CARING NATURE

Sustainable solutions for healthcare

D2.1- Report on requirement definition

Project Deliverable

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Dissemination level	Deliverable type
☒PU – Public ☐SEN – Sensitive	☒R - Document, report ☐DEM - Demonstrator, pilot, prototype, plan designs ☐DEC - Websites, patent filings, videos, etc. ☐ETHICS - Deliverables related to ethics issues ☐DMP - Data Management Plan ☐OTHER - Software, technical diagram, algorithms, models, etc

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Abstract

This deliverable includes the results of WP2 - Requirement Definition. It is articulated in two sections.

The first section provides the output of Task 2.1, consisting in an original sustainability framework for the healthcare sector, which will be the basis of Knowledge Sharing System that will be developed by the CARING NATURE project. The core of the framework is a catalogue of all the possible actions for implementing the transition of the healthcare providers towards more environmentally sustainable operations, while safeguarding the quality of care and optimizing the use of economic resources, identified through an extensive literature review and a rigorous Delphi process.

The second section provides the output of Tasks 2.2 and 2.3, and includes, for the 10 Solutions developed by the CARING NATURE project, the end user requirements, the definition of the Use Cases distributed among the five Healthcare organizations partnering the project, and the methods for testing, verifying and validating the Solutions using suitable KPIs. It also identifies the applicable standards issued by the standardization technical committees.

The section also describes the methodologies designed and applied to ensure efficient and effective requirement elicitation, homogenous and meaningful definition of the Use Cases and of the KPIs, together with the underlying logic of the testing/verification/validation methods and of the roles of the involved actors.

The content of the deliverable is based on extensive data/information collection and interaction between the partners responsible for the development and the five healthcare organizations partnering in the project as end-users, and on input from the Reference Stakeholder Group, which includes 50+ members, and from 13 experts for the Delphi consultation.

Keywords

User requirements, Use Cases, Key Performance Indicators, Testing, Verification, Validation, Target Adopters

History of changes

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v0.1	14/06/2024	Paolo Finocchi, Mauro Mini	Circulate for internal review
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v0.2	21/06/2024	Paolo Finocchi, Mauro Mini	Integrate feedback from reviewers and send it to the Project Manager
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ACRONYMS

Acronym	Description
AHU	Air Handling Unit
AI	Artificial Intelligence
ARB	Antibiotic Resistant Bacteria
ARG	Antibiotic Resistant Genes
CBD	Circular Building Design
CD or co-D	Co-Developer
CN	Caring Nature
CoP	Community of Practice
CSRD	Corporate Sustainability Reporting Directive
DSS	Decision Support System
DT	Digital Twin
E-LCA	Environmental Life Cycle Assessment
EBS	Existing Best Solution
EER	Elenco Europeo dei Rifiuti
EFRAG	European Financial Reporting Advisory Group
ESRS	European Sustainability Reporting Standard
EU	European Union
GA	Grant Agreement
GHG	GreenHouse Gases
GLSS	Green Lean Six Sigma
GTE	Green Transition Engagement
HC	HealthCare
HCGT	Healthcare Green Transition
HCP	HealthCare Provider
HCS	HealthCare Service
HVAC	Heating Ventilation and Air Conditioning
HWW	Hospital Waste Water
IAQ	Internal Air Quality
ICT	Information and Communication Technology
ICU	Intensive Care Unit
IT	Information Technologies
KPI	Key Performance Indicator
KSM	Knowledge Sharing Model
KSS	Knowledge Sharing System
JCI	Joint Commission International
LCA	Life Cycle Assessment
LD	Lead Developer
LSS	Lean Six Sigma
NBI	Natural Based Infrastructure
NG	Natural Gas
OR	Operating Room
PREM	Patient-Reported Experience Measure
PROM	Patient-Reported Outcome Measure
PV	Photovoltaic
RSG	Reference Stakeholders Group
S-LCA	Social Life Cycle Assessment
SFEM	Sustainable Finance Evaluation Model
SH	Stakeholders
SWOT	Strength Weakness Opportunities Threads
TA	Target Adopter
WP	Work Package

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Executive summary

This deliverable includes the results of WP2 - Requirement Definition. It is articulated in two sections, according to the Tasks of the WP: Task 2.1 (EU healthcare environmental sustainability model), Tasks 2.2 ("Results' requirements") and 2,3 ("Use cases and validation methodology definition").

SECTION A

The first section provides the output of Task 2.1, consisting in an original framework, the ***CARING NATURE HealthCare Doughnut framework***, meant to support the governance of the transition of the healthcare providers towards more environmentally sustainable operations, while safeguarding the quality of care and optimizing the use of economic resources.

The framework will also support the design of the Knowledge Sharing System (which is part of one of the 10 Solutions developed by CARING NATURE).

The framework, represented in the Figure 1 below, shows that the actions belonging to different domains (e.g. Buildings) must be implemented looking for an optimal trade-off between environmental impact reduction and health equity assurance, assessed in terms of the **"quintuple aim" metrics** (patient experience of care, health of the population, care providers' wellbeing, per capita cost of care, health equity).

Figure 1: CARING NATURE healthcare doughnut framework.

Its core component consists of a **catalogue of 105 possible actions clustered into 11 domains**, identified through a literature review based on 83 meaningful articles and 15 reports/guidelines/white papers and a subsequent shortlisting through a rigorous Delphi consultation that has involved 13 experts.

The catalogue includes (see the summary Table 1 below)

- 81 actions with **direct impact** in sustainability, clustered into 8 domains (Building, Energy, Food, Pharmaceuticals and Chemicals, Waste, WASH-Water, Sanitation, and Hygiene, Travel and Transport, Supply Chain
- 24 actions with an **enabling role**, clustered into 3 domains (Public Health Initiatives, Staff and Community Engagement, Financing and Funding Mechanisms).

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Table 1: Domains and actions of the CARING NATURE healthcare doughnut framework.

Domain: BUILDING *Environmentally sustainable hospital constructions and maintenance*
Actions
1) High-quality insulation materials and improvement of window glazing
2) Prioritize health impacts of material extraction, transport, use, disposal; use of replenishable and sustainable materials
3) Avoid harmful chemicals and hazardous substances
4) Refer to green building organizations guidelines
5) Substitute materials containing persistent bio-accumulative toxic chemicals (PBTs)
6) Include sustainability standards in the planning and construction
7) Provide financial support for energy-saving initiatives
8) Aspire to be carbon-neutral
9) Employ healing architecture and evidence-based design
10) Install air pollution filtration systems
11) Plant indigenous trees and plants
12) Optimize site planning
13) Use Local and Recycled Materials
14) Employ passive systems
15) Implement real-time energy monitoring systems
16) Use high reflectance roofing and paving or “green roof” systems
17) Design buildings with narrow floor plates and corridors
Domain: ENERGY *Adopting energy-efficient practices and integrating renewable energy sources to reduce the carbon footprint and improve the resilience and reliability of energy supply*
Actions
1) Choose an energy system based on factors pertinent to the facility
2) Assess health care facility’s energy use and practices
3) Install energy-efficient lighting
4) Install hybrid energy systems
5) Monitor air conditioning usage and adjust it
6) Reduce air changes overnight and weekend
7) Commit to transitioning to green
8) Prioritize energy sources and saving measures
9) Implement controls to turn off lights and appliances
10) Integrate occupant education and awareness programs
11) Defrost freezers and refrigerators regularly
12) Forge partnerships with local government
13) Conduct regular energy audits
14) Integrate heat pump technology
15) Perform an inventory of medical and other equipment
16) Implement renewable energy system
17) Replace older air conditioners, refrigerators and other appliances
Domain: FOOD *Reducing food waste, promoting sustainable nutrition, educate and raise awareness, increase plant-based options*
Actions
1) Minimize and beneficially reuse food waste
2) Promote healthy and sustainable nutrition
3) Redesign the menus both for visitors and staff
4) Educate and communicate within the hospital or health care system, as well as to patients and community
5) Establish patient-adjusted portion sizes
6) Supply food that is produced without synthetic pesticides and hormones
Domain: PHARMACEUTICS AND CHEMICALS

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Reducing the environmental impact of pharmaceuticals in hospitals, including the education of patients about the appropriate use of medications
Actions
1) Reduce the use of single-use items and promote sterilization and reuse of medical items
2) Substitute products with safer alternatives
3) Use floor-care products that are free of zinc, heavy metals, phthalates, glycol ethers and ammonia
4) Prevent disease exacerbation
5) Educate patients on appropriate inhaler use and shift from carbon-intensive MDIs to low-carbon alternatives
6) Improve packaging, labelling and identification of chemical waste
Domain: SUPPLY CHAIN *Hospitals and healthcare providers ought to adopt environmentally responsible supply chain management strategies, by leveraging their remarkable purchasing power*
Actions
1) Implement procurement policies
2) Emphasize efficient supply usage
3) Review procurement practices and local favour suppliers
4) Implement a sustainable purchasing agenda
5) Advocate for Extended Producer Responsibility
6) Placing importance on low-carbon substitutions
7) Coordinate hospital purchases to increase buying power and prioritize suppliers and products with circular economy approaches
Domain: TRAVEL & TRANSPORT *Healthcare organizations should explore alternative transportation options, such as electric or hybrid vehicles, and implement more efficient travel planning strategies*
Actions
1) Develop strategies for telemedicine communication
2) Improve digital health and telemedicine
3) Ensure that planning and design for new healthcare infrastructure take into account accessibility via public transportation and active mobility
4) Encourage cycling, walking, and alternative transportation modes
5) Provide healthcare in easily accessible locations
6) Renovate fleet vehicles
7) Install electric vehicle charging infrastructure
8) Incentivize staff to embrace electric vehicles
9) Purchase from local suppliers
10) Dispose of waste near the point of generation
Domain: WASH (water, sanitation and hygiene) *Effective water saving and good water management in hospitals are crucial for both environmental sustainability and operational efficiency*
Actions
1) Implement water conservation strategies
2) Regularly analyse water quality
3) Reinforce messaging about water use
4) Surveillance of diseases related to insufficient quality water, and sanitation
5) Implement on-site wastewater treatment
6) Manage wastewater safely through the use of on-site treatment
7) Eliminate bottled water facility-wide
8) Increase patient and visitor awareness
9) Landscape grounds using drought-resistant plants to minimize water use
***Domain:* WASTE** *Effective waste management practices, such as waste minimization, segregation at the source, proper treatment, and disposal, are essential for ensuring that healthcare activities do not compromise environmental quality and public health*
Actions
1) Implement and monitor a waste reduction programme

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2) Ensure adequate management of healthcare waste
3) Dispose of hazardous wastewater and liquid waste
4) Separate bins for potentially infectious waste
5) Develop medical device reprocessing initiatives
6) Develop and implement measures to manage and minimize the production of healthcare waste
7) Create incentives for healthcare facilities to be more sustainable
8) Minimize the production of general non-hazardous waste
9) Phase-out of incineration of medical waste
Domain: PUBLIC HEALTH INITIATIVES *Public health initiatives help constrain the demand for health services, thus minimizing the environmental impact of healthcare facilities*
Actions
1) Improve the performance of and access to environmental and occupational health services
2) Inform local communities about health systems activities and opportunities
3) Boost 'out-of-hospital' care
4) Use local green spaces for health promotion activities
5) Implement rapid diagnostic centres
Domain: STAFF AND COMMUNITY ENGAGEMENT *The staff and community engagement in sustainability initiatives can drive significant changes through daily practices and decision-making processes*
Actions
1) Build regional and national networks for climate resilience and sustainability
2) Educate healthcare professionals and build their capability
3) Raise public and workforce awareness
4) Call for research and funding for materials and processes
5) Take intersectoral action
6) Engage the health workforce and its associations and unions
7) Ensure healthcare facilities have sufficient numbers of healthcare worker
8) Develop a Roadmap and/or Action Plan
9) Advocate for specific policies, regulations, and legislation
10) Communicate and increase awareness
11) Make sure hospitals, health systems and health professionals advocate for environmental health policy and promotion
12) Establish a centralised authority
Domain: FINANCING AND FUNDING MECHANISMS *Access to adequate funds and the development of effective financing mechanisms to support the transition towards sustainability in hospitals*
Actions
1) Work with the government to access funds for net zero
2) Develop tools for an informed decision-making process
3) Review contractual mechanisms
4) Build a financial and clinical case for climate action.
5) Establish financial incentives to drive change
6) Integrate climate into the health system's financial decision-making process
7) Incorporate climate criteria with the aim of cost-effective decarbonization and resilience

SECTION B

The second section of the deliverable provides the output of Tasks 2.2 and 2, and includes, for the 10 Solutions[1] developed by the CARING NATURE project, the end user requirements, the definition of the Use Cases distributed among the five Healthcare organizations partnering the project, and the methods for testing, verifying and validating the Solutions using suitable KPIs. It also identifies the applicable standards issued by certified technical committees.

[1] According the Grant Agreement, the CARING NATURE project develops 10 Results. In this document, these **Results** are also named **Solutions**,

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Methodologies

To ensure homogeneity across the 10 Solutions, five specific methodologies have been designed and applied:

- A methodology for an efficient and effective requirements elicitation, based on the concept of "Target Adopter" needs
- A methodology for a meaningful definition of the Use Cases, based on the relevance for the end users, both internal and external to the project
- A methodology to get a set of more complete and SMARTer[2] set of KPIs (fine-tuning and enriching those already included in the GA), assessable during the project life through the validation activity.
- A method to ensure the as much as possible complete identification of the applicable standards based on the idea of referring to the relevant ISO/CEN/CENELEC Technical Committees
- A methodological framework to associate meaningful and implementable testing/ verification/validation methods (e.g. Questionnaires to assess quality, relevance and usability), taking into account types of solutions (methodologies, software, equipment, etc.) and of KPIs (performance, quality, relevance, usability), and including the indication of who will perform, for the testing, verification and validation:
    - the preparation of the methods (e.g. the detailed drafting of a Questionnaire).
    - the evaluation, i.e. will express the evaluation through the methods (e.g. fills the Questionnaire).

A sixth methodology has been defined for performing the activities of Tasks 2.2 and 2.3, to make sure that, despite the high number of solutions and partners, all the relevant partners and stakeholders could meet in highly focused meetings to elicit the requirements and define the Use Cases.

Given the tight connection between defining requirements and the testing and validation processes, T2.2 and T2.3 were conducted concurrently. This was achieved through a series of scheduled meetings aimed at gradually increasing the involvement of target adopters. The logic of the execution of the two tasks has been to group the meetings into three consecutive phases to gradually increase the interactions between the different organizations involved and the data acquisition for each Solution:

- Phase 1: bilateral meetings between the Lead Developer (LD) and the co-Developer (co-D), also using two forms on the Solutions (one filled by the LD, on filled by the co-D) and one filled by all the five end users to provide a profile of their organization
- Phase 2: meetings among the LD and the end users that will act as validators of the Solutions.
- Phase 3: five workshops (one per CN Objective) with external stakeholders of the Reference Stakeholder Group and the remaining end-users, to collect their needs. The RSG is composed of 50+ members, including healthcare providers, European associations, policymakers, and supply chain representatives. 22 of them have contributed to the Phase 3.

Key features of the End Users

The CARING NATURE Consortium includes five Healthcare Providers (HCPs) that have a key role both in the development and the validation process of the CARING NATURE Solutions. They represent a meaningful sample of "target" adopters of the Solutions, due to their differences in terms of geography/culture, type of health & care delivery, size (see Table 2)

Table 2: Summarized HCPs' key features.

Healthcare Provider	Country	HCP type	Size
FPG-Fondazione Policlinico Gemelli	Italy	Hospital	1.580 beds
FHAG- Fundación Privada Hospital Asil Granollers	Spain	Hospital	365 beds
UKHD- Universitatsklinikum Heidelberg	Germany	Hospital	2.600 beds
WPH- Wellbeing services county of Päijät-Häme	Finland	Health & Care Region	300 beds, 220.000 inhabitants served
7HRC-7th Health Region Crete	Greece	Health Region	2500 beds, 617.000 inhabitants served + 5 million tourists (2022)

[2] Specific, Measurable, Achievable, Relevant, Time-bound

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Furthermore, each of them has its own specific experiences with regard to the green transition, including energy and water management (FPG), initiatives in Photovoltaic Energy Generation and electricity, gas and water consumption reduction (FHAG), new building construction applying sustainability principles (UKHD), an environmental programme drafted in 2022 targeted at achieving carbon neutrality by 2035 (WPH). internal regulations for the management of Hazardous Medical Waste and projects on wastewater management (7HRC).

Solution 0+ requirements

The description of the 10 Solutions provided in the GA (named Solution 0) has been enriched with the requirements emerged from the meetings with the internal end users and the workshops with the members of the Reference Stakeholder Group (RSG), thus generating the Solution (named Solution 0^{+}) that will be developed.

The following Table 3 summarizes the key problems that the Solutions aim to solve in order to implement the Healthcare Green Transition (HCGT) (and whose relevance has been confirmed in the discussions with the end-users/stakeholders) and the additional requirements that the Solutions should satisfy in order to solve them.

Table 3: Problems and additional requirements per Solution.

#	Result/ Component	Key problems and Key requirements
R1.1	KSS-DSS (E-LCA, S-LCA, LCC, SFEM)	*How to convince funders to do HCGT investments?* • Make sure that R1.1, its components and R1.2 are well integrated one each other and with the GLSS-HC methodology • Allow what-if simulations • Customise the indicators by type of decision maker • Show the impact on the Sustainable Development Goals
	KSS-DSS (CSRD)	*How to efficiently and reliably comply with the new EU reporting regulation?* • Consider the specificities of the healthcare sector, for instance about the type of waste, staff, "clients" (the patients), stakeholders, supply chain, governance structure • Set guidelines to identify the sources of reliable information and the accountability for the quality of the data • Ensure that the qualitative information is informative and non-ambiguous • Ensure that the quantitative data that are already stored in the organization's databases are automatically collected and made available • Include in the software a workflow connecting all the actors and providing forms/checklists/instructions • Include a sound methodology for the execution of the materiality assessment. • Structure the report in a way that makes easy to identify the future priority areas in the green transition of the HCP • Explore how the Community of Practice methodology could be used in connection with the drafting process of the CSRD report
	KSS-DSS (KSS)	*How to capitalize and diffuse the knowledge on HCGT distributed in Europe?* • Use and enrich the *CARING NATURE HealthCare Doughnut framework* described in Section 2 with a model that links the actions to the Healthcare Green Transition processes and identifies and maps the Stakeholders contributing to the processes to identify the knowledge that they generate and need, and the relevant knowledge sharing community. • Leverage the CSRD reports as knowledge content of the KSS • Consider leveraging the variety of knowledge sources and destinations, in addition to individuals, facilitating the involvement of existing knowledge communities • Make the educational package fit with the shortage of time
	KSS-DSS (IT infrastructure)	*How to facilitate exchange/access between/from distributed users?* *How to minimize the data management effort?* A comprehensive set of 46 functional and 45 non-functional requirements have been identified

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		• The functional requirements are categorized into three groups: common to KSS and DSS, KSS-specific and DSS-specific. • The non-functional requirements apply to the entire KSS-DSS infrastructure and are classified into technical requirements, Security requirements, and Hardware requirements
R1.2	**GLSS-HC**	*How to do Business Process Re-engineering for HCGT in an efficient, effective and accepted manner?* • Include the Patient-Reported Experience Measures (PREMs) and Patient-Reported Outcome Measures (PROMs) in the set of KPIs to assess the process performance. • Define HC-specific methods to engage operators in the business process reengineering activities • Leverage the already available information not only from administrative systems but also from healthcare-specific and energy/facility mgmt systems
R2.1	**COMPASS**	*How to renovate and build HC facilities in a GT perspective?* • Pay attention to the building envelope and thermal and lighting comfort. • Consider the healthcare buildings' physical, geometric, energy-related, and social characteristics. • Ensure that the guidelines for procurement and design consider the security and confidentiality of the collected and managed data.
R2.2	**ENER**	*How to apply AI to monitor and reduce energy consumption in HC facilities?* • Pay particular attention to the management of critical areas • Consider the comfort in HC facilities as a priority. • Define the advantages of applying AI not only in a technical way but also in an economic perspective. • Ensure that the Solution takes into account the geometric characteristics, sensors, field data, historical field data, machine data, communication protocols, and maintenance reports. • Ensure that the Solution properly manages the security and confidentiality of the collected and managed data.
R3.1	**WR-MED**	*How to manage the OR waste in a GT perspective?* • Include in the guidelines a scheme for data/info collection • Include in the guidelines indications on how to involve personnel working in OR, since the beginning of the analysis • Define clear instructions to follow in order to perform the right separation of waste
R3.2	**WP-MED**	*How to reduce fossil fuel consumption through waste pyrolysis in HC facilities?* • Define how to use the by-product produced by the pyrolysis • Pay particular attention to the automation of the process • Ensure that the equipment can accommodate the different situations in terms of separation and classification of waste, the quantity of waste, the composition of waste in terms of materials, waste management costs, space available, and fuel used.
R3.3	**WP-FOOD**	*How to treat waste food in a more sustainable manner in the HC context?* • Ensure that the Solution complies with the national regulations related to the storage of waste food in the hospital • Ensure that the treatment process can accommodate the different situations in terms of separation and classification of waste food, quantity of waste food, waste food management costs, methodology of waste food's storage, number/distance/typology of biogas plant near the hospital
R3.4	**WP-WATER**	*How to treat waste water in a more sustainable manner in the HC context?* • Ensure that the treatment process can accommodate different situations, assessed with the chemical analysis of the hospital's wastewater • Ensure that the treatment process can accommodate the different situations in terms of water consumption and costs, wastewater production and costs, wastewater management, specific contaminants
R4.1	**TELEMED**	*How to maximise the diffusion of the specialistic telemedicine?*

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		• Make sure that the guidelines consider the multidisciplinary aspects of the telemedicine service • Find organizational solutions to consider that not all people can use digital services, in particular aging people and vulnerable groups • Provide recommendations on how cope with the poor connectivity in some areas in Europe • Make sure that the methodology to assess environmental, social, clinical and economic impact considers also the changes required at the home • Make sure that the guidelines consider the security and confidentiality of the collected and managed data
R5.1	**ENGAGE**	*How to motivate HCP staff to actively participate to HCGT?* From the **content** point of view, the ENGAGE model should consider that • People's behaviour and attitudes affect already identification of environmentally sustainable solutions • Attitudes may depend on the amount of extra work (Time as scarce resource) • The organizational culture is important to pay attention to • Not only the negative but also positive results must be focused • HC staff (50 million in EU) have a role as ambassadors of green transition, • Engagement in green transition may be hindered by the "we always did it this way" type of thinking, perception that environmentally sustainable solutions may lead to increased cost, feeling of security risk (e.g., reduction in use of gloves). From the **process** point of view, the construction of the CoP for ENGAGE and the implementation in the HCPs must consider that: • Sufficient time is needed. • Informed recruitment and motivating communication are essential. • Involving leading staff members is key, also because staff engagement is a resource question requiring use of working hours. • The CoP should include professional from different health and care services/units and represent different background • Possible staff changes should be considered beforehand so that they do not lead to problems in or even to ending the activities. • Access to instructions and other necessary knowledge must be given so that all participants have access to it • Sociocultural echoing about the process is important; accessible/attractive formats are essential (posters, videos, etc.) and may be country-specific • Special emphasis on the necessary facilitator expertise is a must, being key to the success of the use of the model.

Standards and regulations

Every effort has been done to identify the regulation (National and European) and the standards applicable to the CN Solutions. The following table summarizes the standards issued by the relevant 22 ISO/CEN/CENELEC technical committees and identified by the partner that takes care of the standardization topics in CN (DIN).

Table 4: List of standards and regulations in charge.

Technical Committee	Related CN Solutions
▪ ISO/TC 207- Environmental management ▪ ISO/TC 215 - Health informatics ▪ CEN/TC 251- Health informatics	Knowledge Sharing and Decision Support System (R1.1)
▪ ISO/TC 207- Environmental management ▪ ISO/TC 304- Healthcare organization management	Green Lean Six Sigma methodology for health and care (R1.2)
▪ CEN-CENELEC Joint Technical Committee (CEN-CLC/JTC) 11 - Accessibility in the Built Environment ▪ CEN/TC 67 - Ceramic tiles ▪ CEN/TC 350 - Sustainability of construction works ▪ CEN/TC 371 - Energy performance of buildings	Decision support system for sustainable architecture (R2.1)
▪ CEN/TC 442 - Building Information Modelling (BIM)	AI-powered decision support system for energy management (R2.2)
▪ ISO/TC 34 - Food products	Guidelines for medical waste reduction (R3.1)

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▪ CEN/TC 165 - Waste water engineering	
▪ ISO/TC 45 - Rubber and rubber products ▪ CEN/TC 216 - Chemical disinfectants and antiseptics	On-site medical waste pyrolysis plant prototype (R3.2)
▪ ISO/TC 34 - Food products ▪ CEN/TC 183 - Waste management ▪ CEN/TC 216 - Chemical disinfectants and antiseptics	On-site waste food anaerobic digestion & drying processes (R3.3)
▪ CEN/TC 165 - Waste water engineering ▪ CEN/TC 183 - Waste management	On-site wastewater anaerobic digestion process (R3.4)
▪ ISO/TC 215 - Health informatics ▪ CEN/TC 251- Health informatics	Guidelines for next generation telemedicine exploitation (R4.1)
▪ ISO/TC 283 - Occupational health and safety management	Participatory staff engagement model (R5.1)

Use cases

The Use Cases consist in the application of the CN Solutions in real contexts. Their role is to

- Support the co-development of the Solutions
- Provide evidence (data, information, users' perceptions) for the validation
- Provide lessons/stories/examples that can be used for dissemination purposes and feeding the KSS

The topic of each Use Case is shortly indicated in the following Table 5[3].

Table 5: Use Cases summary per Solution and HCP.

Objective	#	Result	Lead Developer	FPG *Italy*	FHAG *Spain*	UKHD *Germany*	WPH *Finland*	7HRC *Greece*
1-Governance	R1.1	KSS-DSS (E-LCA, S-LCA, LCC, SFEM)	SIMAVI+RINA+ UNIWA	Refrigeration Plant upgrade			Imaging capability centralization	Imaging modernization & decentralization
		KSS-DSS (CSRD)	SIMAVI+ UNIWA	CSRD of FPG			CSRD in 1 Hospital +1/2 local units	CSRD in 1 Hospital
		KSS-DSS (KSS)	SIMAVI+EUR	KSS applied to the RSG				
	R1.2	GLSS-HC	RINA-C	Cholecystectomy Patient Journey	Ophtalmology sugery Patient Journey	Pancreatic Resection Patient Journey		
2-Building	R2.1	COMPASS	4DA-ARPEL		TBD	Surgical pavilion	TBD	
	R2.2	ENER	I75	Research Laboratory Building	Outpatient Building		Rescue stations (TBC)	
3-Waste	R3.1	WR-MED	FPG	Cholecystectomy Operating Room	Ophtalmology Operating Room	OR Pancreatic Resection		
	R3.2	WP-MED	ERCS	WP-MED feasibility study		WP-MED feasibility study	WP-MED feasibility study	
	R3.3	WP-FOOD	CUT	WP-FOOD feasibility study	WP-FOOD feasibility study		WP-FOOD feasibility study	
	R3.4	WP-WATER	CUT			WP-WATER feasibility study	WP-WATER feasibility study	WP-WATER feasibility study
4-Patient's travel	R4.1	TELEMED	FPG	Rehabilitation; Pneum. Adults; Pneum. Children	Rehabilitation		Rehabilitation	
5-Staff engagement	R5.1	ENGAGE	LUT	CSRD CoP	Ophtalmology sugery Patient Journey CoP	Pancreatic Resection Patient Journey CoP	WPH Green Programme CoP	Imaging modernization & decentralization CoP

The Use Cases have been identified according to the following criteria:

[3]Tthe turquoise cells identify the co-development Use Cases. For the KSS there is only one Use case, that starts at M7 and ends at the M32: initially it will involve (as user of the KSS) only the 5 internal end-users and the stakeholders in their country; then it will expand to all the Refence Stakeholder Group members

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- The object(s) include a variety of content sufficient to fit the variety of functions of the result to be developed and validated
- It refers to a real situation
- It satisfies a real need of the Partner or supports another Use Case of the CN project
- It is specific to the healthcare sector.
- It allows to obtain good case studies to be used for dissemination purposes and for supporting the exploitation

All the 12 Use Cases required to develop the Solutions of CN[4] have been identified and sufficiently characterized to allow the start of the co-development phase from M7. Also 21 of the remaining 24 Use cases required for the validation (starting from M19) have been identified[5].

KPIs

The KPIs included in GA (and the final set) are related to the output (neither to the outcome or to the impact). More precisely, they **are qualifiers of the outputs (the results) delivered by the CN project**. The KPIs are needed to provide evidence of the successful development of the results. In order to define the final set of KPIs (based on the KPIs included in the GA), the following steps have been conducted:

- The KPIs included in the GA have been analysed to verify if they were sufficiently SMART; If not, they have been adjusted
- It was also checked if some key aspects of the result were not captured by the set of KPIs included in the GA; if so, some new KPIs have been added

In order to go through the steps in a systematic manner, we have made clear which are the aspects that we need to measure with a KPI: Performance (P), Relevance (R), Quality (Q) and Usability (U). The next table shows the final list of 28 KPIs[6] and the aspects of the Solution that they assess.

Table 6: List of all the KPIs and the aspects of the Solution that they assess.

Result	Result/ Component	Key Performance Indicator	Assessed aspects			
			P	R	Q	U
R1.1	**DSS (E-LCA, S-LCA, LCC, SFEM)**	1) **Relevance, quality and usability of the DSS (E-LCA, S-LCA, LCC, SFEM)**: average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs		x	x	x
	DSS (CSRD)	2) **Relevance, quality and usability of the DSS (CSRD)**: average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs		x	x	x
	KSS (process and content)	3) **Successful start-up of the knowledge sharing network**: at least 20 stakeholders, representing all the groups and least 15 European countries have participated to at least 2 knowledge sharing events	x			
		4) **Relevance, quality and usability of the KSS**: average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs and from 20+ stakeholders)		x	x	x
	KSS (education package)	5) **Relevance and quality of the education**: average satisfaction score >4 in a scale from 1 to 5 by the participants to the delivery of the course to managers of the 5 HCPs of the CN consortium and to external stakeholders		x	x	
	Software infrastructure	6) **Relevance, quality and usability of the KSS infrastructure** >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs and from 20+ stakeholders)		x	x	x

[4] Even if the Solutions are 10, two additional Use Cases are need for the KSS-DSS, because it includes three parts that require different types of Use cases

[5] One of the other 3 is To Be Confirmed (TBC); the other two are expected to be defined in July (M7).

[6] The blue ones were not present in the GA and have been added in WP2

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		7) **Relevance, quality and usability of the DSS infrastructure** >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs		x	x	x
R1.2	**GLSS-HC**	1) **Relevance, quality and usability of the methodology**: average satisfaction score >4 in a scale from 1 to 5 by the participants to the use of the methodology in three HCPs of the CN consortium (one patient journey per HCP)		x	x	x
R2.1	**COMPASS (DSS+ Design Guidelines)**	1) **Waste reduction in case of refurbishment works**: >80% vs standard approaches	x			
		2) **GHG reduction in case of refurbishment works**: >50% vs standard approaches	x			
		3) **Reduction of raw material use in construction**: >40% vs standard approaches	x			
		4) **Relevance, quality and usability of COMPASS (DSS)**: average satisfaction score >4 in a scale from 1 to 5 from the users		x	x	x
	COMPASS (Policy & Procurem. Guidelines)	5) **Relevance and quality of the COMPASS guidelines**: average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs		x	x	x
R2.2	**ENER**	1) **Alarm detection capability**: in the testing environment ENER detects 30% more alarms vs non-ENER monitoring, (in three HCPs of the CN consortium, one testing environment per HCP)	x			
		2) **Relevance, quality and usability of ENER**: satisfaction score >4 in a scale from 1 to 5 in each of three HCPs of the CN consortium		x	x	x
R3.1	**WR-MED (interventions on waste mgmt)**	1) Reduction of the CO2e due to the material used in the Operating Room activities > 10%	x			
		2) **Intention to implement the guidelines for waste management and the new tool**: in at least two of the three HCPs the staff involved gives a score >4 in a scale from 1 to 5 to the improvement interventions		x	x	x
	WR-MED (training)	3) **Quality and relevance of the training package for OR nurses, surgeons, and anaesthesiologists:** average satisfaction score >4 in a scale from 1 to 5 by the participants to the delivery of the training (at least 20 participants in total)		x	x	
R3.2	**WP-MED**	1) **Economic sustainability threshold**: ≤ 1,5 tons of medical waste per day (= a hospital with~350 beds)	x			
		2) **CO2e footprint reduction**: ≥ 30%	x			
R3.4	**WP-FOOD**	1) **A waste food anaerobic digestion plant is sustainable** at least for 500 kg of waste food per day	x			
		2) **A waste food drying plant is sustainable** at least for 200 kg of waste food per day	x			
		3) **The distance of the anaerobic digester from the hospital that makes transporting food waste is** feasible, in the context of the Use Cases	x			
R4.1	**TELEMED (guidelines)**	1) **Rapidity of implementation: the elapsed time to set up the telemedicine service** (from the decision to do it to the first visit done by the medical team) is < 3 weeks	x			
		2) **Relevance, quality and usability of the guidelines for setting-up the telemedicine delivery**: satisfaction score >4 in a scale from 1 to 5 in each of two HCPs of the CN consortium that will apply the TELEMED result developed by FPG		x	x	x
	TELEMED (sustainability assessment method)	3) **Relevance of the assessment methodology**: satisfaction score >4 in a scale from 1 to 5 in each of two HCPs of the CN consortium that will apply the TELEMED result developed by FPG		x	x	x

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R5.1	**ENGAGE**	1) **Contextual attraction power:** Total No. of participants to co-development and validation activities (workshops, events) in the range 70-120	x			
		2) **Model for health and care systems accepted by 5 health and care partners (the HCPs of the CN consortium):** in at least 4 of the HCPs the average "reinforced interaction and trans-professional knowledge sharing for green transition among the staff" score 4 in a scale from 1 to 5 by the participants		x	x	x

Testing, verification and validation methods

All the Solutions will be

- **Tested**, i.e. assessed in terms of "technical" quality vs good design practices and applicable standards
- **Verified**, i.e. assed in terms of fit with the functional description provided in the GA (Solution 0) and satisfaction of the requirements identified in Task 2.2 (Solution 0^+)
- **Validated**, i.e. assessed vs the KPIs (and their target values) derived from those included in the GA, and, for some results, vs additional KPIs to get a more complete evaluation.

The following table specifies for each of the CN Results (or component) the "type of result"[7] and, provides a summary view of the methods that will be used for each of the CN Result. The methods are consistent with the type of Result/Component and with the type of KPI, i.e. the type of aspect to be assessed (as shown by the colour code)

Table 7: Definition of the type of result and related testing/verification/validation method.

#	Solution/Component	Type of result/component	Testing (technical quality)	Verification (vs requirements)	Validation method (vs Result/Component's aspects)			
					Performance	Relevance	Quality	Usabiliy
R1.1	KSS-DSS (E-LCA, S-LCA, LCC, SFEM)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
	KSS-DSS (CSRD)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
	KSS-DSS (KSS process and content)	Methodology without O/P	Logical consistency	Inspection vs list	Parameter assessm.	Questionnaire	Questionnaire	Questionnaire
	KSS-DSS (KSS education package)	Training	Logical consistency	Inspection vs list		Participants' survey	Participants' survey	
	IT infrastructure	SW (transactional)	Sw testing	Inspection vs list		Questionnaire	Questionnaire	Questionnaire
R1.2	GLSS-HC	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
R2.1	COMPASS (Policy & Proc. Guidelines)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
	COMPASS (DSS+Design Guidelines)	SW (algorithmic)	Sw testing	Inspection vs list	Simulation	Questionnaire	Questionnaire	Questionnaire
R2.2	ENER	SW (algorithmic)	Sw testing	Inspection vs list	Simulation	Questionnaire	Questionnaire	Questionnaire
R3.1	WR-MED (interventions on w. mgmt)	Recommendations	Logical consistency	Inspection vs list	Benefit estimation	Questionnaire	Questionnaire	Questionnaire
	WR-MED (training)	Training	Logical consistency	Inspection vs list		Participants' survey	Participants' survey	
R3.2	WP-MED	Treatment equip./process	Sci./Tech testing	Inspection vs list	Feasibility study			
R3.3	WP-FOOD	Treatment equip./process	Sci./Tech testing	Inspection vs list	Feasibility study			
R3.4	WP-WATER	Treatment equip./process	Scientific testing	Inspection vs list	Feasibility study			
R4.1	TELEMED (guidelines)	Methodology without O/P	Logical consistency	Inspection vs list	Parameter assessm.	Questionnaire	Questionnaire	Questionnaire
	TELEMED (sust. assessment meth)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
R5.1	ENGAGE	Methodology without O/P	Logical consistency	Inspection vs list	Parameter assessm.	Questionnaire	Questionnaire	Questionnaire

[7] "Methodology with Output (O/P)" is a methodology that allows the user to obtain a usable output. "Methodology without Output (O/P)" is a methodology that guides the user in performing an activity but doesn't lead to a tangible output.

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Introduction

Hospitals and health facilities actively contribute to the global emission of CO_2, polluting gases and the production of large quantities of waste. Specifically, greenhouse gas emissions are associated with the high consumption of electricity and fossil fuels for heating, cooling, lighting and powering medical machinery. Another non-negligible aspect relates to the production of waste: in addition to the typical types of waste (organic waste, plastic, etc.) a specific category of waste is produced by hospitals and is represented by medical waste which must be appropriately treated.

Moreover, European hospitals are typically located in dated structures that require major renovations as they are technologically obsolete (both in terms of envelope and systems/plants). And many hospitals do not have an optimized energy supply, which offers considerable potential in terms of possible savings following a renovation process [1]

Faced with these challenges, the healthcare sector can benefit from adopting a sustainability framework that integrates different tools and methodologies to evaluate and improve the environmental, social and economic performance of healthcare facilities to develop and test innovative solutions to reduce energy consumption and increase the efficiency and climate resilience of healthcare facilities by promoting the transition towards a low-carbon healthcare sector in Europe.

The CARING NATURE (CN) project fits into this context by developing 10 different Results (or Solutions)[8] to increase the sustainability of the Healthcare Providers' facilities and operations

They contribute to five Objectives, as shown in next table[9].

Table 8: Objectives and Results/Solutions of the CARINGNATURE project

Objective		Results/Solutions		
		#	Short name	Short descriotion
Governance	Obj. 1-To increase the governance capability of the HCPs, policy makers and investors to implement the green transformation	R1.1*	KSS-DSS	Knowledge sharing and decision support system
		R1.2*	GLSS-HC	Green Lean Six Sigma methodology for health and care
Buildings	Obj. 2-To reduce the environmental impact of buildings' construction, renovation and energy demand	R2.1**	COMPASS	Decision support system for sustainable architecture
		R2.2**	ENER	AI-powered decision support system for energy management
Waste	Obj. 3-To reduce/valorise the medical, food and water waste	R3.1**	WR-MED	Guidelines for Operating Room medical waste reduction
		R3.2**	WP-MED	On-site medical waste pyrolysis plant prototype
		R3.3**	WP-FOOD	On-site waste food anaerobic digestion & drying processes
		R3.4**	WP-WATER	On-site waste water anaerobic digestion process
Paient's travel	Obj. 4-To reduce the environmental impact of patient travel due to outpatient/primary care delivery	R4.1**	TELEMED	Guidelines for next generation telemedicine exploitation
Staff engagement	Obj. 5-To obtain staff engagement in the green transition of the HCPs	R5.1*	ENGAGE	Participatory staff engagement model

* "enabling" results, **"primary" results

These Solutions will be developed by subject matter experts. To tailor these Solutions to the specific Healthcare (HC) context, it is important for the developers to be in close contact with the Healthcare Providers (HCPs) and their facilities, personnel and managers, in order to understand their needs and challenges. Additionally, it is important to define pilot Use Cases that are as representative as possible and can be followed and developed over the three years of this project.

The *Work Package 2 (WP2) Requirements definition* has had the purpose to put in contact the developers with the end-users and the external stakeholders and experts to set the basis of the entire

[8] According the Grant Agreement, the CARING NATURE project develops 10 Results. In this document, these **Results** are also named **Solutions**, due to their capability to "solve" the problem of how to reduce the environmental impact while safeguarding the quality of care and optimizing the use of economic resources

[9] "primary" results will directly produce a positive environmental impact in the HCP, while the "enabling" results will enable the adoption of the "*primary*" results

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project in terms of context framework, stakeholders' needs and Results' requirements, testing, verification and validation approach.

This deliverable D2-1 contains the output of the entire WP2. It is organized as follows:

- **Section A,** which provides the output of Task *2.1-EU healthcare environmental sustainability model* of the WP2 , i.e. an original sustainability framework for healthcare sector, which will be the basis of Knowledge Sharing System that will be developed by the CARING NATURE project.

  The Section, after a background Chapter 1, in the methodological Chapter 2 explains the methodology to identify the domains and the actions that are at the core of the framework, describing how the literature review and the subsequent Delphi consultation have been performed. Chapter 3 then presents the outcome of these two activities. Chapter 4 presents the final result of the Task 2.1, i.e. the CARING NATURE Healthcare Doughnut framework, which incorporates the outcome of the Delphi consultation (the domains and the actions)

- **Section B,** which provides the output of Tasks *2.2-Results' requirements* and *2.3-Use cases and validation methodology definition*, i.e., for each of the 10 Solutions developed by the CARING NATURE project, the end user requirements, the definition of the Use Cases distributed among the five Healthcare organizations partnering the project, and the methods for testing, verifying and validating the Solutions using suitable KPIs. It also provides the applicable standards issued by certified technical committees and the key features of the five Healthcare organizations. The section describes the methodologies designed and applied to ensure efficient and effective requirement elicitation, homogenous and meaningful definition of the Use Cases and of the KPIs, together with the underlying logic of the testing/verification/validation methods and of the roles of the involved actors

  The Section, after the methodological Chapter 5, presents in Chapter 6 the five CN end-users to show that they are representative sample of European HCPs. Then, the Chapters from 7 to 11 are dedicated to each one of the 5 Objectives. Each Chapter is articulated by Solution and, for each Solution, provides all the information that will allow its development, testing, verification and validation, i.e.

  - The description of the Solution taken from the Grant Agreement (GA), named Solution 0
  - The requirements emerged from the work done in WP2; they enrich the Solution making it more fitting with the needs of the end-users; the enriched Solution is name Solution 0^{+}
  - The applicable standards and regulations
  - The co-development Use Cases, which will facilitate the development, and the validation Use Cases, which will provide further evidence of the Solutions' validity and input for their finetuning
  - The Key Performance Indicators (KPIs) and the methods that are planned to test, verify and validate the Solutions.

- A **final Section** draws the conclusions for both the Section A and Section B and briefly indicates how this deliverable is expected to contribute to the future activities of the project, both from the content and process point of view.

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Section A - Output of Task 2.1: Sustainability Framework in the HC sector

1. Background

The health sector is a major contributor to climate change, which in turn is expected to cause a global health emergency in the next few years [2]. It is paradoxical that healthcare systems, which are tasked with protecting and promoting health, are undermining it, making themselves co-responsible for the climate crisis. The carbon footprint of the healthcare sector equals more than 4.4% of global net emissions (2 gigatons of carbon dioxide equivalent), comparable to the annual greenhouse gases emissions of 514 coal-fired power plants [3]. More specifically, if the healthcare sector was a country, it would be the fifth-largest emitter on the planet. The three main emitters in the healthcare sector—the United States, China, and collectively, the 27 European Union countries—account for more than half of the healthcare sector's total carbon footprint worldwide (56%) [4]. Most emissions (about 71%) are actually indirect and associated with the supply chain, that is, the procurement of goods needed to carry out sector activities. Examples are the production, packaging, transportation, and disposal of goods and services purchased by healthcare, related to pharmaceuticals and other chemicals, medical and non-medical devices, food, hospital equipment, tools, and more.

At the United Nations Climate Change Conference held in Glasgow in 2021 (COP26), fifty countries committed to developing low-carbon healthcare systems, and fourteen of them also set a target date to achieve net-zero emissions by 2050 [5]. These countries follow the path set by the United Kingdom, which was the first to commit its NHS (National Health System) to becoming "carbon net zero," adopting measures such as increasing community care, greening the vehicle fleet, reducing the waste of consumables, building new zero-emission hospitals and training healthcare staff on energy saving [6].

Two other virtuous examples that propose frameworks useful to support decisions on actions to reduce the carbon footprint are those of the World Health Organization [7] and Health Care Without Harm [8].

The first is provided by the national environmental sustainability policy for health systems, developed by the WHO Europe Regional Office. It expresses the principles, commitments, and priorities of the organization with respect to the environment through a decrease in demand for health services, delivery of appropriate care, a reduction in the overall environmental footprint of health services and endorsement of planetary health action across other sectors and society as a whole.

The second framework aims to protect patients from climate-related hazards, including extreme weather events, hospital buildings from climate-related hazards, including extreme weather events, and to create blue-green infrastructures. These initiatives further suggest how the healthcare system plays a key role as a strategy for adapting to and mitigating climate change.

To raise awareness of the problem, especially among healthcare stakeholders, it is appropriate that all levels of the healthcare system, from hospital management to Local Health Authorities and higher up to the ministries, be aware that the right path must be that of a green transition.

For this reason, **Caring Nature aims to create a framework that serves as a comprehensive guide for environmentally sustainable healthcare governance and management**. It includes recommendations for **mitigation actions** and adaptation measures, ensuring high-quality care while efficiently utilizing economic resources.

2. Methodology

A key component of the framework is the set of mitigation actions. The methodology applied to identify these actions has been a **mixed approach** consisting of (1) a **literature review** to detect existing frameworks of sustainable healthcare, (2) a **Delphi consultation** to test the relevance and feasibility of actions from the viewpoint of a group of European healthcare experts. The study was conducted in compliance with the EU General Data Protection Regulation n. 679/2016.

2.1 Literature review

A literature review (peer-review literature and grey literature) was performed to detect existing models of sustainable healthcare systems and to identify actions to reduce its environmental impact, in order to build a framework that can support the European healthcare sector to govern its green transition while safeguarding the quality of care and optimizing the use of economic resources.

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Scoping review

The scoping review has been developed using the 5-stage methodological framework described by Arksey and O'Malley for scoping reviews [9] and follows the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist [10]. To understand how to target as best as possible our literature search and define the search string and inclusion criteria, a preliminary investigation on the following concepts was conducted using institutional sources and literature reviews: *Definition of Carbon Footprint; GHGs; Scope 1,2 and 3; Telemedicine; Supply chain; sustainability policy for health systems; policy framework.*

Following the preliminary research, the research question was formulated according to the PCC (population, concept, context) framework:

- **P (population)** – Health care workers and other stakeholders (e.g., patients, citizens, politicians)
- **C (concept)** – Sustainable hospital facilities models created and/or implemented
- **C (context)** – Healthcare systems, hospital facilities, public health institutions, health care service and health care workers.

The databases PubMed, Web of Science, Scopus were searched for articles published from January 2009 to January 2024 and written in English. The search was conducted from 07/01/24 to 30/01/24.

The following search string was used: *("hospital*" OR "Healthcare facilities*" OR "Healthcare system*" OR "Health institution*") AND("CO2 emissions" OR "carbon footprint" OR "supply chain" OR "care provision" OR "vehicular emission*" OR "personal travel" OR "business travel"OR "industrial proces*" OR "operating room*" OR "canteen" OR "heating system*" OR "cooling system*" OR "medical equipment" OR "non-medical equipment" OR "anaesthetic gas*" OR "inhalers" OR "pharmaceutical*" OR "chemical*" OR "telemedicine") AND ("waste management" OR "waste reduction" OR "energy efficiency" OR "energy conservation" OR "energy usage" OR "building energy").*

To be included, publications had to meet the following inclusion criteria: peer-reviewed articles analysing the existence of frameworks for sustainable hospital facilities in the international context. In consideration of the research question, no restrictions were made based on article type or study design, thus opinion papers, commentaries and editorials were also considered for the inclusion.

The identified articles were uploaded on Rayyan software [11] and duplicates were removed. Then, two independent researchers performed the first screening based on titles and abstracts. A third researcher examined conflicting records and consensus was reached through discussion. The pertinent articles with full texts available were reviewed independently by two authors and the articles satisfying the eligibility criteria were included in the scoping review.

Three investigators extracted the data. From each eligible article, they extracted information on the first author, journal and year of publication, country, type of author (institutions, independent investigators, research centre etc.), article type, study design, setting, type of sustainable models, bottlenecks/gaps identified.

Grey literature review

The research questions of the grey literature review were:

1) *What do already existing documents from national and international health-related organisations tell us about the characteristics of sustainable healthcare?*
2) *Which key domains/areas should be considered to enhance the sustainability of healthcare systems?*

At this stage and in the following activities of the task, we used the term “domain” to refer to distinct areas of action or categories that encompass various strategies, practices, and initiatives aimed at reducing the Carbon Footprint of healthcare.

To answer these questions, a grey literature review on Google Search was conducted from 15/01/24 to 31/01/24, using the following search terms: *Health system; Sustainable(bility); Resilien(ence)*. Additionally, we performed a snowball search from identified publications, and a hand-searching of specific institutional websites, i.e. international health-related organisations, health authorities, universities and institutes with expertise in healthcare system research and policy, etc. Any documents not usually published as a peer-reviewed article, which contains mainly expert opinion, knowledge synthesis or recommendations were included, i.e.: Position statements, white papers, policies and policy briefs, annual reports, guidelines and recommendations, theses/dissertations, book chapters, opinion

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pieces/essays. Two investigators extracted the data. From each eligible article, we extracted information on institution, title, year of publication, type of model, domains/areas of actions, single actions for each domain.

The results of the scoping review and grey literature review were merged to identify key domains to enhance the sustainability of healthcare systems. Each domain encompasses a list of actions, extracted from literature, that could be implemented to improve the sustainability of healthcare systems. All the actions resulting from the literature were included in the final domain lists with no filters; the researchers reported the actions verbatim, with slight adjustments where needed (i.e. synthesis of redundant actions).

The list of actions, divided into domains, was then sent to the partners of the Caring Nature project [12], who were asked to review, select, and provide feedback on the actions related to their domain/s of expertise. This step led to the final version of the list of actions which were included in the Delphi questionnaire.

2.2 Delphi consultation

A classic Delphi technique was used to build consensus on the relevance and feasibility of each action included in the domains. The classic Delphi technique involves experts in the field answering questionnaires in two or more rounds [13]. After each round, an anonymous summary of the experts' responses from the previous round is provided, with the opportunity for the experts to rethink their response until consensus is met. The questionnaires for each round were distributed online; this method facilitates the collection of responses and feedback within short time frames.

Potential experts were nominated if they had a broad perspective on healthcare management and were divided into three categories of experience: (1) scientific experience (academia, research institutes); (2) practical or managerial experience (hospital managers, local health district managers); (3) policy experience (public health associations, health decision-makers at the national level). We attempted to balance the number of potential experts from each category to ensure each was represented. Potential experts were suggested by the partners of the Caring Nature project (10) and/or by the core study team and were invited by email to take part in the study and asked consent to participate. We used EUSurvey - the European Commission's official multilingual online survey management tool [14] - to create and administer the questionnaires. Our aim was to recruit 8 to 23 experts, which has been described as the panel size to allow meaningful statistical analysis [15].

In the survey, the experts found questions regarding the domains resulting from the literature review. Each domain encompasses a variable set of actions that can be implemented to improve environmental sustainability in healthcare. They were asked to assess the **general relevance** and the **feasibility** of each action, on a Likert scale from 1 to 9 (for general relevance, 1 was not relevant at all and 9 absolutely relevant; for feasibility, 1 was not feasible at all and 9 was absolutely feasible). They also had to express any additional opinions or insights they might have in the free text boxes available throughout the questionnaires.

Table 9: Decision rules for Delphi-General Relevance

		Median (1–3)	Median (4–6)	Median (7–9)
Round 1	Agreement (≤70 %)	Equivocal; discussion Round 2	Equivocal; discussion Round 2	Equivocal: discussion Round 2
	Agreement (≥70 %)	Inappropriate; excluded after Round 1	Equivocal; discussion Round 2	Appropriate; included after Round 1
Round 2	Agreement (≤70 %)	Equivocal	Equivocal	Equivocal
	Agreement (≥70 %)	Inappropriate	Equivocal	Appropriate

To analyse results on **general relevance**, we followed the decision rules shown in *Table 1*, adapted from Valentijn P.P. et al. (2015) [16].

Agreement was reached in the Round 1 if ≥ 70 % of panellists' ratings were within the same 3-point region (that is, 1–3, 4–6, or 7–9) as the observed median. A feature was thus defined as "*appropriate*" in the Round 1 with an overall panel median score of ≥ 7 and a level of agreement of ≥ 70 % within the 3-point region 7–9; appropriate features were included in the final list of actions after Round 1 and were not proposed again in Round 2. A feature was defined as "*inappropriate*" in the Round 1 with an overall panel median score of ≤ 3 and a level of agreement of ≥ 70 % within the 3-point region 1–3; inappropriate features were excluded from the final list of actions after Round 1 and were not proposed again in round

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2. A panel median of 4–6 or every median with a consensus of ≤ 70 % within the same 3-point region was defined as "*equivocal*"; equivocal features were proposed again in Round 2.

In Round 2, a feature was defined as "appropriate" with an overall panel median score of ≥ 7 and a level of agreement of ≥ 70 % within the 3-point region 7–9; appropriate features were included in the final list of actions after Round 2.

For **feasibility**, features where the median was equal to or greater than six and 70% of experts had given a score equal to or greater than 6 were considered "*feasible*". These features were included in the final list of actions after Round 1 and were not proposed again in Round 2. Responses where the median is less than 6 and the percentage of agreement among experts was less than 70% were considered "*equivocal*" and were proposed again in Round 2.

At the end of the two rounds of Delphi consultation, the actions were divided in four classes (Table 10).

Only actions in Class A and B1 were included in the framework.

Table 10: Class stratification of action and definition of classes.

CLASSES	DEFINITION	CONCLUSION
Class A	General agreement that an action is relevant and feasible	Action included in the framework
Class B	Divergence of opinion about the relevance and/or feasibility of an action	
Class B1	Action relevant but not feasible	Action included in the framework- Additional research is required to address feasibility barriers
Class B2	Action not relevant but feasible	Action not included in the framework
Class C	General agreement that an action is neither relevant nor feasible	Action not included in the framework

3. Intermediate results

3.1 Results of Literature review

Scoping review

The scoping review led to the identification of 332 articles (see Fig. 2).

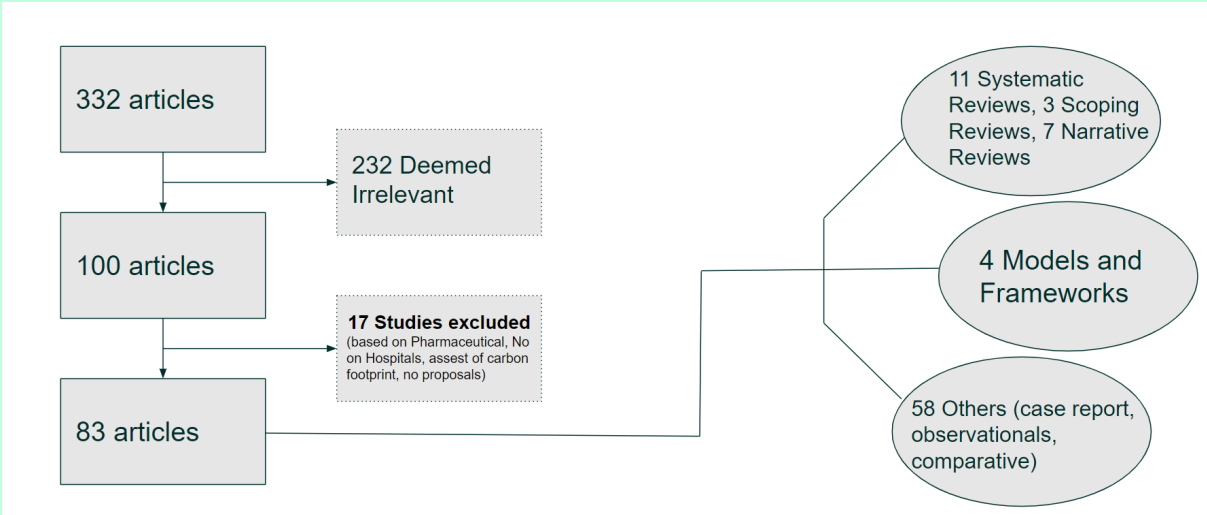

Figure 2: Result of the scoping review based on the PRISMA diagram

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After the screening for abstracts, 100 articles were selected for full-text reading. From the full-text reading, 17 studies were excluded (because based on pharmaceutical and not on hospitals), leaving 83 articles included in the final review. Of these:

- 11 were *systematic reviews,*
- 3 were *scoping reviews,*
- 7 were *narrative reviews,*
- 4 presented *framework models,*
- 58 were *comparative, observational, and case studies*.

This scoping review provided a comprehensive overview of existing sustainable hospital facility models, identifying different types of studies and implemented models. It highlighted the various approaches used in the research on sustainability in hospital environments and the main challenges and gaps present.

Grey literature review

The grey literature review found 15 reports/guidelines/white papers selected for full-text reading. Of this, 9 were included for the data extraction and there were 6 models/frameworks, 2 reports, and 1 strategy. For every document, we extracted all the suggested actions and they were classified into 15 different intervention domains.

This review provides a broad vision of the actual state of the art on healthcare environmental sustainability frameworks and models, developed by international organizations (e.g. World Health Organizations), NGOs (e.g. Sustainability in Healthcare), and academia (e.g. London School of Economics and Political Science).

3.2 Results of Delphi consultation

We asked 36 experts to participate in the Delphi consultation; 13 agreed to participate, 13 completed Round 1, and 11 completed Round 2. Participants had experience in healthcare management in 7 countries of the European region (Poland, Sweden, Italy, Greece, Spain, UK, France) and 1 at the European institutional level. Seven had practical or managerial experience (hospital managers, local health district managers), 4 had policy experience, 2 had scientific experience (academia, research institutes).

The evaluations resulting from the Delphi consultation are summarized in the Annex A.

4. CARING NATURE Healthcare Doughnut framework

4.1 The overall framework

The great heterogeneity and the lack of unified benchmarks in hospital sustainability underscore the urgency of creating a framework that any facility can adopt.

Such a framework would guide these changes effectively, offering standardized guidance for implementing sustainable practices. These results offer a solid foundation for future studies and for implementing policies aimed at improving the sustainability of health systems, ensuring that efforts are cohesive and universally applicable. The Healthcare Doughnut framework aims to provide an overarching tool for environmentally sustainable healthcare governance and management, including recommendations for mitigation actions and adaptation measures while safeguarding the quality of care and optimizing the use of economic resources.

The specific aims of the framework are:

- to present a visual understanding of the complex topic of providing high-quality healthcare for all without harming natural systems;
- to bring together as many actions from different domains into one operational framework;
- to foster transdisciplinary work and effort;
- to identify the different professionals to be involved and that should work together to achieve the best possible result for sustainable and equal healthcare.

The core concept of this framework is inspired by the *Doughnut Economics* theoretical framework by Kate Raworth [17].

The Doughnut (see Fig. 3) consists of two concentric rings: a *social foundation*, to ensure that no one is left falling short on life's essentials, and an *ecological ceiling*, to ensure that humanity does not

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collectively overshoot the planetary boundaries that protect Earth's life-supporting systems. Between these two sets of boundaries lies a doughnut-shaped space that is both ecologically safe and socially just: a space in which humanity can thrive.

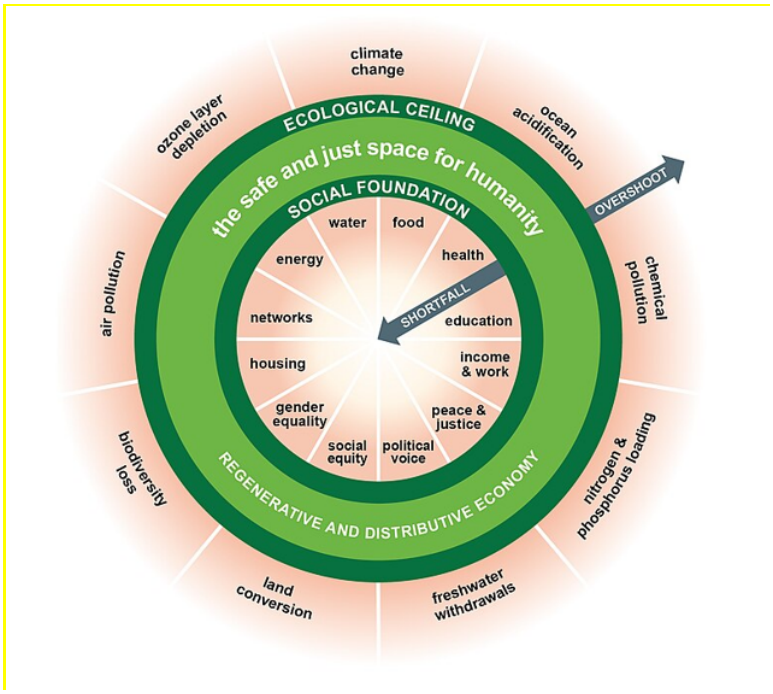

Figure 3: The Raworth Doughnut framework

Adapting the Economic Doughnut to the context of healthcare provision, we build the "**CARING NATURE HealthCare Doughnut framework"** (see Fig. 4).

Instead of the "social foundation", we put the *health equity foundation*, to ensure high-quality care for all and equal healthcare access.

Instead of the planetary boundaries, the *ecological ceiling* is determined by healthcare environmentally impacting sectors, to ensure that healthcare does not turn out to be one of the most polluting sectors and that preserves the Earth's life-supporting systems. Between these two sets of boundaries lies an ecologically safe doughnut-shaped space that provides high-quality healthcare for all: a space where health can be delivered without harming Earth and worsening actual conditions.

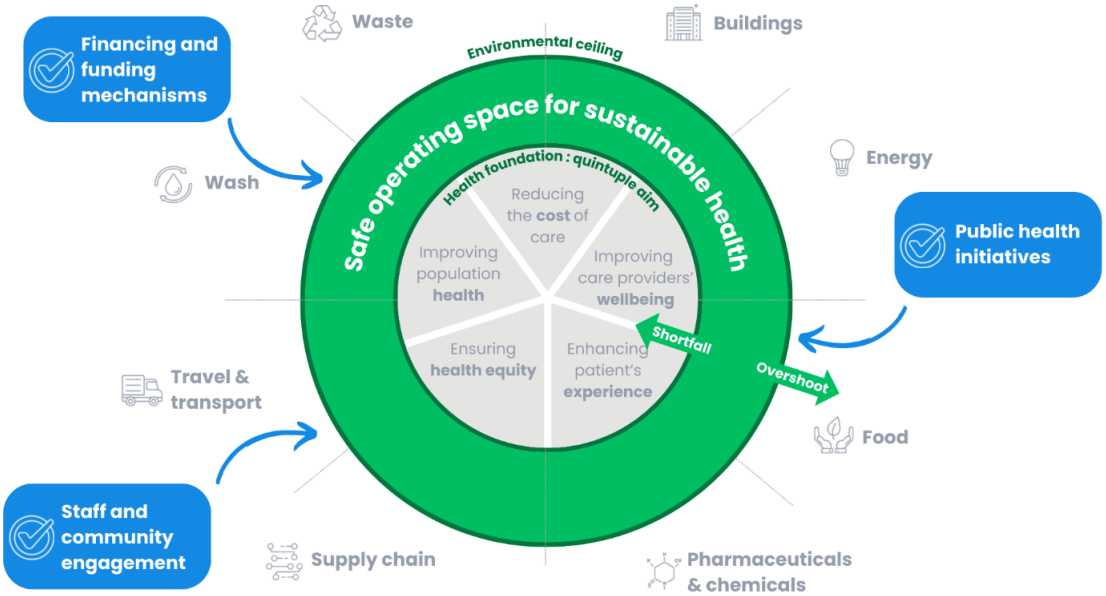

Figure 4: CARING NATURE HealthCare Doughnut framework

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The *health equity foundation* is determined by the *quintuple aim*, which serves as the foundation for optimizing health for individuals and populations by simultaneously improving the patient experience of care (including quality and satisfaction), improving the health of the population and the care providers' wellbeing, reducing per capita cost of care for the benefit of communities and advancing health equity.

A **shortfall** in achieving the Quintuple Aim leads can have a cascading effect, where inefficiencies and challenges in one area exacerbate issues in others, creating a less effective, more strained healthcare system.

The "ecological ceiling" refers to the upper limit on the **use of resources across various domains necessary for care provision** (building, energy, pharmaceuticals and chemicals, waste, WASH - Water Sanitation and Hygiene, travel and transport, supply chain) as determined by the allowable levels of carbon dioxide emissions. This ceiling represents the point beyond which **further resource consumption would result in unsustainable levels of CO_2 emissions**, compromising ecological balance and the ability to provide sustainable care. **Overshooting** the ecological ceiling by exceeding acceptable CO_2 emission levels triggers severe environmental degradation, social disruption, and economic challenges. It accelerates climate change, harms biodiversity, depletes resources, and imposes heavy burdens on health and economic systems.

Between these two limits exists a safe operating space, that could be strengthened by **three principal enablers**: public health initiatives (e.g. prevention programs), financing and funding mechanisms, and staff and community engagement.

For each domain, many **actions** can be implemented to reduce the environmental impact

4.2 Domains and actions of the framework

The domains, and the possible related actions, were identified according to the results of the grey literature review and the scoping review:

1. Building
2. Energy
3. Food
4. Pharmaceuticals and Chemicals
5. Waste
6. WASH (Water, Sanitation, and Hygiene)
7. Travel and Transport
8. Supply Chain
9. Public Health Initiatives
10. Staff and Community Engagement
11. Financing and Funding Mechanisms

Following paragraphs provide a definition of the different domains as well as the related actions shortlisted through the Delphi consensus.

4.2.1 Building

Intervening in the structural aspects of hospitals is crucial to reduce the overall environmental impact of the healthcare sector. The most effective actions to mitigate the carbon footprint of hospitals [18][19] lie in taking action and revolutionising the hospital itself [20], focusing on building interventions such as upgrading insulation, avoiding harmful chemicals, using sustainable materials, and implementing real-time energy monitoring systems. Utilising sustainable materials such as recycled or low-impact products can further reduce the environmental footprint of hospital construction and maintenance [21]. Additionally, implementing real-time energy monitoring systems allows for continuous optimisation of energy use, identifying inefficiencies and promoting energy-saving practices. Adopting sustainable building and urbanistic practices lowers emissions and promotes healthier environments for patients and staff [22].

The Delphi consensus identified the following actions to be included in the *building* domain:

1. Upgrade building insulation like this could foresee the utilisation of high-quality insulation materials and the improvement of window glazing to minimize heat transfer.
2. Prioritize health impacts of material extraction, transport, use and disposal in assessing them for use in health care settings, and use materials that are replenishable and support human and ecosystem health in all phases of their life cycle.

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3. Avoid harmful chemicals eliminating hazardous substances like lead, cadmium, and certain flame retardants from building materials improves indoor air quality and protects occupants' health.
4. Refer to guidelines created by national or regional green building organizations.
5. Substitute materials containing persistent bio-accumulative toxic chemicals (PBTs), including PVC, CPVC, and halogenated and brominated flame retardants, with safer alternatives.
6. Include sustainability standards in the planning and construction of healthcare facilities ensuring that they are energy-efficient, environmentally friendly, and conducive to healing.
7. Provide financial support for energy-saving initiatives to encourage healthcare facilities to invest in sustainability measures.
8. Aspire to be carbon-neutral, setting a goal for carbon-neutral operation entails reducing energy consumption through efficiency measures, utilizing renewable energy sources like solar panels or wind turbines, and potentially investing in carbon offset programs.
9. Employ healing architecture and evidence-based design, including nature and natural lighting in hospitals, thus improving patient recovery and supporting environmental sustainability.
10. Install air pollution filters filtration systems which helps to remove pollutants and allergens, creating a healthier indoor environment for occupants.
11. Plant indigenous trees and plants to obtain health co-benefits, such as the provision of natural shade for patients, staff and visitors during extreme heat events.
12. Optimize site planning based on solar orientation and prevailing wind patterns.
13. Use Local and Recycled Materials: Opting for locally sourced and recycled materials helps reduce transportation emissions and minimizes the environmental footprint of construction projects.
14. Employ passive systems to provide increased resilience and redundancy.
15. Implement real-time energy monitoring systems, coupled with artificial intelligence algorithms.
16. Use high reflectance roofing and paving, or “green roof” systems and pervious paving, mitigate urban heat island effects, manage stormwater runoff, and provide additional insulation.
17. Design buildings with narrow floor plates and corridors featuring exterior walls and strategically placed windows to maximize daylighting and natural ventilation, thereby reducing reliance on artificial lighting and mechanical HVAC systems, and also minimize ACH where feasible based on infection prevention protocol or code.

4.2.2 Energy

The energy consumption of hospitals is a significant contributor to their environmental impact. These facilities operate 24/7, requiring vast amounts of energy for heating, cooling, lighting, and powering medical equipment [23] Adopting energy-efficient practices and integrating renewable energy sources is essential to reduce the carbon footprint and improve the resilience and reliability of energy supply in healthcare facilities [24].

The following actions were included in the *energy* domain, as the outcome of our Delphi procedure:

1. Choose an energy system based on factors pertinent to the facility, including facility size, level of care, budget, operational cost, resource availability, and geographic location.
2. Assess health care facility’s energy use and practices (such as percentage of grid-electricity, percentage of fuel oil and liquid gas used).
3. Install energy-efficient lighting, such as LED lights, to save on energy consumption.
4. Install hybrid energy systems incorporating renewable energy sources, batteries, and backup generators.
5. Monitor air conditioning usage and adjust it according to temperature conditions and plug leaks when present.
6. Reduce air changes overnight and weekends in unused operating rooms.

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7. Commit to transitioning to green and secure energy sources in healthcare systems.
8. Prioritize energy sources and saving measures that are least costly to introduce and/or bring the biggest savings.
9. Implement controls to turn off lights and appliances when not in use, thereby avoiding standby mode, and utilize lighting systems with timers and motion sensors to minimize energy waste.
10. Integrate occupant education and awareness programs with enhanced training for the health workforce to optimize energy consumption related to improving energy access and performance.
11. Defrost freezers and refrigerators regularly when required.
12. Forge partnerships with local government entities to facilitate the installation of off-grid energy systems, ensuring reliable and sustainable energy supply solutions.
13. Conduct regular energy audits and use the results to inform awareness and retrofit programs.
14. Integrate heat pump technology for both hot water production and heating purposes, enhancing energy efficiency and reducing reliance on conventional heating methods.
15. Perform an inventory of medical and other equipment to understand and determine an estimate of the facility's energy needs.
16. Implement renewable energy systems, such as photovoltaic panels, across the property to harness on-site sustainable power generation like installing solar cells placed strategically on the roof and above outdoor parking lots.
17. Replace older air conditioners, refrigerators and other appliances and medical equipment with energy-efficient models.
18. Replace dishwashers and laundry machines with those having water-saving functions, whenever possible or when replacements are needed.

4.2.3 Food

Reducing food waste and promoting sustainable nutrition are important aspects of improving hospital sustainability. Educating and raising awareness about sustainable food practices can have a long-term positive impact on the community. Hospitals adopting these standards have observed reductions in food waste and operational costs, alongside improvements in food quality and patient satisfaction. Furthermore, they underline the importance of plant-based options, which are less resource-intensive than animal products, and can substantially reduce the environmental footprint of hospital food services [26].

The following actions were included in the *food* domain, as the outcome of our Delphi procedure:

1. Minimize and beneficially reuse food waste (for instance, compost food waste or use it as animal feed; convert cooking oil waste into biofuel)
2. Promote healthy and sustainable nutrition by increasing the availability of organic, seasonal and locally produced food in the health facilities and by ensuring suppliers have sustainable production and transportation practices.
3. Redesign the menus both for visitors and staff, limiting the amount of meat and dairy when appropriate and increasing plant-based options.
4. Educate and communicate within the hospital or health care system, as well as to patients and community, about nutritious, socially equitable and ecologically sustainable food practices and procedures.
5. Establish patient-adjusted portion sizes.
6. Supply food that is produced without synthetic pesticides and hormones or antibiotics given to animals in the absence of diagnosed disease.

4.2.4 Pharmaceuticals and chemicals

Managing the use of pharmaceuticals and chemicals in hospitals is crucial to minimizing the impact of healthcare facilities on the environment and human health. Pharmaceuticals like antibiotics often enter water systems through excretion and improper disposal, with wastewater treatment plants unable to

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completely remove these compounds. This contamination can affect aquatic life, and antibiotics promote the development of antibiotic-resistant bacteria [27]. Promoting the sterilization and reuse of medical items, substituting products containing harmful chemicals with safer alternatives, and improving chemical waste management are fundamental measures [28]. Another critical aspect is the use of anesthetic gases in healthcare. While essential for patient care during surgeries and other medical procedures, it has indeed significant environmental and healthcare implications *([29])*. Reducing the environmental impact of pharmaceuticals in hospitals finally relies significantly on educating patients about the appropriate use of medications, ensuring they resort to medical treatments only when necessary [30]. The necessity of use and the challenges in disposal make the pharmaceutical and chemical substances chapter a critical aspect in the field of hospital sustainability.

The following actions were included in the *pharmaceuticals and chemicals domain* from our Delphi procedure:

1. Reduce the use of single-use items and promote sterilization and reuse of medical items.
2. Substitute products or materials that contain Substances of Very High Concern with safer alternatives.
3. Use floor-care products that are free of zinc, heavy metals, phthalates, glycol ethers and ammonia.
4. Prevent disease exacerbation (for example, educating patients about eliminating environmental exposure to allergens and assisting patients with smoking cessation can improve asthma and chronic obstructive pulmonary disease control and reduce inhaler requirements).
5. Educate patients on appropriate inhaler use and shift from carbon-intensive MDIs to low-carbon alternatives when appropriate, such as dry-powder inhalers or soft mist inhalers.
6. Improve packaging, labelling and identification of chemical waste in separate chemical-resistant containers (i.e. not mixing hazardous chemical wastes of different types).

4.2.5 Supply chain

Scope 3 emissions account for 70% of healthcare carbon footprint. Reliance on single-use medical devices, disposable equipment, and packaging materials contributes significantly to this result [33][36]. Hospitals and healthcare providers ought to adopt environmentally responsible supply chain management strategies, by leveraging their remarkable purchasing power [34]. This can involve pursuing waste reduction, higher use of recycled materials, and the promotion of the procurement of lower-impact products.

The following actions were included in the *supply chain* domain, as outcome of our Delphi procedure:

1. Implement procurement policies mandating suppliers to disclose chemical ingredients, safety testing data, and greenhouse gas emissions, while prioritizing those meeting these specifications and requiring high-emitting suppliers to set science-based emission reduction targets.
2. Emphasize efficient supply usage, encompassing commitments, like reducing plastic usage.
3. Review procurement practices and favour local suppliers offering certified sustainable products and adhering to ethical practices.
4. Implement a sustainable purchasing agenda considering environmental impact and human rights throughout all stages of procurement.
5. Advocate for Extended Producer Responsibility and for products designed to generate less waste and use less hazardous materials.
6. Placing importance on low-carbon substitutions and fostering product innovation while prioritizing transparency in supplier decarbonization initiatives.
7. Coordinate hospital purchases to increase buying power and prioritize suppliers and products meeting environmental specifications with circular economy approaches.

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4.2.6 Travel and transport

The frequent travels of healthcare professionals, patients, and medical equipment, as well as the transportation of medical supplies and waste, are all relevantly contributing to the carbon footprint of healthcare *(2)*. Additionally, the reliance on fossil fuels for powering ambulances, helicopters, and other emergency vehicles further exacerbates the issue. To mitigate this, healthcare organizations can explore alternative transportation options, such as electric or hybrid vehicles, and implement more efficient travel planning strategies. Furthermore, telemedicine and virtual consultations can help reduce the need for non-essential travel, thereby decreasing emissions and promoting a more sustainable healthcare system.

The following actions were included in the *travel* domain from our Delphi procedure:

1. Develop strategies for telemedicine, communication by e-mail and other alternatives to face-to-face encounters between caregivers and patients.
2. Improve digital health and telemedicine: implement digitally enabled care models and channels for citizens that will significantly reduce travel and journeys to physical healthcare locations; build net zero into the digital maturity framework; support front-line digitization of clinical records, clinical and operational workflow, and communications.
3. Ensure that planning and design phases for new healthcare infrastructure take into account accessibility via public transportation and active mobility for patients, staff, and visitors.
4. Encourage cycling, walking, and alternative transportation modes by promoting pedestrian and cycling activities, improving infrastructure (including cycle paths, storage, and showers), implementing green travel plans for staff flexibility (negotiating discounts for public transport to provide incentives for its use, establish regional park and ride, active transport infrastructure, bicycling incentives, and staff public transportation discounts).
   Provide healthcare in easily accessible locations without necessitating unnecessary travel, considering community-based primary care, home care, and co-locating medical services with related social services.
5. Renovate fleet vehicles by ensuring the inclusion of low and ultra-low-emission vehicles, committing to a 90% adoption of low-, ultra-low, and zero-emission options.
6. Install electric vehicle charging infrastructure with access for staff and the community.
7. Incentivize staff to embrace electric vehicles by providing increased access to electric bikes through digital platforms.
8. Purchase from local suppliers, and/or suppliers who use fuel-efficient transportation.
9. Dispose of waste near the point of generation.

4.2.7 WASH (water, sanitation and hygiene)

Effective water saving and good water management in hospitals are crucial for both environmental sustainability and operational efficiency. By implementing measures such as low-flow faucets and showerheads, dual-flush toilets, and efficient irrigation systems for landscaping, hospitals can significantly reduce their water consumption. Additionally, the reuse of greywater for non-potable purposes, such as flushing toilets and irrigation, further conserves freshwater resources. These practices not only lower utility costs but also lessen the environmental impact by reducing the strain on local water supplies and decreasing the energy required for water heating and treatment. Moreover, sustainable water management can mitigate the risks of water shortages and contribute to the overall resilience of healthcare facilities. Through conscientious water use, hospitals play a pivotal role in promoting environmental stewardship and fostering a more sustainable future [37].

The following actions were included in the *WASH* domain, as outcome of our Delphi procedure:

1. Implement water conservation strategies: install efficient faucets and toilets, routinely check plumbing and pipes to prevent leaks, eliminate sealing and cooling water on medical air compression and vacuum pumps, and retrofit refrigeration systems.
2. Regularly analyse water quality.
3. Reinforce messaging about water use through signs and notices to promote saving.
4. Surveillance of diseases related to insufficient quality water, and sanitation.

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5. Implement on-site wastewater treatment technologies when no municipal service is available (only if indicated by the permit for the discharge of wastewater from specific services).
6. Manage wastewater safely through the use of on-site treatment (such as a septic tank followed by a drainage pit) or sending it to a functioning sewer system.
7. Eliminate bottled water facility-wide if high-quality potable water is available. Eliminate the use of plastic bottled water in areas where tap water is accessible.
8. Increase patient and visitor awareness about water conservation including signs and notices in patient rooms and visitor restrooms.
9. Landscape grounds using drought-resistant plants to minimize water use.

4.2.8 Waste

Healthcare waste, which includes a wide range of materials such as sharps, pharmaceuticals, chemicals, and radioactive materials, poses significant environmental challenges if not managed properly. Improper disposal can lead to the contamination of soil and water resources, the release of hazardous substances into the air, and the spread of infections and diseases. Effective waste management practices, such as waste minimization, segregation at the source, proper treatment, and disposal, are essential to minimize these impacts [38]. Additionally, adopting practices such as recycling and the use of biodegradable materials can further reduce the environmental footprint of healthcare waste. The WHO highlights the importance of safe and sustainable management of healthcare waste to protect public health and the environment [39]. These efforts are crucial for ensuring that healthcare activities do not compromise environmental quality and public health.

The following actions were included in the *waste* domain from our Delphi procedure:

1. Implement and monitor a waste reduction programme including waste management training for all staff.
2. Ensure adequate management of healthcare waste and promote the minimization of general non-hazardous waste.
3. Dispose of hazardous wastewater and liquid waste that may be infectious.
4. Separate bins for potentially infectious waste, sharps, chemicals, pharmaceuticals, and non-hazardous wastes.
5. Develop medical device reprocessing initiatives and reduce equipment obsolescence.
6. Develop and implement measures to manage and minimize the production of healthcare waste in line with the recommendations of the WHO guidance handbook Safe Management of Wastes from Healthcare Activities.
7. Create incentives for healthcare facilities to be more sustainable, sort and recycle waste, and exchange best practices.
8. Minimize the production of general non hazardous waste through adequate classification, waste reduction, reuse and recycling.
9. Phase-out of incineration of medical waste: a variety of non-burn technologies are available to safely disinfect, neutralize or contain waste (such as autoclaving)

4.2.9 Public health initiatives

Disease prevention and health promotion is a core principle of health systems and can largely contribute to social, economic and environmental benefits [31][32]. Given the expansion of health services demand, the carbon footprint of health systems is projected to triple by 2050, as compared to 2014 baseline, in a business-as-usual scenario [33]. By promoting healthy environments, safe foods, good air quality, for instance, public health initiatives help constrain the demand for health services, thus minimizing the environmental impact of healthcare facilities.

The following actions were included in the *public health initiatives* domain as a result of our Delphi procedure:

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1. Improve the performance of and access to environmental and occupational health services, promoting healthy environments (including healthy workplaces), safe and healthy foods, good air quality, and supply chain safety and security.
2. Inform local communities about health systems activities and opportunities for involvement in health promotion activities and others where appropriate.
3. Boost 'out-of-hospital' care: optimizing the location of care reduces emissions by helping to avoid unnecessary hospital visits and admissions.
4. Use local green spaces for health promotion activities and, where feasible and appropriate, other selected health systems activities (for example, nature-based therapy).
5. Implement rapid diagnostic centres (RDCs): RDCs deliver faster diagnosis and treatment, while also significantly increasing efficiency, and reducing carbon emissions.

4.2.10 Staff and community engagement

Staff engagement is a vital component in the effort to decarbonize hospitals [34]. When healthcare staff are actively involved in sustainability initiatives, they can drive significant changes through their daily practices and decision-making processes [35]. Engaged staff are more likely to adopt and promote energy-efficient practices, waste reduction strategies, and sustainable resource use within their departments. By fostering a culture of environmental awareness, hospitals can harness the collective efforts of their employees to implement green practices. This collective engagement not only helps to lower the hospital's carbon footprint, but also sets a positive example for patients and the broader community, reinforcing the hospital's commitment to environmental stewardship. Empowered health professionals may accordingly contribute to steering other economic sectors and society towards decarbonisation goals [34].

The following actions were included in the *staff and community engagement* domain, as outcome of our Delphi procedure:

1. Build regional and national networks for climate resilience and sustainability to spread and scale what works across the regions and to share the best practices.
2. Educate healthcare professionals and build their capability about the links between health and climate change, the environmental impacts of healthcare, and interventions they can take to reduce emissions.
3. Raise public and workforce awareness on environmental risk factors, healthcare waste, and best practices.
4. Call for research and funding for materials and processes that deliver improved health, and resilience, and reduce carbon to zero.
5. Take intersectoral action: raise awareness and exercise leadership with other sectors in matters to address social and environmental determinants of health.
6. Engage the health workforce and its associations and unions in embedding environmental sustainability and resilience into health system culture.
7. Ensure healthcare facilities have sufficient numbers of healthcare workers with healthy and safe working conditions.
8. Develop a Roadmap and/or Action Plan to make an organizational commitment to a zero emissions trajectory.
9. Advocate, from positions both inside and outside of government, for specific policies, regulations, and legislation that accelerate the transition toward zero emissions in key sectors, like energy, transportation, and agriculture, that affect both public health and health care's climate footprint.
10. Communicate and increase awareness related to climate resilience and environmental sustainability among patients, visitors, target communities, and other sectors.
11. Make sure hospitals, health systems and health professionals advocate for environmental health policy and promotion of public policy at the local, national and international levels and foster their collaboration with national and international jurisdictions.

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12. Establish a centralised authority to ensure progress towards reducing environmental impact.

4.2.11 Financing and funding mechanisms

Access to adequate funds and the development of effective financing mechanisms are fundamental to support the transition towards sustainability in hospitals. Collaborating with the government and other entities to secure dedicated funding and developing tools that consider environmental impacts in financial decisions is crucial. Financially incentivizing sustainable practices can accelerate the adoption of green measures in the healthcare sector [25].

The following actions were included in the *financing and funding mechanisms domain*, as the outcome of our Delphi procedure:

1. Work with the government to access funds directed towards the ambition for net zero, and with trusts to explore alternative ways to fund this investment.
2. Develop tools so that decisions across the government are informed by an understanding of environmental impacts, as well as financial ones.
3. Review contractual mechanisms and levers to understand the opportunities to drive environmental change.
4. Build a financial and clinical case for climate action.
5. Establish financial incentives to drive changes, like favourable remuneration for low-carbon modes of travel, tendering criteria that include a strong percentage of sustainability points, and clinical reimbursement schemes based on positive health outcomes connected to low-carbon pathways.
6. Integrate climate into the health system's financial decision-making process.
7. Incorporate climate criteria with the aim of cost-effective decarbonization and resilience at all levels of health system financing. This includes the public and private health sector budget, aid, lending, and other forms of financing.

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Section B - Output of Tasks 2.2 and 2.3: Requirements, Use Cases, KPIs and Validation methods

5. Methodology

5.1 Introduction

The Tasks 2.2 (“Results' requirements”) and 2.3 (“Use cases and validation methodology definition”) had to deliver four “content” outputs:

- The **Solution So⁺**, i.e. the requirements that enrich and better qualify the features of the Solutions described in the GA (So)
- The **KPIo⁺** list, i.e. the set of indicators obtained finetuning those associated to each Solution in the GA (KPIo)
- The **Use Cases** that will be performed in the Pilots to validate the results and collect lessons; they have been defined starting from the map included in the GA, that shows in which of the five HCPs each Solution was expected to be co-developed or validated.
- The **existing Standards/Regulations** with which the Solutions should comply with and to which future activities they will contribute.

Task 2.3 had also to clarify how the **testing**, **verification** and **validation** should be performed.

Therefore, this Chapter 5. provides **methodologies regarding three sets of methods**:

- The methods for obtaining the four “content” outputs executing the four relevant activities (User Requirement definition, Use Cases definition, KPIs finetuning, Standards identification)
- The methods to perform the future activities of testing, verification and validation
- The methods to execute the Tasks T2.2 and T.2.3

Figure 5 maps the activities performed in the two Tasks T2.2 and T2.3 and tin the rest of the project (and that are influenced by the T2.2 and T2.3 output) and attaches to them the required methods

The “red” methods are the ones that have been developed to perform the activities of WP2. The “brown” methodologies are defined in the WP2, but will be used throughout the project to perform the future activities of testing, verification and validation

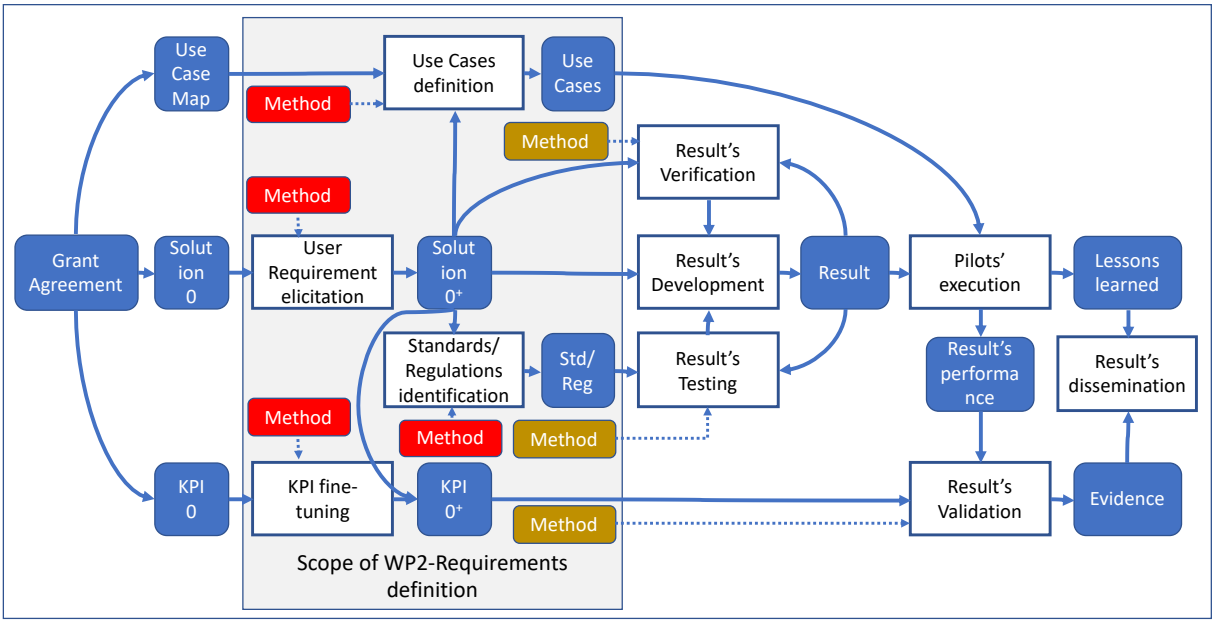

Figure 5: Map of the logic for methodology definition

In the next paragraphs all the five methodologies are described (one for each of the four “red” boxes and one covering the three “brown” boxes) .

A sixth methodology is also described: the methodology to execute the Tasks T2.2 and T.2.3.

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5.2 Methodology for the results' requirements elicitation

CARING NATURE is a Research and Innovation Action, aiming, according to the GA, at getting high adoption of its Solutions[10].

Therefore, the methodology to elicit the requirements has been designed considering the CARING NATURE project as a Product Innovation project, where in a key role is played by the **Target Adopters (TA)**[11].

The purpose of Task 2.2 is to identify for each of the results of the Caring Nature (CN) project a list of requirements that are as comprehensive as possible. While some initial requirements have already been defined in the proposal, they have been written by a limited group of people, which introduces a high risk of being limited and self-referential.

For this reason, discussions with the main CN internal and external stakeholders have been scheduled to understand which are the needs and expectations of the potential TAs, as well as their unmet needs regarding all the topics covered by the CN project.

The TAs are represented by all the individuals within a specific healthcare (HC) facility or organisation, who are directly involved in the topic covered by the Solution. The new Solution must be as innovative as possible compared to the initial Solution and must address all the needs of the TAs.

From these unmet needs new requirements have been derived to enrich and better define the Solution described in the proposal, referred to here as **"Solution 0"**, leading to a new and improved Solution and configuration called **"Solution 0+"**. The requirement elicitation process also leads to a solid value propositions based on the requirements. A value proposition is a text that describes the Solution's features, the needs it satisfies, and the innovations proposed to surpass other Existing Best Solutions (EBSs). Thus, the value proposition text provides the reasons for adopting the new Solution.

The three key aspects adopted to identify good requirements for the CN results are:

- They address an existing and critical problem for the TAs.
- They are tailored to the specific characteristics of each HC facility, which can vary significantly in terms of climate conditions, size, scope of use, management, etc.
- They introduce improvements compared to the existing Solution.

The next figure provides a schematic representation of the logic of the result requirements elicitation process

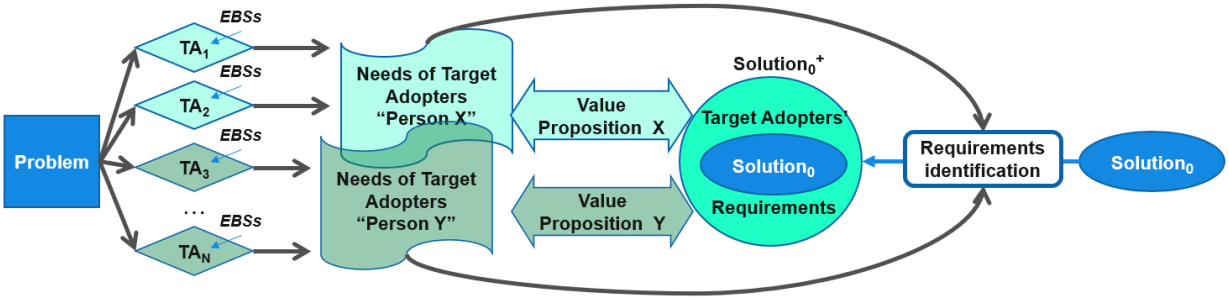

Figure 6: Logic of results' requirements elicitation.

In order elicit the needs, when meeting the internal end-users and the external stakeholders we have started asking the questions listed in following table, which de facto lists the key problems that the CARING NATURE Solutions aim to solve in order to support the Healthcare Green Transition (HCGT)

#	Solution/Component	Question: what do you need to …
R1.1	KSS-DSS (E-LCA, S-LCA, LCC, SFEM)	*… convince funders to do HCGT investments?*

[10] It aims at getting that at least 50 stakeholders in the first three years aftrer the end of the project enter the Knowledge Sharing community and some of them adopt one or more of the other Solutions

[11] The adopted approach is a re-elaboration of the approach to the needs elicitation described in Timothy L. Faley, *The Innovation Pyramid: a strategic methodology for impactful problem solving*, Cambridge University Press, 2021

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	KSS-DSS (CSRD)	*… efficiently and reliably comply with the new EU reporting regulation?*
	KSS-DSS (KSS)	*… capitalize and diffuse the knowledge on HCGT distributed in Europe?*
	KSS-DSS (IT infrastructure)	*… facilitate exchange/access between/from distributed users? … minimize the data management effort?*
R1.2	**GLSS-HC**	*… do Business Process Re-engineering for HCGT in an efficient, effective and accepted manner?*
R2.1	**COMPASS**	*… renovate and build HC facilities in a HCGT perspective?*
R2.2	**ENER**	*… apply AI to monitor and reduce energy consumption in HC facilities?*
R3.1	**WR-MED**	*… manage the OR waste in a GT perspective?*
R3.2	**WP-MED**	*… reduce fossil fuel consumption through waste pyrolysis in HC facilities?*
R3.3	**WP-FOOD**	*… treat waste food in a more sustainable manner in the HC context?*
R3.4	**WP-WATER**	*… treat waste water in a more sustainable manner in the HC context?*
R4.1	**TELEMED**	*… maximise the diffusion of the specialistic telemedicine?*
R5.1	**ENGAGE**	*… motivate HCP staff to actively participate to HCGT?*

5.3 Methodology for the KPIs finetuning

Once that the needs of the TA have been define, and based on this the result requirements, a methodology to validate the Solution and verify the compliance of the results with the expectations is needed. For this reason in WP2 a set of KPIs have been defined starting from the initial list of the proposal.

Since the results of the CN project and their components are very various both in the content and in the type of result it was necessary to categorize them. The analysis of the CN Results and of their components leads to the conclusion that they can be associated to seven types of result, or component of result (see Table 11):

Table 11: Association of every CN result to its type

Objective	#	Solution/Component	Type of result/component
1-Governance	R1.1	KSS-DSS (E-LCA, S-LCA, LCC, SFEM)	Methodology with O/P
		KSS-DSS (CSRD)	Methodology with O/P
		KSS-DSS (KSS process and content)	Methodology without O/P
		KSS-DSS (KSS education package)	Training
		IT infrastructure	SW (transactional)
	R1.2	GLSS-HC	Methodology with O/P
2-Building	R2.1	COMPASS (Policy & Proc. Guidelines)	Methodology with O/P
		COMPASS (DSS+Design Guidelines)	SW (algorithmic)
	R2.2	ENER	SW (algorithmic)
3-Waste	R3.1	WR-MED (interventions on w. mgmt)	Recommendations
		WR-MED (training)	Training
	R3.2	WP-MED	Treatment equip./process
	R3.3	WP-FOOD	Treatment equip./process
	R3.4	WP-WATER	Treatment equip./process
4-Patient's travel	R4.1	TELEMED (guidelines)	Methodology without O/P
		TELEMED (sust. assessment meth)	Methodology with O/P
5-Staff engagement	R5.1	ENGAGE	Methodology without O/P

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- **Methodology with Output (O/P)**. It is a methodology that allows the user to obtain a usable output. An example is the S-LCA methodology, that supports the user in obtaining an evaluation of the social impact of an investment or of a process.
- **Methodology without Output (O/P)**. It is a methodology that guides the user in performing an activity but doesn't lead to a tangible output. An example is the ENGAGE model that supports the users in enhancing and obtaining staff engagement for green transition of the HCPs.
- **Recommendations**. It is a reference set of improvement actions. An example is WR-MED, which will include a set of waste management recommendations.
- **Training.** It is a training delivery package, that is proven during the project and is an output "per se". An example is the WR-MED package.
- **Software (transactional).** It is a software infrastructure that allows to input (or ingest), store and share data, with no or limited calculation capability. As it is the case for the KSS-DSS infrastructure.
- **Software (algorithmic)**. It is a software that, in addition to transactional capability, has also a strong calculation capability. An example for this is ENER, which is based on Artificial Intelligence (AI) algorithms.
- **Treatment equipment or process**. It is a mechanism for treating material inputs to get material or energy output, an example is the WP-MED equipment, that treats the waste.

The KPIs are needed to provide evidence of the successful development of the results. In order to define the final set of KPIs (based on the KPIs included in the GA), have been conducted **the following four steps**:

1) The KPIs included in the GA have been analysed to verify if they were sufficiently SMART[12].
2) If they were not sufficiently SMART, they have been adjusted
3) It was also checked if some key aspects of the result were not captured by the set of KPIs included in the GA.
4) If so, some new KPIs have been added

It is worth noting, making reference to the Theory of Change[13] [40], that the KPIs included in GA (and also the final set defined in Task 2.2) are related to the output (see the Table 12). More precisely, they **are qualifiers of the outputs (the Results, the Solutions) delivered by the CN project**. They are not meant to qualify the outcome or the impact.

Table 12: KPIs characterization in terms of Output, Outcome and Impact

Activity →	**Output →**	**Outcome →**	**Impact**
Is what is done do to deliver the Output	**Is in the sphere of control-Direct influence.** *What the project delivers: the tangible products as a result of the activities*	**Is in the sphere of influence-Indirect influence.** *What depends on who the project works with and through: changes in behaviour, relationships, actions, resulting from the uptake of the outputs*	**Is in the sphere of interest-Outside of project influence.** *Higher level project aims: improved conditions that the project hopes to see*
Example	**Example**	**Example**	**Example**
Develop the ENGAGE model	• *Output: ENGAGE model* • *KPI: more than 80% of the managers and the staff involved in the Community of Practice (CoP) find that the model is motivating, feasible and fruitful*	• *Outcome: Staff engagement for green transition* • *KPI: Increased correct separation between clinical and non-clinical waste of the OR: +30% non-clinical waste*	• *Impact: Progress in the HCP green transition* • *KPI: the HCP, also thanks to ENGAGE, has reduced its CO2e footprint by 30%*

[12] Specific, Measurable, Achievable, Relevant, Time-bound

[13] The **Theory of Change** assumes that a change project impacts on the reality through a logical cause-effect chain from Activity to Impact, through Output and Outcome. See for instance https://www.eur.nl/en/research/research-services/societal-impact-evaluation/impact-evaluation-toolbox/theory-change; the content of the first two rows of the table are taken from this link.

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In order to go through the four steps in a systematic manner, we have made clear which are the aspects of the Output (that we need to measure with a KPI[14]: Performance, Relevance, Quality and Usability[15].

Aspect	Scope
Performance	It is a quantitative measure of the benefits or of the features that are important for the user in the utilization context, such as the number of European participants in the knowledge-sharing events or the time to set up a telemedicine delivery service for pneumology in the WPH county, the economic sustainability of a waste treatment plant at FPG.
Relevance	It is a qualitative measure of the usefulness of the result as it is perceived by the end-users (also on behalf of the patients, if applicable) or by the relevant stakeholders. It is an evaluation of the "fit for purpose" or of the "value added" vs current solutions
Quality	It is a qualitative measure of the robustness/credibility of the output of a tool, from the point of view of the end-users or the relevant stakeholders (e.g. the indications of a S-LCA, the CSRD report built following the guidelines), the adaptability to different contexts/users, or the capability to capture the HC specificities
Usability	It is a qualitative measure the easiness of use of the Solution in the specific context (e.g. the user-friendliness of the KSS-DSS software interface during the decision process involving many decision-makers, the real possibility to feed S-LCA with reliable data)

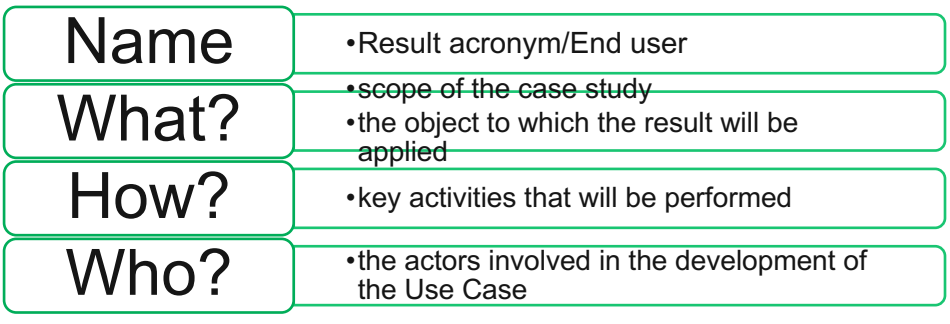
5.4 Methodology for the Use Cases definition

The Use Cases consist in the application of the CN Solutions in real contexts. Their main purpose is to make sure, and show, that the Solution can work in a real context and that can fit the TAs' needs.

Their role is threefold:

1. Support the co-development of the Solutions (this happens mainly in the WPs 3, 4 and 5, but also in WP6 which gathers information to fine-tune the Solution)[16]
2. Provide evidence (data, information, users' perceptions) for the validation, i.e. for the assessment of the KPIs (this happens mainly in WP6, but also in the WPs 3, 4 and 5 as by-product of the co-development)
3. Provide lessons/stories/examples that can be used for dissemination purposes and for feeding the KSS

The description of each Use Case includes the following element:



[14] De facto, we have extracted these aspects analysing the KPIs included in the GA. They are a good basis, because were generated by the Consortium Partners on the basis of their domain expertise

[15] Even if Relevance, Quality and Usability can, in principle, be quantitatively assessed measuring a "proxy" parameter, we will assess them in a qualitative manner (perceptions of the users, experts' evaluations) and consider any quantitative measure as a "Performance" aspect

[16] WP3-Development of KSS-DSS, WP4-Development of organizational results, WP5-Development of Technical results, WP6-Piloting and validation

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The Use Cases have been identified according to the following criteria:

- ✓ The object(s) include a variety of content sufficient to fit the variety of functions of the result to be developed and validated
- ✓ It refers to a real situation
- ✓ It satisfies a real need of the Partner or supports another Use Case of the CN project
- ✓ It is specific to the healthcare sector.
- ✓ It allows to obtain good case studies to be used for dissemination purposes and for supporting the exploitation

The process for identifying the Use Cases has been coordinated by RINA-C (as Technical Coordinator, WP2 leader and T2.2 Leader) and FPG (as T2.3 leader) and has involved all the partners. This process has been quite long and demanding (it has required from two to five meetings for each Use Case) but has generated the important by-product of getting the commitment of the internal relevant departments/functions that will actually perform the Use Cases in each of the five HCPs.

The analysis performed in WP2 has led to 33 Use Cases; other 3 are going to be defined shortly. In total they will be 36, i.e. 3 more than the 33 indicated in the GA, to take into account the different nature of the CSRD reporting vs the other components of the DSS (E-LCA, S-LCA, LCC, SFEM).

The map of all Use Cases is shown in Table 13. In turquoise are highlighted the Use Cases where the co-development will be run (all of them have been identified).

Table 13: Use Cases allocation

Objective	#	Result	Lead Developer	FPG *Italy*	FHAG *Spain*	UKHD *Germany*	WPH *Finland*	7HRC *Greece*
1-Governance	R1.1	KSS-DSS (E-LCA, S-LCA, LCC, SFEM)	SIMAVI+RINA+ UNIWA	DSS/FPG			DSS/WPH	DSS/7HRC
		KSS-DSS (CSRD)	SIMAVI+ UNIWA	CSRD/FPG			CSRD/WPH	CSRD/7HRC
		KSS-DSS (KSS)	SIMAVI+EUR	KSS				
	R1.2	GLSS-HC	RINA-C	GLSS-HC/ FPG	GLSS-HC /FHAG	GLSS-HC/UKHD		
2-Building	R2.1	COMPASS	4DA+ARPEL		COMPASS/ FHAG	COMPASS/ UKHD	COMPASS/ WPH	
	R2.2	ENER	I75	ENER/ FPG	ENER/ FHAG		ENER/ WPH	
3-Waste	R3.1	WR-MED	FPG	WR-MED/ FPG	WR-MED/ FHAG	WR-MED/ UKHD		
	R3.2	WP-MED	ERCS	WP-MED/ FPG		WP-MED/ UKHD	WP-MED/ WPH	
	R3.3	WP-FOOD	CUT	WP-FOOD/ FPG	WP-FOOD/ FHAG		WP-FOOD/ WPH	
	R3.4	WP-WATER	CUT			WP-WATER/ UKHD	WP-WATER/ WPH	WP-WATER/ 7HRC
4-Patient's travel	R4.1	TELEMED	FPG	TELEMED/ FPG	TELEMED/ FHAG		TELEMED/ WPH	
5-Staff engagement	R5.1	ENGAGE	LUT	CSRD/ FPG	CSRD/ FHAG	CSRD/ UKHD	CSRD/ WPH	CSRD/ UKHD

5.5 Methodology for the standards/regulations identification

To identify the applicable technical standards, DIN has started with the identification of the potentially relevant Technical Committees (TCs) working on the topics related to the CN Solutions, obtaining a list of 12 TCs.

In task T7.2 - Standardization activities' DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

The applicable Regulations (National and European) have been identified by CN Partners (both developers and end-users) on the basis of their professional experience.

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5.6 Methodologies for the results' testing, verification, validation

5.6.1 Meaning of Testing, Verification and Validation

To ensure that the CN results are of a sound technical quality, satisfy the TAs' needs and reach the targets set in the Grant Agreement, they will be:

- **Tested**, i.e assessed in terms of "technical" quality vs good design practices and applicable standards
- **Verified, i.e.** assed in terms of fit with the functional description provided in the GA (Solution 0) and satisfaction of the requirements identified in Task 2.2 (Solution 0^+)
- **Validated**, i.e. assessed vs the KPIs (and their target values) included in the GA, and, for some results, vs additional KPIs to get a more complete evaluation.

The Testing and the Verification regard the result "per se", and in general will be performed independently from the Use Cases, by M18 and then by M32.

The Validation, instead, is based on the information and data collected in the Use Cases, both those performed in the WPs 3, 4 and 5 by M18 (the co-development Use Cases) and those performed in WP6.

To be noted, WP6-Piloting and validation has a wider scope than the validation. Its main purpose is to provide evidence that the Solution can work in a real context and that can fit the TAs' needs. It also gathers information to fine-tune the Solution and lessons/stories/examples that can be used for dissemination purposes and for feeding the KSS.

The methods of Testing, Verification and Validation depend on the type of result and, for the Validation, on the type of KPI.

5.6.2 Methods

Table 14 provides a summary of the methods that will be used for each type of result in the CN project, to perform the Testing, Verification and Validation activities.

Table 14: Summary of the methods used for each type of result

Type of Solution/Component	Testing method (technical quality)	Verification metthod	Validation method (vs KPI's aspects)			
			Performance	Relevance	Quality	Usabiliy
Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
Methodology without O/P	Logical consistency	Inspection vs list	Parameter assessm.	Questionnaire	Questionnaire	Questionnaire
Recommendations	Logical consistency	Inspection vs list	Benefit estimation	Questionnaire	Questionnaire	Questionnaire
Training	Logical consistency	Inspection vs list		Participants' survey	Participants' survey	
SW (transactional)	Sw testing	Inspection vs list		Questionnaire	Questionnaire	Questionnaire
SW (algorithmic)	Sw testing	Inspection vs list	Simulation	Questionnaire	Questionnaire	Questionnaire
Treatment equip./process	Sci./Tech testing	Inspection vs list	Feasibility study			

As the Table shows, to each one of the seven types of results is associated a unique set of validation method.

In the following, a short description of the methods is provided.

5.6.2.1 Testing methods.

There are three specific methods:

- **Software testing**. It identifies and eliminates defects within the software infrastructure both at component and integration level. It is performed according to software engineering standards (e.g. ISO/IEC/IEEE 29199)
- **Scientific/Tech testing**. It assesses physical properties of an equipment or chemical treatment process against target values of KPIs and against good engineering standards. It is performed through experiments and statistical analysis of the results.
- **Logical consistency**. It assesses the formal quality of a methodology or a training package. They are analysed by peers and users reading the Deliverable that contains the artifact, checking the following aspects:
  1) internal congruence of the individual components
  2) mutual congruence between the individual components, where applicable

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3) completeness and depth with respect to similar artifacts (if available), given the purpose
4) clarity/readability/non-ambiguity of the text

5.6.2.2 Verification method.

The method consists in checking the result against the description of "Solution 0" and Solution 0^{+}.

5.6.2.3 Validation methods.

For each of the four aspects measured by the KPIs (performance, relevance, quality, usability) there are specific methods.

There are four methods to assess the **performance**:

- **Feasibility study**. It consists in evaluating a CN Solution calculating its economic, environmental and social sustainability in a scenario of utilization. It goes through following steps: definition of the use context(s), definition of the reference solution (e.g. the one currently used), definition of the configuration(s) of how the CN Solution is used, definition of the sustainability metrics, calculation/estimate of the metrics for the refence and for the CN Solution configuration(s), comparison to identify and quantify the pros and cons of the CN Solution. This method will be used for instance for WP-FOOD.
- **Simulation.** It consists in applying a CN Solution (e.g. COMPASS) to a real entity (e.g. a building) and to do a what-if simulation to calculate the benefits (e.g. lower carbon footprint) vs the reference modality (e.g. the material used in the current building) if the CN Solution were used (e.g. COMPASS suggests to use a more **circular building methods and solutions** and user friendly material)
- **Benefit estimation**. It consists in estimating the benefit of an intervention, under the assumption that it is implemented in context in scope. For instance, if at FPG the correct separation of a type of waste is found to be with high impact, the benefit at UKHD can be estimated considering the actual volumes of that waste **at UKHD.**
- **Parameter assessment**. It consists in measuring or counting an entity (a parameter) that is expected to be impacted by the Solution (e.g. the time needed to set-up the telemedicine service)

There are three methods to assess the **relevance** and the **quality**

- **Output evaluation.** It is an indirect method to evaluate a methodology that helps the user in producing an output. It consists in examining the output (typically a document) of the application of the methodology to a specific case. It focuses on the quality of the data/information/assumptions used, the robustness of the elaboration logic, the relevance of the scope and of the conclusions.

  A reference check-list for the output evaluation is the following:

  A. Relevance
  - ✓ the purpose of the document fits with what is required by the user/decision maker
  - ✓ the scope of the document is consistent with the purpose and covers all the aspects that need to be considered to avoid misleading or biased conclusions/recommendations
  - ✓ the conclusions are credible and fit with the purpose

  B. Quality
  - ✓ the quality of the data used is granted, e.g. in terms of their completeness, accuracy, relevance, and representativeness. Verify the sources of the data and consider factors such as data uncertainty and temporal and geographical relevance.
  - ✓ the robustness of the results is granted vs variations in input parameters and assumptions. This can be done through a sensitivity analysis. This helps identify contradictory or counterintuitive behaviours of the decision support model.
  - ✓ the transparency is granted, through descriptions of the methodology, data sources, assumptions, and calculations. Transparency enables others to understand and replicate the study, which is essential for validation and peer review.

- **Participants' survey**. It is a questionnaire administered to the participants of a course to assess their feedback on its quality and relevance

- **Questionnaire.** It is a method to collect the perceptions of the respondents on the quality and relevance of the Solutions. tailored on the specific Result/Solution and on the expected use situations. It is administered to the staff involved in the Use Cases. In some cases, it can also be administered to stakeholders of the RSG in the context of a workshop where the Solutions are

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described. The questionnaire can be just handed to the respondents or can be used as the backbone of an interview.

The **usability** is assessed with a **Questionnaire** that makes reference to use situations and explores aspects such as user friendliness of the user interface, simplicity, clarity, easiness of access to data, effort required to apply the methodology (their applicability and actual phrasing of the actual questions depends on the type of solution).

5.6.3 Roles for testing, verification and validation

This document provides for each of the CN Solutions the indication of the types of methods to be used for testing, verification and validation and specifies the features/content that they should have.

However, these methods need to be "prepared" before being used for the actual evaluation. For instance, for the Questionnaires the actual questions must be defined.

This preparation will be done during the development Tasks, when the configuration of the Solutions (and their components) to be evaluated will become more precise.

This section provides the indication of who will perform:

- the preparation of the methods (e.g. the Questionnaire).
- the evaluation, i.e. will express the evaluation through the methods (e.g. fills the Questionnaire)

The starting point is to make clear who has an interest in the evaluation and why; then the role in the two tables above, leads to the indications provided in the Table 16, (for Testing and Verification) and, for each Solution/component, in the Table 17 (for Validation)

Table 15: Types of actors, interest and roles

Type of Actor	Actual actors that can be involved in a Use Case X	Interest and key role in the evaluation
Solution developer	▪ Development partners **[Dev]**	**Interest**. Wants to know which are the weak/strong point of its solution, to improve it and to show the value **Role.** In general, Prepares. For technical and scientific testing also evaluates, due to the specificity of the required knowledge and expertise. This is counter-balanced by the involvement of the TC, as Quality Assurance officer
Target adopter	As a proxy ▪ HCP Partners that do not do the Use Case X [**Other HCP**]	**Interest**. Wants to understand how good a solution is, before adopting/using it. **Role**. Prepares, making sure that the method allows to collect the required information
European Commission	As a proxy ▪ Partners acting as Deliverable reviewers **[Rev]** ▪ Technical Coordinator (RINA-C) **[TC]** ▪ Task 2.3 Leader (FPG) **[T2.3L]**	**Interest.** Wants to be sure that the CN project Results are as good as is promised in the GA. **Role. TC** does Quality Assurance (QA) both in the preparation and in the evaluation for all methods **T2.3L** provides methodological support and assurance for less technical and known methods

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		Rev evaluates the documental artifacts, anticipating the deep scrutiny of the external reviewers
User in the Use Cases	▪ HCP Partners that do the Use Case X (as Co-developers or Validators) **[User HCP]** ▪ Participants to training **[Part]** ▪ Members of the Community of Practice **[CoP]** ▪ Stakeholders of the RSG involved as users un the Use Case X **[SH]**	**Role.** Evaluates, because has used the Solution

Table 16: Roles for testing and verification

		Prepare					Evaluate					
	Method	**Dev**	**User HCP**	**Other HCPs**	**TC**	**T2.3L**	**Dev**	**User HCP**	**SH**	**CoP/ Part/ Pat**	**Rev**	**TC**
Testing	Logical consistency				QA	x					x	QA
	Sw testing	x			QA		x	x				QA
	Sci./Tech testing	x			QA		x	x				QA
Verification	Inspection vs list				QA	x	x	x				QA

Table 17: Roles for validation

#	Result/component	Method	Prepare					Evaluate					
			Dev	**User HCP**	**Other HCPs**	**TC**	**T2.3L**	**Dev**	**User HCP**	**SH**	**CoP/ Part/ Pat**	**Rev**	**TC**
R1.1	**KSS-DSS (LCA, S-LCA, LCC, SFEM)**	Output evaluation	x		x	QA	Meth		x			x	QA
		Questionnaire	x		x	QA			x				QA
	KSS-DSS (CSRD)	Output evaluation	x		x	QA	Meth		x			x	QA
		Questionnaire	x		x	QA			x				QA
	KSS-DSS (KSS process and content)	Questionnaire	x		x	QA			x	x			QA
	KSS-DSS (KSS education package)	Participants' survey	x		x	QA				x	Part		QA
	Software infrastructure	Questionnaire	x		x	QA			x	KSS			QA
R1.2	**GLSS-HC**	Output evaluation	x		x	QA	Meth		x			x	QA
		Questionnaire	x		x	QA			x				QA
R2.1	**COMPASS (Policy & Proc. Guidelines)**	Output evaluation	x		x	QA	Meth		x	x		x	QA
		Questionnaire	x		x	QA			x	x			QA
	COMPASS (DSS+Design Guidelines)	Simulation	x	x		QA		x		x			QA
		Questionnaire	x	x		QA				x			QA
R2.2	**ENER**	Simulation	x	x		QA		x	x				QA
		Questionnaire	x	x		QA			x				QA
R3.1	**WR-MED (interventions on OR waste mgmt)**	Benefit estimation	x	x		QA	Meth	x	x			x	QA
		Questionnaire	x		x	QA			x				QA
	WR-MED (training)	Participants' survey	x		x	QA							QA
R3.2	**WP-MED**	Feasibility study	x		x	QA	Meth		x			x	QA
R3.3	**WP-FOOD**	Feasibility study	x		x	QA	Meth		x			x	QA
R3.4	**WP-WATER**	Feasibility study	x		x	QA	Meth		x			x	QA
R4.1	**TELEMED (guidelines)**	Questionnaire	x		x	QA			x		Pat		QA
	TELEMED (sust. assessment meth)	Output evaluation	x		x	QA	Meth		x			x	QA
		Questionnaire	x		x	QA			x				QA
R5.1	**ENGAGE**	Questionnaire	x		x	QA			x		CoP		QA

5.6.4 Association of the methods to the Solutions and to their KPIs

The following Table 18 specifies for each of the CN Results (or component if the Result) the "type of result" and, based on the considerations presented in the previous section, provides a summary view of the methods that will be used for each of the CN Result.

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Table 18: Association of methods to the results and to their KPIs

Solution/Component	Type of result/component	Testing (technical quality)	Verification (vs requirements)	Validation method (vs Result/Component's aspects)			
				Performance	Relevance	Quality	Usabiliy
KSS-DSS (E-LCA, S-LCA, LCC, SFEM)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
KSS-DSS (CSRD)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
KSS-DSS (KSS process and content)	Methodology without O/P	Logical consistency	Inspection vs list	Parameter assessm.	Questionnaire	Questionnaire	Questionnaire
KSS-DSS (KSS education package)	Training	Logical consistency	Inspection vs list		Participants' survey	Participants' survey	
IT infrastructure	SW (transactional)	Sw testing	Inspection vs list		Questionnaire	Questionnaire	Questionnaire
GLSS-HC	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
COMPASS (Policy & Proc. Guidelines)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
COMPASS (DSS+Design Guidelines)	SW (algorithmic)	Sw testing	Inspection vs list	Simulation	Questionnaire	Questionnaire	Questionnaire
ENER	SW (algorithmic)	Sw testing	Inspection vs list	Simulation	Questionnaire	Questionnaire	Questionnaire
WR-MED (interventions on w. mgmt)	Recommendations	Logical consistency	Inspection vs list	Benefit estimation	Questionnaire	Questionnaire	Questionnaire
WR-MED (training)	Training	Logical consistency	Inspection vs list		Participants' survey	Participants' survey	
WP-MED	Treatment equip./process	Sci./Tech testing	Inspection vs list	Feasibility study			
WP-FOOD	Treatment equip./process	Sci./Tech testing	Inspection vs list	Feasibility study			
WP-WATER	Treatment equip./process	Scientifific testing	Inspection vs list	Feasibility study			
TELEMED (guidelines)	Methodology without O/P	Logical consistency	Inspection vs list	Parameter assessm.	Questionnaire	Questionnaire	Questionnaire
TELEMED (sust. assessment meth)	Methodology with O/P	Logical consistency	Inspection vs list		Output evaluation	Output evaluation	Questionnaire
ENGAGE	Methodology without O/P	Logical consistency	Inspection vs list	Parameter assessm.	Questionnaire	Questionnaire	Questionnaire

As the Table 18 shows, **for each of the seven types of results there is a unique set of validation method:**

For instance, all the "Methodology with Output" results (or components) are tested through "logical consistency", verified through "Inspection vs list" and validated through two methods: "Output evaluation" and Questionnaire".

The methods are applied to each KPI considering the aspects assessed by the KPI.

For instance, let's consider WR-MED (see Table 19):

- WR-MED is articulated in two components (interventions and training)
- The first component is of the type "recommendations" and is assessed by two KPIs;
  - the first of them is quantitative in nature and can be estimated using the E-LCA methodology
  - the second of them is qualitative in nature and we will validate the reasons for the intention (or non-intention) to implement the guidelines with a Questionnaire that will assess Relevance, Quality and Usability from the point of view of the HCPs
- The second component is of the type "training" and is assessed with a participants' survey on the perceived relevance and quality of the training package for the Operating Room (OR) staff.

Table 19: Example of how the methods are applied to each KPI

Result	Result/ component	Key Performance Indicator	Type of result/	Validation method (vs KPI's aspects)			
				Performance	Relevance	Quality	Usability
R3.1	WR-MED (interventions on waste mgmt)	1) Reduction of the CO2e due to the material used in the Operating Room activities > 10%	Recommendations	Benefit estimation			
		2) Intention to implement the guidelines for waste management and the new tool: in at least two of the three HCPs the staff involved gives a score >4 in a scale from 1 to 5 to the quality, relevance and feasibility of the improvement interventions and to the opportunty to implement them	Recommendations		Questionnaire	Questionnaire	Questionnaire
	WR-MED (training)	3) Quality and relevance of the training package for OR nurses, surgeons, and anaesthesiologists: average satisfaction score >4 in a scale from 1 to 5 by the participants to the delivery of the training (at least 20 participants in total)	Training		Participants' survey	Participants' survey	

5.7 Methodology for the execution of the two tasks

Given the tight connection between defining requirements and the testing and validation processes, T2.2 and T2.3 were conducted concurrently. This was achieved through a series of scheduled meetings aimed at gradually increasing the involvement of target adopters. The logic of the execution of the two tasks can be divided into three phases to increase little by little the interactions between the different organisations involved and the data acquisition for Solution.

- Phase 1: bilateral meeting between the Lead Developer (LD) and the co-Developer (co-D).
- Phase 2: meetings among the LD and the end users that will act as validators of the Solutions.
- Phase 3: workshop with external stakeholders for needs collections.

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The Lead Developers (LD) presented the Solution and discussed together with the co-Developers and the Validators on the definition of the Use Cases. In order to collect the information forms and questionnaires have been circulated and then the results have been discussed in bilateral meetings. **Errore. L'origine riferimento non è stata trovata.** summarizes the process of T2.2 and T2.3 and the actors involved in the different phases.

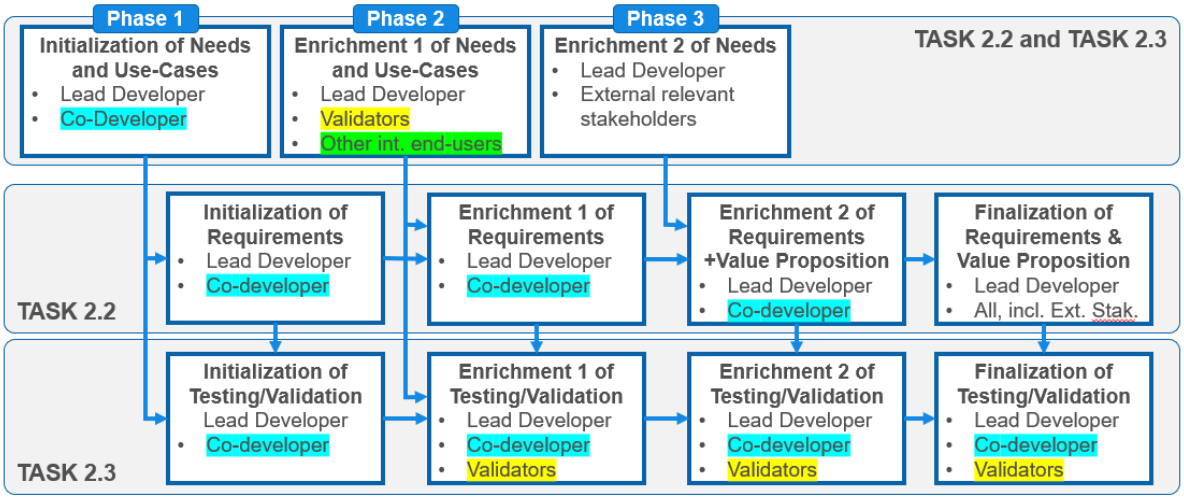

Figure 7: Logic of the execution of the tasks

Table 20 shows for each Result which are the LD, the co-D and the validators.

Table 20: Actors involved in the tasks.

Result	Lead Developer	FPG	FHAG	UKHD	WPH	7HRC	Facilitators
		Italy	*Spain*	*Germany*	*Finland*	*Greece*	
Software infrastructure	**SIMAVI**						***FPG & RINA-C***
DSM	**EUR**						***FPG & RINA-C***
LCC	**UNIWA**						***FPG & RINA-C***
DSRD Reporting Model	**UNIWA**						***FPG & RINA-C***
LCA-SLCA	**RINA**						***FPG & RINA-C***
KSM	**EUR**						***FPG & RINA-C***
GLSS-HC	**RINA**						***FPG***
WR-MED	**FPG**			***XXX***			***FPG***
TELEMED	**FPG**		***XXX***				***FPG***
ENGAGE	**LUT**						***FPG***
COMPASS	**4DA/ARPEL**						***RINA-C***
ENER	**I75**						***RINA-C***
WP-MED	**ERCS**						***RINA-C***
WP-FOOD	**CUT**						***RINA-C***
WP-WATER	**CUT**						***RINA-C***

	Co-Developer
XXX	Validator, acting as Co-dev in WP2
	Validator
	Other end-users

Principally the result is developed by the collaboration between the LD and the co-D. The interaction between LD and co-D is helped by the facilitators (RINA-C and FPG). To increase the applicability of the result also the contribution of external stakeholders and validators is fundamental. Throughout the entire development of the task, conversation between the facilitators and DIN has been put in place to develop a standardization framework as the basis for each result.

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These relationships are graphically represented in Figure 8

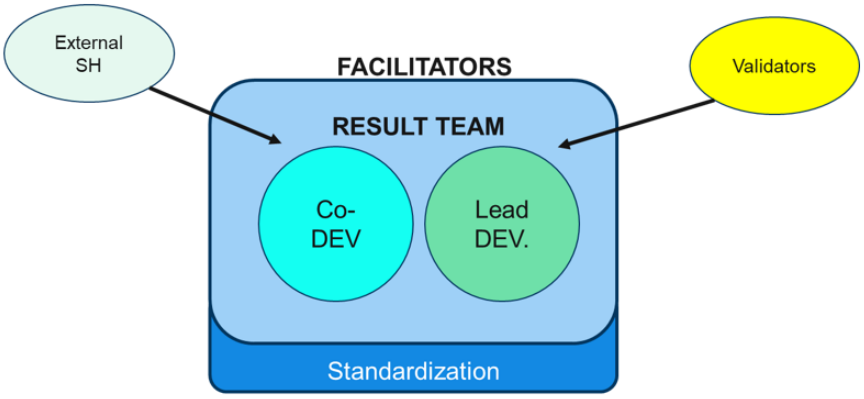

Figure 8: Relationship between the actors involved in the development of the result.

5.7.1 Phase 1

The scope of this phase is to initialize the needs and the Use Cases of the specific result with a first interaction between the LD and co-D. During the first phase, a meeting between the LD and the co-D is scheduled. Before the meetings, two forms were circulated, respectively to the LDs and the co-Ds. In the following sub-chapter a brief description of the content of those forms is provided. The complete version of the form (i.e. the one distributed to the partners) is reported into Appendix D

These forms have been used to set the basis of the conversation and to define initial information, illustrating them during the virtual meetings to enhance mutual understanding of their respective needs and data requirements. The steps done for Phase 1 can be summarised below in Fig. 9:

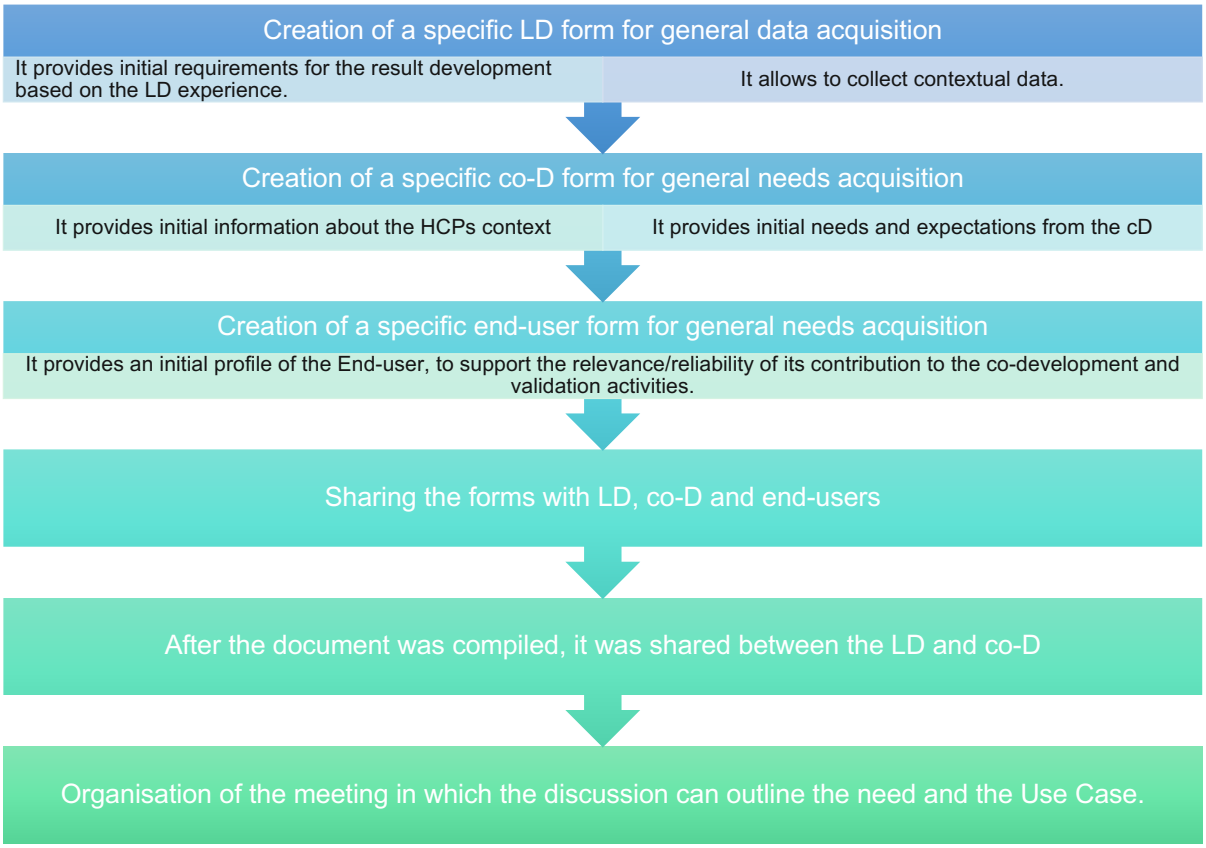

Figure 9: Phase 1 workflow.

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5.7.1.1 Lead developer form

For a better comprehension of the procedure, a brief description of the forms is provided. . The LD form aims to gather the main innovative aspects of the outcome and the primary input variables required for its development. Additionally, the LD form has listed applicable standards to provide them to DIN, along with the testing methodology and applicable KPIs (both proposed and innovative). The LD form is composed of different sections (the template is provided in Annex E):

- Result name and description.
- Innovative aspects of the result.
- Data for result development in the LD context.
- Applicable standard.
- Possible KPIs (from the proposal, to demonstrate innovation)
- Testing methodology.
- Validation methodology.
- Other requirements.

5.7.1.2 Co-developer form

The Co-Developer form, on the other hand, focuses on defining the needs of the individual outcome, thus on the application of the Solution to the specific case and the outlining of the Use Case. It asks about the peculiarities of the structure, the barriers, and opportunities that the installation of the proposed Solution will bring, and the facility manager's knowledge of any good practices present in other hospitals within their awareness. The co-D form is composed of different sections (the template is provided in Annex E):

- Co-developer general information and reference people for CN.
- Peculiarities of the HC facilities.
- Problem, already available solutions and needs, criteria and KPIs for selection and adoption.
- Barriers to the adoption of the specific Solution.
- Opportunities triggered by the adoption of the specific Solution.
- Risks for the development of the specific Solution in CN.
- Applicable regulations (national and EU).
- Applicable standards.
- Other relevant information.

The template of the

5.7.1.3 End user form

The End User form, finally, was circulated to all end users, regardless of the outcomes they are involved in, to gather general information about the facilities (such as the number of beds). It also asked about the approach currently used to accelerate the green transition in these facilities. These pieces of information have been utilised in this report in Chapter 6: End users and their peculiarities. The end-user form is composed of different sections that are more general compared to the previous two (the template is provided in Annex E):

- End user general information.
- Key facts: total beds, in-patient/year, etc.
- Current approach and experiences regarding the green transition.
- Other information.

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5.7.2 Phase 2

The scope of this phase is to enrich the needs defined in Phase 1 and define the Use Cases of the specific result with a first interaction between the LD and Validators. The LD showed the progress of the result after Phase 1 to the validators, with a particular focus on the most critical aspects that emerged during the conversation with the co-Ds.

Even though the validators will not actively participate in the development of the Solution, they will apply the Solution to their specific case at the end of the project, to validate it (as the name suggests). For this reason, it is important for the LD to understand the peculiarities of those HC facilities to define properly the Use Case. This interaction has been made through dedicated virtual meetings and with questionnaires prepared by the LD and circulated among the validators.

5.7.3 Phase 3

The scope of this phase is to further enrich the needs of the CN results through the interaction between the LD and external stakeholders. The external stakeholders represent a diverse group of foundations, private companies, and public entities within the healthcare sector. These bodies have signed a letter of intent with the Caring Nature project aimed at fostering mutual interest. Leveraging their expertise, they enrich the project with new perspectives both in these initial stages and in the dissemination and communication phase. In return, they receive continuous updates on the project's developments. To guide the efforts of external stakeholders, five workshops have been organised, each focusing on Solutions within a specific theme of Caring Nature (see Table 21). See in Annex F the list of the 22 external stakeholder that contributed to the Phase 3.

Table 21: Summary of all the workshops done.

Title	CN Solution	Date	N. of stakeholders
Waste management in HC facilities	WP-MED, WP-WATER, WP-FOOD, WR-MED	09/04/2024	13 (4 internal, 9 external)
Next Generation Telemedicine	TELEMED	22/04/2024	9 (2 internal, 7[17] external)
Governance in HC facilities	KSS-DSS, GLSS-HC	24/04/2024	11 (3 internal, 8[18] external)
Building management in the HC sector	COMPASS, ENER	07/05/2024	8 (3 internal, 5 external)
Participatory staff engagement model	ENGAGE	08/05/2024	7 (2 internal, 5 external)

All the workshops have been structured as follows:

1) Round table with presentation of the external stakeholders and their organizations.
2) Presentation of the results and relative progress by the LDs.
3) Open discussion between LD internal and external stakeholders to define unmet needs. This discussion has been facilitated using the web platform *Miro.*

For each workshop, a list of questions is defined and proposed to the external stakeholders. The Miro interface has been structured as a SWOT matrix (see Table 22). The SWOT Matrix is a strategic planning tool used to identify and analyse the Strengths, Weaknesses, Opportunities and Threats of a project, organisation, or a specific situation. In CN, the situations to be studied were the different topics covered in the project, both regarding the internal environment (strengths and weaknesses) and the external environment (threats and opportunities).

Table 22: Typical SWOT analysis configuration.

SWOT ANALYSIS	Useful to the achievement of objectives	Detrimental to the achievement of goals
Known scenarios	Strengths: Attributes of the that are helpful in achieving the goal.	Weaknesses: Attributes that are detrimental to achieving the goal.

[17] 3 of the 7 stakeholders could not attend the workshop, but were interviewed in 3 one-to-one meetings

[18] One of the 8 stakeholders could not attend the workshop, but was interviewed in a one-to-one meeting

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Other scenarios	Opportunities: External conditions that are helpful in achieving the goal.	Threats: External conditions that could be detrimental to performance.

Miro is a web application that offers an online workspace in which is possible to collaborate and gather live information, putting a virtual "post-it" on a virtual table during the on line meeting (see an example in Fig. 10)

Figure 10: Example of the Miro interface used to facilitate the discussion with stakeholders

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6. End users and their peculiarities

In order to define the different Use Cases it is important to understand which will be the pilot used to develop, test and validate the CN Solution. The Caring Nature consortium include 5 HCPs in 5 different European countries, to provide a wide spectrum of users and to allow the developers to test their Solutions in different scenarios. In this chapter a description of the 5 HCPs is provided together with a summary of the main action that these structures are putting in place (or will put in place) to enhance their environmental sustainability.

6.1 Fondazione Policlinico Gemelli (FPG)

Fondazione Policlinico Universitario A. Gemelli IRCCS (FPG) is a University Hospital located in Rome, and it is the second-largest hospital in Italy. More than 5,000 individuals, including doctors, nurses, technicians, researchers, and administrative staff, are employed within the foundation. The hospital is distinguished by its excellence in various specializations, including oncology, advanced surgery, radiotherapy, and many other medical areas. The Policlinic is then strictly linked with Università Cattolica del Sacro Cuore in Rome regarding research projects, academic integration, scientific collaborations, and shared facilities.

Every day, the hospital premises of Gemelli, host around 30,000 people. In the table below some numbers of FPG are presented

Table 23: FPG Numbers

N° of beds	1.580
In-patients/year	94.700
Operation rooms	52
N° of Surgeries/year	81.000
Outpatient services for in-patients/year	8.000.000
Outpatient services for external patients/year	2.600.000
Employees	5.700
Organizational Units	273

Figure 11: Aerial view of the FPG/UCSC campus in Rome

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FPG comprises a vast campus housing both hospital and university facilities. The sheer scale of this institution results in a substantial generation of **medical waste (EER180103)**, approximately 2,250 tons per year, which is currently managed by outsourcing to an external company. The transportation of this type of waste occurs no later than the day after production, and the destination is a plant in Atessa (Chieti), located 275 km far from the hospital, where the waste is currently sterilized. Regarding the current situation of **solid waste management**, all kinds of waste are brought to the **ecological platform**, before being transported to external disposal sites. The ecological platform is located within the area owned by the hospital Foundation.

From an energy perspective, the Gemelli campus can be compared with a 30'000-people city, with a consumption of 50'000 MWh of electrical energy and around 16 million of cubic meters of NG every year. The campus fulfils roughly 60% of its electrical and thermal needs through a **co-generation plant** situated centrally within the area. This plant consists of two co-generative gas turbines and three gas boilers for generating hot water used in space heating and domestic hot water systems. The cooling need is satisfied through 12 absorption chillers, which use the hot energy coming from cogeneration to produce refrigerated water. Both hot and refrigerated water are sent to the air handling unit and to the other HVAC plant to provide internal comfort throughout all the year. It stands as one of the largest facilities of its kind in Italy, ensuring a degree of independence from the national power grid. The simultaneous production of heat and power results in notably high overall process efficiency. Additionally, a photovoltaic (PV) array is installed atop one of the campus buildings, increasing the proportion of renewable energy sources in use. FPG has installed an **integrated system of remote controlling** with over 50'000 points connected through optical fibre, that allows an optimized management of the electrical and thermal energy, maintaining the requirements of 24h operation typical of HC facilities. This energy plant made possible the obtaining of **ISO 50001:2018** certification (Energy management systems - Requirements with guidance for use), accredited by joint commission international accreditation. FPG is the only hospital in Italy with this type of certification.

Figure 12: FPG- main entrance of the hospital building

Current approach and experiences regarding the green transition

To further increase the sustainability of the area, in 2022 FPG has implemented an investment for the **sustainable re-use of industrial water used in the water refrigeration plants** through **reverse osmosis equipment.** FPG annually consumes significant amounts of industrial water for processes related to the production of chilled water

Thanks to a recycling project involving reverse osmosis, the Foundation has been able to reuse the water destined for disposal, thus avoiding tapping into precious drinking water resources. This sustainable Solution not only preserves the environment but also contributes to the circular economy**.** It has been estimated that this innovative system will allow a **reduction of the 70% of the industrial water consumption**, a substantial saving of drinkable water in summertime (when it is used to compensate the shortage of the industrial water), and an investment payback of less than 5 years

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FPG is certified under the Joint Commission International (JCI) accreditation. JCI is an independent not-for-profit organization that defined standards which serve as the foundation of an evaluation process that can help HC organization in measuring, assessing and improving performance. FPG intends to keep its accreditation also in 2025, when JCI will introduce new criteria on environmental sustainability in healthcare, regarding aspects such as Governance, Employee engagement and empowerment, use of energy and water and sustainable procurement

Considering that the price of energy is strongly correlated to geo-political events, the possibility of a rapid increase in energy costs is real. More efficient and well managed buildings in terms of energy, can reduce the negative effects of cost fluctuation. So, the economic aspect of the renovation is not negligible.

6.2 Fundación Privada Hospital Asil Granollers (FPHAG)

FHAG (Fundaciòn Privada Hospital Asil Granollers) is a university hospital and nursing home located in the municipality of Granollers, in Catalunya region in Spain. The Hospital is renowned for its clinical excellence and commitment to serving the local community. Additionally, as a non-profit private entity, it can establish partnerships with other healthcare organizations and participate in research and development programs in the healthcare sector.

A day in FHAG:

- 57 admissions in the Hospital per day
- 1076 outpatient visits per day
- 237 emergency visits per day
- 3 births per day
- 47 surgical interventions per day

Table 24: FHAG Numbers

N° of beds	**365 beds (295 acute hospitalization, 40 socio-sanitary, 30 psychiatry)**
varieties of professionals	3000
outpatient visits	393.000/y
Geriatric day hospital places	30
Number of consultation rooms	76
Examination rooms	21
Day hospital places (treatments)	38
Psychogeriatric day hospital places	40
Ambulatory major surgery places	10
Inhabitants reached	400000
Net room area	13000 m^2

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Figure 13: Location of Granollers in Spain

The outpatient consultation facilities span 13,000m2 and encompass 76 offices along with 21 exploration cabinets. Additionally, there are 6 general operating rooms and an ICU with 30 beds. The Compact Building housing emergency services consists of 90 boxes, including 8 dedicated to paediatrics, 8 for mild cases, 6 for critical cases, 3 for surgery, and 4 for traumatology.

Figure 14: Aerial view of the FPHAG

In total, FHAG occupies 50.000m^2, divided among 7 buildings. In the following years, it is planned a 50% growth in infrastructure area (up to 80.000m2). The fundacion developed a Waste Management Plan, in force since 2017 and is in the process of being updated, with the aim of rationalizing the management of healthcare waste.

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Figure 15: One of the main building of FHAG

Current approach and experiences regarding the green transition

The sustainability of the FHAG is tied to the principles of social responsibility, environmental commitment, and economic balance. FHAG provides open and transparent health services, grounded in ethical values and respect for all employees, the community, and the environment. The Hospital demonstrates a commitment to reducing environmental risks and impacts in healthcare activities through monitoring and energy use reduction. This commitment extends to sustainable procurement achieved through aggregated purchasing systems and collaborative efforts with suppliers.

FHAG is mainly working in four areas to improve its efficiency and sustainability.

1) Energy Management: Photovoltaic Energy Generation

The first photovoltaic plant of FHAG was installed on the parking in 2018. The photovoltaic plant produces 1.1GWh per year and cover the 12% of the total energy demand. The return of this investment is expected within a significantly shorter period than 10 years.

In 2022 , the new construction of the Compact Hospital allowed to install a new PV plant, expanding by 11% the PV capacity of the Fundacion, increasing it from 800KWp to 900KWp.

In 2023 FHAG is in the bidding phase for the installation project of photovoltaic panels at the Adolf Montanyà Geriatric Center. The installation is planned to begin in 2024. Currently, FHAG has photovoltaic panels installed on 59.57% of the hospital area. Once the Geriatric project is completed, it will increase to 68.80%.

2) Energy Savings, Cooper Onnes

Since 2023 contacts have been established with a local company to install equipment on the hospital's electrical grid, ensuring a minimum 8% reduction in electricity consumption. At the end of the year, a trial of this equipment will be conducted in the geriatric centre building, where consumption will be monitored. If commitments are met, installation will be planned for the general hospital supply.

3) Gas Consumption Reduction

Various actions have been taken to reduce this energy and economic impact, including modulation of boiler burners, installation of a cooling plant with heat recovery for pre-heating the heating system. In 2024 we plan to replace the current boilers in the geriatric centre with high-efficiency ones for greater energy efficiency.

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4) Water Savings

In 2019 the kitchen washing tunnel was replaced with a high-efficiency one. FHAG is part of Interhospitalia, a laundry service that enables more efficient clothing management. Low-consumption atomizers are installed on all faucets. We actively participate in working groups to define actions to reduce water consumption.

A study on reducing the pressure in the fluxor network, achieving savings between 6-12% of consumption has started.

In November 2023, exceptional drought is declared in Catalonia, incentivizing new investment in water equipment. In 2024 the hospital's water softener will be replaced with a more efficient one, saving 1,157,000 litres per year.

6.3 Universitatsklinikum Heidelberg (UKHD)

UKHD is the university hospital of the Heidelberg University. It is located in the German region of Baden-Württemberg, and it is with 2,599 beds the 3rd largest and largest non-conglomerate medical centre in the country. UKHD employs over 14,620 people, divided among physicians, nurses, technicians, functional service and administrative.

Table 25: UKHD Numbers

beds	**2.599**
In-patients/year	85.582
Full days (In-patients)	601.793
Case Mix (In-patients)	107.086
Surgeries (In-patients)	50-60.000
Out-patients/year	280.927
Services (Out-patient)	1.163.491
Surgeries (Out-patients)	8.853
Employees	14.620

Figure 16: Main campus of Heidelberg hospital

The University Hospital of Heidelberg is renowned for its excellence in healthcare, research, and medical education. It serves as both a leading medical facility and a centre for cutting-edge research in various

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fields of medicine. With state-of-the-art facilities and a multidisciplinary approach, the hospital provides a wide range of specialized medical services to patients from across the region and beyond. Additionally, as an academic institution, it plays a vital role in training the next generation of healthcare professionals and advancing medical knowledge through innovative research initiatives.

Current approach and experiences regarding the green transition

In Heidelberg, there are some initiatives regarding green transition, which address daily practices, such as getting a cup instead of a paper cup for a coffee or the future pilot on separating the waste in the operation room (piloting in Caring Nature project). All these initiatives are project based and are individual parts rather than a big hospital campaign.

Regarding architecture, a new Surgical building has been designed according to sustainable principles. Other buildings are older and need special attention referring to the envelope. For these buildings, considered as a heritage, there are some operative limitations. As an example, in some facilities, it could be hard to modify the façade because of local regulations.

Figure 17: New Surgical Building in Heidelberg

6.4 Wellbeing services county of Päijät-HÄme (WPH)

In 2023 a reform of the Finnish healthcare, social welfare and rescue services gave birth to new Wellbeing services counties. These counties, funded by the government budget, are responsible for organizing health, social and rescue services in their geographical area. The decision-making power is handled by the elected Regional Council. The wellbeing services county of Päijät-Häme has the second largest regional hospital in Finland and about 170 service points in the region wide.

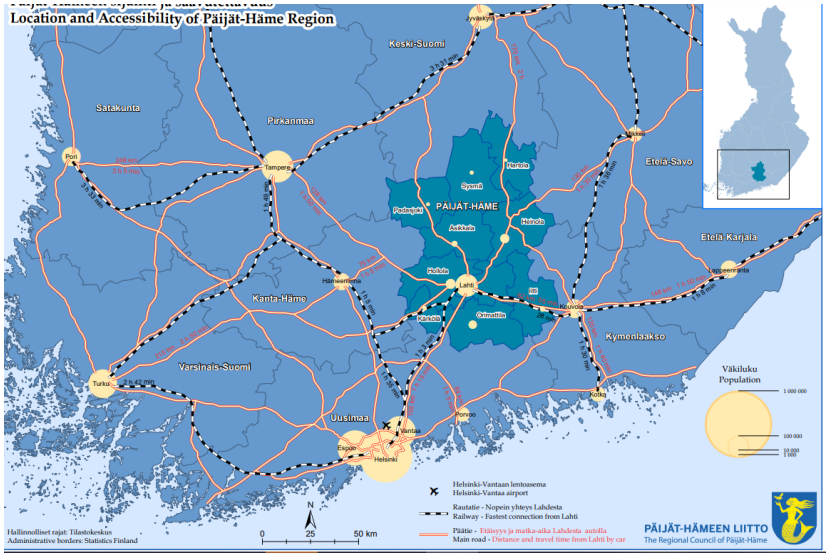

Figure 18: Location of Päijät-Häme county in Southern Finland

Wellbeing services county of Päijät-Häme (WPH) is located in the junction of various transport routes and lake area in southern Finland and has the headquarter in the main city of the region, Lahti. The county services are divided into six main divisions, which are listed below:

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- **Human health and medical care services division,** which provides all the medical, health and pharmaceutical services, outpatient care and oral health care, together with partnership arrangements for health and social services
- **Family and social work division,** which provides services for family, people with disabilities, welfare and psychosocial services for the inhabitants in the region
- **Elderly and Rehabilitation Division,** which manages home care services, housing services and rehabilitation of older people
- **Rescue Services Division** which organizes rescue operations, accident prevention, emergency care and provide technical support services
- **Support Services Division** for ICT information management, human resources management, premises construction and maintenance, safety and security services, support services and sustainable development services
- **County Governance** for the administration of the wellbeing services county, economy and financing and organizational support services

Some characteristic numbers that define WPH are presented in the table below.

Table 26: WPH Numbers

N° of beds	**300**
N° of operation rooms	21
medical specialties	40
medical doctors	450
overall number of employees	8000
Service points	170 service points in 10 municipalities
Inhabitants reached	220 000
Net room area	393 359 m2

Figure 19: The central hospital of Päijät-Häme in Lahti

Current approach and experiences regarding the green transition

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The WPH is an entity established 2023 and set aims for the sustainable service production that reduces the environmental impact. Its task is to create a network of sustainability experts, communication, training and reporting on sustainable development activities and implement the **environmental programme** and its measures.

The compilation of the environmental programme was taken forward by a group of experts from different fields of activity and discussions with various experts during 2022. The aim of the environmental programme is to create an overall picture of various measures related to sustainable development and the environment that can reduce the environmental impacts of the wellbeing services county of Päijät-Häme. Solutions are sought from developing one's own operations to global challenges, such as climate change mitigation, promotion of biodiversity and sustainable development. These Solutions include:

- Low carbon in services, construction and operations
- Low carbon procurement in goods, equipment and supplies, energy and services
- Greater carbon neutrality in construction, energy, chemicals, pharmaceuticals, logistics and transport and services by 2035
- The wellbeing services county's preparedness for climate change, resilience and economically sustainable development.

The programme focuses on the wellbeing services county's actions and means to reduce the use of the planet's resources and achieve carbon neutrality in 2035 in accordance with the national target in the legislation. Ways to achieve carbon neutrality include reducing the consumption of energy, water and materials, reducing waste whenever possible, implementing the principles of the circular economy and moving towards emission-free alternatives in construction, energy, procurement, mobility and logistics, for example. These are also expected to have positive economic impacts in the form of future-oriented operating methods.

Mission: The Wellbeing services county of Päijät-Häme is sustainable with environmentally friendly service provision and achieving carbon neutrality by 2035.

Vision: The goal is an established operating culture in sustainable, environmentally and climate-friendly service production in all units.

The practical measures are led by the director of the wellbeing services counties and the heads of divisions and their personnel. Boards, advisory boards and advocacy bodies are also consulted when necessary.

The practical implementation of the measures is planned in more detail and budgeted in the units responsible for the measures in connection with the planning of normal operations.

The programme covers a wide area of intervention, listed below:

- **Construction, demolition and renewal of the premises**
- Use of carbon neutral energy
- Low carbon procurement
- **More efficient waste sorting**
- Material use and resource efficiency
- Reducing chemical impact
- Reducing the environmental impact of pharmaceuticals
- **Reducing food service waste**
- **Low-carbon logistics and mobility**
- Promoting biodiversity
- **Communication, influencing and competence development**

6.5 7thHealth Region Crete (7HRC)

The 7th Health Region of Crete is the **regional authority** responsible for the specification-development of health policies in the Region of Crete by supervising, coordinating and controlling the operations.

The Ministry of Health is the leading authority, both supervising public and private health sector.

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Public hospitals in Greece are operated by the Ministry of Health, while Private hospitals are regulated by the Ministry of Health.

Table 27: 7HRC Numbers

beds	2.502
hospitals	8 (1 University, 4 General, 3 General Hospitals – Health Centers)
health centers	19
regional medical centers	133
local health units	12
public facilities for mental health	32

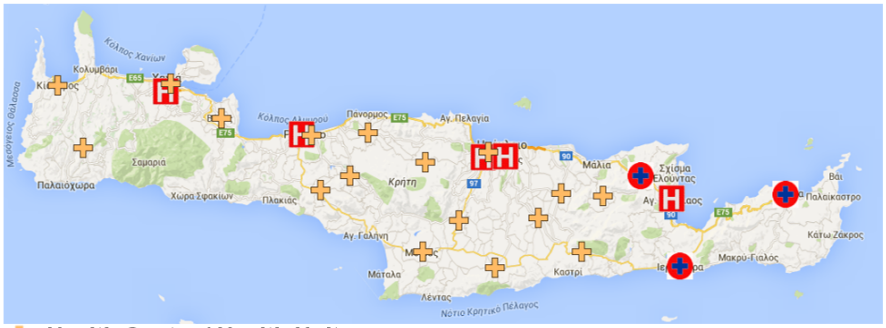

Figure 20: Summary of 7HRC organization

Current approach and experiences regarding the green transition

The 7th Health Region of Crete is already involved in projects to improve sustainability in health.

The Medical Waste Management aims to improve the medical waste management at the national, regional and local level. The drafting of Internal Regulations for the Management of Hazardous Medical Waste aims to determine the strategy for the implementation of specific actions, measures, conditions and restrictions during the collection, transport, treatment and final disposal of medical waste, with the aim of protecting public health and the environment.

Regarding wastewater management on Healthcare Centers (Small and medium sized building with 30-100 employees) and Hospitals (Medium and large sized buildings with 75-775 beds, including Laboratories, Hospitalization, pharmaceutical products, chemotherapies, etc.), there is no wastewater management procedures in place.

Waste water of Healthcare Centers is directed to the public sewerage system without any additional process, monitoring of the quality of water for human consumption within the internal primary healthcare centres' water supply network is in place on a regular basis (detection of E. coli, coliforms, Enterococcus spp, Pseudomonas aeruginosa, Legionella pneumophila SG1, SG2-15, spp, etc).

On wastewater management one project, **DIANYA** dealt with "On-site integrate management of hospital wastewater", funded by the National Action: Research – Create – Innovate [Operational program: "Competitiveness, Entrepreneurship & Innovation (EPAnEK) 2014-2020" (NSRF 2014-2020), with the co-financing of Greece and the European Union]. The project aimed to develop an integrated methodology for the management of hospital wastewater that will succeed, at a competitive cost: (i) satisfactory on-site hospital wastewater treatment and removal of contained organic micro-pollutants, (ii) safe disposal or reuse of the treated outflow.

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Another project called HIPPOCRATES (LIFE funding) aims to develop an holistic approach towards onsite hospital wastewater treatment, started in September 2023.

7. Governance Solutions: requirements, standards, KPIs and Use Cases

7.1 DSS for sustainability-oriented investments and EU-wide knowledge sharing system for green healthcare transformation

The result *Knowledge Sharing System & Decision Support System (KSS-DSS*) has the purpose of facilitating the sharing among the stakeholders of the knowledge on sustainable approaches to reduce the environmental impacts of the HCSs, to measure and benchmark the environmental footprint, to support decisions of HCPs managers, policy makers and investors on the interventions to be implemented, while considering environmental benefits and social and economic sustainability.

The KSS-DSS will be composed of three components (KSS, DSS, CSRD), that make-up the "logical"[19] part, integrated and supported by a forth component, an Information Technology (IT) infrastructure (see Fig. 21).

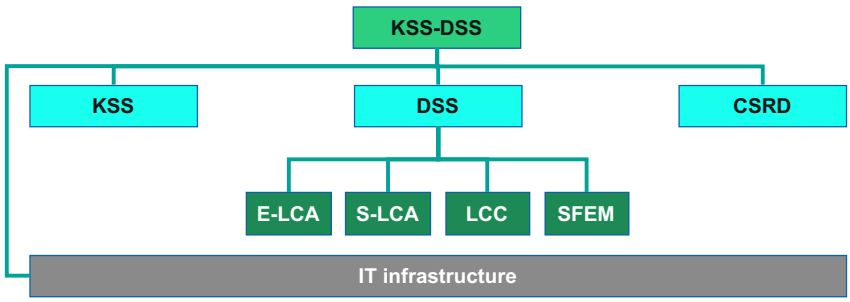

Figure 21; Structure of the KSS-DSS

In the following, paragraphs 7.1.1 and 7.1.2 refer to the "logical" part, while the paragraphs 7.1.3 and 7.1.4 (+ the Annexes B and D) refer to the IT infrastructure. The remaining paragraphs regard both parts.

7.1.1 Solution 0 description (KSS-DSS logical components)

The "logical" part of the KSS-DSS is made-up of three components

1) **KSS-Knowledge Sharing System**, including a) knowledge base **taxonomy**, that is the foundation of the entire **KSS-DSS** b) methods to activate and manage a **knowledge sharing network**, engaging the participants through already existing "hubs" (e.g. professional associations, networks activated by European programmes), c) **guidelines for designing health and care managers' educational programs** to fill the training gap concerning sustainable HCSs among professionals involved in their **governance**. A course will be designed and delivered, as application of the guidelines.

2) **DSS-Life cycle multidimensional assessment and evaluation model for HCPs**, including: a) Life Cycle Assessment of the environmental impact (**E-LCA)** b) Social Life Cycle Assessment **(S-LCA)** and c) Life Cycle Cost to evaluate the economic impact (**LCC)** and d) Sustainable Finance Evaluation Model for HCPs (**SFEM**). They will allow CN to assess not only the AS IS situation, but also the impact of alternative improvement initiatives. Based on customized healthcare service life cycle inventory and according to the cradle-to-grave and cradle-to-cradle approaches, the model defines the data to be collected to feed already existing software tools (e.g. *OpenLCA*). Boundaries of analysis and development will be defined, identifying different processes of the most relevant HCP's operational areas (e.g. Emergency Dept, outpatient services, nursing home).

   The Sustainable finance evaluation model for HCPs is fed by the output of the component above. It includes a) methods to **evaluate the expected benefits of improvement actions,** such as lower costs and operational risks, higher profitability, better environmental efficiency b) methods to

[19] The "logical" component DSS also include "off-the-shelf" software tools for performing lifecycle assessment calculations; they will not be developed by the CARING NATURE project. See the "external applications" in Fig. 22

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calculate **indicators to evaluate alternative initiatives** to support decision makers in allocating capital into the initiatives.

The four sub-components feed a Decision Support Dashboard that allows the joint visualization of the three sustainability dimensions and of the multi-dimensional return (impact) of the investments.

3) **CSRD-Reporting model compliant with the Corporate Sustainability Reporting Directive**. It provides a general framework and set of rules for the disclosure of information about the risks and opportunities arising from social and environmental issues and on the impact of their activities on people, and the environment and other sustainability issues. The CSRD will probably become mandatory from 2026 also for the HCPs. The CSRD will probably become mandatory from 2025 also for the HCPs. This component aims at providing the HCPs with a structure of the Environmental section of the report and of the parts of the Social and Governance sections reporting on the impact of interventions aimed at reducing the environmental footprint. The purpose is to make sure that the content of the report a) is easily fed by the other components, b) allows benchmarking through Sustainable Finance Reports and Sustainability Balance Scorecards in the healthcare systems c) is informative, i.e. helps to identify and prioritize of the environmental issues.

Innovative characteristics. The innovation refers both to the individual components, which will bring a still missing **contextualization to the healthcare sector**, and to the KSS-DSS as an **integrated toolset for the governance of the green transition in the healthcare sector**.

The KSS-DSS aims at developing and validating a completely new integrated set of models, compliant with the EU standards and regulations, supported by an integrated software capable of supporting the HC actors in charge for deciding and implementing the HCS environmental transition with actionable knowledge and a multidimensional set of sustainability indicators, specific to the HC sector. (e. g. social KPIs regarding: patient safety, quality of care, healthcare operators wellbeing). The knowledge sharing processes will be designed to effectively address the challenges faced by virtual communities and will include the design of incentives for virtual collaboration.

7.1.2 Solution 0+ requirements (KSS-DSS logical components)

7.1.2.1 Knowledge Sharing System (KSS)

a) The **CARING NATURE HealthCare Doughnut framework** described in Section 2 should be used and enriched with a **model of the Healthcare Green Transition processes and stakeholders**

- Attaching specific knowledge content to the domains and the actions identified through the literature review and the Delphi consultation
- Making the “quintuple aim” metrics pervasive in the knowledge sharing
- Identifying and describing the processes that make possible the green transition (e.g. Policy making & Regulatory, Funding, Solutions Innovation and Diffusion, Standardization, Healthcare Provider Green Transition Implementation) and their tools/outputs (norms/policies, funding mechanisms, standards, solutions,
- Identifying and mapping the Stakeholders contributing to the processes to identify the knowledge that they generate and need, and the relevant knowledge sharing community.

A tentative model, to be further developed in the project, is shown in Fig. 22

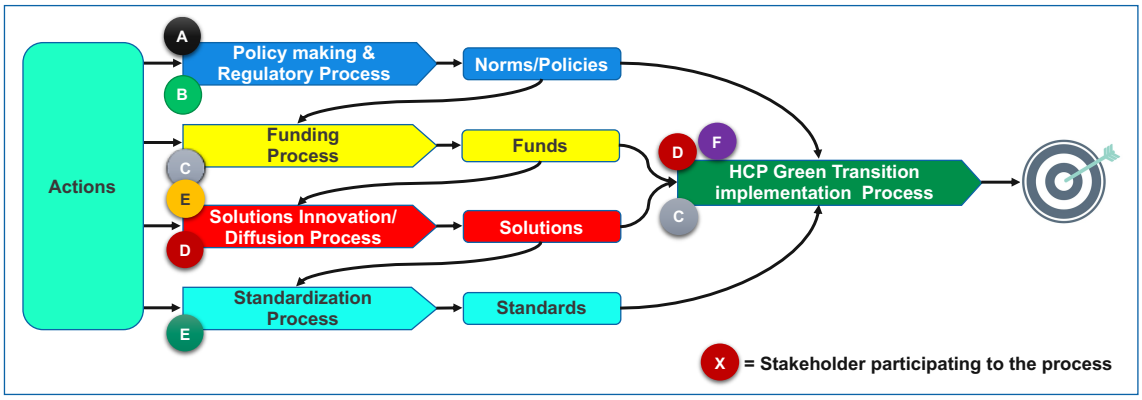

Figure 22: Model of the healthcare green transition underlying the KSS (tentative)

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b) The KSS should leverage the availability of the public sustainability reports that will be mandated by the CSRD from 2026 and include a feature to derive benchmarks and best practices from them

c) The KSS should be designed to connect as sources and destinations of the knowledge a variety of entities, including

- Individuals
- Professionals covering roles related to the sustainability in the HCPs (e.g. sustainability managers, coordinators of the drafting of the sustainability reports) or in the organizations belonging to the supply chain
- Representatives of communities of practice that exchange knowledge (e.g. in Finland the 21 Wellbeing Services Counties regularly meet to share knowledge on a variety of topics including the green transition)
- Associations of professionals or organizations that generate knowledge and, in the same time, are channels to reach their members

d) The educational package for HCP managers should fit with the shortage of time of the HCP managers; therefore, it should be deliverable online, short, content-rich and well-tailored on the HC specificities and the knowledge gaps of the target population.

7.1.2.2 Life cycle multidimensional assessment and evaluation model for HCPs (DSS)

a) The sub-components (**LCA, S-LCA, LCC** and the **SFEM**) must be well integrated one each other and with the **GLSS-HC** methodology.

All of them can be used independently, but their joint use is expected to add a great value to the decision makers

The key relationships between all the parts are represented in Fig. 23 that shows three situations of joint use of the sub-components

- Analysis of a process in a multidimensional perspective (upper part of the figure): the life cycles of all the resources used/produced by the process are analysed using E-LCA, S-LCA and LCC, to complement the typical Lean Six Sigma metrics (e-g. throughput time, errors)
- Analysis of an investment (e.g. a new equipment, a new procedure, a new information system) in a multidimensional perspective (lower part of the figure): the life-cycles strictly related to the entity making up the investment are analysed using E-LCA, S-LCA and LCC; but also the impact of the investment on the process is analysed with the GLSS-HS, so obtaining other indicators (e-g. throughput time, errors) to do the final calculation of the investment and its benefits (e.g. CO2e saved per 1€ invested) with the SFEM. All the calculated indicators can then go in the Dashboard to support the decision on the investment
- Combination of the two previous situations (linked by the dotted arrow): the process is analysed, and its multidimensional evaluation shows that it should be improved; therefore, a simulation is done to verify if an investment X can improve the performance of the process.

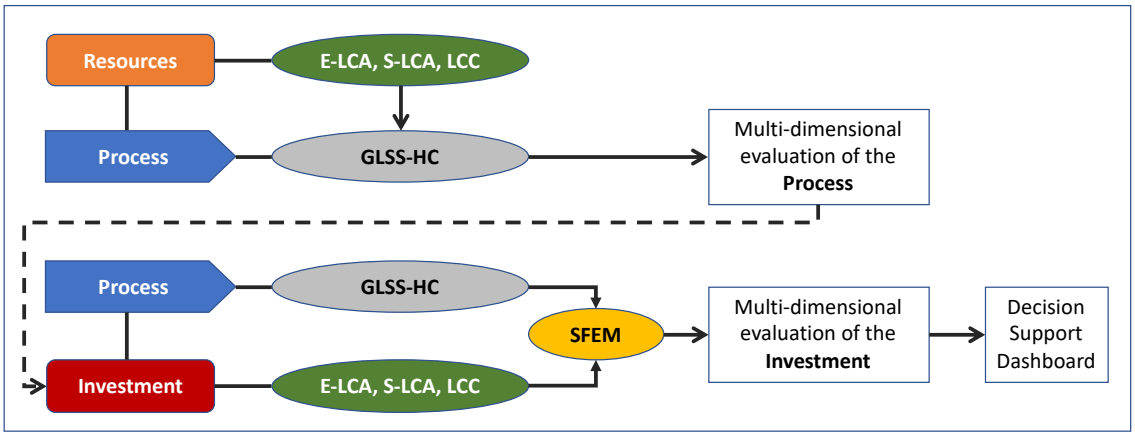

Figure 23: Logic of the relations among the DSS components

b) In terms of requirements, this means that, for instance

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- The representation of the Lifecycle should be done with a "language" consistent with the one used for describing the process in the GLSS-HC methodology (e.g. the SIPOC[20] chart could be enriched including columns regarding the "material" Inputs and Outputs needed to calculate the environmental impact)
- The data bases and the KPIs of the GLSS-HC should be consistent with those of E-LCA, S-LCA, LCC and SFEM
- The S-LCA should include PREMs (Patient-Reported Experience Measures) and PROMs (Patient-Reported Outcome Measures) indicators.
- The DSS dashboard should include indicators that are additional to those calculated by the LCA, S-LCA, LCC and SFEM, e.g.
- Time, Quality of output, Resilience indicators

c) The DSS interface should allow what-if simulations

d) The DSS indicators (in particular those of the SFEM) should be tailored taking into account the different levels of decision makers (e.g. Managers of the HCP, Governing board, Public institution that funds the investment with public money, donors, private investors/banks)

e) To help some decision makers, the DSS should show how and how much the investment under evaluation impacts on related **Sustainable Development Goals**, even they do not directly regard the environmental impact[21]

7.1.2.3 Reporting model compliant with the Corporate Sustainability Reporting Directive (CSRD)

a) The organizations that will draft the CSRD report may count on a series of standards (see relevant section) and on some software application[22] [41]. However, they are not sector specific. HC-specific standards will be prepared in next years. CARING NATURE is in time to provide input to this contextualization, considering the specificities of the healthcare sector, for instance about the type of waste, staff, "clients" (the patients), stakeholders, supply chain, governance structure

b) The CSRD report requires that every year a high quantity of information is collected and elaborated. For instance, the European Sustainability Reporting Standard (ESRS) prepared by the European Financial Reporting Advisory Group (EFRAG) asks to fill an excel sheet with 1.208 data. 70% of them are qualitative. In some cases, it may happen that they are owned by external actors (e.g. suppliers, municipalities). The data collection has been indicated by the stakeholders as the main challenge for filling the report

   Therefore, the Solution that will be developed should contribute to

   - clearly identify the sources of reliable information and the accountability for the quality af the data
   - ensure that the qualitative information is informative and non-ambiguous
   - ensure that the quantitative data that are already stored in the organization's databases are automatically collected and made available

c) The process to prepare the CSRD report will be repeated every year and involves many actors; The KSS-DSS software infrastructure should embed a workflow connecting all the actors and providing forms/checklists/instructions

d) The guidelines should include a sound methodology for the execution of the materiality assessment.

e) The CSRD report should be an opportunity for the HCPs to practice the green transition in a structured and fact-based manner. Therefore the:

   - The CSRD report should be structured in a way that makes easy to identify the future priority areas in the green transition of the HCP and to feed the first steps of the GLSS-C methodology. And it is also important the reverse, i.e. that the DSS tools (E-LCA, S-LCA, LCC, SFEM) and the GLSS-HC provide outputs easily transferrable into the CSRD report

[20] A chart that associates to each activity of the Process, the *Suppliers, Input, Output and Customers)*
[21] See for instance: SEI Stockholm Environment Institute, *SDG Synergies-User Manual*, 2020 version 0.1
[22] See for instance: https://www.openes.io/it

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- The drafting process and the reading of the report should be an opportunity to promote the diffusion and sharing in the HCP staff of the culture of the green transition. The Community of Practice methodology could be recommended as a method to perform the drafting process (see how this idea will be tested in the Use Case ENGAGE/FPG).

7.1.3 Solution 0 description (KSS-DSS IT infrastructure)

Based on the description from DOA, the KSS-DSS IT infrastructure is composed of two main components: KSS and DSS, strongly coupled.

The **DSS** will be a web-based application with three levels: dashboard, application layer, and database layer.

The database layer will be built upon the context as will be specified by each HCP internal system availability. However, the design will follow optimal patterns to be modular and extensible, having the ability to integrate future external databases and huge volume of data coming from relevant internal systems in the HCP, currently not integrated into the usual HCP management systems (e.g. energy consumption monitoring systems, water consumption monitoring, logistic traceability systems etc).

KSS will offer a unified and comprehensive view of the data to all stakeholders. They will have access to the same information and be able to base their decisions on reliable and current data thanks to this centralized approach to data management. The KSS will use a wide range of data optimization techniques to improve the overall quality of the data gathered from various sources. The KSS will enable users to add their own knowledge and best practices to the repository. Due to the KSS's user interface, straightforward and easy to use, users will be able to search for specific information using a variety of search parameters, such as keywords, categories, and other pertinent components. KSS will allow healthcare providers to engage in collaborative co-creation activities related to their sustainability overall activities without compromising critical intellectual property by creating virtual spaces.

The global architecture described in the GA is presented in the next Fig. 24.

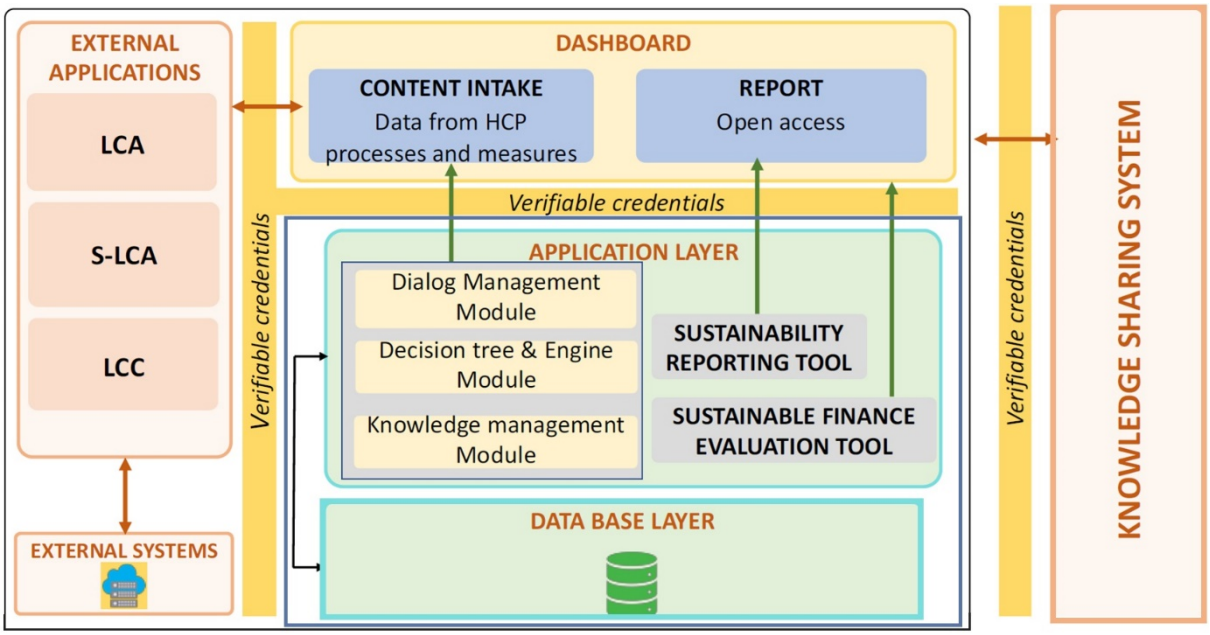

Figure 24. KSS-DSS global architecture

Following the description from the GA, we are defining here a more precise Solution description. The Solution description is from requirements perspective. The full Solution is subject to the whole work package WP3.

7.1.3.1 KSS infrastructure logical structure

KSS will implement the required functionality through the usage of several basic components as described in the next paragraphs. The full description of KSS is subject to task T3.5 and will be reported in D3.2 Software infrastructure of the Knowledge sharing and decision support system v1.

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From the requirements perspective, the components are described in the next paragraphs.

7.1.3.1.1 Metadata

This metadata includes all parameters and data that allow to adapt the KSS in terms of:

a. visual design (logos, icons, images, buttons and colour settings),
b. text in different languages (for user interactions)
c. themes (fields of interest for user profiles, Knowledge Units, Cocreation and events)
d. access rights to different functionalities
e. training and documentation elements

7.1.3.1.2 User profiles

Data subjects are all natural persons, who applied for the KSS and were accepted as participants. Data of rejected participants will be deleted after one month. In total, these are three user categories(i.e. Healthcare Professionals (HCPs), policymakers, investors, and Public), whose records are structured identically[23]:

a. User ID
(automatically generated by the KSS, used only internally to link to other datasets)
b. Name (Title(s), First Name, Surname)*
c. Email address* (the email address is used as a key field for identifying users – therefore the VCP checks if a user profile with the same email address already exists to avoid double records)
d. User-Group* (Healthcare Professionals (HCPs), policymakers, investors, and the Public)
e. Language* (linked to parameters in the KSS settings)
f. A free text that allows users to describe their motivation to join the KSS (as the basis for the decision of the Knowledge Unit Manager)* - this information will only be visible to the individual user and the Knowledge Unit Manager
g. Address
h. Website
i. Year of birth
j. Country of residence
k. User answers regarding his/her fields of interest (linked to themes in the KSS settings)
l. User-answers regarding his/her fields of expertise (linked to themes in the KSS settings)
m. Link to a profile-picture (that will be stored by the KSS)
n. A free text that allows users to describe themselves and thus introduce themselves to other users
o. Date of creation of user record
p. Date of last modification of user record

7.1.3.1.3 Knowledge Units

They are groups of elements representing specific knowledge areas and include the following basic data for each Knowledge Unit:

a. Knowledge-Unit ID
(automatically generated by the KSS, used only internally to link to other datasets)
b. Title (short and informative)
c. Text (entered as free text)
d. Link to an image, picture or symbol for displaying tiles (uploaded by the Knowledge Unit Manager, stored by the KSS)
e. Links to external websites (e.g. to videos on YouTube or Vimeo[24])
f. Attachments (only as PDF)
g. Thematic profile of the Knowledge Unit (linked to themes in the KSS settings)
h. Target audiences (experts, guests, or both)[25]
i. Status (shared, approved, rejected)
j. Deadline for improvements
k. Who created the Knowledge Unit and when (user-ID)

[23] Mandatory fields are marked with *
[24] Links to YouTube or Vimeo sites are the only way to access videos, as no videos will be uploaded to the VCP. For videos shared by the project consortium, an independent YouTube channel will be created.
[25] In release 1.0 Module 4 is only available for experts. A differentiation between target groups should already be included in the data structure since in future releases citizens might also have access to Module 4.

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l. Who approved it and when (user ID of the Knowledge Unit Manager)

The dataset “Participants” links users to Knowledge Units and contains the following information

a. who displayed the individual Knowledge Unit (user ID, date and time)
b. who engaged in the public discussion on the individual Knowledge Unit (user ID, date and time)

Each Knowledge Unit is linked to several discussion fora:

a. bilateral discussion forum for the author of the respective Knowledge Unit and the responsible Knowledge Unit Manager to discuss the Knowledge Unit before it is published
b. public discussion forum, where all experts can discuss it after publication

7.1.3.1.4 Knowledge management mechanisms.

They refer to the mechanism for:

a. Knowledge Capture and Creation
b. Knowledge Sharing and Dissemination
c. Knowledge Retrieval and Access (Search engine)

7.1.3.1.5 Events

They refer to events registered in the system, related to data creation exchange, and cocreation and include the following basic data for each event:

d. Event ID (automatically generated by the KSS, used only internally to link to other datasets)
e. Title (short and informative)
f. User ID of the responsible Knowledge Unit Manager
g. Date when the event was entered the first time
h. Date when the event was updated the last time
i. One-sentence description text (in multiple languages)
j. Half-page description text (in multiple languages)
k. Thematic profile of the Event (linked to themes in the KSS settings)
l. Link to a primary image, picture or symbol for displaying tiles (uploaded by the Knowledge Unit Manager, stored by the KSS)
m. Links to additional images, pictures or symbols (uploaded by the Knowledge Unit Manager, stored by the KSS)
n. Links to PDFs for additional information (e.g. invitation, certificate of participation), uploaded by the Community Manager, stored by the KSS
o. Links to external websites (e.g. to videos on YouTube or Vimeo[26])
p. Start of application date
q. Final application date
r. Language of the event
s. Place (country, street, name of the location)

The dataset “Participants” links users to events and contains the following information:

a. who applied to participate in the respective event (user ID, date and time) and the status of this application (applied/accepted/rejected)
b. who engaged in the public discussion forum of the individual event (user ID, date and time)

Each event is linked to several discussion fora:

a. bilateral discussion forum for the individual applicant and the responsible Event Manager to discuss the potential participation (this is the place where the individual applicant can describe his/her background and motivation)
b. public discussion forum, where all accepted participants can discuss before and after the event

7.1.3.1.6 Cocreation

This refers to the management of activities where several participants work together to create knowledge. It includes the following basic data for Cocreation:

a. Cocreation ID (automatically generated by the KSS, used only internally to link to other datasets)

[26] Links to YouTube or Vimeo sites are the only way to access videos, as no videos will be uploaded to the VCP. For videos shared by the project consortium an independent YouTube channel will be created.

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b. Title (short and informative)
c. User ID of the responsible Knowledge Unit Manager
d. Date when the Cocreation was entered the first time
e. Date when the Cocreation was updated the last time
f. One-sentence description text (in multiple languages)
g. Half-page description text
h. Thematic profile of the Cocreation (linked to themes in the KSS settings)
i. Primary Image/picture
j. Additional images/pictures
k. PDF for invitation
l. Links to external websites (e.g. to videos on YouTube or Vimeo[27])
m. Start of timeline
n. Final deadline (=end of timeline)

Each Cocreation contains a sub-dataset with the starting and end-date of individual activities and the links to the respective discussion forum, surveys and wikis. This relates to

a. Scope and objectives
b. Target groups and expected impacts
c. Resources needed and already available
d. Pros and cons
e. Open questions and next steps

The dataset “Participants” links users to Cocreations and contains the following information:

a. who was invited to participate in the respective Cocreation (user-ID, date and time), by whom (user-ID, date and time) and the status of this invitation (invited, accepted, contributed)
b. who engaged in the different activities of the individual Cocreation (user-ID, date and time)

7.1.3.1.7 Participants

This dataset links users with (a) Knowledge Units, (b) Events and (c) Cocreations. It consists of

a. the respective ID of the user/ Knowledge Unit /Event /Cocreation,
b. some status information (e.g. for events if the user was invited to, applied for participation, was accepted by the Event Manager or even participated in the past)
c. the date when this link was created/updated the last time
d. the ID of the Knowledge Unit Manager who was involved in it

For the individual user only Knowledge Units, Events and Cocreations are displayed that can be found in this linking table.

7.1.3.1.8 Discussion fora

This dataset contains all the discussion forums of (a) Knowledge Units, (b) Events, (c) Cocreations, and (d) new user applications. In terms of access rights to these discussion forums the VCP will differ between (i) general discussion fora (where several users can discuss) and (ii) bilateral discussion fora (where only a user and a Community Manager can discuss).

7.1.3.1.9 Access and activity log

This dataset stores information about the access and activities of all users. It allows to

- analyse interactions via the KSS (e.g. between users and Knowledge Unit Managers),
- trace and identify errors (e.g. malfunctions) and mistakes (i.e. wrong decisions),
- document data input
- analyse use patterns and habits.

7.1.3.2 DSS infrastructure logical structure

DSS will implement the required functionality through the usage of several basic components as described in the next paragraphs. The full description of DSS is the subject of task T3.5 and will be reported in D3.2 Software infrastructure of the Knowledge sharing and decision support system v1.

[27] Links to YouTube or Vimeo sites are the only way to access videos, as no videos will be uploaded to the VCP. For videos shared by the project consortium an independent YouTube channel will be created.

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From a requirements perspective, the components are described in the next paragraphs.

It is a Knowledge-Driven DSS and provides specialized problem-solving expertise stored as facts, rules, and procedures.

7.1.3.2.1 Metadata

This metadata includes all parameters and data that allow to adapt the DSS in terms of:

a. visual design (logos, icons, images, buttons and colour settings),
b. text in different languages (for user interactions)
c. themes (fields of interest for user profiles, Knowledge Units, Cocreation and events)
d. access rights to different functionalities
e. parameters used by rules

7.1.3.2.2 Data management system

This system includes mechanisms used to :

a. Store and manage the data required for analysis.
b. Store and manage the models used
c. Have interfaces to the KSS system
d. Keep historical data,
e. Have links to external data sources.
f. Have interoperability with the external data sources and tools (LCA, SLCA, LCC)

7.1.3.2.3 Rule management system

It includes mechanisms for:

a. Rule storage
b. Rule management (create, edit, delete)
c. Rule filtering
d. Apply parameters on rules

7.1.3.2.4 Rule inference engine.

It includes mechanisms to:

a. Select the necessary rules depending on the input vents and data
b. Apply rules on input data
c. Generate notifications
d. Generate events
e. Create reports on rule application
f. Feed KSS with the results of the rule application

7.1.3.2.5 Workflow engine

It is the mechanism used to specify:

a. the order of expected events and
b. the order rules are applied.

7.1.3.2.6 CSRD Report generator

The CSRD report generator will automate the process of creating comprehensive and compliant sustainability reports in line with the Corporate Sustainability Reporting Directive (CSRD). Here are the key features and functionalities that such a generator should have:

a. **Automated Data Gathering**: Ability to automatically collect data from various sources offered by the KSS
b. **Data Integration**: Seamlessly integrate with different data formats and sources, ensuring all relevant information is captured accurately.
c. **CSRD Compliance:** Ensure the report meets all CSRD requirements, including the latest EU sustainability reporting standards developed by the European Financial Reporting Advisory Group (EFRAG).
d. **Customizable Templates**: Provide templates that can be customized to fit the specific needs and branding of the organization.

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e. **Modular Reporting Sections:** Allow users to add, remove, or modify sections of the report as needed.
f. **XBRL Tagging**: Support for digital taxonomy tagging (e.g., XBRL) to facilitate the electronic submission and comparison of sustainability data.
g. **User-Friendly Interface**: An intuitive interface for entering and managing data, ensuring that users with varying levels of expertise can easily navigate the tool.

7.1.4 Solution 0+ requirements (KSS-DSS Infrastructure)

KSS-DSS Infrastructure pertains to the hardware and software support designed to facilitate all activities encompassed by the KSS-DSS framework. To address the tasks outlined in the framework, we have defined a comprehensive set of functional and non-functional requirements, which will be detailed in the subsequent sections.

The functional requirements are categorized into three groups: Common to KSS and DSS, KSS-specific, and DSS-specific. This categorization enhances the clarity of the concept, considering the close integration between KSS and DSS.

The non-functional requirements apply to the entire KSS-DSS infrastructure and are classified into technical requirements, Security requirements, and Hardware requirements.

Throughout the presentation of these requirements, the term "KSS-DSS infrastructure" may also be referred to as the "KSS-DSS system."

Each requirement is categorized according to the MoSCoW[28] system.

For sake of synthesis, the complete list of requirements have been put in a dedicated Annex B.

7.1.5 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the Knowledge Sharing and Decision Support System (R1.1):

List of applicable standards (from proposal and emerged from the meetings)

The following technical committees were identified as relevant on European or international level:

- ISO/TC 207- Environmental management
  - ISO/TC 207/SC 5 - Life cycle assessment
  - ISO/TC 207 Sub-Committee (SC) 7 - Greenhouse gas and climate change management and related activities
- ISO/TC 215 - Health informatics
- CEN/TC 251- Health informatics

The following applicable standards were identified as relevant on European or international level:

- EN ISO 14001 - Environmental management systems - Requirements with guidance for use
- EN ISO 14002 series - Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area
- EN ISO 14040 - Environmental management - Life cycle assessment - Principles and framework
- ISO 30401 - Knowledge management systems - Requirements
- ISO 37001- Anti-bribery management systems - Requirements with guidance for use
- EN ISO 9001 - Quality management systems – Requirements
- ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection — Information security management systems — Requirements
- ISO 7101:2023 Healthcare organization management — Management systems for quality in healthcare organizations — Requirements DIN EN 15224 Quality Management System in Healthcare
- ISO 13131:2021 Health informatics — Telehealth services — Quality planning guidelines

[28] Must-have, Should-have, Could-have, Won't-have

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- ISO 32210:2022 Sustainable finance — Guidance on the application of sustainability principles for organizations in the financial sector

The following applicable regulations were identified as relevant in the lead developer survey in Task 2.2 – Results' requirements.

For E-LCA and S-LCA

- Guidelines for Social Life Cycle assessment of Products and Organisations 2020: https://www.lifecycleinitiative.org/library/guidelines-for-social-life-cycle-assessment-of-products-and-organisations-2020/
- Methodological Sheets for Sub-categories in Social Life Cycle Assessment (S-LCA) : https://www.lifecycleinitiative.org/wp-content/uploads/2013/11/S-LCA_methodological_sheets_11.11.13.pdf

For the CSRD

- Corporate Sustainability Reporting Directive (CSRD) by European Commission (Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting
- European Sustainability Reporting Standard (ESRS) by European Financial Reporting Advisory Group (EFRAG) which takes into account the EU Taxonomy Climate Act and on international level
- Global Reporting Initiative (GRI): Sustainability reporting standards, which cover topics that range from biodiversity to tax, waste to emissions, diversity and equality to health and safety.
- SASB Standards by the International Financial Reporting Standards (IFRS) that have established the International Sustainability Standards Board (ISSB).
- ISQua (International Society for Quality in Health Care) Guidelines and Principles for the Development of Health and Social Care Standards
- EU Sustainable Taxonomy principles and standards
- Environmental footprint methods by European Commission Sustainable Finance Disclosure Regulation (SFDR)
- Corporate Sustainability Due Diligence Directive (CSDDD)
- EU Carbon Removal Certification Framework (CRCF)
- European Green Deal

In addition, the ISO 9001 and ISO 37001 principles will be applied in the Work Package 3 execution, with focus on the Plan-Do-Check-Act (PDCA) circle.

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

7.1.6 KSS Use Case

The KSS-DSS result will be developed, tested and validated making reference to seven Use Cases, to properly cover all the three components: KSS, DSS (including E-LCA, S-LCA, LCC, SFEM and their joint use), and CSRD.

All the Use Cases include the proof of both the "logical" components and the IT infrastructure.

The purpose of the Use Case is to support the development of the component "Knowledge Sharing System", providing a meaningful sample of actors and contents and, at the same time, creating a critical mass for the further expansion at European scale after the end of the project.

The Use Case will cover the **two sub-components of the KSS**.

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For t**he knowledge-sharing model and system** the key element of the Use Case is the actual set of actors that will provide a meaningful representation of the target users. This set will gradually expand during the project. Once designed, the KSS (model and information system) will be applied in sequence: to all the 5 HCPs of the project, to all the members of the Reference Stakeholder Group (RSG)[29], to all those that belong to their networks (e.g. the Associations of the RSG will be invited to involve as active users of the members of the Association). In each step the user will be invited to share the knowledge through the sharing modalities that will have been defined. At least two knowledge sharing workshops will be organized.

For the **educational program for health and care managers**, the Use Case will consist in delivering the training package to a population of HCPs' managers. We aim to deliver two online editions of 2-3 hours each.

The target population includes managers from:

- The five HCPs of the CN project
- The HCPs that are members of the Reference Stakeholder Group

7.1.7 DSS Use Cases

7.1.7.1 Use Case DSS/WPH (co-developer)

The purpose of the Use Case is to support the co-development of the component "Life Cycle Multidimensional Assessment and Evaluation Model for HCPs" of the DSS.

The Use Case will involve performing a sustainability evaluation of a real investment concerning the centralization of imaging capabilities at WPH.

Currently magnetic resonance imaging (MRI), computed tomography (CAT scan), X-ray, and ultrasound equipment are dispersed across five locations within WPH.

Recentralizing them to fewer locations would bring certain advantages and disadvantages. Gathering the necessary information for LCA (Life Cycle Assessment), S-LCA (Social Life Cycle Assessment) and LCC (Life Cycle Costing) analysis could support or not support the plan.

The key dimensions planned to be considered (but not limited) when comparing the pre-investment and post-investment situations include:

1) Dimension, Number and Technology of the Current (decentralized) and New (centralized) Devices and Materials
2) Environmental Impact
    - Energy Consumption
    - Production Cycle of Devices and Materials
    - Waste Generation Related to Imaging.
    - Chemical Usage
    - Newly Designed and Centralized Facilities (hosting staff, devices and materials)
    - Patient Travel; Employee travel
3) Social Impact
    - Healthcare Access and Equity
    - Diagnostic Accuracy and Treatment Planning timeliness
    - Patient Experience and Comfort
    - Ethical and Societal Considerations (e.g. due to potential under-access to imaging services)
    - Skill Development Due to Advanced Technologies
    - Alternative Allocation of the Public Health Spending (vs imaging)
    - Facilitation/penalization of Research (e.g. clinical study execution) and Education
    - Ease of Coordination of Care (e.g. in sharing of patient information and imaging results)
    - Risk of Deviation vs Standardized Protocols and Procedures
    - Quality Due to Specialized Expertise.
2) Economic Impact
    - Overhead Costs

[29] At the moment the RSG has 46 members from 10 European countries; 11 of then are European level Associations, therefore probably the number of countries that can potentially be reached is higher than 10 already at this stage of the project

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- Efficiency of Resource Utilization, Including Staff.
- Complexity of Administrative Workflow (e.g. scheduling, invoice control)
- Capital Investment (initial and in case of future upgrading), Including Equipment and Works
- Operation Costs (for maintenance, material, licenses)
- Non-ceasing Costs (e.g. related to the buildings in the five locations)
- Negotiating Power for Purchasing.

The DSS model will be built and used to:

- Make a comparison between the pre-investment and post-investment situations in terms of Life Cycle Cost, Environmental Impact and Social Impact on staff, patients, relatives
- Make what-if simulations of the effect of measures that could improve the costs, environmental impact and social impact of the configuration of the imaging capability.

The Use Case will allow the definition of specific sets of Key Performance Indicators (KPIs) related to the different decision levels (WPH management, WPH governing council, Ministry that funds the investment)

The WPH has a strong interest in this Use Case because it will:

- Support the decision-making process
- Support the optimization of the different components of the investment (types of equipment and technology, work organization, types of buildings, staff allocation)
- Provide a dashboard of KPIs to monitor the actual results of the investment
- Allow to include the expected impact of the investment in the corporate social responsibility report that will be delivered in 2027.

7.1.7.2 Use Case DSS/FPG (validator)

The purpose of the Use Case is to validate the component “Life cycle multidimensional assessment and evaluation model for HCPs” of the DSS.

The Use Case will consist in performing a sustainability evaluation of a real investment regarding the **upgrading of the refrigeration plant that serves two buildings of FPG**.

It is triggered by the need to comply with new regulations, setting higher standards in terms of staff/patient wellbeing.

The investment consists in

- Installation of the 1 MWf refrigeration unit with modification of the hydraulic circuits of the chilled water, the tower water, the hydraulic balance system, and implementation of the civil, electrical and mechanical works.
- Dismantling of the current evaporative tower system and installation of the cooling system, consisting of 5 Evaporative Towers, serving the refrigeration plant.

The two buildings host a high variety of work/care environment, populated by patients, health operators, students, patients’ visitors, general public:

- Clinical: Intensive Care Unit, Operating Room, Dialysis ward, post-transplant ward, outpatient visit room
- University: classroom, study room/space, library.

The upgrading investment has already been approved and its implementation is in progress.

Therefore, the financial amount of the investment is known (equipment and works).

However, the environmental and social impact and the impact on the operating costs have not been fully evaluated. Historical data (e.g. on energy consumption, room temperature time profile, request for intervention to respond to claims) are available. New relevant data will be collected or estimated during the validation phase.

The DSS model will be built and used to

- Make a comparison between the pre-investment and post-investment situations in terms of lifecycle cost of the plant, environmental impact and social impact (in terms of wellbeing of patients, staff, students, visitors, students), considering the difference between the target level of wellbeing

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- Make what-if simulations of the effect of measures that could improve the future operation costs, environmental impact and social impact of the new plant.

The FPG has a strong interest in this Use Case because it will

- Support the choice of the measures to optimize the future operations of the plant
- Provide a dashboard of KPIs to monitor the actual results of the investment
- Provide a model re-usable in future similar technical investments.
- Allow to include the impact of the investment in the CSRD report that will be delivered in 2027
- Share with the regulatory authorities evidence about the economic and environmental sustainability of higher standards.

7.1.7.3 Use Case DSS/7HRC (validator)

The purpose of the Use Case is to validate the component "Life cycle multidimensional assessment and evaluation model for HCPs" of the DSS.

The Use Case will consist in performing a sustainability evaluation of an investment under evaluation by the 7HRC: it regards the **modernization and decentralization at 7HRC imaging capability**.

This type of intervention is one of the interventions that the Greek Ministry of Health plans to implement in all HC Regions to improve the healthcare delivery.

In the current situation the imaging capability of the 7HRC is concentrated in its hospitals.

The investment consists in modernizing the central imaging equipment in one of the hospitals and deploying some imaging capability (equipment, staff) in the Health Centers/Local Health Units.

The project would bring certain advantages and disadvantages, but gathering the necessary information for LCA, S-LCA and LCC analysis could support or not support the plan.

The key dimensions that are planned to be taken into consideration when comparing the pre-investment and post-investment situations include:

1) Dimension, number and technology of the current (centralized) and new (the modernized-centralized and the decentralized) devices and materials
2) Environmental impact
   - Energy Consumption
   - Production cycle of devices and materials,
   - Waste Generation related to the imaging.
   - Chemical Usage
   - Newly designed decentralized facilities (hosting staff, devices and materials)
   - Patient's travel
3) Social impact
   - Healthcare Access and Equity
   - Diagnostic Accuracy and Treatment Planning timeliness
   - Patient Experience and Comfort
   - Ethical and Societal Considerations (e.g. due to potential increased access to imaging services)
   - Skill Development due to advanced technologies and more diffused imaging know-how
   - Alternative allocation of the public health spending (vs imaging)
   - Facilitation/penalization of Research (e.g. clinical study execution) and Education
   - Ease of Coordination of Care (e.g. in sharing of patient information and imaging results)
   - Risk of deviation vs standardized protocols and procedures
   - Quality due to specialized expertise.
3) Economic impact
   - Overhead costs
   - Efficiency of resource utilization, including staff.
   - Complexity of administrative workflow (e.g. scheduling, invoice control)
   - Capital Investment (initial and in case of future upgrading), including equipment and works
   - Operation costs (for maintenance, material, licenses)
   - Negotiating Power for purchasing.

The DSS model will be built and used to

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- Make a comparison between the pre-investment and post-investment situations in terms of Life Cycle Cost, environmental impact and social impact on staff, patients, relatives
- Make what-if simulations of the effect of measures that could improve the costs, environmental impact and social impact of the configuration of the imaging capability.

The 7HRC has a strong interest in this Use Case because it will

- Support the final decision
- Support the optimization of the different components of the investment (types of equipment and technology, work organization, types of buildings, staff rightsizing)
- Provide a dashboard of KPIs to monitor the actual results of the investment
- Allow to include the impact of the investment in the 7HRC reports
- Provide a model re-usable in the other HC Regions
- Share with the Greek Ministry of Health evidence about the economic, environmental and social sustainability of higher standards.

7.1.8 CSRD Use Cases

7.1.8.1 Use Case CSRD/WPH (co-developer)

The Use Case will cover the entire WPH. However, the actual data collection (or estimation in case they are difficult to collect) will relate to the Hospital and one (or possibly two) territorial unit.

A preliminary analysis of the type of data to be collected has already been done to identify which ones are not yet available or are only partially available (see Table 28)

Table 28: CSRD/WPH Use Case – required data

Environmental data	• Waste management: • Water consumption: • Carbon footprint: • Noise: • Use of vehicles: • Additional data for recycling: • Green building and sustainable data:
Social data	• Patient safety and quality of care: • Health equity and access to care: • Diversity, Equity and Inclusion: • Employee health and Well-being: • Community engagement and Philantropy: • Ethical marketing and patient care: • Supply chain risks: • Procurements: • Health and safety at work • Freedom of association and collective agreements
Economic data	• Financial balance sheet from at least 3 years ago: • Revenue (Total Revenue & Revenue Growth) : • Operating Expenses (costs associated with staffing, facilities, medical supplies, and administrative overhead, identification and analysis of cost reduction initiatives, including efficiency improvements, waste reduction programs, etc.): • Capital Expenditures (capital investments made by the organization, such as the purchase of medical equipment, facility upgrades, or investments in sustainability projects, etc.): • Sustainability Investments (investments specifically allocated to sustainability initiatives, such as energy-efficient upgrades, waste reduction programs, or community health initiatives, etc.): • Cost Savings from Sustainability Initiatives:

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	• Return on Investment (ROI) for sustainability investments (ROI Analysis & Payback Period, etc.): • Financial Performance Metrics relevant to sustainability (profitability, liquidity, debt levels, and cash flow, etc.): • Sustainability-related Revenue Streams from sustainability-related activities (green product sales, carbon offset programs, reimbursement for environmental services, etc.): • Costs of Non-Compliance or Environmental Liabilities (Legal Costs, Environmental Remediation Costs, etc.): • Total Cost of Ownership (TCO) (medical equipment, facilities, or other assets):
Governance data	• Board Diversity and Composition: • Executive Compensation and Incentives: • Ethical Conduct and Compliance: • Risk Management and Oversight: • Transparency and Disclosure: • Board Effectiveness and Independence: • Whistle-blower Protection: • Data Privacy and Cybersecurity:

A more detailed description of the data can be found in Annex C.

The Use Case will allow to identify the key issues in performing the quantitative and qualitative data collection and to define guidelines to overcome the difficulties.

The Use Case will also allow to identify which data can be collected from the already existing data bases of the WPH and if and how they can be captured automatically.

7.1.8.2 Use case CSRD/FPG (validator)

The Use Case will cover the entire FPG. FPG has already started the process for collecting the relevant information and has clearly identified the relevant internal functions in charge for providing the data.

The Use Case is planned to start in M19 (July 2025), therefore it will start with an assessment of the status of the process and will be probably focused on the elaboration and presentation of information in the report.

The Use Case will be conducted in strict connection with the Use Case ENGAGE/FPG, that will regard the activation of the Community of Practice (CoP) focused on preparing the CSRD report and on analyzing it to contribute to the planning of the next steps of the green transition.

7.1.8.3 Use case CSRD/7HRC (validator)

The Use Case will cover one of the Hospitals of the 7HRC. 7HRC has not yet started the process for collecting the relevant information. Therefore, the Use Case, which is planned to start in M19 (July 2025), will start with an assessment of the data already available (a work similar already done by the WPH to start characterizing the Use Case CSRD/WPH) and will be focused on validating the data collection guidelines and the materiality assessment methodology that will have been developed at WPH from M7 to M18.

7.1.9 Testing, verification, validation methodology and KPIs

Testing.

The KSS-DSS framework will be iteratively developed from M7 to M32.

We plan a first test at M15 and a last one at M32.

The KSS-DSS includes two different types of components: software and non-software

The testing of the software will be performed using standard software engineering methodologies (see Annex D)

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The testing of the non-software components (methodologies) will consist in a check of logical consistency, regarding in particular 1) the internal congruence of the individual components and 2) the mutual congruence between the individual components, where applicable

Verification

It will consist in checking how much the KSS-DSS complies with the description provided under "Solution 0" and with the requirements listed under "Solution 0+".

For the verification versus the software requirements, see Annex D

Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability). They are summarized in the following table 29.

Table 29: Summary of KPIs for KSS-DSS
(the new KPIs in addition to the GA are in blue).

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
DSS (E-LCA, S-LCA, LCC, SFEM)	1) **Relevance, quality and usability of the DSS (E-LCA, S-LCA, LCC, SFEM)**: average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs	Methodology with O/P		Output evaluation	Output evaluation	Questionnaire
DSS (CSRD)	2) **Relevance, quality and usability of the DSS (CSRD)**: average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs	Methodology with O/P		Output evaluation	Output evaluation	Questionnaire
KSS (process and content)	3) **Successful start-up of the knowledge sharing network**: at least 20 stakeholders, representing all the groups and least 15 European countries have participated to at least 2 knowledge sharing events	Methodology without O/P	Parameter assessment			
	4) **Relevance, quality and usability of the KSS**: average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs and from 20+ stakeholders)	Methodology without O/P		Questionnaire	Questionnaire	Questionnaire
KSS (education package)	5) **Relevance and quality of the education**: average satisfaction score >4 in a scale from 1 to 5 by the participants to the delivery of the course to managers of the 5 HCPs of the CN consortium and to external stakeholders	Training		Participants' survey	Participants' survey	

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IT infrastructure	6) **Relevance, quality and usability of the KSS infrastructure** *score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs and from 20+ stakeholders)*	SW (transactional)		Questionnaire	Questionnaire	Questionnaire
	7) **Relevance, quality and usability of the DSS infrastructure** *score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs*	SW (transactional)		Questionnaire	Questionnaire	Questionnaire

The meaning of the methods is described in the methodology section of this document.

To be noted,

- For the validation of the IT infrastructure, see Annex D
- The questionnaires will be distinct for five components:
    - E-LCA, S-LCA, LCC, SFEM, for CN users, focused on usability
    - CSRD, for CN users, focused on usability
    - KSS, for CN users and external stakeholders, exploring relevance, quality and usability
    - Software infrastructure interface of DSS, for CN users exploring relevance, quality and usability
    - Software infrastructure interface of KSS, for CN users and external stakeholders, exploring relevance, quality and usability
- The quality of the outputs will regard the outputs produced in the Use Cases: the three DSS uses cases for the joint use of E-LCA, S-LCA, LCC, SFEM; the three CSRD Use Cases for the CSRD methodology. The quality of the output of the joint use of E-LCA, S-LCA, LCC, SFEM will go through steps like the following
    - Review the methodology used in each of the components, including the selection of impact categories, the system boundaries, allocation methods, and the choice of impact assessment models. This ensures that the chosen approach is consistent with established standards and best practices.
    - Assess the quality of the data used, including their completeness, accuracy, relevance, and representativeness. Verify the sources of the data and consider factors such as data uncertainty and temporal and geographical relevance.
    - Perform sensitivity analysis to assess the robustness of the results to variations in input parameters and assumptions. This helps identify contradictory or counterintuitive behaviours of the decision support model.
    - Ensure that the study is transparently documented, including descriptions of the methodology, data sources, assumptions, and calculations. Transparency enables others to understand and replicate the study, which is essential for validation and peer review.

  The quality of the output of the CSRD methodology will be assessed through similar steps.

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7.2 GLSS-HC: Methodology for Green Lean Six-Sigma reengineering of healthcare processes

GLSS-HC will create a methodology for performing process reengineering in health care domain, integrating in the Lean Six Sigma (LSS) with the greening perspective and the specificities of the healthcare organizational context.

7.2.1 Solution 0 description

The Solution will be a comprehensive methodology for conducting process reengineering within the healthcare domain, combining the Lean Six Sigma (LSS) framework with an environmentally conscious perspective and addressing the unique characteristics of the healthcare organisational context—hence the acronym: GLSS-HC. Following established guidelines, the methodology will be specifically tailored for processes occurring in operating theatres. It will then be put into practice and verified in Use Case 6 and Use Case 7, both serving as illustrative examples within GLSS-HC.

The innovative aspects of GLSS-HC have been reported here below:

- **Holistic Integration**: GLSS-HC integrates Lean Six Sigma with green thinking, providing a comprehensive and holistic approach that considers both process efficiency and environmental sustainability. This integration is unique and addresses a gap in the existing methodologies.
- **Environmental Perspective**: Unlike traditional process reengineering methodologies in healthcare, GLSS-HC explicitly incorporates an environmental perspective. It recognizes the need for sustainability in the healthcare sector, aligning with the global focus on green practices.
- **Novelty in Research**: While Lean Six Sigma approaches are well-established in healthcare, the combination with the Green Lean approach is relatively underexplored. GLSS-HC contributes to the advancement of knowledge in the field by exploring this novel combination.
- **Sustainability Goals**: GLSS-HC goes beyond traditional process optimization by actively contributing to sustainability goals. The methodology addresses the healthcare sector's responsibility to reduce pollution and greenhouse gas emissions, aligning with the growing emphasis on environmental stewardship.
- **Specifically Tailored for Healthcare**: GLSS-HC is a fully healthcare-specialized methodology. It recognizes the unique challenges and requirements of the healthcare sector, providing a management tool specifically designed for healthcare managers and operators.
- **Process Optimization**: The primary goal of GLSS-HC is to increase process optimization, lower service costs, and reduce lead time. This emphasis on efficiency aligns with the continuous improvement mindset in healthcare but introduces an environmentally conscious dimension.
- **User-Friendly Design**: GLSS-HC prioritizes simplicity of use for healthcare managers and operators. This user-friendly design facilitates adoption and implementation, ensuring that the methodology is accessible and practical for those working in the healthcare sector.
- **Cost Reduction**: By combining Lean Six Sigma with green thinking, GLSS-HC aims to not only optimize processes but also reduce service costs. This cost reduction can have a significant impact on the financial sustainability of healthcare organizations.
- **Adaptability to Structural Changes**: GLSS-HC allows for the embedding of the environmental perspective in other structural changes, such as digital transformation. This adaptability ensures that the methodology remains relevant and effective in the face of ongoing changes in the healthcare landscape.
- **Response to Green Pressures**: GLSS-HC addresses the limitations related to limited reactions to external greening pressures. By providing a framework that actively incorporates green aspects, it enables healthcare organizations to proactively respond to environmental expectations and regulations.

7.2.2 Solution 0+ requirements

In the methodology, the importance of incorporating specific indicators directly related to the healthcare domain has emerged. This is essential for comprehending the quality of care. This includes integrating Patient-Reported Experience Measures (PREMs) and Patient-Reported Outcome Measures (PROMs). PREMs focus on gauging patients' experiences with healthcare services, while PROMs are utilised to assess and elucidate health outcomes from the patient's perspective.

Furthermore, engaging operators in business process reengineering activities is vital, considering their diverse roles within the healthcare system (e.g., surgeons, anesthesiologists, nurses, material

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suppliers). Their involvement is necessary for data collection, gathering insights for process enhancement, and securing acceptance of solutions devised by the GLSS-HC.

To gather pertinent data effectively, it's essential to leverage information not only from administrative systems but also from healthcare-specific systems such as the Electronic Health Record, Laboratory Information System, Energy Management System, Pharmaceutical Products Management System, and Material Management System.)

7.2.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the Green Lean Six Sigma methodology for health and care (R1.2):

The following technical committees were identified as relevant on international level:

- ISO/TC 207- Environmental management
  - ISO/TC 207 SC 1 - Environmental management systems
- ISO/TC 304 - Healthcare organization management

The following applicable standards were identified as relevant on European or international level:

- EN ISO 14001 – Environmental management systems – Requirements with guidance for use
- EN ISO 14002 series - Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area
- ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection — Information security management systems — Requirements
- ISO 7101:2023
- Healthcare organization management — Management systems for quality in healthcare organizations — Requirements ISO 13131:2021 Health informatics — Telehealth services — Quality planning guidelines
- ISO 32210:2022 Sustainable finance — Guidance on the application of sustainability principles for organizations in the financial sector
- ISO 37001- Anti-bribery management systems - Requirements with guidance for use
- EN ISO 9001 - Quality management systems – Requirements

The following applicable regulations were identified as relevant in the lead developer survey in Task 2.2 – Results' requirements:

- Guidelines for Social Life Cycle assessment of Products and Organisations 2020
- Methodological Sheets for Sub-categories in Social Life Cycle Assessment (S-LCA)

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

7.2.4 Use Cases

The three Use Cases have a similar content and consist in the application of the GLSS-HC methodology to the journey of a patient that enters the hospital to be operated.

The journey includes the phases and the working stations shown, at high level, in Fig. 25.

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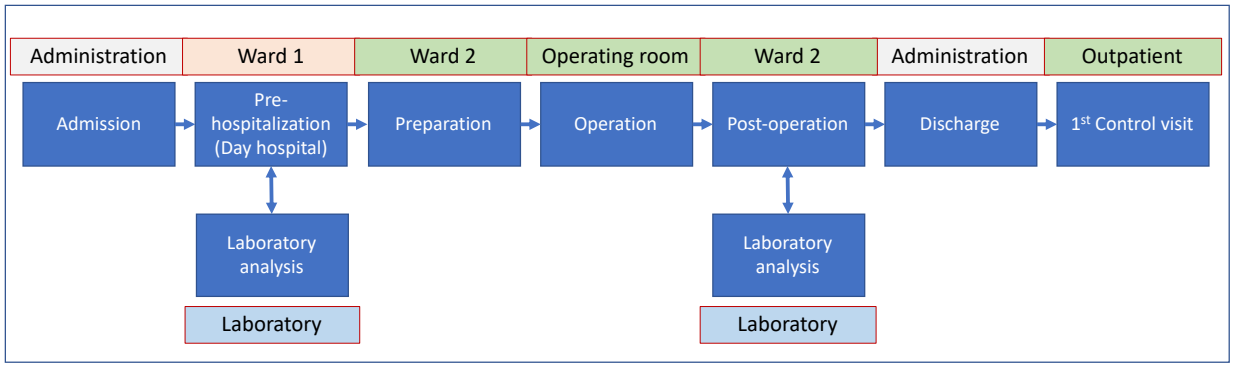

Figure 25: Phases and working station of the journey for patients' operation

7.2.4.1 Use Case GLSS-HC/FPG

The Use Case regards the **cholecystectomy patient journey**, which includes the OR wing for elective general surgery, which has 12 ORs. At FPG there are 800-1.000 cases per year.

The Use Case will provide a real case for developing a GLSS-HC methodology that can be used also in other Hospitals. This will include the identification of which data can be provided by the typical Hospital Information Systems.

However, it will also be explored how the methodology can take advantage of the existence of a software application, named GESTA[30]. GESTA is a modular and interconnected information system with the aim of providing the multidisciplinary patient journey team with a management dashboard for near real time access to clinical data and events of interest to identify patients to enrol. in specific paths, determine the patient's progress and intercept, as promptly as possible, any organizational critical issues that require corrective measures.

GESTA is interesting for two reasons: 1) it collects monitoring and outcome evaluation data related to the patient journey in scope, 2) it embeds the detailed description of the patient journey.

7.2.4.2 Use Case GLSS-HC/FHAG

The Use Case regards the **retinal surgery patient journey**, which regards 200+ cases per year and includes the OR of Ophthalmology

7.2.4.3 Use Case GLSS-HC/UKHD

In the discussion among the stakeholders it emerged how a suitable Use Case for the application of GLSS-HC at UKHD is the **patient journey of the patient operated for pancreatic reception**

7.2.5Testing, verification, validation methodology and KPIs

Testing

The testing will consist in assessing the logical consistency of the methodology. peers and users reading the Deliverables D4.3 and D4.7, checking aspects such as:

- internal congruence of the individual components of the methodology
- mutual congruence between the individual components
- completeness and depth with respect to similar methodologies for other sectors (e.g. for manufacturing)
- clarity/readability/non-ambiguity of the text and check lists

Verification

The verification will consist in checking that the methodology, as described in the Deliverables D4.3 and D4.7 satisfies the descriptions of Solution 0 and Solution 0^+

Validation and KPIs

[30] GESTA stands for "GEStione Team Assistenziali" which means "Management of the Care Teams". It is not a commercial tool, that has been developed at FPG.

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The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability) They are summarized in the following table:

Table 30: Summary of KPIs for the GLSS-HC Solution (the new KPIs in addition to the GA are in blue).

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
GLSS-HC	1) **Relevance, quality and usability of the methodology:** *average satisfaction score >4 in a scale from 1 to 5 by the participants to the use of the methodology in three HCPs of the CN consortium (one patient journey per HCP)*	Methodology with O/P		Output evaluation	Output evaluation	Questionnaire

To be noted:

- The KPI is the same included in the GA, only with the addition of the usability as criterion of evaluation
- The output evaluation considers relevance and quality of the GLSS-HC through its three outputs, i.e. the final reports of the reengineering studies regarding the patient journeys. It consists in examining the Deliverables D4.3 (for the FPG Use Case) and D6.1 (for the other two) focusing on the quality of the data/information/assumptions used, the robustness of the elaboration logic, the relevance of the scope and of the conclusions. The procedure to perform the evaluation can be found in the methodology section. A particular point of attention will be the level of customisation vs the generic Lean Six Sigma (LSS) with regard to the HC and green aspects
- The usability is assessed in terms of perception with a questionnaire administered to the staff involved in the execution of the studies. The usability will regard aspects such as
    - The perceived complication of the tools
    - The difficulties in collecting the data
    - The feasibility of involving the staff during the different steps of the methodology
- The questionnaire content and administration for FHAG and UKHD must be phased with the questionnaire that will be used to evaluate ENGAGE

8. Buildings Solutions: requirements, standards, KPIs and Use Cases

The objectives of this solution group are to reduce the environmental impact of buildings construction and renovation and energy demand, by a design support decision-making tool and an AI-powered energy management tool.

8.1 COMPASS: Guidelines and DSS for sustainable building construction and renovation

COMPASS is a decision support system for sustainable architecture, developed by 4DA and Archipelago. Using the information about the building (such as energy consumption, transmittance of the materials, orientation of the building, etc.) this tool will evaluate the degree of sustainability and circularity of the building.

8.1.1 Solution 0 description

In recent decades, the obsolescence of healthcare buildings has accelerated, leading to a shorter life cycle for infrastructure that needs to be changed before its physical life cycle ends. This may be due to technological advances, societal changes, and crises such as the coronavirus pandemic, which have highlighted the limitations of healthcare buildings in the face of unforeseen situations. This results in a frequent need for retrofit, and since healthcare buildings have the highest average carbon content per

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m² of all building types, a design strategy and assessment tool focused on building adaptability and circularity is becoming increasingly attractive to researchers and practitioners concerned to reduce the environmental impact of these infrastructures. Most adaptability assessment tools in the literature do not focus on the health sector. COMPASS will be a software-based toolkit for multicriteria decision support for the standardization, development, design, and management of green healthcare facilities at all life cycle stages; therefore, it will apply to both new construction and renovation of existing buildings. The toolkit guides design decisions through three KPIs:

1) Circularity profile (based on data and analysis of circular buildings),
2) Carbon profile (based on a methodology to assess and improve the carbon balance of buildings),
3) Healing Environment Profile (based on assessing spaces and their impact on patient wellbeing).

COMPASS will be tested on eight reference buildings to provide three components:

1) Guidelines and protocols for designing circular buildings to improve their adaptability, carbon balance, and users' wellbeing.
2) Guidelines for the procurement of green and circular healthcare buildings.
3) Dashboards based on the Digital Twin for circular flow management of buildings and building materials at all stages of their life.

COMPASS will incorporate the Nature-Based Infrastructure (NBI) and Circular Building Design (CBD) approaches as foundational elements to inform its design principles. These will serve as key guidelines for developing COMPASS. The goal is to establish a cornerstone for more efficient and climate-neutral resource management in the healthcare sector, enabling key players in the value chain to make more informed decisions and act toward circular, resilient, and green healthcare facilities. The provided inputs will encompass strategies to minimize or eliminate building interventions and waste generation, close material cycles, reduce carbon emissions, and create a building that actively contributes to healing patients and supporting healthcare workers.

8.1.2 Solution 0+ requirements

As a result of the many meetings held, several needs and insights related to COMPASS were collected. The application of COMPASS is a good opportunity when there is a well-defined renovation program. especially when the building has been designed and built before the 2000s. For this kind of building, special attention should be given to possible constraints (for example historical constraints) that could limit the intervention's range and varies state by state.

During the discussion with internal and external stakeholders, it emerged that the area of greatest interest concerns the building envelope, particularly in terms of thermal transmittance and especially the percentage of **glazed surface**. The natural illumination of the rooms, is a crucial point in designing HC facilities building because it can affect not only the practical aspects related to work and all kinds of operations which need natural lighting but also the psychological aspect of the people that occupies the room. This aspect can be obtained with different strategies like modifying the glazed area (increasing the area for example) and considering different glass technologies (like selective glass or low emissivity glass that can change the quantity of light that enters the window). On the other side, it is important to remind that the glazed area is limited by some specific regulation that can vary state by state and that should refer to a more general European regulation.

The renovation is one of the most important interventions for old buildings since the application of new materials and solutions can considerably improve the thermal behaviour of the facility. A good envelope can considerably reduce the thermal consumption of the building and the perception of people since the distribution of heat should be steadier. If the envelope is correctly insulated there are fewer walls with high dispersions and all the thermal bridges should be corrected. In this case, all the room under examination has a uniform distribution of the temperature. COMPASS can provide information about this type of renovation, suggesting intervention that are as much sustainable as possible.

Another important aspect is related to **thermal comfort** which can be divided between physical and psychological. Given the potential psychological discomfort patients may experience during hospitalization, it's essential for the architectural environment to make them feel comfortable, avoiding additional sources of discomfort. The creation of a healing environment should therefore be greatly considered in the development of this Solution.

The application of COMPASS could be affected by some issues that emerged during the calls between LD and co-D. At first, it could be hard to identify a specific reference person from the HC facility to follow the COMPASS workflow. The presence of an architect or an engineer in the HC facility's team would

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help the development of a result The main bottleneck in the development phase is related to the difficulty of finding accurate information of the building needed to configure the DT in COMPASS, such as materials used, stratigraphy and building plans. All the input data needed have been listed in a form realized by 4DA in which all the information needed to develop the Solution is reported based on its importance. This document is composed into parts:

- Data needed from Archipelago.
- Data needed from the building owner.

For each part, specific information is required. The colour scale reflects the importance of the information (see the tables on the next page):

Orange	CRITICAL DATA
Light Green	Must-have
Dark Green	Nice to have

After the introduction of these more practical aspects, there are also other relevant considerations to do. HC organizations manage a wide type of data and the importance related to data security is a key point. So, all the input data that are necessary to COMPASS must be treated with **confidentiality** and security must be guarantee. One of the possible limitations to the exploitation of COMPASS is that also similar types of software could be actually available on the market. The advantages of applying COMPASS could be linked to its innovative aspect and will be studied in the exploitation WP of the CN project.

From the economic side, the biggest limit to applying and using the solutions proposed by COMPASS can derive from a limited budget and from the difficulty in managing the demolition and reconstruction phases.

The development of the COMPASS toolkit will be based on the collection of a variety of data on healthcare buildings:

- Physical and geometric characteristics.
- Composition of materials.
- Simulations of energy performance (shading and ventilation).
- Social perceptions (e.g., healthcare workers' and patients' feelings about the space).

All the data will be collected through questionnaires, interviews with stakeholders, literature, and national databases.

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Table 31: List of input data needed by COMPASS.

Building Owners	
Definition of data requirement	**Description of information**
Drawings, material specification, technical information	**General information**
	Construction year
	Short description of the hospital
	Which parts of the hospital are frequently being changed
	Typology aspects:
	CAD drawings: building site, floorplans, sections, facades, etc.
	BIM (Revit files) if available
	Structural drawing, drawings with installation services
	Technical aspects:
	Material specification, connection details of the building, existence of hazardous material (for existing buildings)
	Energy performance information
	Passive measures applied to reduce need for heating and cooling such as: sun shading, high insulation level, natural ventilating, etc.
	Active measures applied to guaranty thermal comfort: PV panels, heat exchange systems, AHU, etc.
	Healing environment measures
	Healing environment measures applied for example: focus on natural light, open view on green, sky, type of material, etc.
	Indicting spaces within representative building typology where measures for realisation of healing environment have been taken

Archipelago		
Definition of data requirement	**Description of information**	**Description of output**
Spatial and material specification of repesentative typologies	**General information**	
	Construction year	
	Short description of the hospital	
	Which parts of the hospital are frequently being changed	
	Typology aspects:	
	Overview of hospital typologies in last 100 years	
	CAD drawings of 4 representative typologies: building site , floorplans, sections, facades,	
	Structural drawings	
	CAD drawings with installation services	
	BIM (Revit file) where available	
	Technical aspects:	
	Material specification, connection details of the building, existence of hazardous material (for existing buildings)	
	Energy performance information	
	Passive measures applied to reduce need for heating and cooling as: sun shading, high insulation level, natural ventilating, etc.	
	Active measures applied to guaranty thermal comfort: PV panels, heat exchange systems, AHU, etc.	
	Energy peformace calculation expressed in kWh and if possible in kg CO2	
	Energy peformace calculation expressed in kWh and if possible in kg of CO2	
	Healing environment measures applied	
	Overview of healing environment indicators focusing on perception	
	Overview of projects where selected set of indicators has been applied	
	Overview of measures taken to realise particular healing environment concept in exemplary building for example: focus on natural light, open view on green, sky, type of material, etc.	
	Indicting spaces within representative building typology where measures for realisation of healing environment have been taken	

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8.1.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the decision support system for sustainable architecture (R2.1):

The following technical committees were identified as relevant on European level:

- CEN-CENELEC Joint Technical Committee (CEN-CLC/JTC) 11 - Accessibility in the Built Environment
- CEN/TC 67 - Ceramic tiles
- CEN/TC 350 - Sustainability of construction works
  - CEN/TC 350/WG 2 - Building Life Cycle Description
  - CEN/TC 350/WG 4 - Economic performance assessment of buildings
  - CEN/TC 350/WG 5 - Social performance assessment of building
- CEN/TC 371 - Energy performance of buildings

The following technical committees were identified as relevant on international level:

- ISO/TC 59 "Buildings and civil engineering works" SC 17 - Sustainability in buildings and civil engineering works
- ISO/TC 207 "Environmental management" SC 5 - Life cycle assessment
- ISO/TC 323 - Circular Economy

The following applicable standards were identified as relevant on European or international level:

- ISO 20887 - Sustainability in buildings and civil engineering works - Design for disassembly and adaptability - Principles, requirements and guidance
- ISO 59020 - Circular economy — Measuring and assessing circularity performance

There were no applicable regulations identified as relevant in the lead developer survey in Task 2.2 – Results' requirements.

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

8.1.4 Use cases

8.1.4.1 Use case COMPASS/UKHD (co-developer)

The building selected for the application of COMPASS is the new surgical pavilion at Heidelberg Hospital. This is a newly constructed building, which does not present clear heritage constraints and can yield good results in terms of circularity and sustainability. Additionally, this type of building makes it easy to gather the necessary information for the development of the tool, since it is a new construction. However, to apply COMPASS in the hospital context, it is necessary to fine-tune the software to adapt it to the specificities of the healthcare environment. To achieve this, 4DA and ARPEL will conduct a benchmarking process using data from various hospitals across Europe. Among the selected hospitals is also the old surgical pavilion at UKHD, which will be analysed through an on-site visit by the two architectural firms in the very early stages of the project. This creates an interesting parallelism between the two buildings, where the old one will serve as a reference for analysing the new one in greater detail.

8.1.4.2 Use case COMPASS/FHAG (validator)

Not yet identified. Further information will be collected to properly validate the COMPASS Solution.

8.1.4.3 Use case COMPASS/WPH (validator)

Not yet identified. Further information will be collected to properly validate the COMPASS Solution.

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8.1.5 Testing, verification, validation methodology and KPIs

Testing

Two specific methods will be applied:

- **Software testing**. for the DSS. It identifies and eliminates defects within the software infrastructure both at component and integration level. It is performed according to software engineering standards (e.g. ISO/IEC/IEEE 29199)
- **Logical consistency for the policies and guidelines**. It assesses the formal quality of guidelines. They are analysed by peers and users reading the Deliverables D5.4 and D5., checking the following aspects:
  1) internal congruence of the individual components
  2) mutual congruence between the individual components, where applicable
  3) completeness and depth with respect to similar artifacts (if available), given the purpose
  4) clarity/readability/non-ambiguity of the text

Verification

The method consists in checking the result against the description of "Solution 0" and Solution 0^{+}.

Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability).

They are summarized in the following table:

Table 32: Summary of KPIs for the COMPASS Solution (the new KPIs in addition to the GA are in blue).

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
COMPASS (DSS+Design guidilines)	1) **Waste reduction in case of refurbishment works:** *>80% vs standard approaches*	SW (algorithmic)	Simulation			
	2) **GHG reduction in case of refurbishment works:** *>50% vs standard approaches*	SW (algorithmic)	Simulation			
	3) **Reduction of raw material use in construction:** *>40% vs standard approaches*	SW (algorithmic)	Simulation			
	4) **Relevance, quality and usability of COMPASS (DSS):** average *satisfaction score >4 in a scale from 1 to 5 from the users*	SW (algorithmic)		Questionnaire	Questionnaire	Questionnaire
COMPASS (Guidelines)	5) **Relevance and quality of the COMPASS guidelines:** *average satisfaction score >4 in a scale from 1 to 5 by the prospective users (from the CN consortium HCPs*	Methodology with O/P		Output evaluation	Output evaluation	Questionnaire

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To be noted

- two KPIs are added to assess the point of view of the users and the methodological components (policy, protocol, guidelines)
- even if 4DA and ARPEL will collaborate, the role of Lead Developer will be played as follows
    - Compass and dashboard: LEAD DEVELOPER 4D Architects
    - Design protocol and guidelines: LEAD DEVELOPER 4D Architects
    - Policy and standards recommendations: LEAD DEVELOPER Archipelago
    - Guidelines for procurement: LEAD DEVELOPER Archipelago
- Depending on the component, there are two types of users:
    - The HCPs, that will provide input on the buildings of the Use Cases, but that will mainly benefit from the Policy and standards recommendations and the Guidelines for procurement
    - The constructors/renovators/designer, that will mainly benefit from the DSS (Compass and dashboard) and the Design protocol and guidelines

  Therefore, a separate user group will be created in the RSG, both for running the development and validating the relevant component (the DSS)
- The simulation consists in applying COMPASS to a real case (an existing building or a building to be designed/constructed) and in doing a what-if simulation to calculate the benefits (e.g. lower carbon footprint) vs the reference modality (e.g. the material used in the current building) if the CN Solution were used (e.g. COMPASS suggests using a more user-friendly material)

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8.2 ENER: AI-based energy management

ENER is an energy management software solution powered by AI and cloud technologies for healthcare buildings. It can provide the possibility to monitor energy consumption and make decisions with predictive functioning.

8.2.1 Solution 0 description

Cloud platforms for the generation of digital twins (DTs) based on physics or data provided by suppliers are now widespread. The literature shows several examples of analysis platforms for generic energy monitoring systems with manual interventions. ENER aims to considerably improve the state of art by introducing innovative AI technologies capable of automatically identifying and calibrating models, producing reliable KPIs and DTs without requiring manual calibration by specific expert personnel for the HC sector. ENER will be a system that includes a cloud-based processing engine with AI-based algorithm processing systems, an edge gateway with intelligent and computing capabilities to acquire data from existing sensors and systems, a data analytics dashboard based on cloud with site and user management controls, plant data visualization, AI-based KPI explanation and trend analysis results, digital twin analysis of plant-specific elements, decision support functionality. The platform will offer the following key points:

- An integrated approach to monitoring, forecasting, optimization, and evaluation towards sustainable structures.
- Direct data processing in the integrated energy and plant engineering system.

8.2.2 Solution 0+ requirements

Healthcare (HC) facilities represent a complex and unique case study from an energy perspective, as they are characterized by an inhomogeneous typology of energy loads that can vary depending on the time and type of machines installed. In particular, the scope of use of the buildings requires several **round-the-clock electricity loads**, which cannot be managed, postponed, or dimmed due to medical purposes (such as all the machines in the ICU). Furthermore, hospitals contain several areas where **stringent indoor air quality (IAQ) conditions** are required, in terms of temperature, humidity, and ventilation, to guarantee mandatory internal conditions for both people and machinery. Consider, for example, the areas dedicated to transfusions, where blood bags must be maintained at specific temperatures with a very limited, if not zero, margin of tolerance. Additionally, the air exchange rate in hospitals in Italy is 15 air changes per hour throughout the entire facility, which is more than three times the rate required for office spaces. In this context, energy efficiency is subordinate to patient well-being and healthcare requirements, making it crucial to identify areas with basic indoor air quality requirements and analyse **space occupancy patterns**.

The previously discussed information highlights how energy consumption is a highly sensitive issue in healthcare facilities (HCF). It is often assumed that there is little that can be done to mitigate this; however, there is significant potential for improvement in the management of HVAC systems in non-critical areas, like for example introducing AI in the energy management. ENER will use the potential of AI to improve the management of energy consumption with a predictive approach in which the continue data flow can optimize the usage of the machinery installed in the specific HC facility. The extraction and analysis of data information to have immediate support for operational control decisions is a key need for the HC buildings since the complexity can make it difficult to make decisions. Another important point is that certain environments change configuration over time without the knowledge of the system controller (variations compared to the shared configuration). In the end, should be considered the difficulty to perform an unstructured analysis of the available data to obtain information on the trend of environmental and energy parameters.

The comfort in the HC facilities has a key role not only in a physical view but also in a psychological one for the patients and workers and so it needs to be considered as a priority.

The level of automation and technology can change in relation to the specific destination of use of the HC facility and the great variety of environments (emergency buildings, surgical pavilions, etc). This aspect could reflect a poor integration of sensors in the buildings. On the other hand, newer buildings could have a more specific and modern instrumentation. For example, FPG has a modern system of load management and if an HC building has a good implementation. The general perception is that most of the needs could be resolved with the classical approach (for example increasing the number of programmable and remote controllable devices) so it is important to define the advantages of the

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application of AI not only in a technical way but also in an economic perspective. On the other hand, when the HC facility has a poor monitoring system, installation becomes necessary with the consequent increase in costs.

Another key aspect related to the development of this Solution is represented by the **communication protocols** that can be strongly different between the buildings under examination. This consideration makes it difficult to standardize the ENER Solution. At least, it is fundamental to focus on data security and share with the respective organization all the security protocols used, similarly to what is done for the COMPASS Solution.

The requirements of the area chosen to test ENER can be summarized as follows:

- **Environment Specification**: The environment to be monitored and controlled should be a defined, non-critical area in terms of hospital activities, not including spaces such as operating rooms, resuscitation areas, or intensive care units.
- **Existing Sensor Infrastructure**: Preferably, the area should already be equipped with sensors for monitoring environmental conditions such as CO2 levels, temperature, humidity, and particulate matter (PM1, PM2.5, PM10).
- **Energy Consumption Monitoring**: Sensors should be in place to monitor energy consumption, including voltage, current, and power of energy-intensive systems within the selected environment.
- **Controllable Energy-Intensive Systems**: Energy-intensive systems within the environment, such as HVAC systems, should be operable and configurable to manage efficiency. This includes isolated ducts, adjustable temperature and humidity settings, and controllable air exchange.
- **Signal and Protocol Availability**: A comprehensive list of available signals and the protocols for acquiring these signals should be known and accessible

The development of the ENER Solution will be based on the collection of a variety of data on healthcare facilities:

- Geometric characteristics (areas and volumes).
- Typology of sensors installed.
- Field data (energy consumption, current, voltage, power, temperature, relative humidity, etc.)
- Historical field data (energy consumption, current, voltage, power, temperature, relative humidity, etc.)
- Machine data (load profile, generators, etc.)
- Communication protocols.
- Maintenance reports.

All the data are collected through questionnaires, interviews with stakeholders, literature, and national databases.

8.2.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the AI-powered decision support system for energy management (R2.2):

The following technical committees were identified as relevant on European level:

- CEN/TC 442 - Building Information Modelling (BIM)

The following applicable standards were identified as relevant on European or international level:

- EN ISO 14001 - Environmental management systems - Requirements with guidance for use
- ISO 50001 - Energy management systems - Requirements with guidance for use
- IEC 61010-1 - Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements
- IEC 61970 series - Energy management system application program interface (EMS-API)

The following applicable regulations were identified as relevant in the lead developer survey in Task 2.2 – Results' requirements:

- Communication standards and protocols (e.g. ModbusRTU/TCP, OPC UA, MQTT)

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- Machinery directive 2006/42/CE
- Electromagnetic Compatibility (EMC) Directive 2014/30/UE

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

8.2.4 Use Cases

8.2.4.1 ENER/FPG (co-developer)

The FPG is one of the biggest hospitals involved in the project of CN, and due to recent improvements related to the power plant it was updated and now it is in line with the state of art of the technology.

FPG can be compared to a smart city also equipped with a remote co-management/monitoring system which is based on the control of over **50,000 device points** through a fibre optic network, thus allowing optimal management of distributed electrical energy and thermal energy for the 24-hour operation of the facility. The hospital is completely power supplied by natural gas turbines, and modern control systems control all the energy flows. The heated or cooled water is then distributed to a large number of Air Handling Units (AHUs), each serving a specific area (usually one floor). In the AHUs, the air is treated to ensure the required temperature and humidity conditions within all the environments served by the AHU, as well as mechanical ventilation. There is no differentiated system for different environments served by the same AHU. Regulation is achieved through control of the return air and all the units are equipped with equipment to meter electricity, heating and cooling energy.

The definition of the best area to test ENER passed through different considerations. Initially, the transfusion centre was considered a suitable case study, but due to the severe prescription of maintaining the temperature as constant as possible to preserve the medical elements, it offered very few flexibilities in the management of the AHU. Then, another case study was individuated in the **laboratory plant of the hospital**. It is again a delicate environment, but it fits better for the application of ENER due to the variability in terms of occupancy. This area therefore represents a good compromise between the specifical HC framework and more traditional occupancy patterns. In this space, there are laboratories for medical personnel, with many sensors to measure internal comfort. That can be connected with the AHU.

The communication protocol is defined as follows:

- The Sauter's controllers use the BACnet TCP/IP protocol.
- The supervision system supports REST API protocol.

To start the tests, it is necessary to update the software in the hospital and enable the API connection. So, I75 will be able to connect to the FPG's system and start with the testing phase.

Further information will be collected to properly define the study of the ENER's application

8.2.4.2 ENER/FHAG (validator)

In FHAG a suitable area for developing the ENER Solution has been identified in the **outpatient consultations building**. In this building (built in 2009), outpatient consultations, minor surgery, and day hospital activity are carried out. During the weekend there are no activities in this centre and during the week, occupation is totally under control since consultations are 100% scheduled. There is management of the lighting and building air conditioning through an extensive existing sensor infrastructure. In this area, there are no CO_2 meters, but it should be not a problem since there a good knowledge of occupancy due to the scheduled medical examinations. On the other hand, there are sensors related to light, temperature, and humidity and also temperature probes for the regulation of the air conditioning equipment. To monitor energy consumption, it is possible to refer to general water and electricity meters. The control of air conditioning and lighting refers to external sensors and there is also the possibility to schedule the hours of operation of the components.

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The last point to consider refers to the signal and protocol that are used. The management system is a TREND Control System and uses a TREND protocol, being compatible with BACnet, Modbus protocols, etc. If necessary, a list of signals already available in the system could be provided.

Further information will be collected to properly define the study of the ENER's application.

8.2.4.3 Use case ENER/WPH (validator)

Regarding WPH's suitable area for developing ENER Use Case, **rescue station** might be the appropriate area. In relation to hospital, the sensors are under guarantee and therefore not available for piloting.

Moreover, three rescue stations could be monitored, but they are not equipped with appropriate sensors. Water and electricity meters are already installed in these buildings. General meters are provided for the whole building. It is possible to regulate the switching on-off of lighting by schedules and external sensors.

Further information will be collected to properly define the study of the ENER's application.

8.2.5 Testing, verification, validation methodology and KPIs

Testing

The testing will be performed to identify and eliminate defects within the software infrastructure both at component and integration level. It is performed according to software engineering standards. It will include:

- Communication test (field data gathering and processed data transmission evaluation through latency, throughput evaluation);
- Elaboration test (raw data gathering and pre-processing, edge processing, etc.);
- Security and data integrity test;
- AI Algorithm test (e.g. R2, MSE, RMSE, MAE, accuracy, precision, etc.)
- Integration of the ENER Edge module with the ENER Cloud module for validation of the project solutions in a real operating environment. An analysis of the metrics known in the literature will also be carried out to evaluate the performance of the system elements both from a "stand alone" and integrated point of view. These metrics will be applied to the evaluation activity for a quantitative analysis of the achievable performances.

Verification

The method consists in checking the result against the description of Solution 0 and Solution 0^{+}.

Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability).

They are summarized in the following table

Table 33: Summary of KPIs for the ENER Solution (the new KPIs in addition to the GA are in blue).

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
ENER	1) **Alarm detection capability:** *in the testing environment ENER detects 30% more alarms vs non-ENER monitoring, (in three HCPs of the CN consortium, one*	SW (algorithmic)	Simulation			

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	testing environment per HCP)					
	3) **Relevance, quality and usability of ENER:** *satisfaction score >4 in a scale from 1 to 5 in each of three HCPs of the CN consortium*	SW (algorithmic)		Questionnaire	Questionnaire	Questionnaire

To be noted:

- A new KPI has been added vs the GA to assess the economic sustainability of ENER, considering both the investment (and substitution) and operation costs
- The **simulation** has the purpose to measure the "Alarm detection capability" KPI in three Use Cases.
  it consists in applying ENER and simulate with real/realistic input data the rate of alarm detection and to compare it with the rate of the current monitoring modality, in each of the three HCP
- The **questionnaire** collects the perceptions of the respondents on the quality, relevance and usability of ENER. It is administered to the staff involved in the Use Cases to assess
  - **the Relevance**. It regards the perceived usefulness of ENER from the point of view of the end-users It is an evaluation of "fit for purpose" or "value added" vs current energy monitoring
  - **the Quality**. Regards the scope of the output of ENER and its adaptability/scalability to different contexts/users or the capability to capture the HC specificities (e.g. wellbeing of the patients)
  - **the Usability**. Regards the easiness of adopting and using ENER in the specific context. It is assessed making reference to use situations and explores aspects such as 1) User-friendliness of the user interface 2) ease of installation 3) ease of expanding the use of ENER coverage in the HCP premises

9. Waste Solutions: requirements, standards, KPIs and Use Cases

The objectives of this Solution group are to reduce the environmental impact of waste produced by HC facilities. Through waste reduction and innovative processes to treat medical waste, food waste, and wastewater is possible to give added value to all these components. Parallelly to the reduction of environmental impact, is possible to reduce costs related to waste management.

9.1 WR-MED: Clinical waste reduction

WR-MED will provide a methodology for a paradigmatic change in the life-cycle of waste produced in the Operating Room (OR), by adding knowledge, implementing management with new tools, addressing unmet needs, promoting re-use, limiting overuse, disseminating guidelines and teaching new behavioural practices to health-care personnel. These actions have also the ambition to be cost-effective and dramatically reduce the HC carbon footprint, encouraging positive behaviours.

9.1.1 Solution 0 description

The result will include the following components:

a) Guidelines and Operational Models for waste management produced in the operating theatres. These guidelines will be aimed to cover all the trajectories of waste products starting from the selection and reduction of disposables, targeting those that can be re-used and recycled, reduction of overage of drugs and surgical instruments, up to the disposal and appropriate segregation of materials. Operational models will be not limited to waste but will also include water consumption and alternative measures for scrub personnel, monitoring of anaesthetic gas and reuse of linen and devices.

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b) A tool to discard products, implement their recycling, label and identify recyclable components. On this basis, the discard of labelled products in appropriate collectors will be facilitated.
c) The identification of reusable medical devices introduced already in the market but not widespread employed as an alternative to single-use products.
d) A training package on the management of hospital waste for HC workers in the operating room including nurses, surgeons and anaesthesiologists.
e) Knowledge. Previous four components will be based on a deep analysis of the production of waste materials in different OR settings, that will generate valuable research output. The analysis will be performed for the first time in literature, in simultaneous study scenario including emergency/trauma OR, elective sub-specialty OR (i.e. day surgery), and ORs dedicated to complex procedures including robotics and laparoscopy (i.e. in the field of surgical oncology). Other than measuring the waste, type of waste will be categorized to target products with recyclable components.

9.1.2 Solution 0+ requirements

The OR produces great quantity and variety of waste, strictly related to the type of surgery and also personnel with different background and expertise work in ORs.

In order to set-up a successfully methodology, all these aspects are to take into account. To prepare the development of the Solution with the codeveloper it was performed a 2-weeks audit on waste in operating rooms to measure and quantify the OR waste and to identify areas and issues suitable for implementation aiming to reduce surgical waste and impact OR carbon-footprint.

The data collected will include the following:

- Surgical waste: weight in Kgs of surgical bins at the end of the surgical procedures, millimetres of fluids in OR collectors.
- Surgical activity: Number of procedures performed each day in each OR
- Sub-specialty and related procedures: surgical approach (robotics, laparoscopic, conversion or open surgery), operative room time, estimated Blood Loss (EBL), sub-specialty (colorectal, hepato-bilio-pancreatic -HPB-, upper-gastrointestinal -UGI-, hernias and abdominal wall procedures, thoracic, vascular, urologic, gynaecologic, plastic surgery etc) concomitant procedures performed.
- Personnel: number of surgeons (including trainees and fellows), number of anaesthesiologists and number of nurses for each procedure.

Requirements highlights are:

- To Include in the guidelines a scheme for data/info collection regarding aspects such as quantity of surgical waste by type, n, of surgical procedures by type, surgical procures, personnel by type
- To involve all the personnel working in OR since the beginning
- To create clear instructions to follow in order to perform the right separation of waste

9.1.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the guidelines for medical waste reduction (R3.1):

The following technical committees were identified as relevant on European or international level:

- ISO/TC 34 - Food products
  - ISO/TC 34 SC 20 - Food loss and waste
- CEN/TC 165 - Waste water engineering

The following applicable standards were identified as relevant on European or international level:

- EN ISO 14040 - Environmental management - Life cycle assessment - Principles and framework
- EN ISO 14064 series - Greenhouse gases
- ISO 50045 - Technical guidelines for the evaluation of energy savings of thermal power plants
- ISO 50047 - Energy savings - Determination of energy savings in organizations

The following applicable regulations were identified as relevant in the lead developer survey in Task 2.2 – Results' requirements:

- Good Clinical Practice (GCP), in accordance with

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- Good Clinical Practice Guideline (cpmp/ich/135/95).
- EU Directive 2001/20/EC, 2005/28/EC'.
- Declaration of Helsinki (1964, and its amendments).

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

9.1.4 Use Cases

9.1.4.1 Use Case WR-MED/FPG (co-developer)

The OR wing for elective general surgery is provided with 12 ORs, and each room has an average area of approx. 50 sqm. The rooms have been equipped with the latest technological standards and plant engineers, including robotics and the 4K laparoscopy image recording system. The project will be conducted in the surgical wing for elective general, colorectal, hepato-biliary-pancreatic, upper gastro-intestinal, gynecologic-malignant, urology, and thoracic surgeries, which include 12 ORs

9.1.4.2 Use Case WR-MED/FHAG (validator)

The surgical cases will regard the OR of Ophthalmology, with particular focus on retinal surgery, which regards 200+ cases per year

9.1.4.3 WR-MED/UKHD (validator)

The surgical cases will be the same of the FPG Use Case.

A particular attention will be dedicated to

1) metal sieves
2) differentiation of waste into
   a. contaminated waste
   b. non-contaminated waste
      - plastic
      - paper
      - others
   c. glass

Regarding 1) it is expected that the sterilisation process is significant factor for waste and energy. It could be optimised in design of the sieves, packaging etc.

Regarding 2) the differentiation will provide detailed specific recommendations. While differentiating between contaminated and non-contaminated, it can be explored the magnitude of separating waste (as also there is the standard of not separating it). As an example, non-contaminated recycling of paper and plastic would be quite effective regarding the carbon footprint, and also cheap for the hospitals.

9.1.5 Testing, verification, validation methodology and KPIs

Testing

The logical consistency. Of the recommendation and of the training package are assessed in terms of formal quality. They are analysed by peers and users reading Deliverables D41 and D4.5 checking the aspects such as:

2) internal congruence of the individual components

3) mutual congruence between the training and recommendations

4) completeness and depth with respect to the scope of the OR waste and to given the purpose

5) clarity/readability/non-ambiguity of the recommendations and of the training material

Verification

The method consists in checking the result against the description of “Solution 0” and Solution 0^{+}.

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Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability).

They are summarized in the following table:

Table 34: Summary of KPIs for the WR-MED Solution (the new KPIs in addition to the GA are in blue).

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
WR-MED (interventions on waste mgmt)	1) **Reduction of the CO2e due to the material used in the Operating Room activities** > 10%	Recommendations	Benefit estimation			
	2) **Intention to implement the guidelines for waste management and the new tool:** in at least two of the three HCPs the staff involved gives a score >4 in a scale from 1 to 5 to the quality, relevance and feasibility of the improvement interventions and to the opportunity to implement them	Recommendations		Questionnaire	Questionnaire	Questionnaire
WR-MED (training)	3) **Quality and relevance of the training package for OR nurses, surgeons, and anaesthesiologists**: average satisfaction score >4 in a scale from 1 to 5 by the participants to the delivery of the training (at least 20 participants in total)	Training	Participants' survey	Participants' survey		

To be noted:

- The first KPI has been added to the GA list, to get a quantitative indication of the benefits obtainable if the interventions were implemented
- The second and third KPI have been slightly rephrased to make them less ambiguous, without modifying the target value
- WR-MED is articulated in two components (interventions and training). The first component is of the type "recommendations" and is assessed by two KPIs;
    - the first of them is quantitative in nature and can be estimated using the E-LCA methodology
    - the second of them is qualitative in nature and we will validate the reasons for the intention (or non-intention) to implement the guidelines with a Questionnaire that will assess Relevance, Quality and Usability from the point of view of the guidelines of the HCPs

  The second component is of the type "training" and is assessed with a participants' survey on the perceived relevance and quality of the training package for the Operating Room (OR) staff.

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9.2 WP-MED: On-site clinical waste pyrolysis plant for energy production

WP-MED is a prototype plant for the treatment of medical waste on-site and producing energy, through sterilization and pyrolysis. The main perspective is to treat the medical waste on-site, reducing energy and carbon footprint for transportation, for processing and from the energy needs of the hospital in total.

9.2.1 Solution 0 description

Hospitals produce enormous quantities of medical waste every year. This waste must be transported to special units to be further processed (sterilization) and then sent to landfill. WP-MED consists of a prototype plant for on-site medical waste treatment and energy production, respectively using sterilization and pyrolysis. The main perspective is to treat medical waste on-site, reducing the energy and carbon footprint for transportation, medical waste treatment, and the total energy needs of the hospital. Throughout the project, innovation will consist of processing waste at lower temperatures and with a more environmentally friendly process, increasing energy efficiency and minimizing the total need for external energy sources. The entire system will be fully automated, minimizing the human presence. The design plans consider keeping the system small to be compatible with different hospital environments, but at the same time, it will be able to work together with multiple units if necessary. At the present time, most hospitals choose to transport the waste to authorized partners for its management, some others have a sterilization unit installed in the hospitals. The challenge is to design an affordable unit that can be employed in any Hospital making energy efficient and autonomous and minimizing the carbon footprint.

9.2.2 Solution 0+ requirements

The main problem to solve for the co-developer is **reducing waste disposal costs**. The fight against the COVID-19 pandemic, with the resulting health emergency, has produced an enormous amount of medical waste, much of which is at risk of infection, in both public and private healthcare facilities, and in private homes where COVID-positive individuals are present. In many cases, the medical waste disposal system has been overwhelmed, having to deal with an exceptional quantity of waste to be treated in authorized plants, also due to the shortage of such facilities in some areas. To address this new need and contain the risk of infection, while promoting the sterilization of medical waste, the legislator had to introduce specific regulations, included in Law No. 4/2020, which converted the Legislative Decree Liquidity, capable of reducing the quantity of infectious medical waste to be sent to authorized plants for processing.

Investing in the installation of an internal sterilization plant should reduce operational costs but represents a significant capital expense and introduces the problem of finding adequate space (at least 450 sqm). Once sterilized, the material still needs to be transported, with related costs, although these would be reduced due to the lower hazard and reduced weight.

It has been certified that the **minimum temperature** required for the sterilization process is achieved by the pyrolysis process. Consequently, the introduction of this type of plant makes sterilization no longer necessary, resulting in significant savings in energy and space. The introduction of the pyrolysis plant would require less space (about 200 sqm compared to 450 sqm for the sterilization plant) and lower transportation costs. The pyrolysis process is versatile and can be used with any type of waste, including municipal waste. To properly size the plant, it is necessary to understand the amount of medical waste produced by the co-developer and validating structures, and the percentage breakdown by type of waste (cardboard, plastics, etc.).

The versatility of pyrolysis also allows its **application to municipal waste**, not just for medical material. This Solution will be investigated, even though it seems challenging to apply in large structures like the Policlinico Gemelli, being more feasible in smaller facilities. The co-developer needs from the financial point of view, to have a payback time of around 5/7 years. During the workshop dedicated to Waste Management, both internal and external stakeholders pointed out the need of a better management of medical waste, which now is sorted poorly. They seemed very interested in the creation of a circular process that exploits this waste creating a new energy vector.

The main issue remains to find adequate space to install the new technology and manage the environmental impact, considering that, for example, the Policlinico Gemelli is in a protected area. In general, it is necessary to investigate **local legislation** that can limit the Solution's applicability since HC facilities are very sensible organizations.

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The development of this Solution involves the inclusion not only of waste management officials but also the energy managers of the structure, as pyrolysis produces a **useful by-product** (like diesel fuel). The plant aims to be as much automated as possible, but obviously, more personal will be required to manage and carry out maintenance. The use of this diesel fuel must be integrated with the existing energy infrastructure of the facility to maximize the overall efficiency of the plant. This aspect could be critical: HC facilities' variety and complexity make it difficult to apply the Solution in a standardized way. As an example in the FPG hospital, energy is produced by gas turbines that can operate only with methane. So, in some cases, it is necessary to individuate an alternative in the management of the diesel fuel produced (for example it could be sold to other organizations). The development of the WP-MED Solution will be based on the collection of a variety of data on healthcare facilities:

- General information about the hospital.
- Separation and classification method of medical waste.
- Quantities of different categories.
- Quantity of medical waste produced per day by the HC facility.
- Composition of the medical waste in terms of materials (plastic, paper, metal, etc.)
- Actual management of medical waste (sterilization, incineration, external organization, etc.)
- Cost of medical waste management.
- Typology and quantity of fuel used for hospital needs.
- Space available in the building

9.2.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the on-site medical waste pyrolysis plant prototype (R3.2):

The following technical committees were identified as relevant on European or international level:

- ISO/TC 45 - Rubber and rubber products
  - ISO/TC 45/SC 2 - Testing and analysis
- CEN/TC 216 - Chemical disinfectants and antiseptics
  - CEN/TC 216/WG 3 - Food hygiene and domestic and institutional use

There were no applicable regulations identified as relevant in the lead developer survey in Task 2.2 – Results' requirements.

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

9.2.4 Use Cases

9.2.4.1 Use Case WP-MED/FPG (co-developer)

Fondazione Policlinico Gemelli is the largest hospital in the Caring Nature project, and therefore the Solution will be studied to handle a huge quantity of medical waste. At the present time, the medical waste is stored for a maximum of one day and then transported to a facility in Chieti, 275 km away from the hospital, where it is sterilized and then incinerated. The on-site management of the waste can lead to a sensible reduction of the GHG emissions linked with the transportation of the waste by truck. In first approximation, every two-way travel of the truck generates around 60 kg of CO2. The transportation affects not only the emissions but also the cost.

FPG produces approximatively **2500 tons of medical waste per year**, around 6 tons per day. This big numbers lead the management of FPG to think about the introduction of a sterilization plant inside the hospital. As already described in chapter 8.2.2 the pyrolysis process allows to reach the minimum temperature for the sterilization, therefore introducing this type of reactor will allow to avoid the construction of the sterilization plant, with a sensible space saving.

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A **detailed feasibility study** will be conducted to see which are the benefits of introducing pyrolysis in FPG. The feasibility study will consider this main aspect, but not only them:

- Money paid to the external company now in charge of collecting, transporting, and sterilizing the waste
- Capital cost of the installation of the pyrolysis system
- Possible revenue of the selling of the synfuel generated by pyrolysis
- Possible revenue from selling other pyrolysis by-products

Since the thermal plant of FPG is running completely on NG, it seems unfeasible to use the diesel oil obtained from pyrolysis in the current energy system, therefore the possibility of selling the oil to neighbouring or partner activities will be investigated. The same will be done for the solid by-product (ashes).

In terms of space requirements, it is estimated that for processing 1.5 tons of medical waste 30 sqm are required. The design of the reactor will be suitable for any hospital, and depending on the flow of medical waste the type of process (**batch** or **continuous**) will be chosen. There is also the possibility of operating more units simultaneously, for example adding a second unit to process up to 3 tons of medical waste per batch, or adding in the same unit a second pyrolysis reactor.

ERCS will try to reduce the temperature required by the process down to 300-450 °C to reduce the heat production and increasing the overall efficiency of the process, being more environmentally friendly and minimizing the external sources of energy in total.

9.2.4.2 Use Case WP-MED/WPH (validator)

Contrary to what happens with the co-developer, WPH represents an entity **spread across the territory** and therefore includes both a medium-sized hospital (the central hospital of Päijät-Häme region) and small primary health, social and rescue facilities scattered throughout the region. This allows for the study of a case very different from FPG. Currently, the central hospital in Lahti sends its hazardous medical waste to an incinerator located 65 km from the hospital, which handles the entire sterilization and combustion process. In this case, as well, it is important to evaluate the environmental and economic impact of transportation. This organization will provide the opportunity to study a different scenario, especially in terms of size, which will make it possible to validate the Solution developed in FPG

9.2.4.3 WP-MED/UKHD Use Case (validator)

Heidelberg Hospital represents in terms of size an intermediate between FPG and WPH. Further information will be collected to properly define the feasibility study of the pyrolysis reactor also for this HC facility.

9.2.5 Testing, verification, validation methodology and KPIs

Testing

The testing assesses the physical properties of the equipment. It is performed through experiments and statistical analysis of the results.

It will at least assess the following features:

- **KPI: Process temperature 350-450 ºC**

  Target: 350-450°C

  Through the experimental part of the program, ERCS will try to reduce the temperature required for the process. Instead of the reference temperature of 650, it will be reduced to 300-450 to reduce the heat. So, minimize energy needs and increase thermal efficiency. The result will be extracted throw-out the testing phase

- **KPI: Conversion rate Kg/L**

  Target: 350-450°C

  Through the experimental procedure, several variables will be considered like temperature, time of the procedure and type of waste. The result will be extracted through the testing phase, regarding the ratio. Regarding the oil quality will be used ASTM and ISO standards.

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- **KPI: Process area**

  Target: <20 mq/tons MW

  The aim is to reduce the total volume of equipment and consequently the area of the needed space.

  The main aspect is to design and manufacture a device that can find a use in any scale of HC facilities.

The result will be extracted through the design and unit manufacturing.

Easy installation and modularity will also be assessed.

Verification

The method consists in checking the result against the description of "Solution 0" and Solution 0^+.

Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability).

They are summarized in the following table:

Table 35: Summary of KPIs for the WP-MED Solution.

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
WP-MED	1) **Economic sustainability *threshold:* ≤ 1,5 tons of medical waste per day** *(= a hospital with~350 beds)*	Treatment equip./process	Feasibility study			
	2) **% CO2e footprint reduction:** ≥ 30%	Treatment equip./process	Feasibility study			

To be noted:

- The feasibility study will be the core "user oriented" activity of the Use Cases. It will allow to calculate the two indicators
- In particular, for the KPI 2) "CO2 footprint reduction (%)" the calculation of CO2 footprint reduction will be done using LCA methodology and dedicated calculators and standards, and it will take into consideration the following aspects:
  - There will be no transfers from the hospital to the waste treatment facility for sterilization and after that, transportation to landfill or incineration facilities.
  - It is possible to gain a significant amount of CO2 footprint from not landfill or incinerate medical waste.
  - Reduction of the use of fossil fuels in transportation and energy because we will use our produced oil as an alternative fuel (where possible)

9.3 WP-FOOD: On-site food waste processing for energy production

WP-FOOD will conduct a feasibility study to better understand the potential for processing food waste in HC facilities or to examine other alternatives for treating food waste. The study will evaluate methods for producing value-added products or energy from food waste to reduce the carbon footprint.

9.3.1 Solution 0 description

In hospitals, food waste makes up the largest percentage of total waste. Within the various food sectors, hospital food waste has been estimated to be two to three times higher than that of other sectors, such as restaurants, workplaces, and schools. When food waste is disposed of in landfills, it decomposes, producing methane and carbon dioxide. If hospital food waste is collected and disposed of separately

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from general hospital waste, it can be bio-processed to produce value-added products. The bioprocessing of hospital food waste could improve the sustainability of hospitals and reduce their carbon emissions.

In CN, first, the concentration of anti-microbial resistance (AMR) genes in hospital food waste before treatment and after treatment will be evaluated. Despite the relatively large number of studies in the field of hospital wastewater, no work has been done on AMRs in food waste. This is significant because it is likely that this waste will not be treated through composting or considered animal food in case of high ARGs.

In this task, the biogas potential of food waste will be evaluated in the laboratory with and without pre-treatment. However, a large volume of food waste is required for the installation of anaerobic digestion on-site, which will be evaluated. Alternatively, the waste can be transported to a nearby anaerobic digester, contributing to transportation costs.

Another option to be explored is on-site drying of food waste. On-site drying of food waste will reduce its volume and moisture content and allow storage for a relatively long period. Anaerobic digestion of dried food waste will be examined in the laboratory, while other options will be studied theoretically.

In addition, the pre-treatment of food waste over various temperatures such as heating at 90°C and 120°C for 30 minutes and 1 hour at each temperature.

Based on the laboratory results and actual hospital data, a techno-economic analysis will be carried out to evaluate CO2 reduction and energy efficiency. The study, based on laboratory results, will demonstrate the feasibility of two plants that can operate on-site that are economically and environmentally sustainable. The two processes will be compared, to assess which is the best under which conditions. Both local processes are expected to generate overall CO2 emission savings, thanks to transport reduction and local generation of energy:

- Biogas production from waste food, by anaerobic digestion.
- Food waste drying: the dried waste can then be transported (lower weight) or used for producing gas.

9.3.2 Solution 0+ requirements

The co-developer (FPHAG) has been asked to provide information about the food management in their facility, to better understand the needs and the context. The issue of food waste generation in hospitals arises from various factors, including the large-scale food service operations necessary to accommodate the diverse dietary needs of patients and staff. Hospitals often engage in advance meal preparation, which can result in overproduction and subsequent waste if meals remain unconsumed. Recognizing their social and environmental responsibility, hospitals seek to minimize their ecological footprint by improving food waste management practices, thereby reducing their contribution to landfill waste and associated environmental concerns.

During the discussion between LD and Co-D, it emerged that a key variable in developing the feasibility study is the distance to the nearest anaerobic digester. The greater this distance, the more profitable the on-site process or the possibility of drying food waste before transportation to an anaerobic digester becomes. The analysis will be based on the existing nearby digester of Co-D. Additionally, laboratory results will be taken into consideration during the analysis. Drying lowers transportation expenses but raises the costs associated with installing an on-site dryer. Therefore, the amount of biogas from dried food waste, the reduction in transportation costs, as well as the capital and operational costs of the dryer, should be taken into account.

During the Waste Management workshop, food waste management emerged as a key issue. External stakeholders suggested setting agreements with food banks to donate unused food trays and collaborating with the food service provider to monitor and reduce food overproduction and waste.

Apart from this, another topic raised by external stakeholders was the best option for converting food waste to biogas through anaerobic digestion. A discussion followed regarding different scenarios, such as building an anaerobic digester on-site, transporting food waste to a nearby digester, or drying the food waste and then transporting it to a digester. Drying reduces transportation costs but increases costs related to installing a dryer on-site. Implementing the initiatives mentioned above faces several barriers. Economic constraints must be considered, along with the time and effort required from staff for the separation or segregation of food waste. Overcoming these challenges necessitates increased awareness and the adoption of more conscientious waste management practices among hospital

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personnel. During discussions, significant differences were noted among various structures in terms of food waste management, food production organization, and current biogas infrastructure. If food waste is stored on-site, a cold chamber will likely be present to slow down decomposition. However, there is a general barrier related to waste storage in hospitals due to potential national regulations and social perceptions linked to possible odors.

Additionally, if food waste (dried or raw) is transported to an anaerobic digester near the hospital, an agreement between the hospital or the authority for hospital waste and the regulatory body overseeing the digester needs to be established. The removal of water during drying can take place in a closed dryer to eliminate odor problems. By drying the food waste, its volume is reduced, pathogens are eliminated, and transportation costs are minimized. If the digester is public, this process may be easier. On the other hand, if the digester is private, more barriers may arise.

Practical aspects such as the fees that the hospital needs to pay to the digester and the proper separation of food waste from other types of waste need to be addressed. This Solution will relieve the hospital of the responsibility to build and operate a digester, with the main responsibility being the separation of food waste. The primary costs would be transportation and the fees paid to the owner of the digester.

Most biogas plants that receive food waste or slaughterhouse waste must adhere to specific regulations when processing these materials. According to Regulation (EC) No. 1069/2009 of the European Parliament and Council, and Regulation (EU) No. 142/2011, concerning health rules regarding the treatment of animal by-products and derived products, pasteurization at 70 °C for 60 minutes is mandatory. Pasteurization is a critical step in ensuring the safety of these biofertilizers. Both Regulation (EC) No. 1069/2009 and Regulation (EU) No. 142/2011 highlight the importance of this process in preventing the spread of diseases through biofertilizers applied to crops. By adhering to these standards, biogas plants can effectively convert waste into valuable agricultural inputs while maintaining high safety and environmental standards.

As previously reported, by drying the food waste, the hospital can reduce the cost of the biogas plant since the dried food waste will not require pasteurization. Therefore, an agreement can be made between the hospital and the digester owner (public or private).

In addition, based on the pasteurization requirements, the project will conduct experiments related to this process. The experiments will involve pasteurizing food waste for at least one hour. Several scenarios will be examined, such as pasteurizing food waste at 70 °C. Another option is to submerge the food waste in water at 70 °C for one hour or longer to enhance hydrolysis and further release sugars and volatile fatty acids from the food waste. This product will be further treated through anaerobic digestion under mesophilic conditions, which will improve the anaerobic digestion process. Additionally, hydrolysis in the presence of anaerobic granular sludge may further promote the breakdown of food waste. This will take place at 70 °C, with the food waste exposed to both anaerobic granular sludge and water. During the laboratory experiments analysis regarding the biogas, the pathogens and the antibiotic resistance genes will be conducted.

The development of the WP-FOOD Solution will also be based on the collection of a variety of data on healthcare facilities, data from the literature and from experimental results at the Cyprus University of Technology

- Separation method of the waste.
- Separation method of the waste food.
- Quantity of waste food: total, per person and day.
- Quantity of waste food transported per day/week to biogas plant.
- Methodology of waste food's storage.
- Number, distance and typology of biogas plant near the hospital (private or municipal plant).
- The status of the digester – if it is private or public and a potential agreement between hospital and digester
- Number and distance of compost facility or cement plant from the hospital.
- Collaborative practices between the hospital and the biogas plant.
- Costs related to the disposal of the waste food.
- Cost related with installation of food waste dryer and its operational cost
- Cost (capital and operational) related with the possibility of anaerobic digester installation on-site
- Value of biogas and the possibility of biogas to be converted to energy (electricity) or to be upgraded and to be used in the natural grid or as a transportation fuel.

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To summarize, the aim of the Solution is to collect data regarding the status of food waste management. Based on the experimental results, three scenarios will be examined:

1) To study the potential of an on-site anaerobic digester based on the experimental findings regarding biogas production from food waste.
2) To examine the transportation of food waste to the digester. In this case, the pasteurization cost needs to be considered, as well as determining the best pasteurization process for the food waste. The following pasteurization process will be evaluated (food waste pasteurization, food waste hydrolysis during pasteurization, and food waste acidification using anaerobic granular sludge at 70 °C).
3) To examine the drying of food waste in the hospital as a way to reduce the volume of food waste and transportation costs. In this scenario, the biogas plant will eliminate its pasteurization cost since the food waste will have already been exposed to a temperature above 70°C for more than one hour. This can potentially be a win-win scenario between the hospital and the owner of the biogas plant. The hospital can potentially reduce transportation costs, and the biogas plant owner (public or private) can avoid the pasteurization cost.

9.3.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the on-site waste food anaerobic digestion & drying processes (R3.3):

The following technical committees were identified as relevant on European or international level:

- ISO/TC 34 - Food products
  - ISO/TC 34 SC 20 - Food loss and waste
- CEN/TC 183 - Waste management
- CEN/TC 216 - Chemical disinfectants and antiseptics
  - CEN/TC 216/WG 3 - Food hygiene and domestic and institutional use

There were no applicable regulations identified as relevant in the lead developer survey in Task 2.2 – Results' requirements.

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

9.3.4 Use Cases

9.3.4.1 Use Case WP-FOOD/FHAG (co-developer)

FHAG is a hospital highly committed to food management and waste reduction. It has researched and is about to adopt a cold kitchen system to better rationalize food preparation. Currently, the hospital does not have data on food waste as they do not separate the organic fraction of their waste.

The hospital pays approximately €70,000 per year to the waste management company for around 1 ton of mixed waste per day.

In Granollers, there is a Wastewater Treatment Plant that collects wastewater from several municipalities in the region. Granollers hosts the Vallès Oriental Regional Waste Treatment Center, which includes an anaerobic digestion and composting plant located 10 km from the hospital. Based on the laboratory findings and the literature data a techonomic analysis will take place and the three scenarios will be examined. However, regarding the second scenario, "To examine the biogas production from waste food, by nearby anaerobic digester" specific initial parameters will be set based on the anaerobic digester that is located 10 km from the hospital.

A) To examine the biogas production from waste food, by anaerobic digestion on-site of hospital
B) To examine the biogas production from waste food, by nearby anaerobic digester

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C) To examine first the food waste drying and then the dried waste can be transported (lower weight) or used for producing gas to nearby anaerobic digester

9.3.4.2 Use Case WP-FOOD/FPG (validator)

FPG is a large-scale hospital, the second largest in Italy and the largest in the Caring Nature project, producing 1.3 million meals per year. The organic fraction is separated from other types of waste, with 330,000 kg of organic waste produced in 2023. This separation is carried out by an external supplier. Currently, the organic fraction is managed by this supplier, who takes it to a facility for treatment. The entire process is external to the FPG structure. A feasibility study will be conducted to explore the possibility of internalizing this process, leveraging food drying, and assessing potential economic and environmental benefits. The possibility of the three scenarios will also take into consideration:

a) To examine the biogas production from waste food, by anaerobic digestion on-site of hospital
b) To examine the biogas production from waste food, by nearby anaerobic digester
c) To examine first the food waste drying and then the dried waste can be transported (lower weight) or used for producing gas to the nearby anaerobic digester.

9.3.4.3 Use Case WP-FOOD/WPH (validator)

In WPH, food waste is collected, compounded, and stored on-site before being transported by a waste management company for conversion into biogas. The hospital maintains a conditioned space for waste storage. In the Wellbeing Services County of Päijät-Häme, approximately 300 kg of food waste is transported twice a week to the LABIO biogas plant, which is 13 km away. The food waste is collected and transported by a single lorry with a capacity of approximately 4.5 to 5 cubic meters, sufficient to handle the bi-weekly collection.

The cost of emptying a 240-liter biowaste container is €12.30 per container. Collected food waste is stored with a cooling system to ensure it remains fresh until transportation. LABIO Ltd. treats all types of bio-waste and wastewater treatment sludge according to strict environmental criteria, maintaining reliability with no shutdowns since 2005. The plant has processed over 500,000 tons of bio-waste and sludge.

Labio Ltd. receives biowaste from various sources, including households, the food industry, shops and wholesalers, municipal utilities, wastewater treatment plants, farming, forestry, fisheries, horticulture, and commercial and industrial bio-waste. Inspections are conducted by the plant to ensure compliance. The transportation costs are covered by a contract between the Wellbeing Services County of Päijät-Häme and Labio Ltd

Comparatively, Finland appears to have a more advanced biogas infrastructure than Spain and Italy. Consequently, the implementation of the CUT Solution is expected to have a lesser impact in Finland. Nonetheless, it presents a valuable opportunity to explore a case study that diverges significantly from the co-developer's context. In this use case, drying the food waste can lead to energy savings by reducing the need to maintain cold conditions in the food waste storage area and lowering transportation costs. Additionally, the scenario of exposing the food waste to water for longer than one hour will be examined as a strategy to increase biogas production from food waste.

9.3.5 Testing, verification, validation methodology and KPIs

Testing

The testing assesses the physical properties of the processes. It is performed through experiments and statistical analysis of the results. It will at least assess the following feature:

1) Reduction of the anti-microbial resistance genes by food treatment
   Target: -90%
   Methodology: measurement of the concentration of this type of genes before and after the food treatment
2) Requirement of pasteurization of higher than 1 hour.
   Target: To increase the biogas yield by 20% compared to standard biogas production without the proposed pasteurization process. Several pasteurization processes longer than one hour will be examined, such as exposing food waste to water for more than 1 hour and utilizing hyper thermophilic hydrolysis.

Verification

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The method consists in checking the result against the description of "Solution 0" and Solution 0+.

Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability).

They are summarized in the following table:

Table 36: Summary of KPIs for the WP-FOOD Solution (the new KPIs in addition to the GA are in blue).

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
WP-FOOD	1) **Processed food daily – anaerobic digestion** It measures the minimum amount of food that is needed to make the process economically feasible for installing anaerobic digester to hospital. Target: 500 kg Methodology: feasibility study done merging food waste production data from the hospital and cost-revenues analysis	Treatment equip./process	Feasibility study			
	2) **Processed food daily – drying plant** It measures the minimum amount of food that is needed to make the process economically feasible Target: 200 kg Methodology: feasibility study done merging food waste production data from the hospital and cost-revenues analysis	Treatment equip./process	Feasibility study			
	3) **The distance of the anaerobic digester from the hospital that makes transporting food waste feasible.** Target: Determine the economically feasible distance for transporting food waste based on the amount of waste generated, in the context of the Use Cases	Treatment equip./process	Feasibility study			

To be noted

- The feasibility study will be the core "user oriented" activity of the Use Cases. It will allow to calculate the two indicators
- In particular, the calculation of the environmental impact reduction will be done using the LCA methodology and dedicated calculators and standards.

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9.4 WP-WATER: On-site wastewater processing for purification

The WP-WATER is a Solution that offers some innovative procedures to manage wastewater in healthcare facilities based on laboratory studies on innovative chemical treatments.

9.4.1 Solution 0 description

Hospitals around the world require large amounts of water for their proper functioning. Hospital wastewater (HWW), among all other medical wastes, poses a serious hazard to human health and the environment because of its ability to enter watersheds and pollute surface and groundwater if inappropriately managed. HWW is also characterized by the presence of various emerging contaminants, such as pharmaceutically active compounds (PhACs), various microorganisms, including antibiotic-resistant bacteria (ARBs), antibiotic-resistant genes (ARGs), persistent viruses, etc. Over the years, various treatment technologies, including biological methods, have been implemented to treat HWW. New processes for treating hospital wastewater will be evaluated on a laboratory scale to test their ability to reduce pollution and their economic and environmental sustainability in healthcare settings. The treatment process will consist of two stages:

For the first process two solution will be tested:

1) **Submerged anaerobic membrane bioreactor**, for producing biogas simultaneously with the treatment of hospital wastewater
2) **Microbial electrolysis system**, for production of biohydrogen simultaneously with treatment of hospital wastewater

After this a second process will be studied in order to post-treat the effluent from the first process. For this second step, three possible processes will be studied:

a. column filled with powdered activated carbon.
b. column filled with metallic iron.
c. aerobic membrane bioreactor.

We propose to examine several new hospital wastewater treatment systems that could be applied at the hospital facility level. Several criteria will be proposed to evaluate each system including energy requirements, energy production, removal of antimicrobial resistance (AMR) genes, removal of Chemical Oxygen Demand (COD), removal of pathogens, and removal of solid suspended residue.

9.4.2 Solution 0+ requirements

In Europe, there are no specific EU-wide regulations mandating the treatment of hospital wastewater before discharge into the sewage system. The Urban Wastewater Treatment Directive (91/271/EEC) provides general guidelines for urban wastewater treatment but does not specifically address hospital effluents. Consequently, the management of hospital wastewater is typically governed by individual countries' regulations, which can vary widely. These local regulations often require pre-treatment to meet specific standards before hospital wastewater is released into public sewage systems for further treatment at municipal wastewater treatment plants. This conclusion was found during the first six months of the Caring Nature project and was based on communication with involved hospitals, stakeholders in the field, and workshop discussions and by studying the EU the regulations.
Hospital wastewater can contain harmful substances such as emerging contaminants, pathogens, and antibiotic resistance genes that are difficult to treat even in WWTPs. Based on Solution 0, two integrated systems were proposed for the on-site treatment of hospital wastewater (with five processes to be tested in different combinations). However, since there is no regulatory necessity for extensive treatment of hospital wastewater, it is more sustainable to examine a single treatment step using these five processes. The focus should be on the removal of antibiotic resistance genes, organic compounds, and pathogens in a sustainable one step process, with the potential for energy generation if possible.

Recently, the Environmental Engineering Lab discovered a process for producing hydrogen from zero-valent iron (ZVI) or scrap iron using soluble CO2 and organic ligands. Part of this method was published in the Journal of Sustainable Energy Technology Assessment (Constantinou et al., 2023), and the patent application has been approved. This patent has also been submitted for approval in the USA and the EPO. This developed process can be integrated with biological systems or other physicochemical methods [42] [43].

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Instead of the Microbial Electrolysis System for hydrogen production, which has been studied in the laboratory for more than 15 years, we propose using the ZVI or scrap iron in process (Constantinou et al., 2023) for hydrogen production and simultaneous hospital wastewater treatment. Specifically, the liquid containing soluble iron from the ZVI process will be further used to treat hospital wastewater using hydrogen peroxide (Fenton process). In the regular Fenton process, commercial iron salt is used. However, in the proposed process, the iron will be dissolved based on the reaction we developed, and then the liquid with the soluble iron will be used for the Fenton process. By integrating these two processes, hydrogen production by ZVI and hospital wastewater treatment, the iron generated from the ZVI reaction will be utilized in the Fenton process. Additionally, we propose using the biochar generated by the pyrolysis of hospital plastic waste (WP-MED Task 8.2) as an adsorbing material for hospital wastewater. This biochar will connect two tasks: Task 8.2 WP-MED and Task 8.4 WP-Water, aligning the project with the circular economy concept. When the biochar material becomes saturated, it will be treated through pyrolysis to regenerate the biochar. This concept emphasizes the connectivity between the pyrolysis plant and the hospital, not only for treating plastic waste but also for providing adsorbing material for hospital wastewater. This innovative approach has never been examined before and presents a low-cost, sustainable solution. By integrating this process, we can potentially replace the aerobic membrane bioreactor, a well-studied technology, with a new concept that may be implemented at a lower cost. This integration highlights the circular economy and provides an effective, sustainable solution for hospital waste management and wastewater treatment. Based on communication with the main hospitals involved in the project, the current practice is to discharge wastewater to the sewage system for further treatment at a sewage plant. Instead of this two-step process, we propose examining a one-step treatment process for hospital wastewater using the following systems:

1) Submerged anaerobic membrane bioreactor, for producing biogas simultaneously with the treatment of hospital wastewater.
2) Hydrogen production by ZVI-ligand integrated with the Fenton process, for simultaneous hydrogen production and hospital wastewater treatment.
3) Treatment of hospital wastewater in a column filled with powdered activated carbon.
4) Treatment of hospital wastewater in a column filled with metallic iron.
5) Treatment of hospital wastewater in a column filled with biochar generated by the pyrolysis of hospital plastic waste.

Only if the organic removal is less than 60% then integration of this system will be done.
Regarding the examination of wastewater, one solution would be to collect a sample of the co-developer's wastewater (approximately 5 Liters) and send it to CUT. However, this introduces logistical difficulties. Therefore, an alternative solution has been developed: on-site analysis of the wastewater can be conducted, and the results sent to CUT. The water analysis needs to be performed by a specific laboratory. The concentration of chemicals and antibiotic-resistant genes can influence the efficiency of the processes. CUT will provide a list of requirements to define the components of the water that need to be monitored. After this first phase, with an accurate definition of the HC facility's water characteristics, it will be possible to decide which process fits best. Another solution is for CUT to collect wastewater from the public main hospital in Limassol (Cyprus) and test this wastewater using the aforementioned processes. The co-developer can then send only relatively small amounts of samples to compare with the wastewater.

Other relevant information to develop the feasibility study includes:

- Yearly water consumption.
- Yearly volume of wastewater produced.
- Yearly water cost.
- Yearly wastewater cost.
- Actual wastewater management (i.e. presence of treatment/pre-treatment system, direct discharge in sewage or environment).
- Wastewater monitored parameters (consider also antibiotic resistance genes and/or microbes).
- Presence of specific contaminants.
- Local regulations.
- Description of planned projects to improve wastewater treatment.
- Responsible for monitoring the wastewater discharge from hospitals.

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9.4.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the on-site wastewater anaerobic digestion process (R3.4):

The following technical committees were identified as relevant on European level:

- CEN/TC 165 - Waste water engineering
- CEN/TC 183 - Waste management

There were no applicable standards or standardisation activities identified as relevant in the lead developer survey in Task 2.2 – Results' requirements.

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

9.4.4 Use Cases

9.4.4.1 Use Case WP-WATER/7HRC (co-Developer)

7HRC is a large organisation with 8 hospitals and 11 HC centres of various sizes. Therefore, it is necessary to identify possible case studies among these 19 facilities (e.g., a large university hospital, a smaller facility, etc.) to understand potential differences in application. The choice of the facilities on which the feasibility study will be carried out is still being defined.

9.4.4.2 Use Case WP-WATER/UKHD (validator)

At University Hospital Heidelberg (UKHD) in Germany, the current wastewater treatment practices involve removing petrol, oil, and grease in separators; neutralizing wastewater based on pH value; treating radioactive wastewater separately through a decay system; and using lint traps to remove small fibres from the wastewater and control its temperature to ensure it is not too hot when released. The wastewater is pre-treated according to the guidelines of the wastewater association before being discharged into the public network, where it is further treated by the association's wastewater treatment plant (WWTP). Parameters such as pH value, radioactivity, and regular cleaning intervals of the treatment plants are monitored, although detailed data is not available. Emerging contaminants or antibiotic resistance genes are not measured. Local regulations, specifically the guidelines for wastewater discharge from the wastewater association, are applied. There are no known ongoing or planned projects to improve hospital wastewater treatment in the region, and the responsibility for monitoring wastewater discharge lies with the Wastewater Association and the City of Heidelberg. Hospitals, including UKHD, do pay fees to WWTPs for discharging their wastewater.

9.4.4.3 Use Case WP-WATER/WPH (validator)

In the Wellbeing Services County of Päijät-Häme, including the county's hospital and other health, social, and rescue service points, there are no on-site wastewater treatment facilities. Instead, these facilities rely on municipal water and wastewater companies and the existing sewage infrastructure for processing and treating wastewater. Wastewater from these points is discharged into the municipal sewage system and transported to municipal wastewater treatment plants (WWTP) for proper treatment, ensuring compliance with national environmental laws, regulations, and standards before being released into the environment. Some pre-treatment measures, such as amalgam filters in dental care units, are in place. Parameters monitored include those specified by the Finnish Environment Institute, Centres for Economic Development, Transport and the Environment (ELY), and the City of Lahti, which oversee compliance with discharge regulations. Although emerging contaminants and antibiotic resistance genes are not currently measured, a large-scale research project has investigated the cost-effectiveness of purifying pharmaceutical residues at their source. No ongoing or planned projects to improve hospital wastewater treatment are known, and Lahti Aqua, along with the City of Lahti's

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environmental protection and ELY, are responsible for monitoring wastewater discharge. The Wellbeing Services County of Päijät-Häme pays fees for clean water and wastewater discharge based on Lahti Aqua's price list and a wastewater connection-specific basic fee.

9.4.5 Testing, verification, validation methodology and KPIs

Testing

The testing assesses the physical properties of the processes. It is performed through experiments and statistical analysis of the results. It will at least assess the following feature:

- A waste treatment plant that achieves reductions of over 90% in antimicrobial resistance genes, over 80% in COD, and over 95% in pathogens is economically sustainable for a hospital with 350 or more beds. This plant not only ensures effective wastewater treatment but also operates efficiently without consuming excessive energy. Given the quantity of wastewater produced by such a hospital, this advanced treatment process balances cost-effectiveness with environmental and health benefits, making it a viable solution for large healthcare facilities.

Verification

The method consists in checking the result against the description of "Solution 0" and Solution 0^{+}.

Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability).

They are summarized in the following table:

Table 37: Summary of KPIs for the WP-WATER Solution

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
WP-WATER	1) A plant for waste treatment that **reduction of the antimicrobial resistance genes** >90%, is economically sustainable for the quantity of wastewater produced by a hospital with 350 beds or more.	Treatment equip./process	Feasibility study			
	Reduce the COD >80%, is economically sustainable for the quantity of wastewater produced by a hospital with 350 beds or more.	Treatment equip./process	Feasibility study			
	Reduce pathogens >95 %, is economically sustainable for the quantity of wastewater produced by a hospital with 350 beds or more.	Treatment equip./process	Feasibility study			

To be noted

- The feasibility study will be the core "user oriented" activity of the Use Cases. It will allow to calculate the KPI
- In particular, the calculation of the economic sustainability will be done using the LCC and SFEM methodologies.

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10. Patient travel Solutions: requirements, standards, KPIs and Use Cases

10.1 TELEMED: Guidelines and devices for quicker and evidence-based Telemedicine adoption

TELEMED will make available a set of tools and methods to help decision-makers with a complete and convincing assessment methodology to plan and prioritize low environmental and high clinical impact of telemedicine services. Thus, to quickly implement them, also using a training package to overcome the resistances of the staff (e.g. on the legal side) and the concept of "briefcase with devices".

10.1.1 Solution 0 description

TELEMED will provide an Advanced Telemedicine service that includes the use of digital health devices which substitute physical ones allowing doctors to remotely diagnose more complicate health conditions that so far can only be diagnosed in presence at the clinic/hospital. Some similar digital solutions are currently used as private services (insurances or out-of-pocket) in several countries, in USA, Canada, Israel, Brasil, Ukraine, both in urban and rural context. In all these case studies the environmental impact linked to the avoided travels (and relative GHG emissions) has not been approached.

The TELEMED Solutions includes:

- The definition of a methodology to explore the possibility of moving a pathology from a non-telemedicine to a telemedicine treatment, also considering the opportunity offered by the continuous innovation in the medical device sector
- The study of an all-in-one 35x35 cm suitcase containing devices for the patient/care giver to implement telemedicine services focused on prevention and chronic diseases; other than for the medical benefits, the choice of the devices that will be included in the suitcase will be selected also considering the GHG emissions of their supply chain.
- The development of suitable protocols and organizational models for delivering telemedicine services using the "briefcase" and other resources (e.g. proximity lab/pharmacies) minimizing the environmental impact
- The study of an essential practical training package for physician and nurses including operating models, Use Cases, legal issues, environmental impact concepts and recommendations
- The definition and application of a methodology to assess environmental, social, clinical and economic impact of new telemedicine interventions, based on LCA, S-LCA and LCC methodologies

All above components of TELEMED will be implemented for three pathologies representing the variety of the pathologies with potential for a wider application of the telemedicine, such as follow-up of respiratory diseases (needs auscultation, vital signs and spirometry), heart failure (needs auscultation, vital signs, ECG, weight monitoring); neoplastic infectious complication due to chemotherapy induced immunodeficiency.

10.1.2 Solution 0+ requirements

- The Telemedicine service embraces different kinds of topics. It raises aspects both related to technology, infrastructure, reliability of the technology, connectivity, integration with the electronic medical record, security and data protection, and either society and culture, clinical acceptance and the need for training on new technologies and the sense of distance between patients and doctors.
- Due to the connection with the HCP information system and to the treatment of patient's data, the security and compliance with the GDPR must be granted
- Several projects have been implemented to foster telemedicine initiatives in different countries[31], but not all people can use digital services, in particular aging people and vulnerable groups.
  On the other side cultural organization change management, law, legal obstacles, and reimbursement policies are well known barriers.
  To address these issues, some HCPs have adopted "hybrid" solutions, delivering the telemedicine service, not at home but in premises (such as the General Practitioner's office or a pharmacy) that are better connected and where health operators can support the patient, even if they are not specialist.

[31]For instance: in Germany (DiGA, https://dermanostic.com/health-journal/digitale-gesundheitsanwendung-diga/)

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- The environmental impact evaluation must be based on a careful comparison between the in-person delivery in the clinic and the telemedicine delivery[32], considering the different factors:
  - For the in-person visit, e.g. travel to and from the clinic, energy used, disposable supply chain, Waste generated (PPE, gloves, paper exam table cover, speculum, tongue depressors, etc), 1 pump of hand sanitizer/pz
  - For the telemedicine delivery, e.g. electricity needed to power a cellular phone for the duration of the visit, run video conference software, run clinician's computer.
- In some areas the connectivity is poor, and this could be a barrier to the adoption of the telemedicine.

Therefore, when developing the TELEMED, following aspects should be addressed:

- Make sure that the guidelines take into consideration the multidisciplinary aspects of the telemedicine service delivery (e.g. technology, connectivity, integration with the electronic medical record, security and data protection, and societal, cultural and clinical acceptance, reimbursement policies
- Make sure that the guidelines consider the security and confidentiality of the collected and managed data
- Find organizational solutions to consider that not all people can use digital services, in particular aging people and vulnerable groups
- Make sure that the methodology to assess environmental, social, clinical and economic impact considers also the changes required at the home of the patients (e.g. electric power consumption)
- Provide recommendations on how cope with the poor connectivity in some areas in Europe.

With regard the last need, a member of the RSG[33] has given a useful suggestion that will be explored during the development phase. The suggestion is based on the consideration that in many areas with poor signal coverage, signal availability is varying in time, depending on number of active users, weather conditions, and other factors. To mitigate these factors a solution could be the Data Aggregation and Transmission. It consists in collecting data locally on a wearable/local device and transmit when good connectivity is available. So if at the time of measurements signal throughput is not sufficient, the collected data could be transmitted when network capacity is sufficient.

This solution could fit with the "Rehabilitation" Use Case (see next paragraph 10.1.4.1), where patient and specialist to not need to interact during the care delivery.

10.1.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase, the kick-off meeting and the lead developer survey in Task 2.2 – Results' requirements, the following technical committees (TC) and applicable standards were identified as potentially relevant for the guidelines for next generation telemedicine exploitation (R4.1):

The following technical committees were identified as relevant on European or international level:

- ISO/TC 215 - Health informatics
  - ISO/TC 215/WG 4 - Security, Safety and Privacy
  - ISO/TC 215/TF 7 - Telehealth and Virtual Care (TVC) Standards
- CEN/TC 251- Health informatics

There were no applicable standards or regulations identified as relevant in the lead developer survey in Task 2.2 – Results' requirements.

In task T7.2 - Standardisation activities DIN with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the

[32] van der Zee, Casper et al.. (2023). Methods for Calculating the Carbon Footprint of Telemedicine: A Systematic Review. 10.21203/rs.3.rs-2998664/v1
[33] Rinicom Ltd

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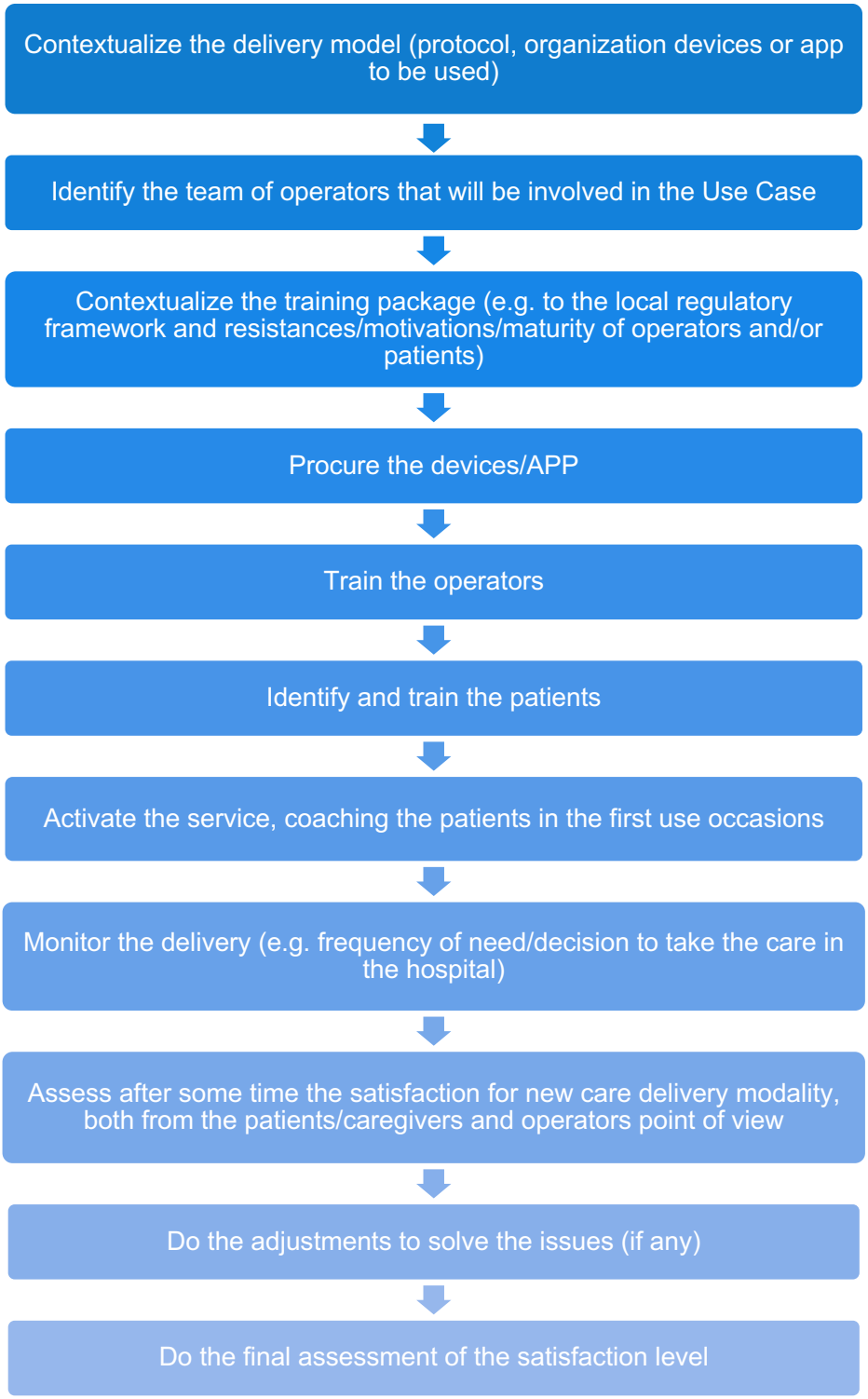
analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

10.1.4 Use Cases

Three uses cases have been defined. These Use Cases share the same type of activities to be conducted, characterised by three lines of activity plus a final one:

1) **Set-up of the telemedicine service**



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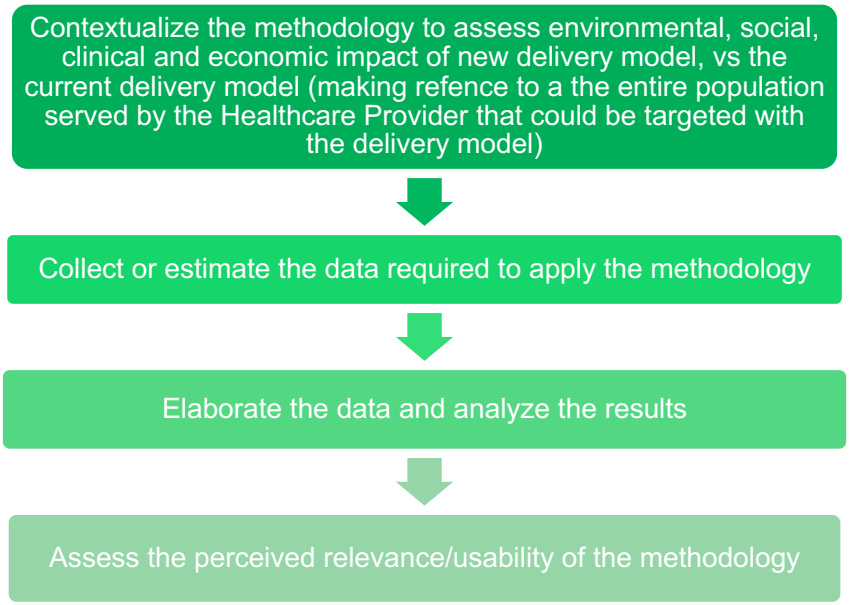
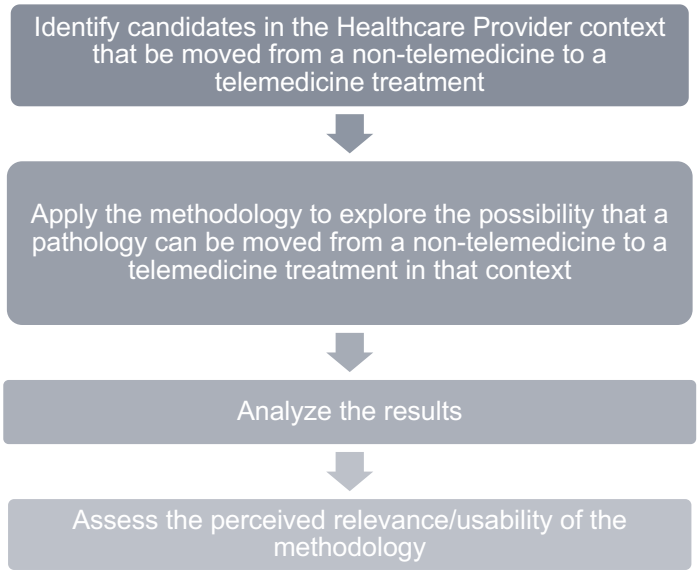
2) **Evaluation of the impact of the telemedicine for the selected type of patients/care**



3) **Identification of opportunities for new telemedicine applications**



10.1.4.1 Use Case TELEMED/FPG (co-validator)

At FPG, TELEMED will be developed for three types of care/assistance:

- **Rehabilitation**. The Solution consists in using an already existing APP [46] that helps the patient in making the exercises by herself. The APP allows the physiotherapist to configure the therapy on the needs of the patient. The APP informs the physiotherapist on the behavior of the patient and signals deviations from expected paths. So, the physiotherapist can monitor in an asynchronous manner) many patients and can contact them in case of deviations.
- **Chronic Respiratory Diseases in adults** (e.g. COPD). The Solution consists in equipping the patient with a spirometer and a certified medical device[34] that measures some parameters from the

[34] The devices is named TytoCare: https://www.tytocare.com/how-does-tytocare-work/

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body of the patient. The specialist asks the patient (or the care giver) to use the devices to collect the data. The data are transmitted via the wi-fi or the router of the smartphone to the specialist, that will be able to do the visit.

- **Chronic Respiratory Diseases in children**. The same as Option 2, but with children

For the first two, the activities 1) and 2) will be both performed.

For the last one only activity 2) will be performed, because the Solution is already operational

Moreover, also activity 3) will be performed

10.1.4.2 Use Case TELEMED/FHAG (validator)

This Use Case will regard the **Rehabilitation**. In particular the intention is to focus on the rehabilitation for broken femur.

Currently, the patients with broken femur stay in the hospital for the first period of rehabilitation.

The Use Case will try to understand if the patient can leave the hospital and do the exercises at home.

25 patients are expected to be enrolled and involved for a period of 6 months each.

10.1.4.3 Use Case TELEMED/WPH (validator)

This Use Case will regard the **Rehabilitation**.

The Wellbeing Services County of Päijät-Häme offers extensive physiotherapeutic rehabilitation services in three different locations in Päijät-Häme region: Heinola, Jalmari and Orimattila. We have statistics from the year 2023 and 2024. During the year 2023 there were 2.945 patients, and the number of visits were 27.337 in all of the three locations all together.

In the physiotherapeutic rehabilitation hospital (at least in Jalmari) an app called Medanets is in use. The Medanets app [47] has been developed in collaboration with healthcare professionals. The main focuses are patient safety, workflow efficiency, cost reduction, and user experience. Every functionality and feature of the app makes nursing work smoother, reduces the workload, and supports decision-making[35].

All the patients treated in the rehabilitation hospital are living in Päijät-Häme area. Travel distances per patient can be traced.

In principle, no connectivity issues in relation distance physiotherapy or related issues.

The Use Case will try to understand if the patient can leave the hospital and do the exercises at home.

25 patients are expected to be enrolled and involved for a period of 6 months each.

10.1.5 Testing, verification, validation methodology and KPIs

Testing

The test consists in assessing the logical consistency of the guidelines and of the sustainability assessment model. It assesses the formal quality of a methodologies, including the training sub component of the guidelines. They are analysed by peers and users reading the Deliverables D4.2 and D4.6 checking the following aspects:

1) internal congruence of the individual components
2) mutual congruence between the individual components, where applicable
3) clarity/readability/non-ambiguity of the guidelines and of the training material

Verification

The method consists in checking the result against the description of “Solution 0” and Solution 0+.

[35] Primary health care transitioned to the mobile era in Lahti region – direct patient work will increase and multidisciplinary collaboration will become more efficient - Medanets.

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Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability).

They are summarized in the following table:

Table 38: Summary of KPIs for the TELEMED Solution (the new KPIs in addition to the GA are in blue).

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
TELEMED (guidelines)	1) **Rapidity of implementation:** *the elapsed time to set up the telemedicine service (from the decision to do it to the first visit done by the medical team) is <3 weeks.*	Methodology without O/P	Parameters assess.			
	2) **Relevance, quality and usability of the guidelines for setting-up the telemedicine delivery:** *satisfaction score >4 in a scale from 1 to 5 in each of two HCPs of the CN consortium that will apply the TELEMED result developed by FPG.*	Methodology without O/P		Questionnaire	Questionnaire	Questionnaire
TELEMED (sust. assess. method)	2) **Relevance of the assessment methodology:** *satisfaction score >4 in a scale from 1 to 5 in each of two HCPs of the CN consortium that will apply the TELEMED result developed by FPG.*	Methodology with O/P		Output evaluation	Output evaluation	Questionnaire

To be noted: that the KPI 3) "Relevance, quality and usability of the guidelines for setting-up the telemedicine delivery" is additional vs the GA because this KPI assesses the capability of TELEMED to be easily adopted

An effort will be done to get a reliable indication of the percentage of patients (we expect 75 in total) that will keep themselves in the telemedicine care delivery modality

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11. Staff engagement Solutions: requirements, standards, KPIs and Use Cases

11.1 ENGAGE: Participatory staff engagement model

ENGAGE aims to obtain participatory staff engagement in the green transition of the HCPs through health and care-specific participatory methods for Communities of Practice (CoPs).

11.1.1 Solution 0 description

People's behaviour and attitudes can promote (or hinder) the adoption and implementation of environmentally sustainable solutions (for example, recycling) and technologies in hospitals and primary care. On the other hand, environmentally sustainable solutions and technologies affect work and organizational practices in hospitals and primary care.

The purpose of developing novel methods for people's engagement is to raise awareness of status, challenges and opportunities of environmental sustainability in health and care systems, find people's innovative ideas and solutions for green transition in the organizational contexts of health and care systems and contribute to mainstreaming the practical solutions developed by CN or other available solutions.

Participation can encourage people to take more active roles, and these roles can serve as mechanisms for transforming and democratizing health and care systems to make them more sustainable, thus addressing climate change.

Participation and knowledge-building taking place in Communities of Practice (CoP) involves much more than the development of technical skills. CoP has been understood as a group of people who share a concern, a set of problems, or a passion about topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis. CoP was originally developed to provide a template for examining the learning that happens among practitioners in a social environment, but over the years the focus had shifted to personal growth and the trajectory of individuals' participation within a group as well as application of CoP as a managerial tool for improving an organization's competitiveness. Based on this definition, CN's ambition is both theoretical and practical: people's engagement in CoPs which share an interest in green transition in health and care systems' organizations.

The result includes the following components:

1) Description of the learning approach for engagement in health and care systems' CoPs, with reference to the green transition
2) Library of participatory methods for engagement in green transition context
3) Guidelines for applying participatory methods
4) Training for using participatory methods
5) Engagement for green transition model (covering and integrating all previous 4 points)

The methods are developed for use in health and care organizations' CoPs, notably by health and care workers and providers of health and care (care professionals, such as medical doctors, nurses, etc., and managers). The methods include the use of, for example, future scenarios, visual images, cartoons and storytelling. Participants becoming "owners" of the solutions is at the core of this methodology for the CoPs.

The innovative aspects are as follows:

- The close and multidirectional connections between people's ways of doing things and environmental sustainability are only starting to be understood and ENGAGE advances this kind of understanding.
- ENGAGE considers the considerable body of research and practice on participation[36] and builds on understanding the role of situated learning and informal learning when creating spaces for people's engagement.
- ENGAGE pushes the knowledge frontier to enable better advancement of the green transition by developing methods to support engagement in and between Communities of Practice (CoPs) in HC organizations.

[36] Such as the pioneering work of Arnstein [45].

This project has received funding from the European Union's Horizon Europe research and innovation action programme under the grant agreement n°101137340.

- ENGAGE reinforces interaction and knowledge sharing and building a sense of belonging within networks/teams/groups when co-designing and mainstreaming innovative solutions for green transition in the practical circumstances in HC organizations.
- ENGAGE provides an innovative way to make it clear that green transition is a key responsibility of all staff, to advance trans-professional knowledge and awareness in environmental matters (also with other sectors) and to contribute to building or strengthening regional and national networks for climate resilience and sustainability.
- ENGAGE contributes to identifying key actors and strategies for health and care providers and professionals in advocating for green transition in health and care systems.

11.1.2 Solution 0+ requirements

The meetings with the internal end-users and workshops with the external stakeholders showed that environmentally sustainable solutions and engagement in green transition may be seen as too time-consuming, too expensive, adding an extra burden, and not making daily activities at work easier.

In particular, from the **content point of view,** the ENGAGE model should consider that

- People's behaviour and attitudes affect already identification of environmentally sustainable solutions (for example, recycling) and technologies in hospitals and primary care, in addition to their adoption and implementation.
- Attitudes may depend on the amount of extra work, for example. Time is a scarce resource, and there is a general shortage of nursing staff.
- The organizational culture is important to pay attention to in order to advance environmental topics. The last few years have changed people's minds, but there is still a lot of work to do in making the organizational structure support the staff's agency in green transition.
- Not only the negative points – what is done wrong – but also positive results and opportunities must be focused on in the communication and management.
- Staff members have a role to play towards patients, too, as they can give green transition related advice. Staff should be seen as ambassadors of green transition, as the sector is very large with 21 million health and care workers in the EU27[37]
- Engagement in green transition may be hindered by standard procedures – "we always did it this way" type of thinking.
- The perception that environmentally sustainable solutions may lead to increased costs especially at the beginning (staff and material costs). They also affect supply chains.
- Barriers may include even a feeling of security risk (e.g., reduction in use of gloves).

From the **process point of view**, the construction of the CoP for ENGAGE and the implementation must be done carefully in the HCPs:

- Sufficient time is needed.
- Informed recruitment and communication are essential ("you are an important member for the CoP").
- Involving also leading staff members is key. Seeing things in a new light is essential, and clever ways to communicate and manage the engagement processes are also needed.
- The management's informed acceptance is important because staff engagement is a resource question requiring use of working hours. The participants need to be permitted to participate.
- The CoP should include professional from different health and care services/units and represent different background (e.g. nurses, medical doctors, other HC professions, service managers for hospital, technical staff, administrative employees)
- Possible staff changes should be considered beforehand so that they do not lead to problems in or even to ending the activities. Each organizer, in particular, and the participants should have named substitutes. Managers should also have named substitutes.
- Access to instructions and other necessary knowledge must be given so that all participants have access to it, and even responsibility to follow them. Updating of responsibilities should also be specified.
- Sociocultural echoing about the process is important – making the activities visible in different formats, not just written ones. Accessible and attractive formats are essential (depending on the

[37] https://www.cedefop.europa.eu/en/tools/skills-intelligence/sectors?sector=06.16&country=FI

This project has received funding from the European Union's Horizon Europe research and innovation action programme under the grant agreement n°101137340.

context, they can be, for example, posters, videos, or alike – there may also be country-specific differences in preferences and needs).
- Special emphasis on the necessary facilitator expertise is a must, being key to the success of the validation and the use of the model.

11.1.3 Relevant technical committees and applicable standards and regulations

During the CARING NATURE proposal preparation phase and the kick-off meeting, no technical committees and applicable standards were identified as potentially relevant for the participatory staff engagement model (R5.1).

The following technical committees were identified as relevant on European or international level:

- ISO/TC 283 - Occupational health and safety management
  - ISO/TC 283/TG 8 - OHS risks arising from climate change
  - ISO/TC 283 WG 7 - Climate change

The following applicable regulations were identified as relevant in the lead developer survey in Task 2.2 – Results' requirements:

- ILO C187 - Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187)
- WHO guidance for climate resilient and environmentally sustainable health care facilities

In task T7.2 - Standardisation activities, DIN, with the support of the CARING NATURE partners, will continue its research and identification of potentially relevant technical committees, published standards and standards under development. This landscape will allow the use of existing standards, while defining a strategy to contribute to ongoing activities or to initiate new ones. The outcomes of the analysis will be compared with standardization needs in CARING NATURE and opportunities identified by the project partners.

11.1.4 Use Cases

There will be one co-development Use Case and four validation Use Cases.

Co-development activities

The ENGAGE model will be iteratively co-developed with WPH.

The steps to be taken at this stage include the following:

1) Design the learning approach for engagement,
2) Incorporate in the approach the potential of NBI (nature-based infrastructure) to motivate staff engagement behaviour,
3) Test the approach for engagement for green transition with the co-development partner WPH (using physical presence, in the local language), in workshops. Collect data with the help of the participatory approach in workshops of the chosen CoP, including reflection of present situation (and past paths to the present) and future scenarios in engagement for green transition in the health and care CoP,
4) Refine the approach and convert the methods into a library of participatory methods for engagement in green transition context.
5) Design and provide the guidelines for the validating partners to apply participatory methods in their local circumstances and training (in English) to partners for using participatory methods in their circumstances (in their local languages), i.e., the chosen CoPs;
6) Compile the Engagement for green transition model.

In the following, some of the above-mentioned steps are described in further detail:

Designing the learning approach for engagement in health and care systems' Communities of Practice (CoP), with reference to the green transition, includes:

1) Description of the Situated learning theory (based on literature)
2) Co-creation of the pedagogical strategy for green transition with the sustainability expert, unit managers in question, (other managers as appropriate), and staff
3) Preparation of the Engagement plan with the above-mentioned participants

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4) Green Transition Engagement (GTE) process in action:
   - Determining the green transition thematics and compilation of knowledge related to it
   - Outlining, naming and illustrating the role, identity and tasks of the CoP together with the staff, and designing a visual form for it
   - Designing the knowledge related to the two points above so that it is in a usable form for managers and staff (to be used in, for example, communication events and knowledge inputs – designer expertise needed for this stage)
   - Recognizing/identifying problems related to green transition thematics and their root causes; forming questions about the problems and root causes
   - Recognizing and describing situations, practices, power relations and basic beliefs that cause the problems
   - Producing ideas for solutions to these situations with the staff; analysing the ideas from the perspectives of usability, implementability, time and costs; testing the ideas and reflection concerning the testing
   - Preparing a communication strategy for health and care associations (such as unions, and other associations that may be related to the topic in question)

The approach will be refined and the methods converted into a library of participatory methods for engagement in green transition context that includes:

- Short reasoning regarding the practice of participation (why it is needed)
- Short introduction to what is ideation, implementation and reflection (Organizing reflection praxis by Russ Vince) for engagement in situated learning
- Description of ideation methods for imagining possible solutions
- Description of implementation methods for action planning for testing solutions, and actual testing in a particular time and place
- Description of reflection methods for evaluating the testing, and evaluation of what resources and decision-making processes are needed for implementation
- After the testing period: using selected participatory methods for green transition engagement (e.g., 10–20 ways to improve staff engagement provided in diverse forms (forms to be decided; a common way to describe the methods is needed; “a recipe”)
- Dramaturgical Characters can be used to communicate and describe the issues (for example, a visual character with green hair will be used as an artful inquiry tool; an ideation, distancing, reflection and communication tool)
- Description of a facilitation script for staff engagement (a pedagogical script which describes when, with whom, why and how to organize staff engagement)

Guidelines for applying participatory methods include:

- To be designed and provided for the validating partners in a digital format (graphic designer expertise needed for the design) so that they can apply participatory methods in their local circumstances
- Structure: 1) What is GTE (staff engagement for green transition = Green Transition Engagement)? 2) What are participatory methods in the health and care GTE (including a brief description of the theoretical framework of participatory methods)? 3) Why to apply participatory methods in the health and care GTE? 4) How to organize recruiting and informing the Engagement process, and how to document the process and collect feedback from the participants (organizational cultures and hierarchies affect these activities in each Engagement process, and those cultures and hierarchies need to be carefully identified)? 5) Other necessary topics (to be determined; these may be related to, e.g., diverse environments such as hospitals vs. primary care, or differences between countries, or the facilitation script as a tool for process planning)?

Validation activities

The approach towards Engagement for green transition model for health and care systems will be validated in each validation HCP (4 HCPs) by their relevant CoPs. These CoPs validate the co-

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development of the participatory strategy, participatory training and library of participatory methods for engagement in the green transition context.

- They will choose the methods that are appropriate for their chosen context from the library of methods.
- Live intensive training (in English) will be provided to the validating HCPs on the use of the methods for successful implementation.
- Validation occurs through the participatory process, in workshops conducted in local languages.
- The model will be fine-tuned based on learnings from the Use Case execution.

Before the live training, webinars will be organized to prepare, and a facilitator's manual will be provided for each validating HCP's team. Each validating team will be consulted when they implement their own staff engagement process, using evaluative reflection tools.

Special attention will be paid to providing documentation instructions for the validating HCPs so that knowledge is compiled for the fine-tuning of the model. Documentation plays an essential role in monitoring and assessing how validation succeeds. The validating HCPs will receive a (co-created) form for the documentation. They will also be asked to provide other complementary forms of documentation such as photos, case descriptions, participants' testimonies, Mentimeter results or alike gained during the events, etc.).

Special emphasis will also be given to supporting the validating teams in finding the necessary facilitator expertise for their national culture and environment, and the validating CoP. The question of who organizes and facilitates the validation process in each HCP is key to the success of the validation and the use of the model.

Characterization of the individual Use Cases

The Use Cases for ENGAGE have been identified considering that the CoPs should i) involve staff members representing different functions/professions (including HC-specific professions) and different levels (operators and managers), ii) deal with topics that are of actual interest for the organization AND/OR iii) may support development of one of the other CN results.

In the following, each Use Case is described in terms of CoP membership, key engagement topics, and points of attention.

11.1.4.1 Use Case ENGAGE/WPH (co-validator)

This Use Case will support the development of ENGAGE from M7 to M18.

The Use Case will deal with topics related to the implementation of the Environmental Programme of WPH for 2023-2025. It was established to develop sustainable and environmentally friendly service production and to achieve carbon neutrality in the county by 2035.

It will also incorporate the potential of NBI to ENGAGE to motivate staff engagement behaviour, as appropriate.

WPH's commitment to promoting environmental sustainability has led to the establishment of a network of *environmental partners* to support this goal.

This already existing network will function as WPH's CoP to advance staff engagement for green transition within WPH.

The *environmental partners' network* aims to:

- Support environmental management from the employee level
- Support the environmental programme and its objectives (see the Section on WPH for information about the programme's priority areas)
- Implement and embed the environmental programme into concrete actions and practices
- Increase the environmental awareness of personnel
- Reduce negative environmental impacts: energy savings, sustainable purchasing, mobility choices, reduction of waste, including food waste
- Potentially bring cost savings.

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The CoP is thus a multi-professional network consisting of professionals from different health and care service units (located in different parts of the larger geographic area) and different backgrounds, such as nurses, rehabilitation and catering & nutrition specialists, service managers for hospital services and elderly care as well as ICT development, and representatives from medical equipment maintenance and sterilization as well as administration.

Each *environmental partner* carries out meaningful environmental work in their service unit, together with the supervisor and colleagues – communicating, training, motivating, etc., other employees for environmentally friendly choices. Their tasks are to:

- Promote an environmentally responsible operating culture in their own work community
- Participate in trainings for their tasks, and maintain and develop their environmental competence
- Find out the state of environmental issues at their workplace
- Participate in setting environmental goals
- Guide and encourage the members of their work community to engage in environmentally responsible activities, such as energy saving, reducing consumption and sustainable mobility
- Inform their work community regularly about the progress of environmental goals.

Each participant may devote one day of their working time per month to promote environmental issues. The network has regular thematic meetings. The service units may register a participant in the training of *environmental partners* (May and November annually). The future environmental partner asks the supervisor for permission to participate in the training and to use working time for this task.

The participants thus have a strong intrinsic motivation that connects them – making this CoP highly relevant and appropriate for CN's co-development activities.

The CoP is directly relevant for engaging the staff in the green transition, in terms of both developing the CoP itself further and developing its members' competence in acting as environmental "agents" or "hubs" in their service units. These two arenas also allow to experiment a wide spectrum of engagement methods, as part of the ENGAGE library, thus contributing to ENGAGE's relevance for the four validating HCPs and their diverse CoPs.

11.1.4.2 Use Case: ENGAGE/FPG (validator)

This Use Case will be implemented from M19 to M32.

The CoP will deal with topics related to the preparation of the CSRD report of the FPG. Therefore, the CoP will also contribute to the Use Case CSRD/FPG, where FPG plays the role of validator. It is planned from M19 to M32.

FPG has already started the process to collect data to feed the report and the relevant organizational functions have already been identified and involved.

The CoP membership will include the managers of these functions. This could be sufficient to support the duty to fill the report. However, FPG aims at using the CSRD reporting as an opportunity to diffuse the sustainability "mindset". Therefore, the CoP will also include operators (medical doctors, nurses, administrative staff, technicians) from all sectors of FPG.

FPG with this Use Case aims also to establish a network of *environmental partners*, similar to the one of the WPH.

FPG intends to apply the ENGAGE model (that will have been developed in the WPH context) for engaging the CoP on two main activities:

- Collaborate for filling the parts of the CSRD report that are more linked to the social aspects (own workforce, workers in the value chain, affected communities, consumer and end users)
- Analyse the report to identify weak areas and suggest ideas for improvement.

The CoP will also be invited, and empowered, to consider the NBI approach in these two activities.

In order to "energize" the CoP, it will be considered the possibility that it uses some already existing opportunities. For instance:

- Prepare and manage the participation of FPG to public events (e.g. the Earth Day)

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- Publish articles on the internal newsletter
- Use the internal cinema, *Medicinema*[38], to show movies on the environmental/climate issues and run a discussion triggered by their content, also possibly involving the patients and their relatives.

11.1.4.3 Use Case ENGAGE/FHAG (validator)

This Use Case will be implemented from M19 to M32.

The CoP will deal with topics related to the Use Case GLSS-HC/FHAG. It is planned from M19 to M32.

Th CoP will involve the staff working in the “Ophthalmology surgery patient journey”, which includes medical doctors, nurses, laboratory staff, administrative staff.

FHAG with this Use Case also aims to create the first core of a wider network of *environmental partners*, similar to the one of the WPH (see the Use Case ENGAGE/WPH).

FHAG intends to apply the ENGAGE model (that will have been developed in the WPH context) for engaging the CoP on the improvement of the process in scope, making it more sustainable.

11.1.4.4 Use Case ENGAGE/UKHD (validator)

This Use Case will be implemented from M19 to M32.

The CoP will deal with topics related to the Use Case GLSS-HC/UKHD. It is planned from M19 to M32.

Th CoP will involve the staff working in the “Cholecystectomy patient journey”, which includes medical doctors, nurses, laboratory staff, administrative staff.

UKHD with this Use Case also aims to create the first core of a wider network of environmental partners, similar to the one of the WPH (see the Use Case ENGAGE/WPH).

UKHD intends to apply the ENGAGE model (that will have been developed in the WPH context) for engaging the CoP on the improvement of the process in scope, making it more sustainable

11.1.4.5 Use Case ENGAGE/7HRC (validator)

This Use Case will be implemented from M19 to M32.

The CoP will deal with topics related to the Use Case DSS/7HRC, which consists in performing a sustainability evaluation of an investment regarding the modernization and decentralization at 7HRC imaging capability. This investment is under evaluation by the 7HRC and could provide a model re-usable in the other HC Regions

It is planned from M19 to M32.

The CoP will involve the staff working in the “Cholecystectomy patient journey”, which includes medical doctors, nurses, imaging technical staff, administrative staff.

7HRC with this Use Case also aims to create the first core of a wider network of environmental partners, similar to the one of the WPH (see the Use Case ENGAGE/WPH).

7HRC intends to apply the ENGAGE model (that will have been developed in the WPH context) for engaging the CoP on the diverse aspects of the investment, on how it can improve the imaging capacity from the environmental point of view.

11.1.5 Testing, verification, validation methodology and KPIs

Testing.

The ENGAGE model will be iteratively developed from M7 to M32.

We plan a first test at M18 and a last one at M32.

The testing will consist in a check of logical consistency, regarding:

- internal congruence of the individual components
- mutual congruence between the individual components, where applicable

[38] Medicinema is a real cinema integrated into the hospital structure, a space intended for 'cinematherapy' and relief therapy for patients and their families, thanks to the magic of cinema brought into the hospital.

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It will be performed analysing the Deliverable D4.4 (first test) and D4.8.

Verification

It will consist in checking how much the ENGAGE model complies with the description provided under "Solution 0" and with the requirements listed under "Solution 0+".

Validation and KPIs

The validation methods depend on the type of result/component and of KPI, i.e. on the aspects that it measures (performance, relevance, quality, usability) They are summarized in the following:

Table 39: Summary of KPIs for the ENGAGE Solution

Result/ component	Key Performance Indicator	Type of result/ component	Validation method (vs Result's aspects)			
			Performance	Relevance	Quality	Usability
ENGAGE	1) **Contextual attraction power:** Total No. of participants to co-development and validation activities (workshops, events) in the range 70-120	Methodology without O/P	Parameter assessment			
	2) **Model for health and care systems accepted by 5 health and care partners (the HCPs of the CN consortium):** in at least 4 of the HCPs the average "reinforced interaction and trans-professional knowledge sharing for green transition among the staff" score 4 in a scale from 1 to 5 by the participants	Methodology without O/P		Questionnaire	Questionnaire	Questionnaire

To be noted:

- Both KPIs are based on the KPIs included in the GA; they have been slightly adjusted to make them more specific and measurable.
- The first KPI has the purpose to assess if the ENGAGE model is found motivating, feasible and fruitful by the managers and the staff involved in the CoPs.
- The second KPI assesses, from the point of view of the HCP's staff, the perceived relevance, quality and usability of the model. It is an indication of reinforced interaction and trans-professional knowledge sharing for green transition among the staff.
- The contextual attraction power is assessed in terms of rate of attendance. However, this will depend on many contextual actors, including organizational missions concerning sustainability, related strategic organizational decisions and resulting staff engagement structures as well as related practices (such as permission to use working time), attitudes towards the HCP's initiatives39, quality of CoP construction, management and facilitation, quality of the ENGAGE model, and the workload and the actual agendas (e.g., shift work) of the involved staff. The questionnaire of the second KPI should help to explain the actual rate of attendance.
- The second KPI will be assessed with a survey based on a questionnaire that will include questions to explore
    - The reasons of the level of attendance assessed with the first KPI, eliciting the weight of the different contextual factors

[39] E.g., in some HCPs, the participation to the CoP activities will be voluntary.

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- The perceived relevance of the ENGAGE model, e.g. its capability to raise the environmental awareness and enhance and obtain staff engagement for green transition
- The perceived quality of the model, e.g. the completeness of the library in terms of different types of methods (along the continuum from more traditional to more radical ones), the fit-for-purpose of the individual methods for CN, the fit-for-purpose of the training and guidelines to the validating HCPs
- The perceived usability, e.g. the fit of the model and its components (such as the training) with different kinds of HCP cultures, the clarity and actionability of the participatory methods, the clarity and actionability of the guidelines.

- The questionnaire will be administered to all participants. To better analyse the results, it will be useful to distinguish, if possible, between those with low and high level of attendance, between the operators and those that construct, manage and facilitate the CoP. With the last ones the questionnaire could be delivered in the form of an interview.

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Conclusions and contribution to the next steps

The work of the WP2 was performed in the first six months of the project to provide the project with the foundation for the work to be undertaken in the following 30 months for the development WPs (WP3, WP4, WP5) and the validation WP (WP6).

This deliverable provides a framework that will allow to engage the external stakeholder in a fruitful knowledge sharing community and, at the same time, to position the CN Solutions in the context of the possible actions for implementing the transition of the healthcare providers towards more environmentally sustainable operations, while safeguarding the quality of care and optimizing the use of economic resources

This deliverable also provides the developers with as much as possible input to develop their solutions in the right direction and accessing meaningful Use Cases. For each Solution, at least three Use Cases were defined, one of which (the co-D) will play a predominant role in the development of the Solution, while the others will provide input for finetuning and insights into replicability.

Two important technical indications have emerged

- the importance of building a structural access of the DSS to the data that are already normally collected by the information systems of the healthcare providers
- the opportunities for synergy among the 10 Solutions, in particular i) GLSS-HC, CSRD and the lifecycle assessment tools make up an integrated toolkit for governing the green transition, ii) the CSRD report maybe a powerful content for the KSS, iii) all the waste-related Solutions make-up a modular collection that can be configured to fit with different HCP contexts, iv) COMPASS (including the NBI) and ENER make up an integrated means to reduce the buildings' environmental impact and increase the comfort in HC facilities, v) ENGAGE could be a methodology to facilitate the involvement of the staff in the CSRD report preparation and valorisation, the process reengineering with the GLSS-HC, the NBI consideration when constructing or renovating the healthcare buildings

The portfolio of Use Cases has been designed in a way that will allow to explore both above technical indications.

Roadmaps for feasibility studies and other verification and validation methods were agreed upon and will drive the results' assessment homogenously across the 10 Solutions.

The content of this deliverable also sets the basis for feeding the activities of WP7, having defined content already usable for dissemination purposes (e.g. the CARING NATURE HealthCare Doughnut framework), KPIs that will provide, once assessed, evidence of the performance, relevance, quality and usability of the CN Solution for exploitation purposes, the relevant Technical Committees to be considered for the management of standardization opportunities.

The modalities of execution of WP2 have produced not only "content" results, but also "process" results, which are quite important in view of the implementation of the project:

- Bilateral meetings and workshops allowed healthcare providers and developers to deepen their reciprocal knowledge and highlight their needs and the specificities of healthcare organizations structures.
- In each of the five HCPs have been identified and involved the functions and the managers that during the rest of the project are expected to provide their contribution
- A productive relationship has been established with many of the Reference Stakeholder Group members.
- During the WP2 execution the RINA team responsible for Technical Coordination and the Project Manager have facilitated all the meetings and led the drafting of the deliverable. This has provided them with the knowledge of the content and of the partners; this will facilitate the governance of the project.

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Annex A-Detailed results of the Delphi consultation

Domain: Building					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Upgrade building insulation like this could foresee the utilization of high-quality insulation materials and the improvement of window glazing to minimize heat transfer.	Appropriate (100%)	Feasible (81%)	-	-	Class A
2. Prioritize health impacts of material extraction, transport, use and disposal in assessing them for use in health care settings, and use materials that are replenishable and support human and ecosystem health in all phases of their life cycle.	Appropriate (100%)	Feasible (100%)	-	-	Class A
3. Avoid harmful chemicals eliminating hazardous substances like lead, cadmium, and certain flame retardants from building materials improves indoor air quality and protects occupants' health.	Appropriate (100%)	Feasible (100%)	-	-	Class A
4. Refer to guidelines created by national or regional green building organizations.	Appropriate (100%)	Feasible (91%)	-	-	Class A
5. Substitute materials containing persistent bio-accumulative toxic chemicals (PBTs), including PVC, CPVC, and halogenated and brominated flame retardants, with safer alternatives.	Appropriate (100%)	Feasible (91%)	-	-	Class A
6. Include sustainability standards in the planning and construction of healthcare facilities ensuring that they are energy-efficient,	Appropriate (100%)	Feasible (100%)	-	-	Class A

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environmentally friendly, and conducive to healing.					
7. Provide financial support for energy-saving initiatives to encourage healthcare facilities to invest in sustainability measures.	Appropriate (100%)	Feasible (100%)	-	-	Class A
8. Aspire to be carbon-neutral, setting a goal for carbon-neutral operation entails reducing energy consumption through efficiency measures, utilizing renewable energy sources like solar panels or wind turbines, and potentially investing in carbon offset programs.	Appropriate (91%)	Feasible (82%)	-	-	Class A
9. Employ healing architecture and evidence-based design, including nature and natural lighting in hospitals, thus improving patient recovery and supporting environmental sustainability.	Appropriate (90%)	Feasible (80%)	-	-	Class A
10. Install air pollution filters filtration systems which helps to remove pollutants and allergens, creating a healthier indoor environment for occupants.	Appropriate (82%)	Feasible (91%)	-	-	Class A
11. Plant indigenous trees and plants to obtain health co-benefits, such as the provision of natural shade for patients, staff and visitors during extreme heat events.	Appropriate (82%)	Feasible (82%)	-	-	Class A
12. Optimize site planning based on solar orientation and prevailing wind patterns.	Appropriate (82%)	Feasible (73%)	-	-	Class A
13. Use Local and Recycled Materials: Opting for locally sourced and recycled materials helps reduce transportation emissions and minimizes the environmental footprint of construction projects.	Appropriate (82%)	Feasible (73%)	-	-	Class A
14. Employ passive systems to provide increased resilience and redundancy.	Appropriate (73%)	Feasible (91%)	Appropriate (90.9%)*	Feasible (72.7%)*	Class A

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15. Implement real-time energy monitoring systems, coupled with artificial intelligence algorithms.	Appropriate (72.7%)	Feasible (91%)	-	-	Class A
16. Use high reflectance roofing and paving, or “green roof” systems and pervious paving, mitigate urban heat island effects, manage stormwater runoff, and provide additional insulation.	Appropriate (72%)	Equivocal (60%)	-	Not feasible (54.54%)	Class B1
17. Design buildings with narrow floor plates and corridors featuring exterior walls and strategically placed windows to maximize daylighting and natural ventilation, thereby reducing reliance on artificial lighting and mechanical HVAC systems, and also minimize ACH where feasible based on infection prevention protocol or code.	Equivocal (64%)	Equivocal (54%)	Appropriate (72.7%)	Not feasible (54.54%)	Class B1
18. Design within local natural and social contexts to better integrate the building with the community and natural environment.	Equivocal (64%)	Feasible (73%)	Not appropriate (54.54%)	-	Class B2

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Domain: ENERGY					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Choose an energy system based on factors pertinent to the facility, including facility size, level of care, budget, operational cost, resource availability, and geographic location.	Appropriate (100%)	Feasible (100%)	-	-	Class A
2. Assess health care facility's energy use and practices (such as percentage of grid-electricity, percentage of fuel oil and liquid gas used).	Appropriate (100%)	Feasible (100%)	-	-	Class A
3. Install energy-efficient lighting, such as LED lights, to save on energy consumption.	Appropriate (100%)	Feasible (100%)	-	-	Class A
4. Install hybrid energy systems incorporating renewable energy sources, batteries, and backup generators.	Appropriate (100%)	Feasible (91%)	-	-	Class A
5. Monitor air conditioning usage and adjust it according to temperature conditions and plug leaks when present.	Appropriate (100%)	Feasible (91%)	-	-	Class A
6. Reduce air changes overnight and weekends in unused operating rooms.	Appropriate (100%)	Feasible (91%)	-	-	Class A
7. Commit to transitioning to green and secure energy sources in healthcare systems.	Appropriate (100%)	Feasible (82%)	-	-	Class A
8. Prioritize energy sources and saving measures that are least costly to introduce and/or bring the biggest savings.	Appropriate (100%)	Feasible (82%)	-	-	Class A

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9. Implement controls to turn off lights and appliances when not in use, thereby avoiding standby mode, and utilize lighting systems with timers and motion sensors to minimize energy waste.	Appropriate (91%)	Feasible (100%)	-	-	Class A
10. Integrate occupant education and awareness programs with enhanced training for the health workforce to optimize energy consumption related to improving energy access and performance.	Appropriate (91%)	Feasible (91%)	-	-	Class A
11. Defrost freezers and refrigerators regularly when required.	Appropriate (91%)	Feasible (82%)	-	-	Class A
12. Forge partnerships with local government entities to facilitate the installation of off-grid energy systems, ensuring reliable and sustainable energy supply solutions.	Appropriate (91%)	Feasible (73%)	-	-	Class A
13. Conduct regular energy audits and use the results to inform awareness and retrofit programs.	Appropriate (91%)	Feasible (73%)	-	-	Class A
14. Integrate heat pump technology for both hot water production and heating purposes, enhancing energy efficiency and reducing reliance on conventional heating methods.	Appropriate (82%)	Feasible (73%)	-	-	Class A
15. Perform an inventory of medical and other equipment to understand and determine an estimate of the facility's energy needs.	Appropriate (73%)	Feasible (91%)	-	-	Class A
16. Implement renewable energy systems, such as photovoltaic panels, across the property to harness on-site sustainable power generation like installing solar cells placed strategically on the roof and above outdoor parking lots.	Appropriate (82%)	Equivocal (64%)	-	Feasible (90%)	Class A
17. Replace older air conditioners, refrigerators and other appliances and medical	Appropriate (82%)	Equivocal (64%)	-	Feasible (81.81%)	Class A

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equipment with energy-efficient models.					
18. Replace dishwashers and laundry machines with those having water-saving functions, whenever possible or when replacements are needed.	Appropriate (82%)	Equivocal (64%)	-	Feasible (81.81%)	Class A

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Domain: FOOD					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Minimize and beneficially reuse food waste (for instance, compost food waste or use it as animal feed; convert cooking oil waste into biofuel)	Appropriate (100%)	Feasible (91%)	-	-	Class A
2. Promote healthy and sustainable nutrition by increasing the availability of organic, seasonal and locally produced food in the health facilities and by ensuring suppliers have sustainable production and transportation practices.	Appropriate (100%)	Feasible (82%)	-	-	Class A
3. Redesign the menus both for visitors and staff, limiting the amount of meat and dairy when appropriate and increasing plant-based options.	Appropriate (91%)	Feasible (73%)	-	-	Class A
4. Educate and communicate within the hospital or health care system, as well as to patients and community, about nutritious, socially equitable and ecologically sustainable food practices and procedures.	Appropriate (82%)	Equivocal (73%)	-	-	Class A
5. Establish patient-adjusted portion sizes.	Appropriate (73%)	Equivocal (55%)	-	Feasible (81.81%)	Class A
6. Supply food that is produced without synthetic pesticides and hormones or antibiotics given to animals in the absence of diagnosed disease.	Appropriate (91%)	Equivocal (36%)	-	Not feasible (63.6%)	Class B1

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7. Provide on-demand inpatient food services.	Equivocal (64%)	Not feasible (27%)	-	-	Class C

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Domain: PHARMACEUTICS AND CHEMICALS					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Reduce the use of single-use items and promote sterilization and reuse of medical items.	Appropriate (100%)	Feasible (82%)	-	-	Class A
2. Substitute products or materials that contain Substances of Very High Concern with safer alternatives.	Appropriate (100%)	Feasible (82%)	-	-	Class A
3. Use floor-care products that are free of zinc, heavy metals, phthalates, glycol ethers and ammonia.	Appropriate (91%)	Feasible (91%)	-	-	Class A
4. Prevent disease exacerbation (for example, educating patients about eliminating environmental exposure to allergens and assisting patients with smoking cessation can improve asthma and chronic obstructive pulmonary disease control and reduce inhaler requirements).	Appropriate (91%)	Feasible (73%)	-	-	Class A
5. Educate patients on appropriate inhaler use and shift from carbon-intensive MDIs to low-carbon alternatives when appropriate, such as dry-powder inhalers or soft mist inhalers.	Appropriate (82%)	Feasible (82%)	-	-	Class A
6. Improve packaging, labelling and identification of chemical waste in separate chemical-resistant containers (i.e. not mixing hazardous chemical wastes of different types).	Appropriate (82%)	Feasible (82%)	-	-	Class A

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7. Do not provide samples of medications to patients (these often end up in the waste stream).	Equivocal (64%)	Feasible (82%)	Not appropriate (54.4%)	-	Class B2

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Domain: SUPPLY CHAIN					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Implement procurement policies mandating suppliers to disclose chemical ingredients, safety testing data, and greenhouse gas emissions, while prioritizing those meeting these specifications and requiring high-emitting suppliers to set science-based emission reduction targets.	Appropriate (91%)	Feasible (91%)	-	-	Class A
2. Emphasize efficient supply usage, encompassing commitments, like reducing plastic usage.	Appropriate (91%)	Feasible (82%)	-	-	Class A
3. Review procurement practices and local favour suppliers offering certified sustainable products and adhering to ethical practices.	Appropriate (91%)	Feasible (82%)	-	-	Class A
4. Implement a sustainable purchasing agenda considering environmental impact and human rights throughout all stages of procurement.	Appropriate (91%)	Feasible (82%)	-	-	Class A
5. Advocate for Extended Producer Responsibility and for products designed to generate less waste and use less hazardous materials.	Appropriate (91%)	Feasible (82%)	-	-	Class A
6. Placing importance on low-carbon substitutions and fostering product innovation while prioritizing transparency in supplier decarbonization initiatives.	Appropriate (91%)	Feasible (73%)	-	-	Class A

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7. Coordinate hospital purchases to increase buying power and prioritize suppliers and products meeting environmental specifications with circular economy approaches.	Appropriate (91%)	Equivocal (64%)	-	Feasible (81.81%)	Class A

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Domain: TRAVEL AND TRANSPORT					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Develop strategies for telemedicine, communication by e-mail and other alternatives to face-to-face encounters between caregivers and patients.	Appropriate (100%)	Feasible (91%)	-	-	Class A
2. Improve digital health and telemedicine: implement digitally enabled care models and channels for citizens that will significantly reduce travel and journeys to physical healthcare locations; build net zero into the digital maturity framework; support front-line digitization of clinical records, clinical and operational workflow, and communications.	Appropriate (100%)	Feasible (82%)	-	-	Class A
3. Ensure that planning and design phases for new healthcare infrastructure take into account accessibility via public transportation and active mobility for patients, staff, and visitors.	Appropriate (91%)	Feasible (91%)	-	-	Class A
4. Encourage cycling, walking, and alternative transportation modes by promoting pedestrian and cycling activities, improving infrastructure (including cycle paths, storage, and showers), implementing green travel plans for staff flexibility (negotiating discounts for public transport to provide incentives for its use, establish regional park and ride, active transport infrastructure, bicycling	Appropriate (91%)	Feasible (91%)	-	-	Class A

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incentives, and staff public transportation discounts).					
5. Provide healthcare in easily accessible locations without necessitating unnecessary travel, considering community-based primary care, home care, and co-locating medical services with related social services.	Appropriate (91%)	Feasible (82%)	-	-	Class A
6. Renovate fleet vehicles by ensuring the inclusion of low and ultra-low-emission vehicles, committing to a 90% adoption of low-, ultra-low, and zero-emission options.	Appropriate (91%)	Equivocal (64%)	-	Feasible (72.72%)	Class A
7. Install electric vehicle charging infrastructure with access for staff and the community.	Appropriate (73%)	Feasible (82%)	-	-	Class A
8. Incentivize staff to embrace electric vehicles by providing increased access, to electric bikes through digital platforms.	Appropriate (73%)	Feasible (73%)	-	Feasible (72.72%)	Class A
9. Purchase from local suppliers, and/or suppliers who use fuel-efficient transportation.	Equivocal (64%)	Equivocal (64%)	Appropriate (72.72%)	Not feasible (63.63%)	Class B1
10. Dispose of waste near the point of generation.	Appropriate (82%)	Equivocal (45%)	-	Not feasible (54.54%)	Class B1

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WASH (water, sanitation and hygiene)

Domain: WASH (water, sanitation and hygiene)					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Implement water conservation strategies: install efficient faucets and toilets, routinely check plumbing and pipes to prevent leaks, eliminate sealing and cooling water on medical air compression and vacuum pumps, and retrofit refrigeration systems.	Appropriate (100%)	Feasible (100%)	-	-	Class A
2. Regularly analyze water quality.	Appropriate (100%)	Feasible (91%)	-	-	Class A
3. Reinforce messaging about water use through signs and notices to promote saving.	Appropriate (91%)	Feasible (100%)	-	-	Class A
4. Surveillance of diseases related to insufficient quality water, and sanitation.	Appropriate (91%)	Feasible (91%)	-	-	Class A
5. Implement on-site wastewater treatment technologies when no municipal service is available (only if indicated by the permit for the discharge of wastewater from specific services).	Appropriate (91%)	Feasible (82%)	-	-	Class A
6. Manage wastewater safely through the use of on-site treatment (such as a septic tank followed by a drainage pit) or sending it to a functioning sewer system.	Appropriate (91%)	Feasible (82%)	-	-	Class A
7. Eliminate bottled water facility-wide if high-quality potable water is available. Eliminate the use of plastic bottled water in areas where tap water is accessible.	Appropriate (82%)	Feasible (82%)	-	-	Class A

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8. Increase patient and visitor awareness about water conservation including signs and notices in patient rooms and visitor restrooms.	Appropriate (73%)	Feasible (91%)	-	-	Class A
9. Landscape grounds using drought-resistant plants to minimize water use.	Appropriate (73%)	Feasible (82%)	-	-	Class A
10. Wash eating utensils immediately after use.	Equivocal (54%)	Feasible (73%)	Equivocal (72.72%)	-	Class B2
11. Limit manual cleaning of cooking utensils (trays, pots, etc.) and have specific dishwashers for this material.	Equivocal (64%)	Feasible (91%)	Not appropriate (54.54%)	-	Class B2
12. Utilize safely harvested rainwater or grey water to flush toilets, and clean outdoor pavement areas and water plants when possible.	Appropriate (73%)	Equivocal (54%)	Not appropriate (63.63%)	Feasible (72.72%)	Class B2

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Domain: WASTE					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Implement and monitor a waste reduction programme including waste management training for all staff.	Appropriate (100%)	Feasible (100%)	-	-	Class A
2. Ensure adequate management of healthcare waste and promote the minimization of general non-hazardous waste.	Appropriate (100%)	Feasible (100%)	-	-	Class A
3. Dispose of hazardous wastewater and liquid waste that may be infectious.	Appropriate (100%)	Feasible (100%)	-	-	Class A
4. Separate bins for potentially infectious waste, sharps, chemicals, pharmaceuticals, and non-hazardous wastes.	Appropriate (100%)	Feasible (100%)	-	-	Class A
5. Develop medical device reprocessing initiatives and reduce equipment obsolescence.	Appropriate (100%)	Feasible (100%)	-	-	Class A
6. Develop and implement measures to manage and minimize the production of healthcare waste in line with the recommendations of the WHO guidance handbook Safe Management of Wastes from Healthcare Activities.	Appropriate (100%)	Feasible (100%)	-	-	Class A
7. Create incentives for healthcare facilities to be more sustainable, sort and recycle waste, and exchange best practices.	Appropriate (100%)	Feasible (91%)	-	-	Class A
8. Minimize the production of general nonhazardous waste through adequate classification, waste	Appropriate (91%)	Feasible (91%)	-	-	Class A

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reduction, reuse and recycling.					
9. Phase-out of incineration of medical waste: a variety of non-burn technologies are available to safely disinfect, neutralize or contain waste (such as autoclaving)	Appropriate (91%)	Equivocal (64%)	-	Feasible (90.9%)	Class A
10. Dispose of hazardous wastewater and liquid waste into the sanitation system through pre-treatment (such as oils and fats, corrosive waste and other wastes, depending on the level of concentration).	Appropriate (82%)	Feasible (82%)	Not appropriate (63.63%)*	Feasible (91.81%)*	Class B2

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Domain: PUBLIC HEALTH INITIATIVES					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
Improve the performance of and access to environmental and occupational health services, promoting healthy environments (including healthy workplaces), safe and healthy foods, good air quality, and supply chain safety and security.	Appropriate (100%)	Feasible (82%)	-	-	Class A
Inform local communities about health systems activities and opportunities for involvement in health promotion activities and others where appropriate.	Appropriate (91%)	Feasible (91%)	-	-	Class A
Boost 'out-of-hospital' care: optimizing the location of care reduces emissions by helping to avoid unnecessary hospital visits and admissions.	Appropriate (73%)	Feasible (82%)	-	-	Class A
Use local green spaces for health promotion activities and, where feasible and appropriate, other selected health systems activities (for example, nature-based therapy).	Appropriate (73%)	Equivocal (64%)	-	Feasible (81.81%)	Class A
Implement rapid diagnostic centres (RDCs): RDCs deliver faster diagnosis and treatment, while also significantly increasing efficiency, and reducing carbon emissions.	Equivocal (64%)	Equivocal (73%)	Appropriate (72.72%)*	Feasible (81.81%)*	Class A

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Domain: STAFF AND COMMUNITY ENGAGEMENT					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Build regional and national networks for climate resilience and sustainability to spread and scale what works across the regions and to share the best practices.	Appropriate (100%)	Feasible (100%)	-	-	Class A
2. Educate healthcare professionals and build their capability about the links between health and climate change, the environmental impacts of healthcare, and interventions they can take to reduce emissions.	Appropriate (100%)	Feasible (91%)	-	-	Class A
3. Raise public and workforce awareness on environmental risk factors, healthcare waste, and best practices.	Appropriate (100%)	Feasible (91%)	-	-	Class A
4. Call for research and funding for materials and processes that deliver improved health, and resilience, and reduce carbon to zero.	Appropriate (100%)	Feasible (91%)	-	-	Class A
5. Take intersectoral action: raise awareness and exercise leadership with other sectors in matters to address social and environmental determinants of health.	Appropriate (100%)	Feasible (91%)	-	-	Class A
6. Engage the health workforce and its associations and unions in embedding environmental sustainability and resilience into health system culture.	Appropriate (100%)	Feasible (73%)	-	-	Class A

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7. Ensure healthcare facilities have sufficient numbers of healthcare workers with healthy and safe working conditions.	Appropriate (100%)	Equivocal (73%)	-	Feasible (81.81%)*	Class A
8. Develop a Roadmap and/or Action Plan to make an organizational commitment to a zero emissions trajectory.	Appropriate (91%)	Feasible (82%)	-	-	Class A
9. Advocate, from positions both inside and outside of government, for specific policies, regulations, and legislation that accelerate the transition toward zero emissions in key sectors, like energy, transportation, and agriculture, that affect both public health and health care's climate footprint.	Appropriate (91%)	Feasible (73%)	-	-	Class A
10. Communicate and increase awareness related to climate resilience and environmental sustainability among patients, visitors, target communities, and other sectors.	Appropriate (82%)	Feasible (82%)	-	-	Class A
11. Make sure hospitals, health systems and health professionals advocate for environmental health policy and promotion of public policy at the local, national and international levels and foster their collaboration with national and international jurisdictions.	Appropriate (82%)	Equivocal (64%)	-	Feasible (90.9%)	Class A
12. Establish a centralised authority to ensure progress towards reducing environmental impact.	Appropriate (73%)	Equivocal (64%)	-	Feasible (72.72%)	Class A

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Domain: FINANCING AND FUNDING MECHANISMS					
Action	**Round 1**		**Round 2**		**Conclusion**
	General relevance (% agreement)	**Feasibility (% agreement)**	**General relevance (% agreement)**	**Feasibility (% agreement)**	
1. Work with the government to access funds directed towards the ambition for net zero, and with trusts to explore alternative ways to fund this investment.	Appropriate (100%)	Feasible (91%)	-	-	Class A
2. Develop tools so that decisions across the government are informed by an understanding of environmental impacts, as well as financial ones.	Appropriate (100%)	Feasible (73%)	-	-	Class A
3. Review contractual mechanisms and levers to understand the opportunities to drive environmental change.	Appropriate (91%)	Feasible (91%)	-	-	Class A
4. Build a financial and clinical case for climate action.	Appropriate (91%)	Feasible (82%)	-	-	Class A
5. Establish financial incentives to drive changes, like favourable remuneration for low-carbon modes of travel, tendering criteria that include a strong percentage of sustainability points, and clinical reimbursement schemes based on positive health outcomes connected to low-carbon pathways.	Appropriate (91%)	Feasible (82%)	-	-	Class A
6. Integrate climate into the health system's financial decision-making process.	Appropriate (91%)	Equivocal (64%)	-	Feasible (90.0%)	Class A
7. Incorporate climate criteria with the aim of cost-effective decarbonization and resilience at all levels of health system financing. This	Appropriate (100%)	Equivocal (55%)	-	Feasible (81.81%)	Class A

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includes the public and private health sector budget, aid, lending, and other forms of financing.					

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Annex B-Functional, technical, security and hardware requirements for the KSS-DSS Infrastructure

Functional Requirements for KSS-DSS Infrastructure

The functional requirements presented here are common to all components of the KSS-DSS infrastructure.

Code	Description	MoSCoW
FR-KD-U1	Users must be able to self-register (Healthcare Professionals (HCPs), policymakers, investors, Public) or be pre-registered (Consortium Members).	M
FR-KD-U2	Access is permitted only for registered users	M
FR-KD-U3	Users must categorize themselves into one of the user groups upon registration.	M
FR-KD-U4	The system is offering functionality based on user groups/roles	M
FR-KD-U5	User groups/roles should be configurable at runtime	S
FR-KD-U6	Users should have the possibility to create and manage communities of practice, user groups, and interest groups within the organization.	M
FR-KD-U7	Each community has a community manager, which approves the acceptance of new users	S
FR-KD-U8	For communities, there will be workflows to approve the content available	S
FR-KD-U9	The system should allow users to request the deletion of their profile	M
FR-KD-U10	Community Managers can delete profiles and reassign associated content	M
FR-KD-U11	Engagement Mechanisms: Utilize existing hubs and networks to facilitate stakeholder engagement.	
FR-KD-U12	They should be administrative functions to set parameters for running the application	

Table 40: *KSS-DSS Functional requirements*

Functional Requirements Specific to KSS Infrastructure

The functional requirements presented here are specific to the KSS infrastructure

Code	Description	MoSCoW

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FR-KSS-1	The system should be able to capture explicit and tacit knowledge from various sources, including documents, databases, other Knowledge systems, CMS, and individual experts.	M
FR-KSS-2	The system should offer mechanisms to classify and categorize knowledge in a structured manner (e.g., taxonomy, ontology).	M
FR-KSS-3	The system should offer efficient and secure storage solutions for knowledge repositories, ensuring that information is easily retrievable.	M
FR-KSS-4	The system should offer advanced search and retrieval functions to enable users to find relevant knowledge quickly.	M
	The system could use natural language processing and semantic search, to help users find relevant information.	C
	The system should offer Data Mining and Analysis (identify trends and extract insights).	S
FR-KSS-5	The system will contain Collaboration Tools: discussion forums, wikis, and collaborative workspaces to enable users to work together and share knowledge.	S
FR-KSS-6	The system should offer the possibility for community managers to create Knowledge units	M
FR-KSS-7	Users will be able to search for or browse the knowledge units	M
FR-KSS-8	Users will be able to select the knowledge unit based on their interests.	M
FR-KSS-9	The system will automatically update the user profiles based on their work and collaboration	C
FR-KSS-10	The system should be able to identify the experts for a knowledge unit based on their activity and profile	C
FR-KSS-11	The system will Implement a user-credit system for Experts	W
FR-KSS-12	The system should contain Tools to create, edit, and update knowledge content easily.	M
FR-KSS-13	The system will offer Communication Channels: chat, and email to facilitate real-time interaction and information exchange.	M
FR-KSS-14	A User Feedback Mechanism will be part of the system to collect feedback from users about the system's usability and content quality.	S
FR-KSS-15	It should provide tools to measure and benchmark the environmental footprint.	M
FR-KSS-16	It should provide tools to create CSRD reports	M
FR-KSS-17	It should be possible to organize events	S
FR-KSS-18	It should be possible to organize workshops	S

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FR-KSS-19	Should offer the possibility to extract data specific to a training program	C
FR-KSS-20	The system will include convincing non-financial indicators of return, that are relevant for Governments, to move up in the priority list of investments with positive environmental impact	S

Table 41: *KSS Functional requirements*

Functional requirements specific to DSS Infrastructure

The functional requirements presented here are specific to the DSS infrastructure

Code	Description	MoSCoW
FR-DSS-1	The system should offer a repository of rules and policies. Rules and policies have logical expressions, periods of variability, applicability	M
FR-DSS-2	The system should offer a repository of processing workflows. Workflows should describe the sequence of the application of rules and the time intervals between rule applications.	M
FR-DSS-3	The system should offer the possibility to edit rules and policies	M
FR-DSS-4	The system should offer the possibility to edit processing workflows	M
FR-DSS-5	The system should be capable of gathering data from various sources and KSS	M
FR-DSS-6	The system will deploy an Inference Engine: Mechanism to apply rules and workflows to data to derive conclusions and recommendations.	M
FR-DSS-7	The system will offer features to generate and evaluate different decision alternatives.	C
FR-DSS-8	The system will offer tools to determine how sensitive outcomes are to changes in input variables.	C
FR-DSS-9	The system will offer functionality to help identify and understand problems.	C
FR-DSS-10	The system will have functionalities for conducting what-if analysis and scenario planning.	S
FR-DSS-11	The system will offer features to identify the best possible solutions given constraints and objectives	S
FR-DSS-12	The system should offer the ability of the system to learn from past decisions and improve over time.	S
FR-DSS-13	The system should offer the ability to document decisions, assumptions, and processes for future reference.	C

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FR-DSS-14	The system should listen to the events registered in the application and apply the inference rules	C

Table 42: *DSS Functional requirements*

Technical requirements for KSS-DSS infrastructure

Code	MoSCoW	MoSCoW
TR-KD-1	**Availability**: Support high-availability requirements, operating without outages within certain periods, but still allowing for scheduled maintenance downtimes outside of committed hours.	M
TR-KD-2	**Scalability**: Support both horizontal and vertical scalability for capacity expansion scenarios.	M
TR-KD-3	**Workload**: Must support agreed workload and response time performance requirements guaranteeing operation within considered time limits.	M
TR-KD-4	**Performance**: Must support agreed performance requirements guaranteeing operation at considered peak workload with minimal hardware configuration.	M
TR-KD-5	**Platform independence**: Must be designed to allow running server-side services on different hardware platforms (x64 compatible).	M
TR-KD-6	**Virtualization:** Support virtualization options for hardware resources	M
TR-KD-7	**Loosely coupled**: Must integrate internal components and external systems in a loosely coupled way; as such each of its components has, or makes use of, little or no knowledge of the definitions of other separate components.	M
TR-KD-8	**REST API:** Must expose and consume data in a standardized way, by using REST services.	S
TR-KD-9	**Asynchronous communication:** Must publish and describe exposed interfaces towards other systems by managing a set of message brokers (Kafka, RabitMQ) towards other systems.	S
TR-KD-10	**Data format:** Must describe the syntax and format used for data exchange messages, while also specifying the semantics of data fields. Standardization of messages ensures that messages are robust, interoperable and reusable. The proposed syntactic format is JSON.	S
TR-KD-11	**Open standards**: Must leverage open standards, where available, to communicate with external systems, as opposed to implementing custom means of data exchange.	S
TR-KD-12	**Common look and feel:** Must provide a common look-and-feel through a portal-like user interface to guide the user to the underlying functionality of the internal components such as a portal-like approach, which is common practice for integrating	M

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	distinct functional components and providing an integrated presentation layer.	
TR-KD-13	**Intuitive:** Must provide intuitive general navigation methods. At least two of the following navigation methods should be provided: main menu, site map, and search engine. Breadcrumbs must be used to indicate the current feature and to provide easy hierarchical navigation	S
TR-KD-14	**Unambiguous.** The text used for the user interface should be unambiguous. Typefaces and fonts used should be easily readable and should support international accents. Where symbols are used consider associating descriptive text as well. Beware of cultural differences related to naming and symbols	S
TR-KD-15	**Localization:** Must support localized texts for international end-users, by using Unicode compliance for global text display, independent from a specific language/character set encoding, while also supporting right-to-left languages.	M
TR-KD-16	**Consistency:** Must provide consistent labels for buttons and fields. An explicit label must be provided for each form field. Each label must be placed close to the field to which it is attached. Group together related fields. Indicate mandatory fields and provide help for entering data.	M
TR-KD-17	**Size of downloads and uploads:** Must indicate the size and format of each document that can be downloaded or uploaded. For each link that points to a document that can be downloaded, link text should include the document name, file format and size	S
TR-KD-18	**Visualization Tools**: Capabilities for data visualization (charts, graphs, dashboards) to help users understand complex data.	C
TR-KD-19	**Interactive Capabilities:** Features that enable users to manipulate data and models dynamically and receive immediate feedback.	S
TR-KD-20	**Customization**: Options to customize the interface and reports according to user preferences and requirements	C
TR-KD-21	**Accesibility** : Follow WCAG 2.2 gudelines for accesibility[40]	S
TR-KD-22	**Flexibility:** Adaptability to changing business needs and the incorporation of new technologies	C
TR-KD-23	**Communication Tools**: Support for communication among users (e.g., messaging, conferencing).	C
TR-KD-24	**Shared Workspaces**: Collaborative platforms where users can work together on decision-making tasks.	S
TR-KD-25	**Technical Support:** Availability of technical support for users.	C

[40] https://www.w3.org/TR/WCAG22/

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TR-KD-26	**Maintenance:** Regular updates and maintenance to keep the system functional and up-to-date	C

Table 43: KSS-*DSS Technical requirements*

Security Requirements for KSS-DSS Infrastructure

Code	Description	MoSCoW
TR-SEC-1	**Authentication:** The system must provide an interface to authenticate itself with the system. When users are authenticated with this interface, they should have restricted access to functionality and data. These restrictions should be configurable by access controls defined for user profiles.	M
TR-SEC-2	**Roles**: Users of the system must be restricted to what data they can access based on role. Users should be restricted on a case level as well as by specific types of data. These access controls should be configurable based on the hierarchical role system.	M
TR-SEC-3	**System-to-System authentication:** All devices must authenticate with the KSS-DSS system and modules using JWT tokens where possible.	M
TR-SEC-4	**Second-factor authentication:** For users to authenticate with the KSS-DSS system, a Two-Factor (TFA) method should be used, for example, One-Time use of Passwords.	S
TR-SEC-5	**Token expiration:** All authentication tokens must have a finite lifespan. A recommended expiration period is 90 days.	S
TR-SEC-6	**Revocation:** The KSS-DSS system must have a centralized system to create, revoke and invalidate any tokens.	M
TR-SEC-7	**Finite lifetime:** All data stored must be kept for a finite lifetime. When stored/cached data is no longer needed it must be securely deleted from data stores/caches.	S
TR-SEC-8	**Rate limit:** Modules with exposed endpoints must implement rate limiting as protection against Denial of Service (DoS) caused by external attackers or malfunctioning modules.	M
TR-SEC-9	**Clear functionality**: All entry points to the KSS-DSS system must be restricted in what functionality they expose. An endpoint should only expose the data that is needed.	S
TR-SEC-10	**HTTPS: The** KSS-DSS system must encrypt all communications between a user of the system. All web pages must be served over HTTPS.	M
TR-SEC-11	**Log:** Must provide a secure centralized location for the storage of logs from the system and individual modules Log contents must be concise and only expose what is needed for debugging purposes.	S
TR-SEC-12	**User events: The** KSS-DSS system must record any user events, such as user creation, password changes, new logins and failed logins.	S

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TR-SEC-13	**Messages**: The KSS-DSS system must keep logs of received events from the message hub. Including the topic and the originating module.	S
TR-SEC-14	**GDPR:** The system should follow GDPR**.**	

Table 44: KSS-*DSS Security requirements*

Hardware requirements for the KSS-DSS infrastructure

We are presenting below the recommended hardware infrastructure for the development of the KSS-DSS system, necessary for the duration of the project.

The deployment of the system after the project finishes will depend on the business requirements defined at the time of implementation.

The requirements are valid for bare metal configurations, virtual machines or cloud.

Code	Description	MoSCoW
HW-M1-1	**Reverse proxy: 1 server with** **4 CPU** **8 GB RAM** 100 GB storage (SSD) 1 Gb network	M
HW-M1-2	**Master node: 1 server with** **8 CPU** **16 GB RAM** **260 GB storage (SSD)** **1 Gb network**	M
HW-M1-3	**Worker nodes: at least 3 servers** 16 CPU 64 GB RAM 1 TB storage (SSD)	M
HW-M1-4	**Shared storage** 10 TB	C
HW-M1-5	**Clients: Laptops with:** **8 CPU** **16 GB RAM** **500 GB storage (SSD)**	S

Table 45: KSS-*DSS hardware requirements*

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Annex C-Data for the CSRD/WPH Use Case

Here below, a more detailed description of the data which will be collected in the CSRD/WPH Use Case is provided.

Environmental data	• Waste management: - Reporting of waste types and quantities are available in most premises based on separate requests from service providers - Due to the change in sorting methods, the amount of mixed waste has slightly increased, while the amount of energy waste has decreased. Energy waste is sent to an incineration plant. - The changes in sorting requirements and responsibilities in legislation foreseen. • Water consumption: - Total amount of litres consumed and the overall cost known in the hospital and rescue stations, but not for the rental properties. • Carbon footprint: - Carbon footprint from construction, energy consumption and digital services can be calculated to some extent. - In rental properties, use of energy and monitoring are the responsibility of the property owner and costs are included into the rent. • Noise: - Data not collected as not an issue. Labour protection equipment for noise are freely available for employees and consequences of noise are monitored by the occupational health services. • Use of vehicles: - Over all 250 vehicles in use in which 1/3 are hybrid vehicles and changes are made based on mandating legislation and changes of leasing contracts - For employees occupational benefit package in relation to bicycles and use of city bikes. - Logistics of goods, equipment and products to various service points are outsourced • Additional data for recycling: - Everything which is recyclable should be recycled except hazardous waste to support circular economy • Green building and sustainable data: - There is a new construction law, which requires construction field to monitor their carbon footprint. - Circular economy in construction is supported - COMPASS will provide added value to build green premises.
Social data	• **Patient safety and quality of care:** - The personnel submits incident reports related to customer/patient safety concerns in social and health services, occupational safety, information security and the safety of the working environment through the online system. The supervisor processes occupational incident reports within 10 working days of receiving the report, and near incidents and safety observations within 30 days. - Quality of care: In-house control system plan and system in place • **Health equity and access to care:** - Respecting human rights is a strong principle guiding the operations and legislation of social and healthcare. - Access to care followed on the monthly basis - Data available on national level and local level • **Diversity, Equity and Inclusion:** - Diversity, equity and inclusion are guided by the equality and non-discrimination plan. - The plan includes objectives, indicators and measures for monitoring the realisation of equality.

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- Equality refers to equal treatment of genders, people of different ages, different cultural backgrounds, different occupational groups, different work communities, etc.
- Equal pay is a prerequisite for fair and productive work.
- According to the Equality Act, equal pay must be paid for equal work of equal value regardless of gender. Equal pay has been promoted and pay differentials have been systematically reduced in connection with the development of pay systems and wage harmonisation.

- **Employee health and Well-being:**
  - Comprehensive occupational health services for all employees
  - Large occupation benefit schemes, promotion of well-being and health, including opportunities for relaxation, ergonomics and physical activity.
- **Community engagement and Philantropy:**
  - A plan for the community engagement and particiaption of inhabitants for the development of services in implementation
- **Ethical marketing and patient care:**
  - Data not available
- **Supply chain risks:**
  - The most significant sustainability risks related to the supply chain (such as human rights and occupational safety risks) have been identified and efforts are being made to prevent them: The Multi-Sourcing Program renewed procurement and emphasized economically, socially, and environmentally sustainable acquisitions. The Wellbeing services county of Päijät-Häme requires systematic responsibility from service providers.
  - Risks of child labour have also been identified in terms of supply chains: Yes in cooperation with national and other institutes and wellbeing services count ies
  - Risks of forced labour have also been identified in supply chains: Yes in cooperation with national and other institutes and wellbeing services counties
  - The human rights assessment has been carried out as needed (e.g. if production takes place in so-called high-risk countries):
    Yes in cooperation with national and other institutes and wellbeing services count ies
  - Human rights training for staff:
    Done for the procurement personnel and personnel in different departments res ponsible for procurement
  - Demanding responsible operations also from partners:
    Yes with annexes in procurement processes
  - Partners are required to act in a socially responsible manner: Yes and monitored during the contract time
- **Procurements:**
  - Suppliers have been evaluated according to social responsibility criteria: In different procurement phases the social responsibility criteria is used as one of the evaluation criteria
  - The organization does not use direct or indirect child labor: Requested in the procurement process from the service providers
  - The organization does not use direct or indirect forced labor: Requested in the procurement process from the service providers
- **Health and safety at work**
  - Extensive occupational health services and occupational safety measures for personnel as required by law
  - Employees have the opportunity to be on sick leave on their own notice for some days: Data available
  - The well-being of personnel is monitored, for example, through surveys, the number of sick leaves with a decrease: Job satisfaction is monitored regularly
  - Work ergonomics discussed during orientation of the new employee and followed by occupational health services in case of challenges
  - Occupational protection equipment is available for employees based on the needs
  - The personnel have received the necessary training to work safely:

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        - Through Work Well Card training sessions, practical tools are provided for individual employees and workplace communities to enhance well-being and occupational safety.
        - The training package, designed by the Occupational Safety and Health Center, consists of two half-day sessions or one full-day session tailored to the preferences of the workplace. The training sessions were conducted on-site in familiar locations for the employees. Occupational safety promotes well-being, supports operations, and enhances capability to work.
        - The phone application for reporting occupational safety incidents was introduced. The number of positive reports increased, and as a new feature in the system, reports of inappropriate behavior (EKIt) were initiated.
    - The workplace and tools enable safe working:
        - Occupational protection equipment is available for employees based on the needs
    - The personnel have been provided with a means of reporting potential occupational safety risks and encouraged to report:
        - In cooperation with occupational health care and employer representatives the workplace surveys and assessments of occupational safety risks are conducted. They guide employees to report incidents of workplace violence, and during workplace visits, they instruct employees on how to identify and anticipate the risks and threats of workplace violence. Together with work units, they update various safety guidelines. Acting within our respective areas, they aim to prevent occupational accidents.
    - There is zero tolerance for harassment and bullying:
        - Occupational safety and health professionals help in resolving conflicts and inappropriate treatment. There are guidelines for the processes, the practical application of which often requires joint consideration.
        - It is important to strengthen the interaction skills of work communities. Occupational safety representatives have developed workshop activities, one of which emphasises good work camaraderie and the other a well-functioning work community.
        - In cooperation, occupational safety and health is included in working groups, the most important of which are the occupational safety committee, the well-being at work group, the indoor air working group and the cooperation committee
    - Employees have the opportunity to report unequal treatment, workplace bullying or other problems confidentially and, if necessary, anonymously: Occupational safety and health helps in resolving conflicts and inappropriate treatment.
    - The means to intervene in possible harassment and bullying have been considered in advance, and a way has been created for the personnel to report these.
- **Freedom of association and collective agreements**
    - The organization provides employee representatives with the necessary workspaces, working hours and tools employee representation: Yes; The wellbeing services county has six full-time occupational safety representatives and two part-time delegates.
    - The employer does not interfere in the representation work of workers' representatives (trade union matters can be obtained as needed to be done at the workplace and during working hour): Trade unions have their own workspaces, working hours and tools; they are represented in various management groups and others

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Economic data

- **Financial balance sheet from at least 3 years ago:**
  - Available for the year 2023 since the Wellbeing services counties started 1.1.2023
- **Revenue (Total Revenue & Revenue Growth) :**
  - Data is available
- **Operating Expenses (costs associated with staffing, facilities, medical supplies, and administrative overhead, identification and analysis of cost reduction initiatives, including efficiency improvements, waste reduction programs, etc.):**
  - Operating expenses available
  - Operating profit available
  - Financial income available
- **Capital Expenditures (capital investments made by the organization, such as the purchase of medical equipment, facility upgrades, or investments in sustainability projects, etc.):**
  - Capital expenditures available
  - Financial contributions to investment expenditures available
  - Disposal proceeds of non-current assets available
- **Sustainability Investments (investments specifically allocated to sustainability initiatives, such as energy-efficient upgrades, waste reduction programs, or community health initiatives, etc.):**
  - Available, but need further study
- **Cost Savings from Sustainability Initiatives:**
  - Not available
- **Return on Investment (ROI) for sustainability investments (ROI Analysis & Payback Period, etc.):**
  - Not available
- **Financial Performance Metrics relevant to sustainability (profitability, liquidity, debt levels, and cash flow, etc.):**
  - Not available
- **Sustainability-related Revenue Streams from sustainability-related activities (green product sales, carbon offset programs, reimbursement for environmental services, etc.):**
  - Not available
- **Costs of Non-Compliance or Environmental Liabilities (Legal Costs, Environmental Remediation Costs, etc.):**
  - Not available
- **Total Cost of Ownership (TCO) (medical equipment, facilities, or other assets):**
  - Not available

Governance data

- **Board Diversity and Composition:**
  - The highest decision making body is county council of WPH
  - The CEO and leads of five main entities, Directors of Communication, Finance and Legal Affairs form the Board of WPH
  - Trustee committees includes Wellbeing and Health Promotion Committee, Client and Participation Committee, Safety and Preparedness Council, Audit Council and Regional Election Council.
- **Executive Compensation and Incentives:**
  - The purpose of rewards is to encourage productive, productive and high-quality work and to take success in work into account.
  - Remuneration is fair, clear and understandable, and it is communicated openly and comprehensively. The purpose of the awards is to promote a positive employee experience and support the goal of being the best public workplace in the industry.
- **Ethical Conduct and Compliance:**
  - To combat corruption and bribery and to prevent conflicts of interest, guidelines on disqualification available
- **Risk Management and Oversight:**
  - Effective risk management is an integral part of the governance and management system of WPH

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- Risk management involves identifying, analysing, assessing, managing, and addressing threats and opportunities related to operations and the operating environment.

- **Transparency and Disclosure:**
  - The document of council, board and councils are available online and actively communicated to the inhabitants
  - Annual report and financial statement are available online
  - Audit council follows the financial issues
- **Board Effectiveness and Independence:**
  - Board of the WPH is responsible for decision taken to the elected county council and the Ministry of Finance and Ministry of Social Affairs and Health
- **Whistle-blower Protection:**
  - Internal Whistle-blower reporting channel was introduced in April 2023 in WPH.
  - Through this channel, staff can confidentially report serious misconduct or suspicions thereof, such as in public procurement, financial services, food safety, or consumer protection.
  - It is based on the EU's whistle-blower directive and the national whistle-blower protection law that came into force at the beginning of the year.
- **Data Privacy and Cybersecurity:**
  - The protection of critical infrastructure both physically and in information networks is based on the risk analysis; personnel is trained in concerns of data privacy and cybersecurity

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Annex D-Testing, verification and validation methodology for the KSS-DSS IT infrastructure

The testing methodology used is based on ISO/IEC/IEEE 2911941 and is described in the next subchapters.

The validation of the system, referred also as acceptance tests follows the same methodological principles.

Methodological approach

Testing is conducted to assess the quality of software products, ensuring they meet specified requirements and are fit for purpose. Validation involves verifying that the test results and system outcomes meet the necessary conditions.

The testing approach is influenced by the adopted software development methodology and the acceptance and conformance procedures. Generally, the majority of testing efforts take place after requirements have been defined and coding is complete.

For the KSS-DSS infrastructure, the following types of testing will be performed:

- **Unit Testing**: Outside the scope of the current deliverable.
- **Functional Testing**: Evaluates individual component functionalities based on test cases.
- **Business Protocol Testing**: Assesses the business value of the system using scenarios and Use Cases, including integration tests.
- **Nonfunctional Testing**: Covers security and performance tests, with initial tests planned in this project phase.

The primary activities during the testing period include:

- Preparing a Test Plan with test scenarios, preconditions, and expected results.
- Organising the necessary organisational structures for testing.
- Setting up the testing environment.
- Training participants.
- Executing the tests.
- Resolving defects.
- Reporting test results, with recommendations regarding acceptance.

The testing procedure outlines the acceptance conditions for each KSS-DSS module. The final acceptance decision will be based on the user acceptance testing report, with predefined software acceptance criteria.

The main goal of **verification** and **validation** is to ensure that the KSS-DSS systems align with the requirements and expected results. The methodology for the KSS-DSS Infrastructure is based on feature-driven testing, a pragmatic, feature-focused approach for front-end testing that aligns with the overall Solution Integration method. This approach allows partners to test integrated software and provide feedback at both the component and feature levels.

Test design specifications address the features to be tested. A standardized form for designing test specifications involves defining high-level test cases that fulfil business requirements and ensure traceability.

A Test Case (TC) comprises conditions and detailed instructions to determine whether the system under test satisfies requirements or functions correctly. Test cases provide comprehensive information, including preconditions, input data, output data, and postconditions, with defined inputs to yield expected outputs.

[41] https://www.iso.org/standard/81291.html

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Test Case Specification involves defining features tested within a testing scenario and requires test scripts or procedures. Following the guidelines of ISO/IEC/IEEE 29119 (Software Testing), a test case includes:

- Description of the test case objective.
- Test actions.
- Expected results.
- Preconditions for execution.

The proposed test case template is as follows:

Table 46: Test scenario template of the KSS-DSS

Test scenario				
Code: TS MPC-01				
Description	Description of the objective of the test case including the system function that is part of the test			
Initial operations:	Conditions that must be met by the user before performing the influx actions			
Initial conditions:	Conditions must be fulfilled by the system, data, user or configuration before performing the actions in the flow. This might be also a reference to another test case There are configurations made for the application components			
Backup:	It is specified if, before the testing, it is necessary to make copies of the situation at that time.			
Files:	Specify whether certain files are required for testing			
Notes:	Specify whether certain additional notes are required for testing			
Case No.	**Name**	**Description**	**Main Flow**	**Result**
	Brief name of the test case	Description of the objective of the test case including the system function that is part of the test	Action 1	Result after action 1

A schematic representation of the described overall approach for the testing activities is presented Fig. 21 below.

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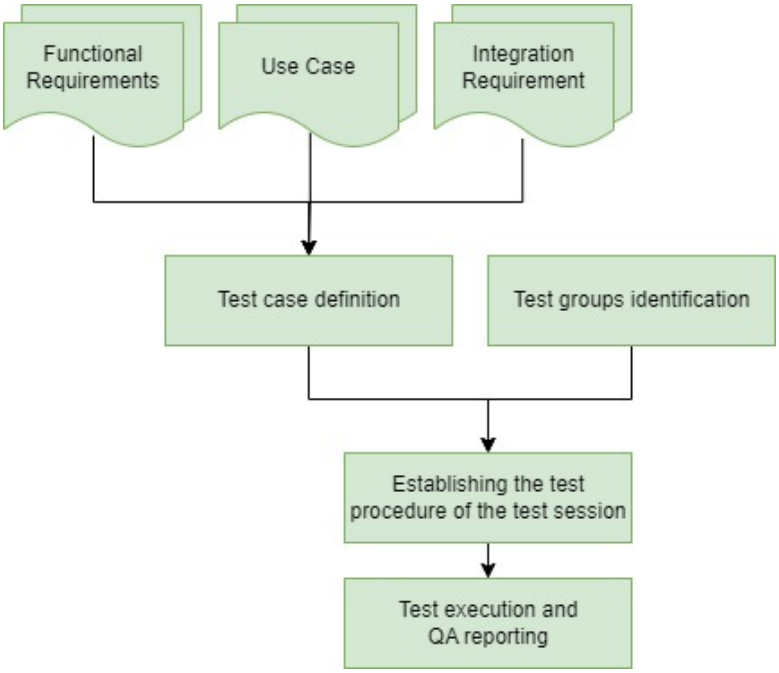

Figure 26: Test case definition and execution

The integration testing is considered the testing of the system as a whole; it gets all the integrated modules of the various components from the integration testing phase and combines all the different parts into the system which is then tested.

In the system testing process the system will be checked not only for errors but also to see if the system does what was intended, the system functionality and if it is what the end user expected.

The main components of the test definition include:

- Test Case (TC)
- Test Data (TD)

Most of the test cases have been done and also simple testing has been done to ensure there are no bugs at the first demonstration to the users.

The main application components have been defined during the architecture design and described in the logical architecture as modules that support the functional architecture and make up the proposed solution for building the KSS-DSS system.

Each component testing has been realized by each partner on their system during the design and development of the components.

Responsibilities

Tests should be performed by teams, with one team leader and at least one tester.

Testing team:

1. Test leader is responsible for coordinating, planning, and verifying the results of testing activities;
2. One or more testers (reviewers) is/are responsible for testing execution (ex: running test cases, logging the results of each action, and logging defects)
3. The test environment will be set up before starting the tests by a System engineer, who also will maintain the environment.

Collection of results

The results of each test, based on the test case, will be placed in the summary table.

The testing report will contain all the tables with test cases, with the column's remarks and test results filled in. A summary of the results (passed/not passed/passed with remarks) will be added at the end of the report.

Finally, the proposed questionnaire will be filled in the summary of the results be placed in the report.

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Annex E-Forms used to collect input from lead developers, co-developers and end-users

Lead developer (FORM 1), co-developer (FORM 2) and end user (FORM 3) forms are provided in the following pages.

FORM 1
Preliminary form for results' lead developer

Please fill in as many sections of the form as possible, if a section cannot be filled, please specify the reason.

Result	
Insert the short name (es: COMPASS, ENER…)	*Insert the complete name of your result.*

Description
Insert a complete description of the result you are developing.

Innovative aspects
Insert a list of reasons why your result is innovative, especially about the HC sector.

Data for result development	
What are the input data/information from the co-developer that are needed to develop the result?	
Variable (to be filled by Lead-developer)	***Value information (to be filled by the co-developer)***
Es: Amount of waste produced	

Applicable standards
Please list all the international standards that can be relatable with the result you are developing. • *Standard #1* • *Standard #2* • *….* • *…*

Possible KPIs	
KPI from proposal	• KPI #1 • KPI #2 • …

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KPIs to demonstrate innovation	• KPI #1 • KPI #2 • …
Testing Methodology	
Please describe which are the forecasted steps for the testing of the technology, based on your experience.	
Validation Methodology	
Please describe which are the forecasted steps for the validation of the technology, based on your experience.	
Other requirements	
Based on your experience, is there any other requirement needed to develop the innovative part of your result (the one related to the CN project)?	

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FORM 2
Preliminary form for co-developer to provide context.

Please fill in as many sections of the form as possible, if a section cannot be filled, please specify the reason.

Result	
Insert the short name (es: COMPASS, ENER…)	*Insert the complete name of your result*
Co-developer	
Insert the short name (es: FPG)	*Insert the complete name of your organization*
Reference person/people	
Insert the name of the reference person	*e-mail*
Needs identification	
Problem description	
How do you describe the problem referring to your organization?	
Are you trying to solve this problem? If yes, how? And what are the limits?	
Did you hear about any solutions to solve the problem? In your opinion, what are the limits/shortcomings?	
What are the constraints to solve this problem? (e.g. social, managerial, budget…)	
Which criteria do you use to select the solution for the problem?	
Peculiarities of your facilities	
Please fill this section with the specific features of your HC facility that can impact the resulting development.	
Barriers	
Please fill this section with a list of possible barriers (physical, social, managerial…) that can affect the development of the result.	
Opportunities	
Please fill this section with a list of possible opportunities that can be sorted out during the development of the result.	
Risks	

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Please fill this section with a list of possible risks that may occur during the development of the result (Please refer to the Critical Risks & Risk Management Strategy table contained in Annex 1 (part A) of the GA as a starting point to specialize risks in our context for the result).
Applicable regulatory (to be filled by the co-developer)
Insert any specific regulatory that can be applied to the result (national prescription, peculiarities that can be applied in the HC sector).
Possible KPIs
KPIs to convince the potential adopter. *KPI description and target value* • *KPI #1* • *KPI #2* • *…*
Other information
Based on your experience, is there any other information about the context of your facility that is needed to develop the innovative part of your result (the one related to the CN project)?

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FORM 3
Preliminary form for end user to provide context.

Please fill in as many sections of the form as possible, if a section cannot be filled, please specify the reason.

End User	
Insert short name (es: FPG)	*Insert the complete name of your organization*
Key facts	
e.g. (number of Hospitals, number of territorial primary care units, number of total numbers of beds… … for 7HRC and WPH) *e.g. (Total beds, Operating rooms… for Hospitals)*	
e.g. Total beds	*e.g. 2000*
…	
…	
Current approach and experiences regarding the green transition	
Describe the current approach and experiences of your organization regarding the green transition.	
Other information	
Based on your experience, is there any other information about the context of your facility that is needed to develop the innovative part of your result (the one related to the CN project)?	

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ANNEX E-Members of the Reference Stakeholder Group that provided input

All the members of the Reference Stakeholder Group were invited to attend the five Workshops of the Phase 3 and to select the ones that best fitted with their interests.

Due to agenda conflicts, some of them could not attend. Here is the list of those that had the opportunity to attend the Workshops (or to provide input in a one-to-one interview).

Organization	EU/Country
1. **ECHAlliance - The Global Health Connector**	EU/Global
2. **EHMA-European Health Management Association**	EU
3. **ESTES-Nursing Committee**	EU
4. **HOPE-European Hospital and Healthcare Federation**	EU
5. **KitNewCare Project**	EU
6. **BeWell Project**	EU
7. **PVCMed Alliance**	EU
8. **Azienda Sanitaria Locale del Verbano-Cusio-Ossola**	Italy
9. **Azienda Ospedaliero Universitaria di Sassari**	Italy
10. **Azienda Sociosanitaria Ligure n. 4 (Als4)***	Italy
11. **Community of Practice: "Green Prescription in perspective One Health /Planetary Health"**	Italy
12. **ENEA (Italian Agency for the New Technologies, Energy and Sustainable Economic Development)**	Italy
13. **Osservatorio ESG/Associazione Dottori Commercialisti Nazionale (ADN)***	Italy
14. **PVC Forum (Italian Association of the PVC industry)**	Italy
15. **SIAIS (Italian Society for Healthcare Engineering and Architecture)**	Italy
16. **Groene Zorg Alliantie (Dutch Green Health Alliance)**	Netherlands
17. **Acció Climàtica, Generalitat de Catalunya**	Spain
18. **Consorci de Salut i Social de Catalunya**	Spain
19. **Sistema comunitario de gestión y auditoría medioambiental (EMAS)**	Spain
20. **Nordic Welfare Centre**	Sweden
21. **Jansen AG**	Switzerland
22. **RINICOM Ltd***	UK

* input collected in a one-to-one interview

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