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FOUNDATION FOR THE METHODOLOGY TO EVALUATE MARKET TRANSFORMATION POTENTIAL OF D2GRIDS

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1.Introduction

1.1. D2Grids project

The EU has a target of at least 32% RES in its final energy consumption by 2030. However, in 2016 the actual share of RES reached only 16.9%. In 2020 it reached 22.1%, partly due to the lower consumption levels resulting from the Covid-19 pandemic. All three of the EU-28 which failed to meet their Renewable Energy Directive indicative targets in 2016 were from NWE: France, Luxembourg, and the Netherlands. These three also failed to meet their indicative trajectories set in their National Renewable Energy Action Plans (NREAPs). However, in 2020 only France did not reach it targets, since the other two were again helped by a lower consumption due to the Covid-19 situation.

Heating and cooling account for 50% of the EU's total energy consumption but, at present only 19.1% of this is sourced from renewables, while in 5 countries out of 7 in North-West Europe the same ratio is below 8.2%. This makes heating & cooling an obvious target sector for efforts to increase the share of RES. Governments in NWE are increasingly considering the phasing out of the currently dominant gas infrastructure. For these ambitions, district heating (DH) is a possible solution that can offer a range of benefits, such as improved energy efficiency, simplified building operations and decreased costs, storage capacity for thermal energy, and most importantly fuel flexibility allowing for effective integration of renewable heat sources. While district heating is widely used in North Europe and Central and Eastern Europe, with market shares often greater than 50%, at the level of the EU the share of district heating is 9%, and only 5% in NWE, indicating a large growth opportunity for the sector.

Current DH systems vary hugely in terms of energy performance and sustainability. 2nd generation systems are built on central power plants serving end-users via a hierarchic top-down heat grid and use pressurised hot water mostly over 100°C as a heat carrier. In 3rd generation systems supply temperatures are often below 100°C. In recent years 4th generation district heating (4GDH) has started to spread. 4GDH systems can supply low-temperature (50-60°C) district heating; to distribute heat in networks with lower grid losses; to recycle heat from low-temperature sources and integrate renewable heat sources (e.g. solar, geothermal, biomass); and to be an integrated part of smart energy systems, but still typically rely on a central plant to supply and store heat.

The 5th generation of district heating and cooling (5GDHC) is a fundamentally new concept based on a decentralized network allowing direct energy flows among and within buildings, not requiring a central heat plant. Its key features are:

1. low exergy grid utilizing low-temperature heat sources;
2. closed thermal energy loops ensuring hot and cold exchange among clusters of buildings;
3. integration and synergy between thermal and electricity grids. These features enable 5GDHC systems to be solely fuelled by RES.

The operational model of this concept has been implemented in Heerlen, where the system was originally based on the exploration of shallow geothermal energy with low source temperatures (about 30°C) from flooded mineshafts. Through the extension of the network, and advancement of the technology for exploiting the closed-loop heat exchange mechanism, the clusters of buildings have been transformed into nearly autonomous energy systems. As a result, the water reservoir in the former mine serves today mainly as an energy storage facility and not as a dominant heat source, proving that the technology can be implemented in a variety of geographical contexts.

The idea of the project is to extrapolate the case of Heerlen through pilots to a wider generic and easily replicable model of 5GDHC systems that can be rolled out across NWE to regions with various geological, socio-economic and regulatory conditions. D2Grids is based on intense territorial cooperation, as it is vital to ensure that the system works in different environments under different conditions, otherwise a fundamental shift in the NWE and wider EU heating & cooling market would not be possible.

1.2. 5GDHC

The project's focus within the heating and cooling sector is on the definition, demonstration and commercialization of a standard and replicable 5GDHC technology model, which can substantially increase the share of RES and decrease GHG emissions in NWE. 5GDHC systems go beyond existing best practices in several ways:

1. It is an ultra-low temperature system based on the principles of low exergy, which allows one energy unit to be deployed multiple times through cascading. It enables the use of low valued energy supplied by sustainable energy sources (low temp. waste heat and RES), instead of fossil fuels, which deliver high valued energy. Due to low source temperatures (ca. 30°C) building energy plants integrating a cloud of heat pumps operate at end-user locations to provide required temperature levels. The decentralized, low-temperature grid with shorter transportation distances reduces distribution losses to 5% compared to 25% typical for conventional heat grids.
2. The system builds on closed thermal energy loops connecting heating & cooling, ensuring hot and cold exchange within and among buildings with the help of a cloud of heat pumps. By closing the loop consumers purchasing heat deliver cold in return, while customers purchasing cold deliver heat. Potential imbalances in heating & cooling demand are equalized by buffering at building, district and cluster levels.
3. The system allows integration of thermal and electricity grids that enables storage of surplus electrical energy generated by RES.

Even in the early design phase, the concept promoted by D2Grids is demand-driven as it is configured in such a way that demand and supply profiles of connected buildings are matched as much as possible. During operation, advanced demand-side management is applied (tackling peak load and demand balancing), which ensures that the system only provides the required temperatures at the right time and place (demand adapted supply) with low grid losses. D2Grids promotes a modular design that allows flexible extension of existing networks or the deployment of new systems in a variety of contexts. The project defines standards for modular plug-and-play components (i.e. pipes, sub-stations, building plants, storage buffers and control units), which can be prefabricated and installed in various environments.

5GDHC is the most suitable district heating and cooling technological model for increasing the share of renewables in the sector: 1) due to low grid temperature, low grid losses and efficient heat exchange mechanisms, total energy demand (incl. thermal and electricity) of the system is substantially reduced, which can be effectively and securely supplied by RES; 2) the system is based on the integration of heat pumps using ambient heat and operated by RES (e.g. solar, wind), and can be linked to the exploration of shallow geothermal energy; 3) through integration with the electricity grid the system can store surplus electrical energy generated by fluctuating green sources; 4) the 5GDHC concept also delivers an (indirect) incentive to lower the heating and cooling demand of the connected buildings (low temperature heating only works properly in houses with a low heating demand). Therefore, it not only prevents unnecessary losses in the grids itself but also in the buildings connected to the grid. This directly helps to improve the share of RES.

1.3. Goals and objectives of D2Grids

D2Grids aims to increase the share of renewable energy in North-West Europe's heating and cooling sector by accelerating the roll-out of 5GDHC technology in North-West Europe. By promoting 5GDHC standards towards the industry and attracting investors, public authorities and project developers will be empowered to implement new 5GDHC investments and to modernize existing DH networks. In order to reach this main objective, the project has three subobjectives:

1. To industrialize the 5GDHC technological model
2. To reduce market barriers hindering the uptake of 5GDHC systems
3. To demonstrate the 5GDHC concept at pilot sites

The project promised key outputs in terms of climate impact as a direct result of the efforts taken in the project. These impacts are defined for three distinct periods in time, which are specified in Figure 1. Of these, the output at the end of the project will mostly be the direct result of the pilot investments (specified in Table 2). Outputs further in the future are the combined results of the expansion of the pilot sites and accelerated roll-out of 5GDHC across North-West Europe as a result of the industrialized standardization and commercialisation of 5GDHC, initialized by the project.

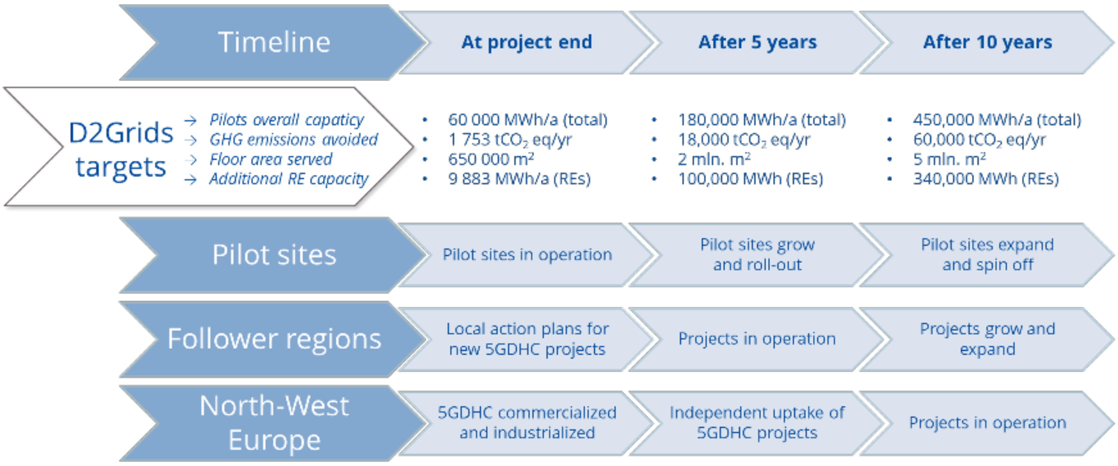


Figure 1. The impact across time and space of D2Grids

The process of how industrialization and reduction of market barriers lead to the stated climate goals, is displayed in Figure 1. Part of the greenhouse gas emission reductions will be realized at the **pilot sites**, even though their main purpose is demonstration of the 5GDHC concept (WP.T3). These sites are expected to grow over the 10 years after the project ends, increasing their positive climate impact. At the end of the project, a number of local action plans for 5GDHC projects in seven defined **follower regions** will be delivered (D.LT.1.4). These plans follow from a regional feasibility assessment (D.LT.1.3), which specifies barriers and opportunities for the roll-out of 5GDHC. In the ten years following, these projects will have grown and expanded, contributing to avoiding greenhouse gas emissions. The last and largest part of the avoided emissions will come from 5GDHC projects that will develop across North-West Europe as a result of the commercialization (WP.T2) and industrialization (WP.T1) actions in D2Grids. These projects will not have been initiated in D2Grids, but the efforts within D2Grids will have generated a market in which 5GDHC development is a competitive and attractive proposition.

The potential contributions of each of the pilot sites were defined in the preliminary transnational roll-out strategy (D.LT.1.1), and the planning of the pilot sites. These contributions are displayed in Table 2.

Table 1. Project general objectives

Project objectives	**Target**
Nr. of technologies meeting 5GDHC standards applied and validated at pilot investments	15
Amount of funding leveraged by the project [€]	35 000 000
Nr. of enterprises co-operating with research institutions	9

Table 2 Renewable energy production and greenhouse gas reduction targets per pilot site

	Estimated annual decrease of GHG [t/a]	**RE production capacity installed [MW]**
Pilot projects		
Brunssum	1 408	4.70
Glasgow	41	1.00
Paris-Saclay	112	0.60
Bochum	92.24	1.30
Plymouth	100	6.00
Capitalisation		
Brunssum	579	1.55
Glasgow	86	0.52
Paris-Saclay	40	0.19

2. Evaluation strategy: Objective and scope of deliverable

D2Grids puts in place a comprehensive evaluation strategy. Socio-economic results will be measurable through the Evaluation of the market transformation potential (D.LT.4.2.), while environmental effects are captured through an Environmental impact assessment (D.LT.4.3). Based on evaluation results, policy implications will be channelled into EU level and national policymakers. In this document, we lay out the methodologies that will be used for assessing the environmental impacts and market transformation potential of 5GDHC.

The overall goal of this deliverable is to define data-collection methods, necessary inputs for setting benchmarks and targets, and content structure of the evaluation report to be prepared (including methodology to monitor impact in 5 and 10 years after project implementation).

The environmental impact assessment includes evaluating the avoided **greenhouse gas emissions**, to see if the project is still on track towards meeting the goals as specified in Table 2 and Figure 1. It also includes **non-climate related impacts**, in order to evaluate the local environmental impact of 5GDHC projects in general and of D2Grids specifically, such as impacts in the sub-surface and water quality on pilot sites. The environmental assessment additionally evaluates whether the project is still on track to reach its feature climate goals. For the pilot projects and the projects in follower regions, the methodology consists on calculating the **renewable energy capacity** and assessing whether the plans of expansion are progressing as scheduled.

For North-West Europe as a whole, a methodology is put in place in order to assess **5GDHC technology's potential to transform the market of heating & cooling** from the perspective of the energy sector, the financial sector, and the wider public. With the aim of evaluate this, a series of indicators (Indicator for Potential Transformation – IPT) were defined in this deliverable. The focus of these indicators lays on assessing the **potential demand** for 5GDHC in the heating and cooling market of NWE.

The process in place for these evaluations goes beyond this report, as its purpose is to describe the methodology that has been developed for this purpose. The actual evaluation through this methods will take place in subsequent project deliverables (i.e. D.LT.4.2 and D.LT.4.3). An overview of the process can be found in the next page. It consists on multiple, interlinked derivable along the project, and the collaboration of various project partners with distinct expertise across Europe.

<table>
<tr><td colspan="2">Definition of the methodology (D.LT.4.1) – preliminary version
<u>Description of main characteristics</u>
Describing the main characteristics of the D2Grids project and objectives regarding market transformation and environmental impacts, which will serve as a basis for the methodology developed
<u>Identification of categories for environmental assessment</u>
Selecting the categories of impacts that will be calculated during the environmental assessment
<u>Identification of indicators for potential transformation</u>
Selecting the IPTs that will be determined for calculating the potential of 5GDHC in the north-west European market</td></tr>
<tr><td colspan="2">Partners and pilots feedback (D.T3.3.6)

All project partners provide feedback on the proposed methodology as they will use the methodology for the evaluation of the pilots to quantitatively measure the performance during the operational phase.</td></tr>
<tr><td colspan="2">Definition of the methodology (D.LT.4.1) – final version

Incorporating feedback from project partners</td></tr>
<tr><td>Data collection for (D.LT.4.2)

Collecting necessary data to calculate market transformation potential</td><td>Data collection for (D.LT.4.3)

Collecting necessary data to calculate environmental impacts</td></tr>
<tr><td>Market transformation calculation and interpretation of the results (D.LT.4.2)

Determination of indicators and analysis of the results</td><td>Environmental impacts calculation and interpretation of the results (D.LT.4.3)

Determination of environmental impacts and analysis of the results</td></tr>
<tr><td colspan="2">Strategy for future evaluations (D.LT.4.5)

Defining benchmarks for future evaluations and specifying roles and responsibilities of partners</td></tr>
</table>

3. Market transformation potential

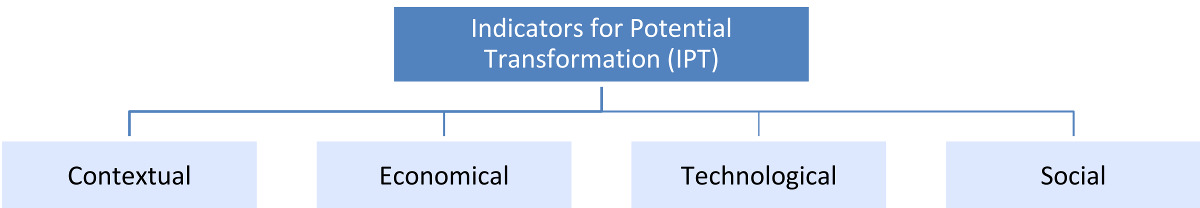
3.1. Introduction

In this section, we aim to assess the potential of 5GDHC to transform the heating and cooling markets in North-West Europe. The potential of a market determines the population who is interested in the product or service which is being made or offered by an organisation. In D2Grids we develop a methodology that will allow us to measure this market potential, concretely for 5th Generation District Heating and Cooling.

Given the early stages of development in which the technology stands at this moment, it is too soon to assess a market potential for 5GDHC. A recent study by Ramboll[1] found that there is a wide range of opinions about the future applications and demand for 5GDHC. This speculation is due to a lack of projects and research in order to base conclusions. However, a number of drivers with potentially significant impact on the future demand for 5GDHC capabilities can be identified and assessed in order to better understand the potential of 5GDHC as the market develops. In the D2Grids project, we have established a number of indicators that will allow us to measure such potential in the future steps of the project (D.LT.4.2). Some of the indicators will be quantitative while others of a more qualitative nature.

The main element of this methodology consists of assessing the indicators described next. This approach was influenced by the well-known concept of Key Performance Indicators (KPIs), which refer to a set of quantifiable measurements used to gauge a company's overall long-term performance. KPIs specifically help determine a company or project's strategic, financial, and operational achievements, especially compared to those of other within the same sector. In this deliverable, measuring the performance of 5GDHC is not the main focus, but we want to assess the future potential for its implementation across North-West Europe.

The market transformation potential will therefore be measured through a series of indicators, titled "indicators for potential transformation" (IPTs), which have been developed jointly by D2Grids project partners, and divided into three different categories: technological, economical and contextual. An additional category is established to address specific targets involved in the project D2Grids.



[1] https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=showPromoted&id=734

3.2. Approach

At the starting point of this deliverable, a series of interviews were carried among several project members with different roles among the project, i.e. from each of the three thematic work packages: Technology, Commercialization, and Pilot Design and Capitalisation.

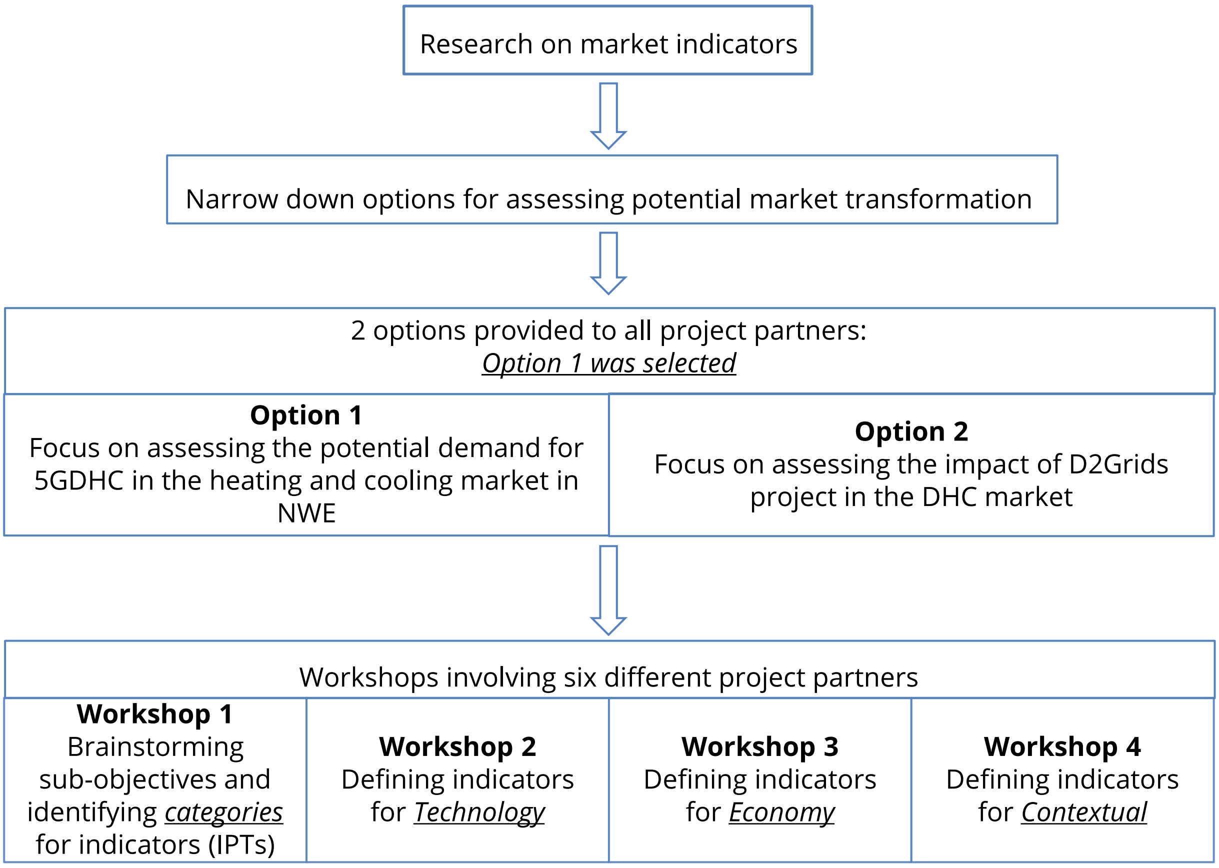
Initially, three categories based on these work packages were preselected to identify a series of key performance indicators (KPIs) to measure the market transformation potential. The three initial categories were defined as follows:

1. Expansion and growth (relates to WP.T3)
    - These KPIs measure whether the pilot sites and the projects in follower regions are expanding and being taken into operation as scheduled.
2. Commercialization (relates to WP.T2 and WP.T3)
    - The goal of these KPIs is to measure if a market of 5GDHC has developed.
3. Industrialization (relates to WP.T1 and WP.T2)
    - A goal of D2Grids is to convince suppliers to industrialize the production of 5GDHC components, bringing the price down and increasing their availability

The project D2Grids already focuses on the categories listed above, and since this report focuses on market transformation potential, it was decided during the thematic meeting in September 2021 that the assessment would focus on the impact that 5GDHC could potentially have in the heating and cooling market in Europe. The initial approach included measuring this potential transformation of the heating and cooling markets through a series of key performance indicators (KPIs). KPIs by definition are used to evaluate the success of an organization or of a particular activity in which it engages (such as projects, programs, products and other initiatives). Since the focus of this deliverable lays in the potential for 5GDHC, this classification is not appropriate. Consequently, a new concept of IPTs is introduced.

IPT stands for "Indicator for Potential Transformation", this concept was developed among project partners and each indicator is designed particularly to measure the potential for a 5GDHC market in Europe. The indicators were divided in four main categories, and together will provide an overview of the market transformation potential for 5GDHC.

The figure below shows the methodology followed for defining the IPTs.



For each of the IPTs, the following table will be filled in in more detail by the end of D4.2. In this deliverable, we fill in the table from a methodological point of view, indicating how we prepare for the final calculations. The scope of each indicator has been highlighted in green on a preliminary basis. However, when determining the IPTs in D.4.2, potential new data might be added and small improvements might be done based on progressive insights, including changes in geographical or temporal scope.

Before describing the different IPTs, we go through the different building blocks of the framework below.

The first row of the framework gives a unique name and ID to the IPT so that it can be referred to in a transparent way.

IPT name		ID	T.1

The second row indicates at which geographical level the IPT will be calculated. When describing the IPT calculation method in the following chapter, we will indicate at which level we would like each IPT to be determined. However, the final decision will only be taken during the calculation itself in D4.2. This is because data availability will be the determining variable to determine the geographical level at which an IPT can be calculated.

Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	

The third row explains the reason why this IPT is included and what we want to achieve with it in the analysis. It explains the reasoning and logic behind it, and explains why it is required information to evaluate the impact on 5GDHC.

Main objective	

The fourth and fifth row are rather self-explicatory. The first one provides the unit in which the IPT will be provided. The second the way it will be calculated. However, the formula itself might for some regions need modification depending on the data available. Ideally, each IPT is determined in the same way for each geographical region. Yet, if data do not allow it, the research team will be flexible and ensure the IPT is determined differently where necessary.

Unit	
Calculation	

To calculate the IPT, specific inputs are needed. Beforehand, it is already thought through where the most important data will come from. These are indicated under inputs. For each IPT the table will be further completed in D4.2 to give a transparent overview of the data resources used.

Inputs	Input	Data Source

Each IPT will also be determined for a specific time period. To estimate the market potential, ideally, we need to know the situation as-is today, and in the future. However, proper predictions on the future situation are today highly uncertain, given the unstable situation on energy markets and the changing socio-political environment (Covid-19, Russia-Ukraine conflict). Where possible, the IPT will therefore be determine for the current and future situation. The final D4.2 will indicate properly for which period the final IPT is determined.

Time unit	☐ During project	☐ 5 years after project ends (2027)	☐ 10 years after project ends (2033)

The following row explains how the result of the IPT needs to be interpreted and what the influence on 5GDHC is. The interpretation, however, could also be linked to other IPTs which influence how the result should be read.

Interpretation	
Link with other IPT	

Finally, not each IPT is equally important during the analyses. Therefore, weights will be determined where necessary. These weights could for instance give more value to a policy decision in one country, than to the current grid infrastructure.

Weight	

3.3. Indicators for Potential Transformation (IPTs)

The following section will allow us to measure the potential of 5GDHC networks in NWE based on a series of carefully chosen indicators. The following indicators can be used as tools for calculating the potential demand for 5GDHC in a specific location. It should, however, be noted, that at the time of writing this report, the global energy crises is driving energy price inflation to high levels and as of today, it is not clear when this period will end. In addition, the negative aspects of energy dependence on fossil fuels coming from countries in conflict (in this case in particular Russia), awakened public awareness of the importance of energy and the need to significantly accelerate the transaction to independent renewable energy. All of this might be beneficial for more climate neutral and sustainable technologies such as 5GDHC, highly increasing its market potential. Energy price inflation could catalyse change towards more renewables, less fossil dependent fuels.

However, in case countries are in crisis, investments might also be cut down, leading to a slowdown of the energy transition, which would be negative for 5GDHC as well. The exercise between these opposing directions is being done today and the outcome of it will not be clear when finalizing this deliverable. Readers should therefore keep this unstable environment in mind and researchers using this deliverable to continue in D4.3 should be openminded with regard to new data sources and improvements to the calculations to take into account specific changes.

Furthermore, due to the circumstances affecting the energy landscape in Europe at the time this report is written (i.e. Covid-19, the war in Ukraine, and these impacts in the gas and electricity prices), some IPTs might only be calculated at project site level in order to obtain a higher level of certainty in the results. At national and higher levels, there are currently too many changes. Nonetheless, it will be possible to calculate some indicators at country, or even European level. This will be specified during the assessment in D.4.2, as well as per indicator.

When it comes to the pilots and the calculation of the IPTs, the five pilots included in the project scope, which will serve as data points for analysis of the market transformation potential of 5GDHC are located across five different countries in North-West Europe and therefore can give us a reliable overview of the current landscape to evaluate the future potential for 5GDHC across this geography. Furthermore, the so-called “follower regions” of the D2Grids project can be used as a basis to calculate the scale-up potential of these indicators 5 and 10 years after the project ends.

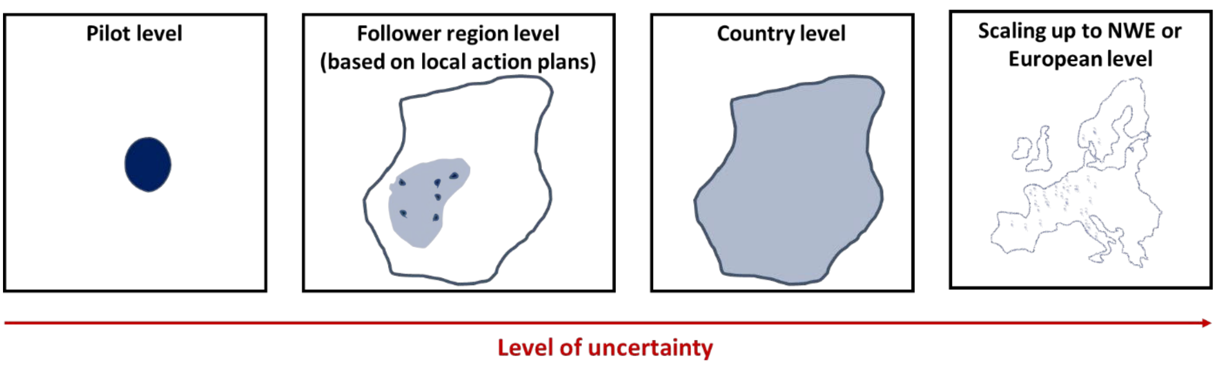


Figure 2. Four level options for the calculation of each IPT

3.3.1. Contextual IPTs

National and EU policies have a significant effect on demand for 5GDHC, both positively and negatively. For example, the planned phasing out of gas in the Netherlands has created a clear incentive for local planners to investigate low-carbon heating, such as 5GDHC. Furthermore, International conflicts (Russia-Ukraine) and trade plunges due to Corona further incentivize policy makers to become more energy independent and less dependent on price-fluctuating fossil fuels.

In addition, district heating is also highly influenced by local legislation, climate ambitions, existing infrastructure and the ability of cities to invest.

The following series of contextual IPTs therefore focus on these aspects as all of them might have an influence on the market potential for 5GDHC in a region or country.

Supporting legislation and energy-climate policies

To ensure a decarbonisation of the buildings sector, the EU Climate Target Plan highlights the need to phase out fossil fuels in heating by 2040 when the direct emissions of the buildings sector will have to decrease by about 80%-89%. To encourage the swift deployment of heating systems with zero direct emissions, the Energy Performance of Buildings Directive (EPBD) proposal includes the requirement that zero-emission buildings do not generate carbon emissions on-site.

As the lifetime of heating systems is about 20 years, the EPBD foresees that fossil-fuel powered boilers will not be eligible for public support as of 2027. While the EPBD proposal does not mandate an EU-level phase out date for fossil fuel boilers, it introduces a clear legal basis for national bans, allowing Member States to set requirements for heat generators based on greenhouse gas emissions or the type of fuel used. Several Member States consider such measures essential to achieve a decarbonised building stock and to improve air quality and health.

To evaluate the performance and the ambition of EU countries, the European Commission introduced national energy and climate plans (NECPs) in the (EU) 2018/1999, agreed as part of the Clean energy for all Europeans package which was adopted in 2019. The national plans outline how the EU countries intend to address energy efficiency, renewables, greenhouse gas emissions reductions, interconnections, research and innovation. All member states had to submit their NECP, indicating how they would achieve the EU targets. In 2020, the EU published all individual assessments of the national plans. Every 2 years, a progress report is submitted per country. These reports will form the basis of information to assess whether different countries have a supporting behavior and ambition towards 5GDHC. The analysis will be complete with local legislation and reports where necessary. Reports focus on the period 2020-2030. In addition, countries were also required to submit by 2020 national long-term strategies looking forward to 2050.[2]

[2] National energy and climate plans. EU countries' 10-year national energy and climate plans for 2021-2030

IPT name	**Supporting legislation and policies**				ID			C.1
Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	The objective of this IPT is to gain insights in the national climate ambition and supporting policies to reach these ambitions. The goal is to look at current and future policies as the EU required both short-term and long-term strategies.							
Unit	Scale							
Calculation	To ensure this indicator is objective, the assessment will be based on the EU assessment of the NECPs in which national climate plans were assessed and compared with other countries. Specific attention will be devoted to: - Phasing out of sources/technologies at national level ➔ this will give insights in whether there will be more or less room for 5GDHC - Use of renewables for heating and cooling ➔ which is a key requirement for 5GDHC - How related legislation has developed over time and at what point of development it is today ➔ which indicates to which extent policy is moving fast (leading to more opportunities in the short run) or indicating that 5GDHC implementation will take more time. - Energy dependency ➔ before submitting this deliverable, due to the current international conflict in the European continent and the Covid-19 pandemic, there is also a higher focus on local energy sources. This IPT will also look into potential new or existing developments in policy with regard to stimulating local energy as this is also a key aspect of 5GDHC A qualitative scale will be set up and the values will be determined only when analyzing the assessment of the EC.							
Inputs	Input: Climate ambitions SR-LR — Data Source: NECPs & EC assessment Input: National legislations and reports — Data Source: National websites							
Time unit	☐ During project			☐ 5 years after project ends			☐ 10 years after project ends	
Interpretation	Higher scores on this IPT indicate that a country has higher climate ambitions and has a higher likelihood in investing in sustainable technologies which focus on renewables.							
Weighting	The policies might determine the relevance of other indicators and could therefore be used to facilitate the development of a weighting scale.							

Building retrofit planned (%) → Current and future energy efficiency of buildings

A defining feature of 5GDHC is the low temperature flow in the main grid. As opposed to 4GDH, which requires the whole network to increase its temperature in case one building requires higher temperature, the 5th generation technology offers advantages for supplying heat to areas with a mixed building stock requiring differing heating system temperatures within buildings. The temperature flow through the main grid is lower than for conventional district heating networks and is used to active and distributed substations which upgrade the temperature to the required level. Therefore, highly efficient buildings that are suitable for lower temperature heating and higher temperature cooling are the most appropriate for 5GDHC. This mostly applies to new buildings; however, it is also possible to retrofit existing building stock to make them more suited for 5GDHC. Retrofitted buildings are beneficial for the economy and efficiency of the grid, but are not an essential feature. It is therefore relevant to take into account initiatives such as the European Commission's Renovation Wave Strategy (MEMO) presented in October 2020 set out measures aiming to at least double the annual energy renovation rate by 2030.

The previous IPT explains the existence of NECPs per country. These NECPs will also serve as an input to understand countries' ambition with regard to retrofitting buildings. Furthermore, national statics on building stock energy labels will be used to gain more detailed insight into the current building stock.

IPT name	**Building retrofit planned (%)**					ID		C.2
Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	
Regional level	☐	☐	☐	☐	☐	☐	☐	☐
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	The energy efficiency of the current building stock (EPC-label) and the extent to which buildings are/will be retrofitted is important for 5GDHC grids as these grids cannot supply low temperature heat to non-renovated buildings in an efficient way. This IPT therefore focusses on quantifying the percentage of energy-efficient buildings and the amount of retrofit planned in a district, region, or country. For a 5GDHC to be possible, buildings with a minimum EPC-label of x should be connected.							
Unit	%							
Calculation	$Percentage\ of\ building\ retrofit\ planned = \frac{\%\ buildings\ planned\ to\ be\ renovated}{period\ of\ time\ (years)}$ $Percentage\ of\ buildings\ with\ energy\ label > x = \frac{number\ of\ buildings\ with\ min.label\ x}{total\ amount\ of\ buildings}$ For this IPT, data on the percentage of buildings planned to be renovated, and data on the existing building stock are needed. Very Likely | Likely | Possible | Unlikely | Very Unlikely							

Inputs	<table><tr><th>Input</th><th>Data Source</th></tr><tr><td>Data on EPC-levels of existing buildings or statics on age of buildings</td><td>National websites</td></tr><tr><td>Policy targets building retrofitting</td><td>NECPs & EC assessment</td></tr><tr><td>National legislations and reports</td><td>National websites</td></tr></table>
Time unit	☐ During project ☐ 5 years after project ends ☐ 10 years after project ends
Interpretation	5GDHC will have a higher likelihood to be implemented in regions where there is a high percentage of retrofitted or new buildings. Countries that score well on this indicator, have a higher potential for 5GDHC. For this indicator, it may be assumed that a municipality who is convinced of 5GDHC, who also has plans to retrofit buildings, then could prioritize the retrofitted building to be connect to the 5^{th} generation grid.

Current district heating network

With this indicator we aim to identify the likelihood to change an existing district heating grid to a 5^{th} generation DHC one. For this, we look at the type and age of the existing energy DH infrastructure in NWE. Locations with existing DH or DHC may have the possibility to upgrade to a 5G network, reusing the existing infrastructure. This can make a region more likely to implement or consider implementing 5GDHC.

Understanding the impact of existing infrastructure is important. On the one hand, if DHC grids are already present, people might already have a pro-district heating mindset. On the other hand, if a DHC grid is only recently installed, it might be less likely to upgrade it to a 5GDHC grid.

IPT name	**% of district heating available**				ID		C.3
Geographical scope	Pilot sites / Follower regions						Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	Identifying the type of DH network available will allow us to address the likelihood to upgrade it to 5GDHC. This indicator alone is not robust enough to quantify this likelihood, as many other factors need to be taking into account, however, it can be a good indication for potential.							
Unit	Scale							
Calculation	The generation of DH available in the location analyzed will be identified as per in the table below. Furthermore, the age of the district heating grids also needs to be account							

<table>
<tr><td></td><td>for. An old district heating grid of the first or second generation which needs to be replace, leads to higher opportunities for 5GDHC to gain market field.

<table>
<tr><th>Generation/age</th><th><10 years</th><th><20 years</th><th><30years</th><th><40 years</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>replace</td><td>upgrade</td><td>Only after 10 years</td><td>Very long run decision</td></tr>
</table>
</td></tr>
<tr><td>Inputs</td><td>The EU requires member states to publish data on district heating on an annual basis. These data will be used as inputs for this analysis. For example, in Flanders, the VREG (Flemish regulator) publishes these results.
Additionally, in work package T1, technical KPIs are provided and can be used to assess existing DHC networks and their suitability for 5G. The technology KPIs from WP.T1 can aid for the interpretation of this IPT.

<table>
<tr><th>Input</th><th>Data Source</th></tr>
<tr><td>Spatial mapping of heat demands and renewable heat resources in 14 countries in Europe</td><td>Heat Roadmap Europe</td></tr>
<tr><td>“Guide to Heat Mapping”</td><td>HeatNet NWE</td></tr>
<tr><td>National district heating data</td><td>National websites, regulator, district heating organizations</td></tr>
<tr><td>Technology KPIs from WP. T1</td><td>WP.T1</td></tr>
</table>
</td></tr>
<tr><td>Time unit</td><td>☐ During project   ☐ 5 years after project ends   ☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td>The higher the generation of district heating network, the easier it is to upgrade the network to a 5GDHC network. The older the network, the more likely it is that the network can be replaced.</td></tr>
</table>

Percentage of gas networks

As of today, the presence of gas networks can slow down and block the implementation of district heating. However, the current energy situation is volatile due to many external factors and can change rapidly depending on the political, geographical or social developments. Nonetheless, in order to evaluate the likelihood of implementing 5GDHC, gas networks, which are a predominant heating system in present NWE should be taken into account, even if their influence can vary swiftly. The interpretation of this IPT could, however, differ significantly from country to country and should be done will accounting for other IPT.

For instance, in the Netherlands, gas networks are well spread out over the country and they have their own gas supplies. However, the Netherlands have decided to phase out gas and therefore existing heating systems need to be replaced. The presence of fossil gas today therefore has a positive influence on the likelihood of implementation of other systems or energy carriers. In other regions, highly relying on gas networks which are not considering a rapid phase out of gas, the presence of a widely spread out energy distribution system might have a negative impact on the rapid implementation of other energy systems. However, here again, with the unstable situation caused by the Russian war, there seems to be a tendency to become more rapidly independent of fossil fuels. The later will have to be followed up more closely in order to understand how national energy policies and vision are changing.

IPT name	**Percentage of gas networks**					ID		C.4
Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	The goal of this IPT is to get a clear view on large investments in energy infrastructure (specifically gas). These investments need to be paid back throughout their long lifetime and are well-rusted in people's mind. Given the current unstable situation on energy markets, this IPT will attempt to look into the future to understand to which extend these gas networks are likely to be replaced or not.							
Unit	%							
Calculation	$\mathit{Percentage\ of\ consumers\ connected\ to\ gas\ networks} = \frac{\#\ \mathit{gas\ connections}}{\#\ \mathit{consumers}}$ In some countries, these statics will be publicly available, not requiring calculations from our side. The statics will, however, be completed with qualitative research or future projection on the future usage of gas networks.							
Inputs	Input: Gas statistics available at national/regional level					Data Source: - National Websites of gas distribution network operators - *Heat Roadmap Europe* - Eurostat		
	Input: Energy policies					Data Source: NECPs & EC assessment		
Time unit	☐ During project			☐ 5 years after project ends			☐ 10 years after project ends	
Interpretation	The interpretation of this indicator will depend from country to country, and is likely to evolve throughout the project due to the uncertain energy markets (Russia, Covid). The political and social situation and the time and location where the evaluation is carried will determine the way gas networks influence the potential for 5GDHC implementation.							

3.3.2. Technological IPTs

The technological IPTs will evaluate technological attributes that positively or negatively influence the likelihood of 5GDHC implementation. To avoid confusion, it is important to mention that within the D2Grids project, a series of technical KPIs have been developed (WP.T1). Their goal is to quantify the core principles of 5GDHC. The main difference between these KPIs and the indicators below is that the former will assess how current energy networks perform on the 5GDHC principles, providing tools to assess whether a network can be considered 5th generation or not.

The technological IPTs will be determine at different geographical levels (district, region, country…) depending on the data availability per country.

Ratio of cooling and heating demand - balance possibility for a 5GDHC system

The Renewable Heating and Cooling (RHC) Technology Platform predicts that by 2050 in Europe, there will be a reduction of between 20 and 30% in the heating demand, while parallelly the cooling demand will triplicate compared to 2006 values. This tendency is also confirmed by the 600% increase in cooled floor area in the EU between 1990 and 2010[3]. These trends offer great potential for the implementation of 5th generation district heating and cooling networks, as one of its main characteristics is the balancing of cooling and heating within districts.

The balance possibilities between heat and cold demands are an influential factor in the development of 5GDHC networks. In order to assess the (potential) balance of a system, we will compare the amount of cold and heat demand in the locations analysed. A completely balanced system would close the energy loop, a key characteristic in 5GDHC networks. A good ratio will help us predict the potential for such systems in the regions under analysis.

This IPT should ideally be determined at regional / local level as it is (due to the local nature of DHC grids) necessary to have an idea on a local scale on whether cold and heat demand can be balanced. However, whether this is possible will depend on data availability in the selected regions. Therefore, the geographical scope will be determined while calculating the IPT and collecting the data.

[3] 5th generation district heating and cooling systems: A review of existing cases in Europe, Renewable and Sustainable Energy Reviews

IPT name	**Ratio of cooling and heating demand – balance possibility for a 5GDHC system**				ID			T.1
Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	This IPT calculates the ratio between cold and heat demands to show the balance possibilities. A completely balanced system would close the energy loop, a key characteristic in 5GDHC networks.							
Unit	Ratio							
Calculation	$Cooling\ Demand\ Ratio = \frac{Cold\ demand}{Heat\ demand}$							
Inputs	**Input** / **Data Source**: Current heating and cooling demand in the selected data-points (Yearly demand in kWh) — *Guide to Heat Mapping* D2Grids Pilots heat and cold demand (kWh) — *KPIs from WP.T1* In combination with distribution curve over the year (standard can be used)							
Time unit	☐ During project			☐ 5 years after project ends			☐ 10 years after project ends	
Interpretation	Ratio = 0 if there is no cold demand there is no balance possibility Ratio < 1 when there is some balance between heat and cold demands Ratio = 1 when there is 100% balance between heat and cold demands The closer the ratio is to 1, the higher is the indication for 5GDHC potential							

Demand for LT heating

As in the previous indicator, the same principles apply to low-temperature (LT) heating. Energy efficient systems can reduce the need for high-temperature supply of heat. Low-temperature is defined for the purposes of this analysis as **<40ºC**. An <u>increase in low-temperature heating demands</u> is a positive signal for 5GDHC potential in a region, as this allows 5G networks to provide the necessary inputs for heating efficiently, with minimum energy requirements, this is important to consider when assessing the potential for 5GDHC.

Aside from the increase, particularly in LT heating demand, the <u>current LT heating density</u> in a region can further help estimating the potential demand for 5GDHC. In this indicator we will provide an overview of the amount of surface with heating demand in a district. This overview can support the rationale behind 5GDHC potential, as for instance, a district that has currently a small heating demand would be more likely to install other heating sources.

Given the locality of the data required, this IPT will be at a lower geographical scope (pilot or regional level).

IPT name	**Demand for LT heating**					ID		T.2
Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	The goal of this IPT is to gain insights in the LT (<40ºC) heating density and the growth LT heating demand. 5GDHC supplies lower temperature heats, while traditional consumers often desire HT heat supply. For 5GDHC to gain market size, growth in LT heating needs is therefore important. This is measured both in the growth in absolute LT demand and in terms of LT heating density (to take into account the local character of DHC).							
Unit	% / ratio							
Calculation	For the calculation of this indicator, we will collect the yearly demand for low-temperature heating in several regions working as data points, based on actual data when possible, or estimations and forecasts when no data is available. LT-heating demand will focus on both residential and tertiary sector. The resulting indicator will be measured in <u>% of LT heating increase</u> since 2010 (at pilot or regional level – to be specified based on data available). $$Increase\ of\ low\ temperature\ heating\ demand = \frac{Demand\ increase\ for\ LT\ heating}{Total\ demand\ for\ LT\ heating} \times 100$$ The second part of this indicator calculates the <u>density of low temperature heating demand</u> in a district (as per the latest data available in such district – pilot site level). $$Ratio\ of\ low\ temperature\ heating\ demand = \frac{m^2\ heated}{m^2\ in\ district} \times 100$$							

<table>
<tr><td></td><td colspan="3">Again, it should be pointed out that depending on the region, it might not be possible to determine both indicators. Therefore, some regions will only focus on one or the other indicator.</td></tr>
<tr><td>Inputs</td><td colspan="3"><table>
<tr><th>Input</th><th>Data Source</th></tr>
<tr><td>Estimated yearly demand for heating (real data collection or research-based forecast)</td><td>- National websites
- Eurostat
- Energy policy reports</td></tr>
<tr><td>Current LT heating demand (Yearly demand) (< 40ºC)</td><td>- National websites
- Eurostat</td></tr>
<tr><td>Building surface of LT heating</td><td>- National websites
- Eurostat
- District heating organizations</td></tr>
</table></td></tr>
<tr><td>Time unit</td><td>☐ During project</td><td>☐ 5 years after project ends</td><td>☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="3">The higher the demand for LT-heating and the sharper the increase in LT-heating demand, the more likely 5GDHC could be rolled out in that region. Important for DHC is also the local character of the technology, requiring heating demand also to be very dense in one region. Therefore, this IPT is complemented with a calculation of the density of low temperature heating demand.</td></tr>
</table>

Demand for HT cooling

Moreover, having an energy efficient system can mean that cooling temperature supply does not need to be traditionally cold for reaching comfortable living temperatures, and vice versa. High-temperature cooling is defined for the purposes of this analysis as temperatures **> 10ºC**. An increase in high-temperature (HT) cooling, or space cooling, is a positive signal for 5GDHC potential in a region, as these networks focus on closing the energy loop by balancing cooling and heating. Higher temperature demands for cooling allow 5G networks to provide the necessary inputs for cooling efficiently, with minimum energy requirements, therefore this is an important indicator to consider when assessing the potential for 5GDHC.

Aside from the increase particularly in HT cooling demand, the current LT-cooling density in a region can further help estimating the potential demand for 5GDHC. In this indicator we will provide an overview of the amount of surface with cooling demand in a district. This overview can support the rationale behind 5GDHC potential, as for instance, a district that has currently a low cooling demand would be more likely to install other heating sources.

<table>
<tr><td>IPT name</td><td colspan="5">Demand for HT cooling</td><td colspan="2">ID</td><td>T.3</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">The goal of this IPT is to gain insights in the HT (>10ºC) cooling density and the growth LT heating demand. 5GDHC supplies higher temperature cooling, while traditional consumers often desire LT cooling supply. For 5GDHC to gain market size, growth in HT cooling needs is therefore important. This is measured both in the growth in absolute HT cooling demand and in terms of HT cooling density (to take into account the local character of DHC).</td></tr>
<tr><td>Unit</td><td colspan="8">% / ratio</td></tr>
<tr><td>Calculation</td><td colspan="8">For the calculation of this indicator, we will collect the yearly demand for high-temperature cooling in several regions working as data points, based on actual data when possible, or estimations and forecasts when no data is available. HT-cooling demand will focus on both residential and tertiary sector.
The resulting indicator will be measured in % of HT cooling increase since 2010.

$$Increase\ of\ high\ temperature\ cooling\ demand = \frac{Demand\ increase\ for\ HT\ cooling}{Total\ demand\ for\ HT\ cooling} \times 100$$
The second part of this indicator calculates the density of cooling demand in a district (as per the latest data available in such district – pilot level).

$$Ratio\ of\ high\ temperature\ cooling\ demand = \frac{m^2\ cooled}{m^2\ in\ district} \times 100$$</td></tr>
<tr><td>Inputs</td><td colspan="8">
<table>
<tr><td>Input</td><td>Data Source</td></tr>
<tr><td>Estimated yearly demand for cooling (real data collection or research-based forecast)</td><td>- National websites
- Eurostat
- Energy policy reports</td></tr>
<tr><td>Current HT cooling demand (Yearly demand) (< 40ºC)</td><td>- National websites
- Eurostat</td></tr>
<tr><td>Building surface of HT cooling</td><td>- National websites
- Eurostat
- District heating organizations</td></tr>
</table>
</td></tr>
<tr><td>Time unit</td><td colspan="3">☐ During project</td><td colspan="3">☐ 5 years after project ends</td><td colspan="2">☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="8">The higher the demand for HT-cooling and the sharper the increase in HT-cooling demand, the more likely 5GDHC could be rolled out in that region. Important for DHC is also the local character of the technology, requiring heating demand also to be very dense in one region. Therefore, this IPT is complemented with a calculation of the density of low temperature heating demand.</td></tr>
</table>

Number LT heat sources available in the region

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).

These heat sources are in order of preference (highest-ranking forms or energy are mentioned first):

1. Reuse of thermal energy, by exchange between heating and cooling demands
2. Ambient thermal sources from soil, water, air, and low temperature solar heat & low grade thermal storage possibilities
3. Higher temperature renewable sources like geothermal, solar heat
4. Higher temperature industrial waste heat, otherwise rejected in the environment
5. Renewable electricity from local sources like wind, sun
6. Electricity use at times of renewable overproduction, e.g. when spot price is low
7. Electricity mix from the external grid
8. High temperature heat from burning biofuels, biogas, biomass
9. High temperature heat from burning fossil fuels

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. However, the availability of these sources has been discussed in the reports on D2Grids follower regions (D.LT.1.3).

For this IPT, we summarize the findings of the most important LT-energy sources per region, together with possible changes to existing sources and planned additions to the sources.

IPT name	**Number of LT heat sources available in the region**				ID		T.4
Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	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. These could be used to build out a 5GDHC system. This IPT gives insights in the key energy sources available.							
Unit	Color coded map							
Calculation	• **Type and (capacity)** of LT heat sources • **Distance** from LT heat sources – can only be determined at pilot level • **Physical space for heating and cooling storage**							

<table>
<tr><td>Inputs</td><td colspan="3">
<table>
<tr><th>Input</th><th>Data Source (European level)</th></tr>
<tr><td>Geothermal</td><td>GEoDH project: https://map.mbfsz.gov.hu/geo_DH/</td></tr>
<tr><td>Solar</td><td>European Commission – PVGis:
http://re.jrc.ec.europa.eu/pvgis/countries/europe.htm</td></tr>
<tr><td>Data Centre</td><td>Data Center Map: https://www.datacentermap.com/</td></tr>
<tr><td>Industry</td><td>European Pollutant Release and Transfer Register:
https://prtr.eea.europa.eu/#/home</td></tr>
<tr><td>Forestry</td><td>European Forestry Inventory:
https://www.efi.int/knowledge/maps/treespecies</td></tr>
<tr><td>WP LT1.3</td><td>Evaluation of follower regions on LT-heat source availability</td></tr>
<tr><td>D2Grids Pilots</td><td>Information available from project partners and WP.T1</td></tr>
</table>
</td></tr>
<tr><td>Time unit</td><td>☐ During project</td><td>☐ 5 years after project ends</td><td>☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="3">The more LT heat sources available in the close neighborhood of the pilot or the region targeted, the larger the possibility of 5GDHC implementation.</td></tr>
</table>

3.3.3. Economical IPTs

Through the economic data collected from the different pilots and projects, we can identify trends in the costs of financing. For instance, if the costs are shown to go down over time, that represents a positive signal for the future of the technology. Moreover, these indicators will be measured as of today in deliverable LT.4.2, but when compared to other points in time and geographies, across different geographies, we can get each time a better sense of the potential market in contrast to where the market is today. The points in time will be at end of project, 5 years after project end, and 10 years after project end.

Levelized cost of energy for end consumers

The levelized cost of energy (LCOE) provides a comparable metric to assess the cost per unit energy to the consumer over the lifetime of a district heating and cooling network. This metric can be used to assess to competitiveness of 5GDHC technology in comparison with conventional networks.

This indicator will calculate the average LCOE of the 5 pilot sites and contrast the results with the LCOE of conventional technologies (e.g. gas boiler, conventional DH…). This comparison will signal the potential market for 5GDHC based on the level of cost premium (or discount) to conventional technologies, with a key criteria being price-parity with conventional technology.

IPT name	**Levelized cost of energy for end consumers**				ID			E.1
Geographical scope	Pilot sites / Follower regions							Europe
	FR	**UK**	**NL**	**DE**	**SCT**	**BE**	**LU**	**NWE**
Pilot level	☐	☐	☐	☐	☐	☐	☐	☐
Regional level	☐	☐	☐	☐	☐	☐	☐	
Country level	☐	☐	☐	☐	☐	☐	☐	
Main objective	This IPT looks at comparing the cost per unit energy to the consumer over the lifetime of a district heating and cooling network with conventional networks. This indicator can be used to compare assets across regions. Within a region, LCOE is most useful to compare against other heating a cooling technologies							
Unit	€ / GJ							
Calculation	The calculation of the LCOE uses the discounted lifetime costs divided by the discounted lifetime generation of the project as follows: $\textbf{Total Lifetime Cost} = \sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}$ $\textbf{Total Lifetime Output} = \sum_{t=1}^{n} \frac{E_t}{(1+r)^t}$ $\textbf{LCOE} = \frac{Total\ Lifetime\ Cost}{Total\ Lifetime\ Output}$ $\textbf{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$							

<table>
<tr><td></td><td colspan="3">This formula will be implanted for each pilot project and each counter-factual technology benchmark using a standard template model.
LCOE calc should be assessed over the course of the asset life. The only updates from 5-10 years should be the addition of new customers, if any.</td></tr>
<tr><td>Inputs</td><td colspan="3">Core inputs include the lifetime in years of the connection, the total volume of heat and cooling consumed, the cost to the consumer of connecting and received supply of energy and the relevant discount rate.

<table>
<tr><th>Input</th><th>Data Source (D2Grids pilots)</th></tr>
<tr><td>Asset Life</td><td>30 years (TBD) needs to be standardized across projects</td></tr>
<tr><td>Discount Rate</td><td>5% (TBD) needs to be standardized across projects</td></tr>
<tr><td>Capex (NPV) – EUR</td><td>Financial model</td></tr>
<tr><td>Opex (NPV) – EUR</td><td>Financial model</td></tr>
<tr><td>Energy Generation (NPV) - MWh</td><td>Financial model</td></tr>
</table>

*Note we need to think how best to combine heating/cooling generation to allow for comparison of other technologies</td></tr>
<tr><td>Time unit</td><td>☐ During project</td><td>☐ 5 years after project ends</td><td>☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="3">LCOE is useful in comparing the cost competitiveness between pilot projects, other Generation networks and competing tech. (HPs, Gas boilers, Chillers, Etc.). The comparison will signal the potential market for 5GDHC based on the level of cost premium (or discount) to conventional technologies. In case cost for 5GDHC is lower than the cost of conventional networks, this increases the likelihood that 5GDHC is implemented.</td></tr>
</table>

Interreg North-West Europe D2Grids

Financial return (for network owners)

This indicator will help us assess the market potential from the investors' perspective. Having investors that are willing to invest in a technology is critical for market transformation. For assessing this indicator, we again will set a threshold based on the minimum financial return necessary to attract investors to 5GDHC. The internal rate of return (IRR) is a metric used in financial analysis to estimate the profitability of potential investments. There needs to be a minimum financial return in order to attract investors.

<table>
<tr><td>IPT name</td><td colspan="5">Financial return (for network owners)</td><td colspan="2">ID</td><td>E.2</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">This IPT helps to assess the market potential from the investors' perspective. The IRR gives an indication of the estimated profitability of potential investments.</td></tr>
<tr><td>Unit</td><td colspan="8">This indicator will be measured in percentage of IRR (% IRR)</td></tr>
<tr><td>Calculation</td><td colspan="8">A financial model is required for the calculation of IRR – the model template designed in the commercialisation work package of the D2Grids project (D.T2.1.1) can be used. Additionally, a sensitivity analysis on COGS (electricity and Gas prices) can be run due to the volatility of energy prices.</td></tr>
<tr><td>Inputs</td><td colspan="8">Core inputs include the lifetime in years of the connection, the total volume of heat and cooling consumed, the cost to the consumer of connecting and received supply of energy and the relevant discount rate.
<table>
<tr><td>Input</td><td>Data Source (D2Grids)</td></tr>
<tr><td>Construction Costs</td><td>Financial model</td></tr>
<tr><td>Sources of financing and cost of capital (interest rates, preferred investor return if relevant)</td><td>Financial model</td></tr>
<tr><td>Operating costs</td><td>Financial model</td></tr>
<tr><td>Growth of network</td><td>Financial model</td></tr>
<tr><td>Energy sold</td><td>Financial model</td></tr>
<tr><td>Price of energy sold</td><td>Financial model</td></tr>
<tr><td>Lifetime of asset</td><td>Financial model</td></tr>
<tr><td>Other financial and technical inputs which impact the economic case of the project</td><td>Financial model</td></tr>
</table></td></tr>
<tr><td>Time unit</td><td colspan="3">☐ During project</td><td colspan="3">☐ 5 years after project ends</td><td colspan="2">☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="8">- Financial return > 0 is indicative of nascent market potential
- Financial return > 6-8% (threshold will be refined during calculation) is indicative of growing market potential. If the IRR is at least 6-8%, it is possible to start attracting the kind of capital that will invest at scale and invest long term.</td></tr>
</table>

Expected future financial return (optional)

As above, however using a 'theoretical' future project and using cost-curve assumptions to demonstrate the potential returns achievable if certain market development criteria are met (e.g. reducing costs of heat pumps, higher availability of engineers etc.)

<table>
<tr><td>IPT name</td><td colspan="5">Expected future financial return (optional)</td><td colspan="2">ID</td><td>E.3</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">This ITP and its calculation are highly similar than ITP E.2. However, the objective is now to look at future returns depending on certain market developments. The higher financial returns, the more beneficial for the implementation of 5GDHC.</td></tr>
<tr><td>Unit</td><td colspan="8">This indicator will be measured in percentage of IRR (% IRR)</td></tr>
<tr><td>Calculation</td><td colspan="8">A financial model is required for the calculation of IRR – the model template designed in the commercialisation work package of the D2Grids project (D.T2.1.1) can be used.
Similar to Sensitivity analysis we can forecasts LCOE and B&H IRR assuming reductions in Costs to measure potential returns once 5g is fully commercialized.</td></tr>
<tr><td>Inputs</td><td colspan="8">Core inputs include the lifetime in years of the connection, the total volume of heat and cooling consumed, the cost to the consumer of connecting and received supply of energy and the relevant discount rate.
<table>
<tr><td>Input</td><td>Data Source</td></tr>
<tr><td>Construction Costs</td><td></td></tr>
<tr><td>Sources of financing and cost of capital (interest rates, preferred investor return if relevant)</td><td></td></tr>
<tr><td>Operating costs</td><td></td></tr>
<tr><td>Growth of network</td><td></td></tr>
<tr><td>Energy sold</td><td></td></tr>
<tr><td>Price of energy sold</td><td></td></tr>
<tr><td>Lifetime of asset</td><td></td></tr>
<tr><td>Other financial and technical inputs which impact the economic case of the project</td><td></td></tr>
</table></td></tr>
<tr><td>Time unit</td><td colspan="3">☐ During project</td><td colspan="3">☐ 5 years after project ends</td><td colspan="2">☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="8">- Financial return > 0 is indicative of nascent market potential
- Financial return > 6-8% (threshold will be refined during calculation) is indicative of growing market potential. If the IRR is at least 6-8%, it is possible to start attracting the kind of capital that will invest at scale and invest long term.</td></tr>
</table>

Investments trajectory on innovative networks

This indicator consists of tracking the investments made into 5GDHC technology. By assessing the amount of investments over time, objectively and based on historical data, we can identify the trajectory of past investment trends, and predict the potential for new investments in 5GDHC technology in the future.

<table>
<tr><td>IPT name</td><td colspan="5">Investments trajectory on innovative networks</td><td colspan="2">ID</td><td>E.4</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">The objective is to track future investments into 5gDHC. It helps look at whether investors are investing into the space and the pace at which they doing so (i.e. gauging their interest).</td></tr>
<tr><td>Unit</td><td colspan="8">€'000
% growth p.a. following collection of multiple data points</td></tr>
<tr><td>Calculation</td><td colspan="8">Simple sum - tracking of investment into projects across NWE.
• Take all investment made to date per annum into 5GDHC (currently only D2Grids)
• Then add future investment as they are announced (note: privately funded projects will be hard to get exact figure, but can be estimated based on size of network)</td></tr>
<tr><td>Inputs</td><td colspan="8">Total investment in 5GDHC technology in NWE at the moment of the assessment (afterwards, it can be assessed at project end, 5 years and 10 years after the project ends)
<table><tr><td>Input</td><td>Data Source</td></tr><tr><td>Number of 5GDHC project</td><td></td></tr><tr><td>Capital invested</td><td></td></tr><tr><td>Future investment</td><td></td></tr></table></td></tr>
<tr><td>Time unit</td><td colspan="3">☐ During project</td><td colspan="3">☐ 5 years after project ends</td><td colspan="2">☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="8">An increasing investment trajectory is a positive indication for 5GDHC's market position and potential.</td></tr>
</table>

Public statements to commit to 5GDHC

This indicator is of a more qualitative nature and consists on tracking the number of times a public statement or commitment to 5GDHC is done. When investors make public commitments to 5GDHC, it is a good indicator for the technology's potential in the market. These statements are not necessarily binding, but can be indicative.

<table>
<tr><td>IPT name</td><td colspan="5">Public statements to commit to 5GDHC</td><td colspan="2">ID</td><td>E.5</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">Quantifying the number of statements to commit to 5GDHC allows us to analyze the potential for this technology's development in the European markets.</td></tr>
<tr><td>Unit</td><td colspan="8">Number of statements / year</td></tr>
<tr><td>Calculation</td><td colspan="8">Rating: based on the number of such commitments and statements, this rates engagement at local government, national and or European.</td></tr>
<tr><td>Inputs</td><td colspan="8">Number of public statements and/or commitments to 5GDHC by public authorities or private investors.

<table>
<tr><td>Input</td><td>Data Source</td></tr>
<tr><td>Public statements and/or commitments to 5GDHC by public authorities</td><td rowspan="2">- Newspapers
- Official documents</td></tr>
<tr><td>Public statements and/or commitments to 5GDHC by private investors</td></tr>
</table></td></tr>
<tr><td>Time unit</td><td colspan="3">☐ During project</td><td colspan="3">☐ 5 years after project ends</td><td colspan="2">☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="8">A high number of public statements or commitments to 5GDHC projects and investments can signify higher potential for the 5GDHC market. This indicator is of a subjective nature. Over time it will also be more important to look at trends. A growing number of statements means more interest in 5gDHC.</td></tr>
</table>

Ratio of investments by source

The differentiation between source of investment is quite relevant in the context of market transformation potential, as larger private investments are indicative that the technology can stand on its own feet, and does no longer rely on public support and funding. Enough private investments can make the technology commercially stand on its own feet and attract further private investment. All of the funding is provided by the private sector signals that the technology is very mature.

For better understanding of the sources and types of investors, a document was provided in the commercialization work package D.T2.1.2: "Report on investment opportunities in the DHC sector, including a list of criteria necessary for effective commercialization by type of investor"

<table>
<tr><td>IPT name</td><td colspan="5">Ratio of investments by source</td><td colspan="2">ID</td><td>E.6</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">The objective of this indicator is to assess where funding for 5gDHC is coming from (private or public)</td></tr>
<tr><td>Unit</td><td colspan="8">Ratio</td></tr>
<tr><td>Calculation</td><td colspan="8">The ratio of public/private investment will indicate a positive or negative development in the potential of 5GDHC in the market.
$$Ratio\ of\ investments\ by\ source = \frac{amount\ of\ public\ investments}{amount\ of\ private\ investments}$$
Moreover, this indicator can be used to compare and assess the development of the investments ratio over time.</td></tr>
<tr><td>Inputs</td><td colspan="8">Per 5GDHC project
<table><tr><td>Input</td><td>Data Source</td></tr><tr><td>amount of investments of public nature</td><td>Project data</td></tr><tr><td>amount of investments of private nature</td><td>Project data</td></tr></table></td></tr>
<tr><td>Time unit</td><td colspan="3">☐ During project</td><td colspan="3">☐ 5 years after project ends</td><td colspan="2">☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="8">Since we are looking for a shift from public investment into private investment, our target is to reduce this ratio to zero.
The lower the ratio the more positive the development is for the potential of the 5GDHC market.</td></tr>
</table>

Interreg North-West Europe D2Grids

3.3.4. Social IPTs

Level of social awareness

The social awareness and acceptance of 5GDHC can have a great impact on its potential uptake. According to an analysis from Scottish Enterprise[4], the lack of awareness throughout the supply chain is making it difficult for 5GDHC systems to be considered, especially by contractors and developers. This is still a challenge among all kinds of stakeholders from investors, housing corporations, design engineers, to consumers and policy makers and can highly influence the potential for this innovative technology to transform the market.

<table>
<tr><td>IPT name</td><td colspan="5">Level of social awareness</td><td colspan="2">ID</td><td>S.1</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">This IPT offers insights into the awareness of different stakeholders with regard to the existence of different types of DHC grids, and with regard to the benefits of them.</td></tr>
<tr><td>Unit</td><td colspan="8">A Likert scale will be used to identify the level of social awareness<table><tr><td>Complete awareness</td><td>High level of awareness</td><td>Medium level of awareness</td><td>Low level of awareness</td><td>Lack of awareness</td></tr></table></td></tr>
<tr><td>Calculation</td><td colspan="8">4 Different aspects will be examined to gain insight into the level of awareness of different stakeholders.

- Percentage of end consumers connected to DHC (per country)
- Public statements addressing 5GDHC
- Number of test projects
- Newspaper articles

These aspects will be based on research and subjectively scaled as discussed above. Afterwards, all scale are combined into one final scale.

Potentially, a questionnaire will be used to identify further level of awareness among stakeholders (i.e. consumers, technology developers, manufacturers, energy providers, local governments…).</td></tr>
</table>

[4] Analysis of potential for Scotland to be leader in 5th Generation Heating and Cooling Networks

<table>
<tr><td rowspan="5">Inputs</td><td colspan="2">Input</td><td>Data Source</td></tr>
<tr><td colspan="2">The percentage of end consumers connected to DHC (per country)</td><td>Eurostat
National websites</td></tr>
<tr><td colspan="2">The number of public statements addressing 5GDHC, which are measured in the economic category of indicators, can also be used as input to assess the level of social awareness</td><td>Policy reports
Newspapers</td></tr>
<tr><td colspan="2">National reports discussing the benefits of DHC grids</td><td>Policy reports</td></tr>
<tr><td colspan="2">Articles on DHC</td><td>Newspapers</td></tr>
<tr><td>Time unit</td><td>☐ During project</td><td>☐ 5 years after project ends</td><td>☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="3">This indicator is calculated in a qualitative way. The higher the awareness on DHC in general, and potentially specific awareness on 5G is, the more positive the influence on the implementation of 5GDHC grids.</td></tr>
</table>

5GDHC Added value and comfort

Heating is a vital commodity for consumers to heat their homes and water. Energy in general is supposed to create comfort which should not be questioned nor impacted. 5GDHC helps to further improve this comfort as it also supplies cooling on top of heating. As discussed previously, the cooling demand increased significantly over the last years, indicating the added value of cooling provided through 5GDHC. Furthermore, 5GDHC system also requires lower levels of maintenance. The question is, however, to which extent stakeholders are also aware of these additional benefits. This is what this IPT examines.

<table>
<tr><td>IPT name</td><td colspan="5">5GDHC added value and comfort</td><td colspan="2">ID</td><td>S.2</td></tr>
<tr><td rowspan="2">Geographical scope</td><td colspan="7">Pilot sites / Follower regions</td><td>Europe</td></tr>
<tr><td>FR</td><td>UK</td><td>NL</td><td>DE</td><td>SCT</td><td>BE</td><td>LU</td><td>NWE</td></tr>
<tr><td>Pilot level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td rowspan="3">☐</td></tr>
<tr><td>Regional level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Country level</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Main objective</td><td colspan="8">5GDHC allows for higher levels of comfort. This is a benefit for consumers and might imply higher investments in 5GDHC. However, this is only on the condition that consumers and other stakeholders are aware of the benefits.

This IPT examines awareness of different stakeholders with regard to higher comfort levels through 5GDHC.</td></tr>
</table>

<table>
<tr><td>Unit</td><td colspan="3">A Likert scale will be used to identify the level of added value
<table><tr><td>Very significant</td><td>Significant</td><td>Moderate</td><td>Slightly significant</td><td>Not significant</td></tr></table></td></tr>
<tr><td>Calculation</td><td colspan="3">This qualitative indicator will initially be based on research and potentially a questionnaire will be developed.

Some of the topics researched will cover 5GDHC's characteristics related to the inputs listed below (and potentially new ones added during D.4.2).

These topics will be ranked according to how significant is the added value that 5GDHC provides (Likert scale above).

The questionnaire will use the following format:
<table><tr><th>Responses</th><th>Ranks</th></tr><tr><td>Strongly Agree</td><td>5</td></tr><tr><td>Agree</td><td>4</td></tr><tr><td>Undecided</td><td>3</td></tr><tr><td>Disagree</td><td>2</td></tr><tr><td>Strongly Disagree</td><td>1</td></tr></table></td></tr>
<tr><td>Inputs</td><td colspan="3"><table><tr><th>Input</th><th>Data Source</th></tr><tr><td>- comfort compared to AC,
- lower levels of maintenance,
- affordability,
- avoiding disposal of waste heat into the outside air,
- end user friendliness…</td><td>Research papers, statistics, interviews, questionnaire…</td></tr></table></td></tr>
<tr><td>Time unit</td><td>☐ During project</td><td>☐ 5 years after project ends</td><td>☐ 10 years after project ends</td></tr>
<tr><td>Interpretation</td><td colspan="3">The higher the levels of awareness of the higher comfort levels in 5GDHC, the more positive the influence on the uptake of 5GDHC.</td></tr>
</table>