D2.3 – Utilities Needs and Best Practice Examples

Renewable and Waste Heat Recovery for Competitive District Heating and Cooling Networks

REWARDHeat

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1 Summary

The present document, entitled 'Utilities Needs and Best Practice Examples' has been prepared in the framework of the elaboration of DHC networks design requirements through a participatory approach. The document is about the definition of the specific needs of potential end-users of the REWARDHeat predesign tool, and their translation into preliminary technical specifications.

REWARDHeat predesign tool will be GIS based, open-source and free to use programme which will be used for the predesign and simulation of district heating and cooling networks (DHCNs).

Within the REWARDHeat project consortium, the managers of the demonstrators' networks and the early adopter partners, have been identified as potential users of the tool and have been directly involved in the survey throughout questionnaires, round tables, bilateral meetings and workshops.

The participants to the survey have been asked about desired scenarios and outputs to be considered in the development of the REWARDHeat predesign tool, and to provide insights on the best practices related to the workflows followed for the design and operation and maintenance (O&M) phases of DHCNs. Three main areas of interest have been investigated in the survey: new construction, retrofit and O&M of DHCNs.

2 Introduction

The present document, entitled 'Utilities Needs and Best Practice Examples' has been prepared in the framework of the elaboration of DHC networks design requirements through a participatory approach.

Following a bottom-up approach, the report has been built around the information collected through a survey carried out involving the managers of the demonstrators' networks and Early Adopter partners[1], with the aim to:

- Understand the specific needs of potential end-users of the REWARDHeat predesign tool in terms of retrofit or new construction of district heating and cooling networks (DHCNs), investigating also the operation and maintenance (O&M) phase.
- Translate the information collected into technical requirements of the REWARDHeat predesign tool.

To carry out the survey, a questionnaire has been prepared and submitted to the selected partners. After the submission a round table (online group meeting) to discuss the information requested has been held, and face to face meetings have been set when further clarifications were needed. In a following phase, a workshop has been organized in order to present the tool concept more in detail and collect further feedbacks. Once collected, the filled questionnaires and the results of the survey have been then processed and translated into technical specifications.

Here in the following the structure of the document is presented: section 3 explains in brief the REWARDHeat predesign tool concept; section 4 explains in details the methodology followed to carried out the survey; section 5 presents the analysis of the outcomes of the workshop and of questionnaires and meetings; in section 6, the outcomes of section 5 are translated into preliminary technical specifications for the REWARDHeat predesign tool; finally section 7 presents the conclusions of the work reported in this document.

[1] The Early Adopters Partners have been involved to extract lessons learnt from the demonstration activities and develop preliminary projects for the upgrade of their networks integrating waste heat from different sources.

3 REWARDHeat Predesign tool concept

The REWARDHeat predesign tool will be a GIS based, open-source and free to use programme which will be used for the predesign and simulation of district heating and cooling thermal networks, and will include:

- Multiple heating and cooling sources (e.g. low-grade renewable energy sources (RES) and Waste Heat)
- Location/climate conditions
- Distribution of energy demands for Heating, Cooling and domestic hot water (DHW)
- The tool will allow estimating techno-economic feasibility of the DHCNs solutions addressed

Special focus will be put on low and ultra-low temperature thermal networks. The tool will be GIS-based which means that the input data and results will be georeferenced. REWARDHeat predesign tool will build on and extend the concept and capabilities of already existing tools, such as PLANHEAT[2], THERMOS[3] and HOTMAPS[4]. The major difference between REWARDHeat predesign tool and existing tools is the consideration of different temperature levels throughout the system: heat source, thermal network and end-user building substation. Besides providing insight on system operation, the tool will also suggest several design options for thermal network. Different key performance indicators (KPI) will be calculated for every design and the end-user will be guided in choosing the most suitable one.

[2] PLANHEAT 'Integrated tool for empowering public authorities in the development of sustainable plans for low carbon heating and cooling'; https://cordis.europa.eu/project/id/723757.
[3] THERMOS 'Thermal Energy Resource Modelling and Optimisation System'; https://cordis.europa.eu/project/id/723636; https://www.thermos-project.eu/home/.
[4] HOTMAPS ' Heating and Cooling Open Source Tool for Mapping and Planning of Energy Systems'.

4 Methodology

The scope of the activity is to follow a bottom-up approach for shaping REWARDHeat predesign tool around potential end-users needs and wishes. In order to do this, a survey has been carried out involving the managers of the demonstrators' networks and Early Adopter partners, identified as potential users of the REWARDHeat predesign tool. An overview of the methodology is provided in the following:

- Preparation of the questionnaire carried out by RINA, with the support of UNIZAG FSB and CARTIF.
- Submission of the questionnaire to the partners involved in the survey, identified as potential users:
  - Arvalla AB (Helsingborg and Mondal demonstrators, Sweden);
  - Albertslund Municipality (Albertslund demonstrator, Denmark);
  - Dalkia and EDF (La Seyne-sur-Mer demonstrator, France);
  - Lječilište Topusko (Topusko demonstrator, Croatia);
  - Mijnwater Bv (Heerlend demonstrator, The Netherland);
  - Wärme Hamburg (Hamburg demonstrator, Germany);
  - EPC, Hunosa and Sampol (Early Adopter partners).
- Organization of a round table (online meeting) to collect feedbacks and comments on the questionnaire and start retrieving the firsts inputs form the partners. When further clarifications or information were requested, face to face (online) meetings have been arranged.
- Organization of a workshop dedicated to the REWARDHeat predesign tool, held during the project General Assembly.
- Collection of the filled questionnaires.
- Analysis of the questionnaires and definition of the preliminary technical requirements for the REWARHeat predesign tool development.

In the following paragraphs, detailed insights of the questionnaire structures, of the partners involved in the survey and of the methods used to process the data is presented.

4.1 Questionnaire overview

The questionnaires have been prepared for collecting information about current practices in designing/retrofitting DHCN networks. In particular, the following aspects have been investigated:

- Scenarios: relevant scenarios for DHCN predesign/retrofit and O&M.
- Workflow: workflows currently adopted for DHCN predesign/retrofit.
- Output data: expected outputs/results of the tool.
- Experience with already existing tools/software for DHCN design.

For each aspect investigated, some examples or suggestions have been proposed to the participants to the survey (see full questionnaire template in the Annex), in order to let them modify or integrate the content.

In the 'Scenarios' section, the intention was to clarify which are the relevant scenarios for the potential users of the tool, identifying, for example, the type of interventions to be considered in DHCN retrofitting, which alternatives could be considered for new constructed DHCNs or which activities are considered in the O&M phase. Table 1 shows the scenarios proposed in the questionnaire. The partners involved have been asked to modify or integrate the list according to their experience and their needs.

Table 1 Proposed Scenarios

Renovation Scenarios

• Integration of new energy sources & technologies:
    o New sources/technologies completely replacing the old one
    o New sources/technologies used together with already existing ones
• Replacing old substations
• New thermal storages implemented
• Change of supply temperature: due to new technologies & sources exploitation; due to heat and cooling demand modification
• Distribution layout modification
• Extension: due to new building connected
• Reduction: dismission of part of the network
• Deviation from previous layout
• Pipeline retrofitting
• Improvement of thermal insulation
• Replacing of old/deteriorated pipeline

New Construction scenarios
• New DHCN in existing urban area (baseline conditions present) • New urban area (no baseline to be considered)
Operation & Maintenance scenarios

• Management:
    o New control rules
    o Fault analysis
    o Fault of the energy production facility
    o Fault of substation
    o Fault on distribution pipeline
• Maintenance:

○ Ordinary maintenance ○ Extraordinary maintenance

In the 'Workflow' section we asked the participants to the survey to indicate the workflow that they normally follow for designing new DHCNs, retrofitting DHCNs or to manage the O&M phase. The aim here is to shape the workflow of the tool according to the best practices of the potential users in their day-to-day work. In order to facilitate the fill in of the questionnaire, an example of workflow for renovation and new construction has been proposed, shown in Table 2.

Table 2 Workflow Example

Renovation/new construction workflow example
1. Baseline scenario definition
2. Baseline scenario simulation
3. Selection of planning criteria and KPIs
4. Future scenario definition
5. Future scenario simulation
6. Comparison between baseline and future scenario

In the 'Output data' section, a list of possible outputs of the REWARDHeat predesign tool have been proposed (Table 3). The participants to the survey have been asked to modify or integrate the list according to what they would need or expect from a predesign tool.

Table 3 Output examples

Output Examples
• Matching of demand and production • Baseline and future scenarios comparison • Temperature drops in the network • Pressure losses in the DHCN • Thermal storage operation simulation • Economic indicators (simple payback period (sPBK); return on investments (ROI)) • Relevant KPIs (Network operational cost; Primary energy saving; Greenhouse Gas emission saving) • Technology sizing (energy source and substation) • Size and number of H&C harvesting stations needed along the network • Size, number and types of storages used • Pipeline optimal layout • Pipe sizing

In the last section of the questionnaire we have collected the experiences of the partners with existing tools for the design or retrofit of DHCNs, focusing on strengths and weaknesses of such tools. The participants have been asked to indicate which tools they use, which are the strengths and weaknesses and if they already had experience with GIS based tools. The aim is to identify additional requirements coming from the state of the art, with the intention to integrate the strengths of existing tools in the REWARDHeat predesign tool and to overcome the weaknesses they present.

A brief description, via a dedicated presentation, of the three existing tools PLANHEAT, THERMOS and HOTMAPS has been provided to the partners in order to better explain which is the starting point from which the REWARDHeat predesign tool wants to advance. The analysis of the three tools mentioned before, and of the most relevant tools indicated by the participants to the survey is presented in section 5.5.

4.2 Participants overview

The idea behind the survey was to involve directly potential end-users in the developing process of the REWARDHEAT predesign tool. For this reason, the partners responsible for the REWARDHEAT demonstrators' networks have been involved, together with the early adopter partners. In this way, following a bottom-up approach, it is possible on one hand to take advantage of their expertise and experience in management, design or new construction of DHCNs and related services, in order to not miss relevant aspects during the whole workflow of the tool. On the other hand, it is possible to collect user wishes and suggestions about the user-friendliness of the tool and the relevant outputs to be considered.

In Table 4 the list of the partners participating to the survey is presented, providing for each one a description of the background and of the main activities carried out in the project.

Table 4 REWARDHEAT partners involved in the survey

Participants	Description
Arvalla AB	Arvalla AB is a demo case leader, responsible for the implementation of the DHC network in Raa, Helsingborg (Sweden). Arvalla AB was established in 2011 as a limited company in Sweden to further develop software for energy management functions in the real estate industry, by digitally connecting the building's energy use to real estate companies' financial systems.
Albertslund Municipality	Albertslund Municipality is the Demo case leader, responsible for the implementation of the DHC network in Albertslund (Denmark). Albertslund Forsyning (district heating supply company) is 100% owned by Albertslund Kommune (Municipality). Albertslund Forsyning supplies 90% of the total heat demand within the municipality area.
Dalkia - EDF	Dalkia is a demo case leader, responsible for the implementation of the DHC network in La Seyne sur Mer, Toulon (France). Dalkia is an energy services subsidiary of the EDF Group and is the leading district heating network operator in France, with more than 370 networks representing 2200 km of piping, of which 50% use more than 50% renewable and recovered energy sources. Only in the

	Mediterranean region, Dalkia realized 18 district heating/cooling networks, 9 of them conceived as "low temperature networks". EDF group is responsible for the demonstration of control algorithms at DALKIA DHC network. EDF group is the world's leading electricity company and a leader energy player in the production of low carbon solutions. Its business covers all electricity-based activities from generation to retail, including energy transmission and distribution, trading activities and energy services.
Lječilište Topusko	Lječilište Topusko is a demo case leader, responsible for the implementation of the DHC network in Topusko (Croatia). Lječilište Topusko is an out- and in- patient centre for physical medicine and rehabilitation owned by Sisak-Moslavina County. Top-Terme Ltd. is wholly-owned subsidiary of the Lječilište Topusko, which closely cooperates and supplements the provision of quality health and hospitality services to its users. Top Terme owns a geothermal based DH network, serving (for supplying heating and domestic hot water) both residential and tertiary (two hotels with spa and swimming pools, a hospital, a cinema) already existing buildings.
Mijnwater Bv	Mijnwater BV is a demo case leader, responsible for the update of the demonstration network in Heerlen (Netherland). It is the operating company of the Municipality of Heerlen, whose scope is to develop, exploit and innovate the low-exergy DHC-grid based on shallow geothermal energy. Mijnwater has the experience of developing a DHC grid in a green field environment and is still expanding its working area towards 1.000.000 m2 (500 dwellings, offices, sports center, supermarket, hotel, data center, etc.) and further on.
Wärme Hamburg	Wärme Hamburg GmbH was the demo responsible of Hamburg Demonstrator network in Hamburg (Germany), (Newly built low-temperature network). Wärme Hamburg GmbH is an urban district heating provider. The company works along the entire value chain: from production to transport to the customer.
EPC	EPC is an Early Adopter partner of REWARDEHAT project. It is an engineering company based in Nürnberg, Germany. It is currently considering different feasibility projects in the field of neutral-temperature DHC networks. In one of these projects EPC is involved in the development of a study on the possibility to implement a neutral-temperature DHC network for heating and 'free' cooling.
Hunosa	Hulleras del Norte, S.A. (HUNOSA) is an Early Adopter partner of REWARDEHAT. It is a state-owned coal mining company based in Asturias, in the north of Spain. It is also involved in renewable energies (meanly biomass and geothermal energy) as a part of its diversification activity. In this respect, nowadays, HUNOSA has a district heating in operation using water from a colliery that

	provides heating and cooling to the Hospital VAB of Mieres, auxiliary buildings of University of Oviedo.
Sampol	SAMPOL Ingeniería y Obras S.A. is an Early Adopter Partner of REWARHEAT. It is a private industrial company specialised on installation of electrical infrastructures and energy services. Sampol is currently involved in the analysis of the Parc Bit power plant, a trigeneration (CCHP) plant located in Mallorca, Spain. SAMPOL will be studying the power plant data and to be part of the development of a big-data tool to do preventive maintenance and KPIs study. The analysis of possible expansion of the actual network with a low-temperature SHC network will be also considered.

4.3 Round Table and Workshop

An online round table has been set up at 27th of March 2020 with all the involved partners to discuss the information requested in the questionnaire and collect the first feedbacks. The questionnaire has been shared with the participants some weeks before the meeting, in order to maximise round table's effectiveness. During the round table, first the concept of the REWARDHeat predesign tool has been presented, then each section of the questionnaire has been shown and discussed and finally the three existing tools, already mentioned, have been shortly presented.

The meeting has been useful to clarify some aspects of the questionnaire, but relevant feedbacks were not collected, since survey participants needed more time to analyse the questionnaires.

A workshop dedicated to the REWARDHeat predesign tool has been organized one month later, during the project General Assembly. Taking advantage of the progress done in the project activities related to the tool development, the REWARDHeat predesign tool has been presented more in detail and some relevant aspects were discussed with the relevant partners. The main outcomes of the workshop are described in section 5.1.

4.4 Results analysis and technical specification definition

The feedbacks and suggestions collected thanks to the questionnaire, the round table and the workshop have been processed in different steps.

First, the outcomes of the workshop have been shown and analysed. Then an analysis of the questionnaires received has been carried out in the four aspects proposed: scenarios, workflows, outputs and existing tools for DHCNs design. As shown in chapter 5, the information collected has been used to create a comprehensive lists of scenarios and outputs reflecting the needs of demonstrators managers and early adopters. The workflows proposed by the before mentioned partners, constitute an example of best practices for the design and O&M phases of DHCNs. The workflow proposed have been harmonized in a unique workflow for each area of interest (new construction, retrofit and O&M of DHCN). Then the harmonized workflow has been used for defining a reference workflow for the REWARDHeat predesign tool.

The workflows, the scenarios and the outputs defined, have been further processed to create the preliminary technical specifications presented in Chapter 6. The processing consisted in identifying, for each point of the reference workflow, the desired functionalities and the related inputs and outputs.

5 Survey on best practices

In this section the information collected from the survey is presented. Section 5.1 shows the outcomes of the online workshop. The workshop has been held during the General Assembly that took place in March, and it was an occasion to have a fruitful discussion with both the potential users and the tool developers.

In Section 5.2 an analysis of the inputs collected through the questionnaires about the relevant scenarios is carried out. Having a wide set of scenarios validated by the potential users, will allow the tool to be flexible and to respond better to the users' needs.

In section 5.3 the workflows suggested by the participants to the survey are shown and analysed, while in section 5.4 an integrated list of possible outputs of the tool is defined, taking into account the modifications and integrations made by the partners.

5.1 Workshop

The workshop took place during the General Assembly of the project with UNIZAG as moderator.

The first part of the workshop was prepared by RINA, who briefly summarized the questionnaire structure and presented the firsts inputs received from the partners. When the workshop took place, five partners had already provided their inputs. A preliminary processing of the info received was presented, showing: an integrated list of scenarios and outputs; a preliminary reference workflow, defined on the basis of the workflows described by the partners; an overview of the partners' experience with existing DHCNs design tools. The presentation was useful to show the status of the work, giving to the partners an insight on how the data would have been processed and to solicit who had not answered yet to provide their contributions.

The second part of the workshop was prepared by UNIZAG to discuss in detail the REWARDHeat predesign tool concept. The main topics and outcomes are presented in Table 5. The outcomes shown do not represent mandatory requirements for the tool, but considerations and recommendations that will be considered and further analysed during the tool development in task 2.4.

Table 5 Workshop discussion

Topic	Outcomes
Demand-driven or supply-driven design	During day-to-day work the design is often driven by both available sources and demand, and the temperature levels are considered on both sides. In fact, the source temperature should match with the required demand temperature and it depends on the source, but also on building characteristics and on the possibility to implement a certain technology (e.g. booster Heat Pump) at building level. Thus, a mixed approach needs to be investigated to be implemented in the tool.
To consider temperature levels in the tool	Usually in existing open-source DHCNs design tool the modelling is at energy level, without considering temperatures levels. A possible upgrade for the REWARDHeat predesign tool is to consider the temperature levels of energy sources, networks and buildings.

	In addition, neutral-temperature networks could have a fluctuating temperature due to the flexibility options in the grid, such as source and TES temperature level, having an impact also to the heat pump's COP. How to consider these issues could be investigated in Task 2.4.3. Considering temperature fluctuations means that it would be not possible to consider precalculated temperature values to speed up the simulation process.
Tool approach: Predefined scenario analysis	The tool doesn't need to be too much detailed, since it is used at predesign stage. For the detailed design are available more detailed (commercial) tools. A scenario analysis is probably more important and could be used with predefined design options, to speed up the modelling and simulation processes. Pre-calculated hourly parameters and predefined controls might be used to speed-up calculations, when possible (see previous topic). Possibility to compare different scenarios is important (e.g. compare LTDH with ULTDH[5] in a specific case and recommend which solution is better based on defined KPIs.) The designed tool should be as flexible as possible (able to consider and compare a wide range of scenarios) and engineering oriented meaning that it should help engineers in predesign process.
Supply technology	Multiple supply technologies and thermal storages should be considered. Among others: Heat Pumps; Existing DH networks, TES (buffer and seasonal). The technology characteristics could be temperature dependent.
Business models and future scenarios.	Operational cost optimization is a typical output of existing open-source DHCNs design tools. The tool should include financial parameters. It is important to consider long-term scenarios (investments are done for 30 years, it would be important to reduce uncertainty and hence risk). For example, rate of refurbishment can be included (demand as a function of time).
Sub-networks	The possibility to consider different subnetworks with different operating conditions is considered very useful (for example consider one zone with high temperature DH and one with ultra-low temperature DH). Also at building level (demand side), the tool should have the possibility to consider different required temperatures for different buildings. When more detailed information is not available, a possibility to simplify the simulations is to consider the buildings in the same neighbourhood having similar characteristics.

[5] LTDH: low-temperature DH. ULTDH: Ultra-low-temperature DH. During the workshop a slightly different usage of this nomenclature was seen among the participants. For DH with decentralized HPs used also for space heating, the term neutral-temperature DH will be favoured in the project.

5.2 Scenarios

The aim of this section is to provide the analysis of the scenarios as outcome of the questionnaires in order to facilitate the translation of some of them into functionalities of the REWARDHeat predesign tool.

For each of the three main areas of interest investigated (Retrofit, New construction and O&M of DHCNs) the input received from the questionnaires have been analysed as shown in Table 7, Table 10 and Table 12. The first column 'contributor' identifies the partners who provided the inputs analysed. The second column 'Input' reports the contributes provided by the partners. The inputs have been divided into direct and indirect inputs: the 'direct input' are items directly added to the list, or modified in the list, while the 'indirect input' are the information and feedbacks included in the comments, or shared by email, that can be used as technical suggestion for the tool. The third column 'input integration' shows how the inputs have been included in the final comprehensive list. Here, different cell colours have been used: yellow cells identify the new inputs added, meaning that they were not present in the suggested list; the blue cells identify the items that were suggested in the questionnaire and that have been confirmed by partners' inputs.

Table 6 Scenarios' Input integration legend

Input type	Colour
Scenario confirmed (already present in the questionnaire list)	
New Scenario suggested	

The results of the analysis are an integrated list of scenarios for each area of interest to be considered in the development of the REWARDHEAT predesign tool, which takes into account the needs expressed by the partners identified as potential users.

5.2.1 Retrofit of existing DHCNs

Table 7 shows the analysis of the input received related to the retrofitting scenarios. The analysis wants to identify new scenarios proposed and also the modification occurred to the proposed list, highlighting if certain scenarios are more interesting for the participant to the survey. In general, the list proposed has not been modified, with the participant confirming all the scenarios except for few cases. In addition, some new scenarios have been extrapolated from the input received.

Table 7 Retrofitting scenarios: survey analysis

Input	Input Integration	Considerations
ARVALLA AB		
No input*	\	*ARVALLA did not provide inputs on Scenarios, Outputs and workflows for their lack of expertise in design DHCN. They provided information on existing tools/software due to

		their work in software development for energy management functions in the real estate industry.
HUNOSA		
No Direct input		No modification or further addition to the scenarios has been proposed by HUNOSA.
Indirect input They stated that, having a unique generating place for district heating and cooling and very short networks, so far they didn't need an integrated software.	• Have multiple generation points in different locations	The need of an integrated software is bigger when bigger is the complexity of the DHCN, e.g. in case of multigeneration and multiple source location.
WÄRME HAMBURG		
Direct input Subnetworks with different technical requirements e.g. temperature, pressure …	• Create subnetworks with different technical requirement (temperature; pressure).	All the other scenarios in the questionnaire have not been modified.
Direct input Integration of additional measurement equipment for an improved (predictive) maintenance.	• Integration of additional measurement equipment for an improved (predictive) maintenance.	The possibility to consider the presence of equipment for predictive maintenance for calculating the O&M cost of a DHCNs could be investigated.
EDF-DALKIA		
No Direct input	\	No modification or further addition to the scenarios has been proposed by EDF-DALKIA.
Indirect input They consider renewable sources analysis as an important step of the workflow for the pre-design of a network.	• Mapping of RES and NON-RES sources. • Prioritize energy sources (e.g. Renewables).	\
EPC		
No input	\	No modification or further addition to the scenarios has been proposed by EPC.

TOPUSKO		
Direct input New sources/technologies used with other → Sorption cooling implemented.	• Integration of new sources used together with other (Multigeneration). • Integration of new technologies used together with other (Multigeneration).	TOPUSKO provided an example confirming the scenario proposed.
Direct input Network Extension due to new building → Hotel Petrova gora connected to the new substation (cooling demand).	• Extend the existing network due to new building connected (additional energy demand).	TOPUSKO provided an example confirming the scenario proposed.
Direct input Demand Reduction due to dismission of part of the network → By managing geothermal water consumption to heat the swimming pool.	• Integration of new technologies replacing the old one.	TOPUSKO provided an example under the scenario 'dismission of part of the network. Actually, the example provided could be considered a confirmation of the scenario 'Integration of new technologies replacing the old one'. In fact, the swimming pool part of TOPUSKO demo case, will be renovated in both equipment and control system, reducing the use of geothermal water.
SAMPOL		
No Direct input	\	SAMPOL provided its contribution answering only to the second part of the questionnaire, declaring that due to their lack of experience in use of GIS based predesign tool their contribution in defining scenarios and output would not have been accurate. In any case, analysing the workflow description they proposed, it has been

		possible to define some indirect inputs.
Indirect input In the predesign phase, they analyse the possibility to install 2 tube or 4 tube pipelines.	• Replace old pipelines with new ones in terms of typology (2 tube; 4 tube) or physical characteristics (thermal insulation).	In the questionnaire a scenario 'Replacing of old/deteriorated pipeline' was proposed. It has been updated according to the inputs received.
Indirect input During the design phase, they sometimes take into account future expansion of the network, when is needed, considering for example an oversizing of the pipeline for possible future expansion.	• Consider an oversizing of the pipes for future addition when retrofitting the pipeline.	\
Indirect input Consider the installation of hot and cold-water reservoirs to fill them up during electricity valley costs.	• New Thermal storages implemented in the existing DHCN.	This input confirms the scenario related to the thermal storage. The control rule mentioned is interesting for the operation of a DHCN, but it is more related to the development of a control management system rather than an option to be included in the REWARDHeat predesign tool.
ALBERSTLUND		
Direct input* Housing areas (for rent) being deeply refurbished.	• Refurbishment of the buildings connected to the grid.	*This scenario was originally proposed among New construction scenarios. It seems more pertinent to include it in Renovation.
Indirect input New sources /technologies → ALBERTLUND buy heat from DH transmission company (mainly). They don't consider potential new sources in their scenarios, but they consider new technologies.	• Integration of new technologies used together with other. • Integration of new technologies replacing the old one.	It is a specificity of ALBERTSLUND business to not consider new sources. The option has been confirmed in other questionnaire, so it has not been removed from the list of scenarios.

Indirect input They offer replacement of old substations to end users, however traditionally the end users they work with own their own substations.	• Replacing old Substations.	\
Indirect input They want to start working with short terms storages. So far thermal storages are assessed/designed by the DH producer or transmission company they work with.	• New Thermal storages implemented in the existing DHCN.	\
Indirect input Pipeline retrofitting: today they substitute old pipes, they don't retrofit pipes anymore.	• Replace old pipelines with new ones considering typology (e.g. 2 tube/4 tube) and physical characteristics (thermal insulation).	Even if it is more common to substitute the old pipeline rather than insulate, the option has been confirmed in other questionnaires, so it has not been removed from the list of scenarios.
Indirect input They used to place pipes underneath buildings – so the buildings could make use of the heat loss from purely insulated pipe. Now they want to move the pipes out, so they are easier to maintain.	• Consider different pipeline location (outside; underground) leading to different thermal losses and different O&M cost.	\
MJINWATER		
No specific input No questionnaire provided.	\	A dedicated conf call has been held and material on 5th generation DHCN has been provided, so it has been possible to define some indirect inputs.
Indirect input 5th generating DHCN will be demand-driven network and bidirectional at the points of delivery. It means simultaneously deliver heating and cooling services at	• Simultaneously deliver heating and cooling services at different temperatures.	\

different temperatures to different customers, exactly as demanded, when demanded, and never more than needed.		
Indirect input 5th generating DHCN will have the ability to exchange demands for heat and cold among customers. For instance, heat pumps create both heat and cold, one is delivered locally, the other one is returned to the grid.	• Exchange energy (heat and cold) among customers.	\
Indirect Input Possibility to operate efficiently at both small and large scale, merge when beneficial: the ability for small or large grids to be designed, built and operated to provide value to clusters of buildings at any scale. These can grow organically or merge into larger networks, when beneficial.		This need can't be translated into a scenario to be considered for a simulation, but into the possibility to enable different projects (with different areas of interest) and allow the user to visualize performance indicators for all of them so he/she can decide what's best according to a set of criteria/constraints previously selected.

In Table 9 the integrated list for renovation scenarios is presented, dividing the scenarios in five categories: Energy Sources, Supply Technologies, Thermal Storages, Energy Distribution and Energy Demand, and Network Retrofitting.

A further analysis has been done assigning a score to each scenario depending on the feedbacks received, in order to provide a prioritization of the scenarios. Actually, two types of prioritization have been carried out: one for the scenarios proposed in the questionnaire (blue bullet) and one for the new scenarios identified in Table 7 (yellow bullet). The scenarios with a blue bullet have been assessed by all the partners involved, while the scenarios with a yellow bullet came from the analysis of the single contribution of each partner and are not assessed by all the other partners. For this reason, the scores of the scenarios proposed are higher than the scores of new scenarios identified, and the two ranking are not directly comparable.

Table 8 shows how the score have been assigned. In particular, two different marks and values have been used for the scenario proposed in the questionnaire, assigning 1 if the scenario was confirmed and not modified in the list (green mark), and 1.25 if the scenario was mentioned through direct or indirect inputs (blue mark).

The prioritization is helpful to define which could be more interesting for the potential end-user. However, all the scenarios will be further analysed in Task 2.4, including the ones obtaining a low score.

Table 8 Score assigned depending on type of scenario and input

Scenario	Feedback	Mark	Value
● Scenario proposed in the questionnaire	Scenario confirmed in the list proposed	✓	1
	Scenario mentioned through direct or indirect inputs	✓	1.25
● New Scenarios	Scenario suggested though direct or indirect inputs	✓	1

Table 9 Integrated list of Renovation scenarios

Scenario	Score	
Energy Sources		
● Integration of new sources used together with other (Multigeneration)	✓✓✓✓✓	5.25
● Integration of new sources replacing the old one	✓✓✓✓✓	5
● Mapping of RES and non-RES sources	✓	1
● Prioritize energy sources (e.g. renewables)	✓	1
Supply Technologies		
● Integration of new technologies replacing the old one	✓✓✓✓✓✓	6.5
● Integration of new technologies used together with other	✓✓✓✓✓✓	6.5
● Replacing old Substations	✓✓✓✓✓✓	6.25
● Change of supply Temperature (due to new technologies & sources exploitation; due to heat and cooling demand modification)	✓✓✓✓✓✓	6
● Have multiple generation points in different location	✓	1
● Simultaneously deliver heating and cooling services at different temperatures	✓	1
Thermal Storages		
● New Thermal storages implemented in the existing DHCN	✓✓✓✓✓✓✓	7.5
Energy Distribution and Energy Demand		
● Design a new layout modifying the existing one (deviation from existing layout)	✓✓✓✓✓✓	6
● Refurbishment of the building connected to the grid	✓	1
Network Retrofitting		
● Improve the thermal insulation of existing pipeline	✓✓✓✓✓	5
● Extend the existing network due to new building connected (additional energy demand)	✓✓✓✓✓✓	6

Dismiss part of the network (energy demand reduction)	✓✓✓✓✓✓	6
Replace old pipelines with new ones in terms of typology (2 tube; 4 tube) or physical characteristic (thermal insulation)	✓✓	2
Consider different pipeline location (outside; underground) leading to different thermal losses and different O&M cost	✓	1
Create subnetwork with different technical requirements (temperature; pressure)	✓	1
Consider an oversizing of the pipes for future addition when retrofitting the pipeline	✓	1
Integration of additional measurement equipment for an improved (predictive) maintenance	✓	1
Exchange energy (heat and cold) among customers	✓	1

According to the score assigned, among the scenario proposed in the questionnaire, the best raking is 7.5 obtained by 'New Thermal storages implemented in the existing DHCN', followed by 'Integration of new technologies replacing the old one' and 'Integration of new technologies used together with other with 6.5'. This underlines how the substitution of existing supply technologies is important in the DHCN retrofitting, as well as the as the implementation of thermal storages to improve the performance of the network.

The lower results are obtained by the "Integration of new sources replacing the old one" and by the "Improve the thermal insulation of existing pipeline". In the first case, the low results can be partially explained considering that some partners participating to the survey have no interest in the possibility to change or integrate new sources, working more on the technology side. When it comes to the pipe retrofitting, the low result is due to the fact that often a complete replacement of an old pipeline is preferred compared to its insulation.

To confirm this, two points have been obtained by the new scenario 'Replace old pipelines with new ones in terms of typology (2 tube; 4 tube) or physical characteristics (thermal insulation)' obtaining the highest ranking among the newly proposed scenarios. Looking to the different categories, two different scenarios (both related to RES) have been proposed for 'energy sources', two for 'supply technology', one for 'energy distribution' and 6 new scenarios for the 'network retrofitting'.

5.2.2 New Construction of DHCNs

Table 10 shows the analysis of the input received related to the new construction scenarios. In the questionnaire, two scenarios were prosed as example: 'New urban area' (implement DHCN in new urban area) and 'Implement new DHCN in existing urban area'. In addition to the confirmation of the two proposed scenarios, some new scenarios have been defined from the analysis, corresponding in some case to the ones defined for the renovation of DHCNs.

Table 10 New construction scenarios: survey analysis

Input	Input Integration	Consideration
ARVALLA AB		
No input*	\	ARVALLA did not provide inputs on Scenarios, Output and workflow for their lack of expertise in design DHCN. They provided information on existing tool/software due to their mainly work in software development for energy management functions in the real estate industry.
HUNOSA		
No Direct input	\	No modification or further addition to the scenarios has been proposed by HUNOSA.
Indirect input They stated that, having a unique generating place for district heating and cooling and very short networks, so far they didn't need an integrated software.	• Have multiple generation points in different location.	The need of an integrated software is bigger when bigger is the complexity of the DHCN, e.g. in case of multigeneration and multiple source location.
WÄRME HAMBURG		
Direct input Subnetworks with different technical requirements e.g. temperature, pressure …	• Create subnetwork with different technical requirement (temperature; pressure).	All the other scenarios in the questionnaire have not been modified.
Direct input New urban area with a possible connection to an existing area.	• New urban area. • Connect a new urban area to an existing area.	Possibility to include information about new constructed buildings considering both the cases where they are part of an entirely new urban area, and an expansion of an existing area.
Direct input New DHCN connected with the big district heating system or island network.	• Consider an existing (high temperature) Network as source for the new DHCN.	In this case, the assessment is carried out only on the performance of the new DHCN, not considering the existing one.

EDF-DALKIA		
No direct input	\	No modification of further addition to the scenarios has been proposed by EDF-DALKIA.
Indirect Input They consider renewable sources analysis as an important step of the workflow for pre-designing of network.	• Mapping of RES and NON-RES sources. • Choose criteria to prioritize the sources (e.g. Renewables).	\
EPC		
No input	\	No modification or further addition to the scenarios has been proposed by EPC.
TOPUSKO		
No input	\	No modification or further addition to the scenarios has been proposed by TOPUSKO
SAMPOL		
No direct input		SAMPOL provided its contribution answering only to the second part of the questionnaire, declaring that due to their lack of experience in use of GIS based predesign tool their contribution in defining scenarios and output would not have been accurate. In any case, analysing the workflow description they proposed, it has been possible to define some indirect inputs.
Indirect Input In the predesign phase, they analyse the possibility to install 2 tube or 4 tube pipelines.	• Possibility to install different pipelines in terms of typology (2 tube; 4 tube) or physical characteristics (thermal insulation).	\

Indirect Input During the design phase, they sometimes take into account future expansions of the network, when it is needed, considering for example an oversizing of the pipelines for possible future expansion.	• Consider an oversizing of the pipes for future addition.	\
Indirect Input Consider the installation of hot and cold-water reservoirs to fill them up during electricity valley costs.	• Implement thermal storages in the DHCN.	\
ALBERSTLUND		
Indirect input To implement DHCNs in new urban areas is a very active sector, with multiple project currently on development. It is since 1990 that ALBERSTLUND haven't worked in implementing DHCN in existing areas.	• New urban areas.	DHCNs built in new urban area scenario is confirmed by ALBERSTLUND while in their case implement DHCNs in existing area is now less common.
Indirect Input They want to start working with short term storages. So far thermal storages are assessed/designed by the DH producer or transmission company they work with.	• Implement thermal storages in the DHCN.	\
Indirect Input They used to place pipes underneath buildings – so the buildings could make use of the heat loss from purely insulated pipe. Now they want to move the pipes out, so they are easier to maintain.	• Consider different pipeline location (outside; underground) leading to different thermal losses and different O&M cost.	\
MJINWATER		
No input No questionnaire provided.	\	A dedicated conf call has been held and material on 5th

		generation DHCN has been provided.
Indirect Input 5th generating DHCN will be demand-driven network and bidirectional at the points of delivery. It means simultaneously deliver heating and cooling services at different temperatures to different customers, exactly as demanded, when demanded, and never more than needed.	• Simultaneously deliver heating and cooling services at different temperatures.	\
Indirect Input 5th generating DHCN will have the ability to exchange demands for heat and cold among customers. For instance, heat pumps create both heat and cold, one is delivered locally, the other one is returned to the grid.	• Exchange energy (heat and cold) among customers.	\

In Table 11 the integrated list for the new construction scenarios is presented, dividing the scenarios in five categories: Energy Sources, Supply Technologies, Thermal Storages, Energy Distribution and Energy Demand, and Network Retrofitting.

As done for the renovation scenarios, a score has been assigned to each scenario depending on the feedbacks received, in order to provide a prioritization of the new scenarios suggested and of confirmed scenarios. The same method of evaluation has been used as per the renovation scenarios, showed in Table 8. As already explained, the score is helpful to identify the scenario more interesting for end-user, but all the scenarios listed will be further analysed in task 2.4.

Table 11 Integrated list of New Construction scenarios

Scenario	Score	
Energy Sources		
● Consider an Existing (high temperature) Network as source for the new DHCN	✓	1
● Mapping of RES and non-RES sources	✓	1
● Prioritize energy sources (e.g. renewables)	✓	1
Supply Technologies		

Have multiple generation points in different location	✓	1
Simultaneously deliver heating and cooling services at different temperatures	✓	1
Thermal Storages		
Implement thermal storages in the DHCN	✓✓	2
Energy Distribution and Energy Demand		
New urban area	✓✓✓✓✓✓	6.25
New DHCN in existing area	✓✓✓✓✓	5
Connect a new urban area to an existing area	✓	1
Network Retrofitting		
Possibility to install different pipelines in terms of typology (2 tube; 4 tube) or physical characteristic (thermal insulation)	✓	1
Consider different pipelines location (outside; underground) leading to different thermal losses and different O&M cost	✓	1
Create subnetwork with different technical requirements (temperature; pressure)	✓	1
Consider an oversizing of the pipes for future additions when retrofitting the pipeline	✓	1
Exchange energy (heat and cold) among customers	✓	1

When it comes to the two scenarios proposed in the questionnaire, the inputs provided by ALBERSTLUND makes the 'New urban area' scenario the scenario with a high ranking. This is because in their current business, the implementation of DHCN in new urban area is more likely to happen compared to the implementation in an existing area.

Among the new scenarios suggested, the possibility to implement the thermal storages obtained 2 points while all the other scenarios have been mentioned once.

5.2.3 O&M

Table 12 shows the analysis of the inputs received related to the O&M scenarios. The aim of the analysis is to identify the scenarios more interesting for partners identified as potential users of the tool, in order to investigate later on (section 6) which one could be translated into desired functionalities to be integrated in a predesign tool.

In Table 13 the integrated list of scenarios and their scores coming out from the analysis is shown. The methods used for the evaluation is the same used in sections 5.2.1and 5.2.2.

Table 12 O&M scenarios: survey analysis

Contributor	Input Integration	Consideration

ARVALLA AB		
No input	\	ARVALLA did not provide inputs on Scenarios, Outputs and workflows for their lack of expertise in design DHCN. They provided information on existing tool/software due to their mainly work in software development for energy management functions in the real estate industry.
HUNOSA		
No input	\	No modification or further addition to the scenarios has been proposed by HUNOSA.
WÄRME HAMBURG		
Direct Input Extensive data mining and data evaluation.	• Data monitoring and data evaluation.	A development of data-mining approach and software will be addressed in the WP5 of REWARDHEAT project. Regarding the predesign tool, it could be evaluated the possibility to take into account the type and quality of monitoring system.
Direct Input Detailed simulation tool of the district heating network.	\	This input cannot be considered a scenario for the pre-design tool. The REWARDHeat predesign tool will be itself a tool providing information about DHCNs performance, through hourly based simulations. Nonetheless the tool is not thought as a tool for the management of a DHCN. In the WP5 of REWARDHeat project a model predictive control will be developed to optimize the management of the DHCNs.
Direct Input Predictive Maintenance.	• Predictive Maintenance.	Algorithms for fault detection and pro-active maintenance will be developed in WP5, and

		will not be integrated in the predesign tool. The possibility to take into account the type of maintenance strategies for calculating O&M cost in the predesign tool could be investigated.
EDF - DALKIA		
No direct input	\	No modification or further addition to the scenarios has been proposed by EDF-DALKIA.
Indirect Input They use diagnostics tools for predictive maintenance (with DALKIA tools).	• Predictive Maintenance.	Same comments as for WÄRME HAMBURG input.
Indirect Input They monitor the energetic performance of DHCNs during operation phase.	• Data monitoring and data evaluation.	Same comments as for WÄRME HAMBURG input.
EPC		
No input	\	No modification or further addition to the scenarios has been proposed by EPC.
TOPUSKO		
Direct Input Operation analysis (e.g. analysing current duty point of DHC network).	• Operation analysis (e.g. analysing current duty point of DHC network).	\
CANCELLED: Extraordinary maintenance.		This scenario has been cancelled by TOPUSKO, but confirmed by other partners. Both ordinary and extraordinary maintenance could be considered in the calculation of O&M cost.
SAMPOL		
No input		SAMPOL provided its contribution answering only to the second part of the

		questionnaire, declaring that due to their lack of experience in use of GIS based predesign tool their contribution in defining scenarios and output would not have been accurate. In any case, analysing the workflow description they proposed, it has been possible to define some inputs.
ALBERSTLUND		
No direct input		No modification of further addition to the scenarios has been proposed by ALBERTSLUND.
Indirect Input They are working to collect more data from end users and distribution systems. They want more data from the DH network.	• Data monitoring and data evaluation.	\
MJINWATER		
No input No questionnaire provided	\	A dedicated conf call has been held and material on 5th generation DHCN has been provided. No specific input for O&M scenarios has been found.

Table 13 Integrated list of O&M scenarios

Scenario	Score	
Management/operation		
● Fault analysis (Fault of the energy production facility; Fault of substations; Fault on distribution pipeline)	✓✓✓✓✓✓	6
● New control rules	✓✓✓✓✓✓	6
● Data monitoring and data evaluation	✓✓✓	3
● Operation analysis (e.g. analysing current duty point of DHC network)	✓	1

Maintenance		
Ordinary maintenance	✓✓✓✓✓✓	6
Extraordinary maintenance	✓✓✓✓✓	5
Predictive maintenance	✓✓	2

No particular modifications or comments have been done about the scenarios proposed in the questionnaire, except for the 'Extraordinary maintenance' scenario, which have been cancelled from the list from one partner, since they don't consider it applicable for their case. However, the scenario has been confirmed by the other partners.

Three new scenarios came out from the analysis. Data monitoring and evaluation obtained a score of 3, highlighting the importance of a monitoring system for DHCNs management. Two points have been obtained from the scenario 'Predictive maintenance', and one point from 'Operation analysis (e.g. analysing current duty point of DHC network)'.

In general, the WP5 of REWARDHEAT project is the one dedicated to the development of dedicated algorithms and tool for datamining, fault detection, pro-active maintenance and model predictive control. Instead, the aim of the REWARDHeat predesign tool is to predesign DHCNs, estimating the feasibility of the DHC network solutions according to the selected planning criteria. The scenarios listed in Table 13 are used in section 6 for defining technical requirements which can take into account aspects of operation and maintenance phase in the predesign of a DHCNs.

5.3 Workflows

The aim of the section 'Workflow' in the questionnaire was to collect information on the best practices followed by the partners for assessing the feasibility of a new construction or renovation scenario and to manage the O&M phase.

The workflows proposed by the partners have been analysed and used to create a harmonized workflow for each area of interest, resuming contribution received. The harmonized workflows represent a possible reference for the REWARDHEAT predesign tool.

Table 14, Table 16 and Table 18 show the analysis of workflows respectively for new construction of DHCNs, retrofit of DHCNs and O&M of DHCNs. In particular, the first column of the tables shows the workflows provided by the partners, the second column shows how the contributions have been translated into the steps of the harmonized workflow, while the third column shows considerations about the contribution analysed, when needed. An additional characterization of the steps is presented between brackets, reporting possible useful specifications indicated by the partners.

The harmonized workflows are presented for each area of interest in Table 15, Table 17 and Table 19. Anticipating the results of the analysis, the workflows presented for new construction and for retrofitting are similar, leading to two harmonized workflows with very few differences. This is because in the two cases, the same steps can be identified even if the activities are declined in different ways. For example, in both cases the baseline definition is important: in case of new construction of DHCNs, demand mapping, technology definition and simulation could correspond to the quantification of the energy demand and the energy consumption considering the current status (e.g. boilers or heat pump used in each building, not connected to a DHCN). In case of retrofitting, the baseline characterization identifies the characteristics and performance of the existing network, to be compared with the renovated one. For this reason, in section 6 a unique reference workflow for the tool is presented.

When it comes to the O&M workflow, section 5.3.3 presents how the different partners participating to the survey approach the O&M phase and Table 19 shows the related harmonized workflow. Even if the predesign tool is not meant for real time monitoring, fault detection or predictive maintenance, the REWARDHeat predesign tool will provide an estimation of the operating costs and performance. Therefore, the O&M workflows analysed could be used not only to present the common practices used for managing the O&M phase, but also to integrate the desired functionalities of the tool.

5.3.1 Workflows for new construction of DHCNs

The workflow proposed for new construction of DHCNs by the partner participating to the survey are shown in the first column of Table 14. Six partners out of nine have provided their contribution. The contributions received have been analysed and translated into a harmonized workflow composed by ten steps presented in Table 15. As anticipated in the previous section, the steps are characterized with an additional description referring to particular indication provided by the partners. The harmonized workflow contains the step 'detailed design', suggested by some partner as last step of the design process, but it is important to remember that the REWARDHeat predesign tool concept is not meant for the detailed design of DHCNs.

Table 14 Workflows for new construction of DHCNs

Contributions	Integration in the harmonized workflow	Considerations
ARVALLA AB		
No input	\	No inputs about workflows have been provided by ARVALLA AB.
HUNOSA		
No input	\	No inputs about workflows have been provided by HUNOSA.
WÄRME HAMBURG		
1. Demand estimation – heating, cooling, electricity	• Baseline definition – Demand Mapping (heating; cooling and electricity demand) • Future scenario definition – Demand mapping	The first point has been included in the 'demand mapping' both for baseline scenario and future scenarios. What is missing in the proposed workflow is the

	(heating; cooling and electricity demand)	source mapping to define the energy source available.
2. Requirements and basic conditions for the energy concepts – key factors – utilisation structure (living, business etc.), technology options, economic framework, resource options, political and social requirements etc.	• User needs, planning criteria, KPIs (Key factors definition; economic framework; resource options, political and social requirements; etc.)	This step represents the analysis of requirements and basic conditions needed for defining all the boundary conditions for design of a DHCN. In the predesign tool, both external (e.g. social or political requirements) or internal (user needs) constraints could be considered when setting the planning criteria and KPIs.
3. Selection of planning criteria and KPIs	• User needs, planning criteria, KPIs	Planning criteria could comprehend, for example, some constraints for the root definition or needs to prioritize some KPIs (e.g. operative cost; CO2 emission; rate of renewable).
4. Definition of rough scenario options within requirements and basic conditions	• Future scenario(s) - Technologies and network definition	The scenario options could be created according to the planning criteria providing indications for technologies and network definition.
5. Simulation of scenario options – detailed simulation of some most realistic options	• Future scenario simulation	\
6. Economic evaluation of some most realistic options and evaluations according to planning criteria and KPIs	• KPI calculation and Results report (economic assessment)	The defined KPIs are calculated according to the planning criteria. If more than one scenario is possible, a comparison of the scenarios could be provided.
7. Future scenario selection	• Future scenario selection	According to the results obtained a final scenario could be selected.

8. Detailed design	• Detailed design*	*REWARDHeat predesign tool is not meant for detailed design, but it stops just one step before with the selection of the best scenario.
EDF-DALKIA		
1. Mapping of demand: precisely, for each building per day or per hour (hourly resolution is very important for networks delivering simultaneously heat and cold): quantity and temperature levels (forward and return)	• Baseline definition – demand mapping (hourly resolution; temperature level definition) • Future scenarios definition – Demand mapping (hourly resolution; temperature level definition)	It highlights the importance of hourly resolution for the analysis, in particular, in networks delivering both heating and cooling.
2. Mapping the renewable sources (quantity and temperature levels)	• Supply mapping (Energy quantity and temperature level- RES and non-RES)	A great importance is given to the renewable energy. Renewables are mapped and analysed in order to maximize their use.
3. Analysis of the part of the need renewable sources can provide and their costs (internal DALKIA tool used for this purpose)	• Future scenarios simulation	
4. Technology definition for the production: renewable and conventional	• Future scenarios - technologies and network definition (RES and non RES technology)	\
5. Modelling of the route with commercial software TERMIS: calculation of tube diameters, pump dimension, electricity consumption	• Future scenarios - technologies and network definition, (tube dimensions, pumps dimension) • Future scenarios simulation (DHCN simulation)	According to the REWARDHeat predesign concept, there should be the possibility to automatically define an optimized pipeline. If needed, the possibility to pre-set some values for the pipeline design should be available.

6. Route optimization to connect most of the buildings and to identify where there is enough place in the basement	• Future scenarios – simulations (Route optimization)	Route optimization is part of the REWARDHeat predesign tool concept.
7. Calculation of state aids for the network	• User needs, planning criteria, KPIs (state aids) • KPI calculation and Results report (economic assessment)	The possibility to consider state aid should be available when defining the future scenarios settings (planning criteria and KPIs).
8. Heat and Cold Costs calculation to respect a minimum profitability	• User needs, planning criteria, KPIs (economic requirements - minimum profitability) • KPIs calculation and Results report (Energy performance and economic assessment)	Minimum profitability criteria should be defined when defining future scenarios planning criteria.
EPC		
1. Scenario definition (heating & cooling demand, approximate pipeline routing, available area for geothermal heat collectors)	• Future scenarios - technologies and network definition • Future scenario(s) - Demand Mapping	In this workflow proposed, an approximate pipeline routing is carried out in the scenario definition. In the REWARDHEAT predesign tool concept, as done in other existing open source tools, the pipeline route is defined thanks to a route optimizer.
2. Scenario simulation	• Future scenario simulation	\
3. Design of the geothermal heat collector and DHN	• Detailed design*	*REWARDHeat predesign tool is not meant for detailed design, but it stops just one step before with the selection of the best scenario.

TOPUSKO		
1. Analysing the existing network/current state – heating and/or cooling demands; dimensional characteristics; heating/cooling sources; condition of existing pipelines and equipment; operation habits/problems; customer experience and demand; client future aspirations etc.	• Source mapping • Baseline scenario – demand mapping (heating and cooling demand) • Baseline scenario Technologies and network definition & simulation • User needs, planning criteria, KPIs • Future scenarios - technologies and network definition	The first step proposed is related to both baseline condition assessment and future scenario definition.
2. Suggesting a solution – suggesting new equipment/pipelines, calculating and verifying the feasibility of suggestion, budgeting	• Future scenarios - technologies and network definition • Future scenario simulation • KPIs calculation and Results report • Future scenario selection	The second step comprehends the definition of the future scenario and its assessment.
3. Designing a solution – providing the documentation of a project (description of the new equipment/pipelines, designing the grid, drawings, final calculations)	• Detailed design*	*REWARDHeat predesign tool is not meant for that purpose, but it stops just one step before with the selection of the best scenario.
4. Commissioning – analysing the occurred problems, calculations, troubleshooting	\	Commissioning is out of the scope since it comes after the design process.
5. Monitoring – lessons learned	\	The REWARDHeat predesign tool is not meant for retrieving monitored data.

SAMPOL		
First step is to study the energy demand of each consumer, both cold and heat thermal demand. Then the definition of the maximum demand of heat and cold water of the overall system	• Future scenarios – demand mapping	\
Depending on the DHC location, the possibility to install a 2 tubes or 4 tubes DHC should be considered (2 tubes installation means that in summer it is a District Cooling and in winter District Heating).	• Future scenarios - technologies and network definition (pipeline typology)	The contribution provided suggests the need of flexibility in the tool for the choose of pipelines typology. (2 or 4 tube typology).
Design the distribution system considering a thermal gap between the forwarding water and the return water of 20ºC, in case of hot water, and 6ºC, in case of cold water (80/60ºC and 6/12ºC for example), in order to know the maximum flowrate for hot water and cold water. The pressure drop in the piping system is needed in order to design the pumping system considering flow and pressure head (for both heat and cold pumps). The regulation of the pumps can be designed in two configurations: - Controlling the pumping by keeping the return temperature constant (60ºC and 12ºC for heat and cold for example) always maintaining the 20ºC and 6ºC gap - Controlling the pumping by keeping a determined	• Detailed designs*	This part of the workflow is entirely focused on the detailed design. *REWARDHeat predesign tool is not meant for detailed design, but it stops just one step before with the selection of the best scenario.

pressure drop between forward and return.		
In case it is needed, pipes design has to consider future additions (oversizing them taking into account potential new consumers) and the power plant shall have enough space to install new heating and cooling machines.	• Future scenarios - technologies and network definition (pipeline oversizing; supply technologies location)	Constraint related to pipe design and power plant position could be included in the future scenario definition.
It is also common in DHC installations to install tanks as a buffer of hot and cold water ready to cover the demand for some hours. This is of special interest if the electricity consumption is cheaper by night, so we can produce hot and cold water in cheap hours and distribute this hot and cold water produced during the day	• Future scenarios - technologies and network definition (operation schedule; storage implementation) • Future scenario simulation	\
ALBERTSLUND		
The design is carried out thanks to years of experience in this field and according to the potential number of dwellings, the square meters, the energy demand and the building regulations. Further development (more buildings) are taken into account if possible, typically using shunts to be able to deliver LTDH to new buildings.	• Future scenario(s) - Demand Mapping (Number of building/dwelling; heated/cooled area connected to the grid)	
MJINWATER		
No input	\	No inputs about workflows have been provided by MJINWATER

Table 15 Harmonized workflow for new construction of DHCNs

New Construction Harmonized workflow
1. Source mapping Energy quantity and temperature level- RES and non-RES
2. Baseline scenario – demand mapping Heating, cooling and electricity demand; Hourly resolution; Temperature level definition.
3. Baseline scenario Technologies and network definition & simulation
4. User needs, planning criteria, KPIs selection Key factors definition; Economic framework; resource options; political and social requirements; state aids and economic requirements (e.g. minimum profitability)
5. Future scenarios - technologies and network definition, RES and non-RES technology; Tube dimensions, pumps definition; Pipeline typology; Pipeline oversizing for future integrations; Supply technologies location; operation schedule.
6. Future scenario(s) - Demand Mapping Heating, cooling and electricity demand; Hourly resolution; Temperature level definition; Storage implementation; Number of building/dwelling definition; heated/cooled area connected to the grid.
7. Future scenario simulation DHCN simulation; Route optimization.
8. KPIs calculation and Results report Energy performance and economic assessment
9. Future scenario selection
10. Detailed design

5.3.2 Workflows to retrofit existing DHCNs

This section presents the workflows for the DHCNs retrofitting proposed by the partners, and their translation into a harmonized workflow. In this case, five out of nine partners provided their contribution. As anticipated in section 5.3 the analysis of the workflows proposed (Table 16) lead to an harmonized workflow (Table 17) having the same steps of the one related to new constructions. In fact, two partners indicated the same workflow for the two areas of interest, and a third one differentiated them only in two points. This indicates that, at high level, the steps to be followed are the same, even if they could be approached in different ways depending on if you are dealing with new construction or with retrofitting cases. For example, the implementation of thermal storages under the future scenario technology definition, comes out specifically from this section, but it is applicable also for the new constructions. In one case it means the possibility to integrate thermal storages in the existing network, while in the other it means to consider the implementation of thermal storages in the new network.

Both the harmonized scenario for new construction and retrofitting of DHCNs will be integrated in a reference scenario for the REWARDHeat tool in section 6.

Table 16 Workflows for existing DHCNs retrofitting

<table>
<tr><th>Contributions</th><th>Integration in the harmonized workflow</th><th>Considerations</th></tr>
<tr><td colspan="3">ARVALLA AB</td></tr>
<tr><td>No input</td><td>\</td><td>No inputs about workflows have been provided by ARVALLA AB</td></tr>
<tr><td colspan="3">HUNOSA</td></tr>
<tr><td>No input</td><td>\</td><td>No inputs about workflows have been provided by HUNOSA</td></tr>
<tr><td colspan="3">WÄRME HAMBURG</td></tr>
<tr><td>1. Baseline scenario definition (status quo) – heating, cooling, electricity demands and progressions</td><td>• Baseline scenario – demand mapping
(heating cooling and electricity demand)</td><td rowspan="2">Wärme Hamburg proposed the same workflow as per New Construction, except two point: ‘Baseline scenario definition’ and ‘comparison between baseline and future scenario’.</td></tr>
<tr><td>8. Comparison between baseline and future scenario</td><td>• KPI calculation and Results report
(comparison between baseline and future scenario)</td></tr>
<tr><td colspan="3">EDF-DALKIA</td></tr>
<tr><td>Same steps as per new constructions.</td><td>\</td><td>See Table 14</td></tr>
<tr><td colspan="3">EPC</td></tr>
<tr><td>No input</td><td>\</td><td>No inputs provided per Retrofit of DCHNs by EPC</td></tr>
<tr><td colspan="3">TOPUSKO</td></tr>
<tr><td>Same as per New construction, excepting ‘Commissioning’ and ‘monitoring’ that are not mentioned.</td><td>\</td><td>See Table 14</td></tr>
</table>

SAMPOL		
Study the whole system and see if it matches with our idea of how a DHC should be designed. If it does not match, consider the economic impact that should be obtained with the whole retrofit. The first step to consider is to see if the cold and heat production machines are too old, in terms of efficiency. The next step to retrofit is to check if the installation is running by keeping the constant temperature drop to 20ºC for hot water and 6ºCfor cold water or by variable pump speed.	• Baseline scenario – demand mapping • Baseline scenario Technologies and network definition & simulation (technology efficiency; baseline operation control rules)	The steps proposed are part of the baseline assessment. In order to assess the current status, they analyse the efficiency of the system and the control rules implemented
Consider the installation of hot and cold water reservoirs to fill them up during electricity valley costs.	• Future scenarios - technologies and network definition, (Storages implementation; operation schedule) • Future scenario simulation	The possibility to include tanks and buffers could be included in the future scenario definition or can be an outcome of the future simulation.
ALBERTSLUND		
Besides what described for the new constructions workflow, there is a focus on improving the layout (pipelines). In the 1960's the pipelines were placed underneath buildings – so the buildings could make use of the heat loss from purely insulated pipes. Today the trend is to move the pipes out, so they are easier to maintain.	• Future scenarios - technologies and network definition (pipeline insulation; pipeline location)	The pipeline characteristics and location have an impact on the network performance and could impact also the estimated maintenance cost.

MJINWATER		
No input	\	No inputs about workflows have been provided by MJINWATER

Table 17 Harmonized workflow for retrofitting existing DHCNs

Retrofit of existing DHCNs Harmonized workflow
1. Source mapping Energy quantity and temperature level- RES and non-RES.
2. Baseline scenario – demand mapping Heating, cooling and electricity demand; Hourly resolution; Temperature level definition.
3. Baseline scenario Technologies and network definition & simulation Technology efficiency definition; Baseline operation control rules.
4. User needs, planning criteria, KPIs selection Key factors definition; economic framework; resource options, Political and social requirements; State aids; minimum profitability; Technology efficiency definition
5. Future scenarios - technologies and network definition, Storages implementation; Pipeline insulation; Pipeline location; operation schedule.
6. Future scenario(s) - Demand Mapping Heating, cooling and electricity demand; Hourly resolution; Temperature level definition.
7. Future scenario simulation RES and non-RES technology; Tube dimension, pumps dimension definition; DHCN simulations; Route optimization.
8. KPI calculation and Results report Comparison between baseline and future scenario; Energy performance and economic assessment
9. Future scenario selection
10. Detailed design*

5.3.3 Workflows for operation and maintenance of DHCNs

The analysis of the O&M workflows is shown in Table 18. Four out of nine partners provided the contribution describing the workflows they use, or would use, for addressing the O&M phase. A harmonized workflow has been defined, shown in Table 19.

Besides providing an analysis of the current practices suggested by the participant to the survey, the harmonized workflow could be used to provide some useful inputs to the definition of the technical requirements in section 6. In fact, the REWARDHeat predesign tool is not thought for real time monitoring, fault detection or predictive maintenance, but it could take into account some of the aspects of the O&M phase when estimating the operating costs and energy performance.

Table 18 Workflows for operation and maintenance of DHCNs

Contributions	Integration in the harmonized workflow	Considerations
ARVALLA AB		
No input	\	No inputs about workflows have been provided by ARVALLA AB
HUNOSA		
No input	\	No inputs about workflows have been provided by HUNOSA
WÄRME HAMBURG		
1. Evaluation of the existing network – gather all accessible information (layout drawing, construction plans, interviews with operators and installers…) and check system in the field randomly	• Evaluation of the network: gather all accessible information • Evaluation of the network: on field audit (check of the system)	The contribution refers to the analysis of documentation and data of the DHCN and to on field verification of the status of the system.
2. Estimation of expenses according to the previous point and working experience	• Estimation of expenses	Estimation of the expenses due to ordinary or extraordinary maintenance
3. Detailed data collection and evaluation within the first years	• Detailed data collection and evaluation	\
4. Adjusting maintenance strategy if necessary	• Adjusting maintenance strategy if necessary	According to the data collected, it is possible to adjust the maintenance strategy if needed
EDF-DALKIA		
Use of maintenance plan	• Maintenance strategy definition	\

Use of tool for diagnostics and predictive maintenance (using own tools)	• Maintenance strategy definition (Diagnostics; fault detection; Predictive maintenance)	\
Monitoring of the operation phase focusing on the energetic performance of DHC networks	• Data collection and evaluation	\
EPC		
No input	\	No inputs about O&M workflow have been provided by EPC
TOPUSKO		
1. Commissioning – analysing the occurred problems, calculations, troubleshooting	• Evaluation of the network: on field audit (check of the system) • Maintenance strategy definition	This contribution refers to the evaluation of the system right after the commissioning. However, the methodology proposed (problem analysis and troubleshooting thanks to calculation) could be exploited also for O&M phase. \
2. Monitoring – lessons learned	• Detailed data collection and evaluation (monitoring)	
3. Future scenario definition	• Maintenance strategy definition	The analysis of the possible intervention for maintenance operation could be translated as maintenance strategy definition and estimation of expenses
4. Future scenario simulation	• Maintenance strategy definition	
5. Comparison between baseline and future scenario	• Maintenance strategy definition • Estimation of expenses	
SAMPOL		
No input		No inputs about O&M workflow have been provided by SAMPOL

ALBERTSLUND		
• We have rules and inspections for the work carried out by external entrepreneurs…	• Evaluation of the network: gather all accessible information	\
• We use thermal inspections, before by planes, today by drones….	• Evaluation of the network: on field audit (thermal inspection)	\
• Today we focus more on detections of leakages…	• Evaluation of the network: on field audit (leakages detection)	\
• We register, in GIS, any leakage – and the people working with inspections report back to the office of what they see and learn	• Evaluation of the network: on field audit	\
• Weekly meetings are carried out with the entrepreneurs who are changing pipes in Albertslund, and are constructing new areas	• Maintenance strategy definition • Ordinary and extraordinary maintenance interventions	\
MJINWATER		
No input	\	No inputs about workflows have been provided by MJINWATER

Table 19 Harmonized workflow for O&M of DHCNs

O&M of DHCNs Harmonized workflow
1. Evaluation of the network: gathering of information and documentation
2. Evaluation of the network: on field audit Check of the system (on field; by drone); thermal analysis; leakages detection
3. Estimation of expenses
4. Maintenance strategy definition Diagnostics; fault detection; predictive maintenance
5. Detailed data collection and evaluation Monitoring and data evaluation
6. Adjusting maintenance strategy if necessary
7. Ordinary and extraordinary maintenance interventions

5.4 Output

The third part of the questionnaire proposed was dedicated to the definition of the possible outputs desired by the potential users of the tool. Each partner participating to the survey has been asked to modify or integrate a proposed list of outputs. Six partners out of nine provided their inputs: in general, the outputs proposed (marked with a blue bullet) have been confirmed, except for four outputs eliminated from the list by TOPUSKO. These outputs have been confirmed by the other partners, and therefore kept in the integrated list of desired outputs. Six new outputs (marked with a yellow bullet) have been proposed by WÄRME HAMBURG, while one new output related to the report generation has been suggested by TOPUSKO. Table 20 shows the integrated list of desired outputs and the related score obtained. One point has been assigned if the outputs have been confirmed or added to the list. The integrated list of output is used, together with the analysis of section 5.1, 5.2 and 5.3, to define the preliminary technical specification in section 6. However, the final decision on the outputs of the tool will be done in the Task 2.4 related to the tool development.

Table 20 Integrated list of desired outputs

Desired Output	Score
• Matching of demand and production	6
• Baseline and future scenarios comparison	6
• Temperature drops in the network	6
• Pressure losses in the DHN	5
• Thermal storage operation simulation	6
• Relevant KPIs (Network operational cost; Primary energy saving; GHG emission saving; Economic indicators (sPBK, ROI,...))	6
• Technology sizing (energy source and substation)	6
• Heat loss and leakages	6
• Size and number of H&C harvesting stations needed along the network	6
• Size, number and types of storages used	5
• Pipeline optimal layout	5
• Pipe sizing	5
• Automatic energy demand compilation for baseline scenario	1
• Accessible energy sources – renewables and other	1
• Existing networks and energy generation facilities in this area	1
• Installation costs	1
• Show urban development plans for this area	1
• Show owners of the property in this area	1
• Report generation	1

5.5 Existing GIS based tool for predesign of DHCNs

This section reports the outcomes of the questionnaire related to the experience of the partners involved in the survey with existing software for DHCNs design, focusing on strengths and weaknesses of such tools. The analysis of the contribution is shown in section 5.5.1.

In addition, three existing tools developed within EU funded projects have been chosen as example to show to the partner which is the state of the art of tools similar to the REWARDHeat predesign tool that is under development. The three tools, PLANHEAT, THERMOSS and HOTMAPS, have been briefly analysed in section 5.5.2, highlighting strengths and weaknesses.

The aim is to identify which feature or strengths of the analysed tools could be integrated or is already part of the REWARDHeat predesign concept, and which weaknesses could be overcome.

5.5.1 Contribution analysis

As described in section 4.1, in the last part of the questionnaire the partners have been asked to provide information on tools they already use for DHCNs design, providing information on strengths or weaknesses of such tool. The aim is to understand which of the feature or strengths could be considered for the REWARDHeat predesign tool development, or which weaknesses could be overcome. Table 21 shows the analysis of the contributions received from each partner.

Table 21 Analysis of the partner's contribution on already existing tools for DHCN design

Questionnaire analysis: existing tool for DHCN design	
ARVALLA	
Tools	https://www.equa.se/en/ida-ice/extensions/borehole https://buildingphysics.com/eed-2/ Both the tools indicated are tools for BTES (borehole thermal energy storage) and building design. Not used for DHCN design.
Strengths	Sound tools with long experience.
Weaknessess	They are not dynamic tools: you cannot adjust the calculation according to on field measurement.
GIS	No
Comments	The tools used by ARVALLA are not for DHCNs design, but for the detailed design of BTES. They suggested a commercial GIS tool that they don't use but it is used by company working with DHCN and energy production plans: Energy Opticon (https://www.energyopticon.com). Energy Opticon is a software for accurate load forecasts and economical optimization of energy production, electricity trading and heat networks. Among other features, it can provide: short and long term computer optimized production plans; automatic scenario calculations using a Work-Flow-Engine; Simultaneous optimization of production plans and contracts; Visualization

	and follow-up solutions for the production planner, trader, management and control room.
HUNOSA	
\	No inputs
WÄRME HAMBURG	
Tools	Wärme Hamburg maintains and uses a tool for hydraulic simulation and planning for the main network.
Strengths	The capability to deal with the complex structure of existing network with focus on optimization, expansion and changes (e.g. re-location works).
Weaknessess	Only technical outputs (hydraulic calculations etc.).
GIS	Yes, the above mentioned tool is GIS based and the underlying structure for various processes is maintained by more than 100 experts and workforce.
Comments	The tool proposed is a specific tool for the detailed design of DHCN, providing only technical outputs. It is not meant to provide information about the operating costs and energy performance of the network in order to provide techno-economic feasibility studies.
EDF-DALKIA	
\	No inputs
Comments	EDF and DALKIA is usually involved in the detailed design of the network, after the planning have been completed. They never used tools like the one presented as example (PLANHEAT, THERMOS, HOTMAPS). They mentioned the use of own tool to perform diagnostic and predictive maintenance in the O&M phase.
EPC	
Tools	DELPHIN and own customized tools in Excel.
Strengths	Very accurate simulation of the soil behaviour; customizable.
Weaknessess	Not easy to use; takes some time and a lot of experience.
GIS	No
Comments	The tools mentioned are tools for detailed design and are not meant for the predesign or the assessment of operating costs and energy performance.

TOPUSKO	
Tools	Customized engineering calculations, Excel based.
Strengths	Universal tool meaning it covers any example, layout and scale of DHCN. It's accurate.
Weaknessess	Slower design process, occasionally needs to be done from scratch, individualized logic (not user friendly).
GIS	No
Comments	TOPUSKO uses its own tool, Excel based. Since they are customizable, they are flexible and can be used for any use case. However, to do this it is required a huge amount of work and experience. They are not easy-to-use tools.
SAMPOL	
Tool	Pipeflow (https://www.pipeflow.com/): program for the design of the piping distribution system including pumps and pipe sizing. Autocad Plant 3D: used for simulating all the isometrics of the DHC system.
Strengths	These tools represent a huge advantage as it is possible to use them to simulate the whole system, from the power plant plot to the overall piping outline. With these programs it is possible to simulate different configurations and see which one is the most efficient solution.
Weaknessess	Not a specific weakness but something that could be useful it is a program combining the feature of both the program mentioned integrating the Autocad 3d exact geometry of all projects in the Pipeflow program. Within Pipeflow now you have to implement the Autocad drawing, with all the errors that may occur.
GIS	NO
Comments	The Pipeflow software is a software for pipe modelling that can take into account multiple supply points, discharge tanks, components, valves, & multiple pumps in series or in parallel in order to calculate flow rates, pipe pressures drop and pumps performance. The software is used for the detailed design of the pipelines. With respect to the weakness mentioned, the REWARDHeat predesign tool concept do not foresee so far to import pipeline drawings, but it defines itself the best pipeline layout according to the constraints and planning criteria provided. To consider multiple supply points and pipe pressure it is a possible need that came out also from the analysis of the scenario in section 5.2.

ALBERTSLUND	
Tool	They do not perform DHCNs design, but they indicated TERMIS as software used by the company who designed the network.
Strengths	No inputs
Weaknessess	No inputs
GIS	Yes
Comments	No inputs related to strengths or weaknesses have been provided for TERMIS software. TERMIS is a hydraulic modelling tool used for District Heating, which simulates flow, pressure and thermal behaviour in the distribution network. TERMIS conducts hydraulic simulations that can be used to optimize the District Heating supply and utility production within your energy system. The hydraulic analysis is based on real time data from the SCADA system that allows the District Heating companies to obtain more information about their entire network and operation. The TERMIS software includes a modular structure that enables the users to conduct a variety of analyses e.g. master planning, feasibility studies and also chilled water distribution. It can be used for calculating flows, temperatures, pressures, pumping head, load on pipes, pressure loss gradients, temperature losses, pressure losses, costs, renovation plans etc.
MJINWATER	
****	No inputs

Six out of nine partners were able to provide information of existing tool used. Among the ones indicated, the most interesting were the two commercial software Energy Opticon and TERMIS.

Energy Opticon is a software for load forecast, economic optimization of energy production and heat networks. Comparted to REWARDHeat predesign tool concept, this software is more focused on optimizing the network operation, rather than the predesign of DHCNs. An interesting feature of Energy Opticon is the possibility to include also economical input data in order to assess the production plan from both energy and cost point of view.

TERMIS is a hydraulic modelling tool used for District Heating, which simulates flow, pressure and thermal behaviour in the distribution network. The main focus of the tool is to allow District Heating companies to manage their network optimizing cost-effectiveness and overall efficiency. It can also be used for the design of DHNs and to carry out feasibility studies or renovation plans. Compared to TERMIS, the REWARDHeat predesign tool cannot retrieve real time data for the network optimization, since the aim of the tool is the predesign of the DHCNs. However, the REWARDHeat predesign tool will support as well for techno-economic analysis of a DHCN design, providing information on the performance of the foreseen network.

In general, many partners mentioned specific tools for detailed design of DHCNs, highlighting the great experience and effort required for using them. One of the aims of the REWARDHeat predesign tool is to overcome this problem providing a user-friendly tool supporting the DHCNs owners, managers and designers in the predesign phase.

5.5.2 Strengths and Weaknesses analysis of existing Open Source GIS based tool.

The aim of this section is to identify additional requirements not coming from the potential future users but from the state-of-the-art of existing open source tool for DHCNs design, in order to see in which aspect the REWARDHeat tool could go beyond the mentioned tool and close the gaps they present. Table 22 Table 23 and Table 24 show a brief analysis of respectively PLANHEAT, THERMOS and HOTMAPS. In each table a short description and the web link is presented. Then, for each strength or weakness identifies, a comparison with the REWARDHeat predesign tool is performed.

The analysis done shows as almost all the features identified as strengths will be part of the REWARDHeat predesign tool or that their integration will be assessed. REWARDHeat predesign tool wants also to overcome the majority of the weaknesses identified, for example considering temperature and pressure levels in the simulations or having a user-friendly GUI.

Table 22 PLANHEAT tool analysis

PLANHEAT Tool		
Short description	PLANHEAT tool is an integrated and easy-to-use tool which support local authorities (cities and regions) in selecting, simulating and comparing alternative low carbon and economically sustainable scenarios for heating and cooling that will include the integration of alternative supply solutions that could balance the forecasted demand. The PLANHEAT integrated tool could support local authorities in: mapping the potential of locally available low carbon energy sources, mapping the forecasted demand for heating and cooling; define and simulate alternative environmentally friendly scenarios; understanding the interactions of these new scenarios with the existing infrastructures and networks and identify potential for further extension and upgrade of district heating and cooling networks; evaluate the benefits (in terms of energetic, economic and environmental KPIs) that the adoption of the new scenarios will generate against the current.	
Link	https://cordis.europa.eu/project/id/723757	
Strengths	• Mapping of hourly demand on the building level	Foreseen in REWARDHeat predesign tool
	• Mapping of supply (different conventional and unconventional waste heat and renewable energy sources) available	Foreseen in REWARDHeat predesign tool
	• Route optimization of the thermal networks	Foreseen in REWARDHeat predesign tool

	• Hourly operation of the system based on optimization approach which includes various technologies	Foreseen in REWARDHeat predesign tool
	• Possibility to model centralized energy storage	Foreseen in REWARDHeat predesign tool
	• Heat pump efficiency isn't constant but depends on the heat source temperature	Foreseen in REWARDHeat predesign tool
	• No privacy issues, since the tool is installed locally at the end-user's PC	To be defined
Weaknessess	• Tool installation is needed – potential issue for non-technical end-users, however some input data are obtained from the webserver	A web-based tool option is under investigation.
	• QGIS-based – end-users should be familiar with the user interface	REWARDHeat pre-design tool will be a GIS based tool. The idea is to develop a user friendly interface to facilitate the end-user.
	• End-user's input data is needed	The idea for REWARDHeat tool is to have the option to receive as input data form both databases and End-User.
	• Doesn't include detailed temperature characteristics of the thermal network such as temperature or pressure levels	The idea for REWARDHeat predesign tool is to take into account temperature and pressure level. It is under investigation.
	• Doesn't include the possibility to model and assess decentralized heat pump and storages connected to the network (Substations)	A crucial point of REWARDHeat concept is to consider decentralized (heat pumps and storages connected to the network, in order to be able to exploit also low-T DHCNs.

Table 23 THERMOS tool analysis

TEHRMOS Tool		
Short description	THERMOS is a web-based software designed to optimise local district energy network planning processes and results according to user and project specific requirements such as budget, climate and energy targets. Free to use and built with and for local energy planners, THERMOS places instant address-level mapping and built-in energy demand estimations within immediate reach. It allows the user to get started with planning the optimal expansion of existing networks, the planning of an entirely new systems, or comparing different network and non-network solutions.	
Link	https://www.thermos-project.eu/home/	
Strengths	Web-based software, no installation is needed	A web-based tool option is under investigation.
	Simplified method for estimating buildings demand and create heat maps in any location based on OSM and local heating degree days	A simplified method for estimating building demand is under development
	User-friendly way to select the area and the buildings to include in the new network	Foreseen in REWARDHeat predesign tool
	Flexibility for selecting technologies and sources (no predefined lists)	Foreseen in REWARDHeat predesign tool
	Optimization of thermal network design (Net Present Values is one of the KPIs that is optimized) to find a cost-optimal network design	Foreseen in REWARDHeat predesign tool
	Incorporation of capital costs for plant, pipes and connection, set against revenues from heat sales and monetised emissions;	Economic KPIs taking account capital cost will be defined.
	Possibility to model centralized energy storage	Foreseen in REWARDHeat predesign tool
	Thermal network heat losses calculation	Foreseen in REWARDHeat predesign tool
	Assessing/comparing the performance of specific networks and non-networked solutions	Comparison between different options and between baseline and future scenarios will be available

	Interoperability with GIS formats, for model results and heat map export	Possibility under investigation
Weaknessess	Cooling model not yet available	Cooling calculation will be part or REWARDHeat predesign tool
	Supply mapping isn't available	Supply mapping will be available for REWARDHeat predesign tool
	Doesn't include detailed temperature characteristics of the thermal network such as temperature or pressure levels	The idea for REWARDHeat predesign tool is to take into account temperature and pressure level. It is under investigation.
	Poor guidance to the user for characterizing demand, supply	The idea is to develop the tool in a user-friendly way along the whole workflow
	Doesn't include the possibility to model and assess decentralized heat pump and storages connected to the network (Substations)	A crucial point of REWARDHeat concept is to consider decentralized (heat pumps and storages connected to the network, in order to be able to exploit also low-T DHCNs.

Table 24 HOTMAPS tool analysis

HOTMAPS Tool		
Short description	HOTMAPS is a GIS-based online software that supports authorities and energy planners to set up a strategic heating and cooling plan for their region. The toolbox will allow public authorities to identify, analyse, model and map resources and solutions to supply energy needs within their territory of responsibility in a resource and cost-efficient way.	
Link	https://www.hotmaps-project.eu/	
Strengths	Mapping of supply available	Foreseen in REWARDHeat predesign tool
	Web-based, no installation is needed	A web based tool option is under investigation.

	User-friendly GUI	The idea for REWARDHeat tool is to develop a User-friendly GUI as well
	Possibility to model centralized energy storage	Foreseen in REWARDHeat predesign tool
	Relatively fast	The idea for REWARDHeat tool is to provide fast analysis
Weaknessess	Simulation is carried on the regional level, i.e. building-level demand can't be obtained	REWARDHeat tool will calculate the demand at building level
	The tool doesn't include network route layout definition	REWARDHeat tool will be able to define the best route for the network
	Doesn't include detailed temperature characteristics of the thermal network such as temperature or pressure levels	The idea for REWARDHeat predesign tool is to take into account temperature and pressure level. It is under investigation.
	Doesn't include the possibility to model and assess decentralized heat pump and storages connected to the network (Substations)	A crucial point of REWARDHeat concept is to consider decentralized (heat pumps and storages connected to the network, in order to be able to exploit also low-T DHCNs.

6 Preliminary Technical requirements for REWARDHeat Predesing Tool

In this section the suggestions and the needs of the potential end-users involved in the survey will be translated into preliminary technical requirements of the REWARDHeat predesign tool. The preliminary technical specifications will be analysed in Task 2.4 'REWARDHeat Predesign Tool' and used to define the detailed functionalities and workflows of the tool.

Section 6.1briefly recaps the overall objectives and the general requirements of the REWARDHeat predesign tool and shows the reference workflow to be considered for the tool development, defined starting from the harmonized workflows of section 5.3.

In section 6.2, for each step of the reference workflow, are identified the desired functionalities and the related inputs and outputs, based on the analysis done in section 5.1, 5.2 and 5.4.

6.1 Overall objective, general requirements and reference workflow

The overall objective of the REWARDHeat predesign tool is the predesign and simulation of district heating and cooling thermal networks, with special focus on low and ultra-low temperature thermal networks. In particular, it will be possible to use the tool to predesign the retrofit of an existing DHCN or the installation of a new DHCN, by performing simulations of the network to assess the operating performance from a techno-economic point of view.

The general requirements of the REWARDHeat tool concept are:

- Open-source
- GIS based (georeferenced input data and results)
- Spatial resolution:
    - Input: building level
    - Output: building level + district level (by aggregating results at building level)
- Temporal resolution: hourly energy profiles
- Web-based or desktop-based

These features constitute the basis of the REWARDHeat predesign concept which will be developed according to these requirements and to the preliminary specifications defined in section 6.2, which will be further assessed in Task 2.4.

A reference workflow is also proposed according to the harmonized workflows defined in section 5.3, that are the results of the analysis carried out on the workflows proposed through the questionnaire. As anticipated in section 5.3, the harmonized workflows for new construction and retrofit of DHCNs present the same main steps, even if with some differences in how the steps are approached. For this reason, the reference workflow is based on the two before mentioned, as shown in Table 25, without considering the last step 'detailed design', since it is out of the scope of the tool. The O&M harmonized workflow is not considered in the reference workflow, since the steps cannot be directly integrated in the tool workflow, involving mostly networks audit and real time data gathered from the field.

Table 25 Reference workflow for the REWARDHeat predesign tool

Reference workflow
1. Source mapping
2. Baseline scenario – Demand mapping
3. Baseline scenario - Technologies and network definition & simulation
4. User needs, planning criteria, KPIs selection
5. Future scenarios - Technologies and network definition,
6. Future scenario(s) - Demand Mapping
7. Future scenario simulation
8. KPI calculation and Results report
9. Future scenario selection

6.2 Desired Functionalities

For each step of the workflow presented in Table 25, desired functionalities have been identified and preliminarily characterized in terms of related inputs and output data as shown in Table 26. The requirements identified in terms of functionalities, inputs and outputs contained in Table 26 do not constitute the final requirement (mandatory) that will be included in the REWARDHeat predesign tool, but are the results of the survey carried out among the partners identified as potential end-user of the tool, and represent a guideline that will be further analysed in Task 2.4 'REWARDHeat predesign tool'.

Table 26 Desired Functionalities and related inputs and outputs

Desired Functionalities	
	Sources Mapping
Functionalities	• To map (GIS Based) local energy sources availability, including RES and WH/C sources. • To include Existing (high temperature) Network among the possible source for the new DHCN. • To indicate energy sources characteristics (e.g. temperature levels, annual availability, etc.; % of renewable energy). • To show existing networks and energy generation facilities in the area. • To show urban development plans for this area. • To show owners of the property in this area.
Input	• Area of interest for the analysis of energy sources availability (e.g. shape file uploaded by the user, end user to draw a polygon around

	the area of interest using support maps; already existing database, such as Open Street Maps). • Parameters related to energy sources for assessment of related extractable potential. • Information about cadaster, public urban development plans, etc.

Output	• For each energy sources the following information could be provided to the user:
	  ○ Location
	  ○ Hourly energy profiles
	  ○ Annual aggregated potential [kWh/y] on a certain area of interest
	  ○ Temperature levels
	  ○ % of renewable
	• Show existing networks and energy generation facilities in the area.
	• Show information on the urban plan of the area.
	• Show information of the owners of areas or buildings.

Baseline scenario – demand mapping	
Functionalities	• To map energy demand at building level (GIS based approach) with hourly and annual resolution for a certain baseline scenario. • To provide information on the supply temperatures requested by the buildings is also needed. • The user should be able to analyse existing areas or new construction areas.
Input	• Selection of buildings to be considered. • Buildings characterization (Building Conditioned area, building typology, building emission system, etc): database or user input.

Output	• Heating, Cooling and Domestic Hot Water demand at building level in terms of:
	  ○ Hourly energy demand profile (1year) on annual basis
	  ○ Peak demand
	  ○ Temperature of demand
	  ○ Total annual energy consumption

Baseline scenario - Technologies and network definition & simulation	
Functionalities	• To allow the users to indicate the energy source & generation technology for each building. (either individual systems or DHCN) to evaluate baseline consumption. • Possibility to select multiple sources in different locations.

	• Technologies allocation according to buildings' peak demand and temperature level of the demand. • In case of existing DHCNs, the user could define the existing DHCN features: connected buildings, supply energy source(s), generating technology(ies) and generation point(s) location, pipeline layout and characteristics, type of substations, operating schedule. • Simulation of baseline energy demand-production match.
Input	• Buildings connected to existing DHCN. • Type/Efficiency of existing DHCN supply technology(ies). • DHCN Building connection. • Pipelines layout and sizing of existing network. • Supply temperature, control regimes and operating schedule of existing DHCN.
Output	• Matching of baseline demand and production for both individual systems and existing DHCN. • Relevant baseline KPIs (e.g. operational costs; primary energy consumption; GHG emission, etc.;...).
User needs, Planning criteria, KPIs	

Functionalities	• To define the economic framework for energy KPIs calculation
	• User should define the planning criteria:
	  o RES prioritization
	  o Energy savings
	  o GHG savings
	  o Operative cost savings
	  o Capital costs

Input	• Target values for each KPIs related to the planning criteria.
Output	• Suggestions for future scenario definition according to target values of selected KPIs. • Parameter to be used for KPI calculation.
Future scenario(s) - Demand Mapping	
Functionalities	• The tool should be able to assess buildings' energy demand in a specific future scenario, taking into consideration future retrofitting of buildings, and thus modified energy demand and temperature levels.
Input	• Reference year for future scenario. • Selection of the refurbished buildings.

	• Buildings future characterization (building conditioned area, building typology, building emission system, etc): database or user input.

Output	• Future Heating, Cooling and Domestic Hot Water demand at building level in terms of
	  ○ Hourly energy demand profile on annual basis
	  ○ Peak demand
	  ○ Temperature of demand
	  ○ Total annual energy consumption

Future scenario(s) - Retrofit/Design of DHCN - Technologies and network definition & simulation	
Functionalities	• The tool should allow the user to select one or multiple energy sources among the ones mapped and available at local level (already existing DHCN network and electricity grid should be selectable in the list of energy sources). • In case of multiple sources available, the user can prioritize the preferred one (e.g. RES prioritization). • Possibility to select multiple sources in different locations. • Different supply technologies should be available to be selected for heating, domestic hot water and cooling generation according to the district/buildings peak demand. • Possibility to include thermal storages in the network. • The tool should include the possibility to have both passive and active (e.g. booster HP) substations at building level. • Possibility to consider buildings connected to the grid providing extra heat of cooling as source for the grid, thanks to bidirectional substations (heat exchange among user). • The tool should propose optimal solution for DHCN layout and pipeline diameter, considering possible constraints given by the user on: buildings to be connected/excluded to the grid; pipeline typology (2 way - 4 way); pipeline route; pipeline location (underground-outside); pipeline oversizing (for future possible network expansion) • Possibility to consider different subnetworks with different technical characteristics (e.g. pressure and temperature level). • Matching of demand and production according to optimization algorithms (e.g. minimization of operative costs related to energy production) taking into account incentives.
Input	• Local energy sources availability and prioritization. • Future district/buildings demand.

	• Energy source(s) selection by user (e.g., from source mapping list).
	• Technology selection and characterization (performance and economic parameters) by user:
	  ○ Supply technology(ies)
	  ○ Thermal storage
	  ○ Substations
	• Pipeline characterization (route constraints, pipeline typology, pipeline dimensions and location).

Output	• Matching of demand and production. • Temperature drops in the DHCN. • Pressure losses in the DHCN. • Thermal storage operation simulation. • Technology sizing (supply technologies and substations). • Heat loss and leakages. • Size and number of H&C harvesting stations needed along the network (Heat Pumps; Heat exchangers). • Pipeline optimal layout. • Pipe sizing. • Installation costs. • Total running costs.
KPI calculation, Results report and Future scenario selection	
Functionalities	• Provide the user with schemes, graphic, detailed and aggregated data on the results of the simulations. • Comparison between baseline and future scenarios. • Comparison among alternative future scenarios.
Input	• Results from tool simulation.
Output	• Baseline and future scenarios comparison. • Relevant KPIs (Network operational cost; Primary energy saving; GHG emission saving; Economic indicators (sPBK, ROI,…) for each scenario. • Targeted results achieved and not achieved for each scenario. • Report generation.

7 Conclusions

The aim of this document has been to identify the utilities' needs throughout a survey conducted among the partners (managers of demonstrator networks and early adopter partners) identified as potential end-users of the REWARDHeat predesign tool, and translate those needs into preliminary technical specifications for the development of the tool.

The survey has been carried out by means of questionnaires submitted to the selected partners and thanks to bilateral meetings, round tables and a workshop. The information and the needs collected from the partners have been then processed to provide technical specifications.

The first relevant outcomes came from the workshop held during the general assembly of the project. Among others, the discussion touched six relevant topics related to the approach to be considered in the tool development. To follow a demand-driven or a supply-driven design was one of the questions raised: a mixed approach has been suggested since in daily work both the approaches are used. To consider source and network temperature levels was another aspect discussed: the currently available open-source tools for DHCNs design do not have this possibility and it is among the objectives of the REWARDHeat predesign tool to go beyond the state of art in this sense. The tool should also be user friendly and flexible, with possibility to compare different scenarios, possibly with predefined design options and the possibility to consider multiple supply technologies. Also, the possibility to consider different sub-networks with different operating conditions has been discussed and will be further investigated. When it comes to the outputs, the possibility to include financial parameters taking into account long term scenarios has been requested and will be investigated.

The other outcomes of the survey came out from meetings and questionnaires analysis. Four topics have been investigated: desired scenarios to be implemented in the tool; workflows they follow in the pre-design phase; desired outputs of the tool; DHCNs design tools they already use. The topics investigated were related to three main area of interest: new construction, retrofit, and O&M of DHCNs.

The outcomes of the scenario analysis have been a list of scenarios per each area of interest, expressing the needs of the partners. In the questionnaire, lists of possible scenarios were proposed, asking the partner to modify and integrate them. The scenarios have been ranked according to the preference obtained in the questionnaire. The final lists of scenarios, shown in Table 9, Table 11 and Table 13, have been then used to define the preliminary technical requirements.

Regarding retrofit of DHCNs, the higher scores have been obtained by the scenarios related to the possibility to implement in the network thermal storages, new supply technologies and substations. When it comes to the new construction, the possibility to work in a completely new urban environment obtained the highest score, while, among the scenarios proposed by the partners, the possibility to implement thermal storages have been suggested twice. Among the scenarios proposed in the questionnaire for O&M, the proposed scenarios 'fault analysis', 'new control rules' and 'ordinary maintenance' have been confirmed by the partners, while among the new scenarios suggested, the scenario 'data monitoring and evaluation' has been indicated three times.

The analysis carried out in section 5.3, dedicated to the design workflows, has been used for two main purposes. On one side, collect the best practices followed by the partners involved in the survey for the design of DHCNs and for managing the O&M phase. On the other side, to define a reference workflow for the tool. The reference workflows, shown in Table 25, have been created starting from the three harmonized workflows, which 'harmonize' the different workflows received in one workflow for each area of interest.

After the workflow analysis, an integrated list of desired outputs has been defined in section 5.4, taking into account the modifications and integration made by the partners to the list proposed in the questionnaire, as shown Table 20. The integrated list of outputs is used, together with the analysis of sections 5.1, 5.2 and 5.3, to define the preliminary technical specification of the REWARHDheat predesign tool.

In section 5.5 the experience of the partners with already existing tools has been investigated in order to collect information on strengths or weaknesses of such tools. The aim was to understand which of the features or strengths could be considered for the REWARDHeat predesign tool development and which weaknesses could be overcome. Two interesting tools have been proposed by the partners, Energy Opticon and TERMIS. However, with respect to REWARDHeat predesign tool, the two tools are both more oriented to the DHCN management and optimization, rather than in the pre-design of DHCN. The other tools proposed were all meant for detailed design of DHCN, and a need of great experience and effort to use them has been highlighted. One of the aims of REWARDHeat pre-design tool is to overcome these issues with an easy to use and user-friendly tool for the pre-design phase.

Besides the analysis of the tools used by the partners, a review of three existing open source tools for DHCN simulation (PLANHEAT, THERMOS and HOTMAPS) has been carried out. Also in this case, weaknesses and strengths have been analysed. The analysis shows as almost all the features identified as strengths will be part of the REWARDHeat predesign tool or will be evaluated, while the intention is to go beyond the state of art overcoming the majority of the weaknesses identified, for example considering temperature and pressure levels in the simulations or defining a user friendly GUI.

The final and most important outcome of the survey are the preliminary technical specifications defined in section 6, starting from the work done in section 5. For each step of the reference workflow, desired functionalities have been defined, together with the associated inputs and outputs, as shown in Table 26. The requirements identified do not constitute the final requirement for the REWARDHeat predesign tool, but are the expression of the needs of the potential end-user of the tool, represented in the REWARDHEAT project by the demonstrator network managers and early adopter partners.

The outcomes of this deliverable will flow into Task 2.4 'REWARDHeat Predesign Tool' where the detailed functionalities and workflows of the REWARDHeat predesign tool will be identified allowing REWARDHeat predesign tool to be developed.

8 Annex

Questionnaire– Requirements for designing DHC Networks

The overall objective the of questionnaire is to collect useful information from potential end-users of the REWARDHeat predesign tool about current practices for designing/retrofitting DHCN network.

REWARDHeat predesign tool - Concept Open source, GIS based tool to predesign new network or network retrofit taking into account: Multiple heating and cooling sources (low-grade RES and Waste Heat) Location/climate conditions Distribution of energy demands for H,C and DHW The tool will allow estimating techno-economic feasibility of the DHC network solutions addressed

According to a bottom-up approach, the collected information about:

- Relevant scenarios for DHCN predesign/retrofit
- Workflow currently adopted for DHCN predesign/retrofit
- Expected output/results
- Experience with already existing tools/software

will be translated into functionalities and requirements of the REWARDHeat predesign tool.

Scenarios

INSTRUCTION
Answer modifying the suggested scenarios or adding new relevant scenario. *Include comments in the dedicated box if relevant. (e.g. doubt on the suggested scenario; why you would not consider certain scenarios; other…)*

Which type of **scenarios** would you consider in the retrofit of an existing DHCN networks?

Renovation Scenarios
• Integration of new energy sources & technologies: ○ New sources/technologies completely replacing the old one ○ New sources/technologies used together with other

- Replacing old Substations
- New Thermal storages implemented
- Change of supply Temperature: due to new technologies & sources exploitation; due to heat and cooling demand modification
- Distribution layout modification
- Extension: due to new building connected → additional energy demand
- Reduction: dismission of part of the network → energy demand reduction
- Deviation from previous layout
- Pipeline Retrofitting
- Improvement of thermal insulation
- Replacing of old/deteriorated pipeline
- ……….

Comments
……

Which type of scenarios would you consider in the predesign of a new DHCN networks?

New Construction scenarios
• New DHCN in existing urban area • New urban area (No baseline to be considered) • ……..

Comments
…….

Which type of scenarios would you consider for the Operation and Maintenance phase?

Operation & Maintenance scenarios

• Management:
    ○ New control rules
    ○ Fault analysis
    ○ Fault of the energy production facility
    ○ Fault of substation
    ○ Fault on distribution pipeline
    ○ ....
    ○ ....
• Maintenance:
    ○ Ordinary maintenance
    ○ Extraordinary maintenance
    ○ ....
    ○ ....

Comments
......

Workflow for designing/retrofitting DHC networks

INSTRUCTION
List the steps and describe the overall workflow you usually follow for assessing relevant scenarios (please find below a workflow example as followed in the PLANHEAT tool). *Include case study/best practice if relevant.*

Renovation/new construction Workflow example
1. Baseline scenario definition
2. Baseline scenario simulation
3. Selection of planning criteria and KPIs
4. Future scenario definition
5. Future scenario simulation

6. Comparison between baseline and future scenario

Which steps do you follow for designing a new DHC network?

New construction Workflow Description
……..

New construction Case study/Best practice description
……..

Which steps do you follow for retrofitting an existing DHC network?

Renovation Workflow Description
……..

Renovation Case study/Best practice description
……..

Which steps do you follow for the Operation and Maintenance phases of a DHC network?

O&M Workflow Description
……..

O&M Case study/Best practice description
……..

Output data

INSTRUCTION
Integrate/modify the list of outputs. Include comments in the dedicated box if relevant *(e.g. doubt on the suggested inputs; why you would not consider certain inputs; other…).*

Which kind of output /analysis would you expect from a pre-design tool?

Output Examples
• Matching of demand and production • Baseline and future scenarios comparison • Temperature drops in the network • Pressure losses in the DHN • Thermal storage operation simulation • Economic indicators (sPBK, ROI,…) • Relevant KPIs (Network operational cost; Primary energy saving; GHG emission saving) • Technology sizing (energy source and substation) • Size and number of H&C harvesting stations needed along the network • Size, number and types of storages used • Pipeline optimal layout • Pipe sizing • ……. • …….

Comments
…….

Experience with already existing tools/software for DHCN design

Which tools/software do you use for DHCN design?

…….

Which are the strengths of those tools?

…….

Which are the weaknesses of those tools?

…….

Have you ever worked with GIS based tool for DHCN pre-design? If yes, describe the tool, the user experience you had with such tool/s (e.g. easy/difficult to use, availability of useful documentation, suitability of functionalities according to your expectations, etc.) and the overall workflow that you followed in the design process

……