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

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Table of content

List of Figures

1. Introduction

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

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

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

Useful Resources

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

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

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

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

2. Characterising the region

2.1. Luxembourg:

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

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

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

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

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

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

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

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

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

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

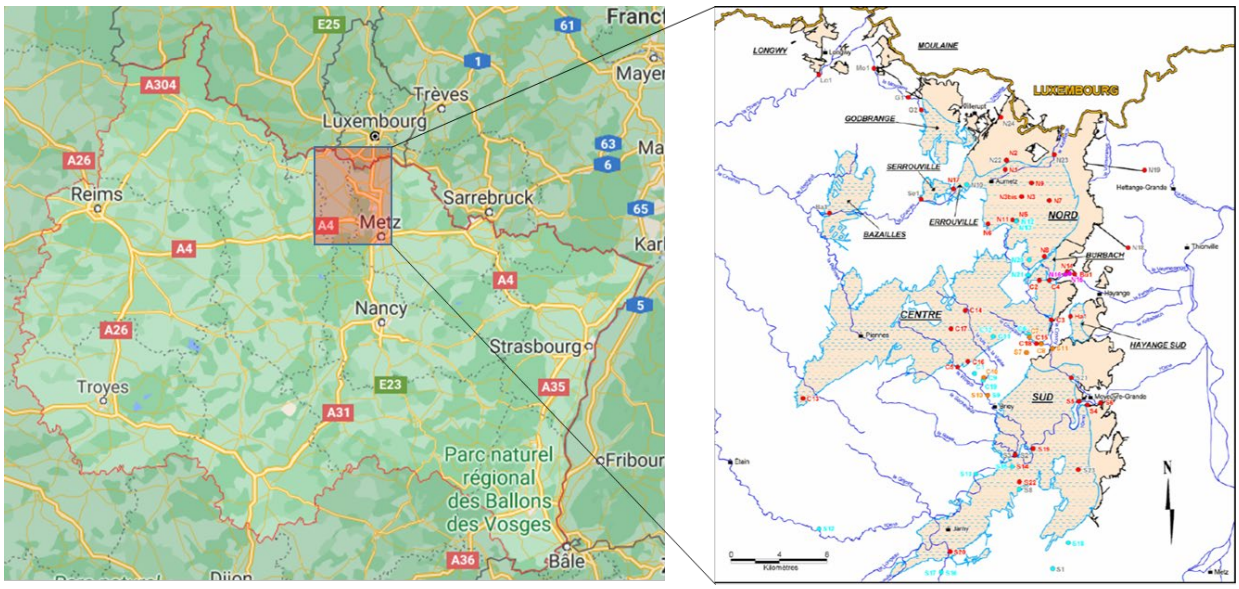

Figure 1. Localization of the Lorrain Iron Basin and main reservoirs (North, Central and South) at the Luxembourg border in "Grand-Est" region (source: report BRGM/RP-67079-FR

3. Analysis

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

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

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

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

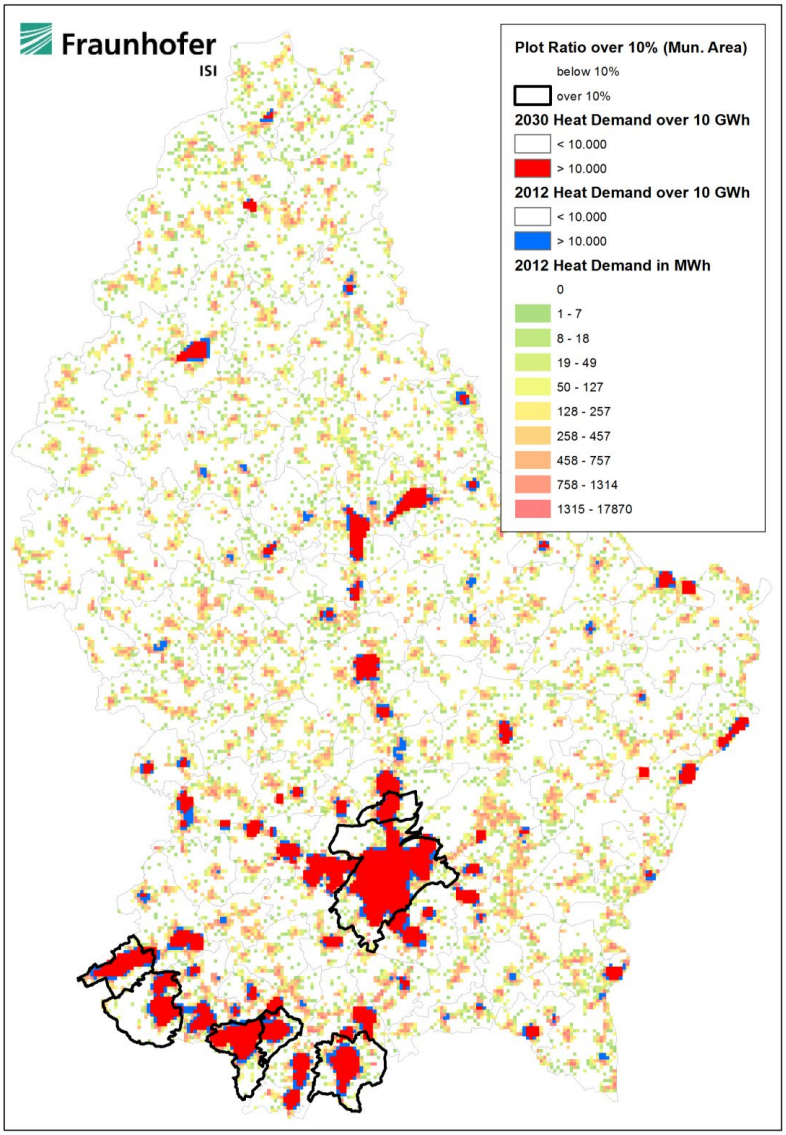

Figure 2: Heat demand analysis for Luxemburg municipalities(Assessment of the potential for the use of high-efficiency cogeneration and efficient district heating and cooling. Report of the Ministry of Economy Luxembourg 2016)

Currently dominant heating technology in the region

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

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

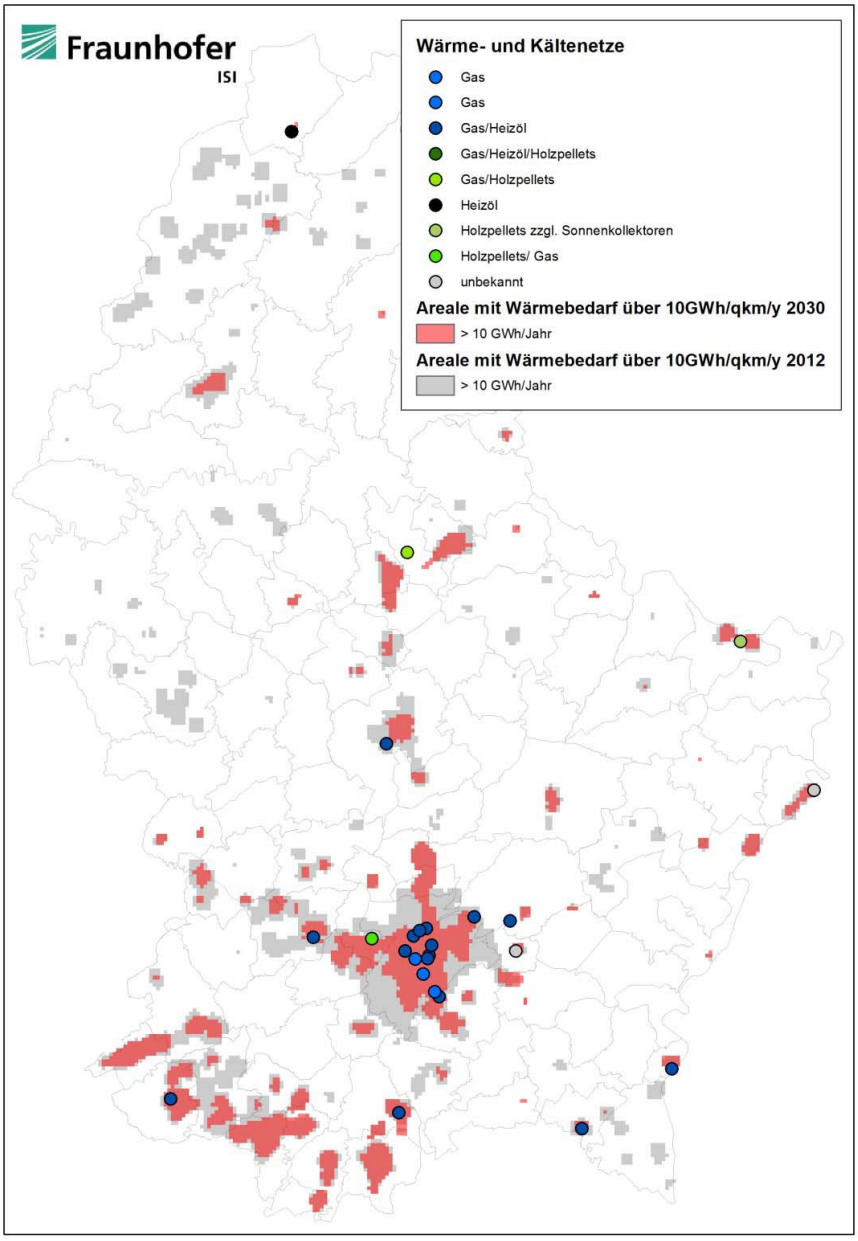

Figure 3: Analysis of existing heat networks Assessment of the potential for the use of high-efficiency cogeneration and efficient district heating and cooling. Report of the Ministry of Economy Luxembourg 2016)

District heating in the current heating regime

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

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

Main actors in the current heating regime

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

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

We have only one national gas and electric provider CREOS.

Legal framework and operational context for these actors

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

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

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

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

Current organization of heating markets

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

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

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

3.1.2. Developments in heating policy and market contexts

Current developments in the legal system and market organization

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

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

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

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

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

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

3.2.2. Ownership and operation of district heating systems

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

3.2.3. Regulation of price setting

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

3.2.4. Role of building owners and building occupants

Deciding the heat source of the building

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

Investments and energy bill

There are at least two models:

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

3.2.5. Financing and subsidies

Localized subsidy or grant mechanisms are available

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

3.3. Available energy sources and storage

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

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

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

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

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

Flooded underground infrastructure

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

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

Aquifers

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

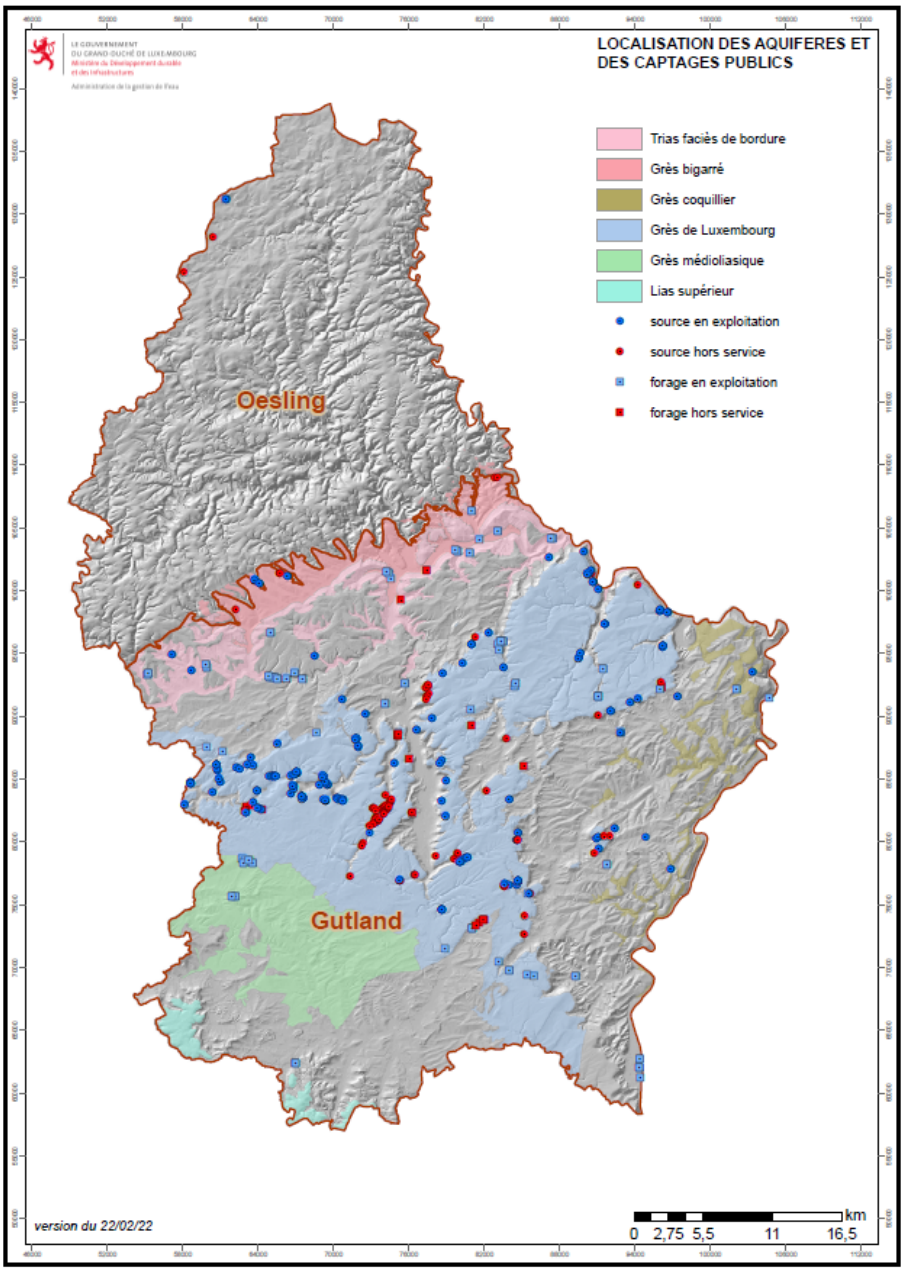

Figure 4. Location of aquifers in Luxemburg

Solar thermal development potential:

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

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

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

3.3.4. Renewable electricity from local sources like wind, sun

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

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

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

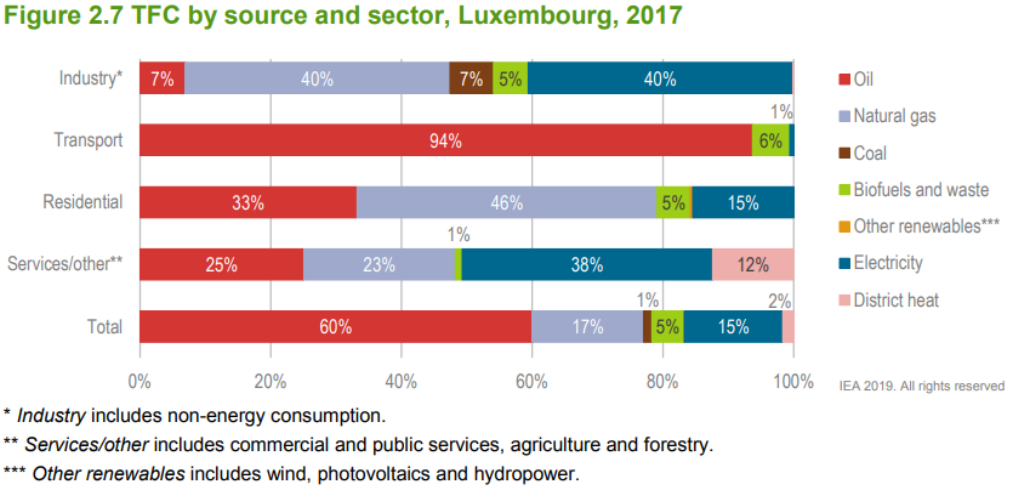

Figure 5. Total final consumption by source an sector.
Source: IEA (2019b), World Energy Balances 2019, www.iea.org/statistics.

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

3.3.6. Electricity mix from the external grid

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

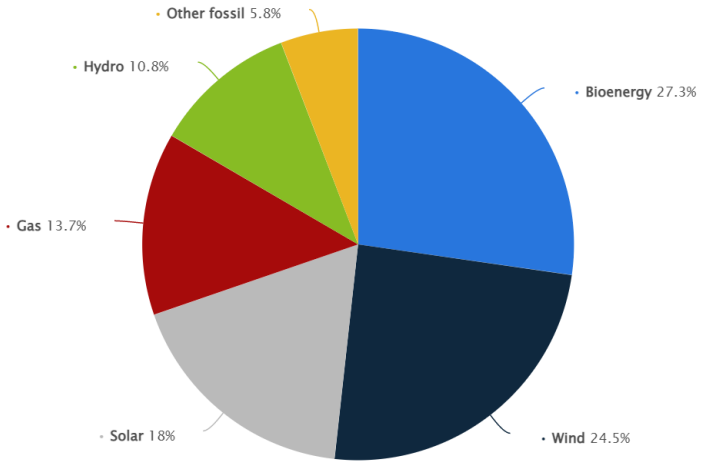

Figure 6. Distribution of electricity generation in Luxembourg in 2021, by source. www.statista.com

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

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

3.3.8. High temperature heat from burning fossil fuels

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

4. SWOT analysis

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

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

5. Regional vision

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

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

5.1. High potential areas and potential pilot sites

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

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

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

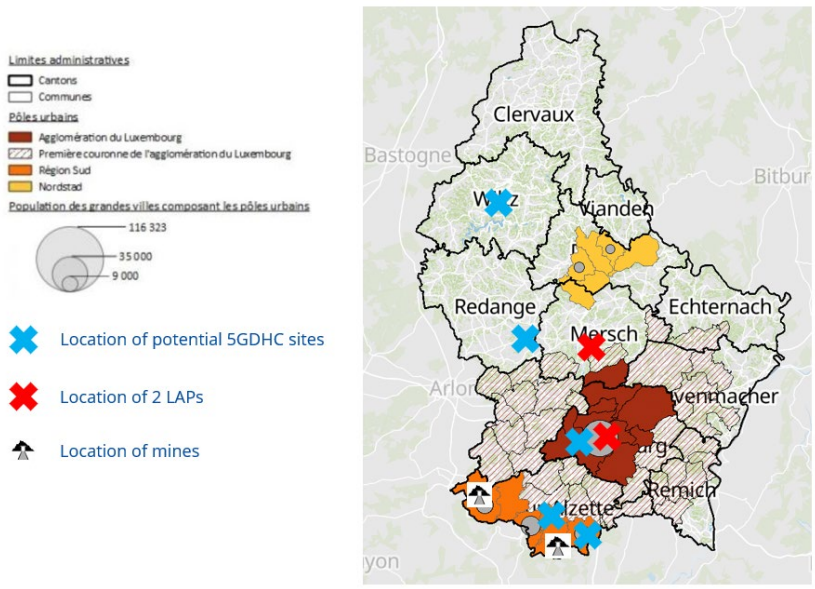

Figure 7: Potential 5GDHC sites in Luxembourg.

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

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

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

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

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

5.2. Roadmap

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

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

6. References

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