

E²District

Deliverable 1.1

Report on requirements for district heating and cooling



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Abstract

This document is the report on requirements for District Heating and Cooling Networks detailing the requirements specifications for district heating decision support and energy management

Keyword list

District heating and cooling network, functional architecture, stakeholders, requirements, use-cases



Document History

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Executive Summary

The objective of this deliverable is to define high-level functional requirements for E²District platform and methodology, based on the needs expressed by all different stakeholders, for the development of a District Management and Decision Support framework for District Heating and Cooling Networks (DHCN).

To do so, a first step has been to identify the stakeholders involved in the design and operation phases of DHCN, and to list what could be their needs, based on the experience and expertise of each project partner. Subsequently services that could answer those needs have been defined, and sorted in three categories: needs, constraints and wishes (needs with low priority levels). Finally, high-level functions, defining how the system could satisfy these services, have been defined. For each function, a list of input data, output data (results) and a description of what should be done by the function is given.

This work should serve as a first basis for the specification and development of the different components of the system (models, algorithms and platforms), within the framework of Work Packages 2 to 4. As the various tasks of the project will be progressing, these requirements will be reviewed and updated if necessary based on the experience the consortium gains in the execution.

Table of Contents

1	Introduction.....	8
2	Stakeholder Requirements Definition.....	8
2.1	Glossary	8
2.2	Methodology.....	9
2.2.1	Stakeholders definition	9
2.2.2	Stakeholders needs definition.....	10
2.2.3	Identification of stakeholders' services of interest	11
3	System definition	13
3.1	Global system purpose and work areas	13
3.1.1	Global system purpose	13
3.1.2	Work areas included in the system	13
3.2	Work areas in detail.....	14
3.2.1	Design of primary heating network.....	14
3.2.2	Operation of primary heating network	15
3.2.3	Group of buildings network.....	16
3.2.4	Value proposition of the heating network	16
4	Work areas functional architecture	17
4.1	Design of primary heating network	17
4.1.1	Functional architecture	17
4.1.2	Functions' list.....	17
4.1.3	Functions' description	18
4.1.4	Design Scenario Definition	22
4.2	Operation of primary heating network.....	22
4.2.1	Functional architecture	23
4.2.2	Functions' list.....	23
4.2.3	Functions' description	24
4.3	Primary Heating Operation Scenario Definition	30
4.4	Group of buildings network	31
4.4.1	Functional architecture	31
4.4.2	Functions' list.....	32
4.4.3	Functions' description	32
4.4.4	Group of Buildings Scenario Definition	35
4.5	Value proposition of the heating network	36
4.5.1	Functional architecture	36
4.5.2	Functions' list.....	36
4.5.3	Functions' description	36
5	Conclusion & outlook.....	38

Tables

Table 1 Glossary.....	8
Table 2 District Heating and Cooling Network Stakeholders.....	10
Table 3 Stakeholders needs as expressed by the different partners	11
Table 4 Stakeholders associated to a reference number.....	12
Table 5 Services of interest for each stakeholder.....	12
Table 6 Design of primary heating network functions' list	18
Table 7 DF01 description.....	19
Table 8 DF02 description.....	19
Table 9 DF03 description.....	20
Table 10 DF04 description.....	20
Table 11 DF05 description.....	21
Table 12 DF06 description.....	21
Table 13 DF07 description.....	21
Table 14 Operation of primary heating network functions' list.....	24
Table 15 OF01 description.....	25
Table 16 OF02 description.....	26
Table 17 OF03 description.....	27
Table 18 OF04 description.....	27
Table 19 OF05 description.....	28
Table 20 OF06 description.....	28
Table 21 OF07 description.....	29
Table 22 OF08 description.....	29
Table 23 Group of buildings network functions' list	32
Table 24 BF01 description	33
Table 25 BF02a description	33
Table 26 BF02b description	34
Table 27 BF03 description	34
Table 28 BF04 description	34
Table 29 BF05 description	35
Table 30 Value proposition of the heating network functions' list.....	36
Table 31 VF01 description.....	37
Table 32 VF02 description.....	37



Figures

Figure 1 E ² District Work Areas	14
Figure 2 Design of primary heating network functional architecture	17
Figure 3 Primary network design optimization of an existing DHCN scenario	22
Figure 4 Primary network design optimization of a new DHCN scenario	22
Figure 5 Operation of primary heating network functional architecture	23
Figure 6 Optimization of production scheduling	30
Figure 7 Supervisory control of primary heat network equipment	31
Figure 8 Anomaly diagnosis for the DHCN.....	31
Figure 9 Group of buildings network functional architecture.....	31
Figure 10 Behavioural long term engagement scenario.....	35
Figure 11 Building flexibility scenario	36
Figure 12 Value proposition of the heating network functional architecture	36



1 Introduction

The deliverable D1.1 gathers and documents detailed requirements for the E²District framework and platforms that capture the expectations and needs from a stakeholder point-of-view for the development of district heating and cooling decision support, intelligent energy management and prosumer engagement. It will address both the requirements for the complete E²District framework and also from the perspective of individual requirements for each work package.

2 Stakeholder Requirements Definition

2.1 Glossary

Term	Signification
DF	Design Function – function corresponding to the work area “Design of primary heating network”
OF	Operation Function – function corresponding to the work area “Operation of primary heating network”
BF	Building function – function corresponding to the work area “Group of buildings network”
VF	Value function – function corresponding to the work area “Value proposition of the heating network”
HN	Heating Network
DHCN	District Heating and Cooling Network. Without any further precision, DHCN will refer to both production and distribution equipment.
BMS	Building Management System
System	The system is a generic term that gathers, under a unique banner, all the technical (algorithms, IT protocols, platforms ...) and non-technical (user guidelines, database ...) developments that will be made during the project, answering all the requirements listed in the deliverable 1.1

Table 1 Glossary

2.2 Methodology

The methodology for the DHCN requirements definition consists of the following four key working steps:

- Definition of the DHCN stakeholders, see Section 2.2.1
- Stakeholders needs definition, see Section 2.2.2
- Identification of services of interest to each stakeholder, see Section 2.2.3
- Identification of the conceptual system to realize these services and associated work areas, see Section 3

In the first step the DHCN stakeholders are identified and defined. In the second step, the needs and high-level stakeholder requirements are listed and documented. Then, based on the stakeholder needs, a number of services are identified (or selected) that satisfy a part¹ of the key stakeholder requirements. Finally, the concept of a system to realize these services is drafted and the key work areas required to realize this concept are detailed. In the following section the key stakeholders for a DHCN are presented and their roles and needs are described in detail.

2.2.1 Stakeholders definition

Stakeholders	Definition
DHC manager	<ul style="list-style-type: none"> ▪ Responsible for providing the service (heating and cooling). Assumes responsibility for all administrative, technical and financial obligations in relation to the subscriber. ▪ Responsible for the short-to-long term (short term: daily; long term: from one to few years) planning of the operation of the DHCN. ▪ Manage the contractual relationship with the subscriber and collect corresponding fees.
DHC operator	<ul style="list-style-type: none"> ▪ Responsible for the real-time operation of the DHCN, applying set-points in accordance with the short to long term planning (similar to goals or objectives) provided by the DHCN manager. Its main task is to secure heat delivery, whatever the DHCN situation. ▪ Also responsible for the maintenance of production & distribution units.
Subscriber	<ul style="list-style-type: none"> ▪ The one who pays the bills and subscribes to a contract with DHCN manager. A main subscriber will divide the bill in between final subscribers (e.g. on the secondary network).
End-User	<ul style="list-style-type: none"> ▪ The one who is the occupant of the building and receives the service (space heating, domestic hot water, space cooling). The end-user can be of several types, depending on the sector (residential, commercial, university). The end-user can be the subscriber itself or can depend on the subscriber

¹ As we won't tackle all the stakeholders requirements in the timeline of the project



Stakeholders	Definition
Local authority - National authority	<ul style="list-style-type: none"> Development planner Delegates or ensures provision of the service (heating and cooling). Approves structural evolution of the DHCN (extension, new connections ...) Usually a municipality or a federation of municipalities Willing to increase its attractiveness (local economic activity, environmental impact, image ...) Complies with local, national and European regulations
DHC Owner	<ul style="list-style-type: none"> Owner of the facilities
Investors/Project backers	<ul style="list-style-type: none"> Finances the DHCN and its extension or refurbishment projects
General Contractor & Designer	<ul style="list-style-type: none"> Carries out technical and economic studies associated with construction or extension of the DHCN. Manage project planning risks, it is in charge of the final executive project, and/or in charge of the construction of new thermal settings or the refurbishment of the existing ones.
Technology Provider	<ul style="list-style-type: none"> Provides hardware (production units, pipes, building's HVAC systems ...) and IT technologies (District Energy Management Systems, control, monitoring ...)

Table 2 District Heating and Cooling Network Stakeholders

2.2.2 Stakeholders needs definition

In order to gather stakeholders needs we have created an excel file in which each project partner could express values or benefits expected by different stakeholders based on the partners' experience and role in the DHCN market. The partners who are key DHCN stakeholders themselves – VERI (representing DH Operator and Manager), UTRCI (its parent company is a Technology Provider), CIT (End-user), CSTB (Technology Provider) and Acciona (Contractor Designer) – collected their own needs but also needs from their clients and other stakeholders which they are working with (DH owners, municipalities, investors). The partners collected and processed the needs in various meetings and in a global stakeholder and requirements partner workshop that took place in Paris, June 2016. The result of this work is shown in the **Error! Reference source not found.**Table 3.

Partner	Stakeholder or project partner expressing a value	Values or benefits waited for by the stakeholder or partner
VERI, CIT, UTRCI	DH manager	Maximize benefits (considering heat production + heat distribution + electricity production) while ensuring the same quality of service (comfort)
CIT	DH manager	access to data in order to evaluate the DH performance
VERI, UTRCI	DH manager	Robustness - Ability to adapt to heat demand evolution (short to long term)
VERI	DH manager	Satisfy current regulation constraints
VERI	DH manager	Robustness - Satisfy future regulation constraints
VERI	DH manager	Improve its attractivity
VERI, UTRCI	DH operator	Well integrated with current tools
CIT	DH operator	Get better situation monitoring overview
VERI	DH operator	Secure heat delivery , whatever the DH situation Technical Robustness , maintenance technical part



Partner	Stakeholder or project partner expressing a value	Values or benefits waited for by the stakeholder or partner
VERI, CIT	DH operator	Cost effective maintenance contracts (assets)
VERI	DH operator	Health & Safety
VERI	Subscriber	Decrease the bill
VERI	Subscriber	Transparency
VERI, CIT	Subscriber	Have tailored offers, answering different user needs and requirements
VERI	Subscriber	Visibility on the evolution of heat prices
VERI, CIT	End-User	Have a good comfort and a reliable heat source
CIT	End-User	Quick and effective response to complains
CIT	End-User	Transparency for users
VERI, CIT, Acciona	End-User	Have a higher control/implication/impact , at an individual scale
VERI	End-User	Simplicity of use
VERI, CSTB, Acciona	Local authority	Positive environmental image and lower impact on air quality (compared to an alternative solution) - Attractivity
CSTB	Local authority (region)	Comply with european/national directives (on land-filling of waste, use of renewable energy, energy efficiency...)
VERI	Local authority	Enhance local economic activity (compared to an alternative solution)
VERI	DH Owner	Improve its attractivity Maximise benefits Make sure that their infrastructures are properly managed Satisfy regulation constraints
VERI	General Contractor and Designer	Manage project planning risk (delay between DHN building period and completion of district program)
Acciona	General Contractor and Designer	Display costs and benefits of the options to be developed: - at three main levels: economy, energy and environment, - at secondary levels: safety of the option (safe supply), energy independence, easy O&M...
VERI	Investors/Project backers	Low the risks and maximize Return on Investment
UTRC-I	Technology Provider (Heating, Ventilation and Air-Conditioning ; District Energy Management Systems)	Increased market penetration thanks to new intelligent district Energy Management Systems - Innovative control and monitoring services for DHCN
CSTB	E ² District Partner (CSTB)	User-friendly , 3D, geographical visualisation of the results and scenarios Offering solutions to support decision making process at different time scale (short to long term) through advanced 3D visualisation of measured/calculated data or simulated results . The targeted users for such solutions are collectivities, district energy managers.
Acciona	Contracting authority and design	Optimize the initial investment in energy systems when constructing the system. (i.e. EPC - Engineering, Procurement and Construct contracts)

Table 3 Stakeholders needs as expressed by the different partners

2.2.3 Identification of stakeholders' services of interest



Based on the needs definition described in Section 2.2.2 we have identified services of interest for the different stakeholders. To do that, we have taken the stakeholders input and identified services of interest considering operation basis, improvement potential, DHCN attractivity, improvement to service provided and economy concerns. In addition, we have divided these services into three categories: need, constraint and wish. This has been done in order to support prioritization of the services that should be taken into account in the project. The results of this work are presented in *Table 5*.

Ref. n°	Stakeholder
1	DHCN manager
2	DHCN operator
3	DHCN owner
4	Subscriber
5	End-user
6	Local and/or national authority
7	General Contractor & Designer
8	Investor / Project backer
9	Technology provider

Table 4 Stakeholders associated to a reference number

	Need		Constraint		Wish	
	Ref n°	Service	Ref n°	Service	Ref n°	Service
Operation basis	1	Quality of service	1 - 3	Current regulations	5	Transparency
	2	Integration	2	Health and safety		
	2	Secure heat delivery	6	Regulation		
	5	Good comfort				
	6	Policy				
	3	Infrastructure properly managed				
	7	Planning risk				
	8	Risk and ROI				
	1 - 2	Technical robustness				
Improve operation	1 - 2	Situation overview			1	Robustness (future regulation)
	2	Integration			4	Visibility of prices evolution
	2 - 5	Simplicity			5	Quick response to problems
Attractivity	1 - 3	Local attractivity			5	Higher control / implication
	1 - 3	DHN attractivity			6	Image
	9	Innovative techno				
Improve service provided	7 - 9	Display costs and benefits (options panel)	4	Simplicity for end-user(s)	4	Transparency
	9	Simplicity			4	Visibility of prices evolution
					4	Tailored offer
Economy	1 - 3	Maximize benefit	1 - 3	Current regulation	4	Tailored offer
	2	Optimize maintenance contracts	1	Quality of service	6 - 8	Display costs and benefits (options panel)
	4	Decrease the bill				
	6	Local economic activity				
	8	Risk and ROI				
	9	Market penetration				

Table 5 Services of interest for each stakeholder²

² The stakeholders are represented in the table by their reference number, see Table 4



3 System definition

Based on the services needs definition presented above, we introduce the concept of a system that will formalize and address the needs of the stakeholders. Below we present a global view of the system, a division in four work areas, then a description of these work areas and finally a division of these work areas in different functions and their description. In this work we highlight also the correspondences between the functions and the tasks in the project proposal.

3.1 Global system purpose and work areas

3.1.1 Global system purpose

The system optimizes design and operation (technical and commercial) of the heating network in order to improve its energy, environmental and economic efficiency (these subjects will be more or less treated in function of the use cases defined later on in the project), and therefore improve mutual economic profit between DHCN manager, DHCN operator, subscriber and end-user.

3.1.2 Work areas included in the system

In order to better represent and define the system, we have divided it in 4 work areas:

1. Design of primary heating network
2. Operation of primary heating network
3. Group of buildings network
4. Value proposition of the heating network

The objectives of these work areas are:

1. Maximize the network efficiency (energetic, environmental and economic), through its design, answering end-users heat demand and taking into account foreseen innovative operation process
2. Maximize the efficiency of the network (energetic, environmental and economic), through operation within the design perimeter defined before
3. Offer new services to the subscriber and the end-user, especially improving interaction between the operator, the subscriber and the end-user
4. Improve DHCN value proposition to attract investors

These work areas, depicted in *Figure 1*, are linked with the others inside the solid black line and there are synergies in between them. Furthermore, they are positioned in an environment represented on the scheme by the dotted rectangles.



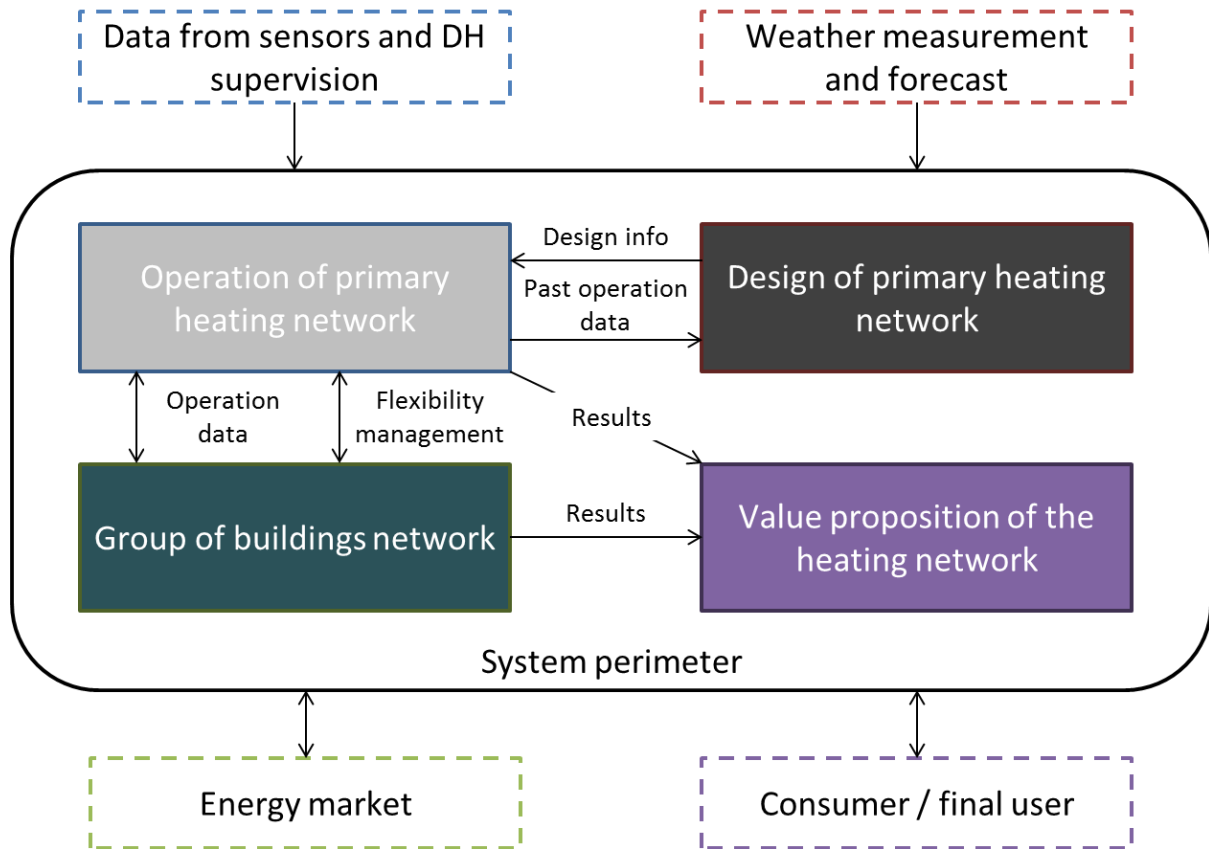


Figure 1 E²District Work Areas

3.2 Work areas in detail

3.2.1 Design of primary heating network

- Scope:
 - Includes all assets from the primary energy to the heat exchanger inside the substation
 - Takes into account innovative operation process developed during the project
 - Considers all kinds of flexibility (heat storage tank, overheating in distribution, buildings inertia, behaviour demand response) that can be taken into account in the optimization/simulation process
 - Optimization/simulation process doesn't include pipes layout and sizing, this is either defined by known rules for new DHCN or as an input constraint for existing DHCN
 - Considers only audit and design studies steps
 - Can use data and results from previous or current operation
 - Includes calculation and visualization
 - Includes IT systems, algorithms, methodologies, user guides, best practices
 - Does not include real-time, on-line, short term calculations (short horizon of time)

- Tasks



- Models the whole DHCN and alternative scenarios in terms of assets
 - Optimizes network design taking into account all kind of flexibilities
 - Makes calculations off-line, at the scale of one (or several) representative year(s)
 - Provides results with changes in demand trends (on several horizons of time) from one year to several years
 - Reports on local economic impact (jobs/direct activity, indirect activity ...)
 - Assesses different options for project and long term operation risks, taking into account district planning
 - Provides KPIs related to relevant energy, economic (esp. maintenance contracts), H&S and environmental aspects
 - Is able to assess different options for project risks, financial risks and technical & operational risks
- Targets
 - Provide a single interface with all necessary information
 - Be modular
 - Interface with external components such as tools, database, operators ...
 - Adapt/comply to different regulation contexts

3.2.2 Operation of primary heating network

- Scope:
 - Includes all assets from the primary energy to the heat exchanger inside the sub station
 - Considers DH operations steps (not the design steps)
 - Uses data and results from the “Design of primary heating network” sub system
 - Includes real-time, on-line, short term calculation, monitoring, control and visualization
 - Includes IT systems, algorithms, methodologies, user guides, best practices
- Tasks:
 - Computes different network operation optimization (as production dispatching, production scheduling and supply temperature) taking into account the different degrees of flexibility, end-users heat demand, asset reliability, Health & Safety, environment
 - Provides all necessary information to operate the network in a single interface, as real-time dashboarding, operation KPIs, ...
 - Detects and diagnoses anomalous performance
 - Reports on process variables relevant to maintenance contracts, regulation and Health & Safety
- Targets:
 - Provide a single interface with all necessary information
 - Provide a simple/intuitive end user interface (user experience)
 - Adapt / comply to different regulation contexts
 - Be modular
 - Be well integrated with current tools : Interfaces with external components such as tools, database but also with operators
 - Be able to make “Quick” data treatment (this target will be precised during WP1.2 and WP3, regarding temporal aspects of the operation decision



process)

3.2.3 Group of buildings network

- Scope:
 - Includes all assets from the heat exchanger in the substation to the building
 - Considers only DH operations steps (not the design steps)
 - Uses data and results from the sub systems “Operation of primary heating network” and more generally interacts with it
 - Includes real-time, on-line, short term calculation, monitoring, control and visualization
 - Includes IT systems, applications, algorithms, methodologies, user guides, best practices (including business models, billing best practices)
- Tasks:
 - Sends reports/recommendations (?) to the subscriber and the end-user to give them the opportunity to have higher control to decrease their own bill / their own consumption / their environmental impact. Models the subscriber behaviour including its sensitivity to different stimuli such as economical, environmental, ...
 - Analyzes feedbacks from the subscriber and the end-users
 - Creates and provides new business models taking into account flexibility of the prosumers. Supports intelligible/understandable tariff structures & bills
 - Provides personalized tariff structures, taking into account different subscriber segments
 - Provides a long term forecast of heat prices
 - Provides abstracted real-time information to “first-line support”
- Targets:
 - Provide a single interface with all necessary information
 - Provide a simple/intuitive end-user interface (user experience)
 - Interface with external components such as tools, database, operators ...
 - Be able to make “Quick” data treatment (this target will be precised during WP1.2 and WP3, regarding temporal aspects of the operation decision process)
 - Be modular

3.2.4 Value proposition of the heating network

- Scope:
 - No calculation, only visualization
 - Uses data and results from other sub systems
 - Can include IT systems, user guides, best practices
- Tasks:
 - Reports on process variables relevant to attractiveness (new technologies, green image...), local economic impact (jobs, direct activity, indirect activity) and policy
- Targets:
 - Be flexible and dynamic to catch attention
 - Offer a “marketing” display



4 Work areas functional architecture

From the needs identified based on the partners' experience, who themselves are stakeholders, we reviewed the system we'll develop through the project. The idea is to visualize the different parts of the district heating on which we'll propose new working opportunities: new tools / new methods.

The objective of this section is to detail the key characteristics of the different functionalities of the 4 work areas: input data, output data and the function description.

4.1 Design of primary heating network

4.1.1 Functional architecture

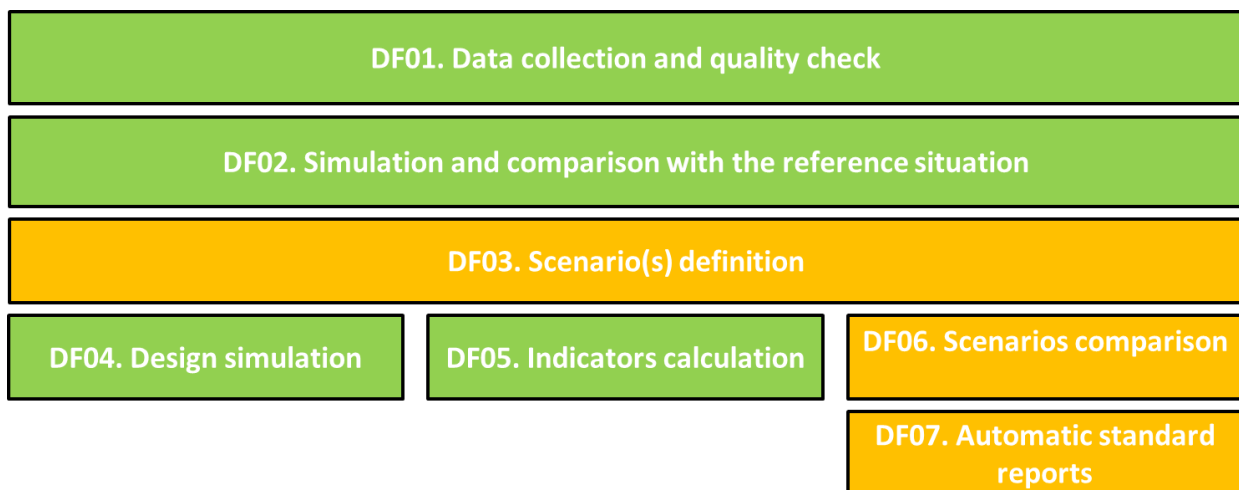


Figure 2 Design of primary heating network functional architecture³

4.1.2 Functions' list

Ref.	Designation	Summary	Stakeholder(s) involved
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³ In green the high level functionalities are explicitly mentioned in the proposal and have to be treated in the project, in orange the secondary level functionalities are not explicitly described in the proposal, but have to be treated in the project anyway. The way to address this point has to be detailed, as well as the corresponding task



DF01	Data collection and quality check	Collect and check data consistency and quality	DHCN manager, DHCN operator, subscriber General Contractor & Designer
DF02	Simulation and comparison with the reference situation	Parameterize and simulate the reference case	General Contractor & Designer
DF03	Scenario(s) definition	Set-up the different configurations to be assessed	
DF04	Design simulation	Calculate the results for each scenario	
DF05	Indicators calculation		
DF06	Scenarios comparison		
DF07	Automatic standard reports	Report the Results of the optimization process; main KPIs are shown	DHCN manager, operator and owner; General contractor & Designer

Table 6 Design of primary heating network functions' list

4.1.3 Functions' description

DF01-Data collection and quality check

Inputs	<ul style="list-style-type: none"> • Characteristics of the equipment and buildings (datasheets, audit) • Operating rules • Weather databases • Energy market • Data from current operation (annual reports, historical measured data from SCADA ...) • CAPEX / OPEX costs (for economic KPIs) • Building thermal properties (available data + audit) • Building geometry, manual or from GIS data (eg CityGML LOD1) • Time-dependent data (occupancy schedules, variable setpoints, weather) • DHCN components characteristics and operating rules
Outputs	Data stored in the IT system and formatted for being used by the simulation platform



Function description	<p>This function imports data from several different sources:</p> <ul style="list-style-type: none"> • From DH and building sources as supervision (historical measured data) • From external sources as datasheets, weather databases (measurement, forecast...), energy market (energy prices...) <p>This function stores data in the system, makes data available and useable for subsequent off-line simulation functions.</p> <p>Some consistency verifications are made :</p> <ul style="list-style-type: none"> - detection of missing value - detection of inconsistent numerical value (outside acceptable range of values) - time consistency - tag for each set of data (unique, standard naming) - All data for simulation are available <p>NB : data recovering will be manual, not automatic</p>
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Table 7 DF01 description

DF02-Simulation and validation of the reference situation (baseline)

Inputs	Data collected and gathered (from DF01)
Outputs	<ul style="list-style-type: none"> • Definition of the model: simulation engine calibrated for the pilot (for the “as-is” scenario), ready to be used for simulations according to improved “to-be” scenarios and • Definition of the “baseline” : calculation of the performance of the actual heating network over a reference period
Function description	<p>The aim to this function is to provide a “baseline” for assessing improved scenarios defined in DF03. The various data collected in DF01 are used to configure and calibrate the simulation engine. Main steps are:</p> <ul style="list-style-type: none"> • First, modeling each pilot district taking into account the description of the actual components like buildings, generators, DHCN, occupancy profiles, etc. • Then comparing results of simulation with actual measures (consumptions, temperatures, flow rates, etc.) – in same environmental conditions – in order to fine tune the simulation model and, so, obtain a validated “baseline” that will be used as a reference for assessing design scenarios.

Table 8 DF02 description

DF03-Scenario(s) definition

Inputs	Evolution of simulation parameters : equipment characteristics, equipment performance, operation strategy , occupant’s behavior, energy markets, financial parameters
Outputs	Scenario definition



Function description	This function aims to configure the model in order to simulate different scenarios: base line, and alternative scenarios that can take into account technical and financial risks or uncertainties.
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Table 9 DF03 description

DF04- Design simulation (of different technical scenarios including equipment sizing, operating strategy...)

Inputs	<p>Scenarios defined in DF03</p> <p>NB. A special attention will have to be paid to the translation of scenario requirements into DIMSOSIM compliant parameters, that will be strongly dependent on DF03 scenario definitions</p>
Outputs	<p>Energy performance associated to the scenario under the form of calculated time series over the year for a set of parameters (as required as input by DF05).</p> <p>All state variables associated to the operation of the DH network</p>
Function description	<p>The aim of this function is to run the simulation engine in different “to-be” scenarios compatible with the existing network (in case of retrofitting). These scenarios include design parameters like choice and sizing of different types of generators (co-generation...), integration of RES, operating strategy... It should be noted that the change of some DHCN geometrical parameters may require a manual intervention on the DIMOSIM calibrated model and can’t be automatically handled from input files.</p> <p>The output format can be multiple</p>

Table 10 DF04 description

DF05-Indicators calculation

Inputs	<p>State variables from Simulation outputs (DF06)</p> <p>Revenues (heat, electricity, other) and costs (fuels, personnel, maintenance, other, ...)</p> <p>Cost of investments</p>
Outputs	<p>Baseline definition for the heat consumption of the DH</p> <p>Technical KPIs to evaluate DH efficiency, cogeneration performance</p> <p>Environmental KPIs (carbon footprint, ratio of renewable energy and heat recovery, factor of primary resources)</p> <p>Economic KPIs (total cost of the heat, gross margin and sale ratio margin, profitability of investment if required)</p>



Function description	<p>This function computes the baseline to validate the amount of energy savings, the IPMVP protocol is used to have a reference of the heat consumption to evaluate the different gains.</p> <p>This function computes also the different KPIs related to the DH with different points of view (technical, environmental and economical) in order to compare different scenarios.</p>
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Table 11 DF05 description

DF06-Scenarios comparison

Inputs	<p>Data about performance (simulation outputs from DF04 + indicators from DF05) for a set of selected scenarios</p> <p>Criteria to be optimized</p>
Outputs	Synthesis presentation allowing decision-making with sorted scenarios according to chosen criteria.
Function description	<p>The aim of this function is to compare the performance of different scenarios for the design of primary heating network. The performance will be evaluated by means of simulation outputs and calculated KPIs (DF04, DF05).</p> <p>Relative difference between reference and alternative scenarios will be calculated</p>

Table 12 DF06 description

DF07-Automatic standard reports

Inputs	The results obtained in the data comparison performed in the previous function DF06 are collected in this function
Outputs	A report that enable to easily review the result of the optimization process, and the comparison among situations (current situation, optimal situation, and maybe in process)
Function description	<p>Information previously gathered are reported, based in the consideration of the next points:</p> <ul style="list-style-type: none"> - Use of the KPIs related to the 'Design of Primary Network'. - Comparison of the different scenarios results, using graphs and diagrams when possible. (It may include links to the visualization of more detailed info). - The report is mainly considered in an online web form, but the printable should be considered. <p>The result of the optimal scenario selected according to the comparison criteria, will be completely showed. A comparison with other best practices ratios in the industry can be shown.</p>

Table 13 DF07 description



4.1.4 Design Scenario Definition

Case 1: Optimize primary network (production and distribution) design of an existing DHCN (initial study and continuous improvement)

This first case only applies to existing District Heating networks, for which operation data are available. After a first phase of data collection and data checking (DF01), a simulation of the DH network is carried out (DF02), whose results and indicators are compared to the real operation parameters and indicators coming from the operation of this network. This comparison helps to check the validity of the model and can lead to an adjustment of the set-up of the models. After that, different scenarios can be defined (DF03), simulated (DF04) and compared (DF06) after step of Key Performance Indicators calculation (DF05). An automatic standard report can then be generated (DF07). Iterations can occur between DF06 and DF03, if, after scenario analysis and comparison, the end-user wants to study additional scenarios.

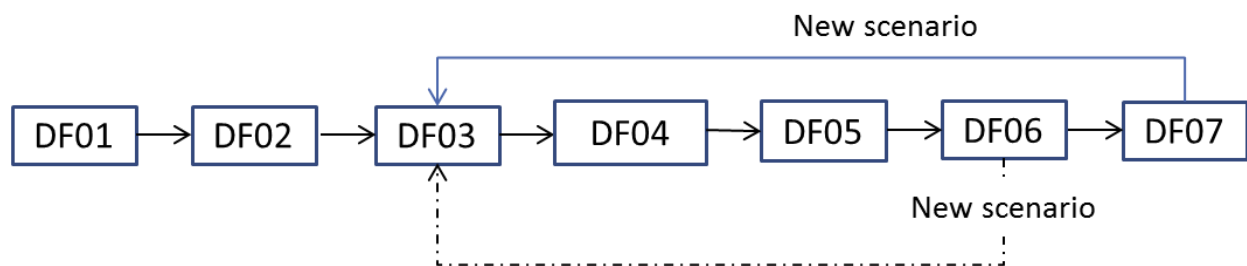


Figure 3 Primary network design optimization of an existing DHCN scenario

Case 2: Optimize primary network (production and distribution) design of a new DHCN

In the case of a new District Heating, the only difference comes from the fact that no comparison with real, existing operation data can be done. DF02 can however be executed, but the validity of the model will be assessed by the user's expertise.

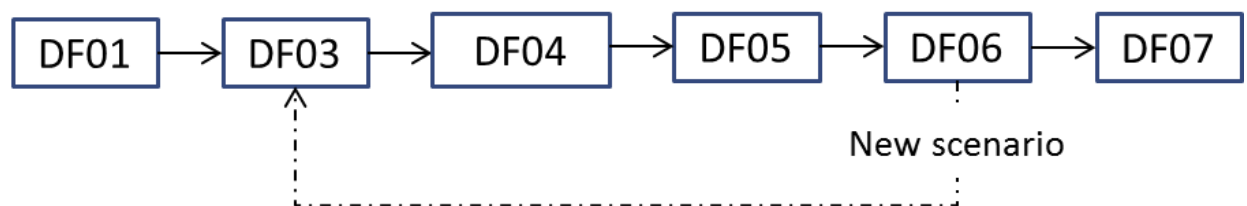


Figure 4 Primary network design optimization of a new DHCN scenario

4.2 Operation of primary heating network



4.2.1 Functional architecture

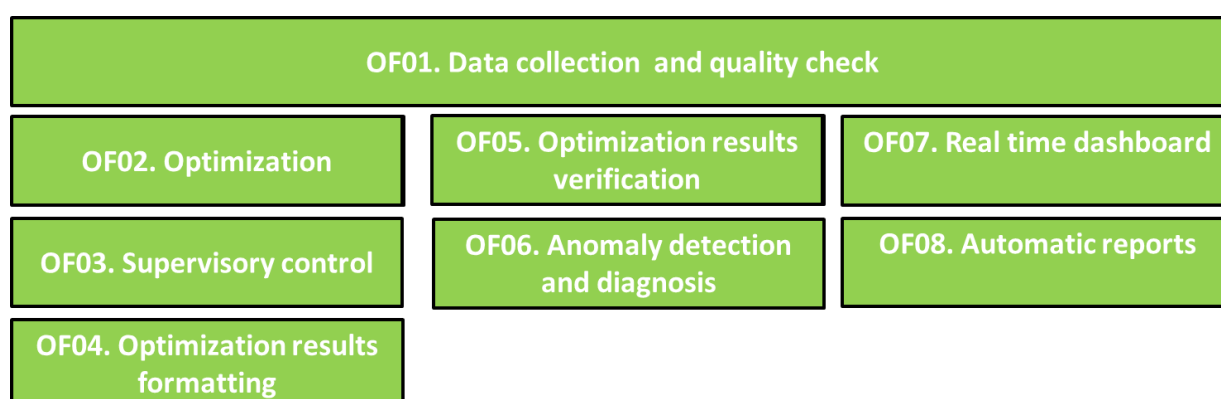


Figure 5 Operation of primary heating network functional architecture

4.2.2 Functions' list

Ref.	Designation	Summary	Stakeholder(s) involved
OF01	Data collection (Real Time and Historical) and quality check	Collect and store all data needed by other OF functions	NA
OF02	Optimization	Calculate the optimal way to operate the DHCN few days ahead from an economical point of view	DHCN Operator
OF03	Supervisory Control	Automatic control system to optimally coordinate different DHCN plant generation equipment (CHP, Boilers, Chillers, thermal storage, etc.) and optimize plant system efficiency	Technology Providers
OF04	Results formatting	Provide access to the stored data	DHCN operator
OF05	Optimization results verification, validation and record	Display results of OF02 and records, allows operator validate the results and record them	DHCN Operator
OF06	Failure Detection and Diagnosis	Detect anomalous performance from nominal system operating conditions.	Technology provider, operator, facility manager, building/system owner.
OF07	Real time dashboard	Visualization of stored data	DHCN operator , manager subscriber



Ref.	Designation	Summary	Stakeholder(s) involved
OF08	Automatic reports	Quick abstract of results for periodic report purposes	DHCN operator, Subscriber, end user

Table 14 Operation of primary heating network functions' list

4.2.3 Functions' description

OF01-Data collection (Real Time and Historical) and quality check

Inputs	Static data Characteristics of the equipment and buildings (datasheets, audit) Operating rules Building thermal properties (available data + audit) Building geometry, manual or from GIS data (e.g. CityGML LOD1)
	Dynamic data Data from sensors and DHCN supervision, data from external sources (as weather databases) Energy market (fuel and electricity prices) Time-dependent data (occupancy schedules, variable setpoints, weather)
Outputs	Data stored in the IT system Must be available for the other functions Alarm if problems of data consistency



<p>Function description</p>	<p>This function gathers, checks, and imports data from several different sources:</p> <ul style="list-style-type: none"> • From DH sources as sensors (temperature, flows, pressures...) or the supervision (alerts, set points...) through the deployed BMS as well as through additionally deployed sensors and/or actuators where necessary • From external sources as weather databases (measurement, forecast...), energy market (energy prices...) <p>This function stores data in the system, makes data available and useable for other system functions.</p> <p>Time consistency is secured: all data updates are stored with UTC timestamps. The semantics of this is such that a data-point is considered valid from this point of update until its next update. It is up to the subscribing modules to take this semantics into account.</p> <p>Data titles are unique: as an example, there can't be 2 data named the same, so in case of 2 "gas boiler outlet temperature", one will be called "gas boiler 1 outlet temperature" and the other "gas boiler 2 outlet temperature". The naming convention of the underlying BMS system will be used. Further information as to the individual context of the data points will be stored in the database as well and can be utilized by subscribing modules.</p> <p>Some consistency verifications are made :</p> <ul style="list-style-type: none"> - detection of missing value - detection of inconsistent numerical value (outside acceptable range of values → defined by experts, best practices, benchmark, historical values, etc) - time consistency - tag for each set of data (unique, standard naming, etc) <p>NB : data check will be made online</p>
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Table 15 OF01 description

OF02- Optimization

<p>Inputs</p>	<p>Defined in OF01 + BF02a and BF02b outputs</p>
<p>Outputs</p>	<ul style="list-style-type: none"> • OF07 → Display optimized parameters proposition for DHCN operation up to 5 days ahead • BF05 in order to give recommendations to end-users



Function description	<p>Calculate the optimal way to operate the DHCN few days ahead from an economical point of view. Forecast is a necessary part of this function. Both distribution and production must be taken into account to ensure a global optimization.</p> <p>The function delivers set-points calculation from a real time updated database providing</p> <ul style="list-style-type: none"> • Operating data (production, distribution) • Weather forecast • Electricity price forecast <p>Objective(s): revenues</p> <p>Degrees of freedom/Decision variables: e.g. production schedule, water supply temperature, delta pressure (or pressure differential), buildings flexibility, etc</p>
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Table 16 OF02 description

OF03- Supervisory Control

Inputs	<p>Real-time and historical data from DHCN, and optimal scheduled energy profiles:</p> <ul style="list-style-type: none"> - real-time data, collected from the system sensors and low level controller (from OF01), like: <ul style="list-style-type: none"> • Temperature • Flows • Pressures • Others - historical data from DHCN (from OF01) - energy price, weather, load and heat/cooling demand measurement and forecast (from OF01) - DHCN operational anomalies (from OF06) - forecast of energy production and distribution (from OF05) <p>BF02a and BF02b outputs</p>
Outputs	<p>Optimized set-point signals to low level DHCN equipment controllers and actuation variables</p>



Function description	<p>The intelligent self-learning supervisory control algorithm implemented in this function is an on-line closed-loop control algorithm. It will coordinate the wide variety of equipment and loads in the DHCN and will assign their set-points in real-time, ensuring the overall energy efficiency and cost-effective operation of the DHCN to varying climate conditions, load demand, end-user preferences/requirements, or operational anomalies.</p> <p>The feedback controller reads, on a regular sampling time, the real-time measurements coming from the DHCN, and possibly also historical data on it, and makes decisions on the control signals to be applied to the system in order to guarantee its optimal performance and energy efficiency operations.</p> <p>The supervisory control will account for the interaction between different DHCN plant generation equipment (chillers, CHPs, boilers), the distribution network and the end-user demand.</p>
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Table 17 OF03 description

OF04-Results formatting

Inputs	Data stored in the system
Outputs	API to access the data
Function description	<p>This function will provide access to the data collected in OF01 in a unified way through a suitable API.</p> <p>Interfaces will be provided that allow all subscribing modules to access the data formatted according to the interface contracts defined.</p>

Table 18 OF04 description

OF05-Optimization results verification, validation and record

Inputs	OF02 – schedule and set points calculated by optimization core
Outputs	<ul style="list-style-type: none"> - Trigger validated by operator <ul style="list-style-type: none"> o launch record result o Send Set points and plants commitment sent for dispatching and control - Trigger : not validated by operator <ul style="list-style-type: none"> o Keep classical operation



Function description	<p>Results of optimization (set points) have to be validated to operator, who decides manually whether the results are suitable with the current operation.</p> <p>The role of this function is to :</p> <ul style="list-style-type: none"> - Allows validating or not the proposal (manually by operator) → trigger - Record the proposal in database <p>NB. As a reminder, for Output of OF02 (optimization) is a recommendation, not directly sent for control</p> <p>KPIS for operator have to be defined</p>
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Table 19 OF05 description

OF06-Anomaly Detection and Diagnosis

Inputs	<p>Historical and real-time data (OF01):</p> <ul style="list-style-type: none"> • Sensor: Water Temperature, Loop temperature, Pressure, Flow rates, Room Temperature, Humidity (if application includes cooling system), Accumulator temperature – Capacity – current state; • Weather: Outside air temperature • Actuator: Valves and Pump commands • Exogenous: Occupancy <p>Meta Data: Building Information (Load, Capacity)</p>
Outputs	<p>Detected Anomalies in usage pattern,</p> <p>Estimation of efficiency loss</p> <p>Root cause information regarding detected issues.</p> <p>On demand report on the system health.</p>
Function description	<p>This task will focus on detecting anomalous performance and operational conditions using hybrid physics and data based diagnostics models. In order to train the models historical sensor, actuator and exogenous (e.g., weather) data will be used. Deviations from the nominal conditions will be detected and analyzed to improve the efficiency, energy consumption and comfort levels of the occupants. Actionable information will be provided to the stake holders (e.g., facility manager) to initiate: (a) appropriate measures to address the detected issues and (b) maintenance scheduling.</p>

Table 20 OF06 description

OF07-Real time dashboard

Inputs	<p>Data stored in the system</p> <p>OF02 – Results for optimized schedule</p> <p>OF03 – Supervisory control decision</p> <p>OF06 – See outputs of this function</p>
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Outputs	Web based dashboard
Function description	<p>This function will present the data stored in the system to interested parties through a web based dashboard.</p> <p>User login and access management will make sure that only publicly available data is visible to everyone, whereas other access privileges may be granted to certain stakeholders to have different views on the data.</p>

Table 21 OF07 description

OF08-Automatic reports

Inputs	The results and messages obtained in the calculations of the KPIs (in OF05), in the generation of alarms (in OF06) and in the detection of failures and diagnosis (OF06).
Outputs	<p>A report that enables the fast review the result of the Operation of the plant, and their evolution over time (behavior respect to the current established baselines).</p> <p>The report summarizes the results for a specific unit of time (week, month and year). This report is mainly oriented operation and management (but other stakeholders can use this periodic report of results.)</p> <p>Technical KPIs to evaluate DHCN efficiency, cogeneration performance</p> <p>Environmental KPIs (carbon footprint, ratio of renewable energy and heat recovery, factor of primary resources)</p> <p>Economical KPIs (total cost of the heat, gross margin and sale ratio margin, profitability of investment if required)</p>
Function description	<p>Information previously gathered in the mentioned modules are reported, based in the consideration of the next points:</p> <ul style="list-style-type: none"> - Use of the KPIs related to the 'Operation of the Primary Heating Network'. - Evaluation of results calculated/expected in the optimal new scenario in comparison with the results in the baseline. - The report is mainly considered in an online web form, but the printable should be considered. - The result of the different steps considered in this stage (diagnosis, supervision and optimization) should be showed here, providing advice about how to consider/implement those results. <p>This function computes the different KPIs related to the DHCN with different points of view (technical, environmental and economical) in order to help the analyze of the optimization results in an effective way.</p>

Table 22 OF08 description



4.3 Primary Heating Operation Scenario Definition

Scenario 1 : optimization of the production scheduling

- If bad quality data are detected (OF01), the alarm is displayed to the operator (OF07) and the default operation is kept
- If no alarm or bad quality data is detected, the function “optimization” (OF02) uses data to calculate the best set-points for production few days ahead.
- These results are displayed (OF07) to the operator, who validates them (OF05). If validation is positive, the production will function with optimized parameters.
- If validation is negative, default operation is kept.
- In parallel, if there is a need of flexibility, the optimization can ask how much flexibility buildings are offering (BF02a & BF02b) and then can trigger recommendations for occupants (BF05).
- For reporting performance of the decisions that have been taken, OF08 uses data stored in the database

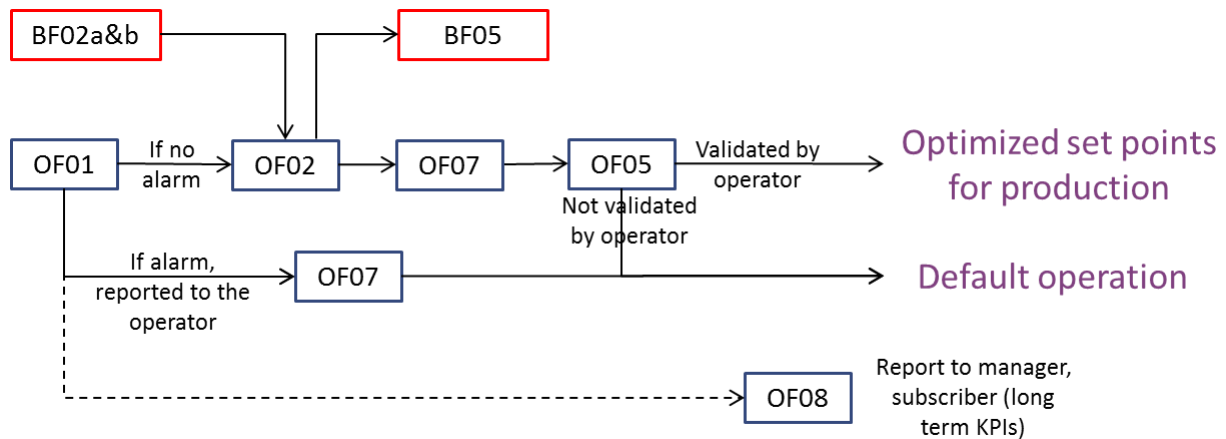


Figure 6 Optimization of production scheduling

Scenario 2: Supervisory control of the network

The supervisory controller reads, at regular time intervals, the real-time measurements coming from the DHCN, and possibly also historical data, which are provided by the OF01 function. The output of OF03 is the DHCN primary network equipment set-points, which are determined, based on the key system measurements and historical data inputs, and is the key decisions made by the supervisory control. The output of function OF03 is applied directly to the Primary Heating Network Actuation. The control decisions of OF03 can also be delivered to the web-based dashboard and ultimately reported for a further analysis and evaluation by the operator. The diagram below shows the simple use-case, described above, for the supervisory control. As the work in task 3.1 progresses in the next year, more relations between supervisory controls and other functions (such as OF02, OF05 and OF06) may be exploited and this use-case will be updated further.



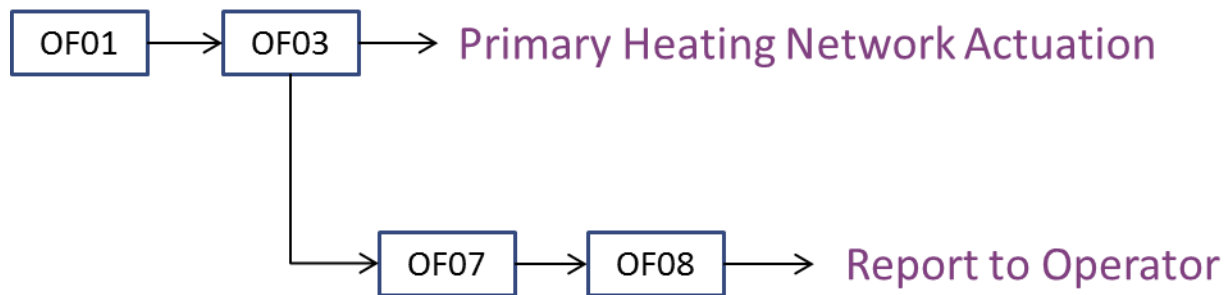


Figure 7 Supervisory control of primary heat network equipment

Scenario 3: Anomaly Diagnosis for the DHCN

From the stored data, two different anomalies can be identified:

- On the data quality (OF01). In this case, the alarm is displayed to the operator (as seen in scenario 1)
- On performance (OF06). In this case, the information is sent to the relevant stakeholders (e.g., facility manager, building/system owner etc.).

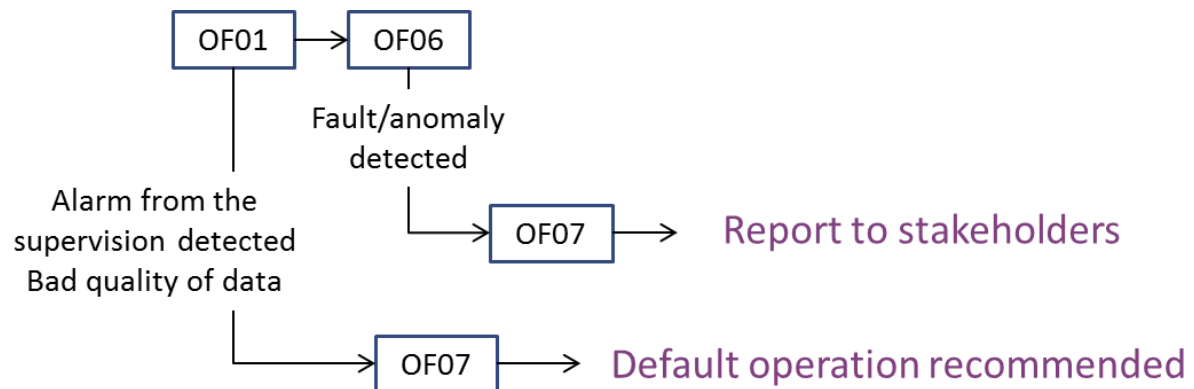


Figure 8 Anomaly diagnosis for the DHCN

4.4 Group of buildings network

4.4.1 Functional architecture

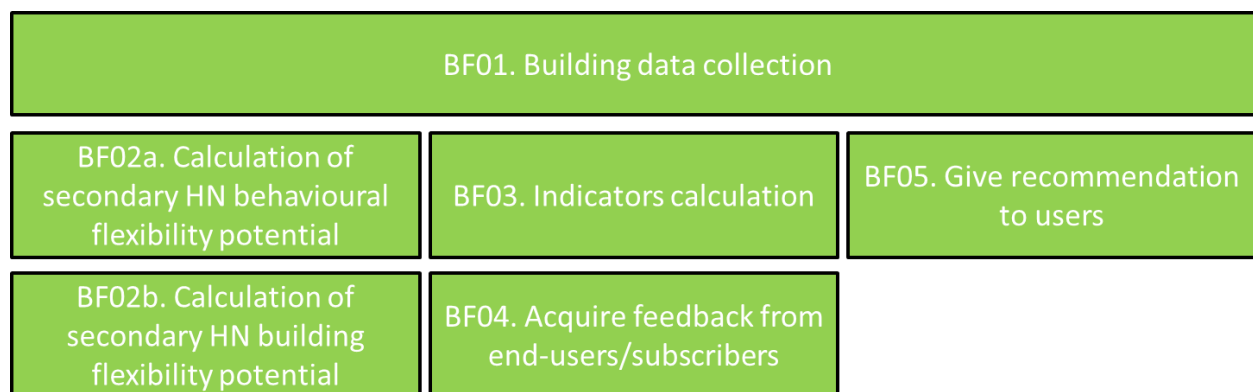


Figure 9 Group of buildings network functional architecture



4.4.2 Functions' list

Ref.	Designation	Summary	Stakeholder(s) involved
BF01	Building data collection	Collect all needed data for other building functions	NA
BF02a	Calculation of secondary HN behavioral flexibility potential	Execution of the behavioural model based on supply side constraints	DHCN Operator
BF02b	Calculation of secondary HN building flexibility potential	Calculate the buildings flexibility forecast of implied buildings	End-users DHCN Operator
BF03	Indicators calculation	cost, consumption, status, comfort	End-user, DHCN operator, manager
BF04	Acquire feedback from end-users/subscribers	Collect calibration data for the behavioural model	DHCN operator, end-user
BF05	Give recommendation to users	Provide action plans to end users based on the behavioural model	DHCN operator, end-user

Table 23 Group of buildings network functions' list

4.4.3 Functions' description

BF01-Building data collection

Inputs	Existing contract and information about buildings (Task 1.2) New business models (Task 6.3)
Outputs	BF02b, BF02a : constraints and rules



Function description	<p>Gather all constraints about buildings that will be necessary to calculate the flexibility</p> <p><u>From existing case:</u></p> <ul style="list-style-type: none"> - Definition of groups of buildings that we consider with a same behaviour - criticality regarding load control (hospital, critical substations ...) - constraints about contract (e.g. minimum supply temperature to deliver to buildings) - Space Heating (SH) only or SH+DHW - Buildings characteristics (size, number of buildings, thermal performance, inertia ...) - Existing load control strategies (night setback, DHW production schedule) - allowed deviation between required and real (with flexibility) T (indoor ? secondary ?) or required P (heat demand) → magnitude and duration - cost of this flexibility (economic compensation for flexibility, cost of complaints, ...) <p><u>From new business models</u> developed in Task 6.3, then can modify some of the aspects listed above (contracts, cost of flexibility, ...)</p>
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Table 24 BF01 description

BF02a-Calculation of secondary HN behavioural flexibility potential (including adaptation of operation of secondary HN)

Inputs	BF01 (constraints and rules for buildings, contracts), Behaviour model input parameters , sensor data, supply side constraints
Outputs	Feedback triggers, flexibility impact State of behavioural flexibility →OF02
Function description	<p>The behaviour model will be learned and adapted in this function based on all relevant information, including calibration data, sensory inputs, and the currently relevant supply side constraints.</p> <p>Potential end-user feedback triggers will be sent out to achieve behavior demand response. The potential expected impact of these behavior demand response triggers will be estimated and reported.</p>

Table 25 BF02a description

BF02b-Calculation of secondary HN building flexibility potential (including adaptation of operation of secondary) HN

Inputs	BF01 (constraints and rules for buildings, contracts), output OF01 (sensor data, ...)
Outputs	State of virtual storage proposed by all buildings inertia →OF02



Function description	<p>Calculate from the rule, the constraints and the historical data the flexibility (available quantity of energy stored in the buildings). It is an aggregation of the flexibility of each building</p> <p>This virtual storage can be defined with characteristics understandable by optimization tool, so as a normal heat storage tank (quantity of energy (MWh), maximum heat flow (MWh/h), temperature (°C))</p>
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Table 26 BF02b description

BF03-Indicators calculation

Inputs	<p>Data collection OF01 (Operation of primary heating network)</p> <p>Internal temperature of the buildings</p> <p>End-user feedbacks regarding the flexibility operations</p>
Outputs	<ul style="list-style-type: none"> • KPIs: Indicators are computed to evaluate: the flexibility rate of substations, the comfort of the occupants (monitoring of the indoor temperature), • Evaluation of the quality of services • Stakeholders and type of output will be defined according to BF04
Function description	<p>This function computes the different KPIs related to the flexibility and define a survey to evaluate the satisfaction of the occupants regarding the terms of contract.</p> <p>The results must be analysed for different cases:</p> <ul style="list-style-type: none"> • 1/ Short term engagement (flexibility and maximization of the efficiency) • 2/ Behavioural long term engagement (minimizing building consumption)

Table 27 BF03 description

BF04-Acquire feedback from end-users/subscribers

Inputs	End user feedback
Outputs	Input parameters for the behavior model calibration
Function description	<p>In this function feedback from end-users and subscribers is collected, either through classical questionnaires or by means of the smartphone app that will be developed and deployed.</p> <p>The relevant parameters of the behaviour model are extracted and used for its calibration.</p>

Table 28 BF04 description

BF05-Give recommendation to users



Inputs	Feedback triggers
Outputs	Recommendations and suggestions to users
Function description	<p>Based on the feedback triggers for behavior demand response generated by the execution of the calibrated behavior model suitable action plans will be provided to the end users.</p> <p>This will be executed through the developed smartphone application, the deployed communication kiosks, or through the web dashboards depending on availability.</p>

Table 29 BF05 description

4.4.4 Group of Buildings Scenario Definition

Case 1: secondary HN behavioural flexibility

In this case, BF02a determines the quantity of flexibility available with behavioral actions, and sends it to operation work area (OF02) to optimize the DHN operation. If required by OF02, then actions are required from end-users. The results of the actions could be used to eventually adapt the contract.

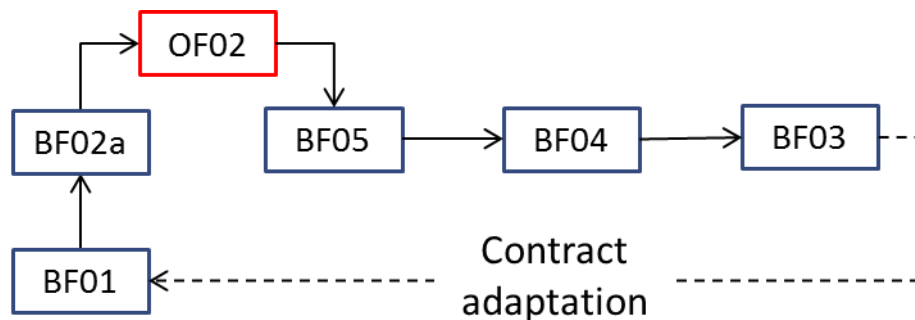


Figure 10 Behavioural long term engagement scenario

Case 2: secondary HN building flexibility

In this second case, it is the same concept, except the flexibility comes from buildings inertia and the control is done through the substations and not by the end-users (substations control is out of scope for the project).

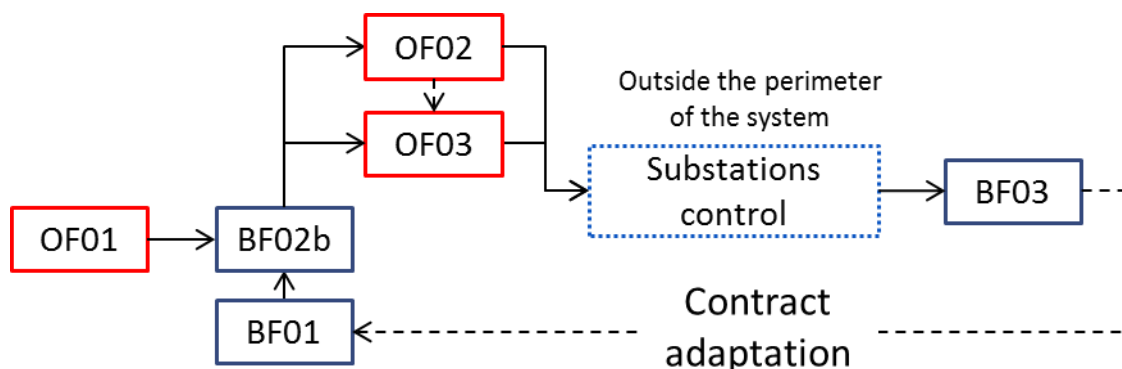


Figure 11 Building flexibility scenario

4.5 Value proposition of the heating network

4.5.1 Functional architecture

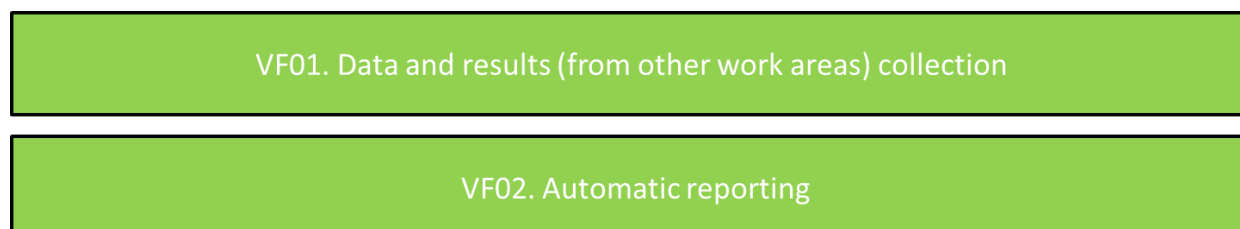


Figure 12 Value proposition of the heating network functional architecture

4.5.2 Functions' list

Ref.	Designation	Summary	Stakeholder(s) involved
VF01	Data and results (from other work areas) collection	Collection of energy performance results and translation to environmental, social effects.	DH operator & owner. All, Local & national authorities
VF02	Automatic reporting	Report the performance of the DH, highlight the environment, energy and over local economy effects.	All, Local & national authorities

Table 30 Value proposition of the heating network functions' list

4.5.3 Functions' description

VF01-Data and results (from other sub systems) collection

Inputs	Results from the other modules and optimization provide energy and design information. Especially for the 'Operation of Primary Network' and from the 'Group of buildings network'
Outputs	Environmental, primary energy, economic results.



Function description	<p>The information can be correlated with their environmental, primary energy and social-economic equivalent aspects that generate numeric results.</p> <p>The use of interactive graphs and visual interfaces are recommended, to provide a visual method to analyse the results.</p> <p>The data base of conversions factors (to primary energy, to CO₂ emissions, cost of energy, etc.) of the specific allocation is used.</p>
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Table 31 VF01 description

VF02-Automatic reporting

Inputs	The results of previous module VF01
Outputs	<p>A report to highlight the positive effects of the implementation or operation of a district at several levels:</p> <ul style="list-style-type: none"> - Fuel savings. - Primary Energy Savings. - CO₂ emissions reduction. - Economic savings (local and national) - Local economy effect attributable. - Other local effects (reduction of air pollution, traffic in fuel distribution, local jobs, direct/indirect activity, etc.)
Function description	<p>Information previously gathered in previous module is reported with a “marketing” perspective, thus is, to highlight the effects of the district in a global and local scope.</p> <p>It should consider the following:</p> <ul style="list-style-type: none"> - Report should be visual and flexible, adaptable to the different stakeholders that require the report. - Evaluation of results expected in the optimal situations in comparison with the calculated using the baseline (business as usual or current situation). - The report is mainly considered in an online web form, but the printable should be considered. <p>Information from the best practices and user guides can be used.</p> <p>Distribution can be also automatic to the closer and more interested/powerful stakeholders, or to be placed in a web to be accessible and downloadable in a more general way.</p>

Table 32 VF02 description



5 Conclusion & outlook

This deliverable aimed to define the requirements associated to the development of the E²District platform for the optimisation of District Heating and Cooling Networks design and operation. To do so, a three-step approach has been applied: identification of the needs of DHCN stakeholders, definition of tasks and proposition of a functional architecture that will help answering stakeholders' needs.

We divided the project work into four interlinked areas. A first one is dedicated to the optimization of the design of the primary heating network, through a scenario-based simulation approach. A second one aims to optimize the operation of the primary heating network and more specifically to optimize its production scheduling, its online supervisory control and includes a failure detection and diagnosis function. The “Group of buildings” section (everything from the substation to the buildings) addresses flexibilities related to the end-users, the buildings and the secondary network. Finally, the last work area is dedicated to the value proposition of DHCN to all stakeholders.

This work sets the basis for the definition of the technical specifications for the development of each platform, namely DSP (Task 2.2), DOS (Task 3.2), SC (Task 3.1) and Prosumer Engagement & Behaviour Analytics (Task 3.4). Besides, it identifies and describes the interactions between all those platforms, whose specifications will be developed in Task 2.1.

