BUILDSPACE

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Enabling Innovative Space-driven Services for Energy Efficient Buildings and Climate Resilient Cities

D2.3 BUILDSPACE Specifications and Architecture

May 2024

Document history

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List of acronyms

Acronym	Description

AI	Artificial Intelligence
AQI	Air Quality Index
API	Application Programming Interface
AR	Augmented Reality
BGI	Blue-Green Infrastructure
BIM	Building Information Modelling
CLMS	Copernicus Land Monitoring Service
CLL	Communication Logic Layer
CMIP	Coupled Model Intercomparison Projects
DACM	Data Acquisition and Control Manager
DBT	Digital Building Twin
DC	Domain Controller
DEM	Digital Elevation Model
DH	District Heating
DHW	Domestic Hot Water
DWH	Data Warehouse
EGNSS	European Global Navigation Satellite System
EPC	Energy Performance Certificate
ETL	Extract Transform Load
EU	European Union
FDAM	Flood Damage Assessment Methodology
GDPR	General Data Protection Regulation
GE	General Enabler

GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
ICT	Information and Communication Technology
IDSA	International Data Spaces Association
IFC	Industry Foundation Classes
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
JWT	JSON Web Token
KPI	Key Performance Indicator
LIDAR	Light Detection and Ranging
MFH	Multi-Family Home
NDVI	Normalized Difference Vegetation Index
OIDC	OpenID Connect
POI	Points of Interest (Data)
PST	Project Status Model
PV	Photovoltaic
RCP	Representative Concentration Pathway
RQ	Requirement
SE	Service
SSP	Shared Socioeconomic Pathway
UAV	Unmanned Aerial Vehicle
UC	Use Case

UH	Urban Heat
UI	User Interface
VR	Virtual Reality

Executive summary

This document marks the final release of the BUILDSPACE Conceptual Architecture, serving as a reference point for the development of the BUILDSPACE Core Platform. The current deliverable provides an outline of the activities undertaken in Task 2.5 – "BUILDSPACE Conceptual Architecture built on existing resources of Copernicus and EGNSS." This task aims to establish and deliver a conceptual architecture to enhance sustainability and efficiency in the construction, renovation, monitoring, and resilience of urban building stock. Specifically, the activities within this task will focus on ensuring compatibility with existing dataset formats across Europe, enabling integration with established building data platforms (such as MATRYCS, BIMSPEED, BD4NRG, etc.), and adhering to EU standards. The resultant open architecture will capitalise on existing frameworks and architectures, utilising satellite services (Copernicus and EGNSS), and providing a cohesive framework conducive to the development of location-based and remote sensing applications. Inputs for this task have been derived from the outcomes of Tasks 2.1-2.4, which identify technical constraints, specifications, desired functionalities, and platform usage. On that reflection, beyond the detailed description of the Conceptual Architecture, dedicated sections to present the updates on the activities prescribed in T2.1-2.4 are also incorporated in this deliverable, namely progress made on the 2nd co-creation session, the user requirements, the use cases, and the wireframes and mock-ups.

1 Introduction

Main goal of this deliverable is to showcase the final version of the BUILDSPACE Conceptual Architecture, following the first draft that was presented in D3.1, in order to be utilised as a reference point for the development of the BUILDSPACE Core Platform. To do so, existing architecture standards and models relevant to the BUILDSPACE project are examined, along with the reference architecture of current EU data platforms. The alignment of the Conceptual Architecture with existing EU standards and initiatives (such as IDSA, GAIA-X, and FIWARE) as well as other European projects (e.g., MATRYCS, BD4NRG, DigiBUILD, BIMSPEED, etc.) is explored to uphold data sovereignty and ensure secure data flow. Subsequently, the BUILDSPACE Conceptual Architecture undergoes a comprehensive analysis, characterised by its modular design wherein each layer seamlessly interacts with the preceding and succeeding layers. Each layer pursues specific outcomes achieved through the provision of distinct high-quality data-driven services. The architecture is depicted alongside descriptions of its different layers and components. A holistic view of these layers and components is presented, elucidating their functionalities. Emphasis is placed on interconnecting the various layers, specifying their interactions and how data traverses from one component to another.

Deliverable D2.3, being the direct outcome of task T2.5, and considering that accommodates also the progress of T2.1-2.4, it is extended beyond just presenting a detailed description of the Conceptual Architecture to highlighting the updates on the activities prescribed in T2.1-2.4 namely the 2nd co-creation session, the user requirements, the use cases, and the wireframes and mock-ups.

Taking into consideration the above, the deliverable is structured as follows:

- **Section 2:** Provides an overview of the insights drawn from the second co-creation session and their impact on the other activities included in WP2 (e.g., user requirements, use cases, etc.). An in-depth presentation of the administrative part of the session is laid out (e.g., material, agenda, etc.) as well as the outcomes categorised per service.
- **Section 3:** Focuses on the presentation of the updates on user requirements. These updates are broken down into two separate parts: the first part seeks to compare the version of the user requirements as elicited following the second co-creation session and the version drafted after the first co-creation session; the second part presents comparative results on the user requirements based on the outcomes of the second co-creation session and another feedback round from the service providers after the pre-pilot phase. The latter essentially marks the final set of fine-tuned user requirements.
- **Section 4:** Presents the updated version of the use cases, incorporating the feedback gathered during the second co-creation session along with the insights of the first technology release (D3.1), in which the service developers faced the development of initial features.
- **Section 5:** Builds upon the progress outlined in deliverable D2.2, focusing on the use cases and design of applications' dashboards, and culminates in the completion of task T2.4, which involves

co-designing innovative user-friendly environments. The objective is to present all designs and mock-ups created following the wireframe guide.

- **Section 6:** Presents the BUILDSPACE Conceptual Architecture. It provides details on the different architecture layers, the associated modules and components, together with their functional description. A brief description of relevant EU standards and initiatives (such as IDSA, GAIA-X, and FIWARE) as well as other European projects (e.g., MATRYCS, BD4NRG, DigiBUILD, BIMSPEED, etc.) is also included.
- **Section 7:** Focuses on the alignment of the BUILDSPACE Conceptual Architecture to the relevant well-established European Architectural Standards (i.e., IDSA, GAIA-X, FIWARE).
- **Section 8:** Main conclusions are outlined.

2 Social engagement for co-creating BUILDSPACE solutions: the second co-creation session

The definition of the solutions in the BUILDSPACE project has been co-created with both internal and external stakeholders engaging during two co-creation sessions (as part of T2.3 “Social engagement for co-creating the BUILDSPACE use-cases and applications”). Stakeholder engagement is a process that takes time and resources, allowing individuals to build strong connections and is mainly based on various existing and established trust relations. It follows an inclusive communication approach, in order to ensure that stakeholders are effectively included and can enjoy a positive, fair and equal experience for more effective interaction.

The co-creation sessions consisted of several steps focusing on for planning and managing the engagement process. The planning of the co-creation sessions follows the principles and procedure steps defined in Deliverable 2.1, in which project partners -mainly service developers- are requested to identify the feedback they might need on their project tasks.

The co-creation sessions were decided to be condensed in the minimum possible number (being finally two sessions), so that stakeholders do not feel overwhelmed, and be provided with enough valuable content and insights on the project. The sessions were also developed in a joint way involving all pilots and services, in order to present the wider BUILDSPACE offer to all, creating synergies between the project and the stakeholders and finding possibilities to apply different functionalities. Both sessions were held in English and in an online format.

The first co-creation session took place in M6, on 14th July 2023, and it was reported in D2.2 “Use cases and design of applications’ dashboards”. The second co-creation session took place in M10, on 24th November 2023, and it is reported in the following sub-sections.

Adding together the attendance to both sessions, the total number of participants is 148, with 104 being external stakeholders. This means that the related target to engage at least 100 stakeholders during the co-design phase has been reached. Table 1 and Table 2 include some details (to the extent of possible) of the external participants (not part of the BUILDSPACE project) to each of the sessions. The name of the participants has not been included for privacy reasons, and in some cases the publishable information was not available (external participants that did not register to the event but did join to it), so in these cases asterisks have been put (***) in the corresponding rows. In addition, Figure 1 and Figure 2 include graphical information for analysis about the external participants in the sessions.

Table 1. Details of the external participants in the first co-creation session

Participant	Entity	Type of stakeholder	Country
#1	EREN (Castilla y León Regional Energy Public Entity)	Public Authority	Spain
#2	Kujawsko-Pomorskie Marshal Office (Regional Support offices in Polish Region of Kujawsko-Pomorskie)	Public Authority	Poland
#3	JSC RIGAS SILTUMS (Major supplier of heat in Riga)	ESCO	Latvia
#4	IUU (University Institute of Urban Planning) of Valladolid University	Research Institution	Spain
#5	València Clima i Energia (Municipality of Valencia)	Public Authority	Spain
#6	ASM Terni S.p.A.	Public sector company	Italy
#7	GRADIANT: Galician Research Center in Advanced telecommunications	Research Institution	Spain
#8	Municipality of Budapest	Public Authority	Hungary
#9	Ramon Llull University, Barcelona. Research Group ARC, Engineering and Architecture La Salle Barcelona Campus	Research Institution	Spain
#10	Agricultural University of Athens	Research Institution	Greece
#11	University of Zaragoza	Research Institution	Spain
#12	***	-	-
#13	Union de Peuples pour le Développement Communautaire Intègre/UPDCI asbl	Public Authority	Nyiragongo en République Démocratique du Congo
#14	Buluttan Weather Intelligence (AI based hyper local weather intelligence)	AI weather company	Turkey
#15	Coopérnico: green energy, sustainability, citizenship	Cooperative	Portugal

Participant	Entity	Type of stakeholder	Country
#16	Antalya Metropolitan Municipality	Public Authority	Turkey
#17	***	-	-
#18	Municipality of Piraeus	Public Authority	Greece
#19	Renesco (Renewable Energy service)	Company (structural waterproofing and injections/ grouting services)	Latvia
#20	SIA Envirotech	GIS/GNSS services provider	Latvia
#21	Birmingham City University	Research Institution	United Kingdom
#22	Geosystems Hellas	Software company	Greece
#23	***	-	-
#24	***	-	Greece
#25	Intermediate Management Authority Integrated Territorial Investments / Sustainable Urban Development of the Municipality of Piraeus	Public Authority	Greece
#26	***	-	Spain
#27	EMSV: Getafe Municipal Land and Housing Company	Public company	Spain
#28	Municipality of Salaspils	Public Authority	Latvia
#29	SIA "Mikrokods" (geospatic information technologies)	Software services company	Latvia
#30	DATI Group	IT infrastructure company	Latvia
#31	CEMOSA	Engineering and quality control services	Spain
#32	Rīgas Namīpašnieku biedrība (Riga Homeowners' Association)	Association	Latvia
#33	VEOLIA	ESCO	Spain
#34	AS "RĪGAS SILTUMS" (Riga Homeowners' Association)	Association	Latvia
#33	Riga City Council Department of City Development	Public Authority	Latvia
#36	Municipality of Bratislava	Public Authority	Slovakia
#37	Ljubljanski urbanistični zavod: LUZ (Ljubljana Urban Planning Institute)	Public Authority	Slovenia
#38	AMS Institute	Research Institution	Netherlands
#39	***	-	-

Participant	Entity	Type of stakeholder	Country
#40	RTU – Riga Technical University	Research Institution	Latvia
#41	METRUM Ltd.	Real Estate company	Latvia
#42	BSEC: Black Sea Energy Cluster	Collaboration Platform	Europe
#43	Ministry of Economics (Ekonomikas ministrija)	Public Authority	Latvia
#44	***	-	Latvia
#45	***	-	-
#46	ITEMA (Leading supplier of quality, high performance weaving machines and support services to the industry)	Support services to industry company	Turkey
#47	NIB (National Institute of Biology)	Research Institution	Slovenia
#48	Antalya Metropolitan Municipality	Public Authority	Turkey
#49	LDA Moldova in Cimislia (ALDA)	Local Demotracy Agency	Moldova
#50	CEMOSA	Engineering and quality control services	Spain
#51	SIA "Mikrokods" (geospatic information technologies)	Software services company	Latvia
#52	Institute for Youth Initiatives and Innovations (IYII)	Social innovation company	Bulgaria
#53	RTU – Riga Technical University	Research Institution	Latvia
#54	***	-	-
#55	State Construction Control Bureau of Latvia	Public Authority	Latvia
#56	BUILDSPACE reviewer	Researcher	Greece
#57	JKP Grosuplje d.o.o. (Public utility company)	Public utility company	Slovenia
#58	Jūrmalas valstspilsētas pašvaldība (Jurmala State City Municipality)	Public Authority	Latvia
#59	***	-	-
#60	RWTH Aachen University	Research Institution	Belgium
#61	TOP DEVELOPMENT	Consulting company	Greece
#62	Municipality of Piraeus	Public Authority	Greece
#63	Fundació València Clima i Energia (Valencia Municipality)	Public Authority	Spain

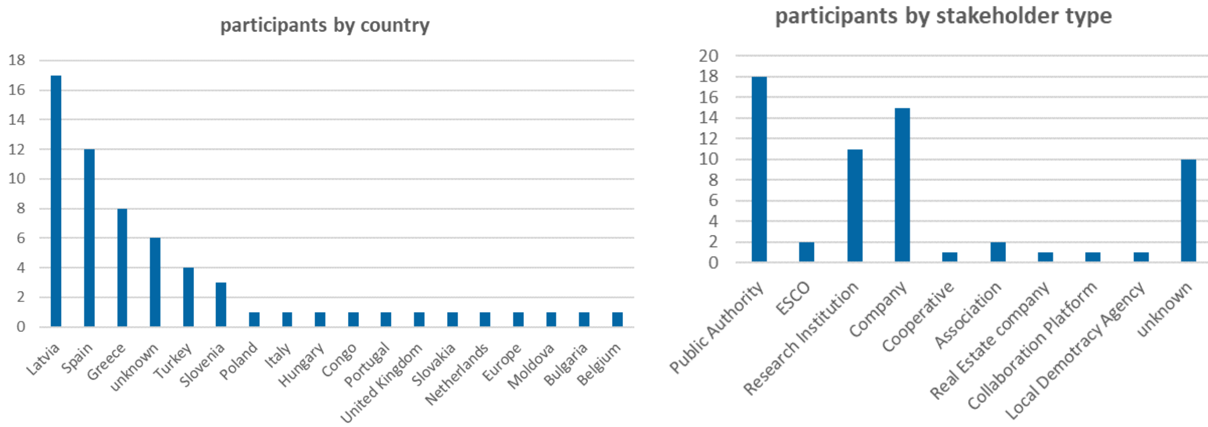


Figure 1. Breakdown of participants by country and by stakeholder type in the first co-creation session

Table 2. Details of the external participants in the second co-creation session

Participant	Entity	Type of stakeholder	Country	Service interest
#1	Būvniecības valsts kontroles bitojs (National construction control)	Public Authority	Latvia	SE1 & SE2
#2	EUSPA	Government – Public Authority	Czech Republic	SE1 & SE2
#3	Union de Peuples pour le Développement Communautaire Intègre/UPDCI asbl	NGO – Public Authority	Democratic Republic of Congo	SE3
#4	ISDR-GI	Educational (Research Institution)	Democratic Republic of Congo	SE3
#5	Coopérnico	Renewable energy Cooperative	Portugal	SE3
#6	EURAC Research	Research Institution	Italy	SE3
#7	Municipality of Piraeus	Public Authority	Greece	SE1 & SE2
#8	***	-	-	-
#9	***	-	-	-
#10	RTU - Riga Technical University	Research Institution	Latvia	SE3
#11	Freelancer	SME	Greece	SE1 & SE2
#12	Salaspils municipality	Public Authority	Latvia	SE3
#13	JRC – Joint Research Centre	Research Institution	Italy	SE3

Participant	Entity	Type of stakeholder	Country	Service interest
#14	***	-	-	-
#15	Mikrokods SIA	Software services company	Latvia	SE1 & SE2
#16	DATI Group	IT infrastructure company	Latvia	SE1 & SE2
#17	AS "RĪGAS SILTUMS" (Riga Homeowners' Association)	District Heating association	Latvia	SE1 & SE2
#18	Latvijas Vides, ģeoloģijas un meteoroloģijas centrs (Latvian Centre for Environment, Geology and Meteorology)	Research Institution	Latvia	SE1 & SE2
#19	Institute for Water of the Republic of Slovenia	Research Institution	Slovenia	SE4
#20	Municipality of Piraeus	Public Authority	Greece	SE1 & SE2
#21	City development department Smart city division	Public Authority	Latvia	SE1 & SE2
#22	Riga City Council City Development Department	Public Authority	Latvia	SE1 & SE2
#23	State Joint Stock Company "State Real Estate"	Real Estate	Latvia	SE1 & SE2
#24	Ministry of Climate and Energy of Latvia	Public Authority	Latvia	SE3
#25	Piraeus Municipality	Public Authority	Greece	SE1 & SE2
#26	BVKB	Public Authority	Latvia	SE1 & SE2
#27	Inštitut za vode RS	Research Institution	Slovenia	SE5
#28	Ministry of Climate and Energy of Latvia	Public Authority	Latvia	SE1 & SE2
#29	***	-	-	-
#30	Slovenian Environment Agency (ARSO)	Government Agency	Slovenia	SE5
#31	JP VOKA SNAGA d.o.o.	Utility Company	Slovenia	SE5
#32	Fuelics	IoT Smart Cities Solutions	Greece	SE1 & SE2
#33	Student	Research	Slovenia	SE5
#34	Ministry of Economics of the Republic of Latvia, Department of Construction Policy	Public Authority	Latvia	SE1 & SE2
#35	Siguldas novada pašvaldība (Sigulda Municipality)	Public Authority	Latvia	SE1 & SE2
#36	***	-	-	-

Participant	Entity	Type of stakeholder	Country	Service interest
#37	Jūrmalas valstspilsētas pašvaldība (Jūrmala State City Municipality)	Public Authority	Latvia	SE1 & SE2
#38	The Slovenian Association for Water Protection (SDZV)	voluntary, independent and non-profit association	Slovenia	SE4
#39	DSS-lab	Research Institution	Greece	SE1 & SE2
#40	Riga Planning Region	Public Authority	Latvia	SE1 & SE2
#41	***	-	-	-

Figure 2. Breakdown of participants by country, by stakeholder type and per service interest in the second co-creation session

2.1 Second co-creation session in a nutshell

The second co-creation session took place in M10, 24th November 2023. It was open to broad audience, as in the first session, with invitation to all stakeholders registered for the first session and with the mobilisation of the pilots' networks of potential interested stakeholders related to the four BUILDSPACE pilots. Key pilot stakeholders were invited as potential end-users of the pilot activities, for an early engagement prior to the full pilot implementation test phase (WP4) and the upcoming stages for the services development (2nd-3rd technology releases).

The level of participation was high, with 63 participants connected to the online session out of which, 42 were externals to the project (what means a 67% of the participants).

The objectives of this second session were: 1) to refresh (or present for the participants that didn't attend the first session) the BUILDSPACE project, its scope and objectives; 2) to present the services through a short description, their functionalities and visualisation, including the feedback received during the first co-creation session; 3) to show the services workflow on a simple diagram and obtain feedback from participants interested in the services, as well as on key aspects of the services (e.g., visualisation aspects, comparable elements, and other key questions around the service potential use that are relevant to each service leader); 4) and to find synergies of the BUILDSPACE project and services with other EU projects and initiatives in which the participants are involved or linked.

The expected outcomes of the session are: 1) making potential stakeholders interested in the BUILDSPACE Project, especially targeted potential end-users from each pilot environment; 2) further understanding of how the potential end-users of the services would use the different functionalities, and their interest on the more concrete ones; 3) better knowledge on how the different visualisations can support users to obtain the information they need from the services; 4) and to gather several EU projects and initiatives to which BUILDSPACE project can establish links and relations for potential collaboration and synergies.

The session's format was online, planned in a 2-hour Zoom meeting, with a 5-minute break. The feedback, presentation and all interactions were be hosted on a Miro Board, similar to the first session.

In the following Table 3, the main aspects of the first co-creation session's planning are presented.

Table 3. Second co-creation session planning

No.	Date	
#2	**M10. 24th November 2023, 11:00 – 13:00 CET**	
Audience	**Invited**	Open to broad audience. Invitation to all stakeholders registered for the first co-creation session and mobilisation of pilots' networks of potential interested stakeholders related to the four BUILDSPACE pilots. Posts in the BUILDSPACE and partners' social media.
	Participation	63 participants connected to the session. Around 67% were externals.
Objectives	- To refresh (or present for new participants) the BUILDSPACE project, with scope and objectives - To present the services through a description, functionalities and visualisation. Link with the feedback received during the first co-creation session (on additional functionalities mainly) - To show the workflow of the services and obtain feedback on key aspects, visualisation, comparable elements and key questions to support the service developers - To find synergies between BUILDSPACE Project and services with other EU projects and initiatives	
Expected outcome	- Make potential stakeholders interested in the BUILDSPACE Project (special target on Pilot-related stakeholders) - Further understanding of how potential end-users of the services would use the different functionalities, and their interest on specific ones (that help them in their work) - To obtain a better knowledge on how the different visualisation can support the user to obtain the information they need	

	- To gather several EU projects and initiatives with which BUILDSPACE could establish collaboration
Type of interaction	Online session (through Zoom) The feedback, presentation and all interactions were done through Miro Board: https://miro.com/app/board/uXjVNP7LSrQ=/?share_link_id=836945300772

2.2 Communication material

The communication material prepared for the session's promotion consisted of the agenda in a visual way, a Flyer (see Figure 3), social media posts templates and pictures for the different social networks, which were shared by the BUILDSPACE main accounts and by the BUILDSPACE partners' social media accounts.

Figure 3. Flyer for the promotion of the second co-creation session

In addition, two invitation templates were prepared to be shared by email to different potential end-users. The first one (Table 4) is generic and for any external stakeholder that may be interested. The second one (Table 5) is to specifically target stakeholders related to BUILDSPACE pilots, that will be kept engaged in the services' testing and upcoming phases of the project development.

Table 4. Invitation letter template to be shared by email to partners' networks (GENERIC)

Invitation letter template to all stakeholders
Dear [Representative's Name], I hope this message finds you well. We are thrilled to invite you and your company/organisation to the second co-creation session of the BUILDSPACE project, which will be conducted online on Friday, November 24th at 11:00 CET. BUILDSPACE is an ambitious initiative aligned with the EU Green Deal, focused on enhancing energy efficiency. It leverages a wealth of data sources, including terrestrial building data, thermal-equipped drone imagery, and satellite-derived location-annotated information, to provide innovative services for the benefit of buildings and urban environments. These co-creation sessions hold immense importance for our project. The initial session successfully laid the groundwork for our collaborative journey, and the second session is a pivotal step toward achieving our goals. In this forthcoming session, we aim to present the project's progress and services workflow, ensuring that all stakeholders are well-informed about the current status and future direction, as well as to seek valuable input from you on the final components of the services and their integration with each pilot project before their implementation. BUILDSPACE extends beyond being only a project; it is a collective mission to drive innovation, sustainability, and progress within our industry. It is about fostering a strong community of stakeholders who share common goals and aspirations. We cordially invite you to be a part of this transformative journey by participating in this co-creation session. Your presence and insights are invaluable to the success of BUILDSPACE. Please confirm your attendance by registering **here**. I remain available for any further information, and I thank you on behalf of the project for your time and attention

Table 5. Invitation letter template to be shared by email to potential interested end-users (pilot stakeholders)

Invitation letter template to Pilot-dedicated stakeholders
Dear [Representative's Name], I hope this message finds you well. We are thrilled to invite you and your company/organisation to the second co-creation session of the BUILDSPACE project, which will be conducted online on Friday, November 24th at 11:00 CET. BUILDSPACE is an ambitious initiative aligned with the EU Green Deal, focused on enhancing energy efficiency. It leverages a wealth of data sources, including terrestrial building data, thermal-equipped drone imagery, and satellite-derived location-annotated information, to provide innovative services for the benefit of buildings and urban environments. As stakeholders whose active involvement we foresee as instrumental in the pilot implementation, your presence and insights are of paramount importance. The first co-creation session successfully laid the foundation for our collaborative journey, and this second session marks a pivotal step toward realizing our shared objectives. In the forthcoming session, our goal is to present the progress of the project and outline the workflow of our services. We aim to ensure that all stakeholders are well-informed about the project's current status and future direction, as well as to seek valuable input from you on the final components of the services and their integration with each pilot project before their implementation. BUILDSPACE extends beyond being only a project; it is a collective mission to drive innovation, sustainability, and progress within our industry. It is about fostering a strong community of stakeholders who share common goals and aspirations. We cordially invite you to be a part of this transformative journey by participating in this co-creation session. Your presence and insights are invaluable to the success of BUILDSPACE. Please confirm your attendance by registering here.

I remain available for any further information and I thank you on behalf of the project for your time and attention.

Since the core of the 2nd co-creation session was on the services, breakout groups were formulated based on to participants' interest in the different services.

2.3 Agenda

The agenda is presented in the following Table 6, together with a description of each objective pursued for each part of the session.

Table 6. Second co-creation session agenda

Start	End	Duration	Topic	Chair	In-depth description and objective pursued
11:00	11:10	10'	**Welcome and introduction**	CARTIF	To introduce the session and present the agenda, and to get participants enter into participation and interaction mode through an ice-breaker. Also, interaction to know who else is in the room through a target groups assignment game.
11.10	11.20	10'	**BUILDSPACE: scope and objectives**	SLG	Introduce the project and objectives, so that participants understand what the project is about, as well as the Core Platform in which the services will be accessible.
11:20	10:40	20'	**Services functionalities and visualisation (and recap of the 1st co-creation session)**	CARTIF & Service Leaders	Present briefly the services, with a description, functionalities (and functionalities from the 1st co-creation session feedback), as well as some insights on how they will be visualised. The objective is also focusing on participants knowing more about the services and are able to select the most interesting one for them in the following breakout sessions.
11:40	12:10	30'	**Services fine-tuning: Breakout sessions [interactive session]**	Service Leaders	Form BREAKOUT SESSIONS. One per service. Prepare similarly (templates etc.), but aim at different service-related results. Present the service workflow (participants to add feedback), present options/ visualisations/ comparison possibilities (participants to feedback). Let participants provide their comments and views on the different questions/topics raised.
		5'	BREAK	-	
12:15	12:40	25'	**Services fine-tuning: Breakout sessions [interactive session continuation]**	Service Leaders	Continuation of the services' session.

Start	End	Duration	Topic	Chair	In-depth description and objective pursued
12:40	12:45	5’	**Back to plenary, services’ groups recap**	Service Leaders	Around 2 minutes recap per breakout room, pointing the highlights derived from each discussion.
12:45	12:55	10’	**Creating synergies: Link EU projects and initiatives to BUILDSPACE [interactive session]**	ALDA & CARTIF	Brainstorm on projects and initiatives that participants know/ collaborate with/ are partners in and in which way BUILDSPACE can collaborate, to establish synergies and potential collaborations and links.
12:55	13:00	5’	**Session wrap up and next steps**	CARTIF	Thank participants for their time and invite them to follow the BUILDSPACE Project newsletter and social media.

2.4 Co-creation session development and feedback received

2.4.1 Topic 1: Welcome and introduction

A first frame in the Miro Board was placed as a welcome note (Figure 4), followed by the agenda presentation (Figure 5).

Figure 4. First frame in the Miro Board to welcome participants

Figure 5. Agenda presentation in the Miro Board

Then, an ice breaker with monster options was presented. Each participant had to pick the monster with which identifies most and place it in a wheel of feelings/mood (Figure 6).

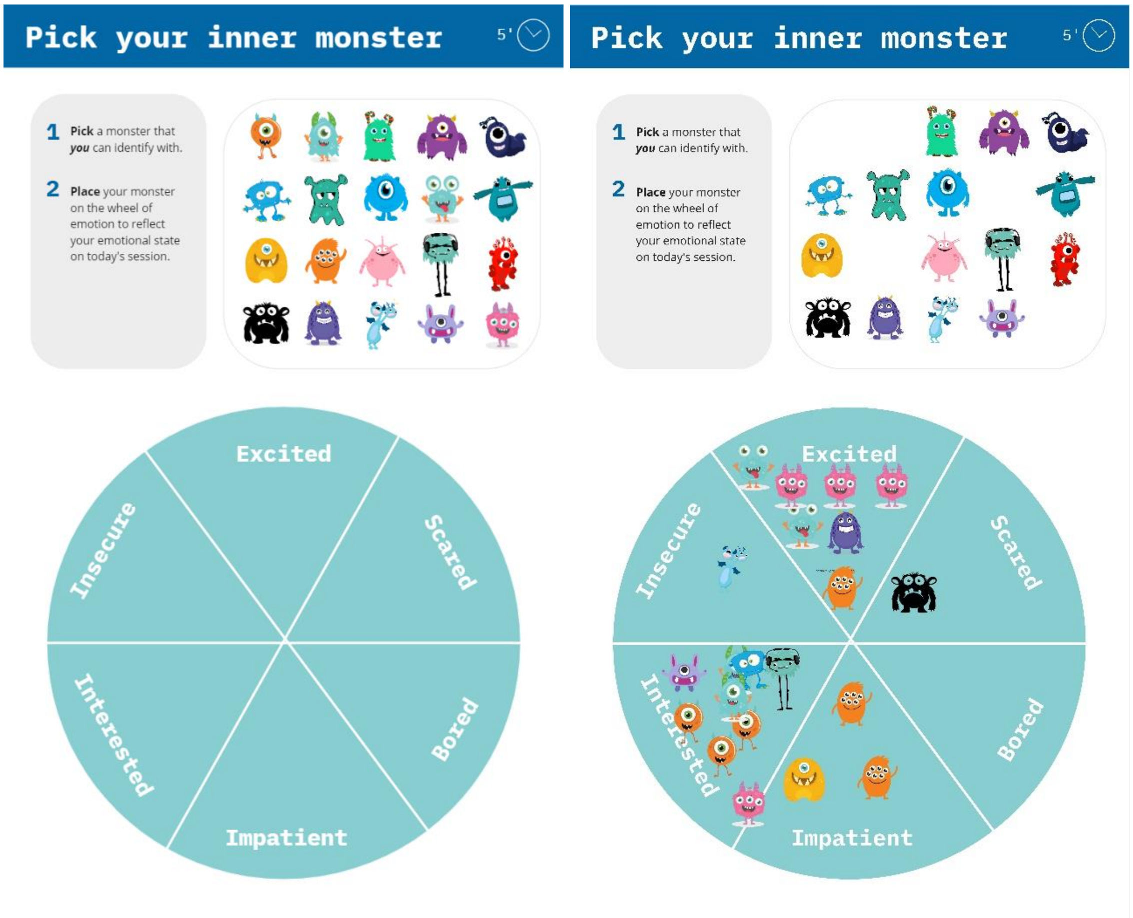


Figure 6. Frame of the ice-breaker, in template form(left), and with results (right figure)

Once participants entered into participation mood, they were also asked to identify with a stakeholder type from stakeholders list provided. This way the service leaders got a better idea of the type of end-users that would provide feedback (Figure 7).

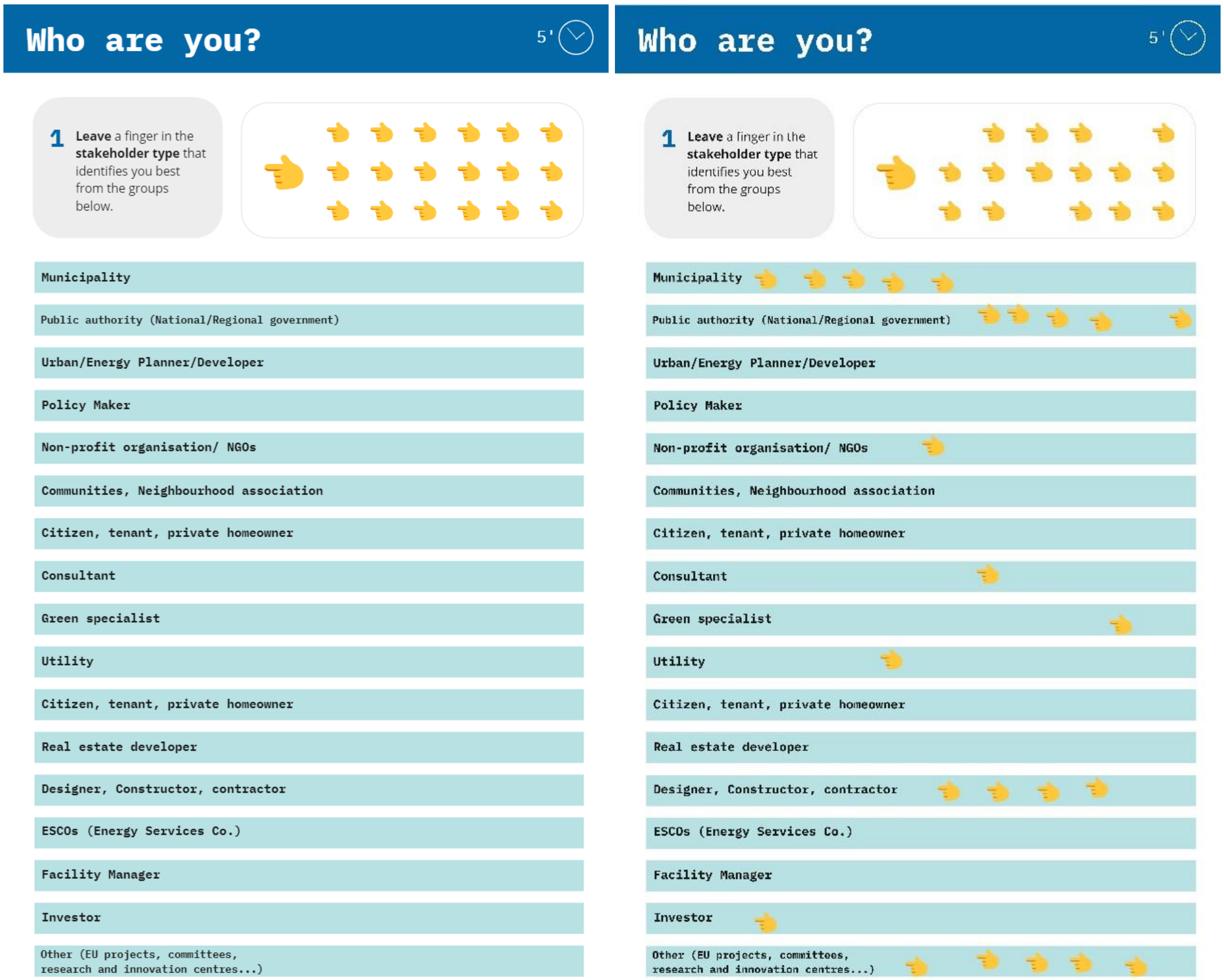


Figure 7. Frame of the Stakeholder Types, in template(left), and with results (right figure

As part of the introductory part, participants were asked to turn on their cameras (Figure 8) to take some pictures (Figure 9).

Figure 8. Frame to take participants' picture

Figure 9. Pictures taken during the session

2.4.2 Topic 2: BUILDSPACE scope and objectives

In the second part of the session, a presentation was given by the coordinator (SingularLogic) as a brief overview of the project (Figure 10), including the aim of the project, the overall BUILDSPACE Concept, the Core Platform, the Pilots and the Project Beneficiaries.

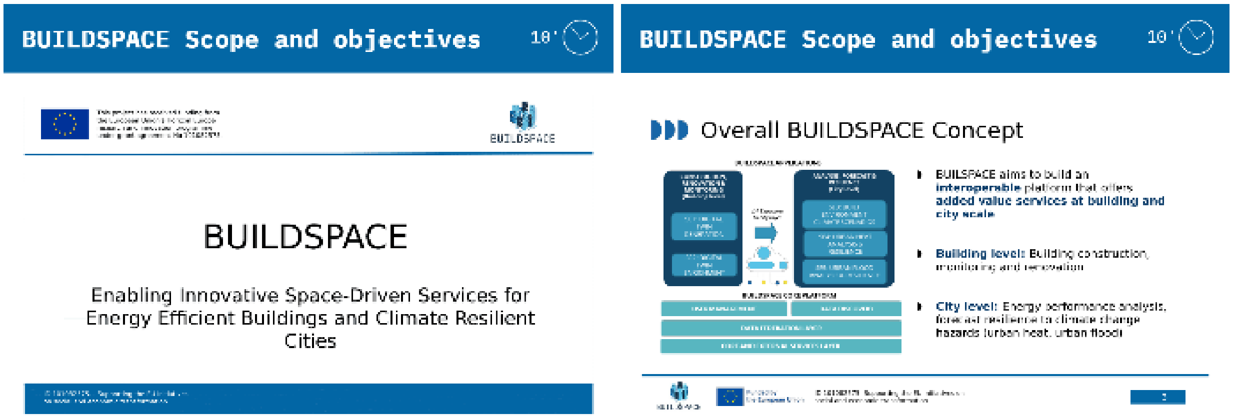


Figure 10. Frame of the session with the BUILDSPACE presentation (view of two of the slides shared)

2.4.3 Topic 3: Services presentation

In this part of the session, the services were briefly presented by each service leader (see Figure 11), through a short description, including main functionalities and functionalities that have been added following the first co-creation session feedback, as well as some insights on how they will be visualised.

The objective was also that participants get to know more about the services so as to select the service group of their interest during the breakouts.

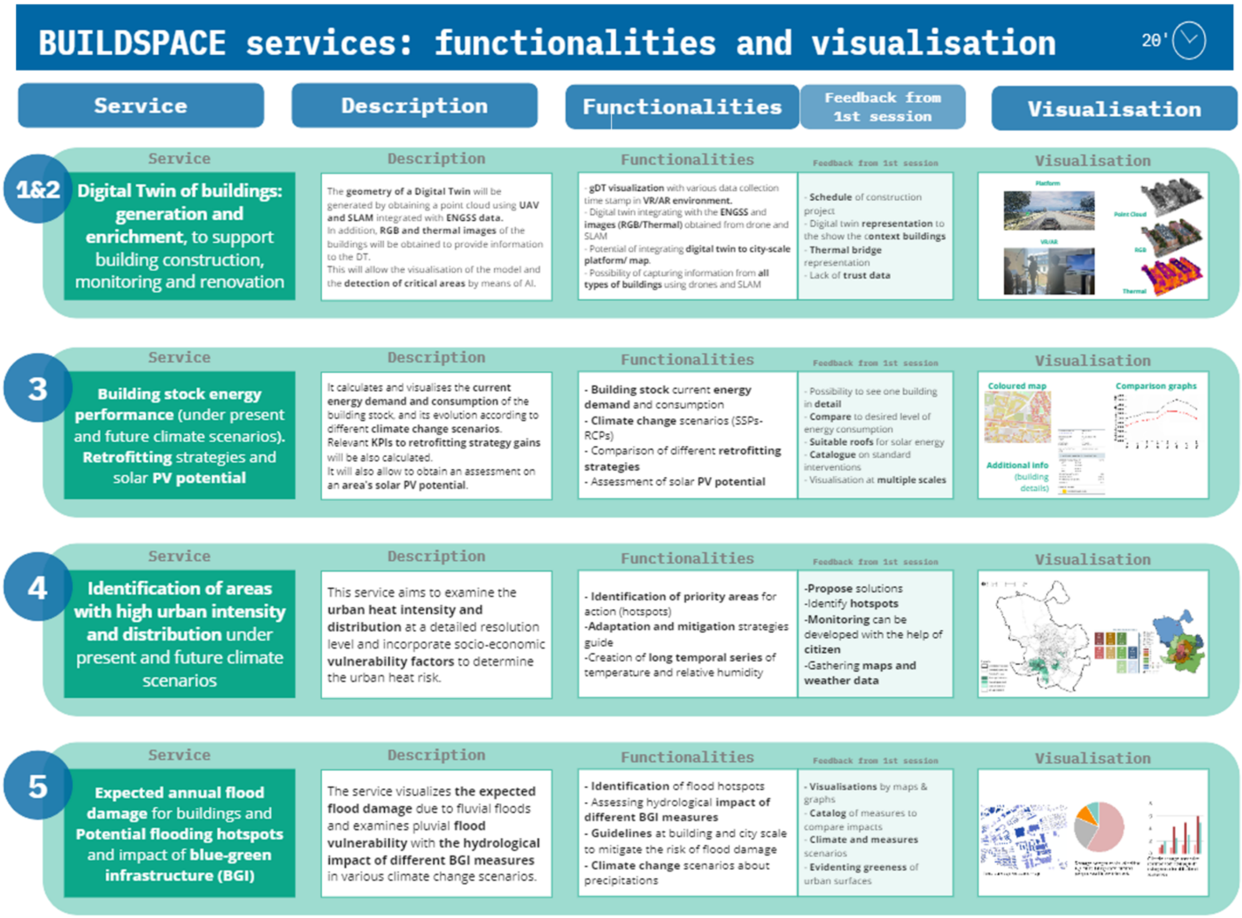


Figure 11. Frame to present some services details

2.4.4 Topic 4: Services fine-tuning

This block was at the core of the 2nd co-creation session. After the introduction of the main purpose and insights on each of the BUILDSPACE services, participants had to choose a breakout group to deep dive into the service characteristics and provide proper feedback to the service developers.

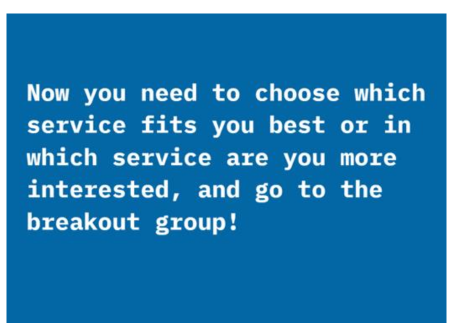
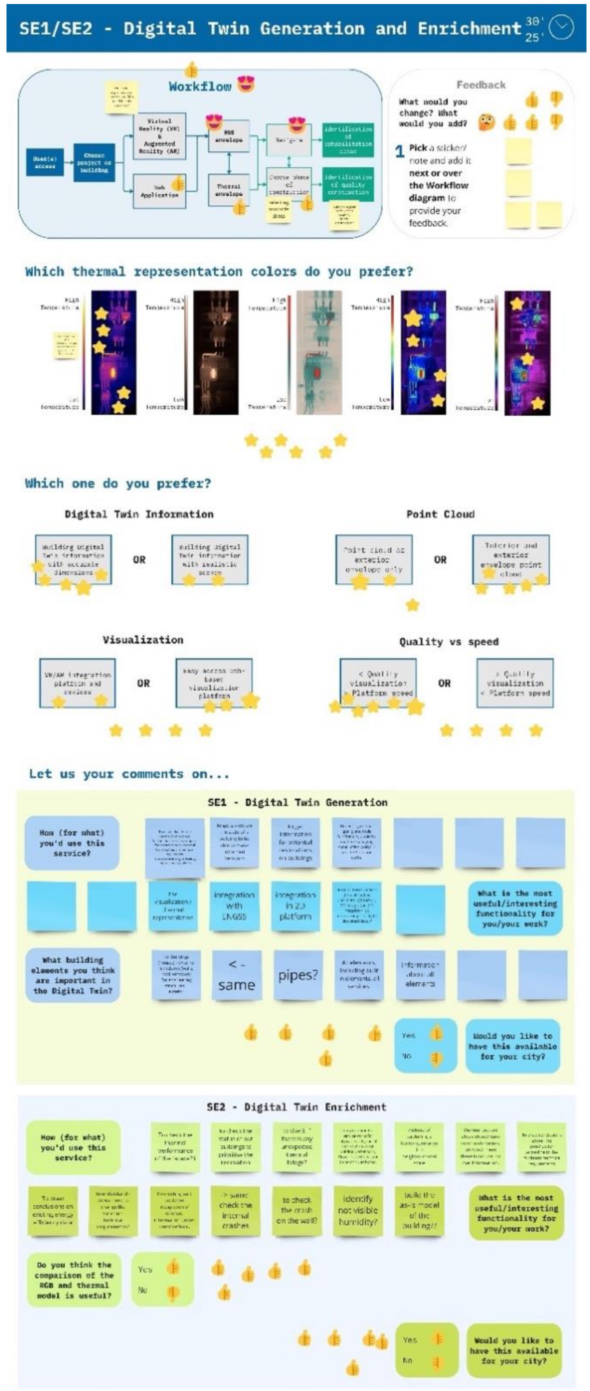


Figure 12. Frame to invite participants to choose the breakout group of the service they are more interested in

In the breakout groups, each service leader was prepared to show the service workflow, in a simple diagram and requested feedback in post-its or other forms (through like/dislike emojis). Then, service leaders asked questions about the comparison possibilities and visualisation options. Finally, service leaders raised also different questions directly addressing the participants on how they would use the service, whether the service seemed easy to use, or whether they like to have it available for their city (for services at city scale).

2.4.4.1 Breakout group 1: SE1 & SE2

The first breakout group focused on the two BUILDSPACE services related to Buildings Digital Twin (both



Generation and Enrichment), SE1 and SE2 (

Figure *13*).

Figure 13. Breakout group 1, for services 1 and 2. Template (left side) and participants' feedback (right side)

The session started with the presentation of the services workflow diagram (Figure 14). Then participants were asked to provide feedback on whether they like the service workflow (overall or some concrete parts of the process) or not, as well as comments on whether they had doubts or any additional feedback to any specific parts.

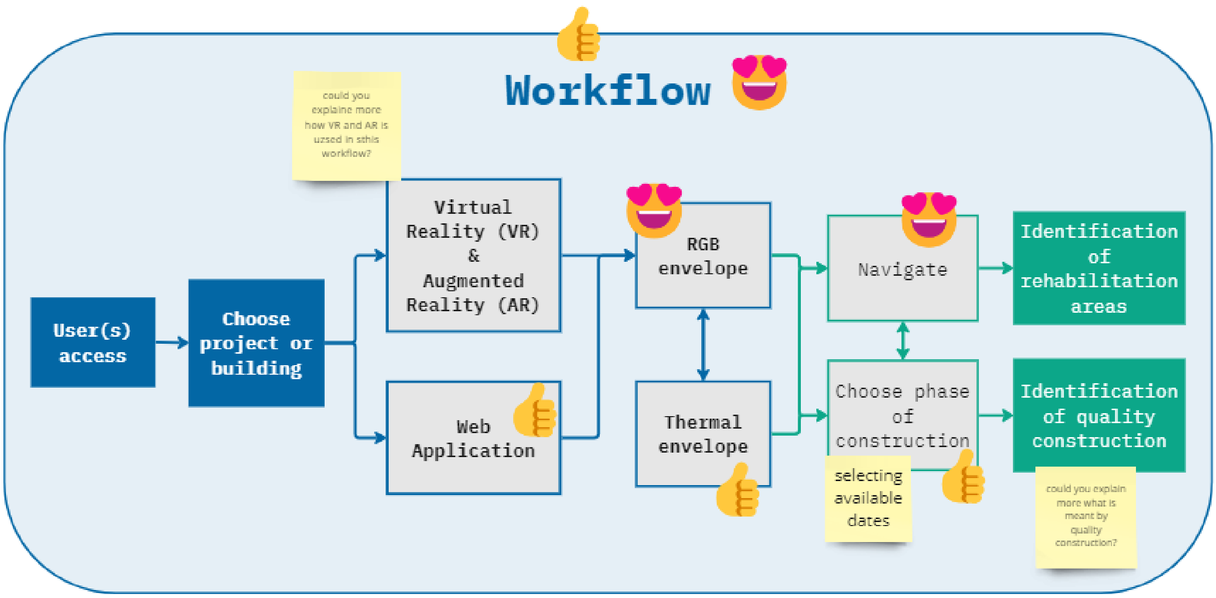


Figure 14. Breakout group 1, SE1 and SE2. Workflow diagram feedback

As per the feedback received, participants liked the SE1&2 service workflow overall, and more specifically the web application, the RGB and thermal envelope functions, as well as the option to navigate and choose phase of construction. Also, they asked for more explanations on how VR and AR is used in the services, regarding an additional option to be able to select available dates also in the choosing of construction phase, and on what they mean by quality construction as service outcome.

- UOC: The VR and AR interface can be used to visualise the point cloud model, the constructed digital twin model as well as the design BIM model. AR/VR allows for a more immersive and detailed visualisation of buildings compared to traditional 2D blueprints or 3D models on a screen. Stakeholders can virtually walk through and experience the space, understanding the scale, layout, and design in a more intuitive way. The point cloud model shows the condition when the data are collected. The constructed digital twin model aims to build a parametric object-oriented digital model for the building. It is the digital reflection of the point cloud model. The point cloud and its corresponding constructed digital twin model can be assigned with a specific time slot, which is the moment the data is collected. These can be visually compared with the design BIM model or 4D BIM model, which means the BIM model with time information associated.

Q: Could you explain more about what is meant by quality construction?

- UPM: With construction quality we refer to the final quality of the envelope, focusing on thermal bridges around windows or doors, floors, walls, corners.
- UOC: The construction quality of the geometric digital twin model mainly refers to the deviation of the parametric information.

In the following part, participants were asked about the thermal colours' representation. As can be seen in the figure below, the favourite option was the first one, followed by the fourth and fifth ones. In addition, a comment was left on the right bar of the graphs that colours should have values in ºC (not only "high" / "low" temperature).

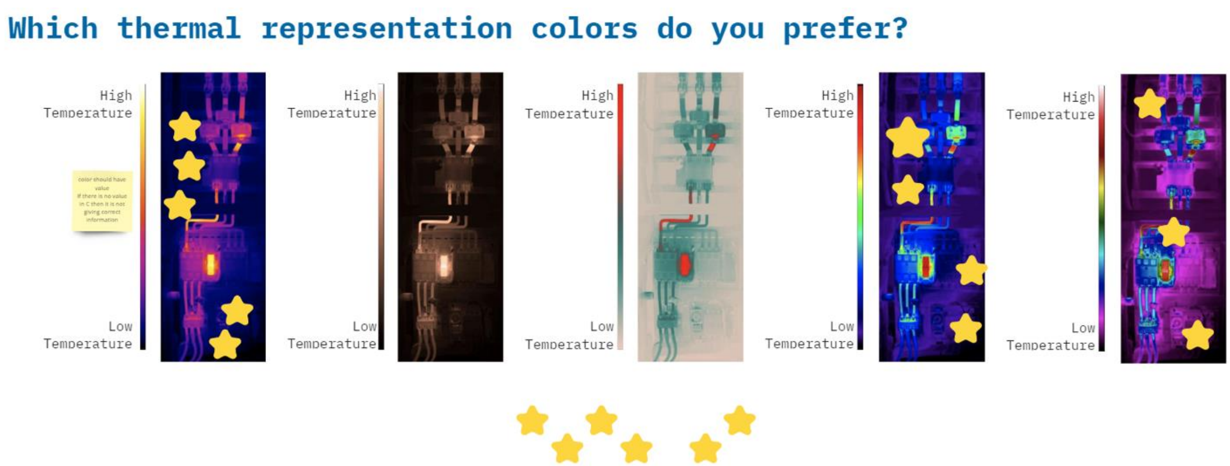


Figure 15. Breakout group 1, SE1 and SE2. Thermal representation colours feedback

Then, a part with two-option questions was presented to participants for feedback (Figure 16), where they had to put a star in their most preferred option.

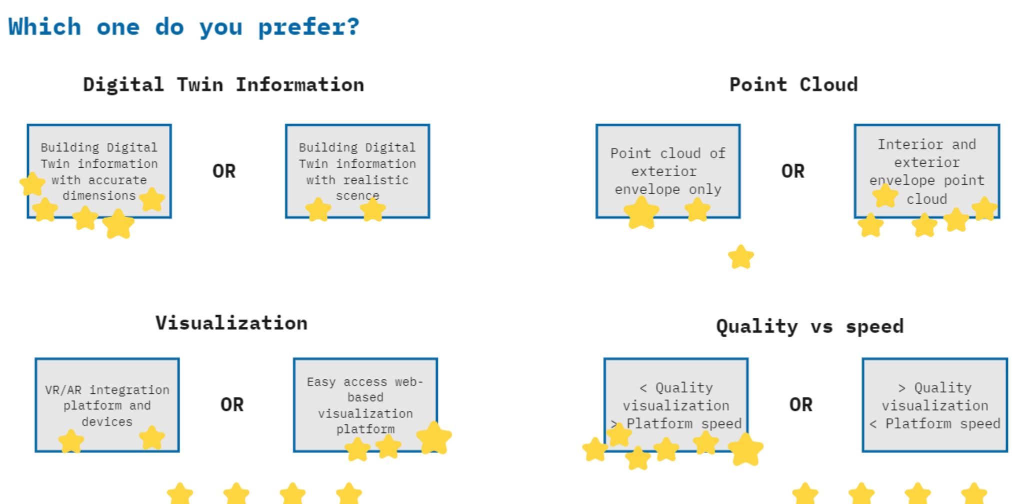


Figure 16. Breakout group 1, SE1 and SE2. Options preference feedback

The questions were the following:

- Do you prefer **Building Digital Twin Information** with accurate dimensions or Building Digital Twin Information with realistic scene?
    - Participants mostly preferred the accurate dimensions.
- Do you prefer **Point Cloud** of exterior envelope only or Interior and exterior envelope point cloud?
    - Where participants mostly preferred both interior and exterior point clouds.

- On **visualisation**, do you prefer VR/AR integration platform and devices or Easy access web-based visualisation platform?
    - Although answers were more balanced in this question, web-based visualisation platform was little more preferred by participants.
- On **Quality vs. Speed**, do you prefer lower quality visualisation with higher platform speed, or higher quality visualisation with lower platform speed?
    - Without doubt, participants selected the option of the higher platform speed, even if the visualisation quality is lower.

Finally, the last part of the session was divided into questions made to participants for SE1 Digital Twin Generation and for SE2 Digital Twin Enrichment (Figure 17).

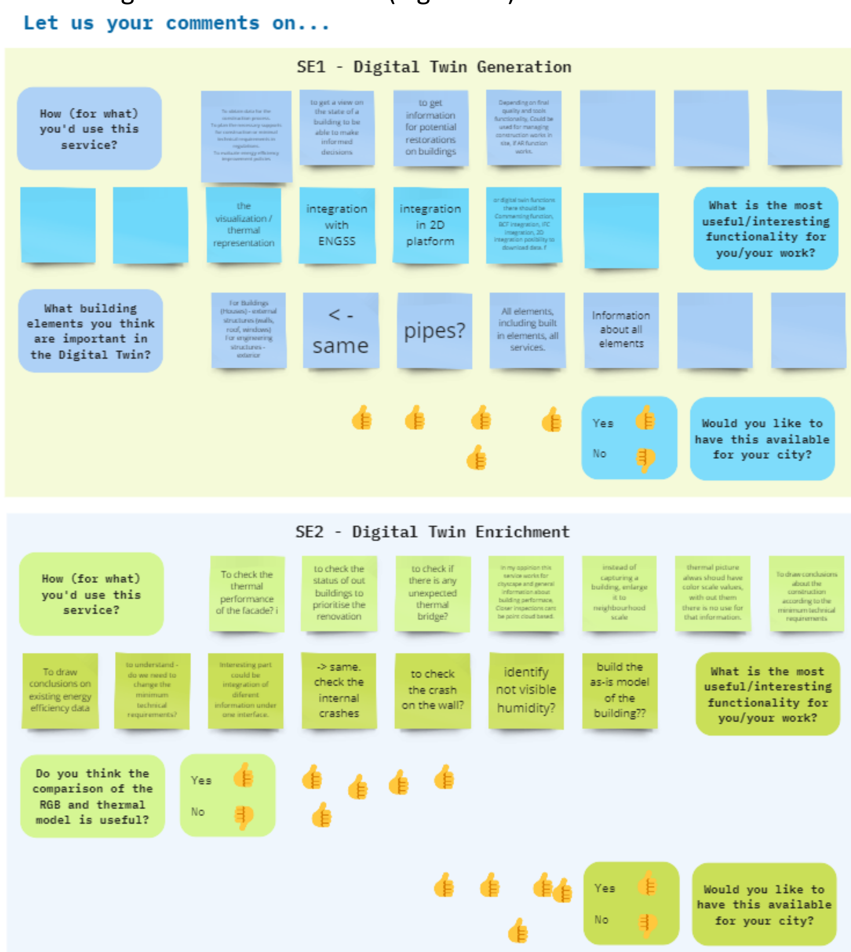


Figure 17. Breakout group 1, SE1 and SE2. Questions and feedback on services 1&2

In Table 7, participants' feedback for each question is presented in detail:

Table 7. Feedback received to the questions made in Breakout group 1 (SE1 & SE2)

SE1 – Digital Twin Generation	
How (for what) you'd use this service?	- To obtain data for the construction process - To plan the necessary supports for construction or minimal technical requirements in regulations - To evaluate energy efficiency improvement policies - To get a view on the state of a building to be able to make informed decisions - To get information for potential restorations on buildings - Depending on final quality and tools functionality, it could be used for managing construction works in site, if AR function works
What is the most useful/ interesting functionality for you/ your work?	- Digital twin functions there should be commenting function, BCF integration, IFC integration, 2D integration possibility to download data - Integration in 2D platform - Integration with EGNSS - The visualisation/ thermal representation
What building elements you think are important in Digital Twin?	- For buildings (houses) – external structures (walls, roof, windows). For engineering structures – exterior. → another participant agreed with it. - Pipes? - All elements, including built in elements, all services - Information about all elements
Would you like to have this available for your city?	- 5 likes (yes) - 0 dislikes (no)
SE2 – Digital Twin Enrichment	
How (for what) you'd use this service?	- To check the thermal performance of the façade - To check the status of out buildings to prioritise the renovation - To check if there is any unexpected thermal bridge? - In my opinion this service works for cityscape and general information about building performance, closer inspection can't be point cloud based - Instead of capturing a building, enlarge it to neighbourhood scale - Thermal picture always should have colour scale values, there is no use for that information instead - To draw conclusions about the construction according to the minimum technical requirements
What is the most useful/ interesting functionality for you/ your work?	- Build the as-is model of the building? - Identify not visible humidity? - To check the crash on the wall? - Interesting part could be the integration of different information under one interface → another participant agreed with it (to check the internal crashes) - To understand: do we need to change the minimum technical requirements? - To draw conclusions on existing energy efficiency data
Do you think the comparison of the RGB	- 5 likes (yes) - 0 dislikes (no)

SE1 – Digital Twin Generation	
and thermal model is useful?	
Would you like to have this available for your city?	- 5 likes (yes) - 0 dislikes (no)

2.4.4.2 Breakout group 2: SE3

The second breakout group focused on BUILDSPACE service 3:Built environment climate scenarios, at city scale (Figure 18).

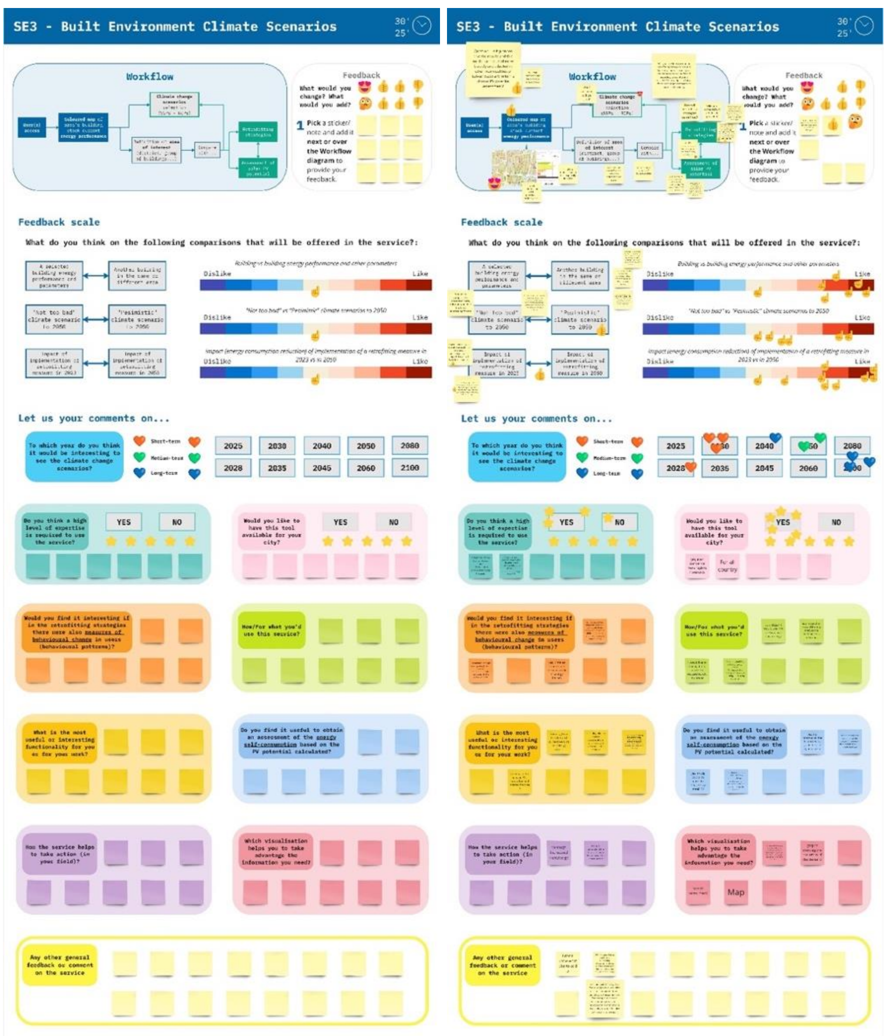


Figure 18. Breakout group 2, for service 3. Template (left side) and participants' feedback (right side)

The session started with the presentation of the service workflow diagram (Figure 19). Then, participants were asked for feedback on whether they like the workflow (overall or some concrete parts of the process) or not, and to provide comments on whether they had doubts or any additional feedback for any specific part.

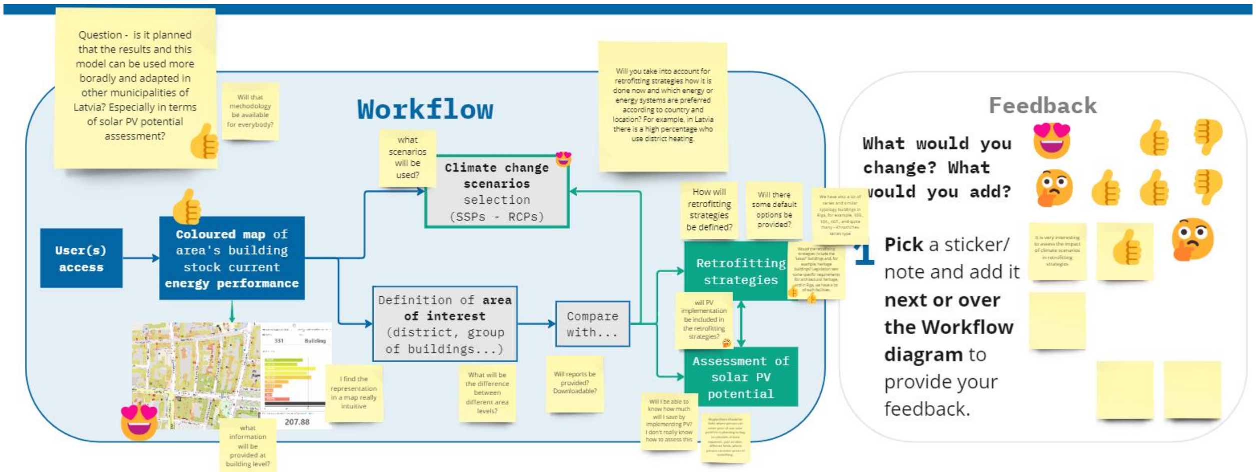


Figure 19. Breakout group 2, SE3. Workflow diagram feedback

As per the feedback received, participants liked different parts (visualisation of coloured map, climate change scenarios part) and the workflow in overall. They had several questions and comments:

- **Q**: Is it planned that the results and this model can be used broadly and adapted in other municipalities of Latvia? Especially in terms of solar PV potential assessment?
  - Not planned in the BUILDSPACE project context (the pilot is only Riga), but it can be analysed as part of the replication of the service.
- **Q**: Will that methodology be available for everybody?
- **Q**: What scenarios will be used?
  - Scenarios from last IPCC report (6th report), both SSPs (Shared Socioeconomic Pathways) and RCPs (Representative Concentration Pathway) combined, provide different scenarios on how the climate will change in the future.
- **Q**: What information will be provided at building level?
  - It is presented (small) in the visualisation of the service presentation (topic 3). Information available from cadastral data will be provided, as well as average geometry characteristics, and the calculated estimated energy values.
- Comment: I find the representation in a map really intuitive.
- **Q**: What will be the difference between the different area levels?
  - At city level the calculated energy performance of the buildings will be available (also available to click on each building and see the details), as well as climate change scenarios can be selected and compared. For the area of interest, the additional functionalities of retrofitting strategies and the assessment of solar PV potential will also be available.

- **Q**: Will you take into account for retrofitting strategies how it is done now and which energy or energy systems are preferred according to country and location? For example, in Latvia there is a high percentage who use district heating.
    - Yes, DH in Riga is already being considered to be able to offer the proper solutions for buildings connected to it, that do not have an option to change energy system.
- **Q**: How will retrofitting strategies be defined?
    - Based on all available information for the city or country.
- **Q**: Will there some default options be provided?
    - Yes, strategies will be presented as a catalogue of measures that can used, in order to see the impact in specific building(s)selected..
- Comment: We have also a lot of services and similar typologies in Riga, for example, 103., 104., 467., and quite many -Khrushchev series type
- **Q**: Would the retrofitting strategies include the “usual” buildings, and, for example, heritage buildings?
    - Legislation sets some specific requirements for architectural heritage, and in Riga, we have a lot of such facilities.
- **Q**: Will PV implementation be included in the retrofitting strategies?
    - Indeed, it will be linked to the measure of change energy system, to cover the heating/cooling demand with a heat pump (electricity production from PV).
- **Q**: Will I be able to know how much I will save by implementing PV? I don’t really know how to assess this.
    - In terms of energy, self-assessment potential data will be offered. Further study needs to take place in terms of offering also economic savings, as there is a lot of uncertainty for those calculations.
- Maybe there should be a field where a user can enter the price of one solar panel they are planning to buy, to calculate at least the expenses. This is just an idea. of have different fields where the user can enter prices of something to be able to provide economic assessment/savings afterwards.
- It is very interesting to assess the impact of climate change scenarios in retrofitting strategies.

Then, a part with two elements compared was presented to participants and their feedback was requested (Figure 20). Participants had to put the finger in the thermometer at the right side to have a say on whether they like or not the comparisons that could be offered. They could also add post-its for additional comments.

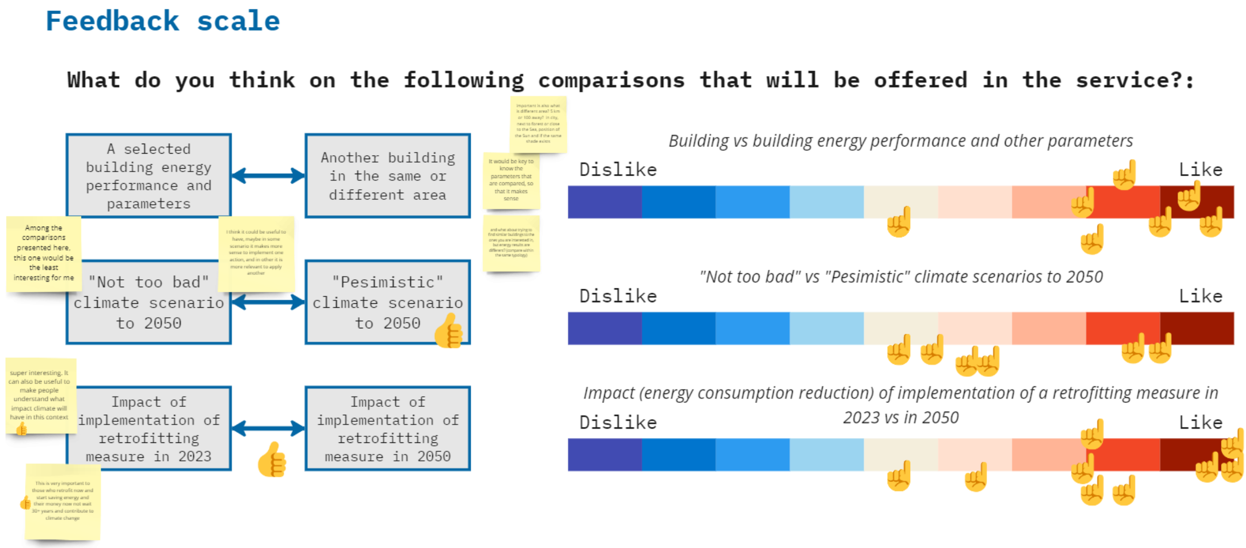


Figure 20. Breakout group 2, SE3. Comparison options preference feedback

The questions were about what participants think on the following comparisons that will be offered in the service:

- **A selected building energy performance and parameters ↔ Another building in the same or different area**
  - Participants liked this comparison. A participant made a question because it is important to know what different area means (e.g. 5km, 100km away), in city, next to forest or close to the sea, the position of the sun and if the same shade exists. They also commented that it would be key to know the parameters that are compared, so that it makes more sense. Participants were also interested in trying to find similar buildings to the ones the users might be interested in, but with different energy results (comparison within the same typology).
- **A “not too bad” climate scenario to 2050 ↔ A “pessimistic” climate scenario to 2050**
  - Participants partially liked this comparison, while it was left a little indifferent on the other hand. For a participant, this is the least interesting comparison out of the three presented. Another one thought that it could be useful to have it, pointing out that maybe in some scenarios make more sense to implement one action, and in another it is more relevant to apply another.
- **The impact of implementation of retrofitting measure in 2023 ↔ The impact of implementation of retrofitting measure in 2050**
  - Participants liked this comparison very much. This was considered as very interesting, since it can also be useful to make people understand what impact climate can have in this context. This was also considered as very important to those who retrofit and start saving energy and their money now and not wait 30+ years to contribute to climate change.

Finally, the last part of the session was divided into questions raised to participants about BUILDSPACE SE3 Built Environment Climate Scenarios (Figure 21).

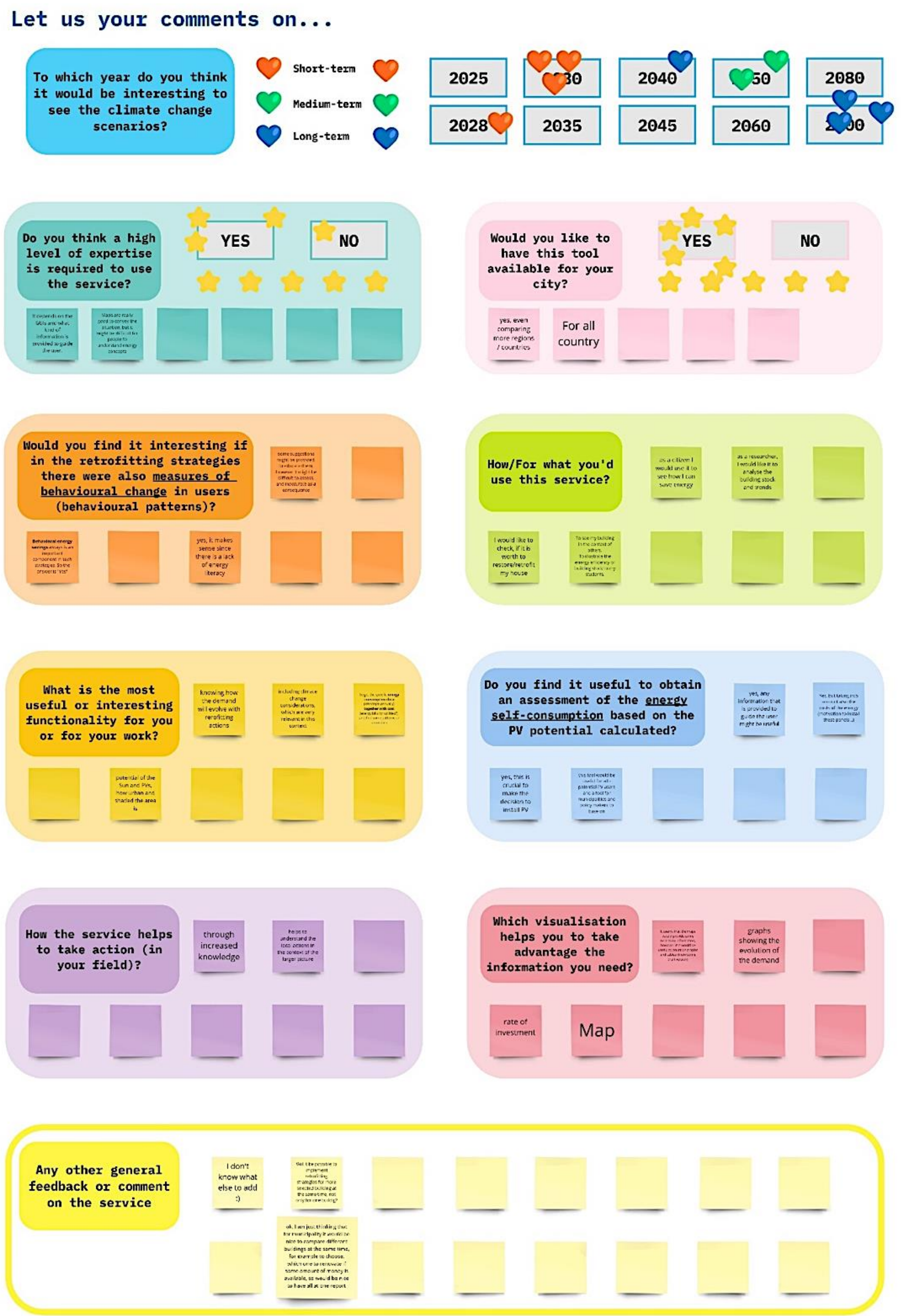


Figure 21. Breakout group 2, SE3. Questions and feedback on Service 3

Regarding the first question, participants were asked about which year do they think it would be interesting to see the climate change scenarios. They were requested to provide their feedback for the short-term, medium-term and long-term. Short-term was mostly agreed to be 2030 (and few feedbacks for 2028). Medium-term was around 2050, and Long-term was agreed to be around 2100. However, some participants considered 2040 as Long-term; This reveals the diversity of the participants' views.

In Table 8, participants' feedback for each question is presented in detail.

Table 8. Feedback received to the questions made in Breakout group 2 (SE3)

SE3 – Built Environment Climate Scenarios	
Do you think a high level of expertise is required to use the service	- 3 Yes, 1 No - It depends on the GUIs and what kind of information is provided to guide the user - Maps are really good to convey the situation, but it might be difficult for people to understand energy concepts
Would you like to have this tool available for your city?	- 5 Yes, 0 No - Yes, even comparing more regions / countries - For all country
Would you find it interesting if in the retrofitting strategies there were also <u>measures of behavioural change</u> in users (behavioural patterns)?	- Some suggestions might be provided to educate the users. However, it might be difficult to assess them, and therefore, be inaccurate as a consequence. - **Behavioural energy savings** always is an important component in such strategies. So, the answer is "Yes" - Yes, it makes sense since there is a lack of energy literacy
How/ For what you'd use this service?	- As a citizen, I would use it to see how I can save energy - As a researcher, I would like it to analyse the building stock and trends - I would like to check, if it is worth to restore/retrofit my house - To see my building in the context of others. To illustrate the energy-efficiency of building stock to my students
What is the most useful or interesting functionality for you or for your work?	- Potential of the Sun and PVs, how urban and shaded the area is - Knowing how the demand will evolve with retrofitting actions - Including climate change considerations, which are very relevant in this context - To get the specific **energy consumption data** (kWh/sqm annually) **together with cost** (energy bills for utilities?) and find some patterns or anomalies
Do you find it useful to obtain an assessment of the energy self-consumption based on the PV potential calculated?	- Yes, this is crucial to make the decision to install PV - This tool would be useful for all – potential PV users and a tool for municipalities and policy makers to base on - Yes, any information that is provided to guide the user might be useful - Yes, but taking into account also the costs of the energy (motivation to install these panels…)
How the service helps to take action (in your field)?	- Through increased knowledge - Helps to understand the local actions in the context of the larger picture

SE3 – Built Environment Climate Scenarios	
Which visualisation helps you to take advantage of the information you need?	- Rate of investment - Map - It seems that the maps would provide some necessary information, however, it would be useful to count on graphs and tables (know some draft version) - Graphs showing the evolution of the demand
Any other general feedback or comment on the service	- I don't know what else to add :) - Will it be possible to implement retrofitting strategies for more selected building at the same time, not only for one building? - Ok, I am just thinking that for municipality it would be nice to compare different buildings at the same time, for example to choose, which one to renovate if some amount of money is available, so would be nice to have all at one report

2.4.4.3 Breakout group 3: SE4

The third breakout group focused on BUILDSPACE service 4: Urban heat analysis and resilience, at city scale (Figure 22).

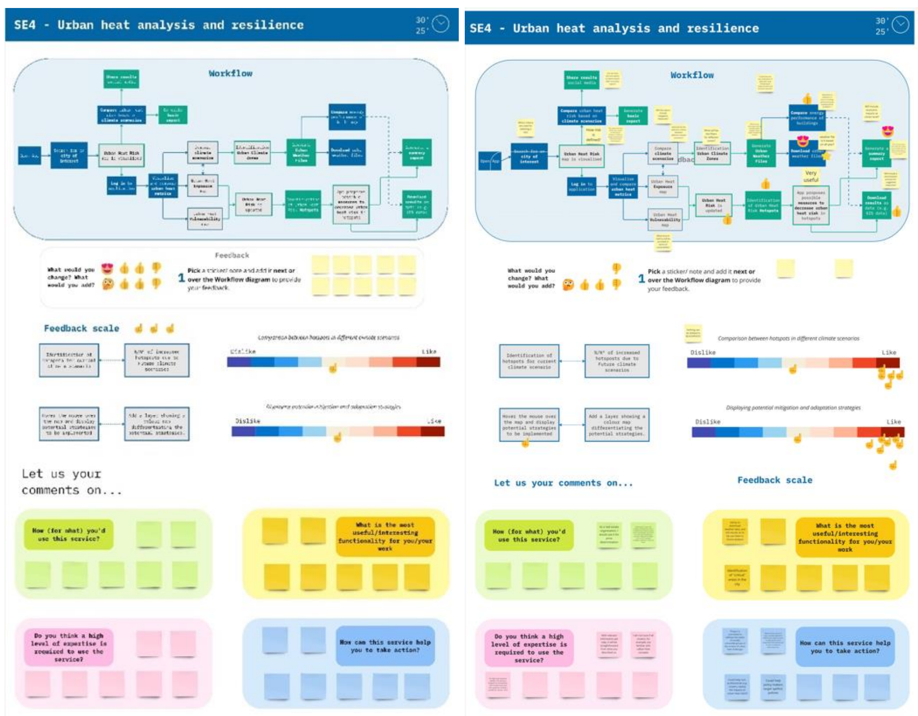


Figure 22. Breakout group 3, for service 4. Template (left side) and participants' feedback (right side)

The session started with the presentation of the service workflow diagram (Figure 23).Then, participants were asked for feedback on whether they like it (overall or some concrete parts of the process) or not, as well as to provide comments if they had doubts or any additional feedback for any of its parts.

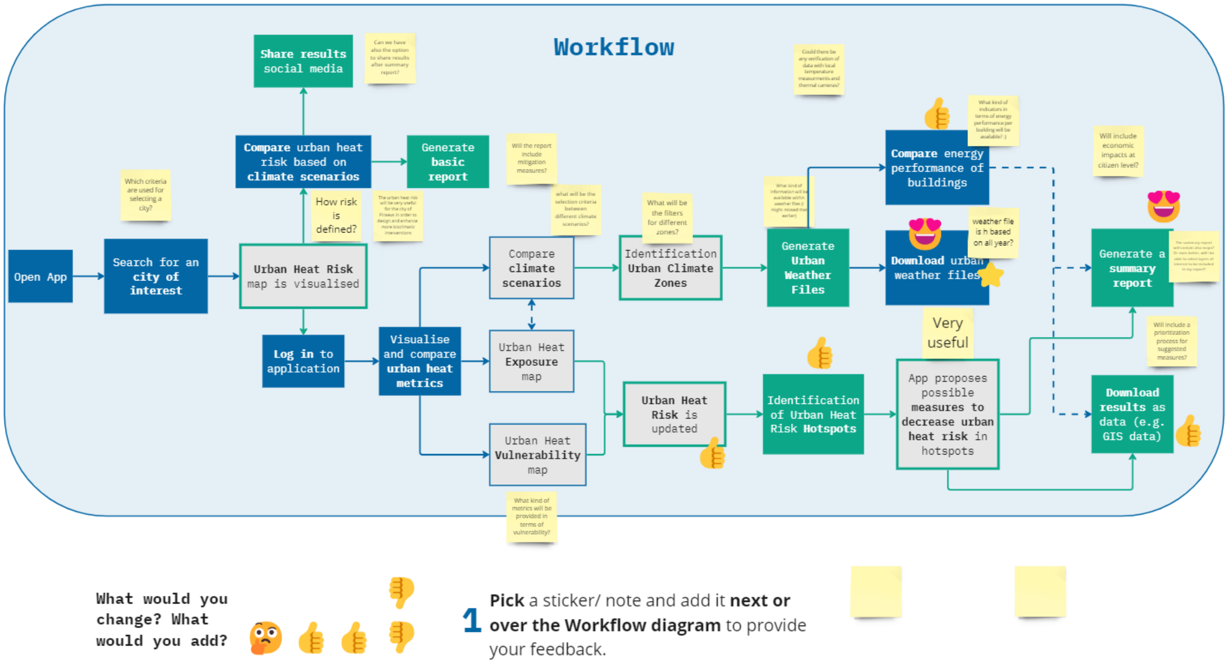


Figure 23. Breakout group 3, SE4. Workflow diagram feedback

As per the feedback received, participants liked different parts (urban heat risk update, download of urban weather files, summary report generated, download of results as data). They had several questions and comments:

- **Q**: Which criteria are used for selecting a city?
  - The user will be the one to select the city for the service. At the moment, it is being developed for implementation in the city of Piraeus.
- **Q**: How risk is defined?
  - Risk is defined by the overlap between heat exposure, vulnerability and response factors.

  Comment: The urban heat risk will be very useful for the city of Piraeus in order to design and enhance more bioclimatic interventions
- **Q**: Can we also have the option to share results after summary report?
  - Yes, it has been proposed to include the option to share information.
- **Q**: Will the report include mitigation measures?
  - We want to develop an adaptation and mitigation proposal based on urban characteristics and vulnerability factors.
- **Q**: What will be the selection criteria between different climate scenarios?
  - Information will be provided for different climate scenarios, the selection of which will depend directly on user interest.
- **Q**: What kind of metrics will be provided in terms of vulnerability?
  - Metrics have not yet been specified, however, we will be working with socio-economic and demographic factors.

- **Q**: What will be the filters for different zones?
  - Depending on the options that are selected, a filter will be performed.
- **Q**: What kind of information will be available within weather files?
  - It shall include the same as that needed for energy simulations of buildings (.epw).
- **Q**: Could there be any verification of data with local temperature measurements and thermal cameras?
  - While multiple databases (reference stations, city measured data, ERA5 data, etc.) will be considered for the development of the service, thermal camera verification will not be included.
- **Q**: What kind of indicators in terms of energy performance per building will be available?
  - As this service is of urban scale, no information on energy performance at building scale has been included.
- **Q**: Weather file is h based on all year?
  - They will be based on a Typical Meteorological Year file.
- **Q**: Will include economic impacts at citizen level?
  - No, this has not yet been included in the service.
- **Q**: The summary report will contain also maps? Or even better, will I be able to select layers of interest to be included in my report?
  - Yes, information will be displayed on maps and layers can be activated/deactivated.
- **Q**: Will a prioritisation process be included for suggested measures?
  - We can evaluate to include measures according to the order of priority.

Next, a part with two elements compared was presented to the participants for feedback (Figure 24), where they had to put the finger in the thermometer at the right side to have a say on whether they like or no the comparisons that was offered.

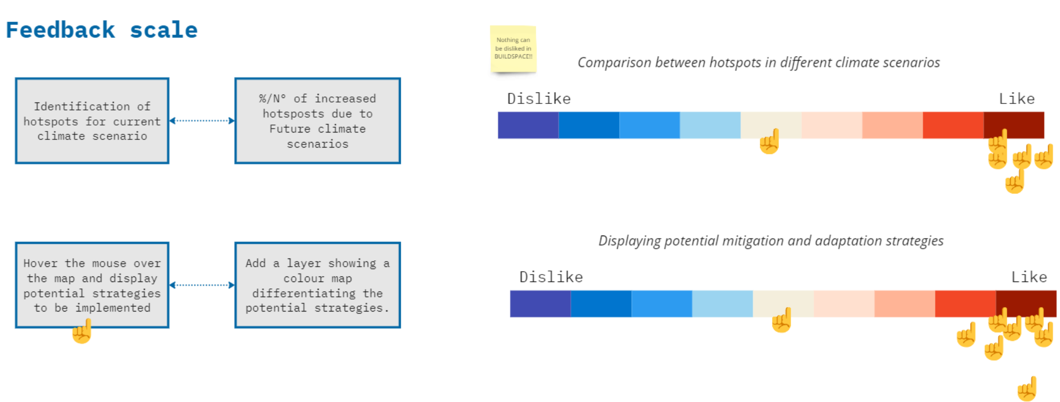


Figure 24. Breakout group 3, SE4. Comparison options preference feedback

The questions were about what the participants think (whether they liked or not) on the following comparisons that would be offered in the service:

- **Identification of hotspots for current climate scenario ↔ % / Nº of increased hotspots due to future climate scenarios**
    - Participants liked very much this comparison (4 fingers moved to the like side)
- **Hover the mouse over the map and display potential strategies to be implemented ↔ Add a layer showing a colour map differentiating the potential strategies**
    - Participants liked very much this comparison (6 fingers moved to the like side)

Finally, last part of the session was divided into questions made to participants about the SE4 Urban heat analysis and resilience (Figure 25).

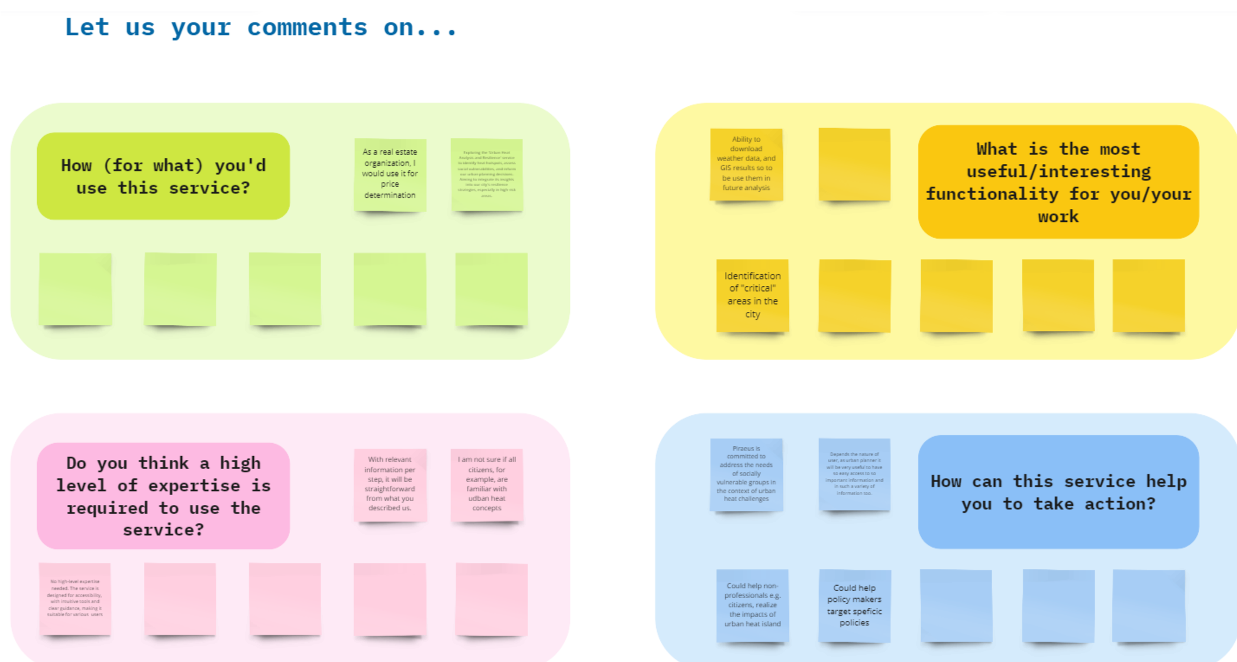


Figure 25. Breakout group 3, SE4. Questions and feedback onservice 4

In the Table 9, participants' feedback for each question is presented in detail:

Table 9. Feedback received to the questions made in Breakout group 3 (SE4)

SE4 – Urban heat island analysis and resilience	
How/ For what you'd use this service?	- As a real estate organisation, I would use it for price determination - Exploring the "Urban Heat Analysis and Resilience" service to identify heat hotspots, assess social vulnerabilities, and inform our urban planning decisions. Aiming to integrate its insights into our city's resilience strategies, especially in high-risk areas
What is the most useful / interesting functionality for you / your work?	- Ability to download weather data, and GIS results so to be use them in future analysis - Identification of "critical" areas in the city

SE4 – Urban heat island analysis and resilience	
Do you think a high level of expertise is required to use the service?	- No high-level expertise needed. The service is designed for accessibility, with intuitive tools and clear guidance, making it suitable for various users - With relevant information per step, it will be straightforward from what you described to us - I am not sure if all citizens, for example, are familiar with urban heat concepts
How can this service help you to take action?	- Piraeus is committed to address the needs of socially vulnerable groups in the context of urban heat challenges - Depends on the nature of user, as urban planner will be very useful to have so easy access to so important information and in such a variety of information too - Could help non-professionals e.g. citizens, realise the impacts of urban heat island - Could help policy makers target specific policies

2.4.4.4 Breakout group 4: SE5

The third breakout group focused on BUILDSPACE Service 5: Urban flood analysis and resilience, at city scale (Figure 26).

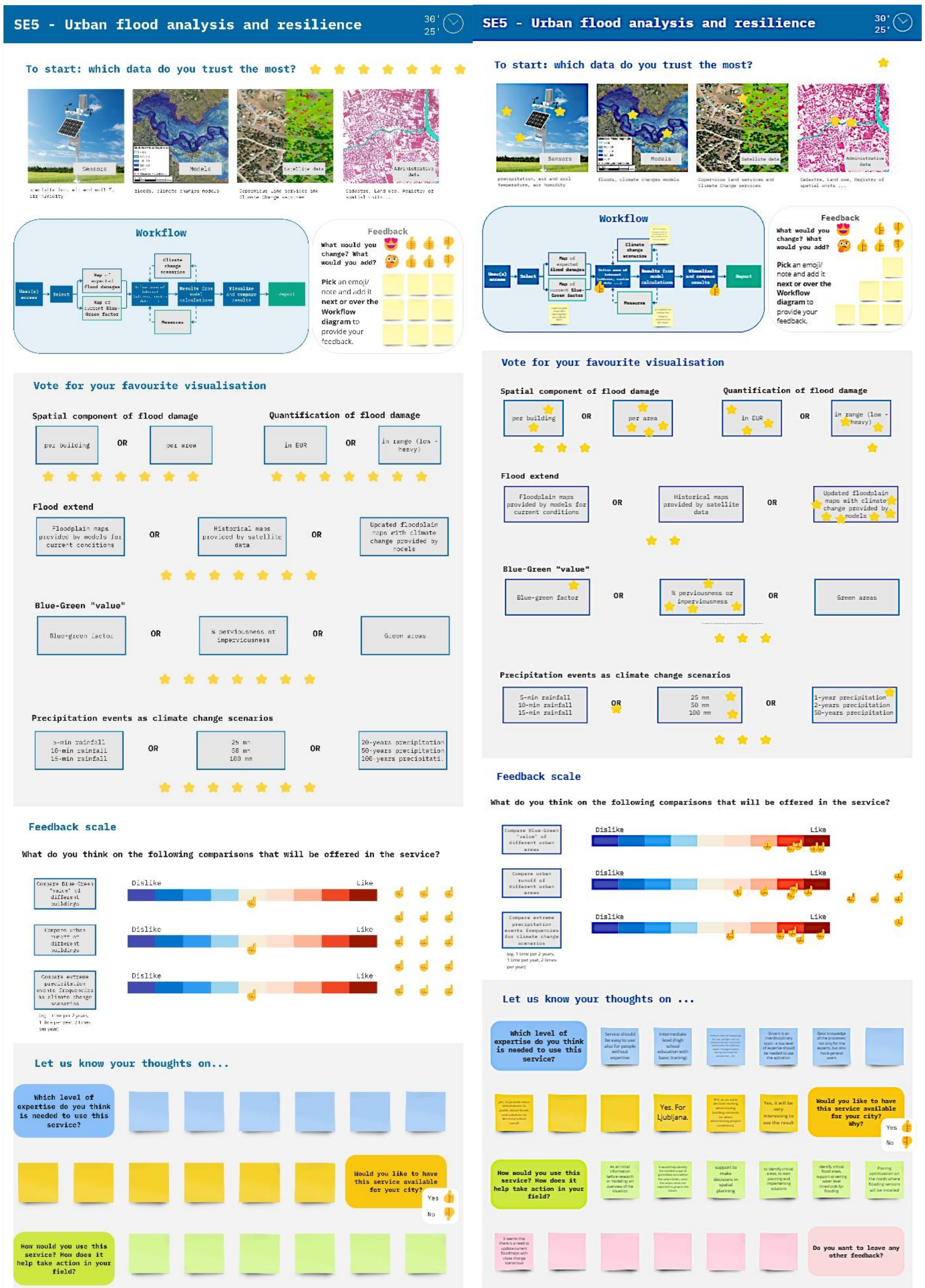


Figure 26. Breakout group 4, for service 5. Template (left side) and participants' feedback (right side)

The session started with an initial question about which data do participants trust the most, between sensors data, models, satellite data and administrative data.

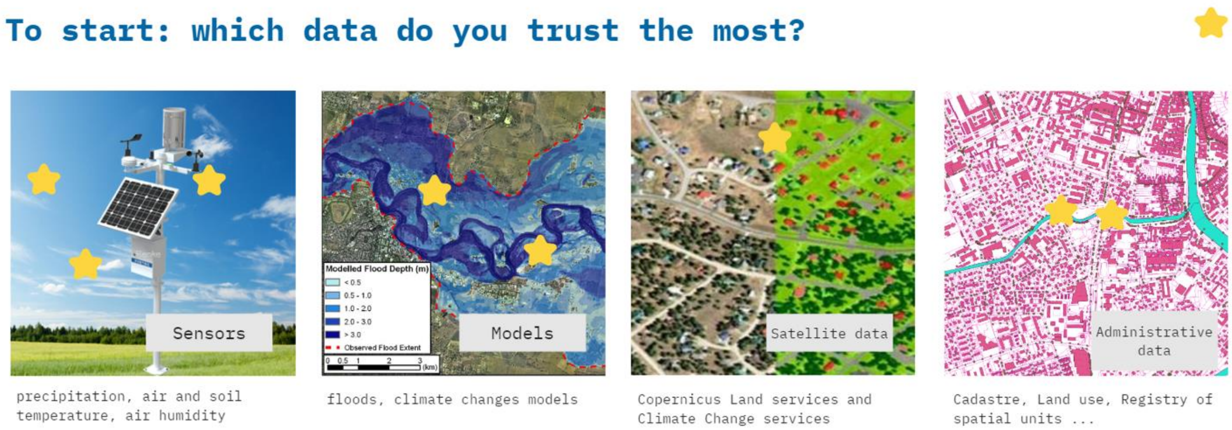


Figure 27. Breakout group 4, SE5. Workflow diagram feedback

The feedback was quite homogeneously among the different options, participants put a star in the data they trust the most. It resulted to be sensors data (3 stars), models and administrative data (2 stars each), and satellite data (1 star).

Then, the service workflow diagram was presented (Figure 28), and participants were asked for feedback on whether they like it (overall or some concrete parts of the process) or not, as well as to provide comments if they had doubts or any additional feedback for any specific parts.

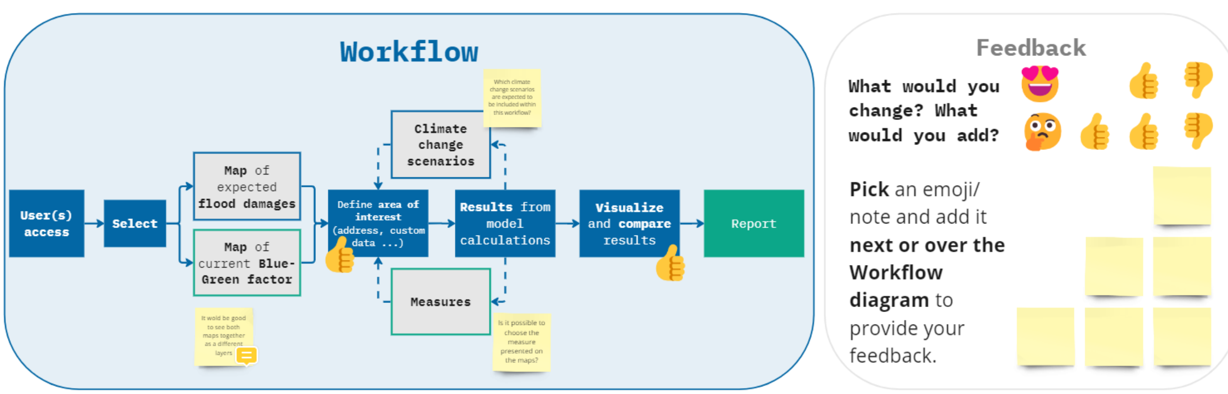


Figure 28. Breakout group 4, SE5. Workflow diagram feedback

As per the feedback received, participants liked different parts (the definition of the area of interest, and the visualisation and comparison of results mainly). They had also some questions and comments:

- It would be good to see both maps together as different layers.
    - We will take this idea into consideration. It is feasible to visualise both of them on the map by using the layer selector.

Comment: It has already been considered to offer a sort of visualisation tool

- **Q**: Can I choose the measure to be presented on the maps?
  - Yes, it has been considered to offer to choose different Blue-Green measures and the effect of these measures will be the visualisation also on the map of Blue-Green factor or on the map of Imperviousness.
- **Q**: Which climate change scenarios are expected to be included within this workflow?
  - We will use precipitation change scenarios. In the first (Pre-pilot Phase) we will use national climate change scenarios; in next phases we intend to combine it with Copernicus Climate Change services.

Then, a part with two or three elements was presented (Figure 29), to obtain feedback of their favourite visualisation. They had to add stars in the option they preferred most.

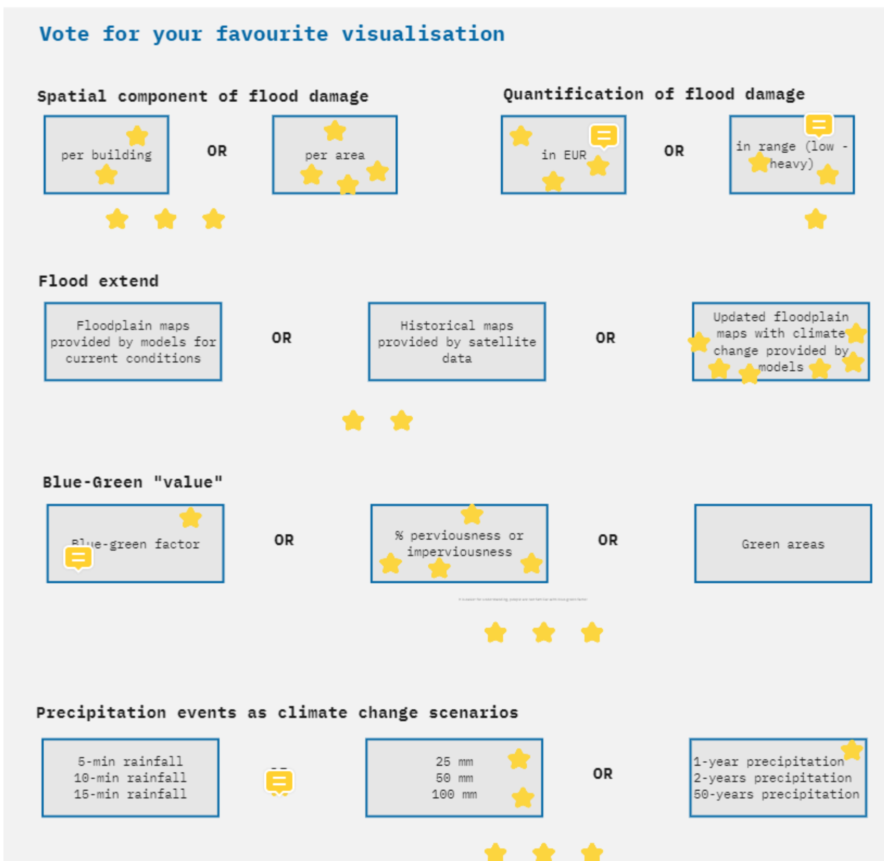


Figure 29. Breakout group 4, SE5. Comparison options preference feedback

The options were the following:

- **Spatial component of flood damage:** visualised **per building** OR **per area?**
  - Participants preferred the visualisation per area (4 stars) over per building (2 stars)
- **Quantification of flood damage**: visualised **in EUR** OR **in range** (low – heavy)?

- The feedback from participants was 3 stars in each option, so it was very balanced. Although it was commented that in range is more reliable, while in Euros is difficult to calculate.

- **Flood extend**: visualise **floodplain maps provided by models for current conditions** OR **historical maps provided by satellite data** OR **updated floodplain maps with climate change provided by models**?
    - The feedback to this was unanimous to the last option (updated floodplain maps with climate change provided by models), with 6 stars.
- **Blue-Green "value"**: visualise the **blue-green factor** OR **% perviousness or imperviousness** OR **green areas**?
    - Participants preferred the % of perviousness or imperviousness (4 stars), rather than the blue-green factor (1 star) or the green areas (no stars). The reason for this is that it is easier for understanding, as people are not familiar with blue-green factor.
- **Precipitation events as climate change scenarios**: visualize **5-min rainfall/ 10-min rainfall/ 15-min rainfall** OR **25 mm/ 50 mm/ 100mm** OR **1-year precipitation/ 2-years precipitation/ 50-years precipitation**?
    - Participants mostly preferred the "mm" option (with 2 stars), with an additional feedback of a participant that they preferred both first options (in minutes and millimeters), and last option only got 1 star.

Afterwards, different comparisons that will be offered in the service were presented to the participants for feedback (Figure 30), where they had to put the finger in the thermometer at the right side to have a say on whether they like or no the comparisons that could be offered.

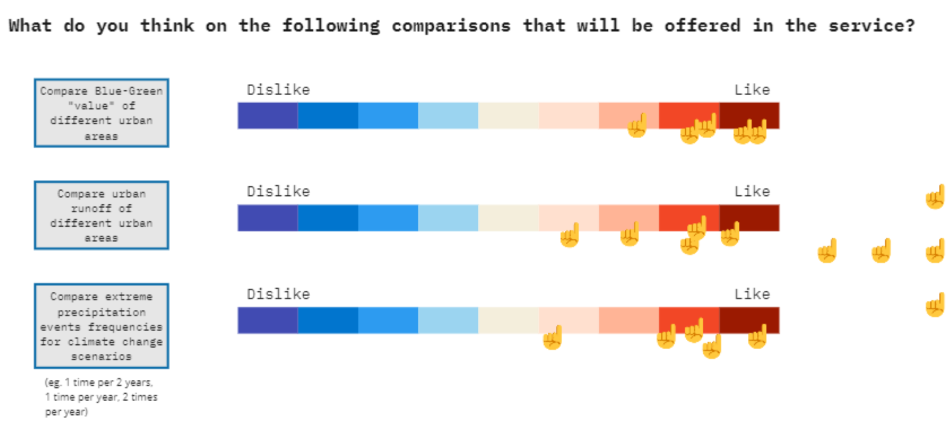


Figure 30. Breakout group 4, SE5. Comparison options preference feedback

The questions were about what the participants think (whether they liked or not) on the following comparisons that will be offered in the service:

- **Compare Blue-Green "value" of different urban areas**
    - Participants liked very much this comparison (5 fingers moved to the like side)

- **Compare urban runoff of different urban areas**
    - Participants liked a lot this comparison too (4 fingers moved to the like side)
- **Compare extreme precipitation events frequencies for climate change scenarios** (e.g. 1 time per 2 years, 1 time per year, 2 times per year)
    - Participants liked very much this comparison as well (4 fingers moved to the like side)

Finally, last part of the session was divided into questions made to participants about the SE5 Urban flood analysis and resilience (Figure 31).

Figure 31. Breakout group 3, SE5. Questions and feedback on Service 5

In the Table 10, participants' feedback for each question is presented in detail:

Table 10. Feedback received to the questions made in Breakout group 4 (SE5)

SE5 – Urban flood island analysis and resilience	
Which level of expertise do you think is needed to use this service?	- Service should be easy to use also for people without expertise - Intermediate level (high school education with basic training) - Medium level of knowledge for use, so that it will be possible to use it by public institutions, for example, sewer managers when issuing approvals for connection, etc. - Since it is an interdisciplinary topic – a low level of expertise should be needed to use the application - Basic knowledge of the processes; not only for the experts, but also more general users
Would you like to have this service available for your city?	- Yes, it will be very interesting to see the result - Yes, as an aid in decision-making when issuing building consents (or when determining project conditions) - Yes, for Ljubljana - Yes, to provide more information to public about floods and solutions to decrease urban runoff
How would you use this service? How does it help take action in your field?	- As an initial information before research or modelling; an overview of the situation - It would help identify the needed scope of green/blue area within the urban limits, since the urban areas are expected to grow in the future - Support to make decisions in spatial planning - To identify critical areas, to start planning and implementing solutions - Identify critical flood areas, support at setting water level thresholds for flooding - Planning optimisation on the roads where flooding sensors will be installed
Do you want to leave any other feedback?	- It seems that there is a need to update current flood maps with climate change scenarios

2.4.5 Topic 5: Synergies with EU projects and initiatives

This part of the session focused on finding EU projects or initiatives related to the overall BUILDSPACE project or with a concrete service, that participants know or are involved in. The Miro frame was prepared with different parts (the overall project and the 4 services seen, as per the previous breakout groups) with space for participants to add post-its. In that way, participants were able to provide further details and explanations (e.g. the link they see, what is the project about, what is the synergy they see, any way of collaboration they are already thinking in etc.).

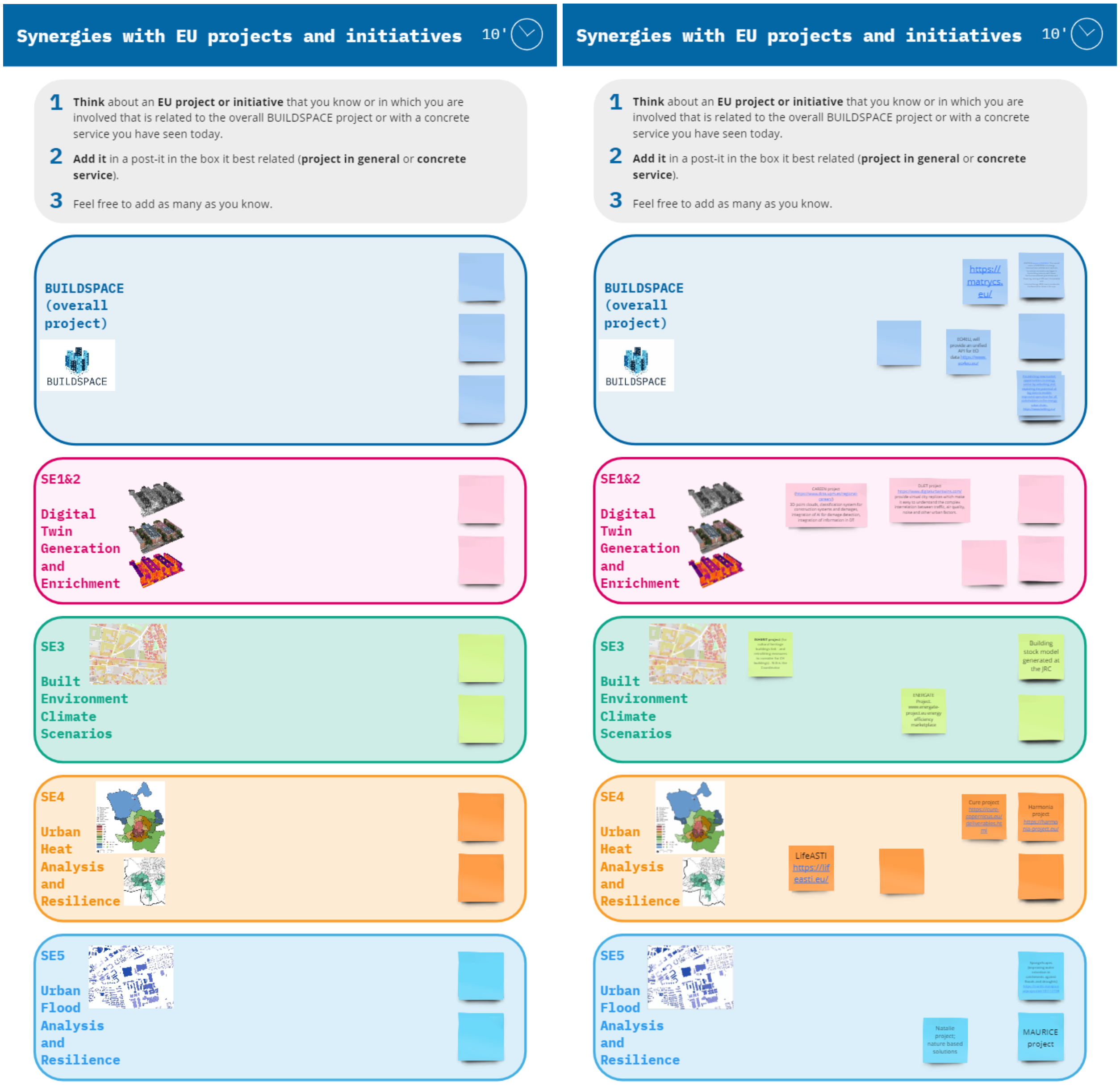


Figure 32. Frame of the Synergies with other EU projects and initiatives.Template (left side), and results (right side)

In Table 11, the feedback on different projects and initiatives proposed to link to BUILDSPACE project (or a specific service) can be seen in detail.

Table 11. Feedback received to the last iterative part of the session "Linked EU projects and initiatives"

Linked EU projects and initiatives	
BUILDSPACE (overall project)	- https://matrycs.eu/ - FORTESIE Home | FORTESIE. The overall vision of FORTESIE is to design, demonstrate, validate and replicate innovative renovation packages in the

Linked EU projects and initiatives	
	building industry with Smart Performance-Based guarantees and financing, aiming at Efficient, Sustainable and Inclusive Energy (ESIE) use to accelerate the Renovation Wave in Europe. - EO4EU, will provide an unified API for EO data https://www.eo4eu.eu/ - Establishing new market opportunities in energy sector by unlocking and exploiting the potential of big data to enable improved operation for all stakeholders in the energy value chain. https://www.bd4nrg.eu/
SE1 & SE2 **Digital Twin Generation and Enrichment**	- CAREEN project (https://www.dcta.upm.es/regional-careen/). 3D point clouds, classification system for construction systems and damages, integration of AI for damage detection, integration of information in DT - DUET project (https://www.digitalurbantwins.com/) provide virtual city replicas which make it easy to understand the complex interrelation between traffic, air quality, noise and other urban factors.
SE3 **Built Environment Climate Scenarios**	- INHERIT project (for cultural heritage buildings link - and retrofitting measures to consider for CH buildings). SLG is the Coordinator: https://inheritproject.eu/ - ENERGATE Project. www.energate-project.eu energy efficiency marketplace - Building stock model generated at the JRC
SE4 **Urban Heat Analysis and Resilience**	- LifeASTI: https://lifeasti.eu/ - Cure project: https://cure-copernicus.eu/ - Harmonia project: https://harmonia-project.eu/
SE5 **Urban Flood Analysis and Resilience**	- Natalie project (https://www.natalieproject.eu/); nature-based solutions - MAURICE project: https://www.interreg-central.eu/projects/maurice/ - SpongeScapes (improving water retention in catchments against floods and droughts). https://cordis.europa.eu/project/id/101112738

2.4.6 Topic 6: Session wrap up and next steps

The session ended thanking attendees for their participation, feedback and comments provided (Figure 33), encouraging them to subscribe to the BUILDSPACE Project Newsletter and social media, to stay tuned for upcoming updates.

Figure 33. Last frame in the Miro Board to thank participants

3 User requirements: current status and updates

Following the second co-creation session, stakeholders were invited to express their views and desires, including the potential use of the five services of the project. From that process, four new user requirements were produced for the services, while the service providers updated the matching of the existing user requirements in context with the development of their service. In addition, the service providers characterised each user requirement according to the feasible implementation to their service.

By analysing the results, 28 out of 49 user requirements were deemed fully addressed (~57%), eight were found partially addressed (~16%) and 13 were deemed out of scope (~26.5%). The feasibility of the user requirements was also in agreement with the updated match of the user requirements with the corresponding services.

Table 12. Updated match of user requirements based on the 2nd co-creation session

RQ ID	Brief description	SE identified	Original Match (based on 1st co-creation session)	Updated Match (based on 2nd co-creation session)	Feasibility
RQ01	Connect district heating consumption data in apartment buildings with available building information (e.g., area, volume, etc.)	**SE1**	Yes (partially)	No	No
		SE3	Yes	Yes (partially)	If available data on DH connected buildings is linked to cadastral data (IDs)
RQ02	Calculate energy efficiency rating of buildings that are connected to the district heating network	**SE3**	Yes	Yes	Yes
RQ03	Visualise building's energy efficiency rating	**SE3**	Yes	Yes	Yes
RQ04	Link "bad" energy efficiency rating buildings with recommended solutions	**SE3**	Yes	Yes	Yes
RQ05	Identify all chimneys by using satellite thermography images	**SE3**	No	No	No
RQ06	Connect every "hot" chimney to building and heated area data	**SE3**	No	No	No

RQ07	Connect every "hot" or used chimney to heat source used in the building	**SE3**	No	No	No
RQ08	Create a list of heated buildings and used heat source	**SE3**	Yes	Yes	Yes
RQ09	Calculate building's heat consumption	**SE3**	Yes	Yes	Yes
RQ10	Calculate air pollution for each heat source	**SE3**	No	No	No
RQ11	Measure the roof area that is available for solar energy generation	**SE1**	Yes (partially)	Yes (partially)	Yes (partially) to calculate the dimension of the specific area
		SE3	Yes	Yes	Yes
RQ12	Measure the shaded roof area	**SE1**	Yes (partially)	No	No
		SE3	Yes	Yes	Yes
RQ13	Calculate the yearly output of solar panels	**SE3**	Yes	Yes	Yes
RQ14	Calculate the available amount of solar energy (solar energy potential of the building)	**SE3**	Yes	Yes	Yes
RQ15	Visual representation of the progress of construction works on daily/weekly basis	**SE2**	Yes (partially)	No	No
RQ16	Identify quickly and accurately hazards that are associated with groundwater levels, taking also into account the weather changes	**SE1**	No	No	No
RQ17	Visual representation of green energy production and related savings	**SE1**	No	No	No
RQ18	Visual identification of thermal bridges of the buildings	**SE1**	Yes (partially)	Yes (partially)	Yes
		SE2	Yes (partially)	Yes	Algorithm that supports the detection of thermal bridges using artificial intelligence and

					categorises them according to type. A report will be generated
RQ19	Detect cracks in the building structure or displacement of the building or surrounding buildings	**SE2**	Yes (partially)	Yes, in Piraeus pilot	Algorithm that supports the detection of cracks using artificial intelligence. A report will be generated
RQ20	Provide a baseline indicator value for the energy performance of municipal buildings, as well as a procedure to replicate on more municipal or other buildings	**SE2**	Yes (partially)	No, just thermal performance (RQ21)	N/A
		SE4	Yes (partially)	Yes (partially)	Baseline indicator value will be addressed from the building's energy demand point of view.
RQ21	Provide a baseline indicator value for the thermal performance, as well as a procedure to replicate on more municipal or other buildings	**SE2**	Yes (partially)	Yes (partially)	Report will be generated with a list of the incidences found in each façades/roof.
		SE4	No	No	N/A
RQ22	Measure the impact of interventions at building scale	**SE1**	Yes (partially)	Yes (partially)	Yes (partially)
		SE2	Yes (partially)	No	N/A
		SE4	No	No	N/A
RQ23	Measure the impact of interventions at city scale	**SE1**	Yes (partially)	No	No
		SE4	No	No	N/A
RQ24	Provide a baseline indicator value for the social vulnerability to urban heat	**SE4**	Yes	Yes	Yes

RQ25	Measure relevant heat indicator values at any time	**SE4**	Yes (partially)	Yes (partially)	Yes (partially)
RQ26	Acquire necessary expertise and equipment to perform building and city level heat analysis at any time, at any building	**SE4**	No	No	N/A
RQ27	Identify specific areas where urban heat is significantly higher than the rest of the city	**SE4**	Yes	Yes	Yes
RQ28	Measure the impact of interventions at the city level regarding urban heat and social vulnerability	**SE4**	No	No	N/A
RQ29	Develop an online version of the already existing Flood Damage Assessment Methodology (FDAM) tool	**SE5**	Yes	Yes	Yes
RQ30	Upgrade FDAM to address the expected damage in urban flooding caused by short-term extreme rainfall events, while also allowing engagement of end-users	**SE5**	No	Yes (partially)	Yes (partially)
RQ31	Make the upgraded FDAM more user-friendly in terms of eliminating the needs for GIS and requiring programming skills by the end-users	**SE5**	Yes	Yes	Yes
RQ32	Visualise flooding hotspots by combining available off-line flooding altitude data, satellite urban floods images and satellite terrestrial altitude data.	**SE5**	No	No	N/A
RQ33	Calculate the flood damage per m2 of urban area	**SE5**	Yes	Yes	Yes
RQ34	Calculate the flood damage per m of urban infrastructure	**SE5**	Yes	No	N/A
RQ35	Calculate the flood damage per building	**SE5**	Yes	Yes	Yes
RQ36	Build evidence of urban planning events by enabling to make individual	**SE5**	No	No	N/A

	georeferenced inputs by the end users				
RQ37	Calculate the terrestrial altitude from satellite LIDAR DEM model with open-source software: QGIS, LAStools, FUSION, SAGA and make a kind of intersection of them	**SE5**	No	No	N/A
RQ38	Calculate the average Normalized Difference Vegetation Index (NDVI) per buildings or buildings‘ plots	**SE5**	Yes	Yes	Yes
RQ39	Assess how blue-green is a building or a building's plot	**SE5**	Yes	Yes	Yes
RQ40	Identify where are the critical points in view of high urban flooding risk	**SE5**	Yes	Yes	Yes
RQ41	Create NDVI trends over seasons and years	**SE5**	Yes	Yes	Yes
RQ42	Monitor existing blue-green infrastructure measures by attaching photos and writing some connected text/descriptions	**SE5**	Yes	No	N/A
RQ43	Calculate the terrestrial altitude from satellite LIDAR DEM model with open-source software: QGIS, LAStools, FUSION, SAGA	**SE5**	No	No	N/A
RQ44	Combine available terrestrial with satellite data to identify potential flooding hotspots	**SE5**	Yes	Yes	Yes
RQ45	Analyse the effects of blue-green infrastructure (BGI) measures on flooding resilience of buildings	**SE5**	Yes	Yes	Yes
RQ46	Identify not visible humidity	**SE2**	N/A	Yes	Algorithm that supports the detection of humidity using artificial intelligence. A report will be generated

RQ47	Identify non-functional solar panels	**SE2**	N/A	Yes, in Mostostal pilot	Algorithm that supports the detection of non-functional solar panels using artificial intelligence. A report will be generated
RQ48	Offer different climate-induced change scenarios	**SE5**	N/A	Yes	Yes
RQ49	Offer different retrofitting non-structural scenarios (measures)	**SE5**	N/A	Yes	Yes

Following the second user requirements update, a third user requirements update was implemented. This third round of updates showcased different results, where 24 out of 49 user requirements were deemed fully addressed (~49%), 9 were found partially addressed (~18%) and 16 were deemed out of scope (~33%). The feasibility of the user requirements was also in agreement with the updated match of the user requirements with the corresponding services. The results of this third round are presented in Table 11 below (In red font the specific, updated RQs):

Table 13. Updated match of user requirements based on a third feedback round

RQ ID	Brief description	SE identified	Original Match (based on the 2nd co-creation session)	Updated Match (based on a third feedback round)	Feasibility
RQ01	Connect district heating consumption data in apartment buildings with available building information (e.g., area, volume, etc.)	**SE1**	No	No	No
		SE3	Yes (partially)	Yes	DH data available
RQ02	Calculate energy efficiency rating of buildings that are connected to the district heating network	**SE3**	Yes	Yes	For residential buildings (focus of the service)

RQ03	Visualise building's energy efficiency rating	**SE3**	Yes	Yes	For residential buildings (focus of the service)
RQ04	Link "bad" energy efficiency rating buildings with recommended solutions	**SE3**	Yes	Yes (partially)	User can create scenarios with different combination of retrofitting measures, and compare and know relevant KPIs
RQ05	Identify all chimneys by using satellite thermography images	**SE3**	No	No	No
RQ06	Connect every "hot" chimney to building and heated area data	**SE3**	No	No	No
RQ07	Connect every "hot" or used chimney to heat source used in the building	**SE3**	No	No	No
RQ08	Create a list of heated buildings and used heat source	**SE3**	Yes	Yes (partially)	The heated system of the residential buildings will be assigned, user will be able to see it in the retrofitting strategies scenarios and can change it if it is not accurate
RQ09	Calculate building's heat consumption	**SE3**	Yes	Yes (partially)	The heat consumption of the residential buildings will be estimated, user will be able to see it in the retrofitting strategies scenarios and can change the heating system if it is not accurate
RQ10	Calculate air pollution for each heat source	**SE3**	No	No	No
RQ11	Measure the roof area that is available for solar energy generation	**SE1**	Yes (partially)	Yes (partially)	Yes (partially) to calculate the dimension of the specific area
		SE3	Yes	Yes	Yes
RQ12		**SE1**	No	No	No

	Measure the shaded roof area	**SE3**	Yes	Yes	Yes
RQ13	Calculate the yearly output of solar panels	**SE3**	Yes	Yes	Yes
RQ14	Calculate the available amount of solar energy (solar energy potential of the building)	**SE3**	Yes	Yes	Yes
RQ15	Visual representation of the progress of construction works on daily/weekly basis	**SE2**	No	No	No
RQ16	Identify quickly and accurately hazards that are associated with groundwater levels, taking also into account the weather changes	**SE1**	No	No	No
RQ17	Visual representation of green energy production and related savings	**SE1**	No	No	No
RQ18	Visual identification of thermal bridges of the buildings	**SE1**	Yes (partially)	Yes (partially)	Yes
		SE2	Yes	Yes	Algorithm that supports the detection of thermal bridges using artificial intelligence and categorises them according to type. A report will be generated
RQ19	Detect cracks in the building structure or displacement of the building or surrounding buildings	**SE2**	Yes, in Piraeus pilot	Yes, in Piraeus pilot	Algorithm that supports the detection of cracks using artificial intelligence. A report will be generated

RQ20	Provide a baseline indicator value for the energy performance of municipal buildings, as well as a procedure to replicate on more municipal or other buildings	**SE2**	No, just thermal performance (RQ21)	No	No
		SE4	Yes (partially)	Yes (partially)	Baseline indicator value will be addressed from the building's energy demand point of view.
RQ21	Provide a baseline indicator value for the thermal performance, as well as a procedure to replicate on more municipal or other buildings	**SE2**	Yes (partially)	Yes (partially)	Report will be generated with a list of the incidences found in each façades/roof.
		SE4	No	No	No
RQ22	Measure the impact of interventions at building scale	**SE1**	Yes (partially)	Yes (partially)	Yes (partially/ visualisation of building)
		SE2	No	No	No
		SE4	No	No	N/A
RQ23	Measure the impact of interventions at city scale	**SE1**	No	No	No
		SE4	No	No	N/A
RQ24	Provide a baseline indicator value for the social vulnerability to urban heat	**SE4**	Yes	Yes	Thresholds for vulnerability factors will be defined.
RQ25	Measure relevant heat indicator values at any time	**SE4**	Yes (partially)	Yes(Partially)	Heat indicator will be available for a determined temporal frame.
RQ26	Acquire necessary expertise and equipment to perform building and city level heat analysis at any time, at any building	**SE4**	No	No	N/A

RQ27	Identify specific areas where urban heat is significantly higher than the rest of the city	**SE4**	Yes	Yes	SE4 will identify hotspots within the city
RQ28	Measure the impact of interventions at the city level regarding urban heat and social vulnerability	**SE4**	No	No	N/A
RQ29	Develop an online version of the already existing Flood Damage Assessment Methodology (FDAM) tool	**SE5**	Yes	Yes	Yes
RQ30	Upgrade FDAM to address the expected damage in urban flooding caused by short-term extreme rainfall events, while also allowing engagement of end-users	**SE5**	Yes (partially)	Yes (partially)	The service will not upgrade the FDAM methodology itself, but will upgrade its application by using different climate and retrofit scenarios (including for short-term extreme rainfall events). Allowing engagement of end-users by photos is out of the scope of the service from technical provider side.
RQ31	Make the upgraded FDAM more user-friendly in terms of eliminating the needs for GIS and requiring programming skills by the end-users	**SE5**	Yes	Yes	Yes
RQ32	Visualise flooding hotspots by combining available off-line flooding altitude data, satellite urban floods images and satellite terrestrial altitude data.	**SE5**	No	No	No

RQ33	Calculate the flood damage per m2 of urban area	**SE5**	Yes	Yes	Yes
RQ34	Calculate the flood damage per m of urban infrastructure	**SE5**	No	No	No
RQ35	Calculate the flood damage per building	**SE5**	Yes	Yes	Yes
RQ36	Build evidence of urban planning events by enabling to make individual georeferenced inputs by the end users	**SE5**	No	No	No
RQ37	Calculate the terrestrial altitude from satellite LIDAR DEM model with open source software: QGIS, LAStools, FUSION, SAGA and make a kind of intersection of them	**SE5**	No	No	No
RQ38	Calculate the average Normalised Difference Vegetation Index (NDVI) per buildings or buildings' plots	**SE5**	Yes	Yes	Yes
RQ39	Assess how blue-green is a building or a building's plot	**SE5**	Yes	Yes	We will do it by Blue-green factor calculation and visualisation.
RQ40	Identify where are the critical points in view of high urban flooding risk	**SE5**	Yes	Yes	We will do it by Blue-green factor calculation and visualisation.
RQ41	Create NDVI trends over seasons and years	**SE5**	Yes	No	The scenario of seasonal and annual changes in the NDVI was discarded due to lack of interest and understanding of stakeholders and proved to be inappropriate for decision-making due to excessive complexity.

RQ42	Monitor existing blue-green infrastructure measures by attaching photos and writing some connected text/descriptions	**SE5**	No	No	No
RQ43	Calculate the terrestrial altitude from satellite LIDAR DEM model with open-source software: QGIS, LAStools, FUSION, SAGA	**SE5**	No	No	No
RQ44	Combine available terrestrial with satellite data to identify potential flooding hotspots	**SE5**	Yes	Yes	Yes
RQ45	Analyse the effects of blue-green infrastructure (BGI) measures on flooding resilience of buildings	**SE5**	Yes	Yes	We will do it by Blue-green factor calculation and visualisation.
RQ46	Identify not visible humidity	**SE2**	Yes	Yes	Algorithm that supports the detection of humidity using artificial intelligence. A report will be generated
RQ47	Identify non-functional solar panels	**SE2**	Yes, in Mostostal pilot	Yes, in Mostostal pilot	Algorithm that supports the detection of non-functional solar panels using artificial intelligence. A report will be generated
RQ48	Offer different climate-induced change scenarios	**SE5**	Yes	Yes	Yes
RQ49	Offer different retrofitting non-structural scenarios (measures)	**SE5**	Yes	Yes	Yes

4 Use cases: current status and updates

Technical Use Cases of BUILDSPACE project have been developed as part of T2.3 "Social engagement for co-creating the BUILDSPACE use-cases and applications", led by CARTIF. The process was initially defined in D2.1 "BUILDSPACE user requirements" and further explained in D2.2 "Use cases and Design of applications' dashboards", building on the outputs of task 2.1 "User requirements elicitation" and on the feedback gathered during the first co-creation session (part of the D2.2), as well as the first version of BUILDSPACE use cases.

The feedback gathered during the second co-creation session has been considered by the different services developers, and in combination with the delivery of the first technology release (D3.1), in which the service developers faced the development of initial features, some of the use cases reported in D2.2 needed to be updated. In the following tables, the updated use cases in respect to those reported in D2.2, are included:

- Table 14 is the updated version of UC2.2, related to Service 2 (deployment in Piraeus Pilot).
- Table 15 and Table 16 are the updated versions of UC3.1 and UC3.2, related to Service 3.
- Both Table 17 and Table 18 are the updated versions of the UC5.1 and UC5.2, related to Service 5.

Table 14. Updated Use Case 2.2 related to SE2 Digital Twin Semantic Enrichment

Use case	**UC2.2 – Piraeus intervention areas of a municipal building**	
Related user requirements	**Functional**	RQ18, RQ19, RQ20, RQ21, RQ22
	Non-functional	RQ46, RQ47, RQ48, RQ49, RQ50
Description	The use case corresponds to pilot 3, MoP	
Actors	Municipalities	
Inputs	-	
Outputs	3D point cloud data, RGB and thermal images of the interior and exterior	
Modules / External tools	Hardware: Drone equipped with thermal and RGB camera (UAV) and GPS (georeferenced) for the external envelope. Software: Pix4D, Agisoft Metashape, Reality Capture or Drone Deploy. Manufacture SLAM software.	
Preconditions	Legal issues (depending on the region), weather.	
Normal sequence	**Step**	**Action**
	1	A date and time are set, considering the weather, flight permits are requested, and legal issues are resolved (UAV)

	2	The place is visited to see if there are any inconveniences when flying. Busy roads, vegetation, electric cables or elements that may interrupt the flight outside. And the best flight path is studied and programmed. (UAV)
	3	The drone is flown to capture the point cloud, thermal and RGB images. (UAV)
	4	A point cloud is obtained with an RGB and thermal model of the outdoor, which have to be overlaid. (UAV)
	5	This information will be used to generate the digital twin (SE1).
	6	Detection of critical and intervention areas through AI
Post conditions	The resolution of the thermal camera is lower than the resolution of the RGB camera, so some details or small elements of the images could be lost in the processing of the model.	
Exceptions	**Related step**	**Action**
	1	In case of the drone does not have thermal camera, the information contained in the 3D point cloud will be RGB and XYZ
Linked use cases	UC1.1 (that will use the information from this UC)	
Importance	High	

Table 15. Updated Use case 3.1 related to SE3 Built Environment Climate Scenarios

Use case	**UC3.1 – Assessment of energy demand and consumption**	
Related user requirements	**Functional**	RQ01, RQ02, RQ03, RQ08, RQ09.
	Non-functional	RQ46, RQ48, RQ49, RQ50, RQ51, RQ52, RQ53
Description	This use case corresponds to the calculation and estimation of the energy demand of the building stock, based on buildings' data (year of construction, geometry, height, use/typology, and other characteristics). It will also calculate the energy demand in the future according to different climate change scenarios: standard accepted CMIP6 scenarios (SSPs and RCPs) through the downscaling of climate data and their bias-correction with historical data from weather stations.	
Actors	Urban stakeholders (urban planners, real estate and construction companies, policy makers…)	
Inputs	Data inputs: on buildings' data (cadastral data, OpenStreetMap…), historical weather data, future climate data (from models and scenarios), energy use profiles…	
Outputs	Tool to show the calculation and visualisation of energy demand data of the pilot building stock focused in residential (especially MFH) but other buildings use would be considered, such us public buildings. Assessment of the evolution of the energy demand in the future taking into account climate change scenarios.	
Preconditions	Data inputs are available.	

	Data related to buildings is collected and categorised according to different building characteristics. Building stock energy performance (heating and cooling energy demand, as well as DHW) is calculated or estimated according to previous processed data and calibrated taking into account real consumption data. Standard CMIP6 scenarios (SSPs-RCPs) climate data are downscaled through bias-correction with historical climate data. Building stock energy performance is calculated according to climate scenarios with different time horizon: short term (in 3-6 years), medium term (in 20-30 years) and long term (year 2100).	
Normal sequence	**Step**	**Action**
	1	A map of the pilot area is shown with building energy performance (heating demand) of the buildings coloured according to the EPC label colour scale.
	2	The user can obtain additional information of the buildings that are seeing in the screen. When clicking on a single building, the specific information about it will be also shown.
	3	The user can select a future climate change scenario (from three options available, which are precalculated) to see how the energy demand of the building stock will be in the future years and scenarios.
	4	The service combines the information of the current energy demand with the climate change scenario selected.
	5	The service provides comparable information (data and visualization) of the current and future (climate scenario selected) energy performance of the buildings.
Post conditions	Rating of energy performance estimation of pilot building stock. Rating of energy performance forecasting of pilot building stock in future scenarios (considering climate change).	
Linked use cases	UC3.2 and UC3.3 need of this UC operative to be executed.	
Importance	High	

Table 16. Updated Use case 3.2 related to SE3 Built Environment Climate Scenarios

Use case	**UC3.2 – Assessment of retrofitting strategies**	
Related user requirements	**Functional**	RQ04.
	Non-functional	RQ46, RQ48, RQ49, RQ50, RQ51, RQ52, RQ53.
Description	This use case corresponds to the calculation of KPIs to retrofitting strategy gains, based on retrofitting measures defined, as well as its modelling according to climate change scenarios in future.	

<table>
<tr><td></td><td colspan="2">A specific retrofitting scenario will be covered using UC3.3 for the heating and cooling energy consumption, through PV deployment.</td></tr>
<tr><td>Actors</td><td colspan="2">Urban stakeholders (urban planners, real estate and construction companies, policy makers…)</td></tr>
<tr><td>Inputs</td><td colspan="2">UC3.1 is executed.
Data inputs: building retrofitting measures defined</td></tr>
<tr><td>Outputs</td><td colspan="2">Tool to show the changes in buildings energy demand (and consumption) with the application of different retrofitting measures. It shows also the change in future energy demand with the application of retrofitting strategies according to the climate change scenarios.</td></tr>
<tr><td>Preconditions</td><td colspan="2">UC3.1 and UC3.3 is available.
Building retrofitting measures are defined.</td></tr>
<tr><td rowspan="5">Normal sequence</td><td>Step</td><td>Action</td></tr>
<tr><td>1</td><td>Selection of a building.</td></tr>
<tr><td>2</td><td>User selects one or more retrofitting measures to apply to the building from those available in the tool, grouped according to the type of measure.</td></tr>
<tr><td>3</td><td>The service combines the outcome information of the UC3.1 with that of the retrofitting measures selected and provides the calculation of how the building energy performance changes.</td></tr>
<tr><td>4</td><td>The service provides comparable information (data and visualization) of the current and future (climate scenario selected) energy performance of the building (UC3.1) and with the application of the selected retrofitting strategies.</td></tr>
<tr><td>Post conditions</td><td colspan="2">KPIs on retrofitting gains are calculated to see how the energy demand and consumption of buildings changes after application of retrofitting measures.
KPIs on retrofitting gains calculation for energy performance of buildings change in future scenarios (considering climate change).</td></tr>
<tr><td rowspan="2">Exceptions</td><td>Related step</td><td>Action</td></tr>
<tr><td>1.1</td><td>User will see the estimated information for the selected building and will be able to edit the parameters so that it is better adjusted to the reality of the building (e.g. if a great energy refurbishment happened, or different energy system that those assigned).</td></tr>
<tr><td>Linked use cases</td><td colspan="2">UC3.1 needs to be executed previously so this UC can be executed.
For some scenarios UC3.3 could be need</td></tr>
<tr><td>Importance</td><td colspan="2">Medium</td></tr>
</table>

Table 17. Updated Use case 5.1 related to SE5 Urban Flood Analysis and Resilience

<table>
<tr><th>Use case</th><th colspan="2">UC5.1 – Flood damage hotspots</th></tr>
<tr><td rowspan="2">Related user requirements</td><td>Functional</td><td>RQ29, RQ31, RQ33, RQ35, RQ48, RQ49</td></tr>
<tr><td>Non-functional</td><td>RQ46, RQ47, RQ48, RQ49, RQ50, RQ51, RQ52, RQ53</td></tr>
<tr><td>Description</td><td colspan="2">This use case is the calculation of expected flood damage for buildings due to fluvial floods with online application-based visualisations. The damage per building or urban area will be assessed by FDAM methodology by overlying flooding map, calculated terrestrial altitude and georeferenced users' inputs. This will be visualised for different climate-induced change scenarios to floods.</td></tr>
<tr><td>Actors</td><td colspan="2">Civil protection, infrastructure providers and public authorities, urban water managers, real estate and construction companies, landowners and building owners and citizens, insurances.</td></tr>
<tr><td>Inputs</td><td colspan="2">Buildings and consolidated cadastre of public infrastructure, flood damage values, current land use, planned land use, registry of spatial units, registry of assets, water cadastre, protection regimes of cultural heritage
Floods extend map</td></tr>
<tr><td>Outputs</td><td colspan="2">Expected flood damage per building or urban area for the selected area on a georeferenced map. A tool will be available to make a comparison between different non-structural measures and climate scenarios.</td></tr>
<tr><td>Modules / External tools</td><td colspan="2">Flood damage values from FDAM methodology.</td></tr>
<tr><td>Preconditions</td><td colspan="2">Uploading the data with the calculated georeferenced maps and corresponding metadata. The user must be logged in to access the reporting features.</td></tr>
<tr><td rowspan="5">Normal sequence</td><td>Step</td><td>Action</td></tr>
<tr><td>1</td><td>An overall map is displayed in the web platform and the user can select the Flood Damage Analysis Module.</td></tr>
<tr><td>2</td><td>The flood damage hotspots map of all pilot area is displayed; the expected annual flood damage hotspots are visualised in red colour scale according to the value of flood damage.</td></tr>
<tr><td>3</td><td>The user can select the area of interest either by uploading own data (e.g. shapefile or geojson) or to draw it directly in the application by a drawing tool.</td></tr>
<tr><td>4</td><td>On the map appears the building stock with data result from model calculations with attributes to selected buildings.</td></tr>
</table>

	5	Scenarios menu appears. User can select different flood scenarios (Q10, Q100, Q5000) and adaptation by non-structural measures scenarios (e.g., buildings without basements, buildings with non-living basements, non-living ground floor), and compare them.
	6	A generic report with information and comparison about the expected annual flood damage can be generated.
Post conditions	Shapefile available for downloading as well as a detailed expected flood damage analysis report in PDF and table or graph can be generated.	
Exceptions	**Related step**	**Action**
	4.1	By hovering the mouse over the targeted buildings, and clicking in one of them, the option to download report file for this building is activated.
Linked use cases	Linked to UC5.2, but independent (not needed to be UC5.1 executed).	
Importance	High; failed execution of UC5.1 it wouldn't block the execution of a following step (UC5.2), but it is a key functionality for the service.	

Table 18. Updated Use case 5.2 related to SE5 Urban Flood Analysis and Resilience

Use case	**UC5.2 – Blue-green infrastructure impact**	
Related user requirements	**Functional**	RQ38, RQ39, RQ40, RQ41, RQ42, RQ44, RQ45
	Non-functional	RQ46, RQ47, RQ48, RQ49, RQ50, RQ51, RQ52, RQ53
Description	This use case corresponds to assessment of the potential of BGI to impact flood vulnerability and resilience to promote BGI measures implementation on the building and neighbourhood level.	
Actors	• Infrastructure providers and public authorities • Potential investors, land developers, landowners and building owners • Urban planners, Urban water managers	
Inputs	Planned land use, Blue-green factor map, map of soil hydrological groups, weather (precipitation) data, NDVI map, catalogue of different BGI measures with condition instructions for building renovations	

Outputs	Runoff volumes hotspots and Blue-green factor per land use unit visualized on a georeferenced map, both with the application of some BGI measures, in the present and in different climate change scenarios. Both results can be compared with another area of interest.	
Preconditions	Uploading the data with the calculated georeferenced maps and corresponding metadata: • NDVI map from Sentinel 2 data, • Blue-green factor map from CLMS high resolution products (Imperviousness Grassland, Tree Cover Density, Small Woody Features), • Different climate change scenarios	
Normal sequence	**Step**	**Action**
	1	A standard (orthophoto) map appears in the web platform, showing the pilot area (Ljubljana metropolitan area) and the user chooses a topic layer “Flood vulnerability hotspots”
	2	By the selected topic, an interactive-colored is displayed with a green color scale according to the Blue-green factor, an assessment of the blue-green infrastructure implementation impact with attributes to building plots, as an indices of building flood resilience.
	3	The user selects the area of interest (either typing, zooming, by uploading own data, e.g., shapefile or geojson, drawing it directly in the application by a drawing tool)
	3	On the map appears the building stock with data result from model calculations with runoff volumes hotspots in blue colour scale according to the value of runoff volumes.
	4	If the user clicks on one building or area, there is shown a value of Blue-green factor and runoff visualisation diagrams (a runoff volume, precipitation high, runoff hydrogram).
	5	When the user has received the information, he can choose to compare certain information. There are three options for this: 1: Compare the statistics with another area. For this, the process from identifying an area of interest until receiving extra info about the area will need to be done again. 2: Select different measures: A list of possible measures will be present. A user can select a measure. If a measure has been selected, the model needs to be ran again to calculate the new results. 3: Select different climate scenarios. Same as option 2, but with different climate scenarios. Also, for this option, the model will need to run again.
	6	User can input georeferenced photo or comments about existing BGI measures.
	7	A generic report with information and comparison about a value of Blue-green factor and runoff can be generated.

Post conditions	Shapefile available for downloading as well as a detailed flood resilience analysis report in PDF and table can be generated.
Linked se cases	Linked to UC5.1, but independent (not needed to be UC5.2 executed).
Importance	High; failed execution of UC5.2 it wouldn't block the execution of a following step (UC5.1), but it is a key functionality for the service.

5 Visualisation of the BUILDSPACE services

This section follows on the work reported in deliverable D2.2 Use cases and design of applications' dashboards, and finalises Task 2.4 Co-design innovative user-friendly environments. The goal is to present all designs and mock-ups that have been produced, using the wireframe guide. First, the methodology and some definitions are explained. Secondly, the updated wireframe guide is portrayed. Finally, the designs are shown for each service.

5.1 Methodology and definitions

In Task 2.4, a comprehensive wireframe guide was developed that portrayed wireframe blocks and could be used by the different service developers to develop their respective applications. The goal was to create a common feel, look and user experience for all BUILDSPACE applications. While the wireframes resulted in a common user experience due to the similar screens and functionalities, they did not assist in creating a common look and feel. To achieve this, it was necessary to create mock-ups with detailed styling elements.

A mock-up is a static visual model of what a web page, website, or web application will look like in its final form. They start from the produced wireframes and resemble exactly what the final application will look like. They can then be used as a tool for developers to code the application. Mock-ups include all styling elements such as colours and fonts. While originally Task 2.4 dictated to create general mock-ups for all services, it was decided that would not be practical. While creating the general wireframes, it became clear that the different services are too different and distinct to create meaningful mock-ups that would apply to all services. Therefore, it was decided to expand the already produced wireframe guide with mock-up examples for Service 5 and include basis styling information that could be used by all service developers. To ensure the common look and feel, it was decided to have the same navigation bar and acknowledgement bar for all services. These two elements were therefore, designed and explained in more detail in the updated wireframe guide.

5.2 Updated wireframe guide

The wireframe guide was updated on two critical parts. The mock-ups and designs as explained in the previous part, as well as some technical information to assist in the application development. This section will first explain the technical editions, which are distributed throughout the guide, linked to relevant wireframes. Then, the mock-ups and designing section will be explained, added as an addendum to the back of the wireframes guide.

5.2.1 Technical update

First a general technical framework was given to assist and advise the service developers:

For the general development of the applications, React (*https://react.dev*) was recommended. React stands out as a powerhouse JavaScript library in modern web development, offering a paradigm shift in building dynamic and interactive user interfaces. One of the most important reasons for recommending React is the vast community of developers and impressive libraries built for React, making development much faster. Most of the libraries we recommend below are for React, as we consider it one of the best frameworks.

As the map is the most vital and prevalent part of the applications, a comparison between different mapping libraries is given:

Choosing the proper mapping library plays a significant role in the developed system's look and feel and the user's interaction with the system. Mapping libraries provide various tools and functionalities for working with maps in web applications. The choice of a mapping library depends on your project's specific requirements and use cases. Below is a small summary of the three mapping libraries that are recommended:

Table 19. Comparison between the most used mapping libraries

Mapbox GL JS	Leaflet	MapTiler
Type: Vector-based, WebGL-powered. **Features**: • High-performance rendering using WebGL. • Supports interactive vector maps. • Excellent for visualizing large datasets. • Offers a wide range of customization. **When to choose:**	**Type**: Lightweight and versatile. **Features**: • Simple and easy to use. • Extensive plugin ecosystem. • Good for small to medium-sized applications. • Works well with other JavaScript frameworks.	**Type:** Tile server and mapping platform. **Features:** • Provides tools for creating custom maps and hosting map tiles. • Supports vector tiles and raster tiles. • Suitable for web and mobile applications • Supports various GIS data formats.

• You require high-performance maps with smooth interactions. • Your application needs advanced customization and styling. • Vector maps are preferable for your use case.	**When to choose:** • You need a lightweight and straightforward solution. • Your application is relatively simple, and you want quick integration. • You want a library that integrates easily with other front-end frameworks.	**When to choose:** • You need a mapping solution that includes both map design tools and tile hosting. • Your project requires customization and design flexibility. • Suitable for applications where hosting map tiles is a primary requirement.

For all icons, we recommend leveraging Font Awesome, a widely recognised and user-friendly icon font library, for enhanced visual appeal and consistent iconography in the designs. Font Awesome is a versatile icon font library that provides a comprehensive set of scalable vector icons.

For developing the layer selector and other dropdowns: 'react-select' caters to your selection needs with elegance and functionality. 'React-select' is a go-to library if you are looking for a consistent design and smooth development in all dropdowns or multi-selects.

For the search box, the recommended API is the Google Places API as it allows users to search both on addresses as POI's.

As toast messages are major interaction points with users, it's always better to provide effective and visually appealing notifications to enhance user experience. One of the remarkable libraries in the space for react development is 'react-toastify'.

To incorporate graphs in the data panel, the following advice is given: In systems that leverage data, charts play a pivotal role as they transcend mere numbers, providing a dynamic canvas for users to explore, analyse, and comprehend the nuances within the data landscape. And when it comes to creating stunning and interactive charts in React applications, Recharts emerges as a powerful and user-friendly charting library. We highly recommend incorporating Recharts to effortlessly bring your data to life through an array of customisable and responsive charts.

5.2.2 Design and mock-up advice

As each service is very distinctive in its functionalities, it is not possible to create meaningful mock-ups that are applicable for all services. Therefore, it is chosen to limit the mockuping to an example for service 5 and some general styling advice. As the navigation bar is an element that is common, this will be explained more in detail. Also, an acknowledgement bar at the bottom will be explained.

5.2.2.1 General styling information

In the overall styling of the Service 5 application, we have curated a cohesive visual identity by incorporating BUILDSPACE'S primary brand colours and IBM Plex Mono font. We have chosen a light theme approach as it enhances the look and feel of the application by increasing minimalism and user-friendliness. The colour palette, drawn from BUILDSPACE's brand identity, plays a massive role in enhancing the aesthetic appeal and keeping brand recognition and consistency similar to BUILDSPACE across the entire application.

We have also implemented different typefaces to increase user experience, as each typeface carries its own personality, adding distinction to the words in the application. Headings are bold to invite attention, while body texts are lighter and friendlier for easy reading. This use of typefaces within the IBM Plex Mono font family weaves a narrative, shaping the tone and guiding you through the application's content.

5.2.2.2 Navigation and acknowledgment bar

To create consistency between all BUILDSPACE services and the core platform, a common navigation bar would be beneficial. The navigation bar has a very simple but modern design. The background of the bar is white. On the left side, the BUILDSPACE logo is presented. Next to the logo, a vertical line separates the logo from the service name. The service name should be written vertically, as can be seen in Figure 34. The middle of the bar remains empty to maintain a clean look and feel. On the right side of the bar, there is room for buttons. Each service is free to add and name the buttons as needed. We suggest limiting the amount of buttons to 3 or 4. A button should be grey when not selected, and blue when selected. These buttons should redirect to a different page in the application where the navigation bar is still visible. This to make sure that easy navigation in the application is possible. If appliable: on the far right side of the navigation bar, a user icon is visible. This can be used to consult which account is used and could also serve as a redirect back to the core platform.

Figure 34. Navigation bar

Besides the navigation bar, an acknowledgement bar is present at the bottom of the application at all times. This bar acknowledges the contribution of the European Union's Horizon Programme. As can be seen in Figure 35, the acknowledgement bar is a simple white bar with a European flag on the left. Next to the flag, the following text is shown: "The BUILDSPACE project has received funding from the European Union's Horizon 2023 Research and Innovation Programme under grant agreement No. 101082575."

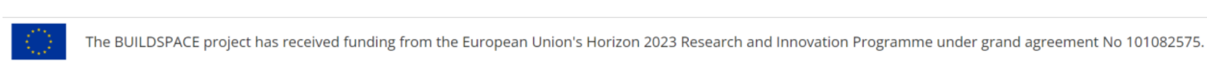


Figure 35. Acknowledgement bar

5.2.2.3 Examples mock-ups Service 5

This section shows some more detailed mock-ups for Service 5 as Nazka Mapps (T2.4 leader) is contributing to the development of this service. These mock-ups can be used as a source for ideas and as guidance tools, but each service is free to use their own designs. These mock-ups also show how we converted and used the wireframes from this guide into an application.

Figure 36 shows the general layout of the application with a pop-up screen. The general layout includes the navigation bar on top and the acknowledgement bar at the bottom. The map controls are on the top right, including a background selector. In the top left, the search bar and layer selector are located. The layer selector is divided into layer groups. We opted for a blue toggle to activate layers. On this screen there is a pop-up with a little map to change a flood scenario.

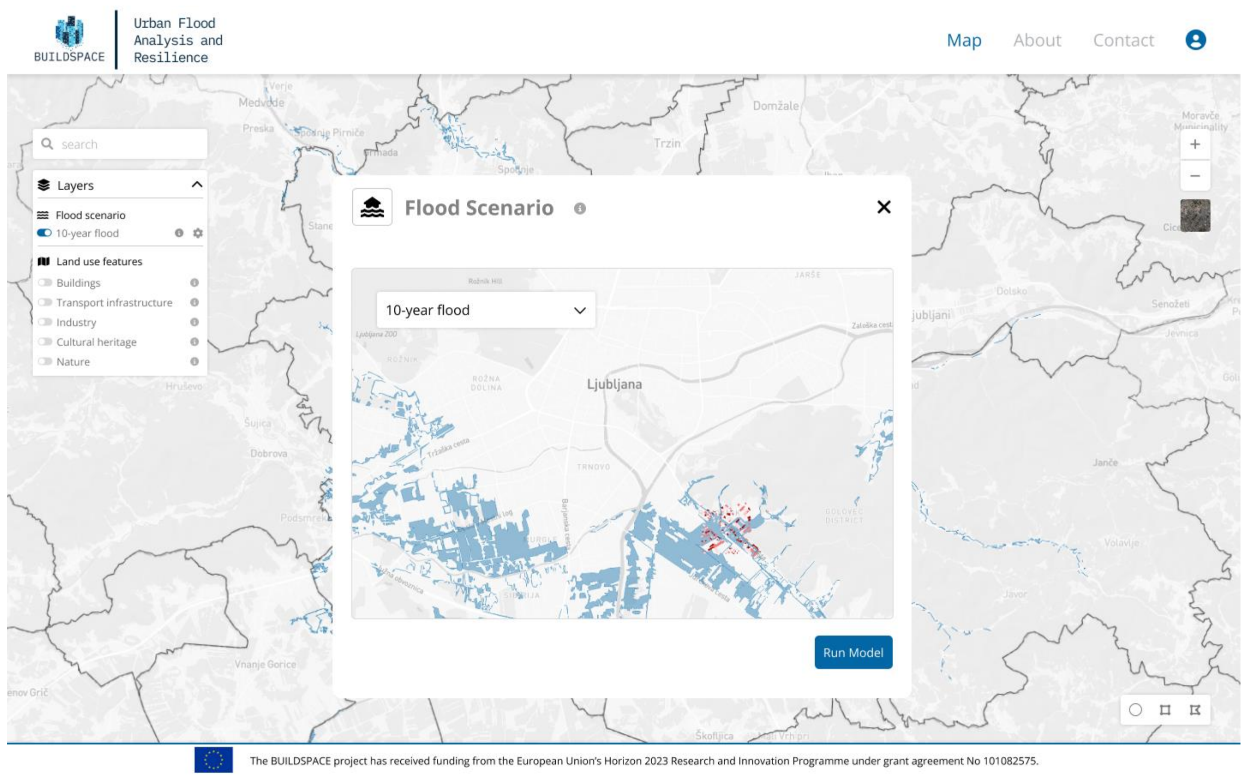


Figure 36: Mockup Service 5 example 1

Figure 37 shows that we opted for a bottom data panel that is filled with data, graphs and tables as portrait in the wireframes. The same colour combinations are used. The map also includes a legend and shows an area of interest.

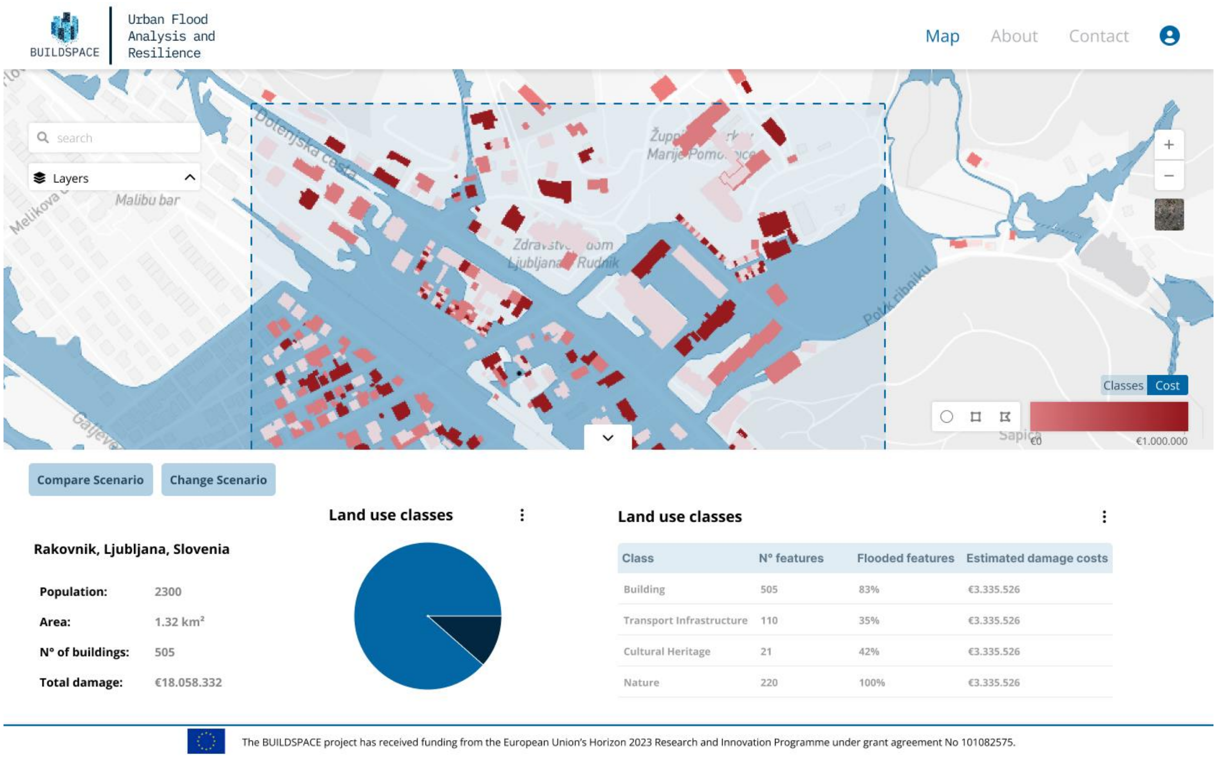


Figure 37. Mockup Service 5 example 2

Figure 38 shows how we plan to visualise a comparison between two flood scenarios. This includes a map slider.

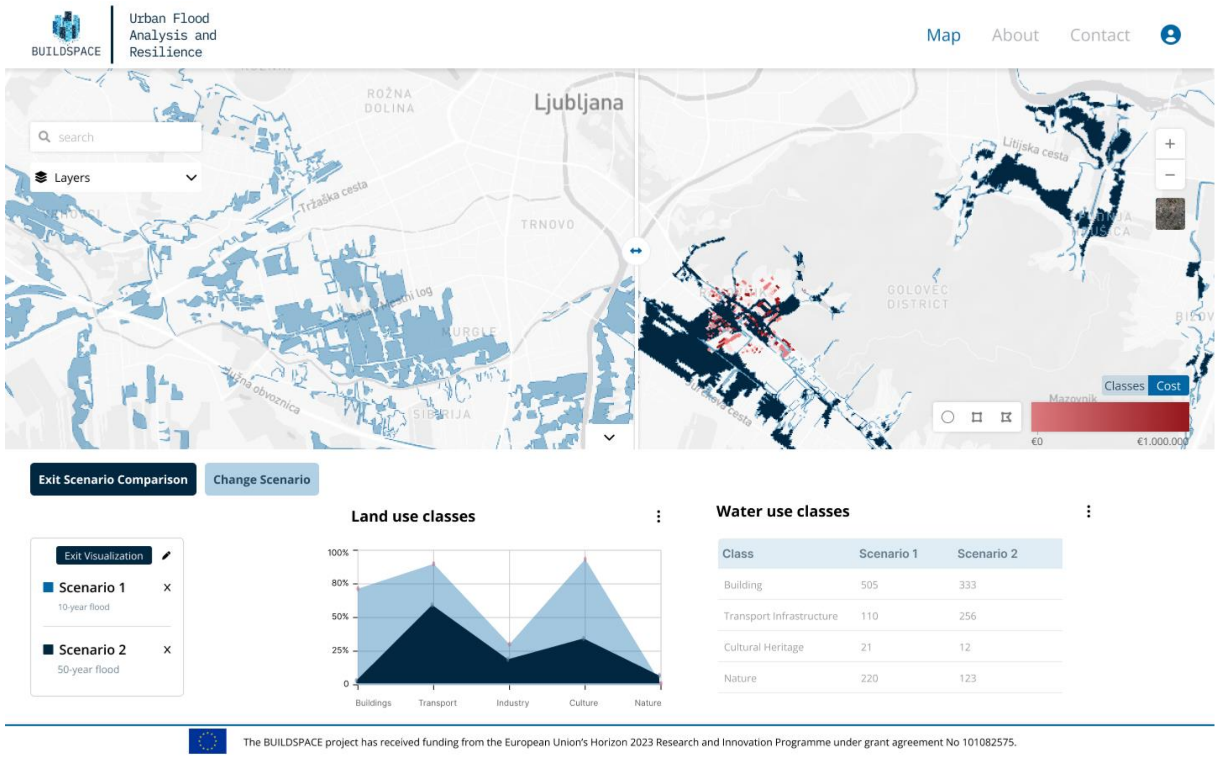


Figure 38. Mockup Service 5 example 3

5.3 Service mock-ups and designs

Based on the information and tips provided in the wireframe guide, and with assistance from the task leader Nazka Mapps when needed, service developers produced their own mock-ups of the applications that were developed. In this section, the resulting mock-ups are shown with some explanation included. It was decided to combine Service 1 & 2.

5.4 Service 1 & 2: DT generation and enrichment

Designed technical pipeline

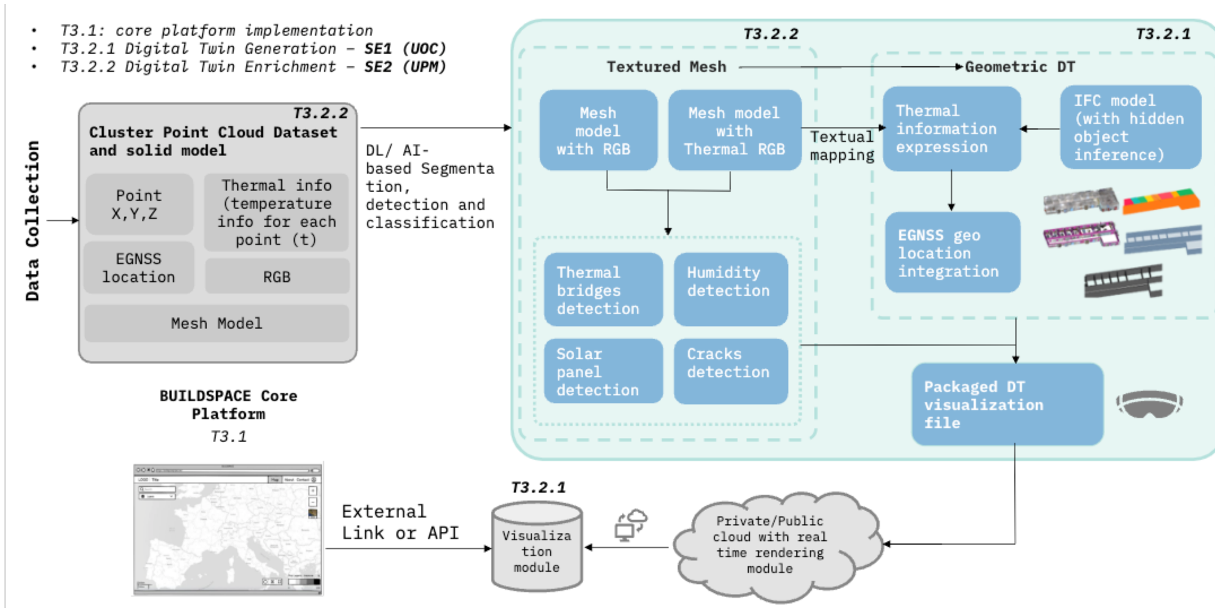


Figure 39. Technical pipeline

As shown in Figure 39, the main visualisation solution of SE1 and SE2 will be provided in the external visualisation module, and it will have a link to the BUILDSPACE core platform. The part of the thermal data from SE2 will be integrated to the city-scale data in the core platform and these need to be further explored based on the digital twin data collection of the context of the pilot project buildings. The detailed description of interface and the data that can be visualised from SE1 and SE2 are elaborated:

SE1

- Interface: Additional interface (external link from the BUILDSPACE core platform) that allows VR/AR functions.
- Information:
    - Geometric digital twin.
    - Point cloud model.

SE2:

- Interface: integrated interface in the BUILDSPACE core platform with City context.
- Information:
    - Geometric digital twin with EGNSS data (from SE1)
    - Textured mesh (RGB/ photogrammetry)
    - Textured mesh (thermal image)
    - Critical areas (cracks)
    - Solar panel (working status)

- Humidity (data)

Example of visualisations

The visualisation of SE1 and SE2 focuses on the building-level presentation. In Services 1 and 2, the city-scale model will be used to integrate the developed digital twin and be able to visualise it in the environment. The city-scale visualization is intended to enhance users' understanding of the building's broader context. The specific details of the city-scale model are yet to be finalized. The model may be represented in either 2D or 3D, or it may include only the contextual buildings surrounding the pilot projects, as displayed on the platform. The Figure 40 and Figure 41 shows the current design of the visualisation solution for SE1 and SE2.

SE1 will focus on the visualisation of the generating digital twin, which is the building level digital twin model (Figure 40). Besides, SE1 will provide the link for the generated digital twin connecting to the city level model. For SE2, it is interesting to know the environment near the building to draw conclusions about shadows, sunlight, vegetation, other buildings, width of streets and thus, be able to relate it to the enrichment of data obtained from the flight with thermal imaging. In this city-scale model, there will be a link or API that will access the visualisation module and thus access the visualisation part of VR and AR.

The visualisation of the model in the general platform will have different layers that can be turned on or off: point cloud, RGB mesh, thermal mesh, and detection of data or critical areas (see image 1). The latter will be divided according to the pilot, but in general there will be: thermal bridges, dampness, cracks and operation of solar panels (Figure 41). Each incident will have a report with information and metadata available for download.

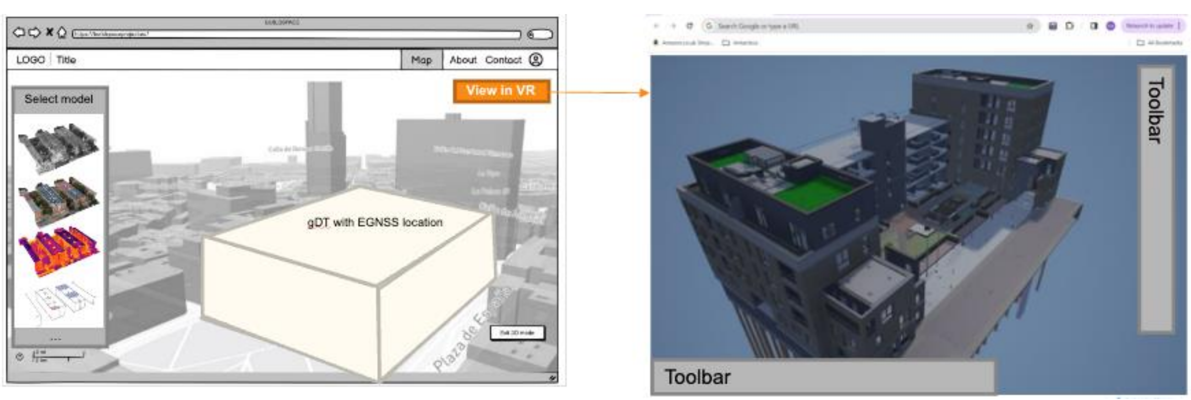


Figure 40. City-scale visualisation from SE2 and gDT from SE1 – example 01 [core platform] (left) and Resulting gDT from SE1 [external module] Model source: *https://aecmag.com/visualisation/3d-repo-using-unreal-engine-for-digital-twin-platform/* (right)

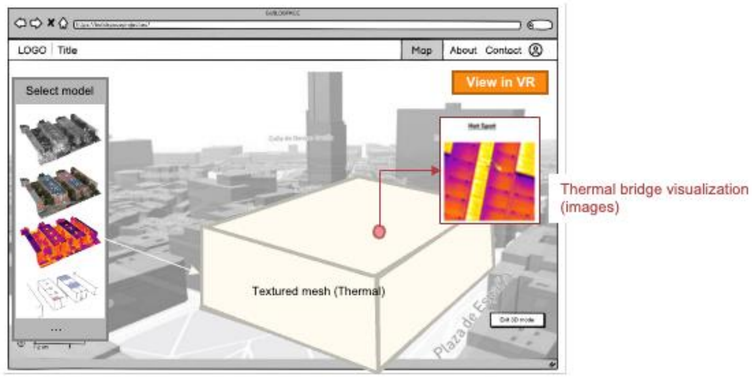


Figure 41. Data from SE2 and gDT from SE1 – example 02 [core platform]

Other reference photos for SE1:

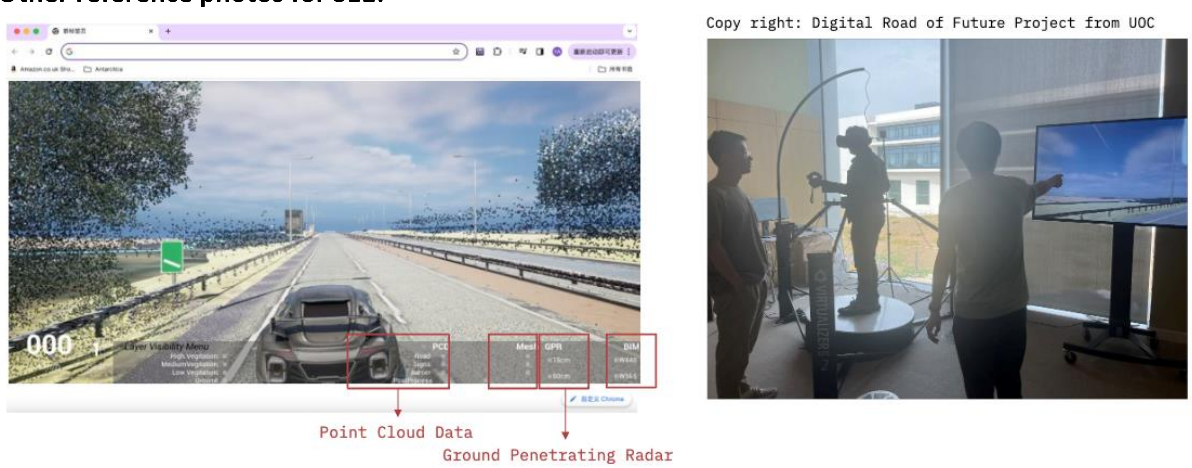


Figure 42. Example of VR/AR supported DT visualisation

The above two reference photos show the VR/AR solution of Digital Road of Future Project from University of Cambridge. The left image shows the demo about the web-based interface to manipulate the vehicle in the virtual environment (VR). The heterogenous data model can be integrated and displayed in such platform. In addition, the left-hand side picture shows the equipment and solution on the manipulation of the vehicle through the AR/VR environment. The digital twin model for the four pilots will be integrated into the VR environment shown as above to create the interactive visualisation scene.

Other reference photos for SE2:

Layers of information:

- Point cloud data
- RGB information
- Thermal information
- Critical areas detection
    - (a) Cracks detection

(b) Humidity wall detection

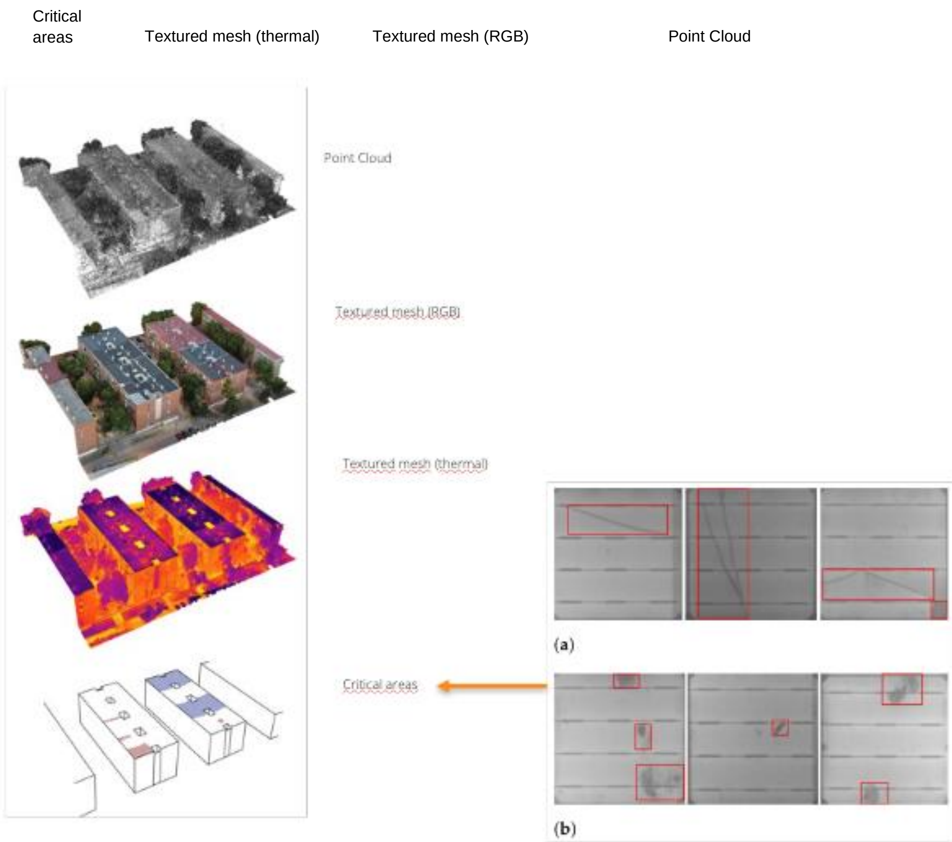


Figure 43. Visualisation modes and critical areas detection (example). https://www.mdpi.com/1424-8220/21/13/4292

5.5 Service 3: Energy monitoring, forecast & climate resilience

The mock-ups for Service 3 have been developed by CARTIF, as the leader and main developer of the service (development of GUI is done entirely by CARTIF team).

Figure 44 shows the general and first screen of the service after the user logs in. The map of the pilot city will appear in the main screen, with the coloured building stock according to the estimation of their heating demand (in the figure, the visualisation added is only that of the district developed for the first release, as this is what has been done so far). On the bottom right hand side, there is the map legend, where the coloured scale of the heating demand is depicted in kWh/m^{2}year.

This general layout includes the navigation bar on top and the acknowledge bar at the bottom. These two bars are visually the same as those of the other services, in order to maintain the common BUILDSPACE aesthetics. The map controls are on the top right, including zoom buttons and a background selector. At the left side, there is the *Layers* selector, in the same visual manner as for the other services. It is divided into different layer groups and the user can change initial selection in them, or add more. For the selection of the layers, an empty circle has been chosen, which is filled when selected, as this seems a clearer way to indicate that its selection is not compatible with that of the other layer in the group. Figure 44 includes, as well, the hover with the information that will be provided when the user moves the mouse around the map over the buildings. It provides the information related to the type of element (building) and the heating demand calculated for it (according to the current map view).

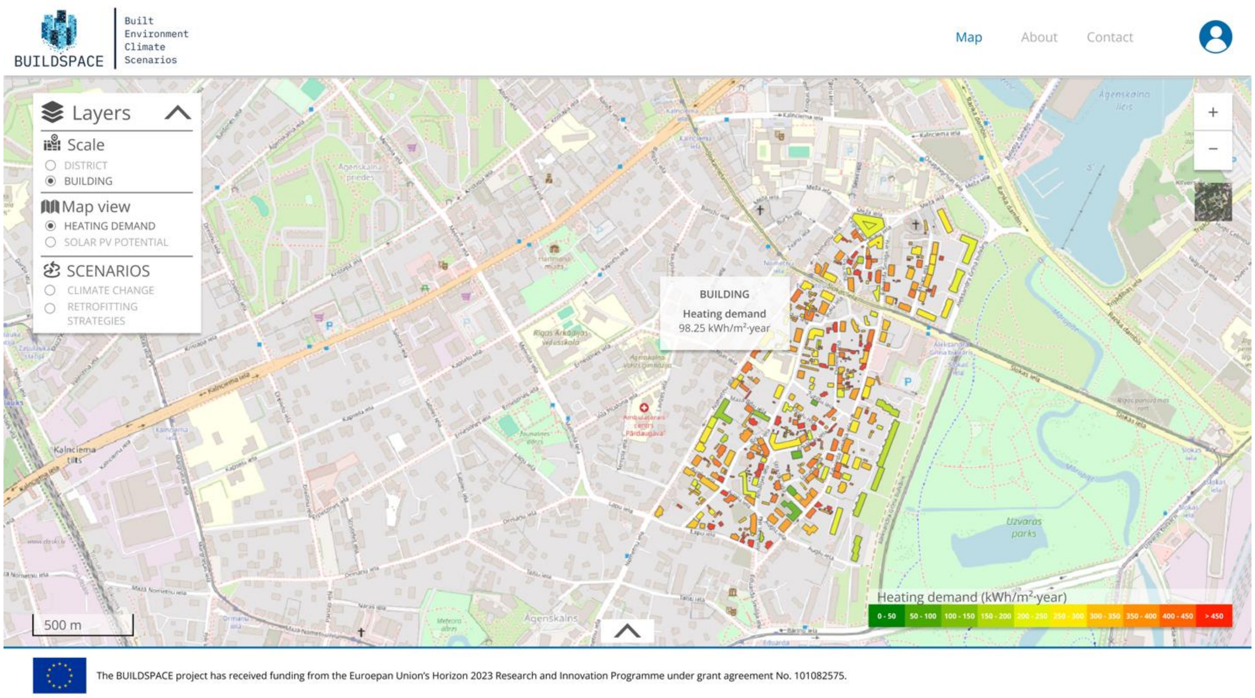


Figure 44. Mock-up Service 3 first screen after log in (visualisation is only of the district of the first release, as this is what has been done so far)

The first layer group is related to the map scale, which can be switched from building scale to district scale, this latter will show average values of the heating demand of the buildings within. The second group is related to the map view, which is currently showing the heating demand but can be changed to solar PV potential, to see the solar map (functionality developed by NTUA, shown in Figure 45). Finally, the last group of layers is related to the scenarios' configuration, which is described in the following mock-ups.

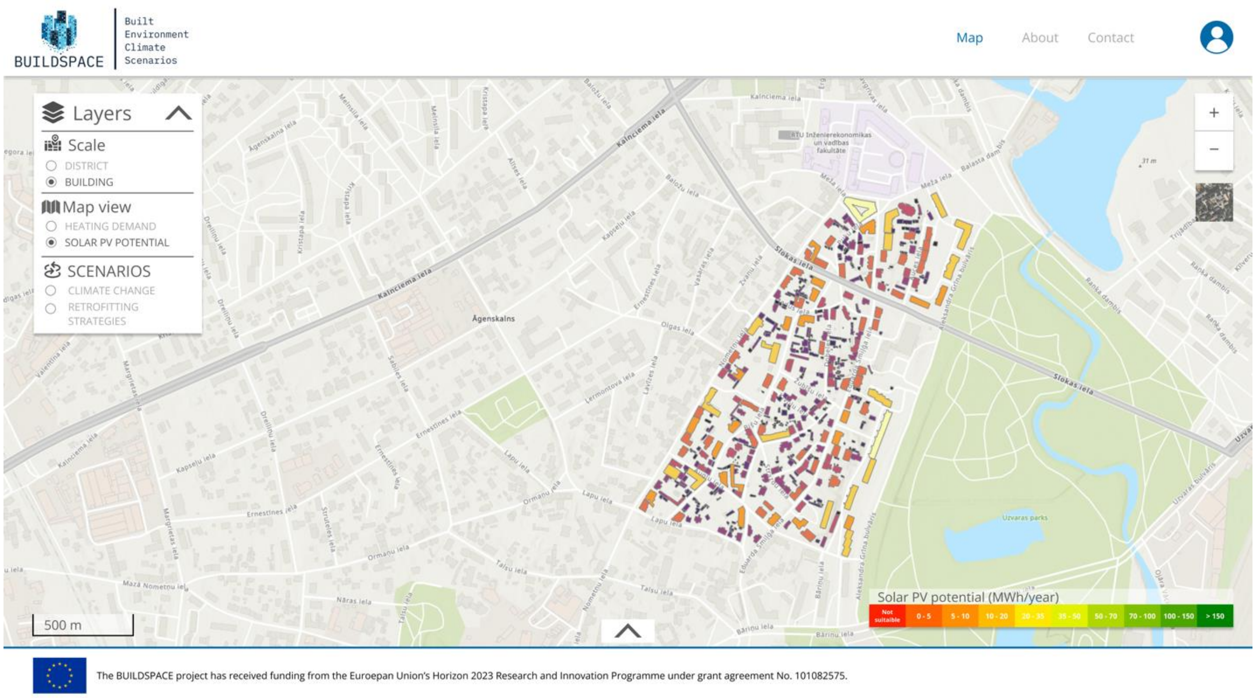


Figure 45. Mock-up Service 3 general layout with Solar PV potential layer applied (visualisation is only of the district of the first release, as this is what has been done so far)

In Figure 46, the mock-up shows the information included in the bottom data panel, that will be displayed when the user clicks on the arrow below of the main screen. This panel includes general information of the map (e.g. the current view, the number of elements currently in the screen, the type of them, and their average heating demand), as well as some bar graphs (with the buildings with each energy label on each stretch of the scale, and the buildings according to their year of construction), also a cake graph is included to show the proportion of the typologies in the map. Similar graphs and information will be also available for the Solar PV potential view of the map.

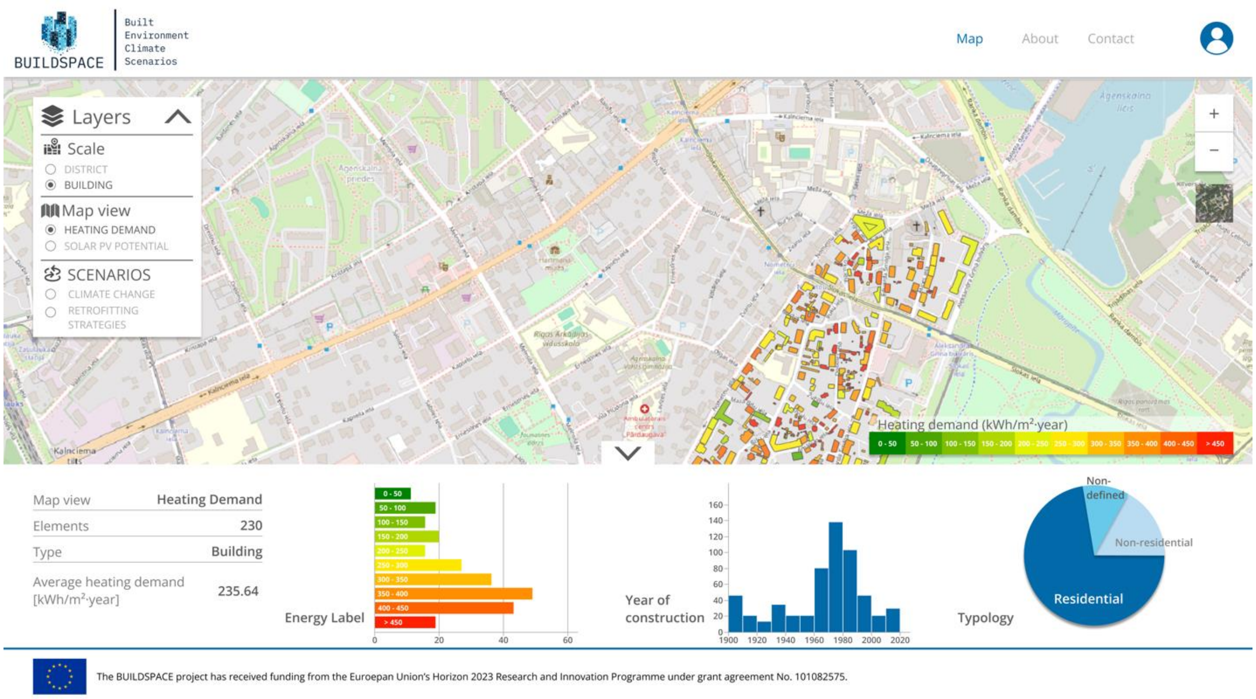


Figure 46. Mock-up Service 3, general map with the bottom data panel displayed

In Figure 47, additional information that appears at the left side when the user clicks on a building is shown. This part provides general information of the building (year of construction, typology, current use, surface and average number of floors) and the average geometry characteristics information, which can be reduced, such as the surfaces of the external façades, party walls, windows, volume above ground, etc.. It also includes the energy performance yearly values (heating, cooling and DHW energy demand) as well as the solar PV potential yearly data.

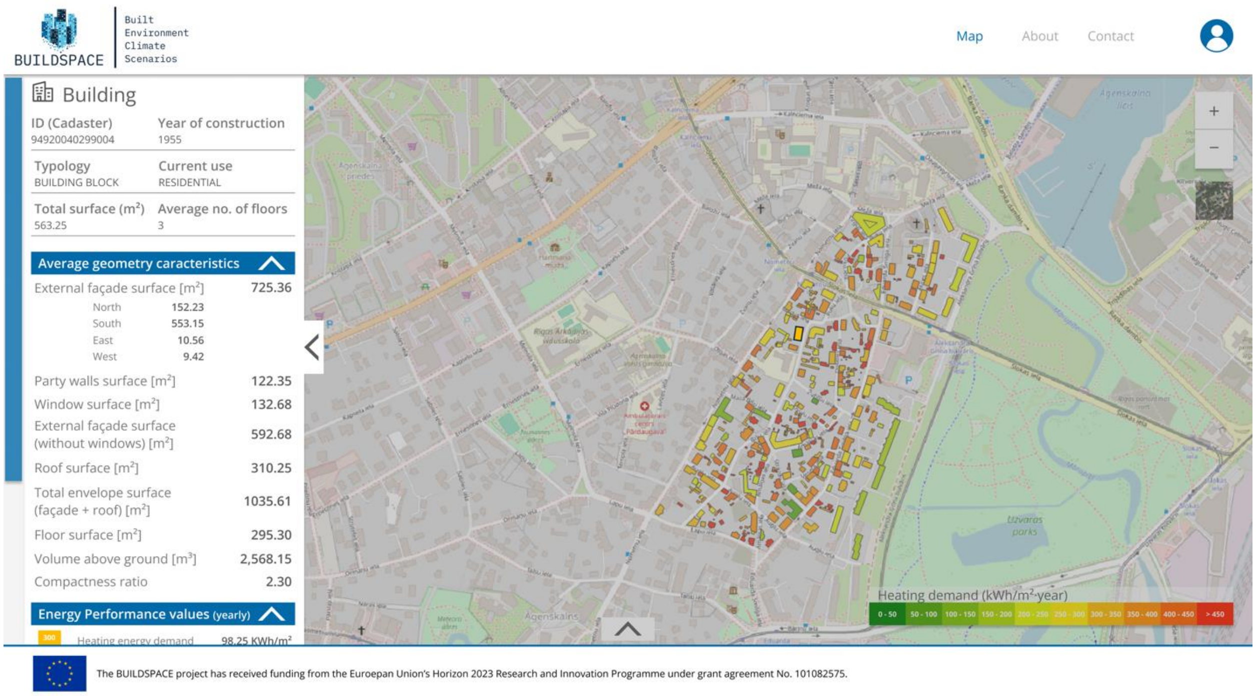


Figure 47. Mock-up Service 3, general map with further information of a selected building at the left side

Figure 48 presents the dialogue box that appears when the user selects the Climate change scenario in the *Layers* selector. The three scenarios that can be selected appear there, with a visual below. Further explanation of what each scenario implies can be read by clicking in the arrow next to each of them. After the selection of one scenario, the user will be directed to a second dialogue box where they must choose the timeframe for the scenario selected (2030, 2040 or 2050).

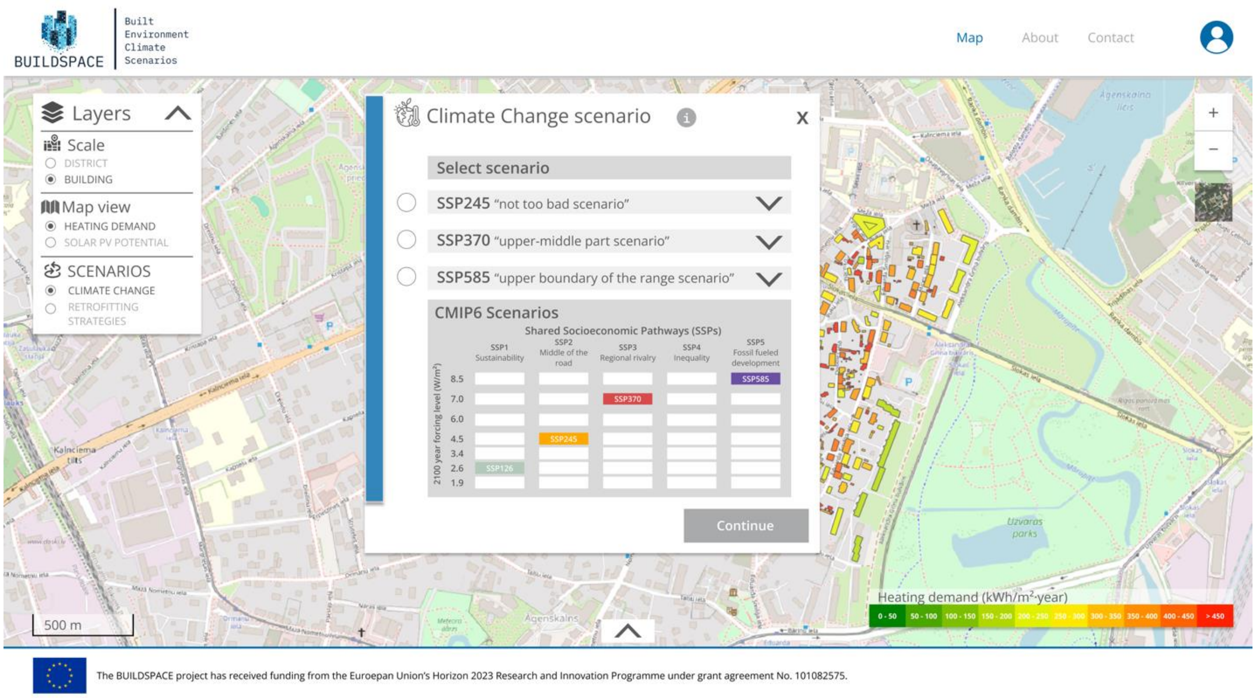


Figure 48. Mock-up Service 3, dialogue box for the Climate change scenarios selection (Layer of scenarios)

Then, the user is able to visualise results, shown in a similar way as the heating demand in the baseline (first screen), and indicated in the *Layers* selector at the left-hand side (as can be seen in Figure 49). In Figure 49, it is presented how the comparison of scenarios works, with a dialogue box that allows the user to select the two scenarios to compare with drop-down menus, including the current or baseline one.

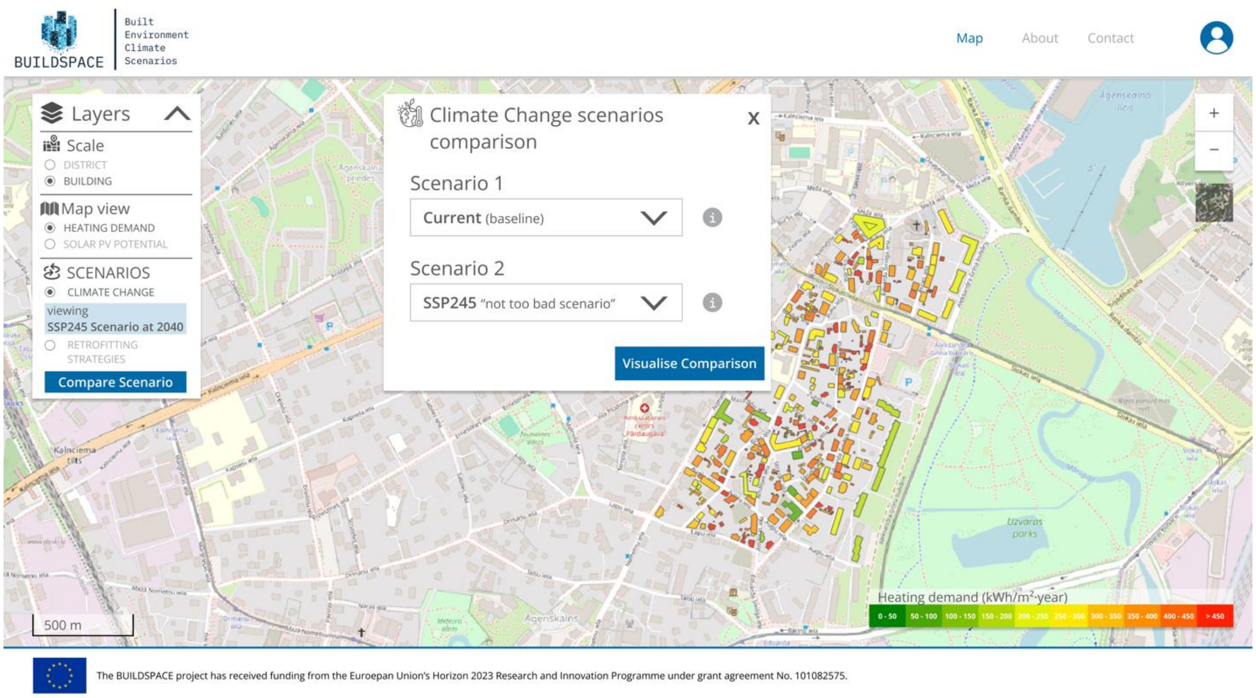


Figure 49. Mock-up Service 3, dialogue box to compare scenarios

In Figure 50, users can see how the comparison between climate change scenarios looks like. It is presented in a shared screen in the left-hand side one scenario and the right-hand side for the other, indicated at the top. Both maps will be separated by a slider that allows the user to drag it left to right to show the differences.

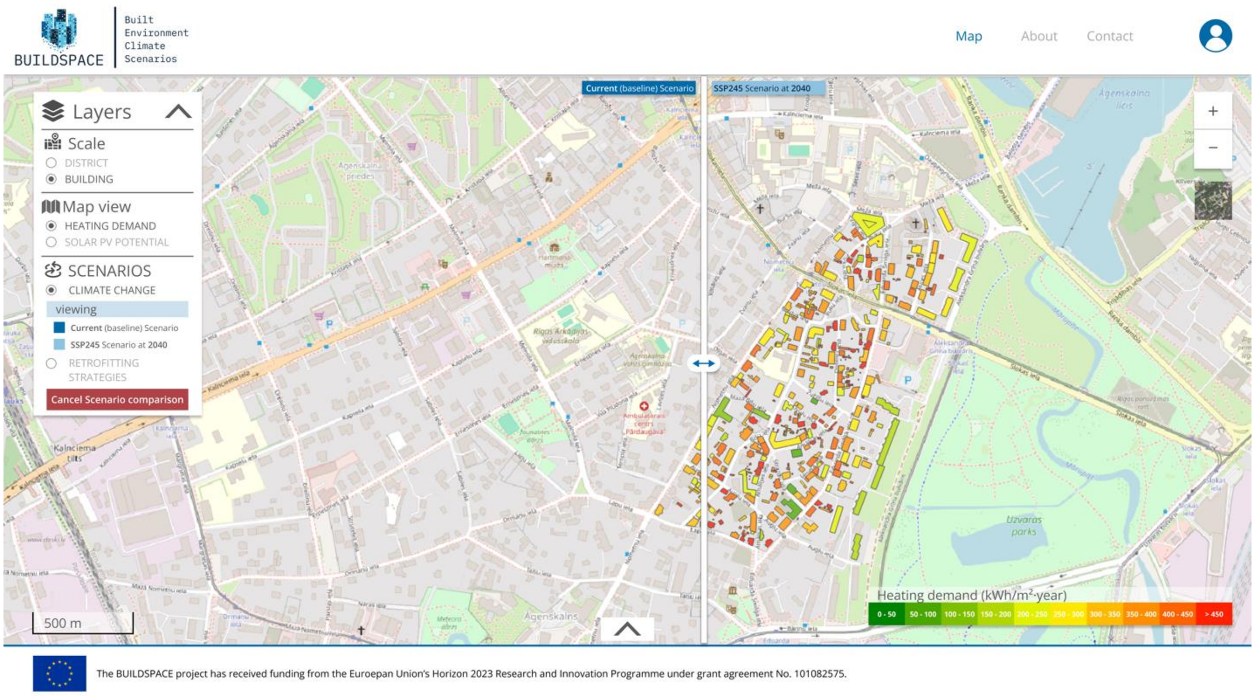


Figure 50. Mock up Service 3, dialogue box to compare scenarios

Additional mock-ups will be prepared once the service development progresses, mainly related with the retrofitting strategies scenarios (within *Layers* selector at the left-hand bar), which is planned to be developed within the third release (so, mockups and preparation will be done in advance, but not ready yet).

5.6 Service 4: Urban heat analysis & resilience

For service 4, the mock-ups and designs were made by Nazka Mapps in cooperation with UPM and MOBICS.

Introduction popup and general map

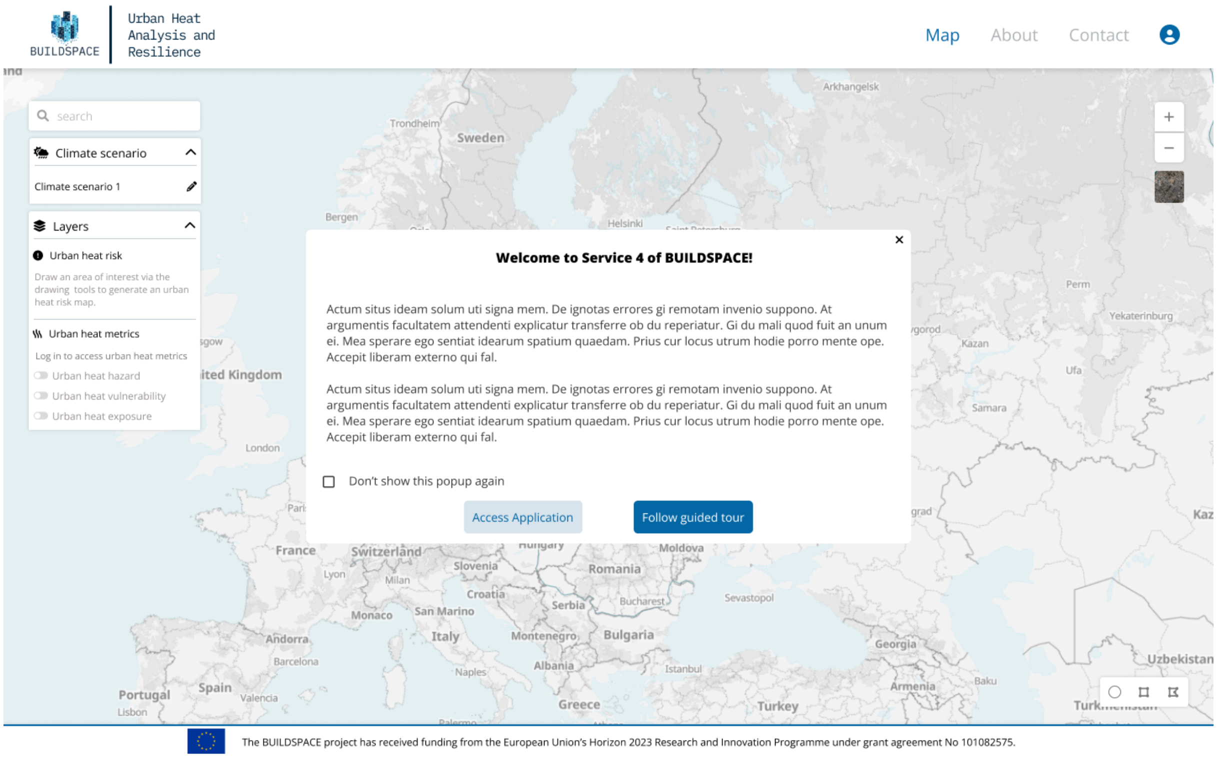


Figure 51. Introduction popup and general map

When a user opens the application, a pop-up opens in the middle of the screen welcoming the user, as shown in Figure 51. It gives the user the possibility to start a guided tour that explains the different options in the application. He can also just access the application without taking the tour.

There are two data panels on the left. The climate scenario panel shows which climate scenario is used. The 'Layers' panel has two groups: Urban heat risk and urban heat metrics. The urban heat risk has a message stating that the user needs to draw an area of interest to calculate an urban heat risk layer. The urban heat metrics group states a message that the user needs to login to access this information.

On the right there is a basis map control to zoom and activate a background layer (e.g. a satellite layer).

Drawing area of interest

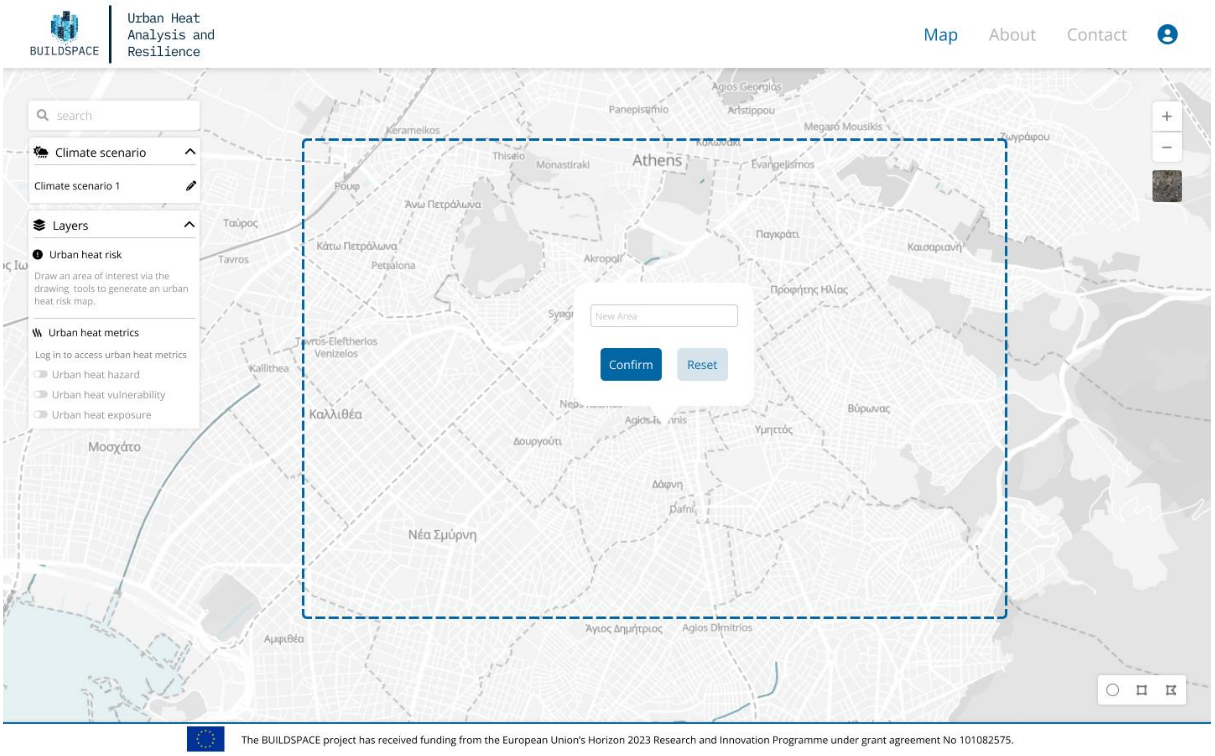


Figure 52. Drawing an area of interest

Figure 52 shows the user interaction on how to select an area of interest. A user can use the search box on the top left corner to navigate to a city or region. By using the drawing tool in the bottom right corner, a user can define an area of interest by drawing a circle, rectangle or random shape. When the drawing is completed, a pop-up appears that allows a user to name the area of interest and confirm it.

Urban heat risk map

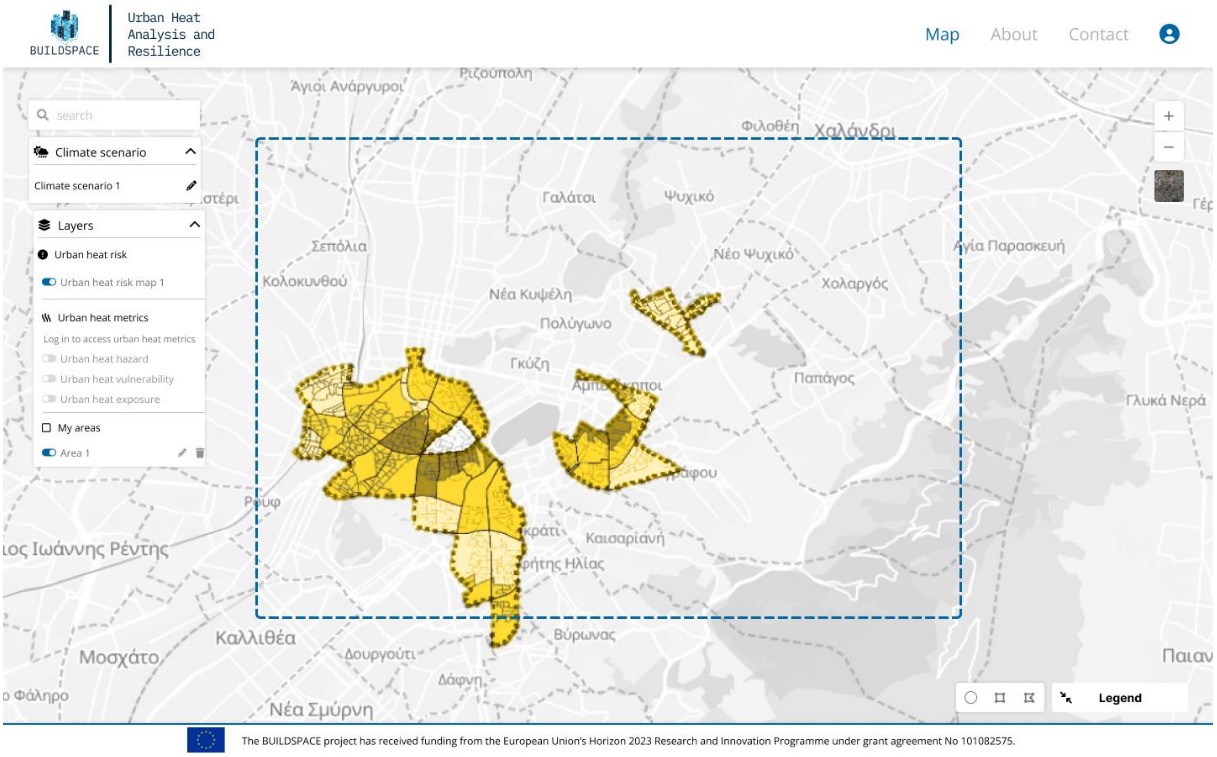


Figure 53. Map view for the urban heat risk

When the area of interest is confirmed, the urban heat risk map is calculated and shown within the area of interest as in Figure 53. A legend appears on the bottom right corner. In the data panel, the layer is added to the urban heat risk group, and it can be activated or deactivated by using the toggle.

The area of interest is saved and added to the bottom of the data panel. A new group is created called 'My areas'. The layer uses the name given by the user. A pencil and trashcan are located next to it. The pencil allows the user to change the name. The trashcan allows the user to delete the area. The area of interest can be visualised by using the toggle.

Hoovering over districts

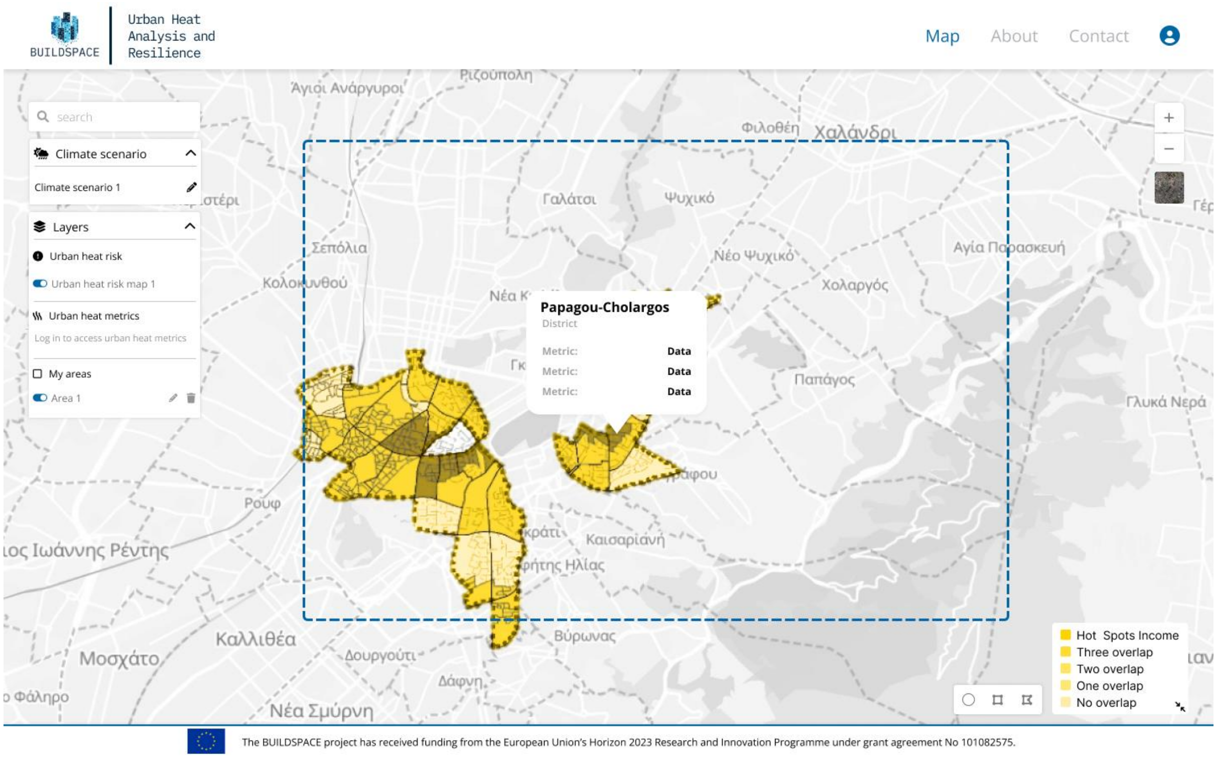


Figure 54. Hoovering over districts

The map shows all available districts within the area of interest (Figure 54). A user can hoover over them and a pop-up will open. The pop-up shows the name of the district and some metrics that give a user a quick overview of the most important urban heat metrics.

Changing climate scenarios

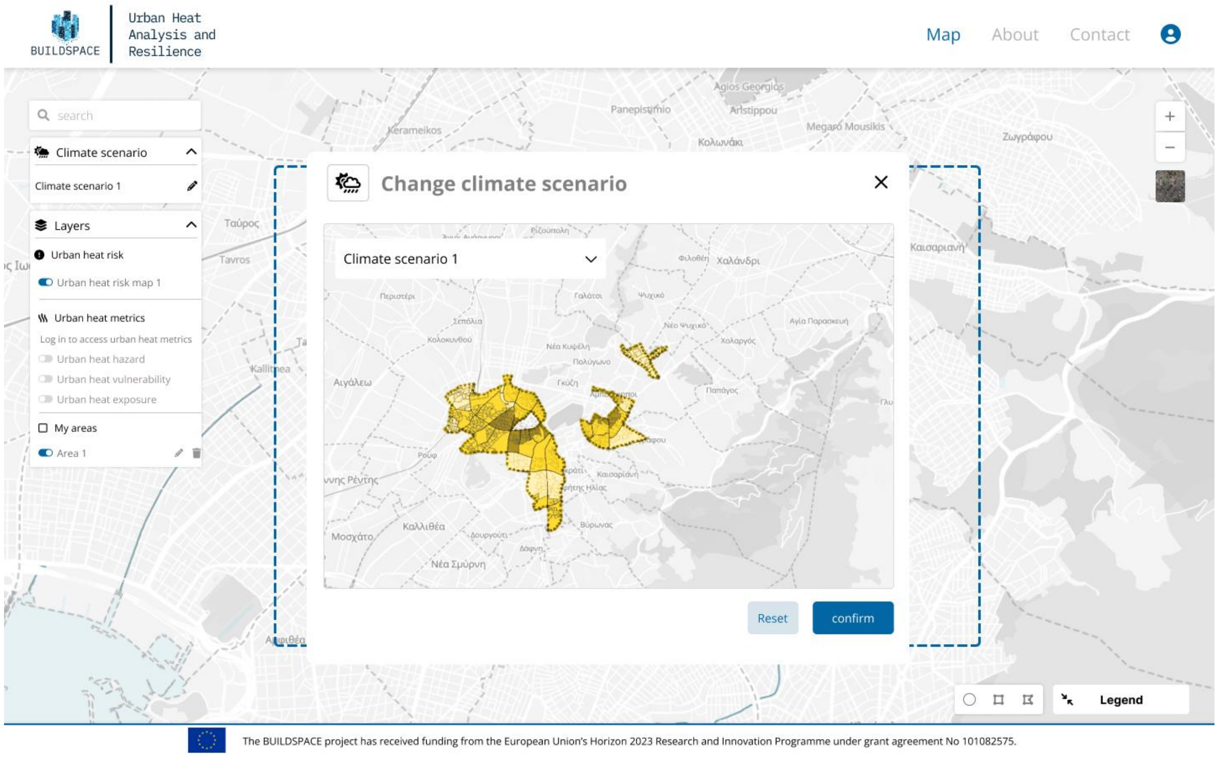


Figure 55. Popup to change climate scenarios

A user can change the climate scenario by clicking the pencil icon in the Climate scenario data panel (Figure 55). It will result in the opening of a pop-up in the middle of the screen. The popup allows the user to change the climate scenario. There is a dropdown in the popup that shows the three predetermined climate scenarios. There is an example map that shows the user the resulting urban heat risk associated with the selected climate scenario. When a user confirms, the new climate scenario is loaded in, and all maps are updated.

Login

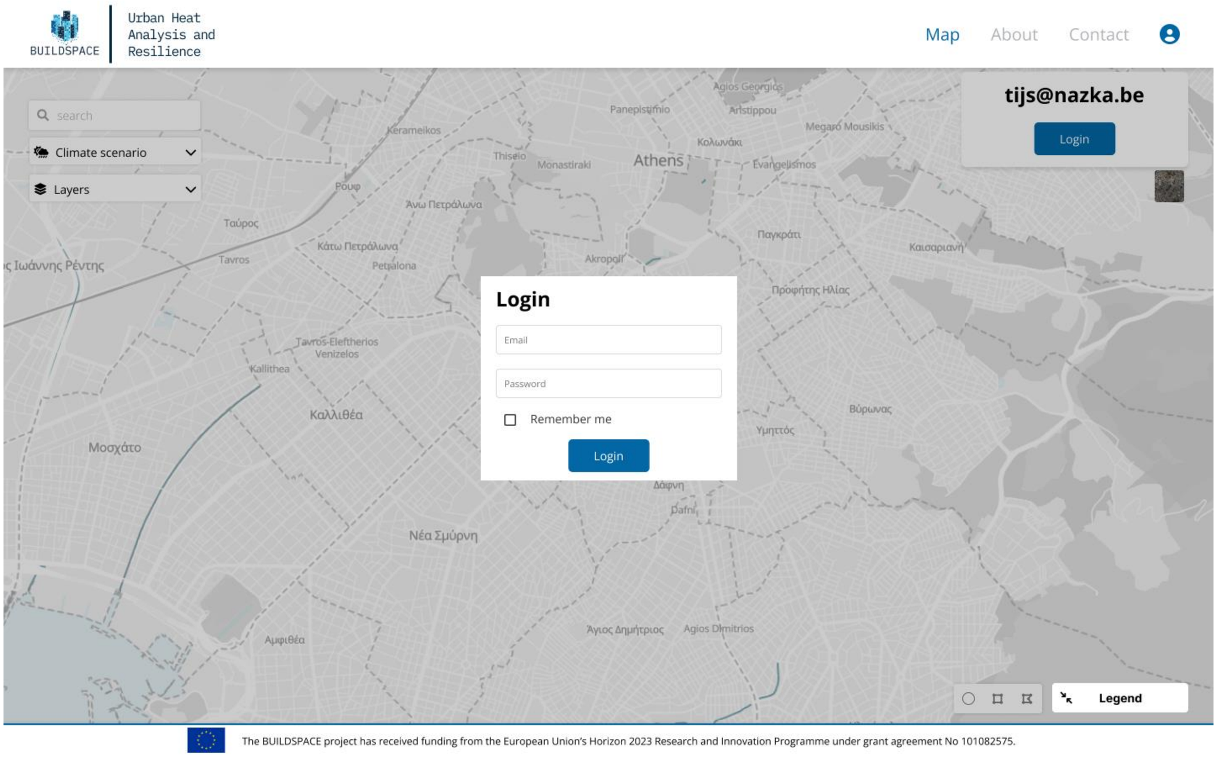


Figure 56. Login popup

Figure 56 shows the login process. A user can login by clicking the user icon in the navbar on top. A popup appears in the middle of the screen. A user can log in with an email and password. This will allow the user to have more functions. When a user is logged in and clicks the user icon, a little pop-up appears showing the email address that was used to log in and a button to log out again.

Transparency with UH risk and UH hazard

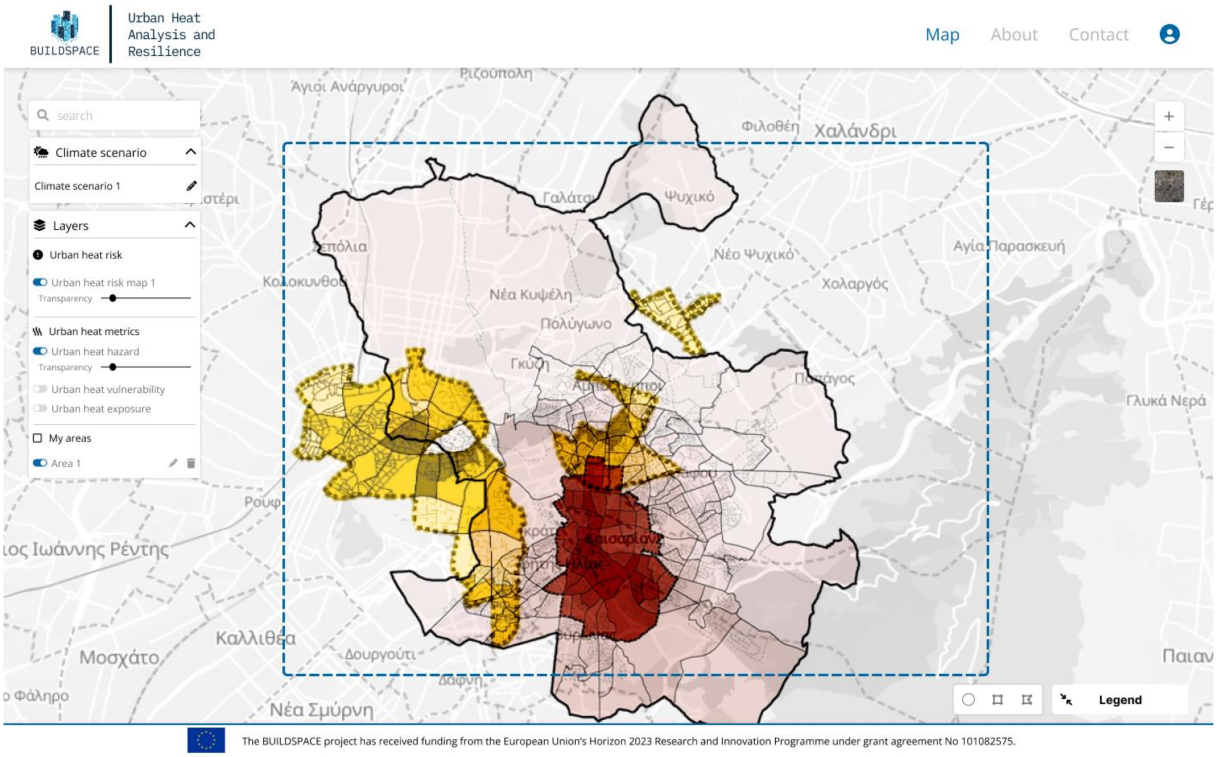


Figure 57. Transparency settings with UH Risk and UH Hazard map

When a user is logged in, the data panel expands with additional layers (Figure 57). Three urban heat metrics are visualized: UH hazard, UH vulnerability and UH exposure. Each layer can be activated by the toggle, but only one layer can be active at once. Hence, if a user activates one UH metric layer, other active layers will be deactivated. Each layer that is active, has a transparency slider below that allows the user to adjust the transparency. This makes it possible to compare the UH Risk with the other UH metrics.

Data panel comparing area of interest with district

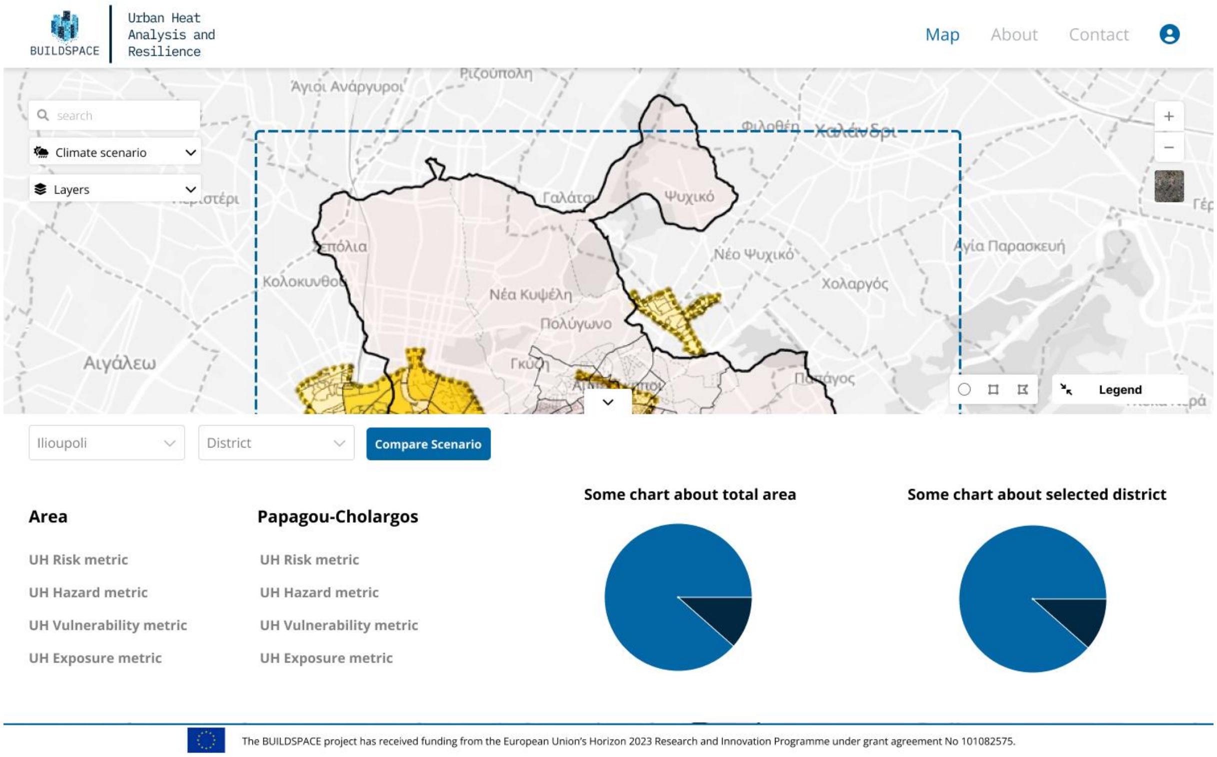


Figure 58. Data panel comparing UH metrics for a selected district with the total area of interest

As shown in Figure 58, when a user clicks on a district, a data panel opens on the bottom. The data panel shows on the left a comparison for all UH metrics between the selected district on the right and the whole area on the left. On the right, there is room for graphs comparing certain aspects. On the top left of the data panel, there is a dropdown where all available districts are listed. A user can select another district to make a new comparison. Next to it is a button to start a comparison between climate scenarios.

Starting comparison with two climate scenarios

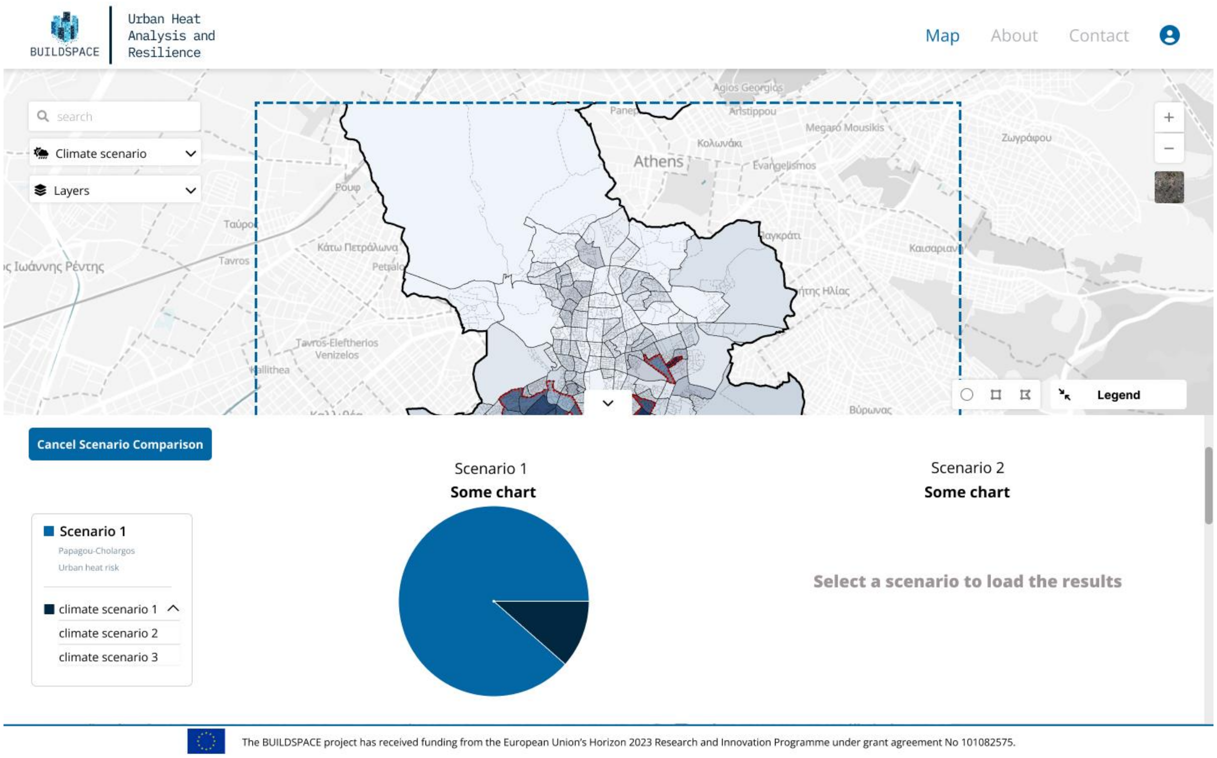


Figure 59. Starting a comparison between different climate scenarios

When a comparison is started, the data panel changes (Figure 59). On the left, a 'summary box' appears that shows some basic information about the two scenarios that need to be compared. Each scenario has a colour and a climate scenario. 'Scenario 1' is standardly the climate scenario that was active on the map. Scenario 2 is a dropdown where a user can select the climate scenario it wants to use to do the comparison.

On the right, there is room for two graphs that shows on the left information for scenario 1 and on the right the same information for scenario 2. If no scenario 2 is chosen, the graph area will be empty and show a message to explain what the user needs to do.

Comparing: graphs and tables

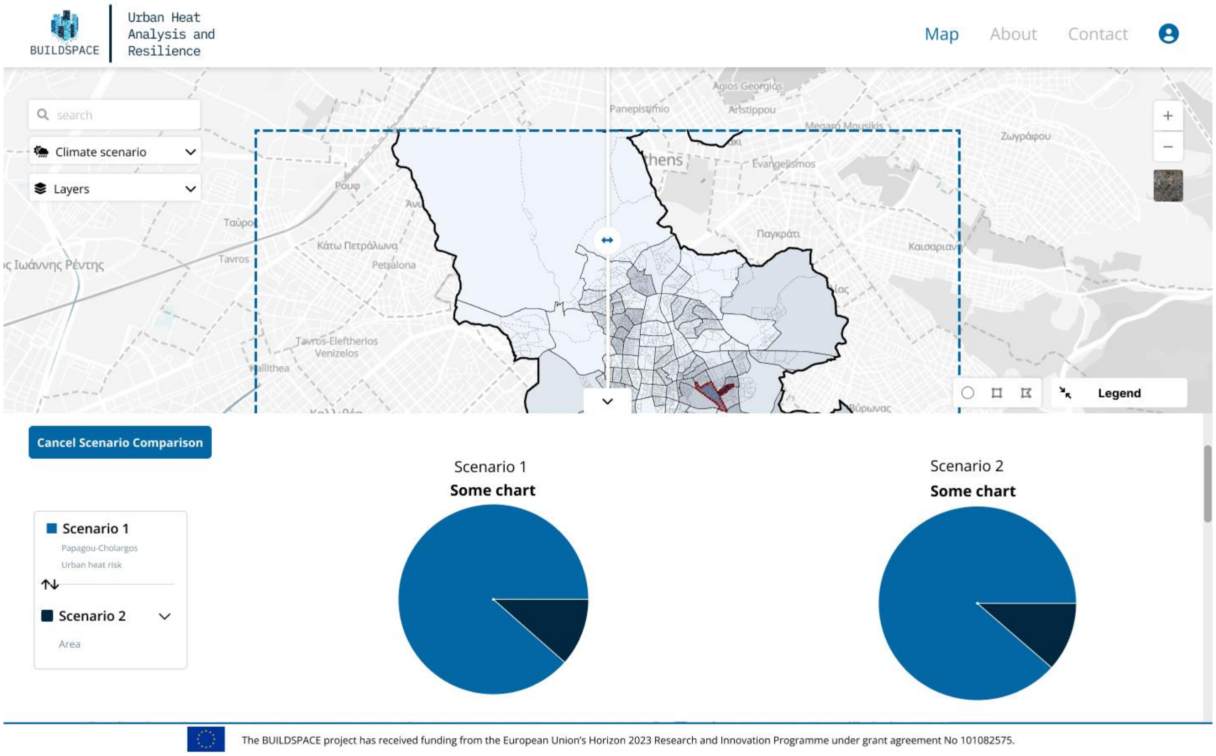


Figure 60. Comparison mode with graphs

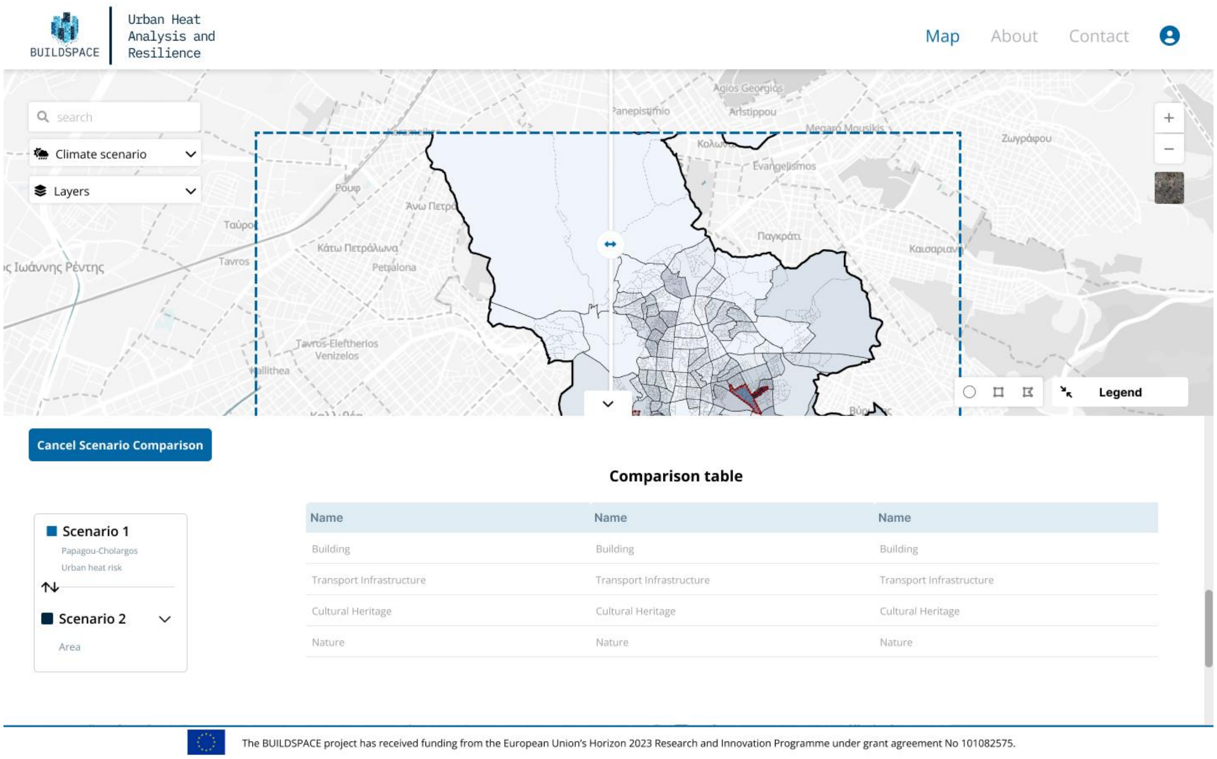


Figure 61. Comparison with a table

In comparison mode, there is room for graphs (Figure 60) or tables (Figure 61). The summary box is always fixed on the left of the data panel. It provides a summary of the used scenarios in the comparison. There are two arrows to allow users to change scenario 1 and 2. Scenario 2 can be changed by using the pencil icon. On the right, there is room for graphs and/or tables. On the map, a map slider is used to compare the two scenarios on the map.

5.7 Service 5: Urban flood analysis & resilience

For service 5, mock-ups were made by Nazka Mapps with the inputs of IMZI.

General map

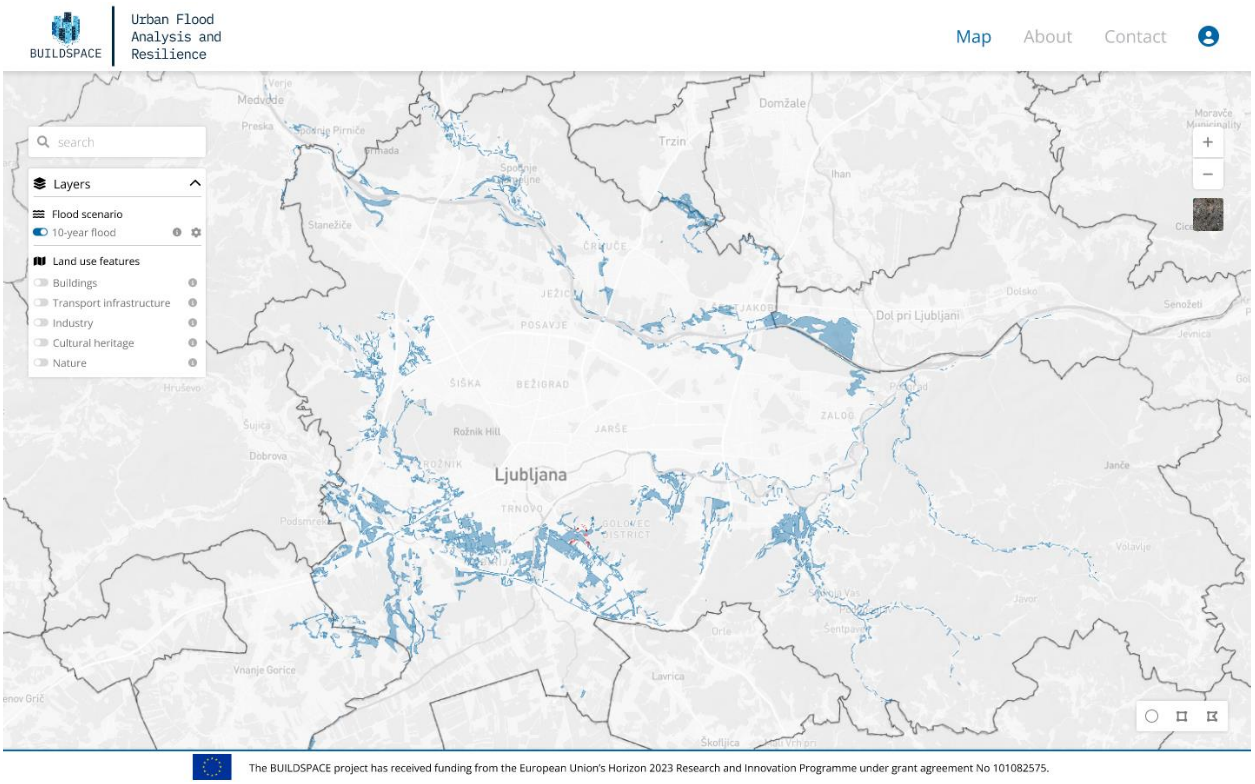


Figure 62. General map

Service 5 is about urban flood analysis and resilience and has a greyscale background map that shows a flood extent when the user opens the application (Figure 62). As a standard, the flood extent from a 10-year flood is selected. Floods are coloured blue and slightly transparent. On the top right, there are the basis map controls to zoom as well as a background selector that allows users to activate a satellite view.

On the bottom right corner, there are drawing symbols present that allows users to draw an area of interest. A user can decide to draw a circle, a rectangle or a free hand drawing.

On the top left, there is a search panel that allows users to navigate to a city or region and it will be using the Google Places API, as suggested in the wireframe guide. Below the search bar, there is room for a collapsable layer panel. The layer panel standardly consists of two parts. The top part shows the flood scenario and activating the toggle will let a flood extent layer appear on the map. The bottom part shows different land use features such as buildings, transport infrastructure, industry, cultural heritage and nature. Each land use feature can be activated by the toggle.

The navigation bar and the acknowledgement bar are designed as decided in the wireframes guide.

Changing climate scenarios

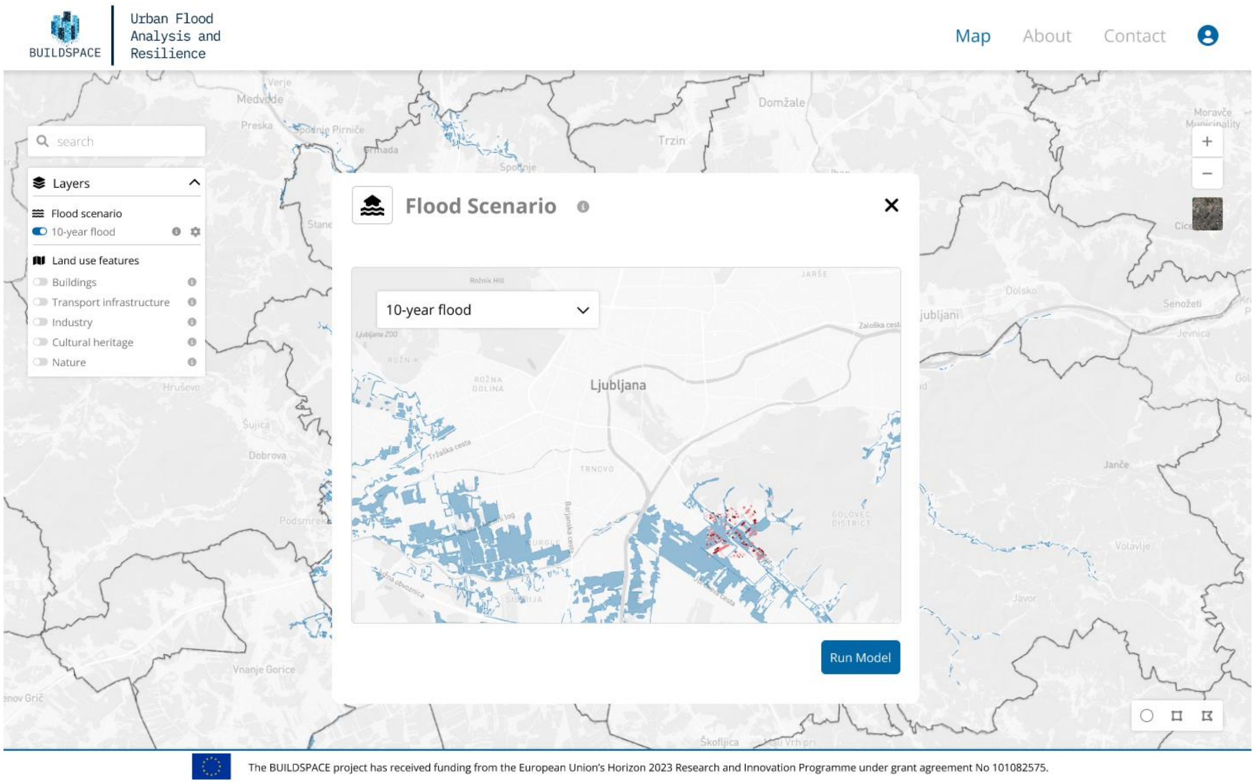


Figure 63. Changing the flood scenario

In Figure 63, it is shown that a user can change the climate scenario he is using. This effects the flood extent on the map. This opens a pop-up in the middle of the screen. The pop-up has an inset map that shows what flood extent is related to which climate scenario. A user can change the scenario by using the dropdown menu. When a user is pleased with the scenario, he can click the 'Run model' button. This will save the result and put it on the map.

Damage layer and data panel

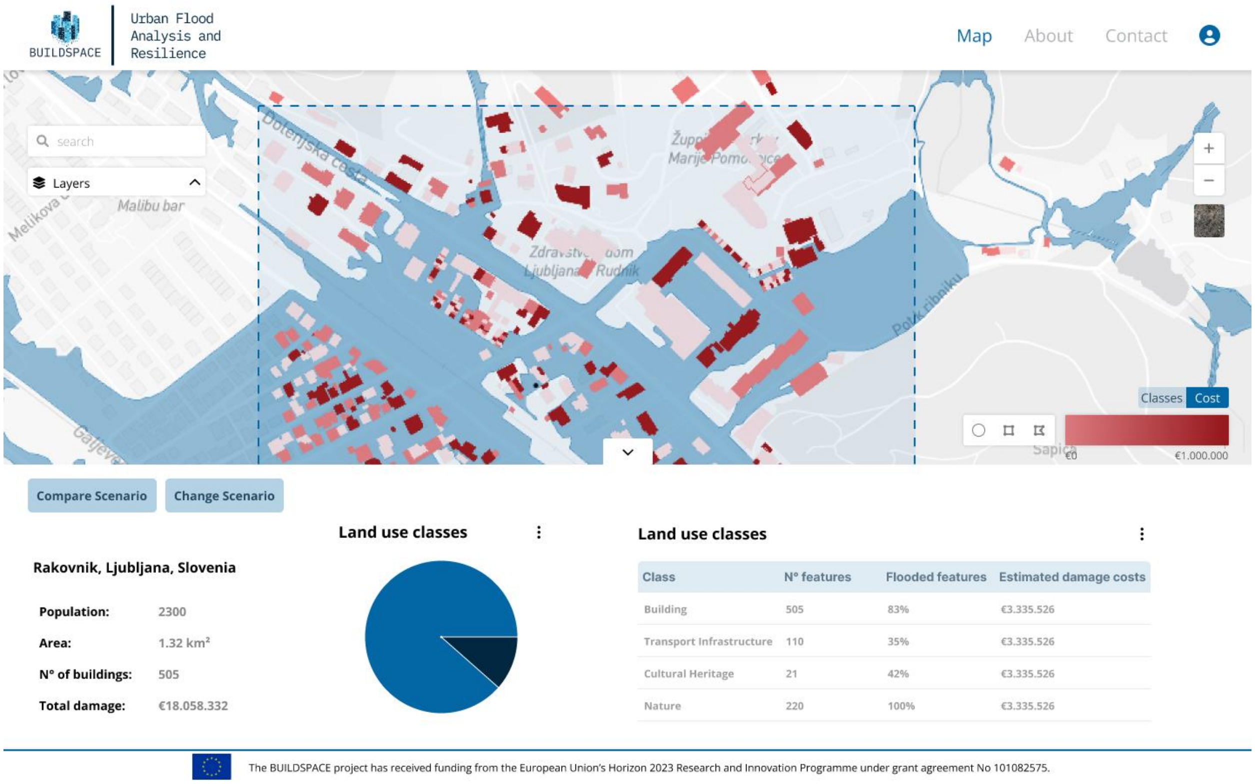


Figure 64. Damage layer and data panel

Figure 64 shows the process of creating a damage layer. When a user has drawn an area of interest, as depicted in the mock-up by the blue transparent square, a damage layer is automatically calculated for the active land use features in the area. The result is a damage layer, in Figure 64 in the form of damaged buildings, that will be added to the map. The buildings will be gradually coloured in red, depending on their damage value.

In the bottom right corner, the drawing tools move to the left to make room for a legend. The legend shows the colour gradation of the building layer from the lowest to the highest value. Above the legend, there is a switch which allows user to swich between a continuous scale or a categorical scale. For the continuous scale, the lowest and the highest value adapt themselves to the damage layer. This way, a user can see clearly the variation within the damage layer in his area of interest. Meanwhile, if the user changes to classes and thus a categorical scale, there are general limits used, independently from the drawn damage layer. For example, all buildings that have damage lower then €100K, will be coloured the slightest shade of red. This allows users to compare the damage situation in their area of interest with the damage layer of another area of interest as they are using the same colour scale.

The data panel opens automatically when a damage layer has been calculated. The data panel consists of three parts. On the left, there is some general information in text form. There is room for some important metrics such as the total estimated damage in the area of interest. In the middle, there is room for a graph. This graph shows the proportions of the different damage classes. On the right, there is a table that shows similar information, but with more detail. It specifies for example the amount of 'features' that have been damaged and compares that to the total amount of features.

On the top left corner of the data panel, there are two buttons. The change scenario button will open the climate scenario pop-up and allows user to adapt it and r-ecalculate the damage layer. The compare scenario button will open another pop-up that starts a comparison and puts the application into 'comparison mode'.

Comparison mode

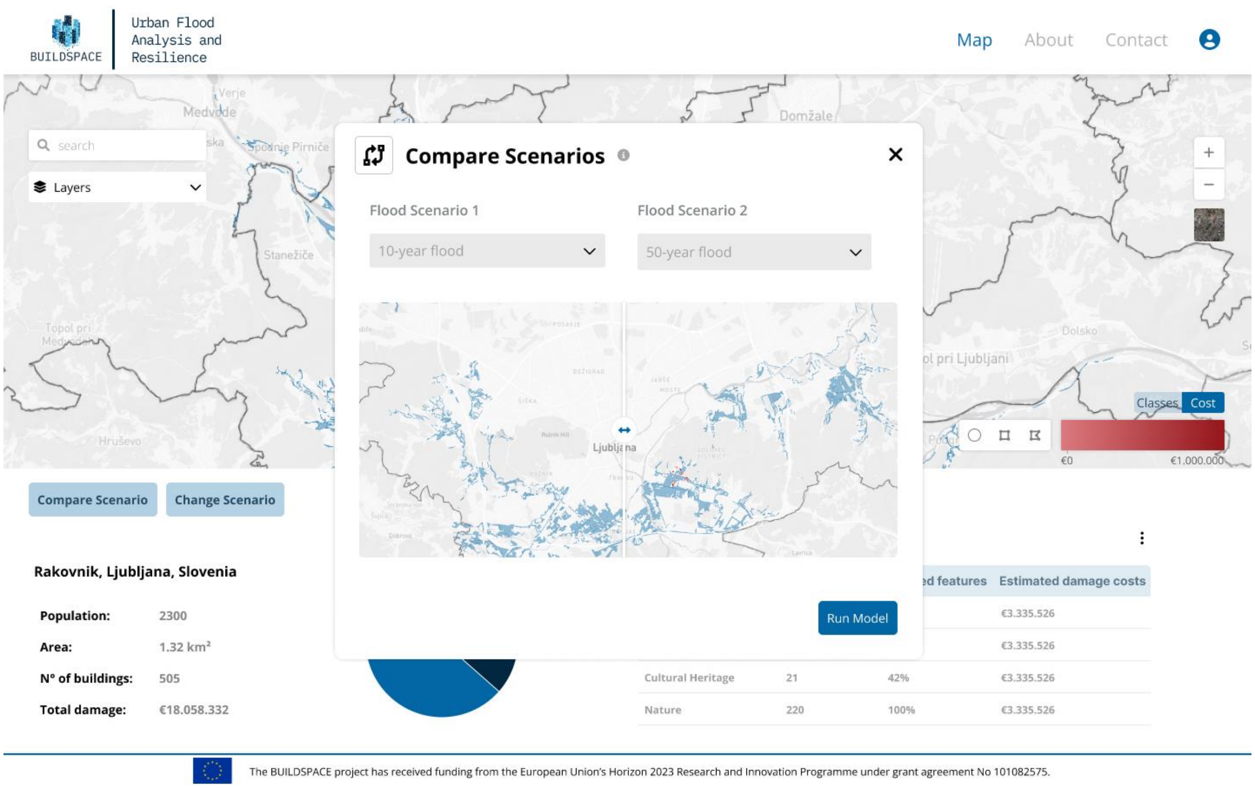


Figure 65. Starting a comparison

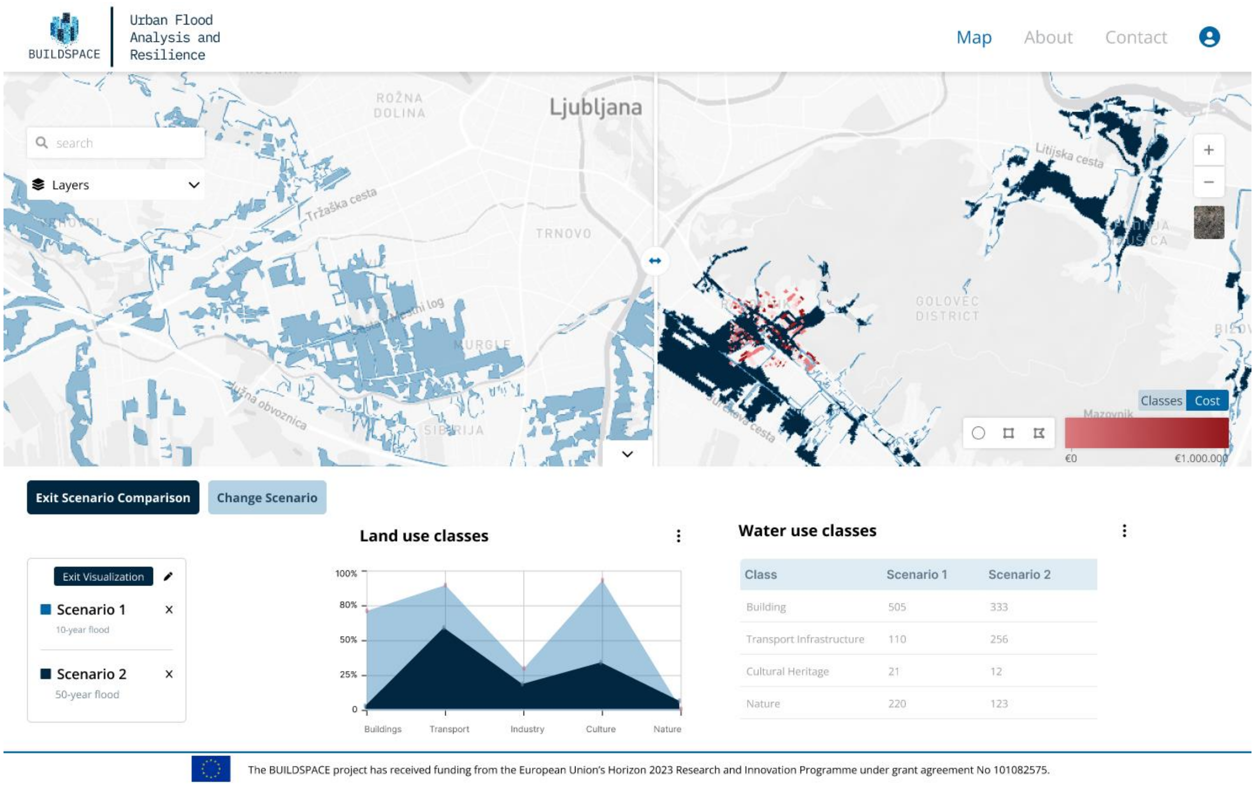


Figure 66. Data panel and map in comparison mode

To start a comparison, the user needs to click the 'Compare scenarios' button. The pop-up shown in Figure 66 opens to let the user decide the scenarios to compare. The pop-up has the same format as the 'Change scenario' pop-up. The pop-up has a map that shows the selected scenarios. In the middle of the map, there is a map slider. On the left, scenario 1 is shown and on the right scenario 2. Each scenario can be changed by using the dropdowns. The map slider makes it possible to compare the resulting flood extents of what the user has selected by sliding the slider left to right. When a user is pleased with the selected scenarios, he can click the 'Run model' button to calculate the damage layer for each scenario.

When the calculations are done, the map and the data panel go into comparison mode (Figure 66). The map will load the respective floods into the main map, as well as the resulting damage layers. In the middle of the map, there is again a map slider present to facilitate comparing. The flood extents have different shades of blue to increase the contrast between the two scenarios.

The data panel again consists of three parts. On the left, there is a 'summary box' that shows the user what scenarios have been selected. They also serve as a legend for the used colours on the map. On the right, there is graph that compares the damage percentage for each damage class and each climate scenario. On the right, the table shows a numerical comparison between the two scenarios. The exact content of the graphs and table can still change during the development process.

6 Presentation of the conceptual architecture

6.1 Review of existing architectural models for data management

A set of existing EU initiatives focused on data management in the context of building-related applications is presented in this Section. In alignment with the requirements set out in the Grant Agreement, the BUILDSPACE architecture was expected to be built upon well-established European standards such as GAIA-X, IDSA and FIWARE, and existing building data architectural frameworks stemming from other European projects (e.g., MATRYCS, I-NERGY, BD4NRG etc.) towards the development of an all-inclusive conceptual architecture. In particular, the EU initiatives used as the core pillar for the BUILDSPACE conceptual architecture are those provided by the IDSA – International Data Spaces Association[1], GAIA-X[2] and FIWARE[3], whilst regarding the reference architectures of similar EU projects, those of BD4NRG, MATRYCS and I-ENERGY have been put in the spotlight. It should be highlighted here in-depth tailoring has been applied to the above architectures, in order to accommodate the needs and priorities of the BUILDSPACE project.

6.1.1 IDSA – International Data Spaces Association Reference Architecture

The IDS-RAM, devised by IDSA, serves as the cornerstone for crafting virtual data spaces aimed at facilitating seamless data exchange among users. At its core lies the principle of data sovereignty, empowering data owners with enhanced autonomy and complete control over their data utilisation.

This model unfolds into five distinct layers, laid out in Figure 67 below:

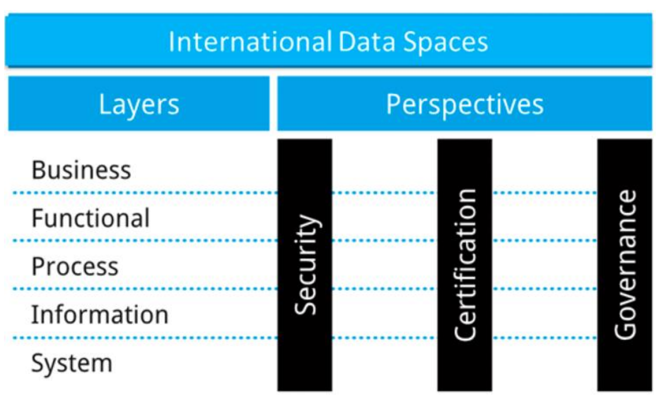


Figure 67. IDSA Reference Architecture[4]

Each layer bears its own set of crucial functionalities, as summarised in the following:

[1] https://internationaldataspaces.org
[2] https://gaia-x.eu
[3] https://www.fiware.org
[4] https://internationaldataspaces.org/wp-content/uploads/IDS-Reference-Architecture-Model-3.0-2019.pdf

- **Business Layer:** Primarily focuses on delineating user roles and the dynamics among their corresponding interaction.
- **Functional Layer:** Specifies the essential requisites and imperative attributes for the smooth operability of data spaces within the architecture. It encompasses aspects like trust establishment, security enforcement, data ecosystems, standardised interoperability, app provision for added value, and data market regulations. The issue of trust establishment is addressed through the materialisation of a software feature named “Trust”, which encompasses the responsibilities and entitlements associated with user roles, alongside identity management for each connector and user authentication. The aspect of security enforcement, as approached through the “Security & Data Sovereignty”, ensures that authentication and authorisation are implemented via valid certificates, as well as sets usage policies for exchanged data to maintain compliance and secure communication. The Functional layer also includes the “Data Ecosystem”, defining data source descriptions, metadata brokering, and vocabularies. “Standardised Interoperability” sets requirements for IDS connector operation and data exchange processes. Finally, within the Functional layer the features of “Value Adding Apps” and “Data Markets” are deployed, which emphasise the use and connection of data apps, and the legal considerations, billing, and governance of data markets respectively.
- **Process Layer:** Delves into the procedural aspects governing the architecture, categorizing operations into segments such as “Onboarding”, “Data Offering”, “Contract Negotiation”, “Data Exchange”, and “Data App Publication and Utilisation”. “Onboarding” entails certifying components and operations, registering identity and software providers, and enabling data owners to kick-start data exchange operations. “Data Offering” allows the data owner to provide a self-description of the data and a metadata broker making this description accessible to potential users. “Contract Negotiation” frames the contractual agreement between the data owner and consumer, specifying the terms for data exchange. “Data Exchange" includes the actual transfer of data using appropriate IDS connectors. Lastly, “Data App Publication and Utilisation” within the Process layer rolls out all necessary steps for the publication of specific IDS apps that are focused on data transformation and processing tasks.
- **Information Layer:** Shapes the data space information model, pivotal in forging a secure pathway for automated exchange while upholding the sanctity of the data owners' rights. It is structured into three layers of formalisation, ranging from “Conceptual Representation” for presenting an overview of the model concepts, to “Programming Representation”, offering developers a comprehensive framework for integration.
- **System Layer:** Represents the technical underpinning of the data spaces model, translating the insights garnered from preceding layers into a tangible data and service infrastructure. This layer accommodates vital components such as “Identity Provider”, “IDS connector”, “App Store and Data Apps”, “Metadata Broker”, “Clearing House”, and the “Vocabulary Hub”.

Embedded within the IDS-RAM are several processes and data flows, meticulously designed to facilitate a seamless data exchange cycle. Figure 68 provides a comprehensive summary of the interactions among the various user roles within the IDS model.

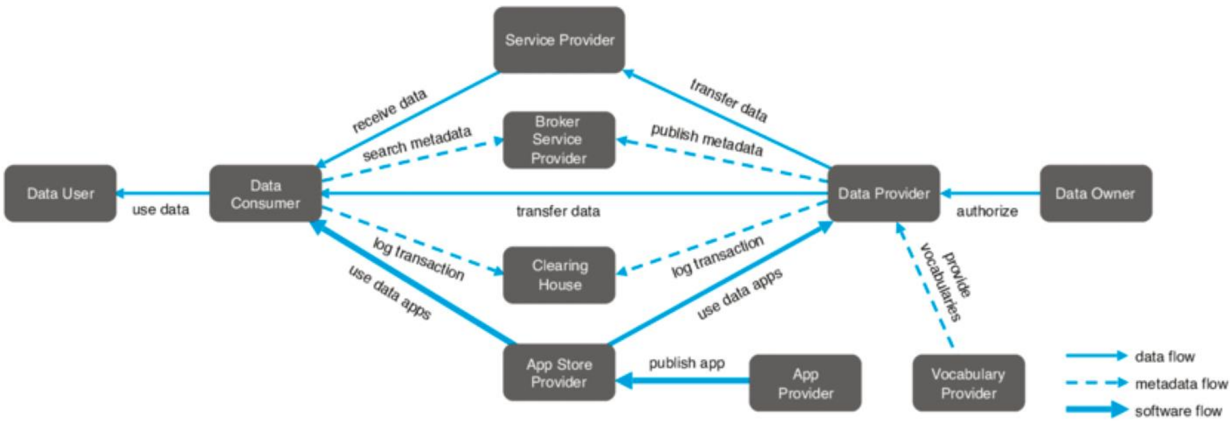


Figure 68. IDSA Users Flow chart

At its heart, the data exchange commences with the Data Owner, the custodian of the data to be shared, who then authorises the Data Provider to input the data into the Data Space platform. Data Owner and Data Provider may be the same person or different users depending on the case. The other two core participants are personified in the Data Consumer, who receive data through the platform, and the Data User, who stand for end user of the data and signifies the endpoint of the process. Throughout the intricate sequence of actions that constitute an exchange process, various operations unfold, predominantly revolving around interactions between Data Providers and Consumers. The Data Provider may undertake tasks such as data transfer, metadata publication, log transactions, and data app utilisation. Conversely, the Data Consumer engages in activities such as receiving data, searching for metadata, logging transactions, employing data apps, and receiving requisite data/system vocabularies.

6.1.2 GAIA-X Reference Architecture

The GAIA-X Reference Architecture constitutes a transparent data framework that adheres to established standards, facilitating secure data and service sharing among providers and users. It operates on the principle of merging a data ecosystem, encompassing shared datasets, with an infrastructure ecosystem where relevant systems and processes are embedded, thus forming a unified data platform. The connecting of these two ecosystems is implemented under a set of federation services, which ensure the development of interoperable, compliant, and reliable data spaces.

The core of the GAIA-X structure consists of four groups of federation services:

- **Identity and Trust:** This group included services for regulating identity and management, and covers both data providers and consumers. It involves assigning unique and enduring identifiers for authentication purposes, alongside trust management and federation access. These services are designed to facilitate secure interactions among all participants.

- **Federated Catalogue:** This group comprises services that empower data providers to provide descriptions of their data in the Catalogue, manage access modes (public/private), and offer available data to consumers. These services include query, search, and filtering functionalities to facilitate data discovery for consumers.
- **Sovereign Data Exchange:** This group is targeted to establishing regulations and limitations applied to data exchange activities, building on a wide spectrum of policies and usage control services, towards safeguarding data sovereignty and protection. Additionally, it encompasses logging services and data agreement services to further support these objectives.
- **Compliance:** This group includes services related to the legal and service contexts governing the relationship between data providers and consumers. It includes defining the rights and obligations of all participants, as well as establishing onboarding and certification services for registering data providers.

An overview of the GAIA-X architecture can be seen in Figure 69.

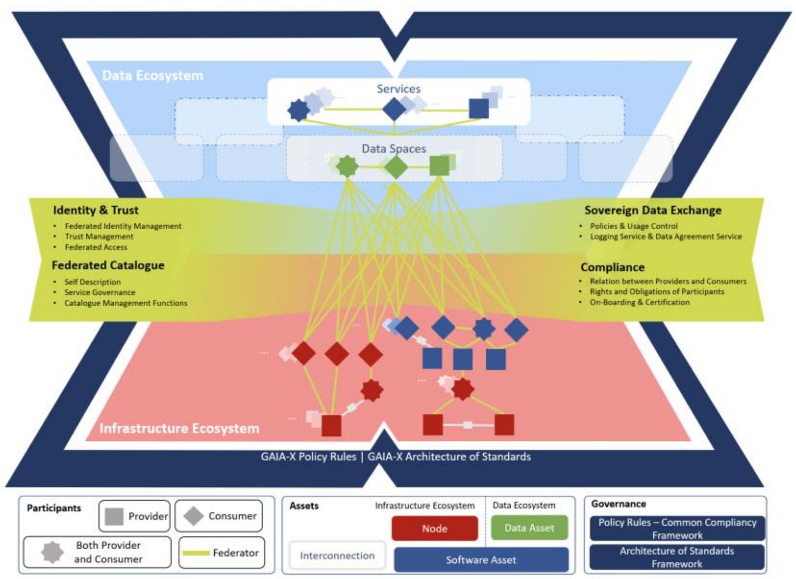


Figure 69. GAIA-X Reference Architecture[5]

In the GAIA-X ecosystem, the primary roles of data provider and data consumer are linked through a data agreement service. This service commences with the data consumer initiating a request to the data provider for data. Upon approval from the data provider, the data consumer is notified, and the data

[5] https://gaia-x.eu/wp-content/uploads/2022/06/Gaia-x-Architecture-Document-22.04-Release.pdf

exchange takes place. Throughout this process, both parties are kept informed by utilising the data logging service, which tracks the transactions and ensures compliance with data usage policies and constraints.

Figure 70 illustrates the interconnection between data providers and data consumers within the GAIA-X model.

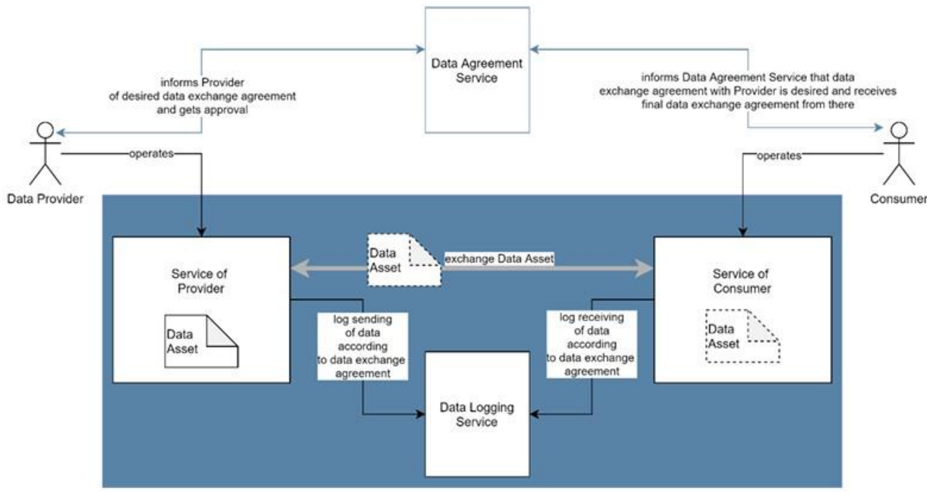


Figure 70. GAIA-X Users Flow chart[6]

6.1.3 FIWARE Reference Architecture

FIWARE offers an open-source software platform built upon open standards and portable components, facilitating the creation of smart solutions for establishing business data spaces. At its core lies the FIWARE Context Broker, which handles system updates, provides access to contextual states, and enables data analysis, processing, visualisation, and publication.

The FIWARE software architecture is based on the concepts of Context and Context Information. Context refers to the collection of Digital Twins associated with the system being analysed. Each Digital Twin is a virtual representation of either a physical asset or a specific concept within the system. The data linked to the attributes of each Digital Twin constitutes the Context Information. Managing and sharing this Context Information is central to the FIWARE architecture. For this purpose, FIWARE incorporates a dedicated Generic Enabler (GE) called the Context Broker, which handles these tasks. The presence of a FIWARE Context Broker is the primary requirement for a platform to be considered “powered by FIWARE”, with other platform components potentially sourced from the FIWARE Catalogue of GEs or third parties.

The operation of the FIWARE Context Broker is outlined in the FIWARE Open Reference Architecture, which consists of three primary layers. The foundational layer encompasses elements necessary for interfacing with Internet of Things, Robotics, and third-party systems, facilitating data collection and

[6] *Ibid*

command execution. The second layer comprises the core management, the context broker itself, which is responsible for managing and developing contextual applications. Finally, the third layer involves processes for data analysis, processing, and visualisation.

Figure 71 below provides an overview of the FIWARE Reference Architecture model.

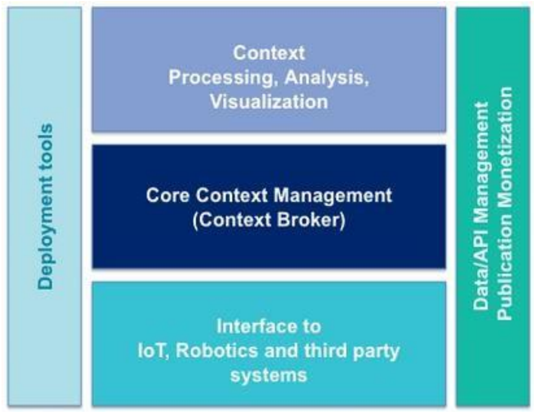


Figure 71. FIWARE Reference Architecture[7]

Figure 72 illustrates an example of implementing the FIWARE model within business ecosystems, focusing on the domain of Smart Energy applications. The architecture's bottom layer comprises the information systems of the data platform, where vertical smart solutions and other data sources are interconnected with IoT platforms and relevant agents. The second layer features the FIWARE context broker, which consolidates information from diverse sources and supplies data to the third layer for analysis and processing. This layer is heavily dependent on the deployment of several advanced AI or machine learning functions for carrying out tasks such as data analysis, visualisation, and additional processing.

[7] *Ibid*

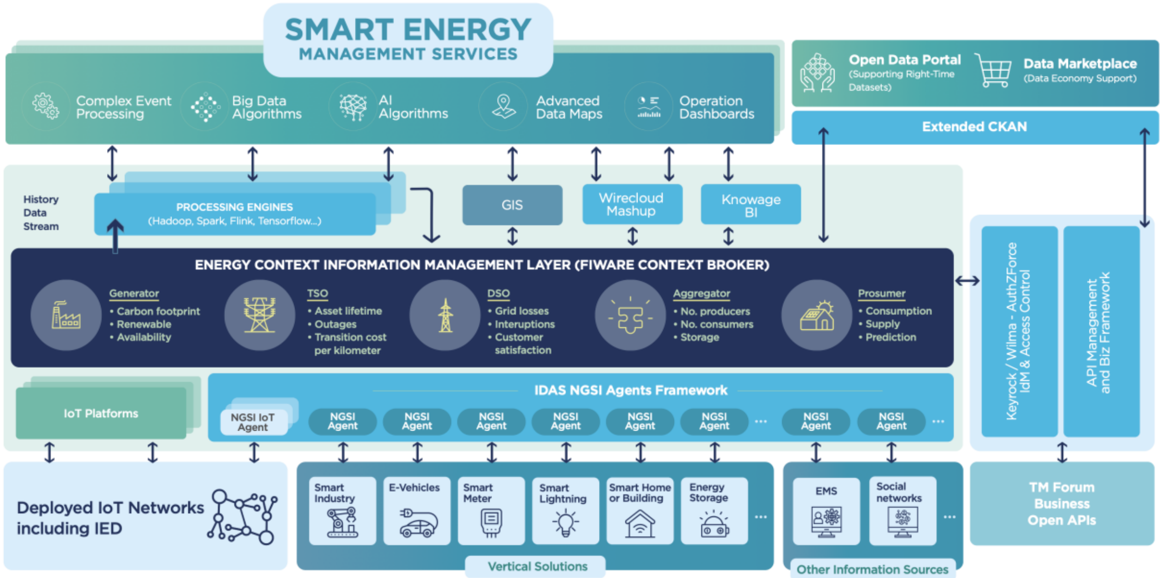


Figure 72. Application of the FIWARE Reference Architecture in Smart Energy Management Systems[8]

6.2 Review of EU-related projects Reference Architectures

This section reports the Reference Architecture of European (FP7, H2020, Horizon Europe) projects similar to BUILDSPACE. Specifically, the Reference Architectures of the following projects are analysed:

- **MATRYCS[9]:** Modular Big Data Applications for Holistic Energy Services in Buildings.
- **BD4NRG[10]:** Big Data for Next Generation Energy.
- **BIMSPEED[11]:** Harmonised Building Information Speedway for Energy-Efficient Renovation.
- **BIM2Twin[12]:** Optimal Construction Management & Production Control.
- **BaaS[13]:** Transition of EU cities towards a new concept of Smart Life and Economy.
- **mySMARTLife[14]:** Transition of EU cities towards a new concept of Smart Life and Economy.
- **DigiBUILD[15]:** High-Quality Data-Driven Services for a Digital Built Environment towards a Climate-Neutral Building Stock

[8] https://ckan.org
[9] https://matrycs.eu
[10] https://www.bd4nrg.eu
[11] https://www.bim-speed.eu/en
[12] https://bim2twin.eu
[13] https://www.baas-project.eu
[14] https://www.mysmartlife.eu/mysmartlife/
[15] https://digibuild-project.eu

6.2.1 MATRYCS Reference Architecture

The MATRYCS Reference Architecture (Figure 73) is comprised of the following three functional layers:

- **Governance:** This layer offers data services facilitating integration, preprocessing, semantic annotation, storage, and heterogeneous data querying for MATRYCS pilot datasets. It also ensures data access security and immutability throughout the MATRYCS Ecosystem. Core components include a) Interoperability Service Module, b) Data Pre-processing Module, c) Data Streaming Module, d) Data Storage & Querying Engine, e) Reasoning Engine, and f) Blockchain/Distributed Ledger System.
- **Processing:** This layer oversees advanced data processing and hosts the intelligent building blocks of MATRYCS, featuring a library of reusable Machine Learning/Deep Learning models. These trained models are accessible through the processing components' serving functionalities. Core components comprise a) Data Feed Module, b) Model Development Module & ML/AI Suite, c) Model Evaluation, and d) Model Serving Framework.
- **Analytics Toolbox:** This layer exposes analytics services to end-users, including Visualisations and Reports Engine, Analytics Building Services (for energy performance, infrastructure design and development support, policy making and impact analysis, and de-risking investments in energy efficiency), Building Digital Twin, and Virtual Workbench.

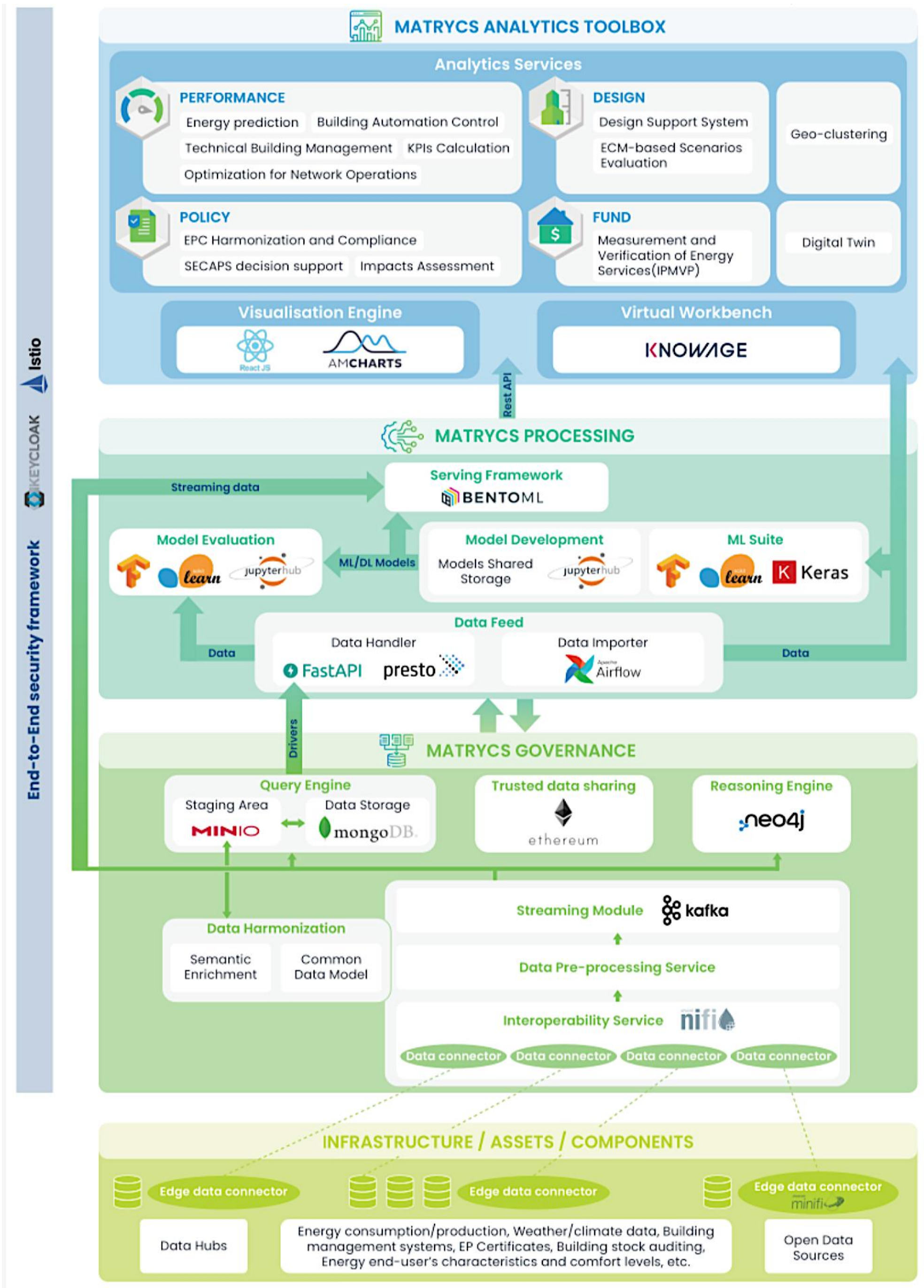


Figure 73. MATRYCS Reference Architecture[16]

[16] https://www.mdpi.com/1996-1073/15/7/2568

6.2.2 BD4NRG Reference Architecture

The BD4NRG Reference Architecture, as shown in Figure 74, includes the Data Interoperability layer and the Innovative Data Analytics Services layer:

- **Data Interoperability Layer:** This layer focuses on identifying communication interfaces with data sources, data formats, and provides data and information models for data transformation. Its goal is to ensure interoperable data exchange and utilisation.
- **Innovative Data Analytics Services Layer:** This layer embeds four sub-layers and outlines: a) Infrastructure necessary for Big Data processing; Utilisation of different analytics methods based on user requirements and specific data analytics scenarios; Analytics services utilizing energy and cross-sector Big Data; and Functional processes supported by analytics services that leverage insights derived from Big Data.

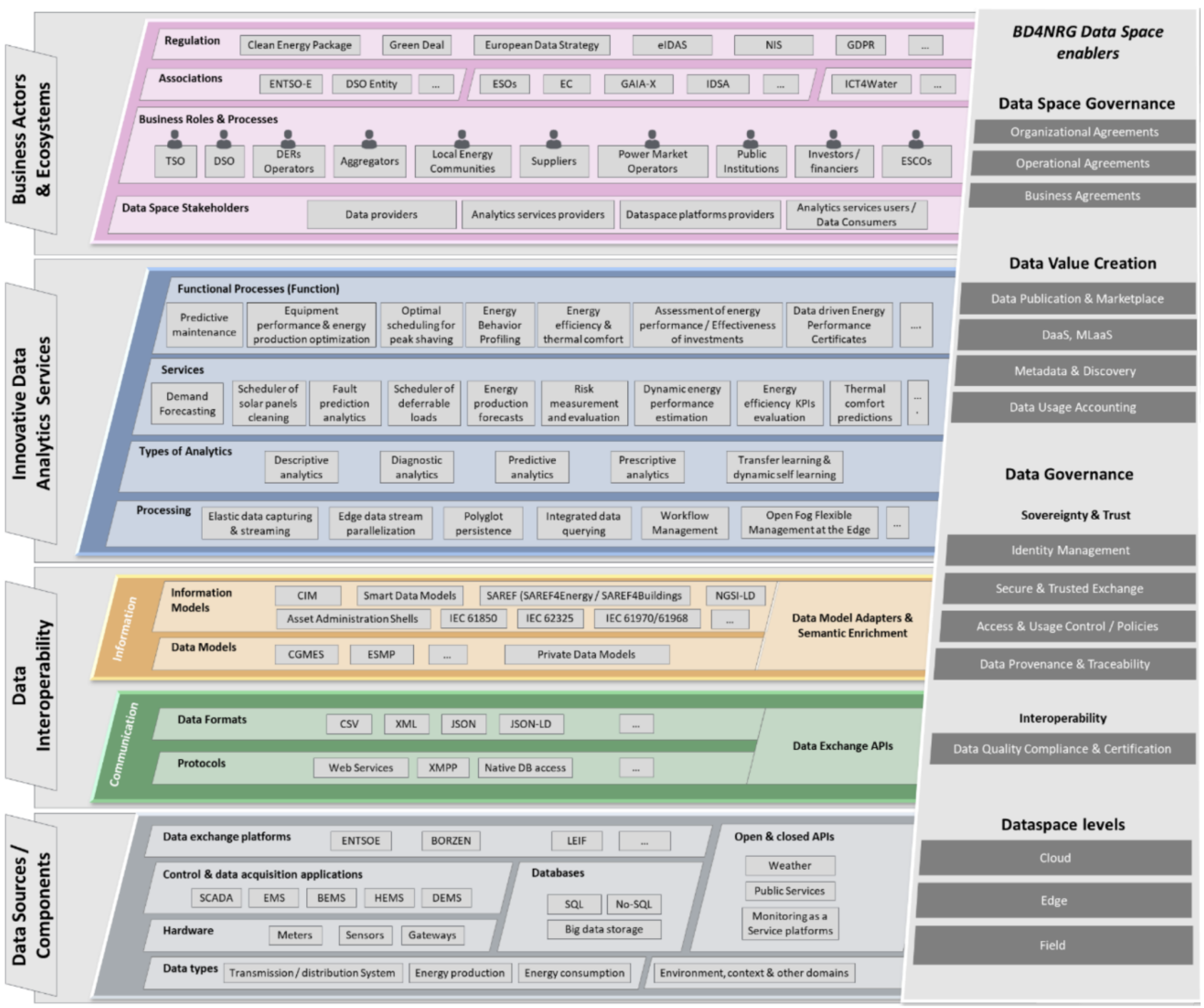


Figure 74. BD4NRG Reference Architecture

6.2.3 BIMSPEED Reference Architecture

The BIM-SPEED[17] (Harmonised Building Information Speedway for Energy-Efficient Renovation) project aims to streamline deep renovation projects towards reducing their implementation time by at least 30%, through an accessible BIM cloud platform, inter-operable tools, and standardised procedures for data acquisition, modelling, simulation, and maintenance. A reference architecture ensures communication among various BIM-based tools and data exchange, enhancing information harmonisation and interoperability. Integration frameworks and BIM Connectors facilitate ETL (Extract, Transform, and Load) processes for data consistency. The architecture, depicted in Figure 75, unifies three main pillars: dynamic data from demo sites, third-party services/tools, and static data from the BIM-SPEED platform repository. Open communication protocols and IoT platforms collect data uniformly. BIM Connectors and ETL processes integrate BIM tools into the platform.

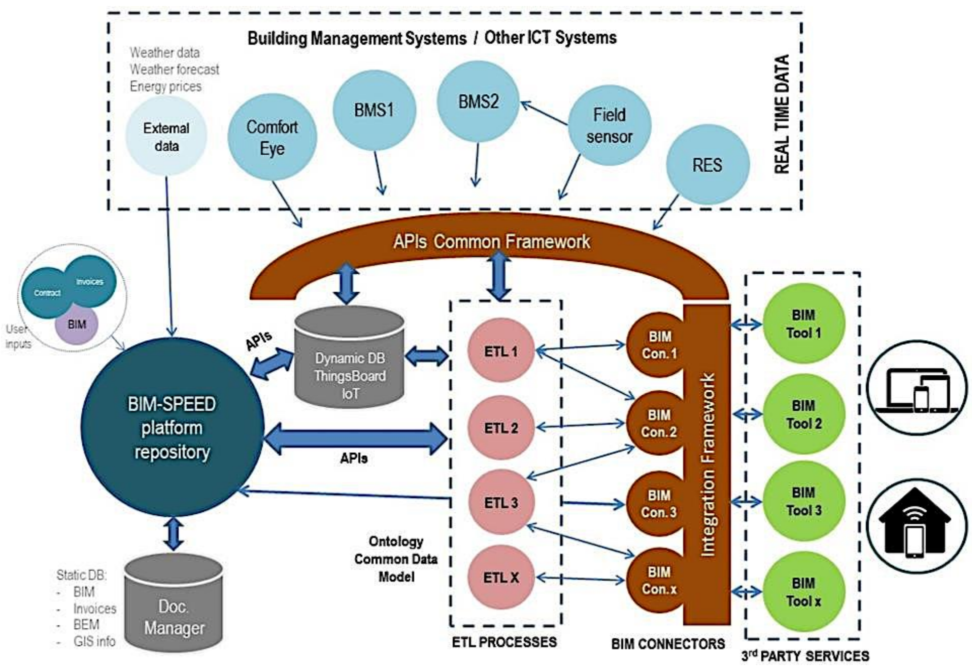


Figure 75. BIMSPEED Reference Architecture

More specifically, to ensure timely data collection from demonstration sites, an integration framework is provided which adopts open communication protocols to connect with specific Building Automation Networks, such as Lonworks[18] or BACnet[19], and/or utilises APIs capable of interfacing with existing Building Management Systems (BMS), for example ENERGOMONITOR[20] or ComfortEye[21]. To this end, the open-source IoT platform ThingsBoard is employed, which builds upon various communication drivers able to handle multiple languages. In this respect, communication with diverse and disparate devices

[17] https://www.bim-speed.eu/en
[18] https://www.rtautomation.com/technologies/lonworks/
[19] https://bacnet.org
[20] https://www.energomonitor.com
[21] https://ucm.buildingsmart.org/use-case-details/2439/en

utilising communication protocols and data formats of various types is facilitated, thereby enabling consistent management of all gathered information.

Secondly, the interoperability framework is responsible for facilitating the unobstructed integration of BIM-based tools within the BIM-SPEED global platform, thus ensuring accessibility to users. To do so, an integration framework for BIM tools and services is available, which utilises a series of BIM-Connectors capable of translating and adjusting the data within the BIM-SPEED platform to ensure alignment with the tailored requirements of individual BIM tools. These connectors also oversee the implementation of ETL processes aiming to gather all necessary information for each tool.

Furthermore, the interoperability framework is tasked with engaging the BIM-SPEED global platform in the data flow process, towards assembling static information from demonstration sites and static outcomes generated by BIM tools. This involves accessing the platform through a few exposed APIs' endpoints. The development of BIM-Connectors and ETL processes accommodates these APIs to retrieve files from the BIM-SPEED global platform (such as IFC files from demonstration sites), store dynamic time series data from ThingsBoard into the BIM-SPEED platform, and store outputs from other BIM-based tools.

Finally, the BIM-Connectors render the functionalities of BIM-based tools accessible by deploying the tool on a web server through a Graphical User Interface, with the backend having been designed to fortify the seamless implementation of the appropriate ETL processes.

6.2.4 BIM2TWIN Reference Architecture

The BIM2TWIN reference architecture (Figure 76) rolls out an approach for applying the digital twin concept upon building construction applications to enhance efficiency during on-site construction phases. Placed at the apex of the Digital Building Twin Platform (DBT), a suite of construction management tools and services leverage Artificial Intelligence techniques and automated processing of images, videos, point clouds, and geometry to facilitate elicitation of real-time knowledge. This extracted information constitutes the Project Status Model (PSM) and encapsulates both the product itself as well as the processes that need to be followed, in terms of providing a detailed snapshot of the Physical Building Twin at its current stage. Considering the constructive nature of the implicated applications, DBT must secure that its constituent information objects correspond to Building Information Model (BIM) representations of both product design and planned construction processes. A critical aspect is the use of open APIs, based on widely adopted technologies such as RESTful web services, and the integration of diverse data standards and ontologies under a common graph representation, with IFC as the main reference point. This approach promotes platform extensibility to other vertical domains and applications, enabling comprehensive digitalisation of the building construction process.

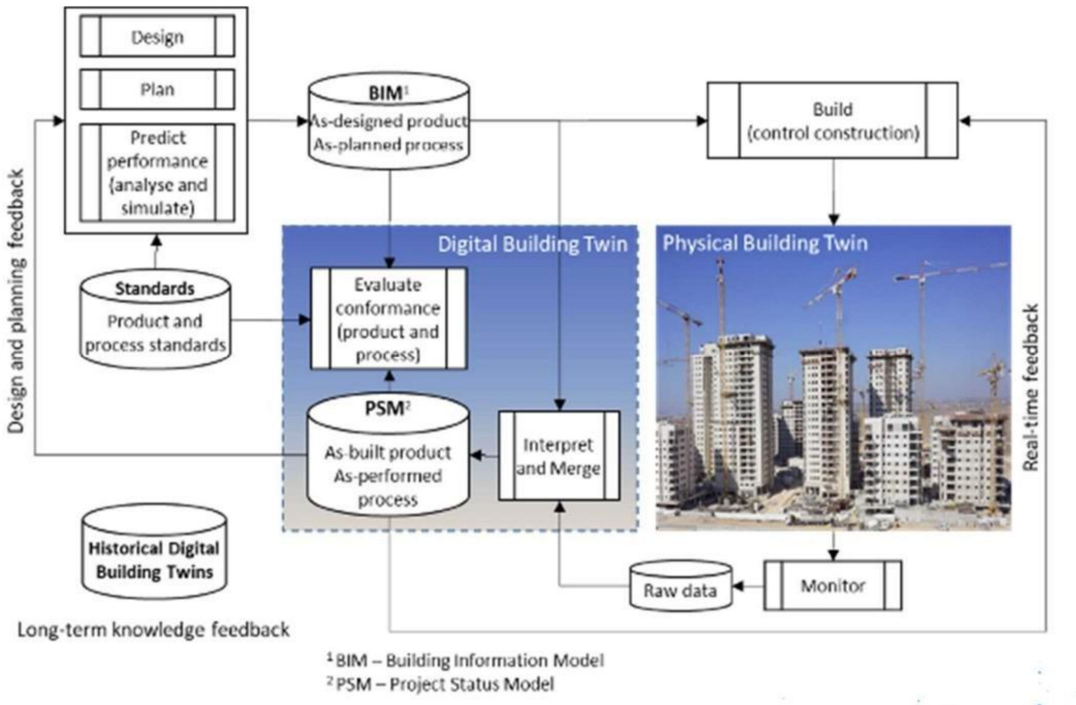


Figure 76. BIM2TWIN Reference Architecture

6.2.5 BaaS Reference Architecture

The BaaS project's[22] primary aim is to enhance the energy performance of non-residential buildings during their operational phase through optimal management of energy systems. This involves three ongoing tasks:

- Gathering information to evaluate the building's current status
- Assessing the impact of actions using Key Performance Indicators (KPIs)
- Efficiently managing resources.

The BaaS solution utilises an ICT platform to gather, integrate, and process data, ensuring consistent treatment of heterogeneous data. The reference architecture[23,24], depicted in Figure 77, comprises three main layers:

- The **Data layer**, responsible for gathering data, consists of four components:
  - Plants (buildings), where raw data from monitoring networks are collected
  - BIM Server, housing the building's BIM data
  - Data Warehouse (DWH), serving as the primary repository compliant with IFC4 format
  - External sources, such as weather forecast services

[22] https://www.baas-project.eu
[23] https://ieeexplore.ieee.org/document/7089063
[24] https://www.scitepress.org/Link.aspx?doi=10.5220/0005371002870294

- The **Middleware layer** facilitates communication between the data and application layers, ensuring harmonisation.
- The **Application layer** provides high-level services based on the gathered data and harmonised communication.

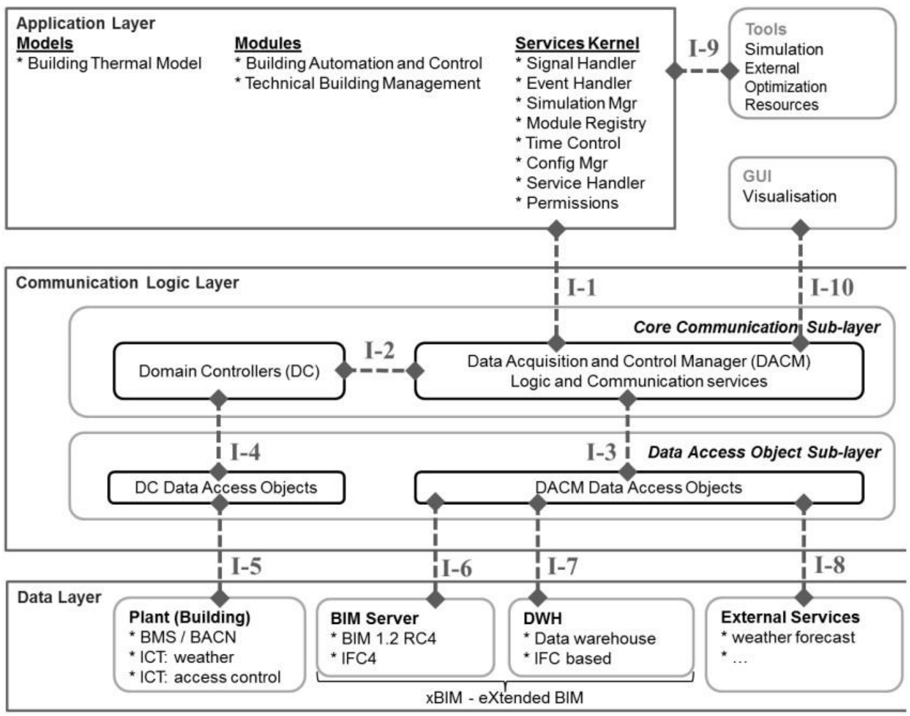


Figure 77. BaaS Reference Architecture

The Communication Logic Layer (CLL) plays a crucial role in achieving interoperability through event-driven communication and is divided into two modules. Firstly, the Domain Controller(s) (DC) interface with the building-specific data. Secondly, the Data Acquisition and Control Manager (DACM) standardises the data from individual buildings into unified datasets, ensuring proper data management when exposed to high-level services.

6.2.6 mySMARTLife Reference Architecture

mySMARTLife initiative represents a Smart City project, offering a data platform reference architecture focused on effectively managing extensive datasets from diverse sources such as energy, mobility, and others in a unified manner. Rooted in standards like ITU-T UNE 17804:2015 [25] or ESPRESSO, the mySMARTLife Reference Architecture is guided by several key principles:

- **Openness**, promoting open data sharing to enhance reusability

[25] https://www.itu.int/rec/T-REC-T.804

- **Interoperability**, enabling connection between diverse data sources to serve multiple city sectors (e.g., energy, mobility)
- **Privacy and security**, ensuring compliance with the GDPR (General Data Protection Regulation)
- **Technology agnosticism**, allowing flexibility for developers to choose implementation technologies

The architecture, illustrated in Figure 78, comprises six horizontal layers and one transversal layer for configuration purposes.

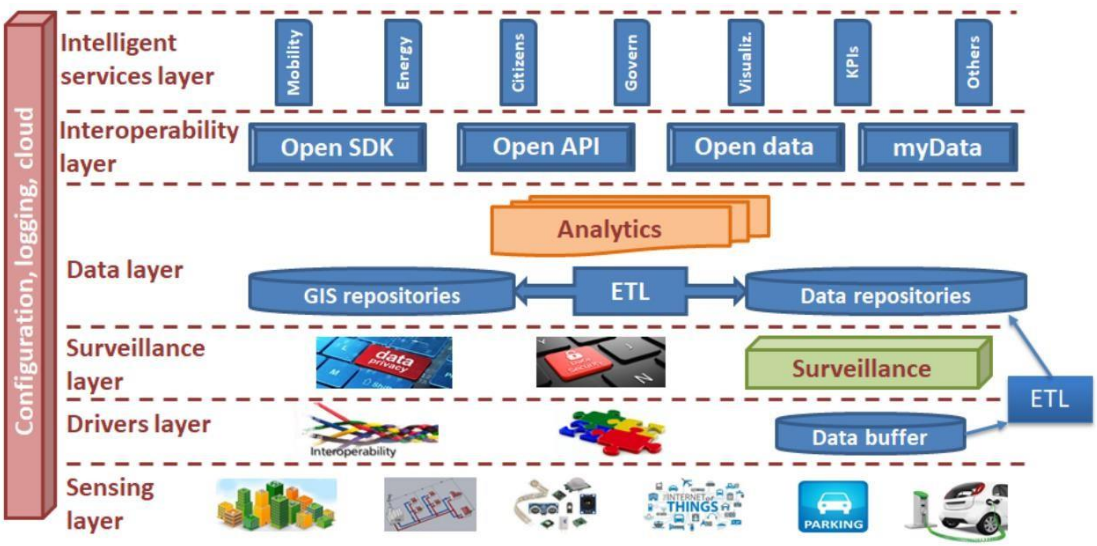


Figure 78. mySMARTLife Reference Architecture

mySMARTLife employs the SensorThingsAPI Data Model to depict data samples within urban environments. This approach involves integrating data from the sensing layer through the drivers' layer, ensuring interoperability via appropriate connectors. Subsequently, the data is translated into a standardised format within the data layer, where repositories are represented. By implementing Extraction, Transformation, and Loading (ETL) components, various repositories are interconnected to enhance the dynamic data derived from physical assets. For example, enriching data with GIS (Geographical Information Systems) for sensor and asset geolocation.

Moreover, the mySMARTLife reference architecture delineates three levels of interoperability:

- **Southbound interoperability**, bolstered by the drivers' layer to facilitate data acquisition via integration procedures based on open and standardised communication protocols.
- **Northbound interoperability**, established by the interoperability layer itself, aimed at sharing data through open interfaces.
- **Semantic interoperability**, achieved through the utilisation of the SensorThingsAPI common data model.

6.2.7 DigiBUILD Reference Architecture

Figure 79 illustrates the architecture, which is structured into layers following a microservices-oriented development approach. DigiBUILD's layers include:

- **Field Layer:** This encompasses the pilot data sources within DigiBUILD, consisting of three pilot clusters:
    - Buildings' Performance
    - Buildings VS Optimal Infrastructure Management
    - Policy & Finance
- **Data Interoperability & High-Quality Data:** This layer aims to integrate data and metadata from various sources to support automated modelling and quality checking services. It ensures application requirements are met and makes data accessible through a standardised interface to analytics and computing tools. Additionally, it implements smart contracts for data accessibility and reusability.
- **AI Services:** This layer focuses on delivering AI Services, including finer-grained energy profiling and forecasting, energy resources management, enhanced comfort and well-being for occupants, renovation roadmaps, energy efficiency financing, and decision-making tools for efficient and climate-resilient buildings.
- **Digital Twin Suite:** Utilising high-quality data from the Data Interoperability & High-Quality Data layer and AI services, the DigiBUILD Digital Twins are developed for informed planning of building infrastructure, designing future buildings and processes, and managing energy-efficient buildings and districts at scale.

The sources of exploited data include information gathered from building stock audits, time-series data collected from various sensors and meters (such as IAQ meters and energy consumption sensors), Digital Logbooks (which maintain records of building functionality), the lifecycle of building data, and real-time data generated by energy systems. More details regarding the building data assets, Digital Logbooks, and passports can be provided upon request.

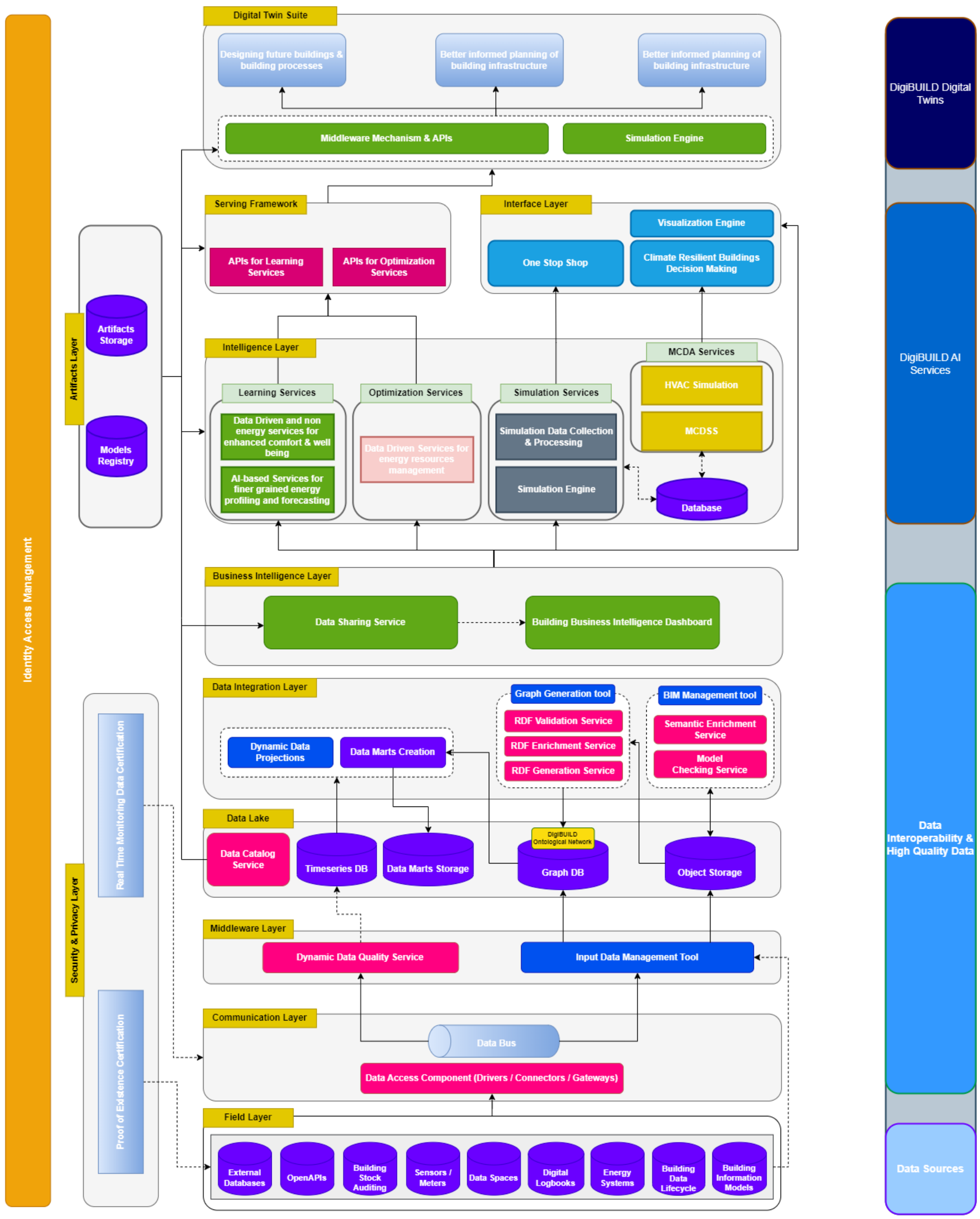


Figure 79. DigiBUILD Reference Architecture

6.3 BUILDSPACE Conceptual Architecture

The BUILDSPACE Conceptual Architecture serves as a comprehensive framework, consolidating the intricate connections and dependencies derived from the technical endeavours within the BUILDSPACE project. Its primary objective is to establish the blueprint for the development of the BUILDSPACE

Platform. On that reflection, the BUILDSPACE conceptual architecture meticulously integrates user requirements initially documented in D2.1 and subsequently refined in later reports (D2.2 and D3.1), incorporating evolving technical specifications. Moreover, the use cases delineated in D2.2 play a pivotal role in pinpointing crucial technical constraints and specifications, thereby laying the groundwork for configuring the architecture's functionalities in a manner that ensures alignment with real-world needs and priorities. Emphasising the functional perspective, the BUILDSPACE Conceptual Architecture has been built following an extensive literature review on well-established European standards governing diverse architectural aspects. These standards include GAIA-X for governance, IDSA for security, and FIWARE for the collection, management, and dissemination of contextual information, as thoroughly presented in the above. Moving one step beyond the relevant European standards, the literature review was extended also to cover other existing building data architectures such as MATRYCS, I-NERGY, BD4NRG etc.

The overall structure of the BUILDSPACE Conceptual Architecture is depicted in Figure 78, segmented into blocks to enhance comprehensibility and facilitate the incorporation of all modifications that emerged as the project progressed. For clarity, this proposed architecture is further detailed in three figures (Figure 81, Figure 82, Figure 83), each highlighting specific layers of information and their components, serving as a guiding reference that the BUILDSPACE platform has been based upon.

It is noteworthy that the below presented version of the Conceptual Architecture has arisen after extensive refinement through three internal feedback rounds involving both platform developers and service providers. The latter implies that all updates gleaned from each feedback cycle, have been successfully accommodated in this final version of the BUILDSPACE conceptual architecture.

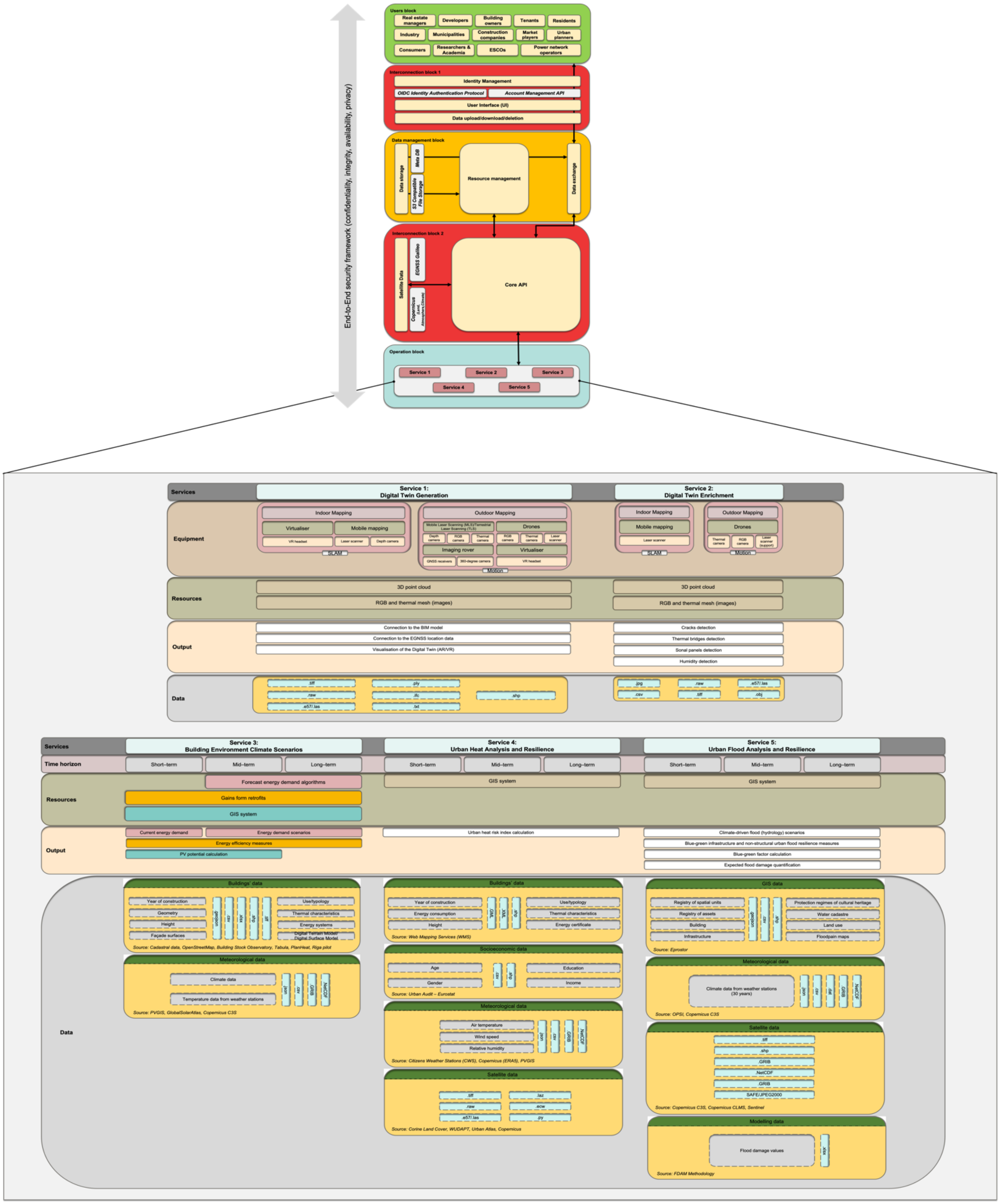


Figure 80. BUILDSPACE Conceptual Architecture

In this context, the blocks within the initial segment delineate a logical partition of the architecture (Figure 81), representing precisely the communication pathways within the architecture implementation. These blocks are approached from a software-centric perspective, their combined functionality achieving a high-level operational capability. The aforementioned blocks include:

- **Users block**: This block illustrates the intended end-users of the BUILDSPACE platform in alignment with the proposed Conceptual Architecture. These users were initially outlined in deliverable D2.1 and are reiterated here to facilitate comprehension of an all-inclusive "data exchange" process. To specify, the implicated end-users' groups are the following:
    - Real estate managers
    - Developers
    - Building owners
    - Tenants
    - Residents
    - Industry
    - Municipalities
    - Construction companies
    - Market players
    - Urban planners
    - Consumers
    - Researchers & Academia
    - ESCOs
    - Power network operators

  The above users are practically involved in a "data exchange" request, a process that is presented as part of the "Data management block".

- **Interconnection block 1:** This forms the connecting link between the platform and the end-user. It encompasses multiple layers serving as a centralised point for user interaction with the platform. Acting as middleware, it facilitates data acquisition, management, and exposure. Initially, it integrates the "identity management" layer, ensuring standardised user login procedures. This enables precise control over user data access based on delegated access rights. Furthermore, it ensures that users sharing a common affiliation possess identical access privileges.

  User authentication is accomplished through OpenID Connect (OIDC), which acts as a secure identity layer, extending OAuth 2.0 for consistent user authentication. Users can utilise their existing credentials to securely access various applications. OIDC issue's identity tokens in JSON Web Token (JWT) format, ensuring the seamless transmission of user data. For deployment, the open-source software Keycloak was selected. In broad terms, the OIDC protocol utilises scopes to clearly delineate access levels during authentication. By leveraging these scopes, the system integrates group-based authorisation provided by OIDC, enabling precise determination of user data access. Within an organisation, users who share a common group affiliation also share access privileges, simplifying data sharing among organisation members. Keycloak's group functionality enhances access control efficiency and accuracy within collaborative environments.

A complementary component to Keycloak, serving as an administrative interface for organisational management, was also developed. Operating as an administrative gateway, this User Interface (UI) enables upload/download/delete data from the platform for the end-users. This data, as elaborated below, is associated with the respective user and stored within the platform, facilitating easy management for the user upon subsequent visits or for other users requesting data via a “data exchange” request.

Data management block: This block comprises the “data storage”, “resource management”, and “data exchange” layers. The “data storage” layer ensures efficient and secure data management and consists of two sub-layers. An S3-compatible file system known as MinIO, is the first sub-layer, offering a scalable and adaptable solution for actual file storage, granting end-users access to uploaded data files associated with them.

MinIO, acting as the primary repository, is seamlessly integrated to facilitate efficient and platform-agnostic data storage. This open-source software is designed to allow object storage with high performance, employing parallelisation techniques and horizontal scalability through the addition of new nodes to the cluster. Moreover, it boasts an array of security features such as encryption, alongside support for secure communication protocols. Its inherent characteristics ensure scalability, reliability, and high availability, in line with the platform's unwavering commitment to data integrity.

The Metadata storage constitutes the second sub-layer of the “data storage” layer, employed to manage data exchange requests among different user groups, and enhance flexibility. Metadata is facilitated by MongoDB, a NoSQL database which offers a dynamic and agile solution for storing metadata linked with the files. MongoDB accommodates several metadata configurations, thus empowering users to conduct detailed searches based on various metadata attributes. The architecture ensures a synchronised workflow between the file system and the storage database through dynamic resource management actions, to facilitate smooth operation of the platform based on the workload and avoid critical conditions such as lags, disconnections, etc.

- **Interconnection block 2:** Functioning as a connecting bridge among various components, this block highlights the pivotal role of a core API, which acts as the central component of the BUILDSPACE Conceptual Architecture (and subsequently the BUILDSPACE Core Platform). It manages communication: a) between the platform (and its services) and individual users, b) among different user groups within the platform (and its services) during ongoing data exchange requests, and c) between the platform (and its services) and external auxiliary services like Copernicus and EGNSS.

The Core API has been developed using Golang (v1.20.3) and adheres to OpenAPI standards, serving as the central conduit for seamless communication and interaction across a multitude of essential functionalities. It has been designed to manage the operations of the Core Platform by receiving and processing HTTP requests. This encompasses tasks such as file uploading, downloading, and deletion, along with the creation of MinIO buckets and organised content folders. Operations like folder creation, deletion, and sharing are executed through this API. Moreover, the Core API serves as the integrator of three Copernicus APIs related to Land, Climate Change, and Atmosphere services. This integration stands at the heart of BUILDSPACE project, aimed at consolidating diverse datasets. By amalgamating information from these services, a unified and comprehensive data repository will be established, enhancing the capabilities of the BUILDSPACE ecosystem. Additionally, the integration of the EGNSS Galileo service is planned, providing a comprehensive and unified gateway for accessing geospatial and environmental data.

In essence, the REST API acts as a vital intermediary for all services within the BUILDSPACE ecosystem, forming a standardised interface for data retrieval and handling. Serving as the primary integration point, it ensures that various services can efficiently consume and contribute to the shared data ecosystem, embodying a unified approach to data management and collaboration.

- **Operation block:** This block encompasses all services hosted on the BUILDSPACE platform, available to end-users for implementing complex location-based and remote sensing applications at either building or city level. The included components of each service are presented within the second part of the BUILDSPACE conceptual architecture that follows.

Throughout all layers, an end-to-end security framework is implemented, integrating necessary security functionalities at every level of the architecture to ensure confidentiality, integrity, availability, privacy, and overall prevention and mitigation of cyber-attacks.

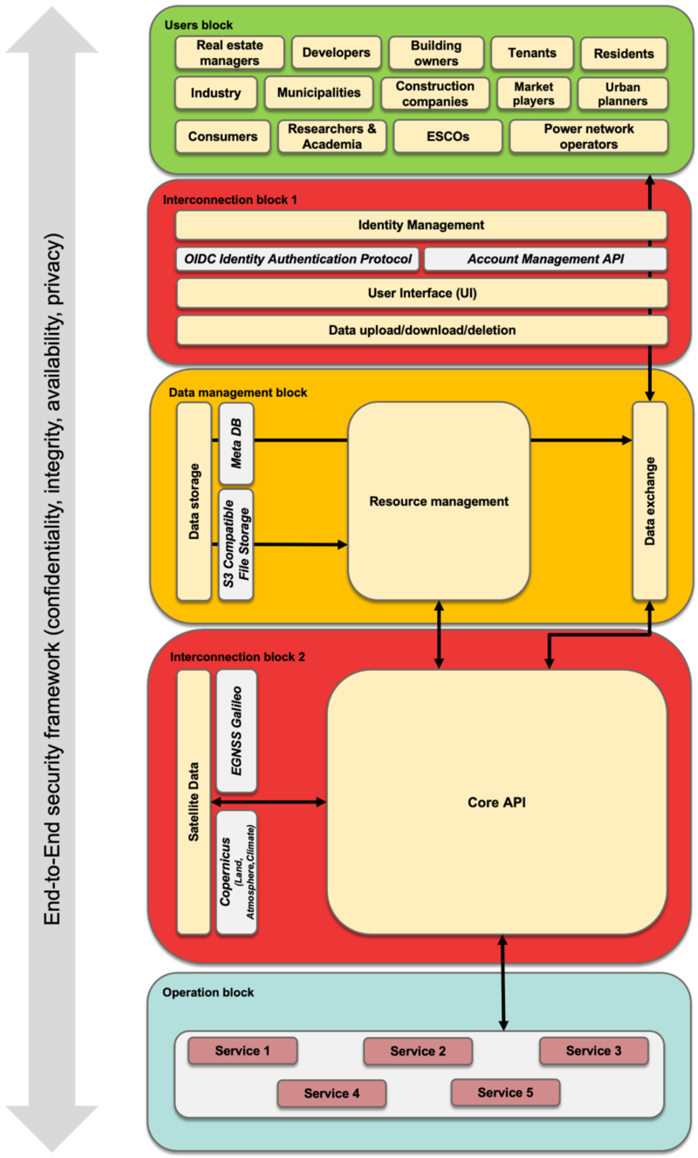


Figure 81. First part (software-oriented) of the BUILDSPACE Conceptual Architecture

Moving into the second part of the Conceptual Architecture (Figure 82 and Figure 83), its aim is to outline the BUILDSPACE Services for: a) digital twin generation, b) digital twin enrichment, c) building environment climate scenarios, d) urban heat analysis and resilience, e) urban flood analysis and resilience. In line with the structure of the first part, the components of these services have been identified and grouped into five distinct blocks. Three of these blocks (Resources, Output, Data) remain consistent across all services, while two blocks (Time horizon, Equipment) differ. Consequently, this distinction gives rise to two groups of services.

To elaborate, the first two services (SE1, SE2) are designed with a prerequisite for equipment usage in both indoor and outdoor mapping of buildings, thus necessitating the inclusion of the “Equipment” block. Conversely, the remaining services (SE3, SE4, SE5) incorporate the concept of time horizon within their functional framework rather than equipment, leading to the development of the “Time horizon” block.

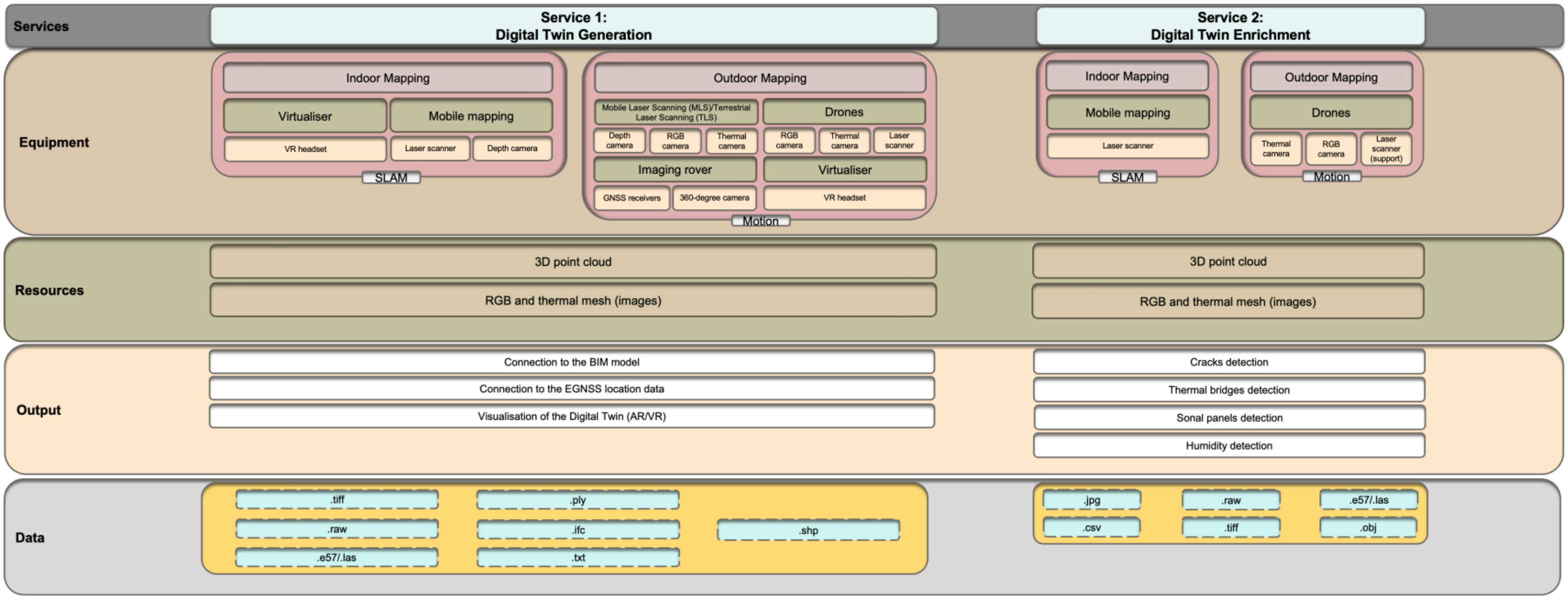


Figure 82. Presentation of the second part (services-oriented) of the BUILDSPACE Conceptual Architecture for SE1 and SE2

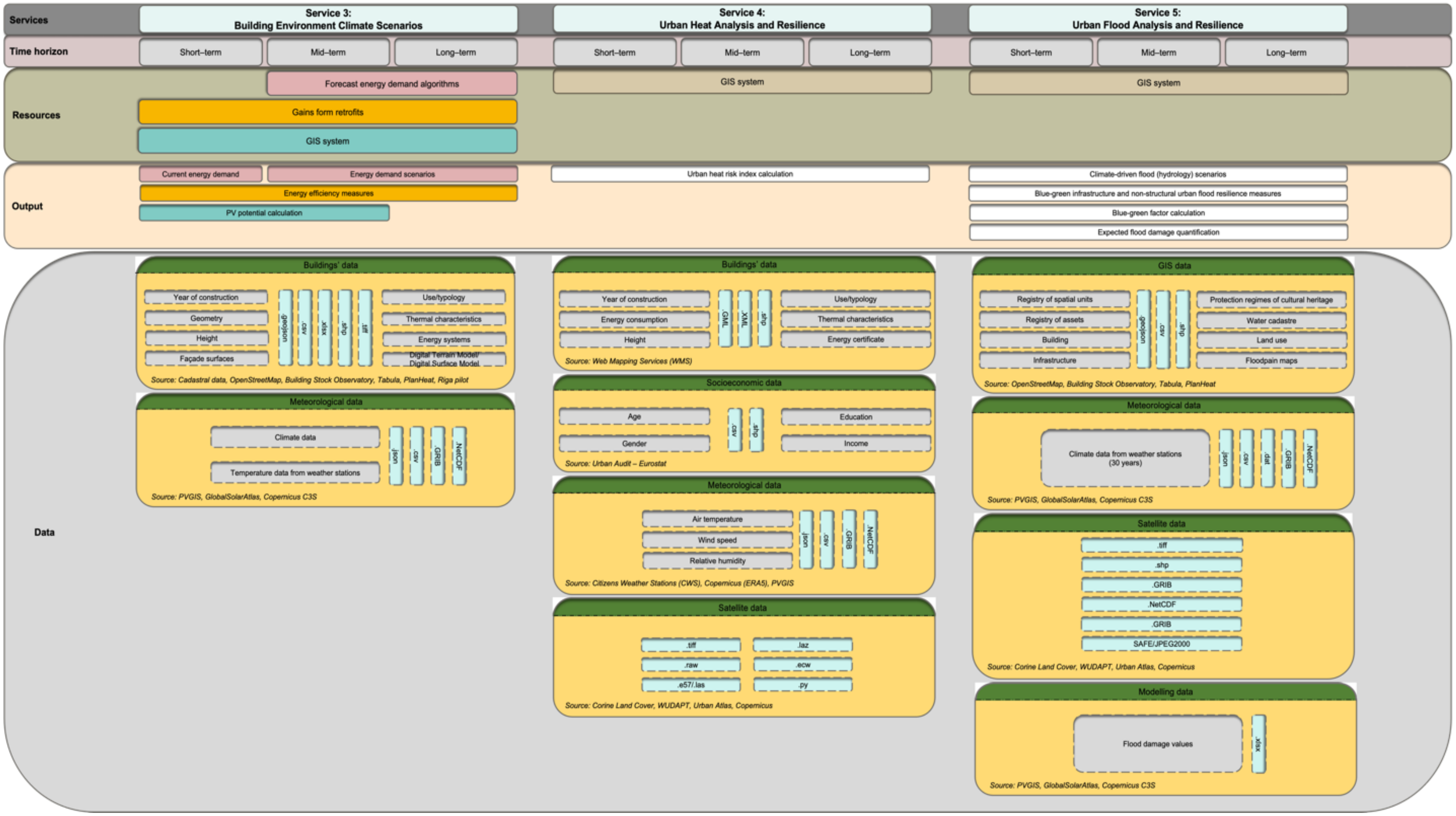


Figure 83. Presentation of the second part (services-oriented) of the BUILDSPACE Conceptual Architecture for SE3, SE4 and SE5

Below is a concise overview of each block's primary focus. For a more comprehensive understanding of the layers included in each service, detailed information can be found in the deliverable 3.1, where all services are deeply analysed:

- **Resources:** This block outlines the key tools utilised within each service to generate the final output. Essentially, it encompasses the essential tools necessary to ensure the achievement of desired output features.
- **Output:** In this block, the outcomes of the services are presented, showcasing their diverse applications for end-users.
- **Data:** This block illustrates the various types of data utilised within each service, along with their respective formats to maintain integrity. This data is stored within the BUILDSPACE platform via the respective UI and exchanged between users through data exchange requests, as presented in the first part of the BUILDSPACE conceptual architecture.
- **Time horizon:** This block pertains specifically to SE3, SE4, and SE5. The rationale for this differentiation stems from the fact that these three services involve future climate scenarios (e.g., SSPs, RCPs, etc.), necessitating a direct alignment of each resource and output with a specific time frame.
- **Equipment:** Exclusive to SE1 and SE2, this block has no impact on the implementation of SE3, SE4, and SE5. Building upon the explanation provided in the "Time horizon" block, SE1 and SE2 require the use of equipment (e.g., drones, laser scanners, thermal cameras, etc.) to deliver the expected outputs, unlike SE3, SE4, and SE5.

7 Alignment of BUILDSPACE Conceptual Architecture to existing European standards

This section examines the relationship between the BUILDSPACE Conceptual Architecture and other prominent architectural solutions discussed in the context of Section 6. The primary objective is to assess the consistency of the various architectural perspectives and to identify any potential gaps in the architectural definitions. The remainder of this section will detail how the BUILDSPACE Conceptual Architecture aligns with the IDSA Reference Architecture, the GAIA-X Reference Architecture, and the FIWARE Reference Architecture.

7.1 Mapping to IDSA Reference Architecture

International Data Spaces (IDSA) is a decentralised ecosystem designed to enable members to share data efficiently and securely. The foundational components of the IDSA ecosystem are (Figure 84):

- **Data Interoperability:** Providing a robust framework for efficient data exchange among participants, ensuring complete decoupling of data providers and consumers.

* **Data Sovereignty and Trust:** Offering technical means to ensure that participants can trust each other and maintain control over the data they share.
* **Data Value Creation:** Supporting the development of multi-sided markets where participants can generate value through data sharing, creating data value chains.

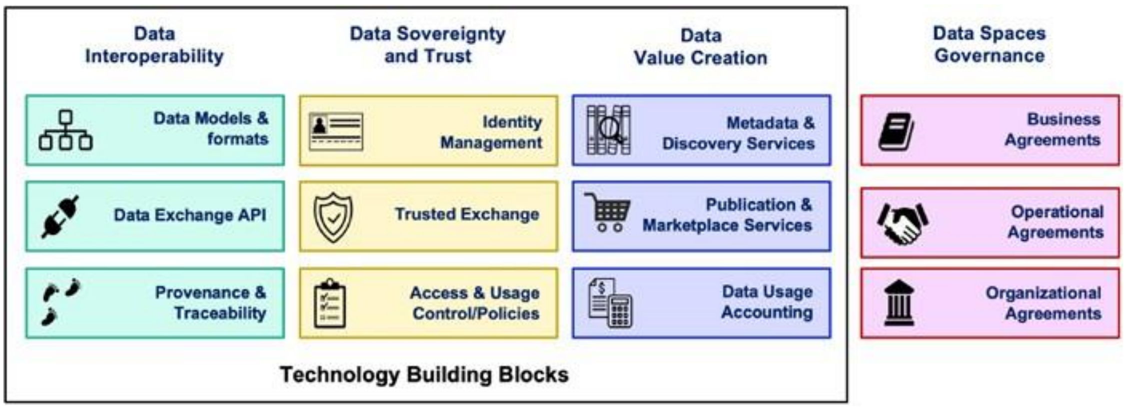


Figure 84. IDSA ecosystem building blocks

According to Figure 83, the mapping of the BUILDSPACE Conceptual Architecture to the IDSA Reference Architecture is implemented through BUILDSPACE's software-oriented blocks. Specifically:

* **BUILDSPACE Users Block** adheres to both the IDSA Data Interoperability and the Data Sovereignty and Trust Layers through prescribing potential users of the BUILDSPACE Core Platform that constitutes an essential component to data exchange processes and requests as well as to identity management and access policies.
* **BUILDSPACE Interconnection Block 1** aligns with IDSA Data Sovereignty & Trust through the Identity Management component as well as the User Interface, which provide mechanisms for trusted data exchange, identity management, and access & usage control policies.
* **BUILDSPACE Data Management Block** aligns with IDSA Data Interoperability by incorporating components for Provenance & Traceability (End-to-End Security Framework), modules for creating Data Models & Formats through the User Interface, and frameworks for data exchange (S3 Compatible File Storage and Meta DB).
* **BUILDSPACE Interconnection Block 2** aligns with IDSA Data Interoperability layer through the Security & Privacy Layer, which provides mechanisms and APIs for trusted data exchange (Core API), identity management, and access & usage control policies.
* **BUILDSPACE Operational Block** includes modules that comply with the functionalities supported by IDSA Data Value Creation modules. Specifically, the BUILDSPACE Services offer capabilities similar to IDSA's Data Usage and Accounting for extracting patterns from stored pilot information. Furthermore, BUILDSPACE Services align with the IDSA Publication and Marketplace services, which manage the results from BUILDSPACE Services and store data.

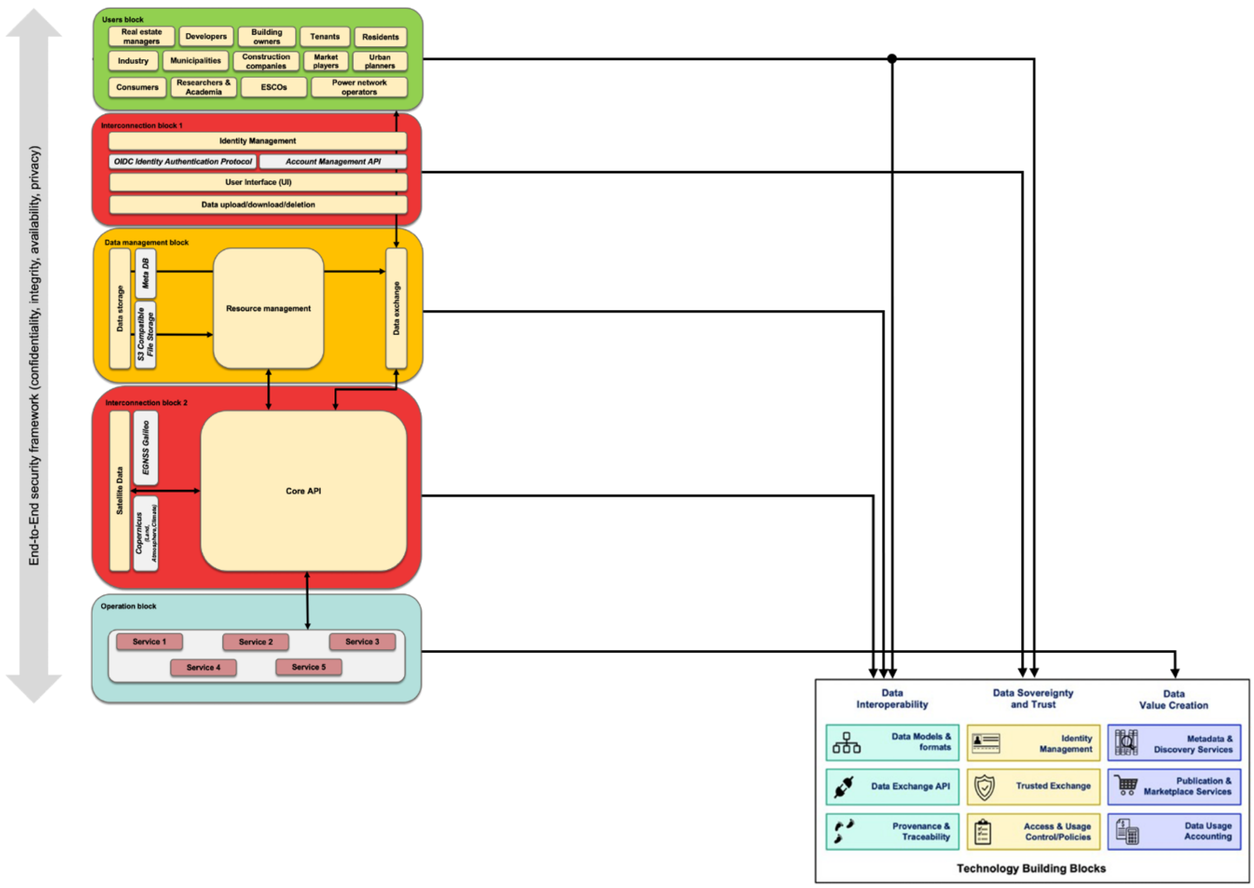


Figure 85. BUILDSPACE Conceptual Architecture alignment with IDSA Reference Architecture

7.2 Mapping to GAIA-X Reference Architecture

The GAIA-X Reference Architecture outlines the infrastructure standards necessary for connecting diverse heterogeneous cloud systems to different Data Ecosystems. GAIA-X core components are federated microservices which are designed to deliver essential GAIA-X functionalities, including:

- **Identity & Trust:** Encompasses authentication, authorisation, credential management, and trust services.
- **Federated Catalogue:** Involves inter-catalogue synchronisation, data cataloguing, and listing.
- **Sovereign Data Exchange:** Includes data contract services and data exchange logging services.
- **Compliance:** Covers data models and formats.
- **Integration & Portal:** Comprises documentation, AI services, business management, workflow orchestration, dashboards, and pattern extraction.

These service groups set the standards that all Reference Architecture building blocks must adhere to in order to comply with GAIA-X. In the case of BUILDSPACE, Figure 86 presents the mapping with GAIA-X. Notably:

- **BUILDSPACE Users Block** adheres to the Sovereign Data Exchange of the GAIA-X Reference Architecture by recommending potential users for the BUILSPACE Core Platform, a crucial component for managing data exchange processes and handling data requests.
- **BUILDSPACE Interconnection Block 1** conforms to the GAIA-X Identity and Trust and Federated Catalogue Layers through its Identity Management component and User Interface. These elements facilitate secure data exchange, manage identities, and enforce access and usage control policies.
- **BUILDSPACE Data Management Block** aligns with GAIA-X Sovereign Data Exchange by incorporating components and frameworks for data storing and data exchange handling (S3 Compatible File Storage and Meta DB).
- **BUILDSPACE Interconnection Block 2** aligns with GAIA-X Sovereign Data Exchange and Compliance Layers through the development of the Core API which is responsible for overseeing the functionalities of the BUILDSPACE Platform as a whole, including data retrieval, handling and monitoring.
- **BUILDSPACE Operational Block** aligns with GAIA-X's Integration & Portal services, offering smart capabilities such as pattern extraction through data-driven techniques, and providing portals and dashboards to display the derived results.

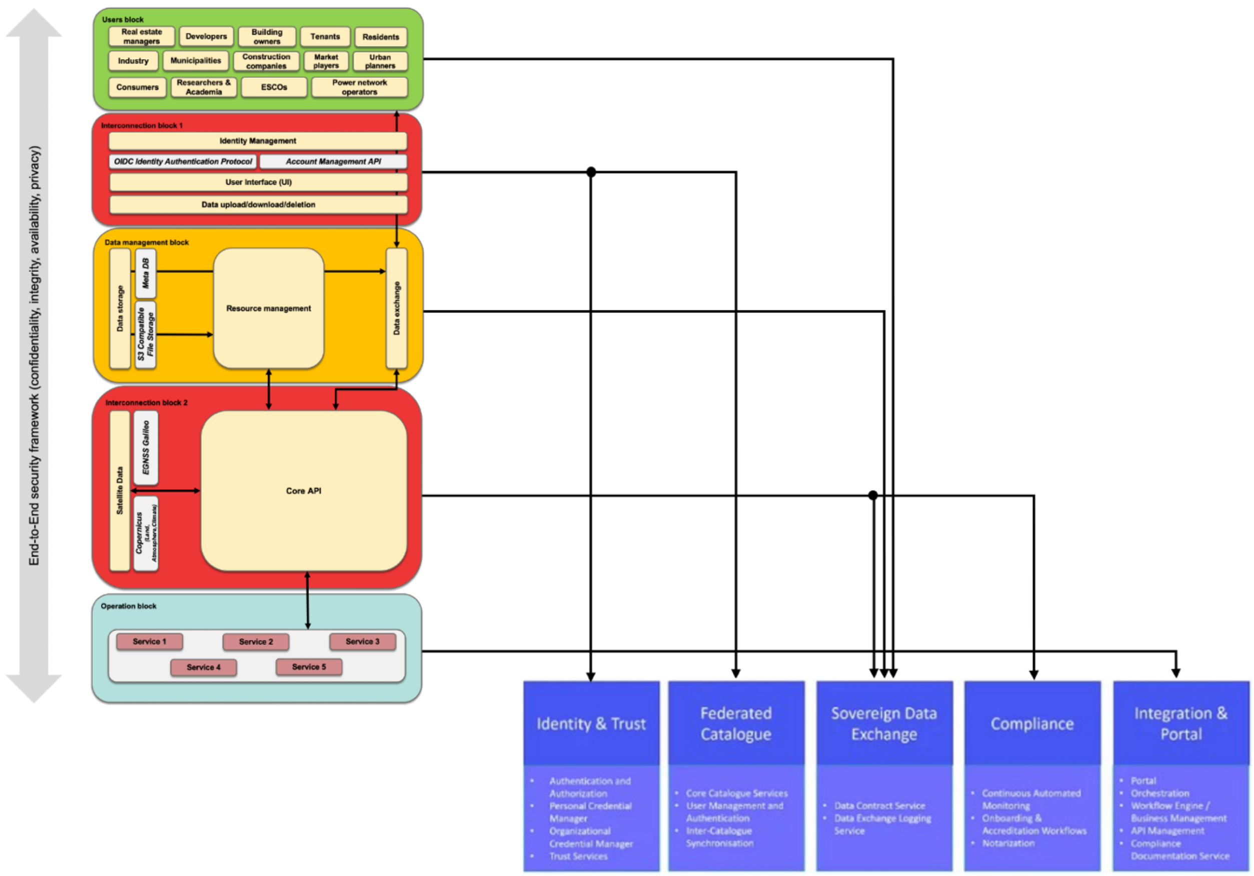


Figure 86. BUILDSPACE Conceptual Architecture alignment with GAIA-X Reference Architecture

7.3 Mapping to FIWARE Reference Architecture

FIWARE introduces an Open Reference architecture that shares many similarities with the BUILDSPACE Conceptual Architecture, primarily focusing on the software and implementation perspectives. As a result, the BUILDSPACE Conceptual Architecture could potentially integrate FIWARE components. The mapping of BUILDSPACE Conceptual Architecture to FIWARE is illustrated in Figure 87.

- **BUILDSPACE Data Management Block** is aligned with the FIWARE Context Processing, Analysis, and Visualization Layer. Specifically, the Resource Management along with the Storage Frameworks are responsible for ensuring a seamless analysis and information extraction from the stored data.
- **BUILDSPACE Interconnection Block 2** and its included components, offer functionalities akin to FIWARE Interfaces on the Field Layer (including IoT, Robotics, and third-party systems) and Core Context Management, supported mainly by the presence of the Core API. BUILDSPACE Interconnection Block 2 enables adding and developing tools as well as displaying the inferred results to end users and stakeholders of the BUILDSPACE Core platform, providing data

management and monetisation similar to FIWARE's Data/API Management, Publication, and Monetization.

- **BUILDSPACE Operational Block** is compatible with FIWARE’s deployment tools, offering portals and dashboards to display the derived results.

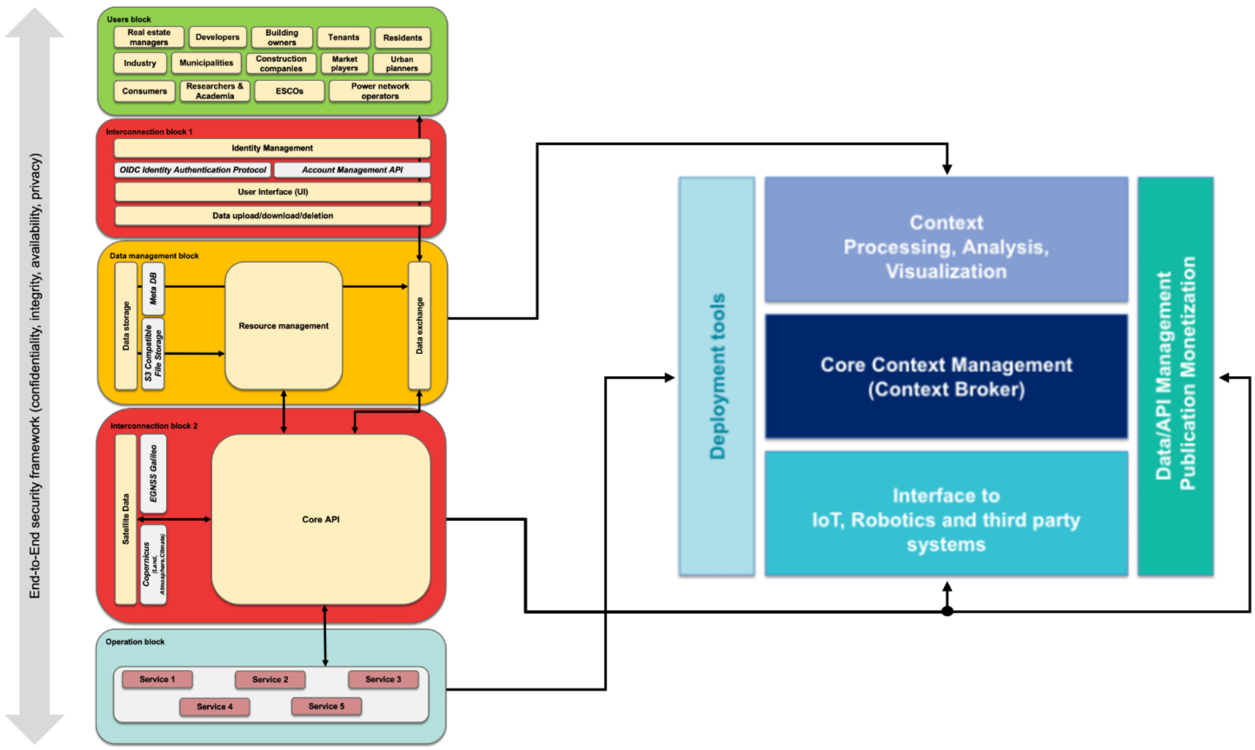


Figure 87. BUILDSPACE Conceptual Architecture alignment with FIWARE Reference Architecture

8 Conclusions

Deliverable D2.3, entitled “BUILDSPACE Specifications and Architecture” outlined the specifications of the BUILDSPACE Conceptual Architecture. Prior to this, a detailed presentation on the updates of user requirements, use cases and graphical visualisations has been also included. The document extensively detailed the blocks of the Conceptual Architecture, including data interoperability & high-quality data. It elaborated on their functionalities, modular architectures, interconnections, and requirements. Additionally, the deliverable provided a concise overview of the core modules within each building block, along with pertinent details about necessary interfaces and functional interactions. Furthermore, it incorporated references and review analysis of key European initiatives that influenced the architectural design of the BUILDSPACE solution and how these models and initiatives contributed to the architecture definition.

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