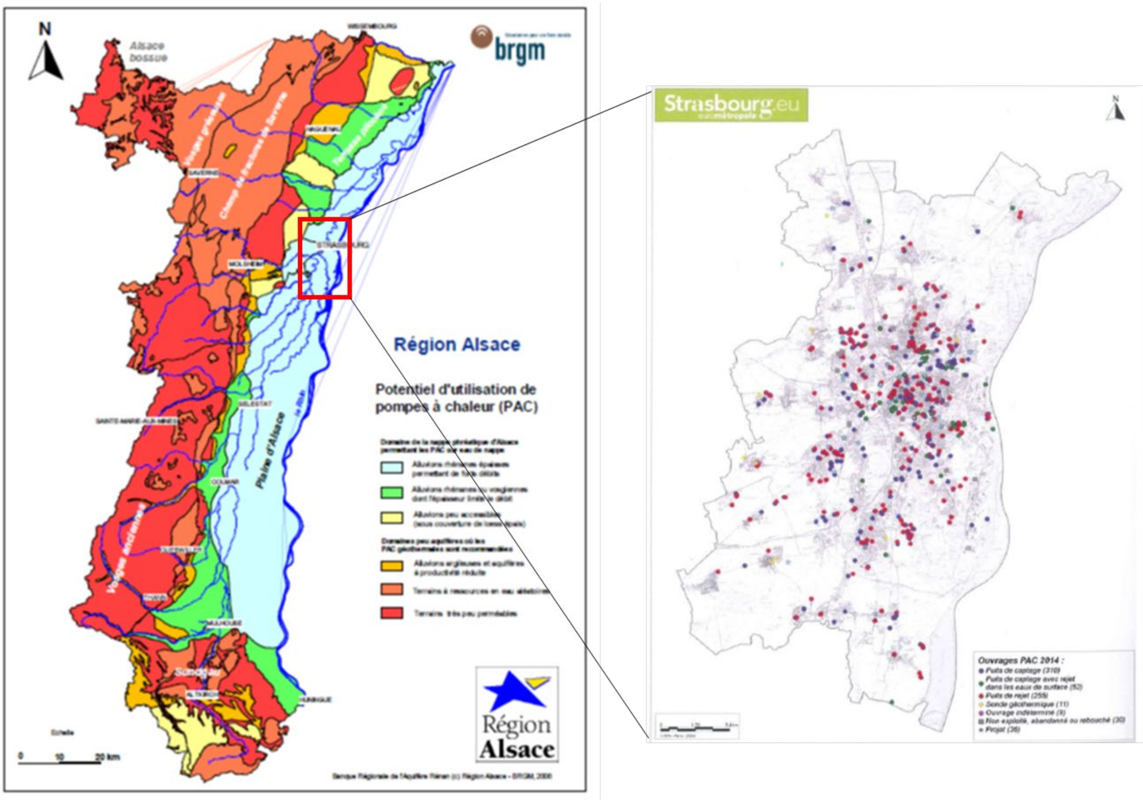


Figure 30. Shallow geothermal potential using heat pumps in Alsace (blue: alluvial Rhine aquifer allowing high flow rates) and location of shallow production and injection wells in the EMS (sources: reports BRGM/RP-59978-FR and BRGM/RP-65094-FR)

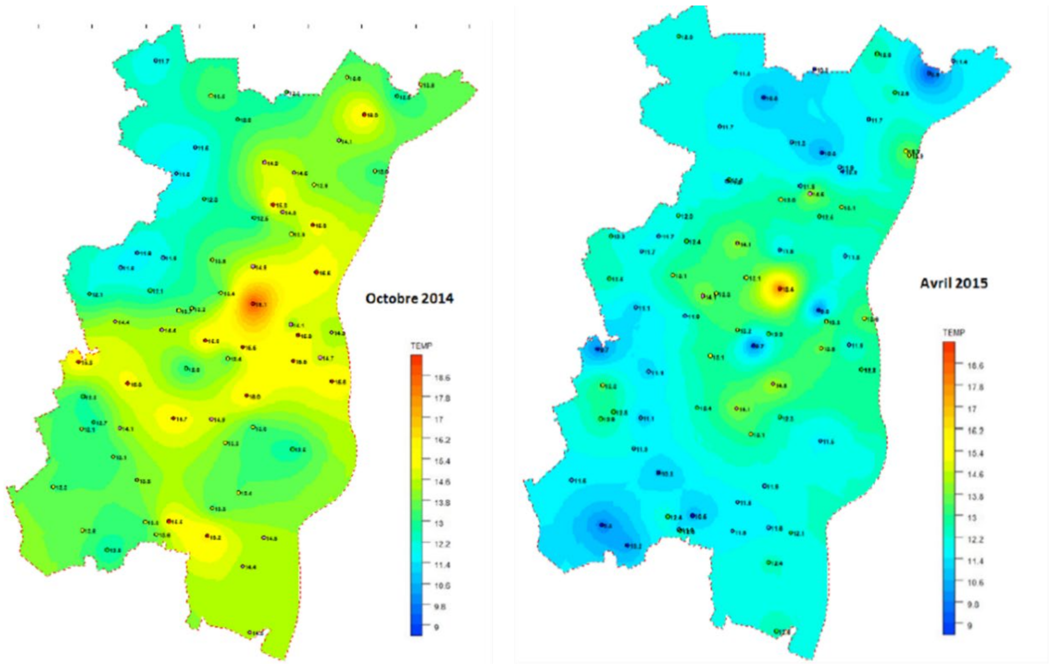


Figure 31. Temperature measurement of the Rhine alluvial aquifer (3 m below aquifer roof) after summer period (October 2014, left) and winter period (April 2015, right) (source: report BRGM/RP-65094-FR)

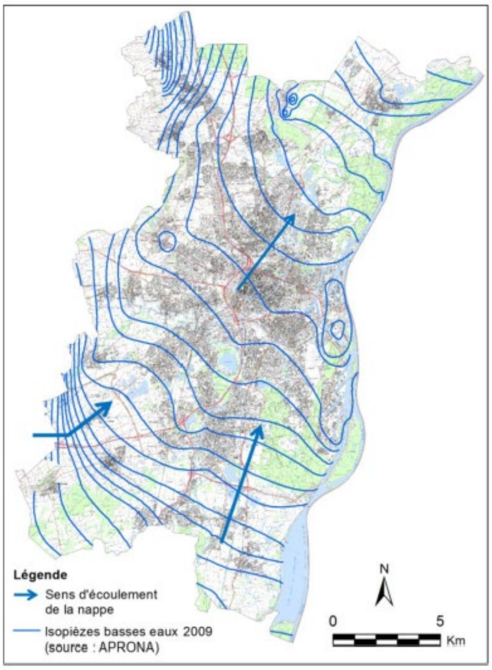


Figure 32. Main direction of flow of the Rhine alluvial aquifer at the EMS scale (source: report BRGM/RP-65094-FR)

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.

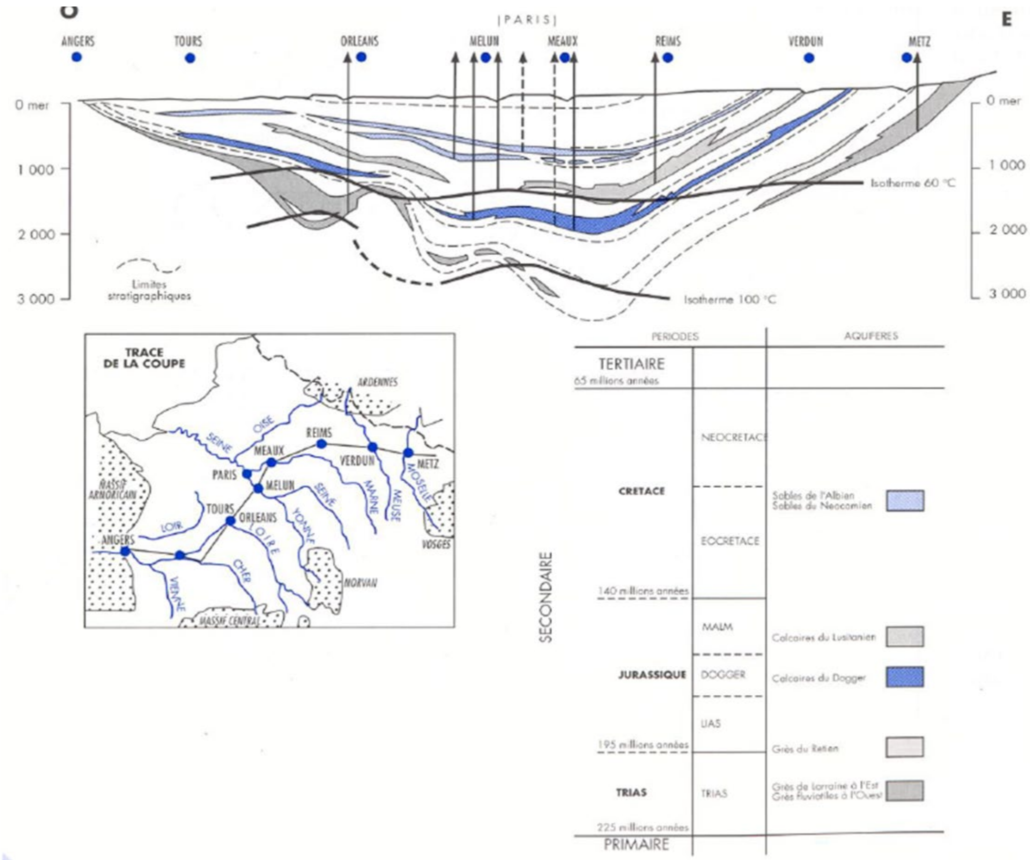


Figure 33. Geothermal deep resources in the Paris Basin

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.

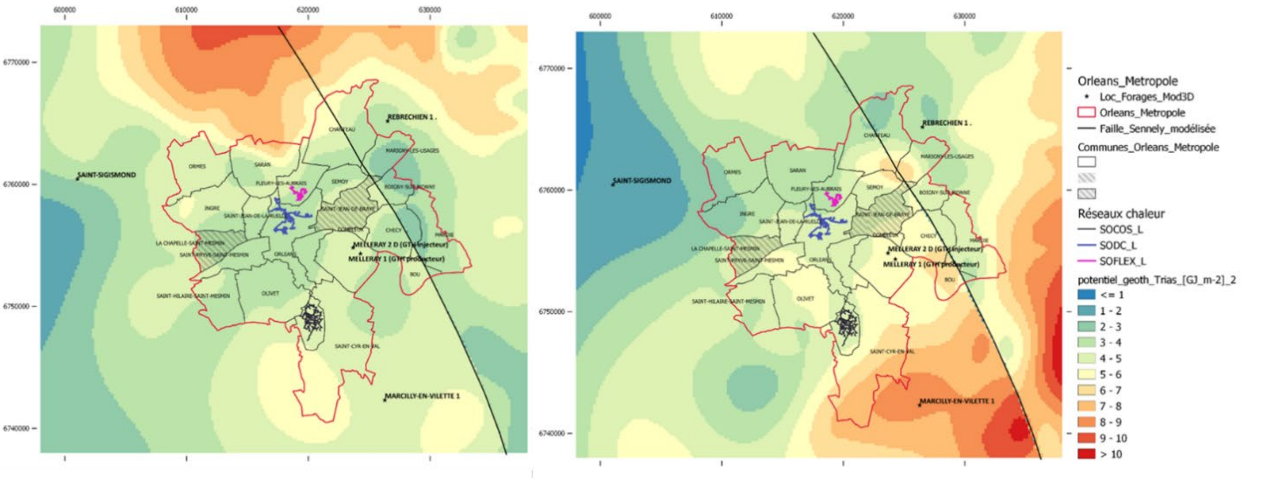


Figure 34. Assessment of the Dogger and Trias geothermal potential in Orleans Metropolis (GJ/m2) (source: report BRGM/RP-70363-FR)

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).

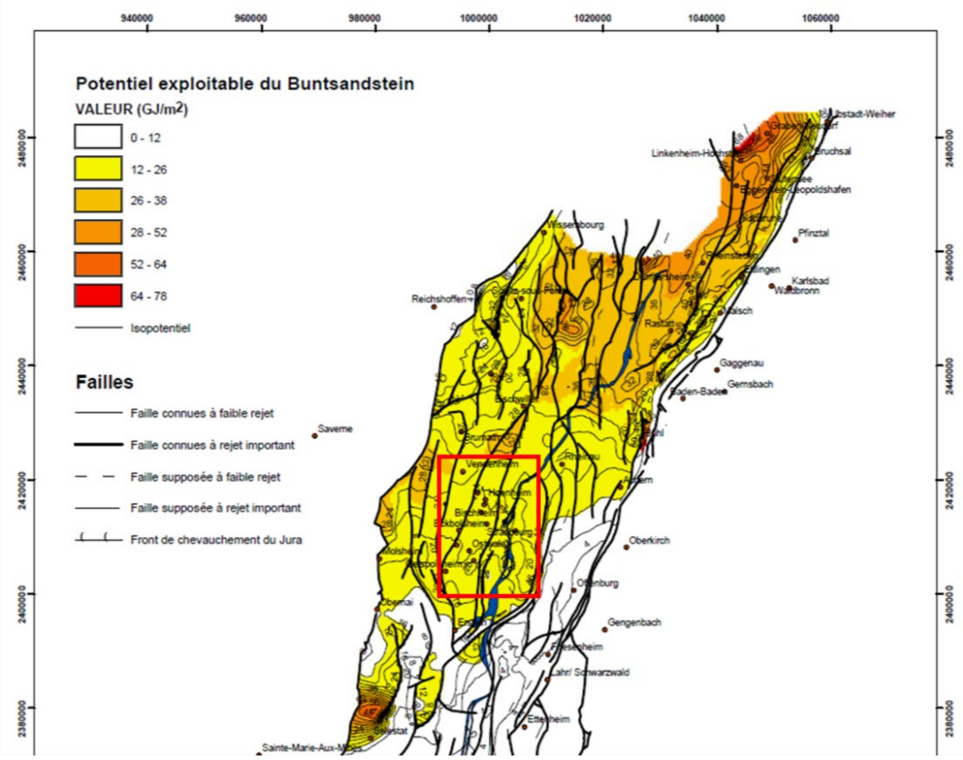


Figure 35. Geothermal potential of the Buntsandstein (GJ/m2) at the Eurometropolis (source: report BRGM/RP-56626-FR

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%).

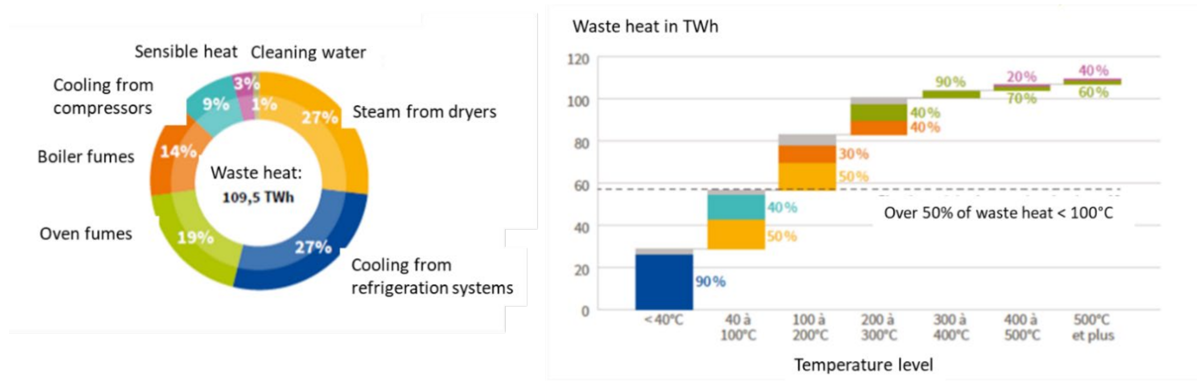


Figure 36. Distribution of industrial waste heat at national level (source: report ADEME on waste heat production, 2017)

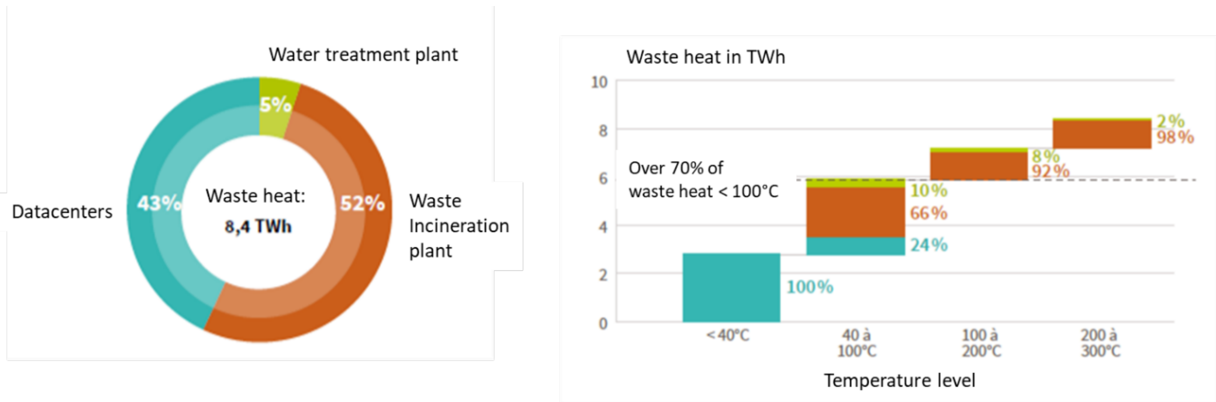


Figure 37. Distribution of waste heat from water treatment plants, waste incineration plants and datacenters at national level (source: report ADEME on waste heat production, 2017)

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).

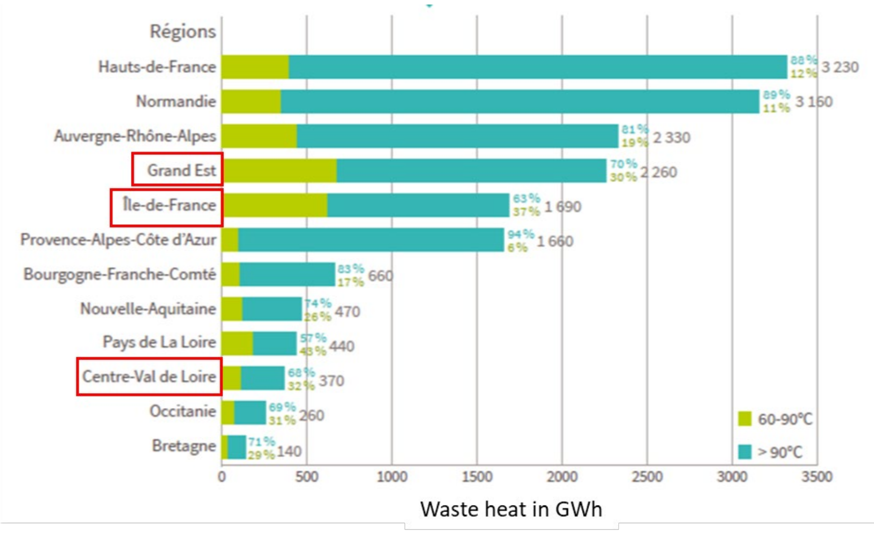


Figure 38. Distribution of waste heat (>60°C) in vicinity of DHN at regional scale (source: report ADEME on waste heat production, 2017)

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 m^2 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.

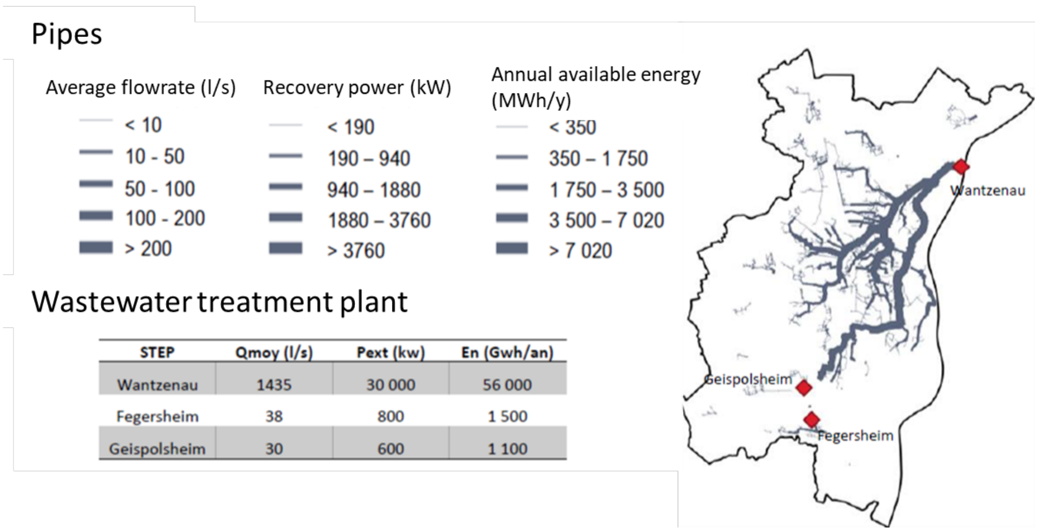


Figure 39. First assessment of wastewater heat recovery (source: "Etude sur le potentiel de récuperation d'énergie des eaux usées d'un territoire urbain – Application Eurométropole de Strasbourg", Antea-Group, 17 juin 2020)

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.

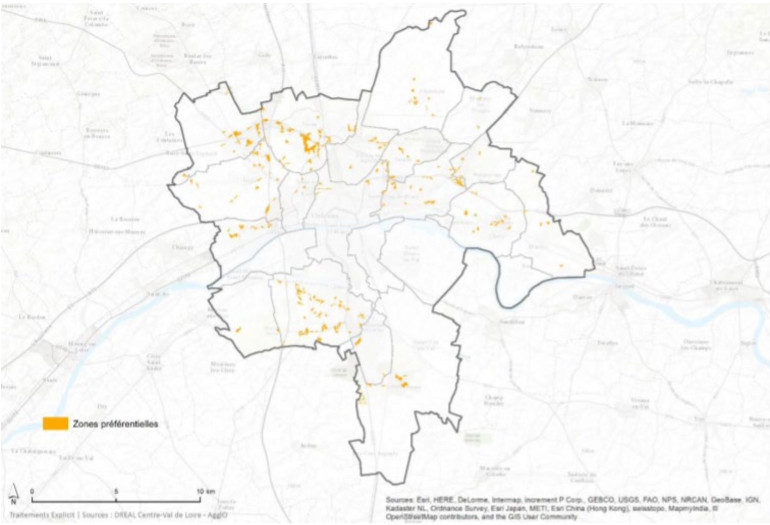


Figure 40. Potential zones for solar plant development in Orleans Metropolis

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

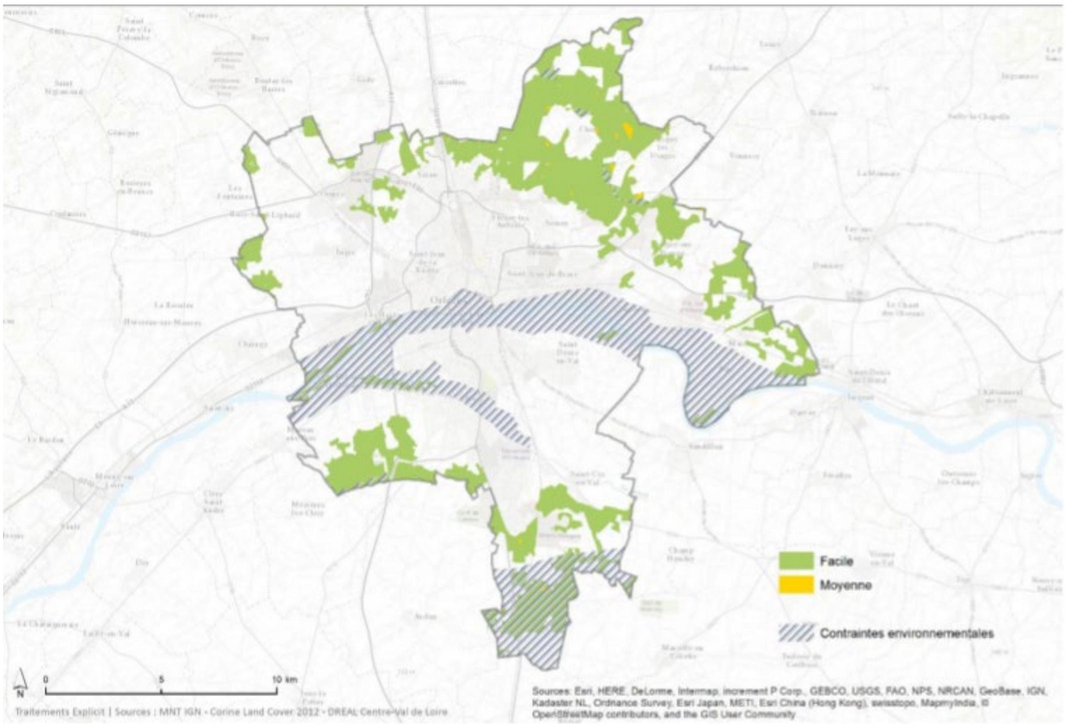


Figure 41. Location of forest areas and their potential of exploitable (easy in green, medium in yellow and under environmental constrain in hatched grey) inside the Metropolis of Orleans (source: Orleans Metropole - *Rapport de diagnostic énergétique*)

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

<table>
<tr><th colspan="2">Diagnosis</th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>
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.
</td><td>
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.
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<tr><th colspan="2">Trends</th></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>
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.
</td><td>
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.
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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 km^2, 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).

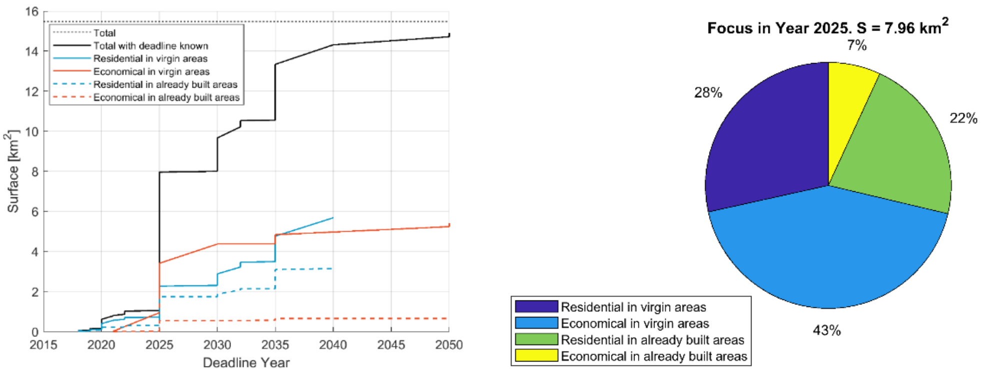

Figure 42 : Cumulated surface of the zones to be urbanized or re-urbanized as a function of the deadline (left). Special focus on deadline 2025 (right)

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.

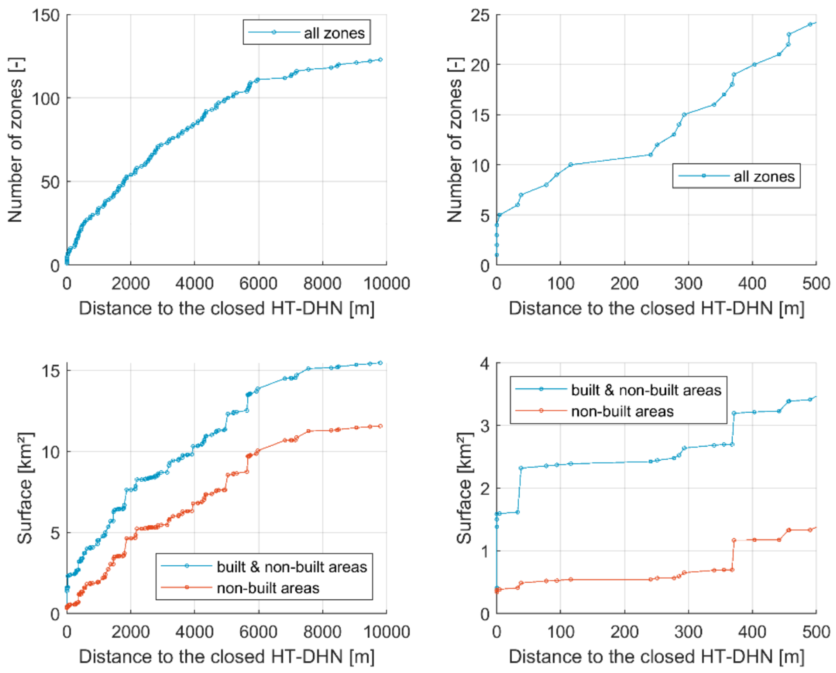

Figure 43 : Zones to be urbanized or re-urbanized: Distance from the zone boundary to the closest 3G-DHN

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.

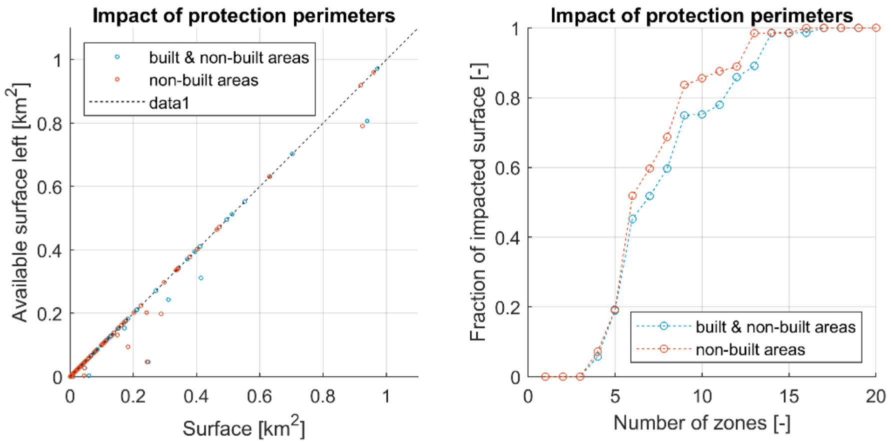

Figure 44 : Zones to be urbanized or re-urbanized: Surfaces impacted by the protection perimeters

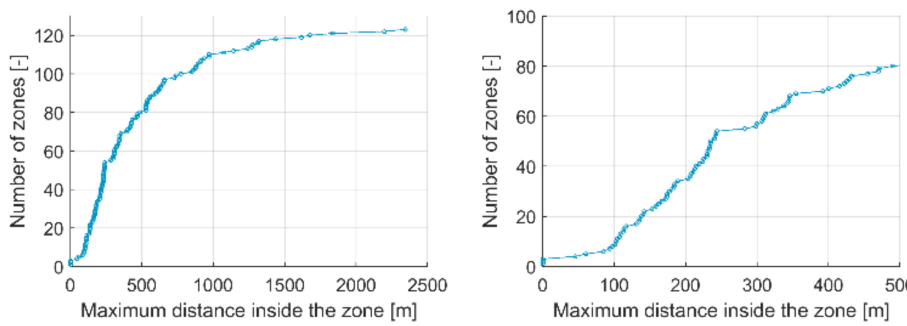

Figure 45 : Zones to be urbanized or re-urbanized: Maximum distance inside each zone for the implantation of doublets once the protection perimeters have been subtracted

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.

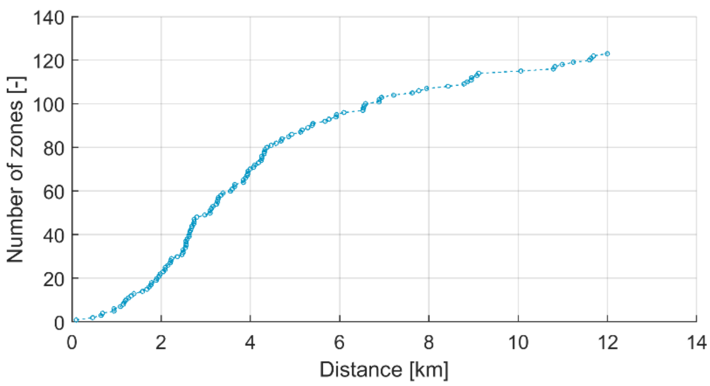

Figure 46 : For every zone to urbanize or re-urbanize, distance between the zone and the closet waste heat producer at a low temperature level

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.

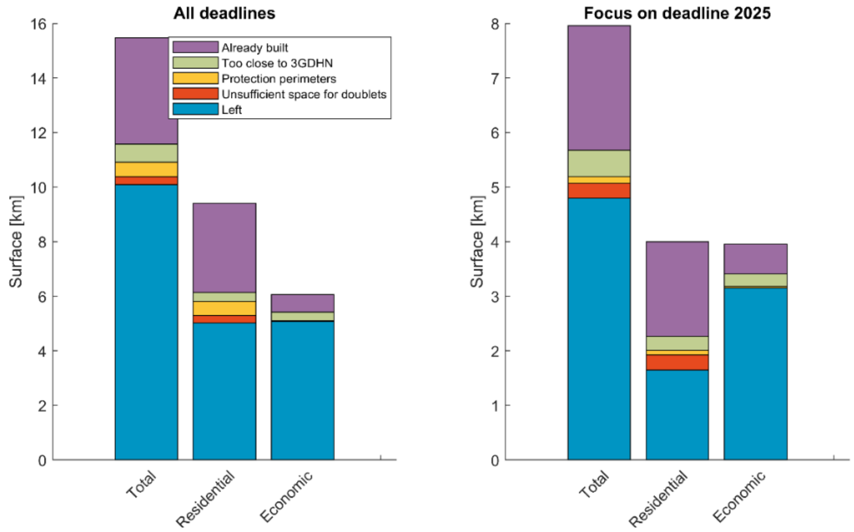

Figure 47 : Surface of zones to urbanized or re-urbanized left for connection to 5GDHC once already built areas, proximity to 3GDHN, protection perimeters for drinkable water wells and insufficient space for doublet has been subtracted

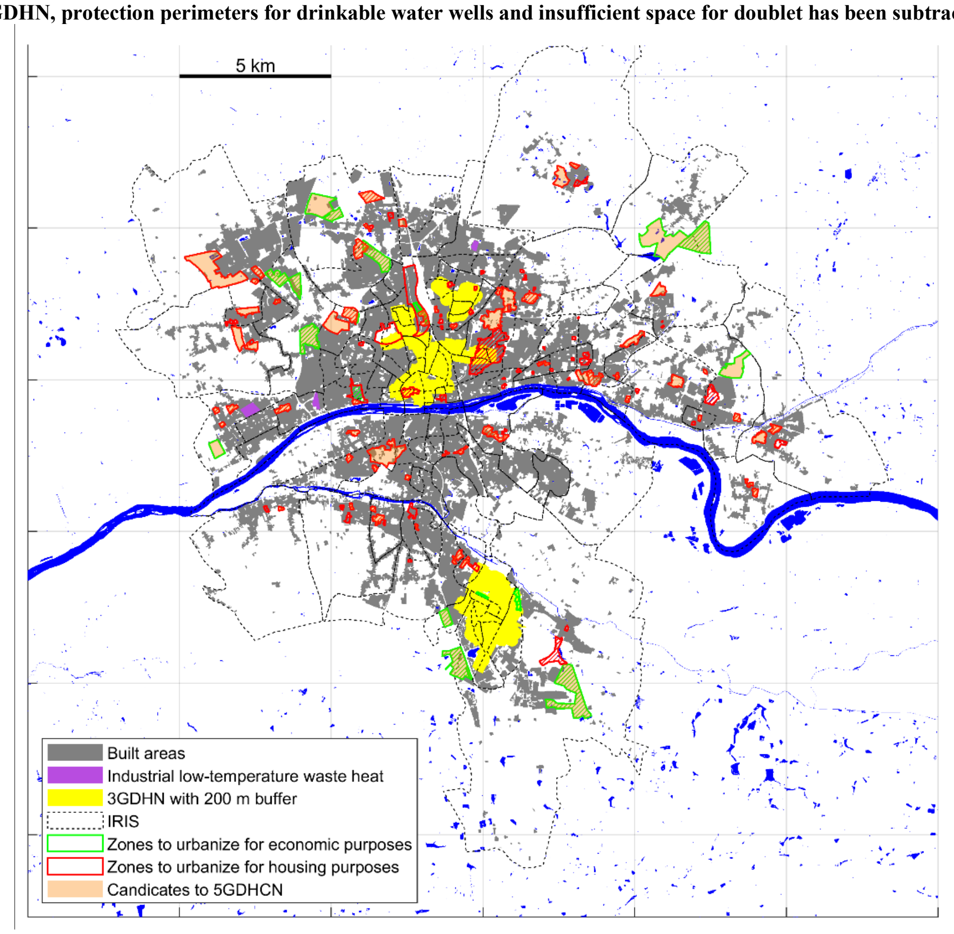

Figure 48. Potential areas for 5GDHC development in Orleans Metropolis. Hatched polygons accounts for zones to urbanize before 2025. Candidates (colored in orange on the map) to 5GDHCN have room for doublets, are 200 m far away from any 3GDHN, are outside protection perimeters of drinking water wells,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

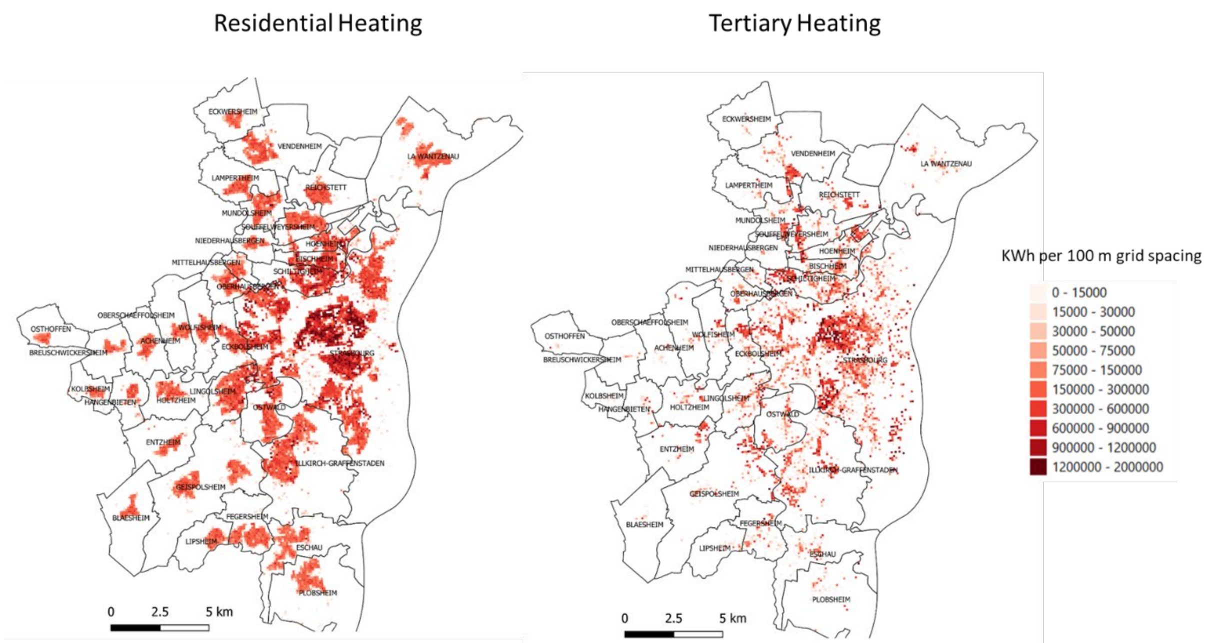

Figure 49. Residential (left) and Tertiary (right) heating needs in Strasbourg Eurometropolis (Source: CEREMA, 2020)

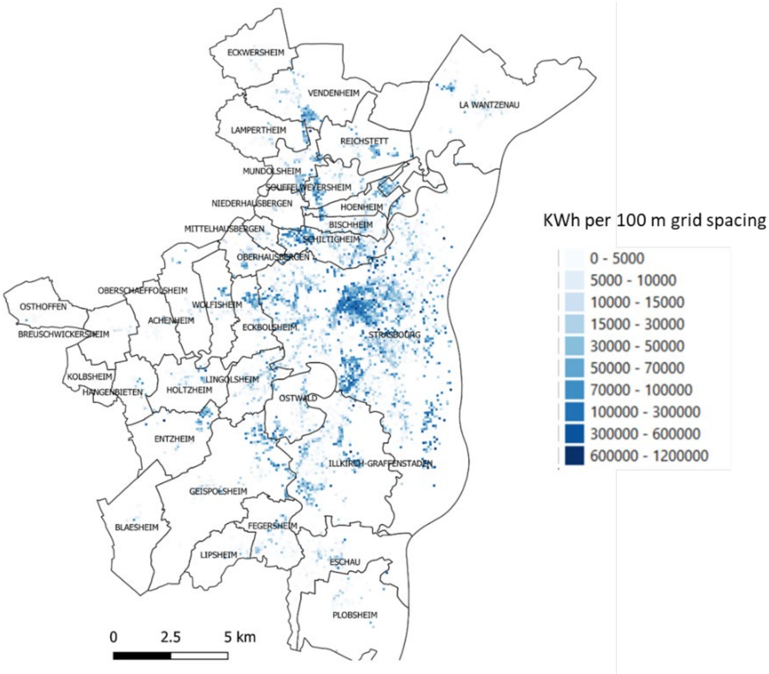

Figure 50. Tertiary cooling needs in Strasbourg Eurometropolis (Source: CEREMA, 2020)

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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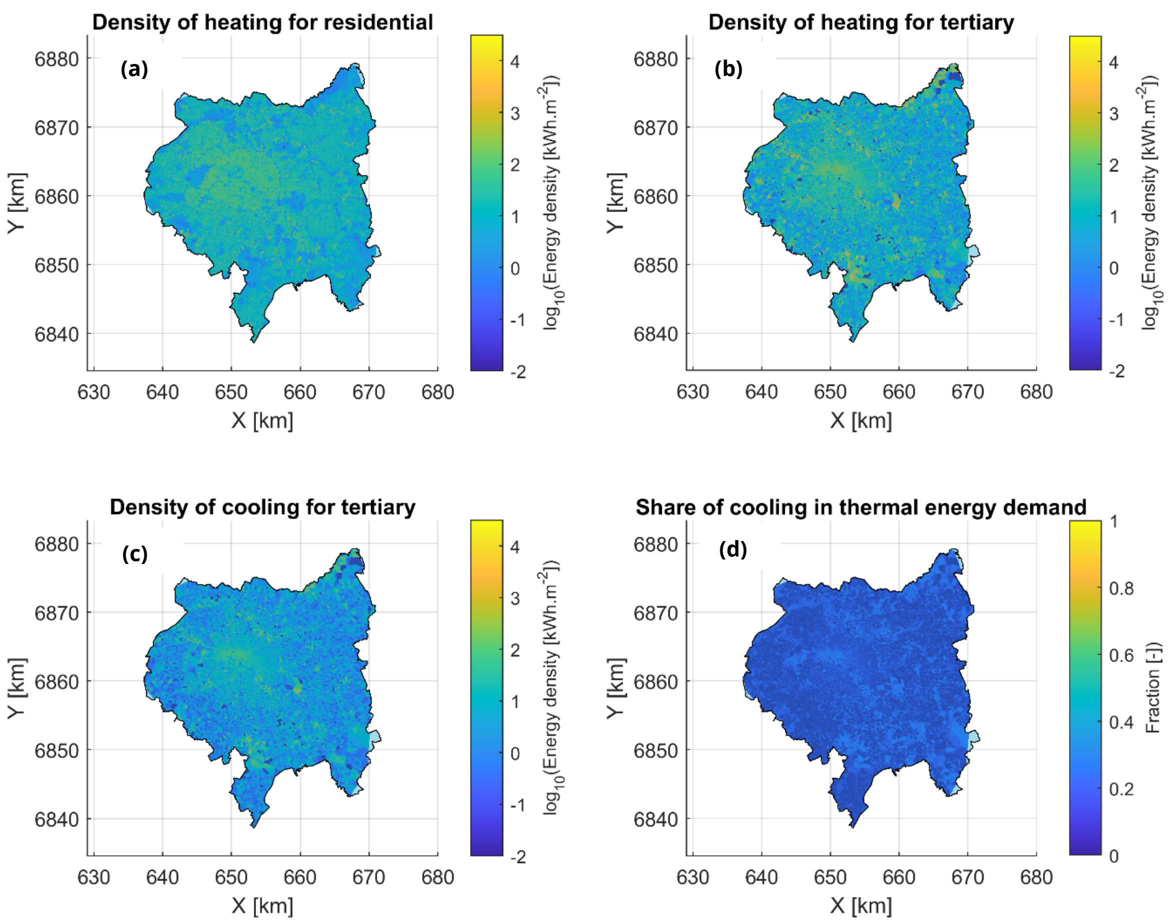

Figure 51. Greater Paris Metropolis : (a)-(c) : Needs for heating in housings (a), in tertiary sector (b) and cooling in tertiary sector (c) ; (d) : share of cooling for tertiary sector in the thermal energy demand (i.e., sum heating and cooling) (Source: CEREMA, 2020). Data are represented at 100 m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

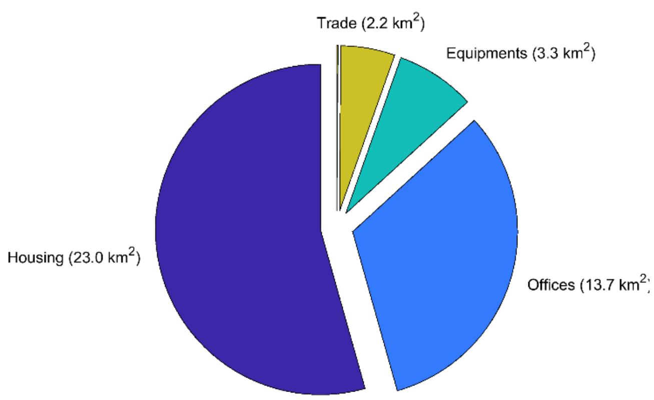

Figure 52 : Repartition of the type of surfaces of floor in the zones covered by the APUR.

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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