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Transition Roadmap Guide

Researched by	Checked by	Reviewed by	First Draft	Final Draft
Odile Lefrère, Cerema		John O'Shea Codema		

Author(s): Odile Lefrère, Cerema
Email: odile.lefrere@cerema.fr
Phone: 33 (0) 20 49 61 22
Address: 44 ter rue Jean Bart CS 20275 59019 Lille Cedex

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About HeatNet NWE

This document has been developed as part of the HeatNet NWE project, which is part-funded through the Interreg NWE programme and aims to increase the uptake of 4DHC networks across North-West Europe. As part of this project, the partners developed the HeatNet Model, which will help the public sector to begin implementing 4DHC networks, and the Transition Roadmaps, which outline the partners' experience in developing six district heating pilots across North-West Europe. The HeatNet Guide to Financing gives a broad overview of the various sources available to finance district heating schemes.

For further information on these reports and on the HeatNet NWE project, please visit www.guidetodistrictheating.eu.

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Summary

To decarbonise a city now and in the future, district heating networks are an efficient tool. However, to deploy a district heating and cooling at a massive scale is a difficult task that needs careful planning. This guide aims to give advice on how to create a transition roadmap toward efficient district heating and cooling, which is the first and necessary step in the development of a low carbon energy solution.

Each stage of the process is described and illustrated with numerous examples, most of them from the pilots of HeatNet North-West Europe. This document can help local municipalities that already possess a district heating and cooling network to improve it but it can also help local municipalities that plan to create one from scratch. It provides advice specific to 4th generation district heating and cooling for local municipalities eager to implement it. The work is mostly based on the experiences from the HeatNet pilots and from two French guides on how to create a new district heating network[1] and how to masterplan a District Heating and Cooling[2].

[1] Guide to create a DHC: key elements for the project holder, 2017, Ademe/Amorce: http://www.amorce.asso.fr/media/filer_public/ac/bb/acbbb3c3-8182-44d7-a432-c59f60691e8a/rct46_guide_de_creation_dun_reseau_de_chaleurv2.pdf

[2] Guide to DHC masterplan for existing DHC, 2015, Ademe/Amorce: http://reseaux-chaleur.cerema.fr/wp-content/uploads/Guide2015_realisation_schema_directeur_RDC_F.pdf

Introduction

Among the technology options to generate low-carbon energy systems, district heating networks stand out as one of the most efficient solutions, especially in high-density areas. District heating systems are therefore destined, to become a major element of urban low-carbon energy strategies.

Energy Master planning approaches are necessary to seize the numerous opportunities for cities, larger towns and settlements to use renewable and low-carbon heat energy. The aim should be for new developments to be future-proofed to ensure that connections to existing or planned heat networks can be taken forward as soon as they are viable.

The aim of this Guideline is to set out the key stages and components of a district heating and cooling (DHC) masterplan and the elements required for a transition roadmap toward 4^{th} generation DHC. The requirements of an energy masterplan depend on local characteristics and this guide describes a series of stages that typically may be used in preparing a DHC or 4DHC masterplan. The methodology presented should be considered as a toolkit to support the development of creative low-carbon solutions and delivering decentralised energy systems. The document draws on examples mainly from the HeatNet North-West Europe (NWE) Interreg project and explains how a transition roadmap assists in the development and delivery of economically viable, sustainable projects.

To be successful, a transition roadmap requires that a lead organisation steps forward and brings stakeholders together. DHC masterplanning is best used to identify opportunities to match resources with demands in the most cost effective and sustainable way. This can be developed at a regional scale, city scale or at a local level to identify a vision for the future energy system and will identify a number of opportunities that can be developed collectively and/or individually.

The transition roadmap should include spatial maps that allow area planners and project developers to identify energy opportunities at the earliest possible stage and can assist the commissioning of projects in consideration of the wider energy context.

What is the Purpose of a Masterplan?

The development of DHC at the scale of a town or a neighbourhood requires extensive programming in a shared document that allows urban planners, land developers, and energy players to integrate DHC in their projects. A transition roadmap or a masterplan is the kind of document that creates those synergies and a successful project.

To Plan DHC Renovation and Transition to 4DHC

The transition roadmap in the case of an existing DHC is even more important as the DHC is already a part of the global energy system and stakeholders are already in place. The roadmap then aims to improve the DHC performance at all levels:

- Environmental impact: improving the use of renewable energy and the energy efficiency of the overall system as well as extend if possible, the network to fossil fuelled areas;
- Social impact: improving the financial viability and if possible, maintaining an affordable price especially in areas with high fuel poverty;
- Users and clients' relationship: improving the communication and the client's satisfaction;
- Economic impact: improving the use of local energy and developing local activities and employment.

To Plan a New DHC

The transition roadmap in the case of a new district heating is an important document to convince stakeholders to come on board and to integrate the project in the broader urban planning. In case of a new DHC, the transition roadmap ensures that key officers have the necessary awareness and understanding of DHC. It can also help with winning political support and stakeholder commitment.

In both cases, the roadmap suggests actions to be taken in the short, medium and long-term to develop DHC in a city or a neighbourhood.

Transition Roadmap Step by Step

Each roadmap is different and depends on the local context and the organisation in charge of this roadmap. Usually 5 or 6 steps are necessary before achieving a good transition roadmap.

Here is an example of how to proceed step by step to create a transition roadmap. Steps can be different and depend for example on the existing studies and the knowledge of the local community on the energy consumption and production on its territory.

Step 1: Steering Committee and Boundary

Defining who is in charge of the DHC project, Defining the boundary of the masterplan,

Creating the steering committee with the key stakeholders identified at this stage (updated throughout the process as more information becomes available).

Step 2: Diagnosis of the Heating Solution - Heat Mapping

For existing DHC, complete diagnosis of the DHC network and heat mapping within the boundary

For new DHC, analysis of the actual situation regarding heating heat demand mapping within the boundary

Step 3: Identification of Energy Sources

Existing heat sources, available land to create an energy centre, other available resources

Step 4 : Prospective Analysis

Forecasting exercise (10, 15 or 20 years) in terms of heating needs evolution, urban renewal, DHC extension, energy centre, etc. with the creation of several scenarios

Step 5: Scenarios Analysis

Evaluation of economical, environnemental, social and legal aspects. Synthesis.

Step 6: Transtion Roadmap Action Plan

Choice of scenario and action plan. Forward schedule

Example: Plymouth City Council (PCC) appointed a main consultant (Buro Happold) to conduct an extensive project focused on introducing 4DHC across the whole Plymouth area. PCC also appointed a 'Concepts Team' comprising Building Energy Solutions, Carbon Descent and Genius Energy Lab to work in parallel and directly with the main consultant in order to use the Plymouth outcomes to develop UK wide learning and guidance on 4DHC for the whole sector. The Concepts Team aimed to develop/standardise the widest possible ideas, concepts and approaches to introducing 4DHC/5DHC.

The Plymouth HeatNet project had 5 stages:

- Stage 1 - Research and evaluation on 4DHC opportunities
- Stage 2 - Heat Mapping
- Stage 3 - Outline Design
- Stage 4 - Techno-economic Analysis
- Stage 5 – Transition Roadmap

PLYMOUTH CITY COUNCIL

Step 1: Steering Committee and Boundary

Before everything else, commitment from local stakeholders is the key to every efficient transition roadmap. The steering committee aims to reach that goal. The definition of the scope helps to identify the potential stakeholders.

The Role of the Steering Committee

The steering committee should be a decision-making entity that meets for each key stage of the project. It makes dialogue easier with stakeholders and they can find answers to why a DHC roadmap is being done and how. Thanks to the exercise of masterplanning, the steering committee members will improve their technical understanding of the DHC and their knowledge regarding the benefits and opportunities of a DHC. The steering committee meets at least four times during the creation of the transition roadmap: at the very beginning, after the diagnosis and during the definition of the scenarios, and at the end for the choice of the scenario and the action plan.

Existing DHC:

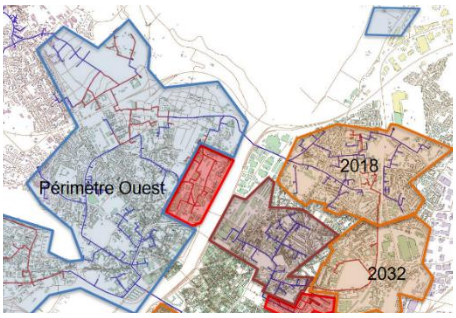


Figure 1. Angers DHC transition roadmap.

Boundary of the masterplan:

For small and medium size DHC networks, the boundary is usually several kilometres around the network or more if there is a high thermal demand density area or a potential energy source. It is possible to include areas that belong to another city or even to include another DHC nearby.

Launching several energy audits for major buildings in the area of the DHC can help to know if they should be included within the boundary or not.

For large DHC networks, it is possible to complete several masterplans (one for each area of the DHC) and then aggregate them.

A dialogue with the urban planning department can greatly improve the pertinence of the boundary and include areas where a major urban renewal is planned, a new district, or major new equipment.

Steering committee members:

The cross-disciplinary structure of a steering committee is essential to deliver a successful DHC roadmap. It ensures that DHC opportunities are reflected in all authority policy and strategy documents. If possible, the committee must include the following:

- The authority currently in charge of the DHC (the energy department of the city, the local energy agency, etc.) who should be responsible for leading the group and chairing meetings;
- The authority and elected officials in charge of urban planning and regeneration
- The authority and elected officials in charge of energy and climate policy,
- The authority and elected officials in charge of housing policy
- The authority in charge of the budget secures necessary budget for the implementation of opportunities
- In case of waste heat, the authority in charge of the incineration plant or the industry generating this heat
- The local energy agency
- The local urban planning agency
- The organisation(s) in charge of the DHC subsidies
- Subscriber representatives (usually one by type of subscriber: social housing, public building, office building, etc.)
- User representatives (tenants, etc.)

Example: Aberdeen City Council and Aberdeen Heat & Power (a not for profit company which develop and operate the DHC) in their transition roadmap toward 4DHC have contacted at an early stage many stakeholders and businesses, such as Bon Accord Care, who manage the operation of the Care Homes which are proposed to be connected. The aim was to have an indicator of the appetite to connect to the DHC. They also involved energy agencies whose jobs is to provide guidance regarding energy efficiency of buildings. Furthermore contacting existing customers is performed as part of an ongoing quality management process.

ABERDEEN CITY COUNCIL

The presence of the DHC current operator depends on the will of the authority in charge of the DHC and the contract linking them. Further individuals may be invited to attend certain meetings as deemed necessary and agreed by the group. For example, an authority in charge of nearby DHC, major industrial actors of the territory, local strategic partnership representative, housing providers or other major public building owners, etc. Once specific opportunities have been identified through the evidence base, the group should be expanded to include all those likely to be involved in the extension, or conversion of the DHC project.

A second steering committee, more technical and with less members, can be formed to discuss technical aspects of the project.

New DHC:

Boundary of the masterplan:

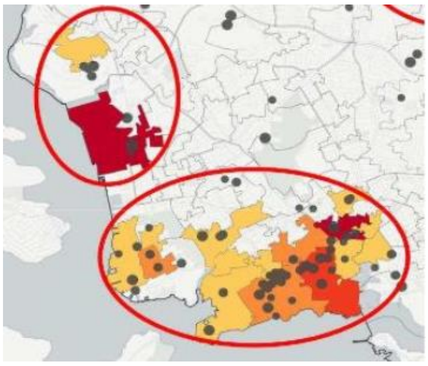
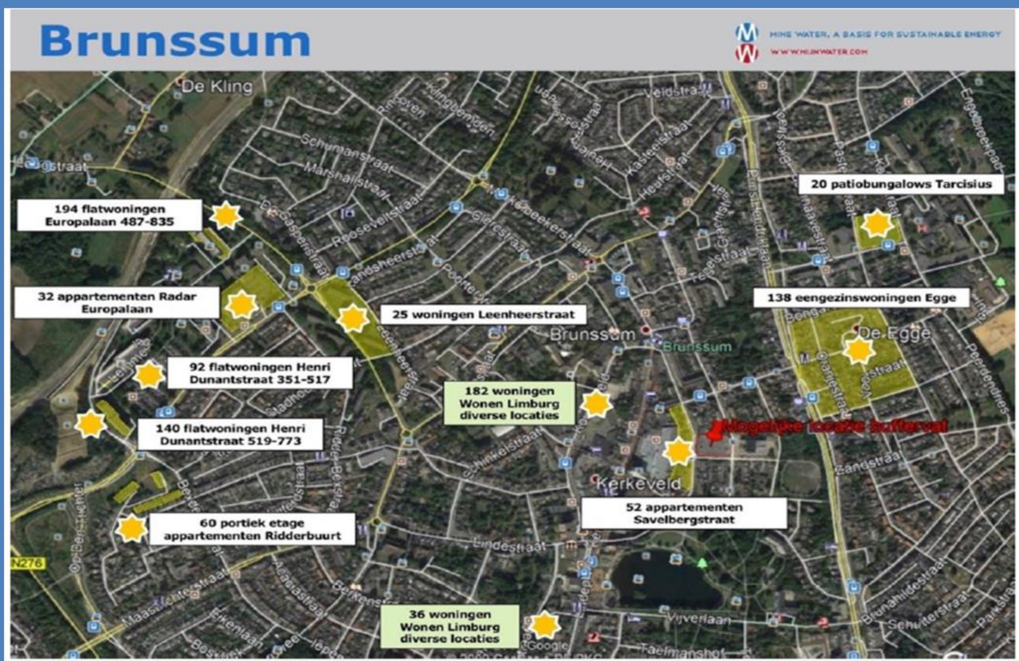


Figure 2; Plymouth City wide energy strategy, BH

Usually, documents and studies already exist on the territory even if there is no DHC. A heatmap[3] for example can be used to define a suitable boundary for a new DHC masterplan. To define the proper boundary of the DHC transition roadmap for a brand new DHC, it is necessary to include most of the high-density areas (>100TJ/km²)[4], future new buildings or new districts, land where it is possible to build the energy centre, local existing energy sources. It must include the buildings that have a high heat or cool demand such as hospital, swimming pool, universities, high schools, town hall, major social

Example: Herleen has decided to extend its model of DHC (Mijnwater) to the city of Brunssum and their ambitious transition roadmap explores replicating the model through the entire Parkstad region by 2040. In order to do so, Mijnwater works closely with regional institutions and they are trying to develop a standard model (in terms of procedure, contract, and technical aspects).



[3] To know more about heatmapping – here is a guide to heatmapping : https://www.nweurope.eu/projects/project-search/heatnet-transition-strategies-for-delivering-low-carbon-district-heat/library/guide-to-heat-mapping/

[4] In Denmark usually 150TJ:km² is used to identify areas viable for DH, in France, a DHC is considered viable from 1.5MWh by meter of DHC but 4DHC can be viable in lower density areas.

housing buildings, etc. these are commonly referred to as anchor loads and provide the backbone of the network.

Before defining the boundary, the project holder must know what funds are available for the project. That is why it is important to consult the authority in charge of the budget. The future scenarios made in the following stage of the transition roadmap can each transform the initial boundary to best fit the project.

Steering committee members:

Once the project holder has some knowledge on the opportunity for DHC on the territory, it becomes clearer which member should be on board of the steering committee. Once again, the cross-disciplinary structure of a steering committee is essential to deliver a successful DHC roadmap. The committee must include:

- The project owner who should be responsible for leading the group and chairing meetings;
- The authority and elected officials in charge of urban planning and regeneration;
- The authority and elected officials in charge of energy and climate policy;
- The authority and elected officials in charge of housing policy;
- The authority and elected officials in charge of waste treatment;
- The authorities in charge of education, leisure and facilities management to know more about buildings that might connect to a DHC;
- The authority in charge of the budget;
- The local energy agency;
- The local urban planning agency;
- Major building owners and potential customer representatives (usually one by type of customer: social housing, public building, office building, etc.);
- The organisation(s) in charge of the DHC subsidies (if available in the country or region);
- The engineering consultant firm supporting the project holder and making the studies;
- The land developer(s) of an area than has an interest for the DHC project.

Whilst a range of departments must be represented on the steering committee, it is recommended that the group is kept reasonably small in the early stages of developing a DHC. When the project become more and more concrete, engaging with future customers and users is important. This will allow them to gain a deeper understanding of the project. It can help avoid future opposition due to misunderstandings. They can even participate financially to support studies or even the DHC as part of a citizen's initiative for financing renewable energy projects become more and more common.

A second, more technical committee with less members can also be formed to discuss technical aspects of the project.

Example: In South Dublin, the transition towards 4DHC is supported at the highest level within the SDCC (South Dublin City Council) and a team of people from the SDCC and Codema (the local energy agency) has been formed to carry one the 4DHC project and the transition roadmap as shown in the figure below.

Specific to 4DHC:

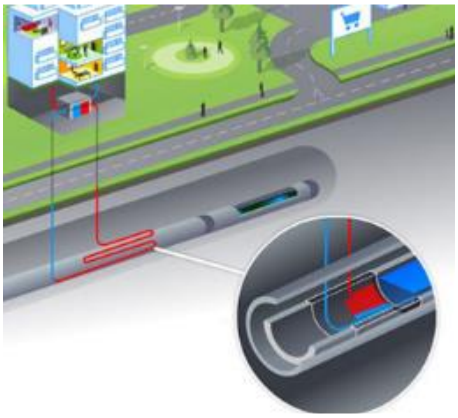


Figure 4: DHC using heat from sewage

Because 4DHC can use low-temperature energy sources such as data-centres or heat from sewage, new actors can join the Steering committee such as the organisation in charge of sewage or datacentre operators.

Furthermore, because 4DHC is particularly suitable for new or refurbished buildings, the participation of urban planners and staff working on urban renewal in the steering committee is even more relevant.

For 4DHC, the focus must be on new urban developments or refurbished districts (or about to be).

Step 2: Diagnosis of the Heating Solution – Heat Mapping

This step is probably the one that requires the most data collection. During this step, it is important to balance having the best possible information against the time to be invested in getting that information.

Existing DHC

Documents needed:

The diagnosis of the existing DHC must be the common base for all stakeholders to discuss facts. The diagnosis should include the following documents, where possible:

- Map of the DHC network (GIS format preferably) with all substations, pipes diameters and connected buildings. If available, a hydraulic model of the network may be used to highlight potential bottlenecks in the network if new connections are added
- Description of the DHC (energy sources for peak load and base load, load curve, energy mix, CO_2 content, operating temperatures etc.)
- History of the DHC with its evolution (legal, technical, economical, etc.)
- Description of each energy centre (equipment, hydraulic framework, etc.)
- Description of the customers (type of building, floor area, number of users, heat needs and evolution, power subscribed, power of the substation, etc)
- Description of energy efficiency measures undertaken for the DHC (variable pump, pipes insulation, reduction of temperatures, individual setting for each substation, etc.) and for the connected buildings (insulation, thermostatic valve, etc.)
- Location of other nearby DHC networks
- All the contracts and administrative documents linked to the network (contract with the operator, with the subscribers, regulations, amendments, contract with waste heat seller, etc.)
- Annual operating reports from the DHC operator (the last 3 years)
- Urban planning documents
- Local and regional Energy Climate policy documents to appreciate the place of renewable heat and DHC in the policy
- Tariff structure and evolution
- Investment plan

Performance indicators:

Thanks to these documents, it is possible to evaluate the performance of the DHC in the current situation through performance indicators. Here is a list of indicators[5] that can help if none already exists:

[5] To know more about those indicators and how to calculate them : https://www.amf.asso.fr/m/document/document.php?id=9911 and https://www.lagazettedescommunes.com/telechargements/IGD_Indicateurs_Reseau_chaleur.pdf (French)

Principal indicator	Additional indicator
Guaranteeing that customers' needs in terms of heat and hot water are met	
Rate of power demand	Equivalent duration of full power usage
Interruption rate (hours of failure/operating period in hours)	interruption rate locally
linear heat density (MWh/m)	development
Temperature regime	
Preserving the environment and the security	
Energy mix CO_2 emissions	atmospheric emissions other pollutant produced (NOx, PM2.5 etc.)
Usage of primary resources Water usage	
cost of damages	frequency and severity of accidents
Insuring the durability of the DHC	
Equipment renewal	Efficiency improvement
Heat Loss	
Customer satisfaction	
Average price of MWh	importance of the cost of the consumption in the total price of MWh
satisfaction inquiry	Number and type of customer complaints
	Meetings with users' representative
initiatives and action toward users	

Table 1. Performance indicators for DHC

Analysis of the contractual context:

The contractual context is crucial with an existing DHC in order to understand the different possibilities and barriers. The analysis of all the contractual documents (service regulations, subscription policies, public service delegation agreement, operating contracts, electricity sales contract, contract for the supply or sale of heat from or outside the network boundary) regarding the network should be examined to:

- give an appreciation for the contractual state of the DHC (age of the documents, integration of specific provisions such as the CO_2 quotas issue, the evolution of the energy mix, adequacy of the price indexing formulas, the revision of the subscribed powers, integration of new regulation),
- know the potential short-term evolution (the expiry date of the subscription policies, the subscribed powers concerned, the modality to change the power subscribed, the expiry dates of heat purchase contracts (with an industry, etc.)
- keep in mind the expiry dates of public service delegation contracts or other form of contract with the operator, any steps already taken to renew them, the provisions already laid down in the contract, for example on the integration of return assets,
- analyse the expiry date of the electricity sales contracts in the purchase obligations on combined heat and power (CHP) installations, the short-term impact foreseen, the envisaged or already validated action for the future.

The technical audit:

It serves as a basis for future technical recommendations that will make it possible to program the improvement of the technical performance of the DHC such as the energy efficiency improvement, the reduction of the temperature, etc. This technical audit is based on:

- visits to primary installations (production plants, distribution network, substations and secondary network,
- the analysis of the different documents related to the regulatory controls and the operation of the site,
- the analysis of the technical reports produced by the operator and any existing analysis report
- analysis of maintenance schedules and reports

The technical audit of the energy centre(s) is also necessary (characteristics of the production equipment, general organisation of staff members, fuel storage, monitoring of the equipment through the boiler room booklet, etc.).

Regarding the primary network, it must be thoroughly characterised (type of pipes, diameters, type of fluids, maintenance work, age of pipe, list of past leakages, thermal loss, efficiency, etc.)

Regarding the substation, the description must include the type of exchange system, the type of control mode, the specificities regarding hot water production and storage, the match between subscribed power and power needed, the presence of the heat meters, the type of insulation, etc.

Regarding the secondary network, the analysis aims at having a better knowledge of the possibilities in terms of energy efficiency and optimisation (switch toward 4DHC) offered by the secondary network equipment. This part also evaluates the energy performances of the connected buildings (through past bills, construction dates, complaints in relation to overheating in buildings etc.) and their heating equipment as well as the temperature regimes. Regarding the size of the network and the number of connected building this part can be done by visiting all of them or through samples.

The economic audit:

It aims to evaluate the financial solidity of the DHC and to compare it with other heating options. It analyses:

- Expenditures (maintenance costs, fuel prices, depreciation charges, etc.)
- incomes (subsidies, bill payments, …)
- Operating accounts and balance sheets
- internal financing capacity
- profitability
- price construction and comparison
- DHC competitiveness regarding other heating solutions using the global cost[6]

Operating accounts and balance sheets must be analysed.

Heat mapping of the boundary

A heatmap is a spatial plan of heat demand and generation equipment. The objective of a heatmap is to identify opportunities for developing or expanding a DHC. It is an essential tool in the transition roadmap. To learn more about heatmapping, you can download the guide on heatmapping: https://www.nweurope.eu/projects/project-search/heatnet-transition-strategies-for-delivering-low-carbon-district-heat/library/guide-to-heat-mapping/

[6] The global cost includes energy cost, initial investment cost, subscription cost, operating and maintenance cost, cost of electricity needed for auxiliaries, etc.

New DHC:

Heat mapping of the boundary

For new DHC, heat mapping is even more crucial since it will also prioritise the areas that are best suited to developing the DHC network. To learn more about heat mapping, you can download the guide on heat mapping: https://www.nweurope.eu/projects/project-search/heatnet-transition-strategies-for-delivering-low-carbon-district-heat/library/guide-to-heat-mapping/

Identifying public buildings and main buildings (or anchor heat loads):

Heat maps usually give a good idea of the heat demand at a district scale but to start a DHC project, more detailed information is needed. Most of the time the transition roadmap and the future DHC are public initiatives (city, town, etc.). The organisation in charge of the transition roadmap usually owns many buildings within the area (schools, city hall, library, etc.). Members of the steering committee might also own other buildings within the boundary (social housing, university, etc.). Therefore, having precise information on those buildings becomes easier. It is also important to detect other buildings that might have a huge influence on the DHC called anchor loads (i.e. major energy consumers, for example: swimming pools, hospitals, hotels etc.).

Figure 5 Map of major public equipment and buildings at a district scale - source Géoportail

Once the list of those buildings is completed, the first action is to roughly estimate the global consumption. It is possible at this stage of the project to use benchmarks[7] instead of real data. Another important aspect to consider is the fuel used for heating (gas, oil, electricity) in those buildings. The buildings using electric heating would usually not be able to connect to the DHC without costly investments so it is not necessary to investigate them further. If possible, another easy action to do is to sort out those buildings by type (homes, offices, health, teaching, etc.) in order to have an idea of the possibility to smooth the heat load curve thanks to the mix of usages (i.e. higher demand diversity). The type of owner also gives an indication of the relative connection willingness.

Here is the list of the kind of buildings that may be of interest:

- Universities
- Schools
- Municipal day nurseries
- Swimming pools
- Ice rinks
- Retirement homes
- Hospitals
- Social housing buildings
- Municipal and other public offices buildings (city hall, post office, government buildings, etc.)
- Museums
- Libraries
- Fire station

[7] Benchmarks can be found according to the age or type of the building (e.g. CIBSE TM46, CIBSE Guide F etc.)

- Police station
- Court house
- Sports hall or stadium
- Malls
- Reception halls or congress centres
- Hotels
- Major private office buildings
- Prison

Energy Audit of the main buildings:

From the list of buildings above, some will play a major role in the sizing of the project thus it is necessary to conduct an energy audit of those buildings. If possible, with details such as:

- Heated floor area,
- Level of energy performance (if not possible at least the year of construction)
- History of energy consumption (gas, electricity over three years) based on actual billing and where possible split by use (space heating, cooling, hot water, steam etc.)
- Heating equipment – including rated heat capacity and date of possible replacement (if not available then age of installation)
- Set temperatures for heating (day, night, weekend, holidays, etc)

Example: Thanks to the active participation of Habit du Littoral, the local main social landlord, the DHC operator of Boulogne-sur-Mer had many information regarding heat needs and power subscribed for the major buildings of the city.

If the project holder is the municipality, it is also the occasion to conduct energy audit on its own property portfolio. If some of the municipally owned buildings can be connected to the DHC then this energy audit will serve the project.

Specification for 4DHC:

Since 4DHC is particularly suited for new or refurbished buildings with a certain type of heating equipment. For step 2 if creating a 4DHC network (or the extension/transformation of 3DHC into a 4DHC). The date of construction of the building (or the year of the major refurbishment) is particularly relevant as well as the heating system in place. Usually, low-temperature underfloor heating systems are particularly adapted to 4DHC.

Step 3: Identification of Energy Sources

In this section, the aim is to identify the potential heat sources located near the existing DHC or near the zone with high potential for a future DHC. It is important to know roughly the annual heat demand and the power that a heat network would probably require, as well as the temperature of the network. Not every energy sources will be able to meet the demand properly.

Example: Boulogne-Sur-Mer possesses 2 district heating operated by Ecoliane. In their transition roadmap toward 4DHC, they looked to a large spectrum of new energy sources. For example, they studied the possibility to connect the aquarium of Nausicaa (biggest in Europe) to one of the DH and install a heat pump there to recover warmth from the refrigeration units of the aquarium. They also looked to improve the efficiency of the existing energy sources for example by using a technology called a terraotherm, which enable to recover heat coming out from the fumes of the biomass boiler and improve the renewable energy mix without adding an additional energy source.

In this step 3 you will need to:

- identifying nearby network (owner name, type of DHC, age, energy mix, power, heat production, possibility to exchange heat, etc.)
- identifying renewable or waste heat sources (UIOM, industries, wastewater treatment plant, geothermal exploration, solar, available biomass nearby, biogas potential, etc.), quantifying and qualifying those resources.
- Identifying the land available for the installation of energy centres and potentially thermal storage or even the installation of thermal solar field. Maps of potential "donor" sites where an energy centre could be developed.

It is also in this part that you can highlight constraints like major linear infrastructure, watercourses, rail lines, motorways etc.

Many data sources can be found online nowadays and the guide to heat mapping can help to identify energy sources and constraints for a masterplan: https://www.nweurope.eu/projects/project-search/heatnet-transition-strategies-for-delivering-low-carbon-district-heat/library/guide-to-heat-mapping/

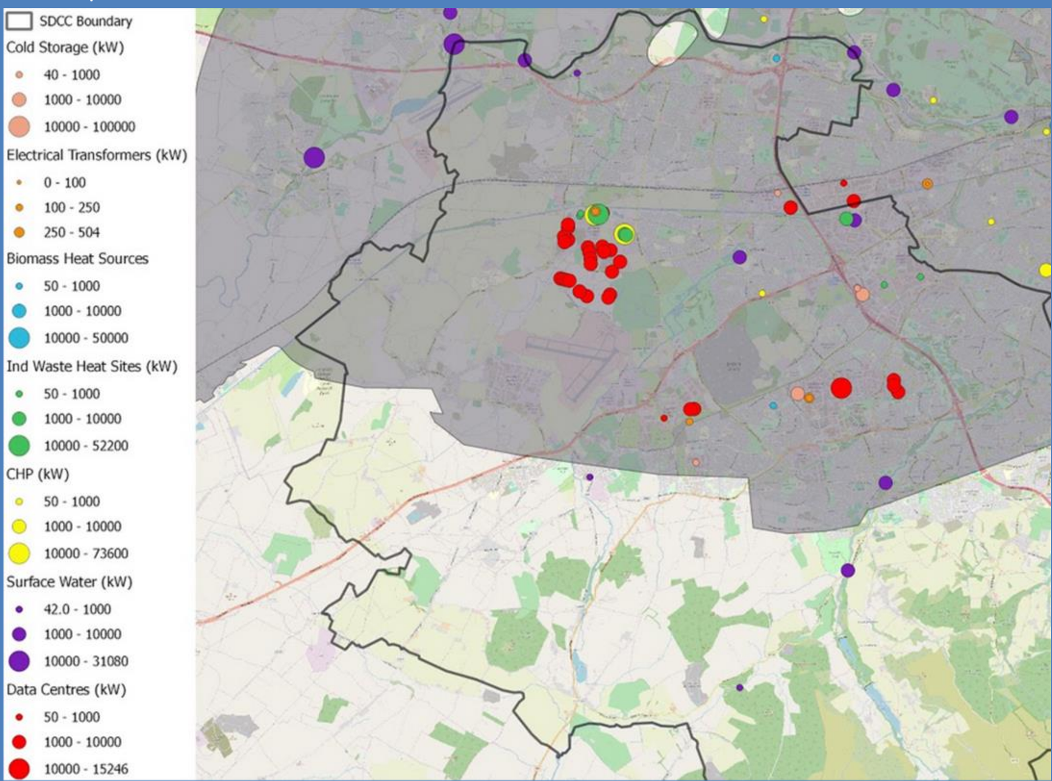
The step 3 must lead to a synthesis with the availability of identified energy sources, their price, their advantages and disadvantages.

Energy source	Risk /Difficulty	Recommendation for the transition roadmap	Thermal Storage	Temperature range
Waste heat	Contractual	If possible, pre-sign contracts	Sometimes useful to maximise the use of waste heat or in the case where heat pumps or electric boiler can be used	Depend on the type of industrial process

			to balance the electrical grid	
Solar	Available space Sunlight Installation	Need for other energy sources	Necessary	The lower the better
Biomass	Dimensioning Biomass storage Particles filtering	Need to pre-sign contracts for the wood supply Power of the boiler no more than half of maximum power required on the DHC	If possible, since it improves the boiler performance	
Geothermal energy	Durability of the source Borehole	Study for the identification of the geothermal source Have a warranty		Depend on the source. It can be compatible with high temperature or only low temperature
Biogas	Heat demand usually not close enough	Try to look for synergy with agri-food industry		High or low temperature

Tableau 2. Comparison of different renewable energy source for DHC

Example: South Dublin City Council maps data-centres, surface water, deep geothermal, CHP, cold-storage, industrial waste, electrical transformer, and existing biomass heat sources in its transition roadmaps.



It is also in this step that the “reference solution” is detailed. Usually this reference solution is “business as usual” i.e. individual gas boilers if there is a gas network in the area or oil-fired boilers if not.

Step 4: Prospective Analysis, Technical Aspects

Once you have your energy sources, your energy centres, and the buildings that might be of interest, it is then, possible to draw network options. For this step, usually tools help greatly to carry out the analysis. Within the HeatNet NWE project, an open source tool from the Danish energy agency has been adapted to the North West European countries contexts. You can find the tool here: https://guidetodistrictheating.eu. Other tools such as EnergyPRO provide detailed models (https://www.emd.dk/energypro/).

Existing DHC

Objectives:

The objective of this part is to describe foreseeable evolutions of the DHC within the boundary of the masterplan area thanks to the work done in other steps by answering a series of questions:

Figure 6. District heating planned growth (blue) in Aberdeen – Aberdeen transition roadmap

- What are the evolutions to come regarding energy consumption of already connected buildings: deconstructions / renovation with thermal improvement of buildings?
- What are the impacts of planned urban operations on the DHC: deviation / deconstruction of network?
- What are the prospects of extension, densification and interconnection of the network?
- What renewable and recoverable energies can be integrated into the heat network?

For these different options, it will be necessary to develop some "consensus" scenarios supported by technical assumptions. Usually 3 to 6 scenarios combining expected changes (low, medium and high assumptions), particularly in terms of the connection schedule of new subscribers is a good choice.

Different technical evolutions of the DHC:

Regarding the evolution of already connected buildings, hypotheses regarding energy efficiency investment by building owners are needed, massive urban renovation can be known in advance. Building owners can also have an energy/refurbishment masterplan that are willing to share. With those elements, it is possible to adjust some hypothesis regarding future energy needs, future heat load and future heat temperatures.

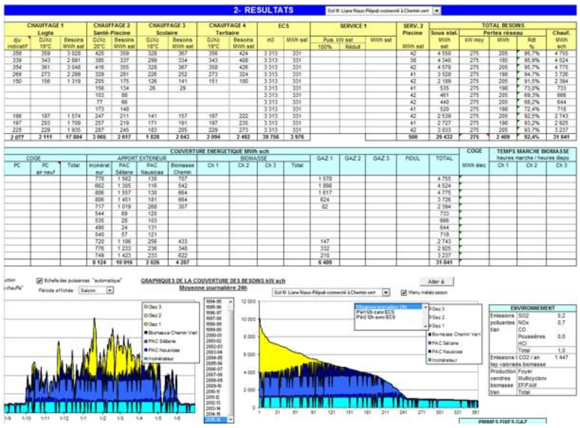


Figure 7. Simulation tool used by Ecoliane to examine several scenarios regarding their DHC development

To analyse the possibility of extension in several years two possibilities can be explored. The first one is the extension to connect to a major heat costumer. In step 2, major existing or planned buildings have already been explored in order to know more about their current or future heating plans, their thermal characteristic, their energy consumption profile, etc. In this step, drawing networks to link the existing DHC with anchor loads will allow you to detect secondary buildings that might connect to the DHC "on the way". The extension toward an entire future development is usually more tricky since the timeline between the DHC and the new development will become co-dependant. The planning authority should possess all the documents regarding energy need of the future building, the land availability to build a potential energy centre and the schedule of the new district development. In this step, it is important to keep in mind the timescales for build-out of the new district.

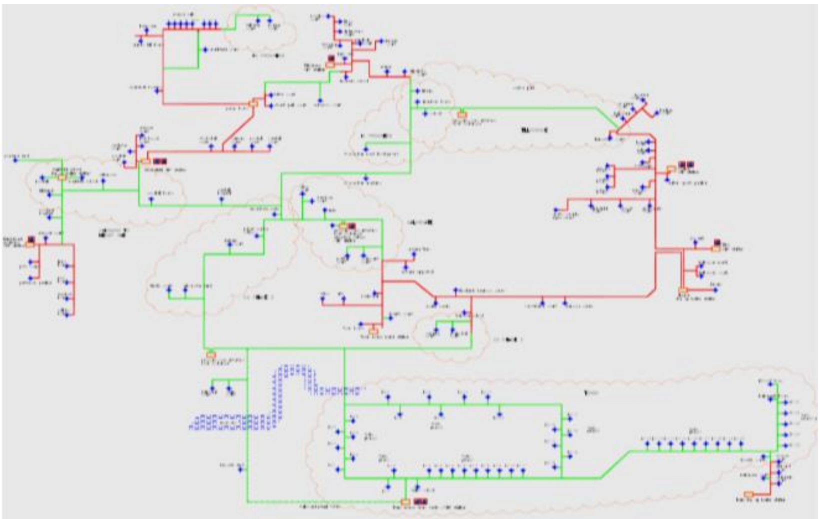


Figure 8. Planned development Schematics - Aberdeen transition Roadmap

Regarding extensions, the technical feasibility of the different scenarios integrating the extension of the DHC should be examined based on elements such as:

- the map and characteristics of the network to be created in order to connect the envisaged substations,
- the technical capacity of the existing network to integrate the new connected power,
- the necessary modifications on the existing network to allow this extension,
- the technical capacity of the existing production equipment to ensure the production of additional energy (by including the projects concerning areas whose development will be progressive and the predictions of reduction of energy consumption on the existing buildings),
- the new installations needed for the extension

Regarding densifying the DHC, the prospecting analysis needs a precise study of the heat needs and the heat equipment of the buildings in close proximity to the DHC (if not done on step2). This is also the time to examine the incentives or obligations for new or existing building to connect to the DHC. The transition roadmap can include actions regarding building regulation or urban planning rules in the areas. For example, changing urban rules to improve heat density, to make buildings compatible with DHC or to forbid the creation of a gas-grid.

The last phase of the prospection analysis is about the integration of renewable energy, waste heat or even heat from another DHC. It is necessary to evaluate the potential of new renewable energy sources or waste heat nearby and how to implement them in the existing DHC by answering several questions:

- How much heat is available and when (all day long, all year long, etc.)?
- What kind of equipment those energy sources require?
- What fuel is required (electricity, gas, biomass, etc.) and can it be brought to site
- How much greener the DHC will become?
- How much CO_2 will be saved?
- What other impact of the environment the use of those new energy sources could lead to (noise, fine particles, etc.)
- Where the new energy centre could be built?

Following this prospective analysis, several scenarios must be shaping up (no more than 6). Those scenarios can differ regarding the renewable energy mix, the technologies or the boundary.

Key Performance Indicators regarding the technical aspects:

Once all the investigations have been conducted, it should be possible to estimate roughly some key indicators for the DHC project such as:

- Power needed (MW)
- Heat loads (MWh, J, etc) broken down by development type and date of connection
- Linear thermal density (MWh/m)
- Temperature
- Network route length

New DHC

In addition to the description of existing buildings that could be connected to the DHC (Step2), the description of urban developments is a must do. In many cases, the project of a new 4DHC is linked to urban renewals or urban developments. It is important to identify the zones controlled by the local community since it might be easier to implement the DHC on those zones. It is also important to know the specific constraints of those new developments (sometimes for example, local urbanism rules make it impossible to build an energy centre or to put solar panels on the roofs). It is the occasion to examine if there are interfaces or synergies possible with other work to come (roads, transports, etc.). It is necessary to approach the project holder of those new developments if it is not already done to know more about:

- Forecasted heated floor area or number of units in the case of residential developments
- Sector of activity (residential, tertiary, industry, etc.)
- Projected construction years (sometimes, those project takes more than 10 years which can be a challenged when developing the DHC)
- Targeted energy performance

Time is a key factor in the development of a DHC, especially new DHC that cannot truly count on the financial stability of the already well running network. The buildings to be connected will be available for connection at different times over many years. Usually, existing buildings are not viable to be connected unless there is a major replacement investment required, and new development takes several years to be built. For both existing and future developments, if the window of opportunity for connection is missed, then it may be another 10-15 years before the next opportunity arises again. Furthermore, it rarely occurs that the planned spatial sequence of connections matches the chronological sequence of opportunities. The earliest connection opportunity might be for a building situated some distance from your energy centre. Since construction of a long network to connect that sole site is unlikely to be viable, it may be necessary to provide an interim heat supply solution to that site, which is designed for future connection when the network does arrive. A Phasing plan is particularly important for DHC when designing the network.

The phasing plan should be more detailed for the first phases and less and less details for the 10 years projection or the 20 years projection.

As for existing DHC, this part must lead to technical key performance indicators (KPIs) as described below. Usually, those KPIs are less accurate since the data is mostly theoretical but those KPIs will make it easier to compare the different scenarios nonetheless.

Specifications for 4DHC

Once again, 4DHC will focus mostly on new areas and refurbished buildings thus in the planning of a 4DHC, it is important to have the maximum information regarding refurbished projects and new urban developments and target those buildings in the scenarios.

In the transition roadmap toward 4DHC, it is also possible to initiate ambitious actions to reduce building consumption and create 4DHC compatible zones. Those initiatives can be:

- Local grants to help building adapt to low temperature heating system
- No new buildings connected to the gas-grid
- Etc.

Example:

Aberdeen plans door-to-door contact and engagement with commercial and domestic properties within areas next to existing DHC to know more about the potential future subscribers.

Step 5: Scenarios Analysis

The different scenarios must now be evaluated regarding several aspects: legal aspects, economical aspects, social aspects and environmental aspects. The scenarios analysis is similar for existing and for new DHC but the legal framework is usually more difficult with an existing DHC since contracts have already been signed several years before.

The scenarios analysis must link the transition roadmap agenda to key existing priorities (cost savings, energy security, climate change, fuel poverty, etc). The scenarios analysis must also underline the key risks for each scenario.

Of course, the viability assessment will be of decreasing relevance for the later phases. The later phase are usually important mostly because actions decisions can have influence on them and so those decisions and actions can be a part of the transition roadmap.

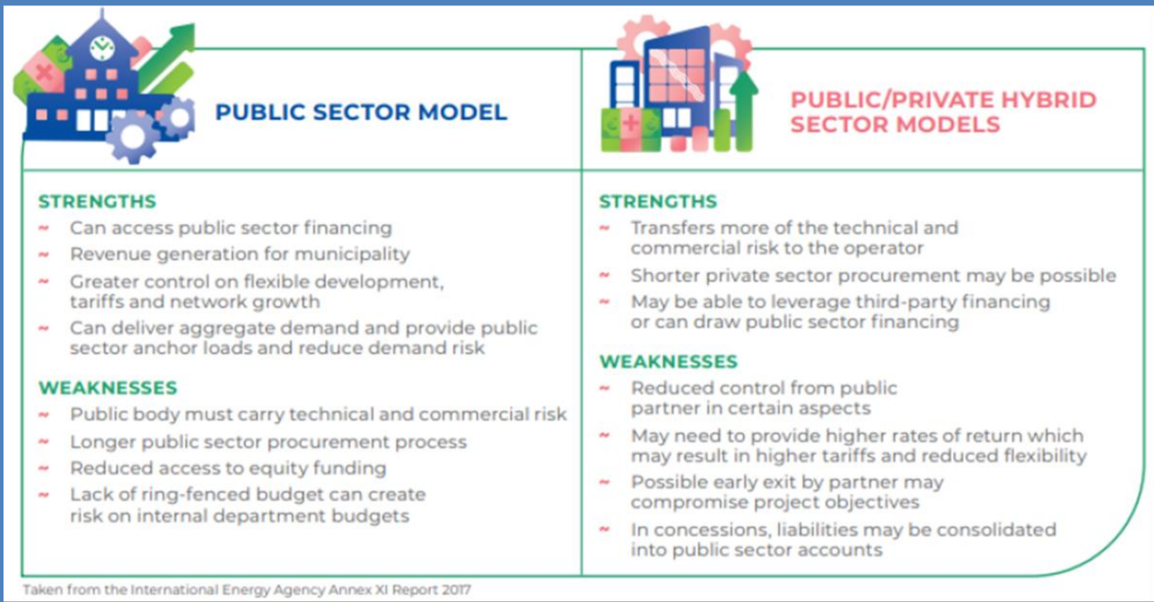
Evolution of the Legal and Contractual Aspects:

In case of an existing DHC, the various scenarios are examined regarding the contractual situation of the DHC, the political support for the project and the legal mode of management. In the case of an existing DHC with a public service delegation, it is necessary to know the possibilities of changing different aspects by amendment to the contract. If a legal procedure to make it mandatory to connect to the DHC exists then evaluate if it is opportune to use it. Numerous questions should be examined to go further and select the proper scenarios:

- What does the existing contracts allow the stakeholders to do?
- Can I buy heat from another heat producer?
- What kind of contract do I want (integrated or with separations between production, transport, distribution and supply)?

In case of a new DHC, it is also the time to question who should be in charge of the future DHC evolution (the city, a dedicated structure, the region etc.), sometimes to scale up it is necessary to transfer the project to another entity or at least to make it possible to do it in the future.

Example: South Dublin City Council analyses the legal and contractual aspect trough a SWOT analysis.



Economic Aspects

It is one of the most crucial aspect but also one of the harder to evaluate. For every scenarios, the following aspects must be examined:

- financial viability for the DHC owner (using IRR, NPV etc.)
- financial consequences for the operator
- financial consequences for the customers
- global cost comparison (integrating the capex, opex, subsidies, taxes, etc.)
- price stability
- investments on each part of the DHC (production, network, substations, etc.) with a timeline
- subsidies, loans and other mean of funding the investments (including crowdfunding, European projects, etc.)
- evolution of the operating costs
- tariff structure and its evolution
- investment on the secondary network (if required)
- economic advantages for new customers such as tax reduction or tax credit

Following this analysis, the economic viability of the different scenarios must be assessed as well as the initial investment needed and the financial impact on the subscribers.

Once more, this part is tricky and using a simulation tool is often a good option. For investment, it is possible to divide the networks into grounds type (hard urban, suburban, brownfield, greenfield) in order to have an approximation of the price. Indeed, the harder the ground, the more expensive. There is also a cost implication with crossing existing infrastructure such as railways or rivers where bridges, directional drilling or reinforced trenching will add to the cost.

Environmental and Social Analysis

The environmental impact compared to the baseline situation of each selected scenario is analysed. This analysis includes:

- the reduction of greenhouse gas emissions (in tons of CO_2 equivalent)
- the improvement of air quality (particulates, NOx, etc.)
- the contribution to the objectives of energy and climate for the city

The social impact of each scenario is also analysed. This analysis includes:

- an estimate of the number of jobs created directly and indirectly
- the impact on fuel poverty (reduction, stability of bills, etc.)
- the relocation of energy expenditure and activity on the territory
- improved health from cleaner air

Example:

Regarding technical and economical evaluation, Boulogne-sur-Mer's DHC operator used a tool called "SIME" (32 Excel tabs) to simulate several scenarios by changing settings such as new heat pump, new consumers, etc.

HeatNet NWE has also adapted an existing powerful Danish tool (excel files) that can simulate a DHC, you can find it freely on the HeatNet web site.

Regarding social impact, Aberdeen transition roadmap emphasises the importance of fighting fuel poverty and areas to develop DHC were chosen based on this criteria.

Step 6: Synthesis and Action Plan

A synthesis of the study is carried out to explain the situation and the choice criteria of the scenario. A SWOT (strengths, weaknesses, opportunities, threats) analysis can act as a synthesis for each scenarios. These criteria are defined in consultation with the Steering Committee. The different scenarios are then evaluated to arrive at the choice of the final scenario.

On the basis of the elements detailed previously, the synthesis and the action plan contains:

- A summary of the actions: legal, policy, extension, densification, production, investment, impact on the heat price, environmental, capacity development required (human resources, knowledge and pipeline of projects), project delivery
- An investment program to strengthen the competitiveness of district heating regarding other heating modes, its environmental performance and its sustainability,
- Measures of adaptation to the expectations of users, possibly via the development of a commercial and pricing policy aimed at keeping customers satisfied and maintaining the financial balance.

The action plan includes for each action a precise definition of the action, a pilot and the partners involved, a deadline and the means (financial, data, etc.) allocated to the action

At this stage an event open to all to communicate the results should be organised (other events can also be organised before if needed).

Example: Aberdeen transition roadmap has an action plan in three phases (short term, medium term, long term). The first phase is the one partly financed by the Interreg project and consists of an extension to a network between three buildings to a family centre and two residential care facilities. When the waste incineration plant is completed in 2022, the phase 1 network will connect to the plant. Phase 2 could begin after that with an extension of the phase 1 network to five non-residential buildings and 800 residential properties within the next five years. Phase 3 consist of crossing the river to expand the network within the city centre. Phase 3 of the scenario will be explored further after the first two phases has been completed since another network within the city centre is also in development. The action plan is resumed thanks to a table such as the one below which describes what to do by thematic area (planning, delivery, etc.):

	Short Term			Medium Term			Long Term		
	2019	2020	2021	2022	2023	2024	2025	2026	2027
Planning									
Delivery									
Stakeholder engagement									
legal									
Policy									
Technical Development									
Capacity Development									

Example: Plymouth transition roadmap has an action plan that focuses primarily on making whole areas "4DHC and 5DHC friendly"

Local Authority roadmap for 5th generation heat networks

2020

- Include Low Temperature Building Zones in Supplementary Planning Guidance (SPG) to develop 4DHC and 5DHC areas/corridors that offer preferential planning approval – give clear signals that these areas will grow
- SPG to include DHN connection future proofing of all new and refurbished buildings (based on Buro Happold connection templates)
- SPG to insist on following CIBSE/ADE Heat Networks Code of Practice CP1.2
- Early adoption of 'no new homes should connect to the gas grid' and should instead rely on low-carbon heating systems such as heat pumps
- Local grants and S106 agreements to help buildings move to 60/40ºC
- Greater enforcement of Building Regulations Part L
- Discourage resistive heating through less preferential planning approval with greater scrutiny
- Publish a local 'connections guide' covering policy, technical and legal DHN guidance

2025

- Extend the Low Temperature Building Zones to cover all new buildings, offer preferential planning approval to buildings able to act as prosumers
- Early adoption of 150g/kWh with even lower overall building carbon targets
- No new non-domestic buildings should connect to the gas grid, and should instead rely on low-carbon heating systems such as heat pumps
- Continue grants and preferential planning approval to help buildings move to 60/40C
- Even more rigorous planning scrutiny/hurdles for proposed resistive heating buildings

2030

- Local Authorities should becomes a single LTBZ where all new buildings must be less than 60/40ºC
- Early adoption of 100g/kWh with even lower overall building carbon targets
- SPG to include even greater encouragement of 5DHC and prosuming buildings

A NEW LOW TEMPERATURE BUILDING ZONE

- All new and refurbished buildings to be less than 60ºC
- Grants to help existing buildings to move to 60ºC

THE PLYMOUTH RULE

Elements Regarding the Transition Roadmap

This section of the report discusses other elements to consider when developing a transition roadmap which may not form part of the Action Plan itself.

Financing and Resources

A DHC transition roadmap requires internal staff and usually external consultancy support. Thanks to heatmaps or past studies much of the early work can be undertaken in-house. Nevertheless, it usually required at least half a full-time staff resource as well as external support to carry out technical feasibility studies (6 to 12 months).

Different actors from the steering committee can finance the masterplan, if this is the case there are usually much more actors involved. In France, major customers can also help with financing (if so, they usually part of the steering committee).

Timeline

Usually it takes around 6 months to do a transition roadmap. If past studies have already been done (such as heatmapping, energy audit on buildings etc.) it can be quicker.

In countries where energy data is open and free the transition roadmap can be done quickly and efficiently. In countries where energy data is hard to get, it will take more time to have a useful transition roadmap.

Legal Framework

In some countries, such as France, DHC masterplanning is mandatory. Indeed, through the French energy transition and green growth act. There is an obligation for local authorities to make a local masterplan of DHC development for installation in operation before 2009. It is also required by the French Energy Agency in charge of DHC subsidies for every financial support demand.

From DHC to a Larger Energy Transition Roadmap – Energy Masterplan

More and more large cities are doing not only a DHC transition roadmap but a much larger energy transition roadmap that includes electricity and gas networks as well as production centres. If it demands much more time and resources, the result can also be much more relevant. It can help to choose what kind of energy is more relevant in a district (gas, DHC, electricity) regarding density, energy centres and opportunities. These wider energy masterplans can improve the overall energy efficiency of a city, improve the use of renewable energy and improve the cost of green energy as well as the social benefits (local resources, employment, etc.). Cities like Lyon, Zurich, and Dublin have developed or are in the process of developing Energy Masterplans.

Conclusion

A transition roadmap is a necessary exercise that helps bring together stakeholders to build an efficient DHC. Without the transition roadmap, the DHC become a one-shot tool that evolves badly and misses opportunities to expand or become more efficient. Even if it demands times and resources the results more than compensate for the investment.

In this guide, a methodology and numerous recommendations are provided to help develop a transition roadmap but this methodology can be adapted regarding the legal, economic and technical context as well as regarding the type of stakeholders involved.

Numerous examples of transition roadmaps or DHC masterplans can be found online and it is also a good idea before starting your own roadmap to have a look at them. On the HeatNet NWE Interreg project online platform you can find 6 roadmaps in 6 cities with different context and constraints (https://guidetodistrictheating.eu/policy-and-planning/transition-roadmaps-and-guide/).

Here are some other transition roadmap in English that illustrates what is possible to do in an energy masterplan:

- City of Sydney, decentralised Energy Masterplan – trigeneration, 2013: https://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0007/193057/Trigeneration-Master-Plan-Kinesis.pdf
- London Borough of Harrow, Energy Masterplan for Harrow & Wealdstone and Grange Farm, 2016 : https://www.london.gov.uk/sites/default/files/energy_masterplan_for_harrow_wealdstone_and_grange_farm.pdf
- Decentralised Energy Masterplan for Westminster, 2013: https://www.london.gov.uk/sites/default/files/energy_masterplan_for_london_borough_of_westminster.pdf
- 2019 New Jersey Energy Master Plan , pathway to 2050: http://d31hzlhk6di2h5.cloudfront.net/20200127/84/84/03/b2/2293766d081ff4a3cd8e60aa/NJBPU_EMP.pdf

Numerous other examples in different languages are available freely online so do not hesitate to have a look and to share your own transition roadmap in order to help others.

Resources

Schéma directeur d'un réseau de chaleur et de froid, guide de réalisation – Amorce/Ademe – 2015
http://reseaux-chaleur.cerema.fr/wp-content/uploads/Guide2015_realisation_schema_directeur_RDC_F.pdf

Guide de création d'un réseau de chaleur –éléments clés pour le maitre d'ouvrage – Amorce/Ademe – 2017
http://www.amorce.asso.fr/media/filer_public/ac/bb/acbbb3c3-8182-44d7-a432-c59f60691e8a/rct46_guide_de_creation_dun_reseau_de_chaleurv2.pdf

Developing Scotland's Energy Infrastructure – a guide to Energy Masterplanning – Scottish Enterprise and Ramboll UK Ltd Copyright – 2015
http://www.districtheatingscotland.com/sites/default/files/A%20Guide%20to%20Energy%20Masterplanning%202015.pdf

Decentralised Energy Masterplanning, a manual to local authorities – Ove Arup and Partner - 2011
https://www.theade.co.uk/assets/docs/resources/DENet_manual_lo_v10.pdf

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