

ET4Digital – Empowering Trainers for Digital Innovation in Construction Ecosystem

Deliverable 3.1

Setting innovative demonstrator for digital ecosystem

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Summary

ET4Digital – Empowering Trainers for Digital Innovation in construction Ecosystem is dedicated to advancing the quality, effectiveness, and innovation in training trainers and teachers within the construction sector for the seamless integration of digital technologies. The initiative involves creating innovative tools and a comprehensive capacity-building program. Trainers will engage with a specially designed digital technologies demonstrator, fostering hands-on experience. The project aims to overcome barriers hindering SMEs from adopting digital technologies by co-designing, testing, and validating training programs. The ultimate goal is to empower trainers to lead the digital transition in the construction industry, tapping into its significant but underexplored potential.
Although digital innovation has grown significantly in recent years, companies are finding it difficult to effectively exploit this enormous potential. Instead, digitization in the construction sector can offer significant opportunities for the entire value chain by not only improving existing practices, but also integrating disruptive technologies and tools that can lead to new processes, business models, materials and solutions. It is important to underline that the combination of digital technologies makes it possible to maximize the benefits associated with digital transformation. For example, BIM, IoT, Augmented Reality and Digital Twins are deeply interconnected, as they refer to technologies that leverage each other and can be seen as different phases or elements of the same digital transformation.

As demonstrated by several European and national researches, the construction sector is positioned far behind the other industrial fields when it comes to digitalisation.
To date, the European construction sector is facing challenges which are hampering its competitiveness. Among these:

- Labour shortage
- Lack of digital skills in some countries
- Lack of interest among entrepreneurs and workers on the digitalisation of processes
- Lack of motivation on the part of young people to work in the sector
- Need to increase productivity while improving quality, cost efficiency and project delivery
- High costs related to technologies and digital tools

Therefore, the specific objective of the project is to deliver customized programs to professional trainers, aiming to equip them with new digital strategies, tools and skills. As intermediaries, these trainers play a crucial role in demonstrating to enterprises and workers the benefits of digitalization and the positive outcomes it can yield. This approach facilitates the upgrading of workers' skills in digitalization, emphasizing that traditional materials and techniques can be innovatively supported by digital technologies, leading to reduced costs and time wastage.

Furthermore, the job market continually evolves, shaping the required profiles and skills that workers need to possess in response to the demands of companies and employers. By updating the professional profiles required in the construction sector and digitalizing its processes, we can attract young, educated workers to a field of work still considered "traditional".

1. Introduction

1.1 Purpose of this document

The ET4Digital project aims to strengthen the capacity of trainers and teachers in the construction sector to support the digital transition of SMEs through innovative training tools and learning methodologies. In a context where the adoption of digital technologies in construction is still at an early stage, ET4Digital provides a coordinated European response by developing practical instruments, experiential learning environments, and a transnational capacity-building programme. The project focuses on key enabling technologies—such as Building Information Modelling (BIM), Digital Twin solutions, Virtual Reality (VR), and other digital tools—that can significantly enhance training effectiveness and foster innovation within the sector.

Within this framework, Work Package 3 – "New Teaching Approach for Digital Transition" plays a central role in defining, developing, and testing an innovative pedagogical model for trainers. WP3 introduces a practice-based and technology-enhanced learning approach which mobilises a digital demonstrator to allow trainers to engage directly with digital tools, simulate realistic construction processes, and experience new forms of interactive and immersive learning. The outputs of WP3 form the foundation for the subsequent capacity-building programme to be developed and validated in WP4.

Deliverable 3.1 represents the first output of WP3 and provides a description of the digital demonstrator created for educational purposes. The demonstrator integrates BIM-based modelling and Digital Twin resources to recreate a realistic and interactive training environment. Its purpose is to enable trainers to explore digital construction processes, understand the potential of the technologies involved, and facilitating the knowledge transfer to SMEs. This report outlines the demonstrator's objectives, conceptual structure, technological components, implementation process, and expected contribution to the overall model.

The development of the demonstrator builds on the analytical work carried out in WP2, which focused on creating a framework of digital technologies applicable to the construction sector and mapping the digital skills of trainers. The functionalities integrated into the demonstrator directly respond to the needs identified in WP2 and ensure continuity between the analysis phase and the methodological development foreseen in WP3 to support the adoption of digital technologies in construction SMEs.

The following sections of this deliverable provide a comprehensive overview of the demonstrator, describing its structure, workflow and functionalities. The document also highlights how the demonstrator will be used within the new teaching approach and how it will feed into the training activities and guidelines to be developed in WP3 and WP4. This introduction therefore sets the framework for understanding the role of the demonstrator as a key for experiential digital training in the construction sector.

2. Construction Digital Twin - CDT Demonstrator

2.1 Transition from Digital Analysis to Demonstrator Development

The WP2 of the ET4D project aimed to analyse the current scenario in the construction sector, identify gaps in knowledge and competencies among professionals and workers and map the skills required by trainers to address the needs of SMEs. This phase served as a market study, providing the groundwork for the subsequent phases focused on the demonstrator design and trainers' education.

The WP3 was built upon these insights and focused on developing new teaching approaches to support the digital transition in construction. The specific objectives and expected outcomes included:

- A functioning Construction Digital Twin (CDT) demonstrator;
- A pilot CDT model of a construction site with BIM, IoT, sensors and if applicable VR;
- A training course for trainers to apply to their teaching or SME projects;
- Guidelines for replicability of the demonstrator in partner institutions, adapted to their national language.

Based on the insights from WP2 and aligned with the objectives of WP3, the first phase involved a comprehensive literature review. This analysis aimed to identify existing methodologies, technologies, and best practices that could help in the design of the Construction Digital Twin demonstrator and the associated training modules.

2.1.1 Literature review

Digital Twin (DT) technology has emerged as a transformative tool in the construction industry, enabling the synchronization of physical assets with their virtual counterparts. This approach provides real-time monitoring, predictive insights, and performance optimization throughout the project lifecycle.

The integration of DT in construction offers several benefits, including enhanced project visualization, real-time progress tracking, and the ability to simulate and optimize construction processes.

Several studies highlight how the integration of DT and BIM can contribute to more sustainable and efficient management of industrial and building assets, improving resource use and supporting better decision-making. However, challenges such as data interoperability, standardization, and the cost of implementation remain substantial barriers to adoption.

A recurring theme is the idea of a progressive evolution approach to Construction Digital Twin, CDT in the construction sector, observing that there is still lack of insight on the possibility of implementation of advanced technologies in the higher generations. The assumption is that the implementation of DT on a building lifecycle will be gradual allowing the merge of virtual models and IOT sensors on a common semantic web platform.

Evolution and definition of Digital Twin (DT)

The first digital twin, although not labeled as such, originated at NASA in the 1960s as a means of modeling Apollo missions. NASA used simulators to assess the failure of Apollo 13's oxygen tanks, but the DT Concept

is by David Gelernter (1991) in the book Mirror Worlds, while the digital twin name (virtual twin) is by Hernández and Hernández (1997). The digital twin concept is by Michael Grieves (2002) Product Lifecycle Management (PLM) center - University of Michigan:

The digital twin corresponds to the digital replica of any physical product. It consists of 3 parts:

1. physical element in real space;
2. virtual element in virtual space;
3. data and information that provide the connections between the physical and virtual system.

The digital twin is not a copy of the physical product (e.g. 3D model) but is such based on the interaction of data and information. A Digital Twin DT is a digital representation of a target entity, construction project, with data connections that can enable convergence between the physical and digital states at an appropriate rate of synchronization.

In the Digital Twin Environment (DTE) there may be Digital Twin Prototype, Digital Twin instance and Digital Twin Aggregate (Grieves, Vickers, 2016) as shown in the following table 1:

Digital Twin Prototype (DTP),	Product design, including graphics, 3D BIM technical specifications, bills of quantities, production process diagrams, for prototype production;
Digital Twin Instance (DTI)	it is the digital twin of every single element of the product to which the DT remains connected throughout its life cycle once it is made. It includes geometric and performance models, other data on past and present performance via sensors, and future prediction.
Digital Twin Aggregate (DTA)	is the aggregation of DTIs whose data and information can be used to query the physical product, for simulations and forecasts

Table 1. Digital Twin categorization by Grieves, Vickers (2016)

Another categorization refers to the different level of data and information flow that can take place between the physical part and the digital part, that develops a digital model, a digital shadow or a digital twin (Kritzinger et alii, 2018).

	Data flow from physical object to digital object	Data flow from digital object to physical object
Digital Model	Manual	Manual
Digital Shadow	Automatic	Manual

Digital Twin	Automatic	Automatic

Table 2, Digital Twin categorization by Kritzinger et alii (2018)

There are three generations of DT (Boje et alii, 2020):

- The Generation #1 – monitoring platforms - consists of an enhanced version of BIM on construction site to date.
- The Generation #2 – intelligent semantic platforms consists of enhanced monitoring platforms with limited intelligence due to integrated BIM models and IoT devices, thus forming a knowledge base. Separate AI – based algorithms enable trained human actors to simulate and forecast future situations and performances.
- The Generation #3 – agent driven socio-technical platforms represents a fully semantic DT, with the use of AI-enabled agents. Machine learning, deep learning, data mining and analysis capabilities create a self-reliant, self-updating and self learning DT, that relates to social and physical environments, requiring only human supervision.

Although this progression provides a useful structure, some authors argue that this classification has some key limitations, that are the followings (Sacks, Brilakis, Pikas, Xie, Girolami, 2020). Firstly, the DT is seen as just an evolution of BIM models, than there is a lack of conceptualization of construction processes and modeling, finally DT is seen as a Decision Support System for construction projects, while instead represents an innovative holistic approach to construction management. Therefore, the ET4 DT should give support to these project management processes in all the PDCA phases with the aim of producing a Generation #1 Digital Twin system as defined by Boje et alii (2020):

Parallel research on Cyber-Physical Production Systems (CPPS) emphasizes the importance of combining physical components, such as machinery and sensors, with digital technologies, including IoT and cloud computing, to achieve real-time process optimization.

The integration of CPPS with DT technology is essential for improving operational efficiency, enabling predictive maintenance, reducing downtime, and optimizing resource allocation. However, issues such as cybersecurity risks and the complexity of implementing CPPS in dynamic construction environments must be addressed to fully realize their potential.

The convergence of DT and CPPS technologies offers a comprehensive framework for managing construction projects in real-time. This integration facilitates the synchronization of BIM models with live data from CPPS, enabling project managers to proactively address challenges. This approach has been instrumental in reducing project delays and improving overall efficiency. Simulation and optimization are key components of this integrated framework.

DT models can be used to simulate various construction scenarios, enabling stakeholders to identify optimal solutions before implementation. The relationship between the Digital Twin and Physical Twin can even revolutionize the construction process organization as we know it (Brilakis, Sacks et alii, 2020).

Despite their potential, DT and CPPS technologies face several challenges in the construction sector. These include high implementation costs, the need for skilled professionals, and the lack of standardized protocols

for data integration. However, addressing these challenges could unlock significant opportunities, particularly in the areas of sustainability and efficiency.

Future research should focus on enhancing data interoperability and developing scalable solutions for integrating DT and CPPS technologies. The adoption of emerging technologies, such as edge computing and blockchain, could further strengthen the capabilities of these systems.

Following the literature review, the subsequent step involved the design and development of a digital platform that supported trainers. At the same time, guidelines and supporting resources were created to enable partner institutions to replicate the demonstrator and implement the platform within their own educational and operational contexts.

2.2 Methodology: generation #2 Digital Twin for the pilot construction project

The ET4D set out to develop a Construction Digital Twin demonstrator for construction projects, designed to enable real-time production control through a Digital Twin that gives a transparent view of the production process. In line with the project's focus on supporting SMEs, the use of open and free-of-charge tools was strongly encouraged to minimise economic barriers to digitalisation.

A Digital Twin is a digital representation of a target entity, the construction site and its processes, supported by data connections that can synchronise the physical and digital twins at an appropriate frequency. This technological advancement has overcome the significance of project control by giving the possibility of interconnecting data from different models and dataset. Therefore, project control can be improved through the integration of building operations modelling (BIM 3D) interconnected with a schedule model forming a 4D BIM. Within this framework, the ET4D Digital Twin was conceived to support project management processes across all PDCA phases, with the objective of delivering a Generation #2 Digital Twin system.

The ET4D pilot construction project was constructed at the vocational construction school IIPLE in Bologna, providing a real physical environment in which to develop and validate the demonstrator. For the creation of the Digital Twin, an existing open digital platform Open Project BIM was used for the CDT implementation. Actually in the ET4 Digital project all the basic components of a digital twin for construction were implemented, as to allow a straight implementation by SMEs.

The Basic components are the following:

Physical Twin:

- Actual pilot construction project under implementation by IIPLEs students;

Digital Twin:

- Site modelling with BIM of the building under construction;
- Project Control processes and tools (WBS, BOQ, Construction Schedule)
- Open BIM digital platform for BIM environment

Data and information flow:

- 3D modelling and manual survey system on site
- automatic data from environmental sensors

- photographs from web camera

2.2.1 Pilot construction and site study



A visit to the IIPLE training construction site was conducted to examine the type of technology, the scale of the work, and the job content used to train new generations of skilled labour. During on site discussions held within the existing mock-up building, constructed by students as part of their training, it emerged that the course follows traditional teaching methods, relying heavily on the trainer's experiential knowledge and lacking formally drafted plans or digital support tools.
The physical twin used in the training program consists of a very simple construction project: a one-storey house mock-up composed of four rooms and a staircase, built by high school students. The structure has no roof and includes only basic finishes. Key construction elements include brick masonry walls made with two different types of units, wall sections incorporating openings for doors and windows complete with timber frames, ground-floor flooring and plaster finishes.
The mock-up is also designed to support multiple stages of learning, not only the construction phase but also partial and complete demolition activities, so students can deal with different practical operations within a controlled environment.



2.2.2 5D BIM model development

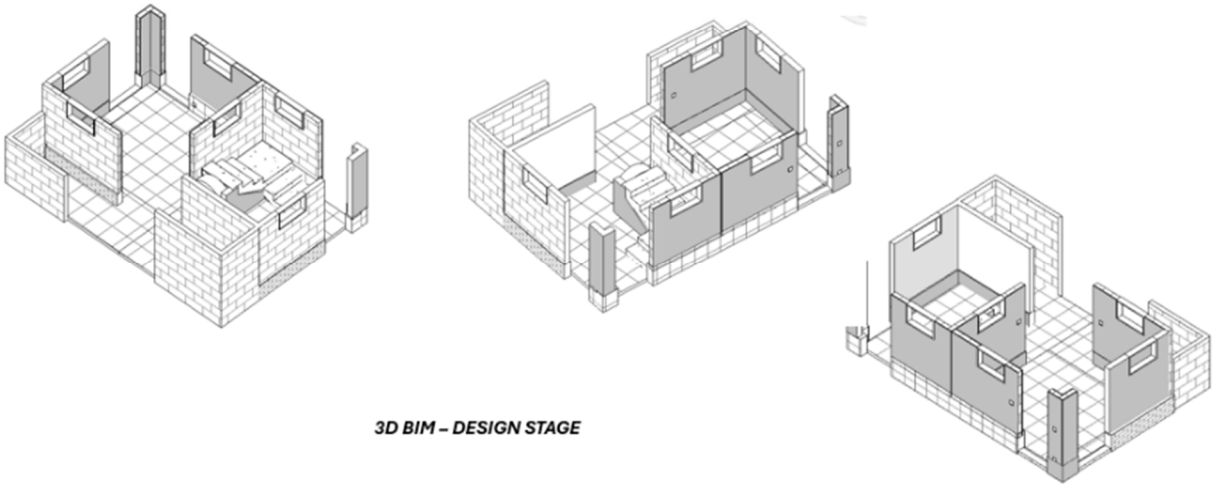
The digital representation of the pilot building was developed using Revit®, providing a detailed Building Information Model (BIM) that supports both visualization and project control activities. The 3D BIM model reflects the conditions observed during site visits, representing a small-scale building with dimensions of 567 × 413 cm (Fig. 1). Despite its limited size, the pilot structure includes multiple wall typologies and two types of floor finishes, making it a manageable yet sufficiently articulated case for training purposes.
To organize the project, the workflow was structured into four phases:

- Initial Construction
- Partial demolition
- Completion
- Dismantle

The initial construction phase covers all activities from the beginning up to the erection of brick masonry walls, installation of flooring and tiles, construction of the staircase and plastering of interior surfaces.
In the partial demolition part, the right and the front wings of the building are removed, while the completion phase corresponds to the demolition of all the vertical surfaces. Finally, the dismantle phase involves the complete demolition of the building and the cleaning of the site.

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ET4D

Generation #2 CDT for the ET4 pilot: BIM



3D BIM – DESIGN STAGE

Item No.	Sub Item No.	Rate Code	WBS Code	Description	Unit of Measure	Number	Length	Width	Height	Quantity	Total Quantity	Rate (€)	Amount	Labour %
1				**Brick masonry**										
		A05.007.005.a		Thickness 12 cm	m²									
	1		A.01.1.	Room1	m²	1	9.09	0.1	1.58	14.3622	30.2067	58.90 €	1,779.17 €	45
	2		A.01.1.	Room 2	m²	1	5.91	0.1	1.58	9.3378				
	3		A.01.1.	Room 3	m²	1	5.29	0.1	1.23	6.5067				
2		A05.004.010.b		with three-hole bricks (5 x 14 x 28 cm)	m²									
	1		A.01.2.	Room1	m²	1	11.37	0.14	0.37	4.2069	5.8201	99.58 €	579.57 €	38
	2		A.01.2.	Room 2	m²	1	4.36	0.14	0.37	1.6132				
3	A05.004.005.a			**Stairs with common solid bricks**										
			A.02.2.	Stairs	m²	1				1.16	1.16	840.18 €	974.61 €	32
4				**Preparation of Wall Subtraits**										
		A20.001.005.a		Preparation of wall surfaces:										
	1			Room 1	m²	1	3.91	0.16	1.9	7.429	14.611	2.39€	5.59 €	46
	2			Room 2	m²	1	3.78	0.16	1.9	7.182				
5		A08.004.005.d		Plaster with cement mortar type 32.5 R and sand, composed of 400 kg of cement per 1.00 m3 of sand										
	1			Wall 1	m²	2	1.6		1.58	5.056	13.825	26.67€	368.71 €	70
	2			Wall 2		1	2		1.58	3.16				
	3			Wall 3		1	1.77		1.58	2.7966				
	4			Wall 4		1	1.78		1.58	2.8124				
		A20.010.005.a		based on vinyl versatic resins, titanium dioxide and calcium carbonate							14.611	8.28 €	120.98 €	66
				Room 1	m²	1	3.91	0.16	1.9	7.429				
				Room 2	m²	1	3.78	0.16	1.9	7.182				
				Wall Tiles										
6		A16.013		Colored porcelain stoneware covering in rectified tiles obtained by pressing, compliant with the UNI EN 14411 standard, water absorption class BIa UGL, installed with suitable adhesive, including cuts, waste and joint filling, excluding special pieces:							0.8917	69.49 €	61.96 €	42
	1	A16.013.015.b		Room 1 Small tiles	sq m	1	0.69	0	0.37	0.2553				
	2			Room 1 Long tiles	sq m	1	1.6	0	0.37	0.592				
	3			Room 2 Long Tiles	sq m	1	0.12	0	0.37	0.0444				
7				**Floor Tiles**	m									
	1	A15.016.015.c	A.04.	45 x 45 cm, thickness 9 mm		1	5.5	0.06	3.75	20.625	20.625	57.89 €	1,193.98 €	38
8														
				Site Fences										
		F01.025.025.b	A.00.1.	Fences height 1.20 m; cost of using materials for the entire duration of the works	m	30				30	30	2.00 €	60.00 €	
				Partial Demolition										
		H01.004		Demolition of masonry, including vaulted, thicker than one head, carried out by hand, including sorting and setting aside of recycled material for reuse:										
9		H01.004.010		Brick masonry	m²									
	1		A.05.1.	Wall 1		1	2.36	0.12	1.95	0.57	1.86	71.24 €	132.26 €	78
	2		A.05.1.	Wall 2		1	2.00	0.14	1.95	0.53				
	3		A.05.1.	Wall 3		1	2.76	0.10	1.95	0.54				
	4		A.05.1.	Wall 4		1	2.52	0.07	1.23	0.22				
10		H01.016.015		Demolition of ceramic tile flooring, including the sub-floor up to 5 cm thick, laid using mortar or glue										
	1		A.05.3.	60 x 60 cm, natural or bush-hammered, thickness 10 mm	m²	6	0.60	0.60	0.01	0.36	2.16	9.83 €	21.23 €	78

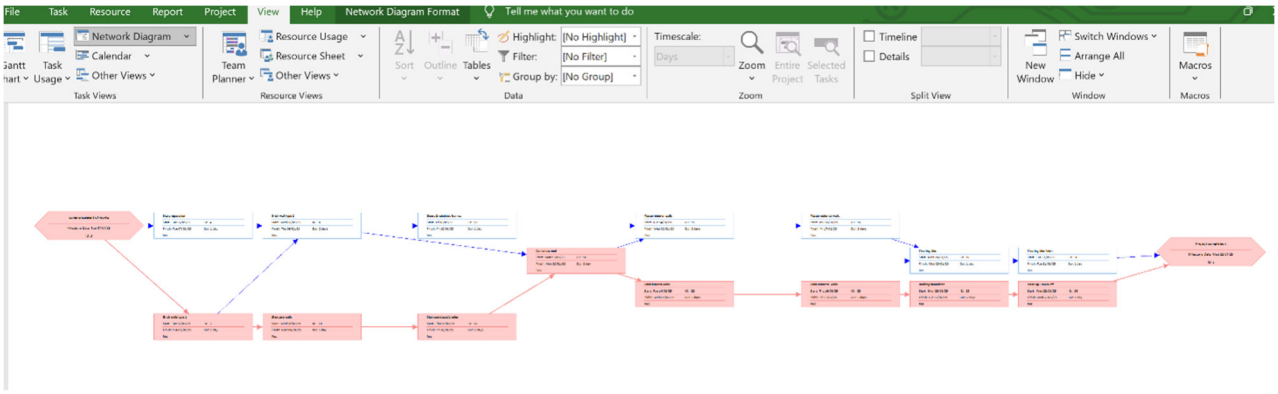


Fig. 3 Project Schedule with MS Project

Within the project control framework, the Work Breakdown Structure (WBS), the Bill of Quantities (BOQ), and the Construction Schedule of the pilot project were created and subsequently uploaded to the platform. The WBS was developed in alignment with the actual academic calendar and incorporated information such as the number of students involved and the actual duration of their presence on site, as provided by IIPLE. Once finalized, the WBS was imported into MS Project® to generate both the Gantt chart and the network diagram of the project.

Quantity take-off operations were performed directly from the BIM model to extract measurements of building components and products along with their associated all-in rates (5D BIM). These quantities were exported into an Excel sheet to produce the priced BOQ (Fig. 2), which was then linked to the regional official price list of Emilia-Romagna (RER) to determine the schedule of rates and, consequently, the total estimated project cost as the sum of the Work Package rates. This process also enabled the simulation of stage payments through a WBS technique for lump sum contracts, where payment percentages are aligned with the value of the completed Work Packages.

The construction schedule was created and progressively updated to reflect the project's sequence of project phases, with activity durations estimated using labour day references from the RER dataset, and the baseline timeline was structured using MS Project® (Fig. 3).

2.2.3 Digital Platform Selection

The principal criteria for the selection of the platform were the platforms capacity to provide open access, especially for organizations with education purposes, which was true for all the participants and the purpose of the project. The other was the capability of the platform to visualize the BIM models without the need for high-tech BIM modelling software. This allows all the partners, trainers and students to be able to access and interpret the construction project, regardless of their technical expertise or the resources available for them.

The selection of the demonstrator platform was carried out by the IT manager, who evaluated the project requirements with different technological alternatives. During the initial stages of the demonstrator development, a BLE-prototype by Unibo (http://ble.unibo.it/), developed for the BENEDICT project was briefly tested to support the integration of digital tools and facilitate data exchange (http://ble.unibo.it/etd4). However, its use was limited, as the project soon adopted an Open BIM approach,

which was found to be a better solution because of its accessibility and suitability for supporting BIM based projects.

This transition enabled the development of a demonstrator capable of supporting trainers in understanding digital technologies and their benefits, thereby facilitating the transfer of knowledge to SMEs. The demonstrator also served as a tool to identify potential challenges that trainees and students might encounter when engaging with digital technologies.

Within this framework, the Open Project BIM platform was used to host all modelling information, with project control tools and resources uploaded or created for each construction stage. The platform also allowed for minor adjustments if required, enabling the IT team to modify its functionalities to the needs of the project. Hence the Open Project BIM stood to be the best suitable adoption for the project.

2.2.4 Platform organizational features

The Open Project BIM® offers comprehensive project management and information handling features that support stakeholder engagement throughout the lifecycle of a project. The platform can host project documentation, BIM models and includes an IFC viewer that allows users to upload and visualize 3D models (Fig. 4). This functionality enables project participants to consult the model for guidance on construction operations, while the availability of both As-Planned and As-Built models supports progress assessment and facilitates the sharing of updated time and cost information, ensuring a common understanding of project control outputs and outcomes.

The platform also enhances collaboration by allowing users to create project, write descriptions and invite members via emails, ensuring that all stakeholders can virtually gathered in the same workspace. Access right to the platform can be controlled by administrator, who can define what each member is allowed to view, modify or add. This controlled framework of permissions ensures clear responsibilities, effective stakeholder management and greater project efficiency.

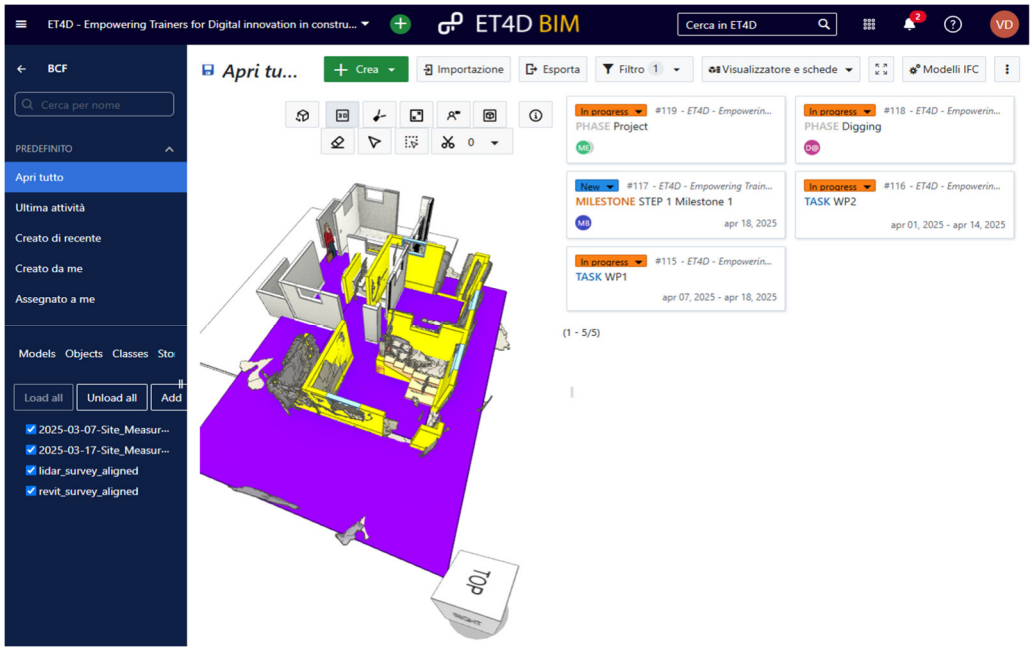


Fig. 4 Open Project BIM platform for the ET4D project

To effectively support these activities, the platform provides several key features, including:

- Work Breakdown Structure (WBS)

The “work packages” feature in the platform enables a systematic decomposition of tasks in hierarchical order and task processing. The work package tab also allows for assignment of tasks to the members, which clearly displays the email of the member. This facilitates transparency in roles and responsibilities; which helps in coordination, while mitigating task overlapping and disputes. This feature also allows the stakeholders to see the status of each task of the project (Fig. 5).

SUBJECT	TYPE	STATE	PRIORITY	% COMPLETION	START DATE	END DATE
A.00. Preparation	PHASE	Closed	Normal	100%	13/01/2025	13/01/2025
A.00.1. Securing the construction site with site fences	TASK	Closed	High	100%	13/01/2025	13/01/2025
A.00.2. Commencement of works	TASK	Closed	Normal	100%	13/01/2025	13/01/2025
A.00.3. Site preparation	TASK	Closed	Normal	100%	13/01/2025	13/01/2025

Fig. 5 Work Packages in the Open Project BIM platform for the ET4D project

- Gantt Charts

The WBS created can also be used to schedule the tasks and represented in the Gantt chart. On setting the tasks order and start dates, the platform does the scheduling automatically. However, it also allows for manual settings and modifications (fig. 6).

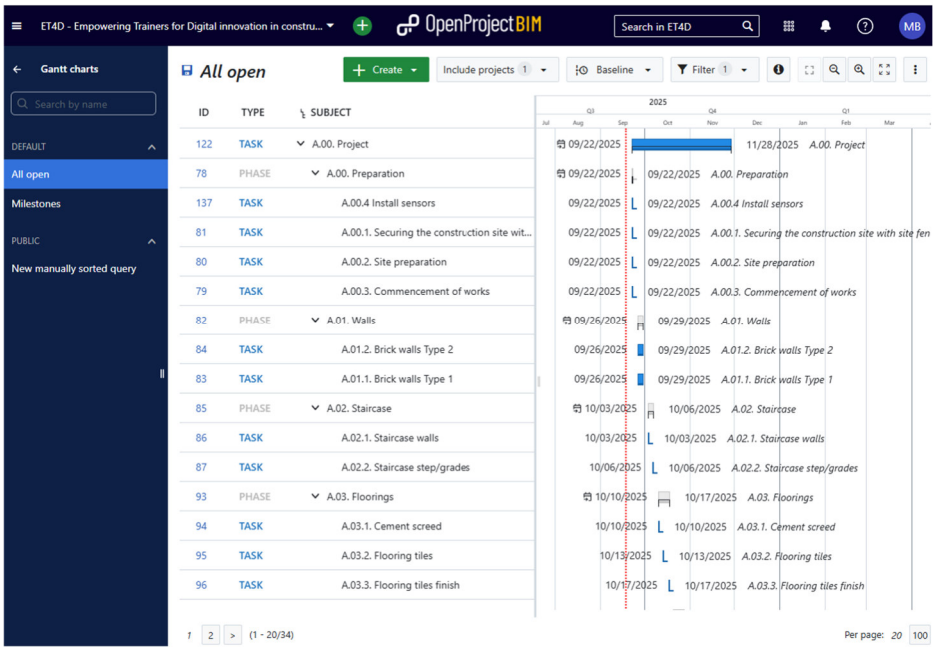


Fig. 6 Gantt chart of the Open Project BIM platform for the ET4D project

- Meetings

The platform allows planning a one-time meeting among the required members or even schedule periodic meeting. Adding agendas, modifying or creating tasks, all can be carried out in real time during the meeting.

- Document sharing

There is a separate section where one can upload files and folders for sharing among the members. The access limitation for each tab in the platform can be modified by the administrator; hence the risk of document loss or communication errors is diminished to zero.

- BIM Collaboration Features (BCF)

The most significant part of the platform is the BCF feature, as discussed above, the platform allows the users to view a whole model, view the models floor level or object level (fig.7). It also allows to view models by cutting sections or slices through desired part. The main criteria are to have an IFC model, which is the only file type permitted to upload in BCF tab.

The IFC models can be overlayed with each other (fig.8). This allows to upload different parts of a same project in different files and view them in correspondence with each other. This feature allows to over lay the models from different disciplines and integrate in the same view without the need for BIM modelling software, for example a Lidar scan was overlaid with the BIM model. No information of the models can be changed, hence there is no risk of data loss.

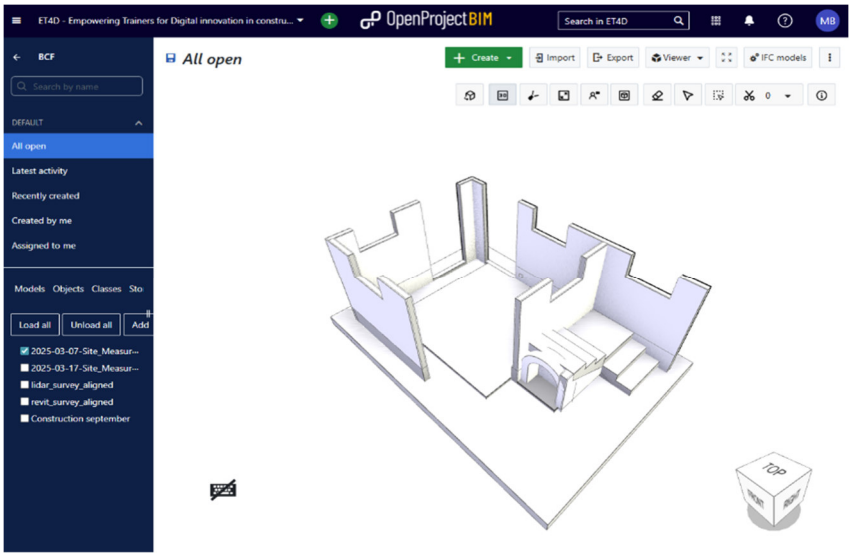


Fig. 7 IFC viewer of as built BIM model - Open Project BIM platform for the ET4D project

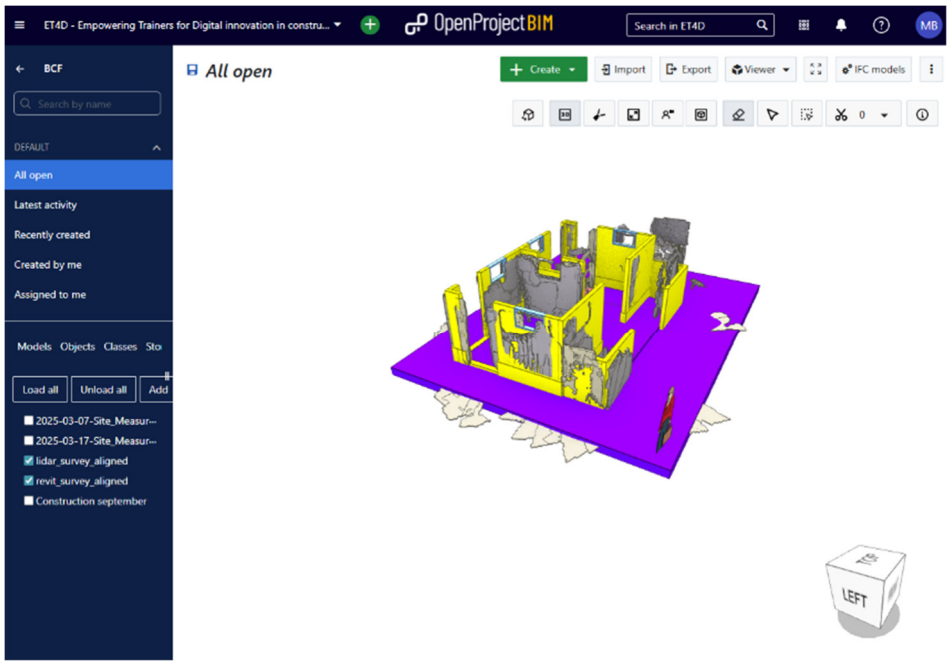


Fig. 8 IFC viewer of overlaid BIM model and Lidar Scan - Open Project BIM platform for the ET4D project

- Accessibility for Non-Technical Stakeholders

With all the functionalities, the platform operates not only as an organizational and managerial tool but also integrates relevant technical aspects. Its browser-based and user-friendly interface significantly reduces the technical barrier associated with digitalization, making it suitable for both technical and non-technical stakeholders. As a result, stakeholders such as clients, managers, administrative faculty, and workers in the site, who have basic knowledge of technological interfaces, can easily access the essential project information without prior training or technical knowledge.

Overall, the platform provides an accessible and inclusive collaboration within a digital environment, enhancing meaningful communication among the stakeholders involved. This contributes to transparency and more informed decision-making. Consequently, the platform plays a significant role in enhancing project efficiency from both a construction and a management perspective.

2.2.5 Digital Twin visualization

For the realization of the Digital Twin, IoT devices were set up in the pilot construction site. The sensors for the pilot construction were intentionally made to be simple, prioritizing feasibility and system compatibility over advance measurements. The main objective was to assess whether the digital platform could effectively support the integration, management and visualization of live sensor data, hence the need for advanced data was secondary.

After some market study and technical advice, Raspberry-Pi compatible sensors were chosen due to their compact size, low cost and wide availability in education and prototyping contexts. These characteristics make them particularly suitable for experimental and exploratory projects, where adaptability and cost-effectiveness are key considerations.

The responsibility of providing the sensors was of IIPLE, so upon delivery, Unibo IT team worked on programming and connecting the sensors to Open Project BIM platform. During the process, the initial tests were done at the office to confirm connectivity and data transfer reliability. Once verified, a custom case and mounting were designed to facilitate the placing in the construction site. This shows the experimental nature of the pilot project where technical solutions were adapted to situational needs rather than predetermined.

The sensor unit was installed at the site in September. The placement was strategically chosen to cover the construction area of concern and not the other parts of the laboratory. The sensor consists of a camera and an environmental sensing component.

The environmental sensing component collects data of range of parameter of the local environmental conditions:

- Air temperature
- Relative humidity
- Pressure
- Carbon dioxide

- Nitrogen oxide
- Particulate matter at 2.5 microns and 10 microns

These variables are commonly use as indicators of the environment quality and can provide early insights into potential safety concerns.

Simultaneously, the camera supports with the data for the organizational part of the project. Unlike the general-purpose surveillance camera, its function is constrained to detecting the number of individuals present within the designated construction area, this supports the attendance tracking and safety monitoring. It also captures a picture of the site at the end of the day, to track the progress of the construction in the site.

All the data form the sensors are transmitted automatically to the platform, where they are stored and updated in real time. Since the site is known to be functioning from 7AM to 12PM, the data collection is deliberately set to this time frame. This selective sampling reduces unnecessary data storage and ensures the required data are collected. The measurements are captured every 5 minutes; this frequency is sufficient to observe the changes in the site while avoiding data overflow.

The raw data collected from the sensors are stored in the “Work Packages” section of the platform, where they can be manually inspected for each time log. However, this format presents information in a highly fragmented manner, making it difficult to interpret. While such raw data can be useful, it is not efficient for analysis, particularly for users with limited technical expertise, and may therefore become effectively meaningless in this context (fig.9).

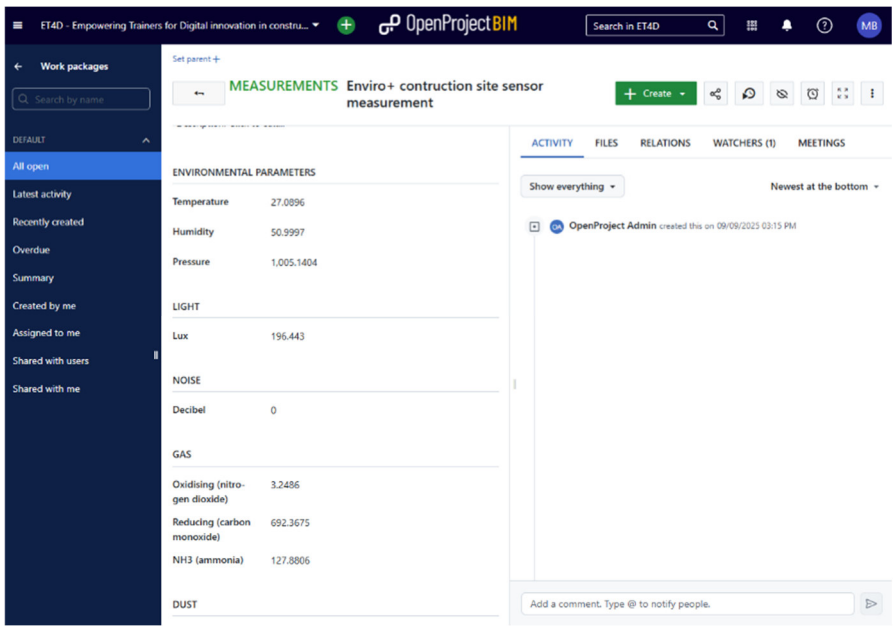


Fig. 9 Sensors’ data - Open Project BIM platform for the ET4D project

To address this issue, a graphical visualization of the data was implemented on the platform by the Unibo IT team, making the data more accessible and user-friendly. These outputs can be accessed from the "Sensors Dashboard" in the Project Overview section. The graphs translate the raw data into time series plot and comparative line graphs, that allow users to observe environmental trends, detect anomalies and correlate the data with the site-activity.

Although these data are only for observation purpose in the present, with further advancement of the system, they can be used to predict and modify the environment of the site in the future.

In addition to these data-driven monitoring tools, 3D site documentation was further enhanced through Lidar based scanning. 3D scanning was performed using a simple application iPhone, such as Polycam 3DScanner, LIDAR 360®. The 3D scanning generated a point cloud by laser sweeping thus creating a viewable model of the as-built pilot building. The point cloud was uploaded in the platform and overlapped to the BIM model allowing verification of the As-Built BIM model. This project control process provides a shared and detailed representation of the actual progress of the construction activities. In particular, the overlapping of the 3D scan with the digital model determines the actual progress of construction processes (fig. 8).

2.2.6 Demonstrator development: web address, outcome and user guidelines

It is important to highlight that the demonstrator developed within WP3 goes beyond the concept of a Digital Twin designed just for training purposes. The result is a digital platform that supports the entire construction process: from design and modelling phases to on-site planning and operational workflows. This scope increases its relevance for SMEs, offering them an accessible and practical environment to understand, test and adopt digital solutions that are often perceived as complex or out of reach. Indeed, the demonstrator delivers more than what was originally foreseen in the application form, intentionally expanding its functionalities to better support SMEs in approaching digital transition and to maximise the project's impact on the construction ecosystem.

The platform developed for the project is accessible at the following link: https://et4d.dt.edili.com.

3. Transnational training course

As defined by the objectives of the WP3.1, a transnational training course for trainers wil be organized to introduce the demonstrator, ensuring that it was simple to use and could be effectively integrated into teaching practices. The training allowed participants to experiment with the technologies and test the various tools available.

UNIBO and IIPLE developed the training program, which will be conducted in English at IIPLE, Bologna (Italy) from 18th to 20th of November 2025. Each partner has selected two or three trainers, teachers or professionals to participate.

The first day of the workshop will focus primarily on presenting the current state of the project, its development process, establishing the foundation for the practical session scheduled for the following morning. Complementary topics, such as construction safety, lean construction and value analysis, were

presented by experts external to the project. By the end of the day, participants will have a clear understanding of the work package and the practical activities they would engage in during the subsequent sessions.

The second day will be the main part of the training, where the participants were given hands-on learning. This day, the theoretical session of the previous day shifted to the practical teachings. Participants first will work individually, following the facilitator to learn how to become familiar with the platform, then collaborate in small groups to complete a structured set of activities. The outcomes from this day will include a set of recommendations and suggested modifications to the platform for better communication and educational purposes.

All activities carried out during the Transnational Training for trainers will be documented, providing material that will form an integral part of the guidelines for using the demonstrator.

Additionally, a specific questionnaire has been designed to evaluate the effectiveness of the training and validate the demonstrator for educational use. At the end of the training, participants will complete the questionnaire to provide feedback on their experience.

The final step will be to distribute the digital platform and the materials formulated during the design phase of this project to the partners. Partners will use the demonstrator for training purposes. They are required to test in their institution with frequent updates and documentation. The results from the test documentations and feedback should be used to analyse and fine-tune the digital platform/materials to ensure their targeted usage. By the end, the project requires to have acquired a detailed set of digital skills required to be a trainer, an elaborate guide for the trainers, a functional digital platform that can be used for trainings, and a validated training program that assures the functionality of the digital platform and training.

ANNEX I

Step-by-step guide to using OpenProject BIM for the Digital Twin demonstrator (for trainers)

Step 1 — Access the platform and verify your account

1. Open OpenProject BIM from your browser (PC or tablet).
2. Select **Sign in** and enter your credentials.
3. After logging in, verify that the **user's initials** appear at the top (login confirmation).

Step 2 — Enter the demonstrator project

1. From the menu, open **Projects** to see the list of available projects.
2. Filter (if necessary) by **active / archived / favourite**.
3. Click on **the name of** the demonstrator **project** to open it.

Step 3 — Read the 'Project Overview' as a control panel

In the **Project Overview** tab, check and use this information:

- **Project description** (useful for introducing students to the scenario and objectives);
- **Status** (general status);
- **Members** (who is participating);
- **Macro overview** (summary view of the project).

Step 4 — Use the side menu to navigate the work areas

On the left-hand side is a list of project sections (Work packages, BCF, Gantt, Members, Meetings, Documents, etc.).

This column is the operational 'map' of the platform for moving between:

- activity organisation,
- BIM visualisation,
- planning,
- collaboration,
- documentation,
- data (sensors).

Step 5 — Manage activities with "Work Packages" (WBS)

1. Open **Work Packages**: these represent the **Work Breakdown Structure (WBS)** of the project.
2. Verify that the activities are organised by **phase** (and that they are legible to students).
3. Check the following for each task:
    - **status**,

- **priority**,
- **assignee** (responsible person).

4. To focus on the student, use the **'tasks assigned to** me' view.
5. Open a Work Package to see the details (description, status, assignments).

Step 6 — View models in "BIM Collaboration Format (BCF)"

1. Open **BIM Collaboration Format (BCF)**.
2. The main window displays the selected model; on the sides, you will find tools for filtering and managing models.
3. In the side panel, you can:
   - activate/deactivate models (check/uncheck),
   - explore **objects, classes, and storeys** (floors).
4. Open the list of IFC models (icon/menu at the top) to see the uploaded files and the options available based on your permissions.
5. To upload a model:
   - click the **green** button (upload),
   - upload an **IFC** file,
   - set (if necessary) the model as **default**.
6. Use the view commands to switch between:
   - 2D/3D,
   - orthographic/perspective,
   - full view,
   - **sections and slices** to enter the model.
7. Load multiple models and use them in **overlay** (e.g. BIM + point cloud) for comparisons and status checks.

Step 7 — Plan and read the work schedule in "Gantt Charts"

1. Open **Gantt Charts**.
2. Here you will find the same information as in the Work Packages, plus:
   - **start/finish dates**,
   - **predecessors/successors**,
   - graphical representation of the Gantt chart.
3. Use the information button (icon 'i') to call up useful details while reading.
4. When available, use the **3D model** view **of the task** to clarify which part of the work a Gantt activity refers to.

Step 8 — Manage participants and roles in 'Members'

1. Open **Members** to see the list of participants.
2. Filter the view by groups or by 'all'.
3. Check/assign **roles** (based on available permissions) and check consistency with assigned activities.

Step 9 — Organise meetings and coordination sessions in "Meetings"

1. Open **Meetings**.
2. Create a meeting with the green button:
    - **one-time** or **recurring**.
3. Enter the title and details; select participants from the member list.
4. Use the meeting as a coordination space: agenda, updates and actions.

Step 10 — Share materials in 'Documents' (File Sharing)

1. Open the **Documents** section for file sharing.
2. Upload documents and folders useful for teaching (instructions, photos, worksheets, assignments).
3. Keep a simple folder structure (e.g. 'Phase 1', 'Phase 2', 'Photos', 'Student work').

Step 11 — Consult sensor data (Sensor Readings)

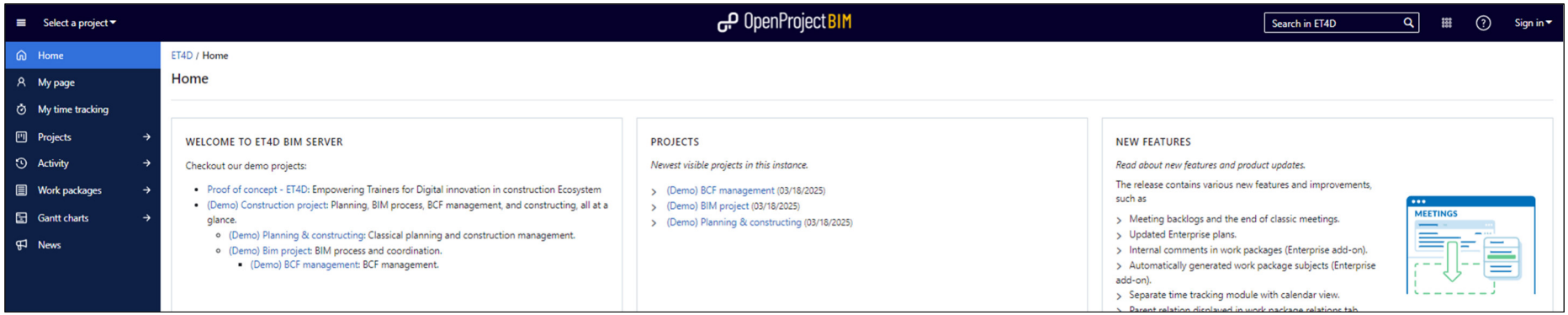
1. Access **Sensor Readings** from the menu (the guide shows access from Work Packages and/or recent activities).
2. View the data by **time stamp** and open the details by clicking on **the ID**.
3. Use the 'Latest activity' view to quickly consult recent readings.
4. Check the collection frequency (in the case of ET4Digital: readings at regular intervals and defined time slots).

Step 12 — Read data immediately with the Sensors Dashboard

When available, consult the **Sensors Dashboard** from **the Project Overview**: here the data is presented in graphical form (trends and comparisons), which is more readable for students and trainers.

ANNEX II

Home screen-Sign in button.



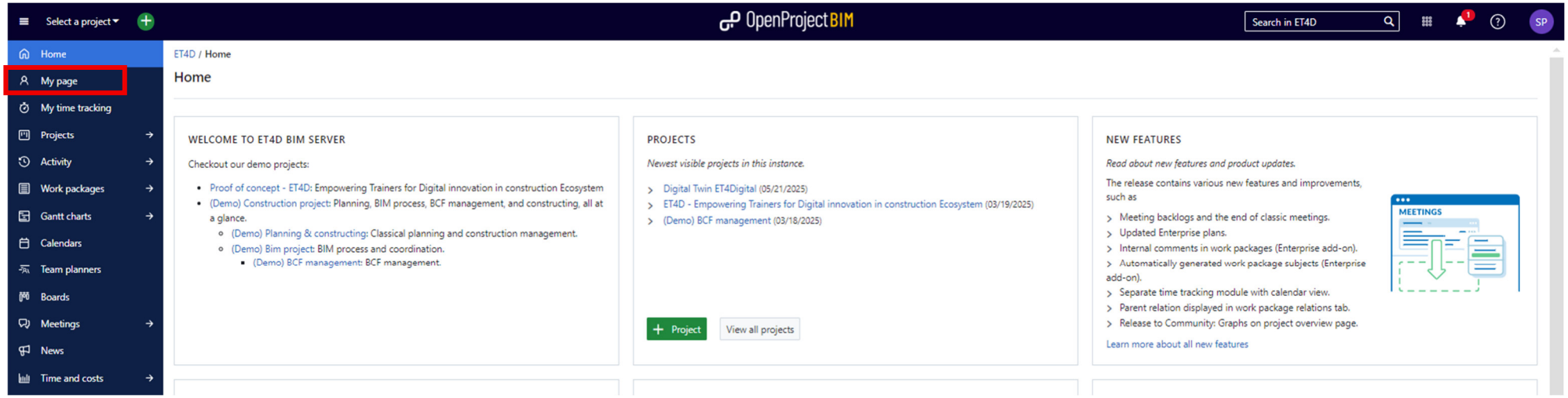
Logging in to the Platform

Once logged in, the initials of the user can be seen if logged in.

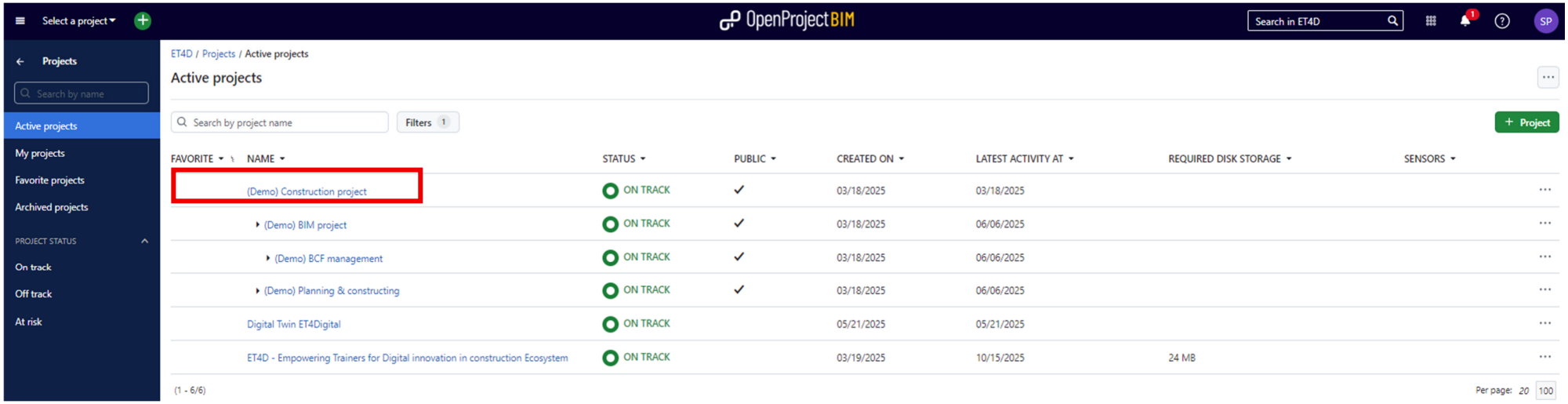


Starting a Project

To start, go to projects to view all the projects with which the logged-in user is associated/engaged.

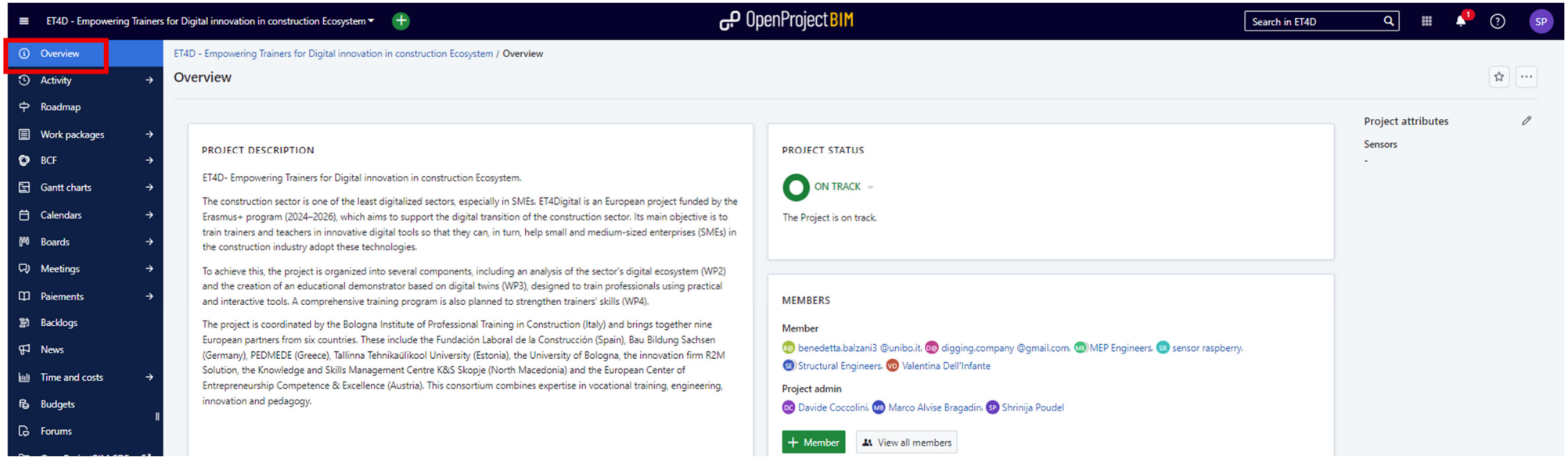


List of all the projects can be viewed, or filtered as per requirement for active, archived or favourite projects. The projects can be accessed by clicking on the name.

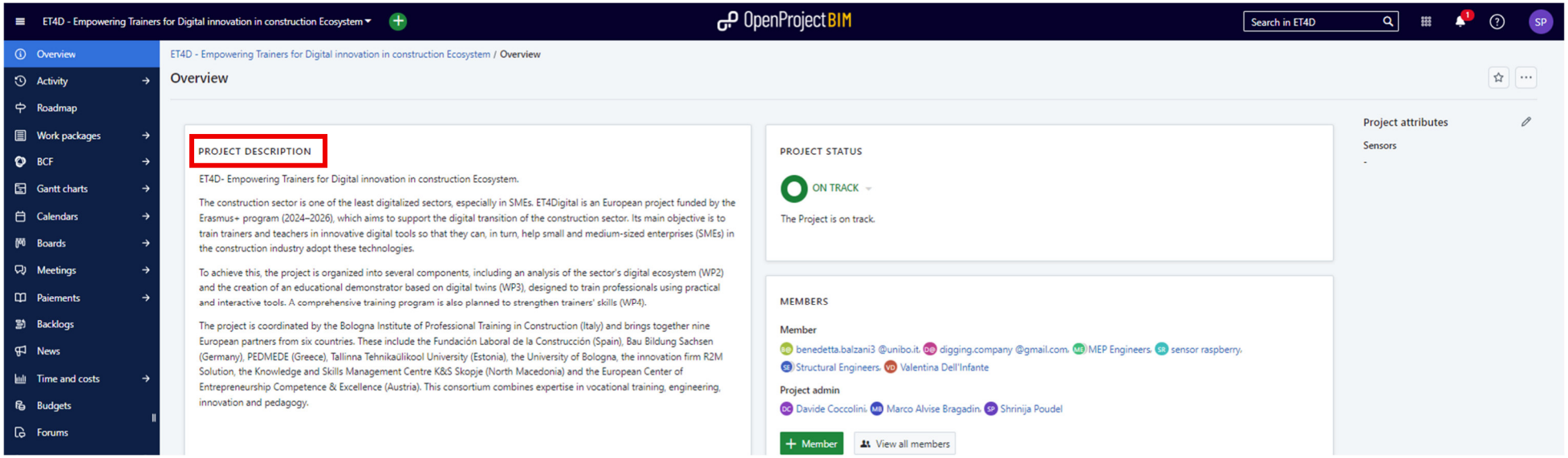


Project Overview

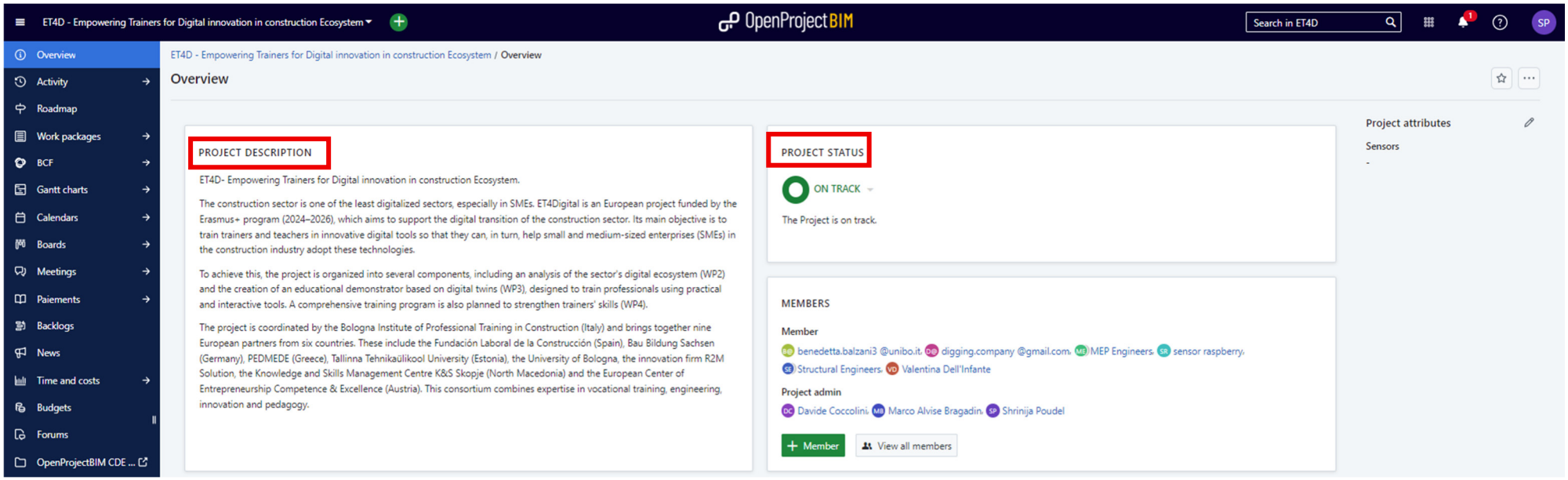
The overview panel opens once you open a project.



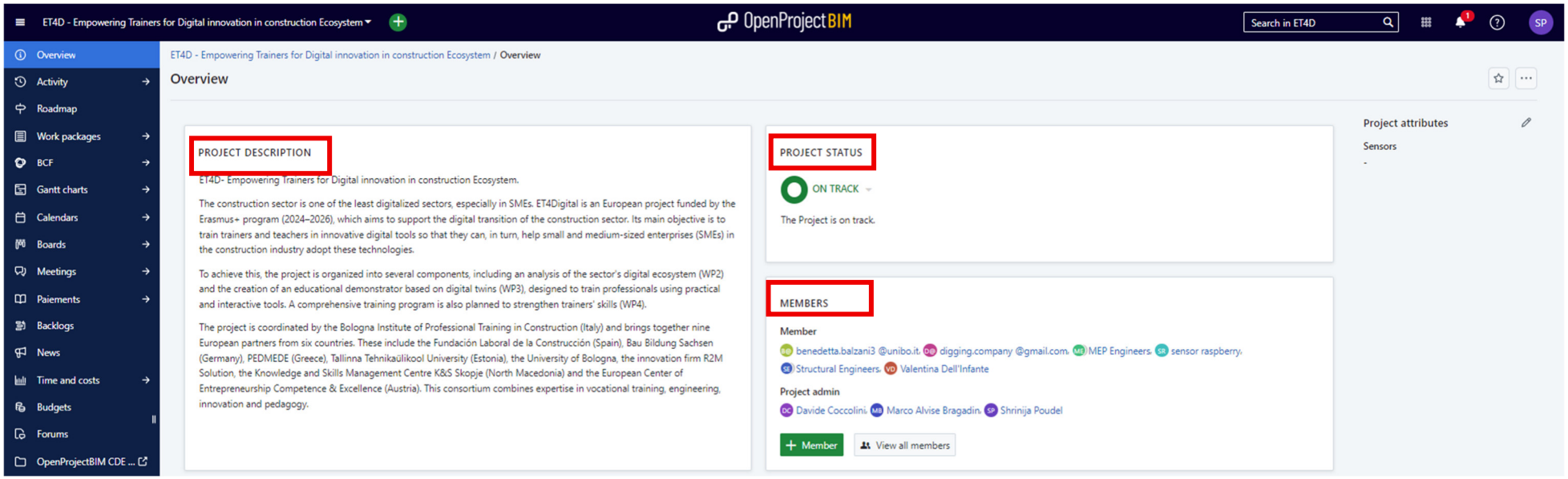
Here you can add the description of the project, and information that might help understand the project by everyone.



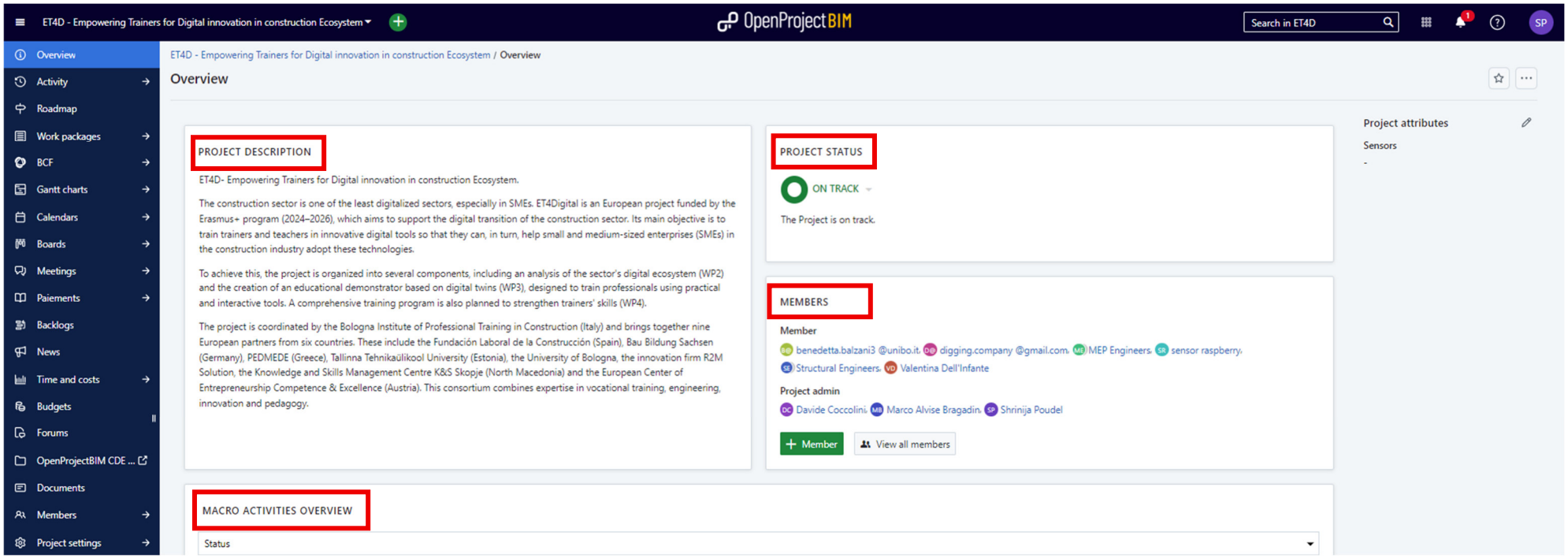
Project status panel shows the summarized progress of the project.



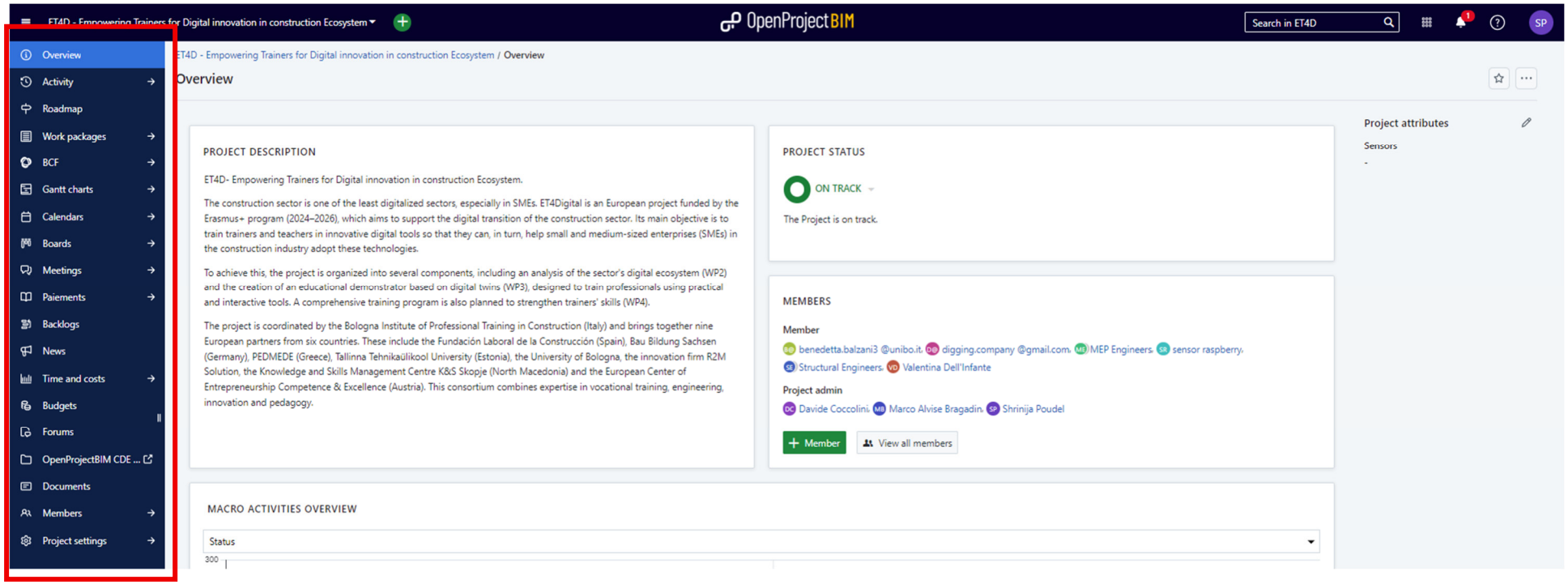
Members panel shows a short list of stakeholders in the project.



Macro activities overview showcases a complex data of selected requirement.

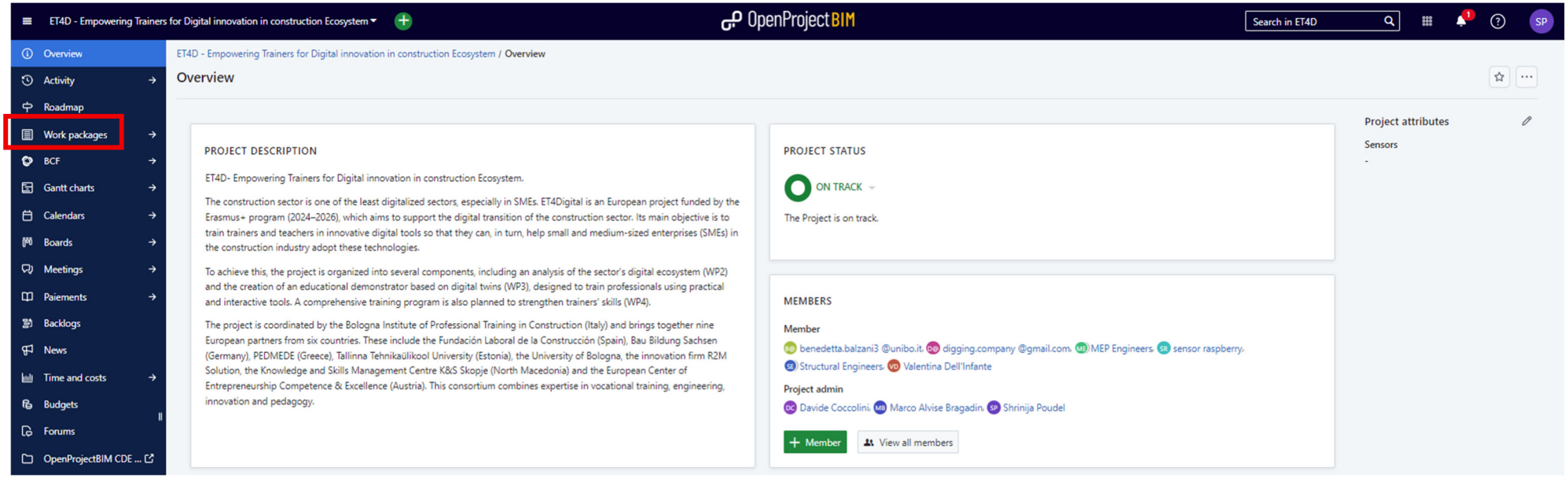


On the left-hand side, this list shows all the different sectors of a project. From here different aspects of the project can be accessed.

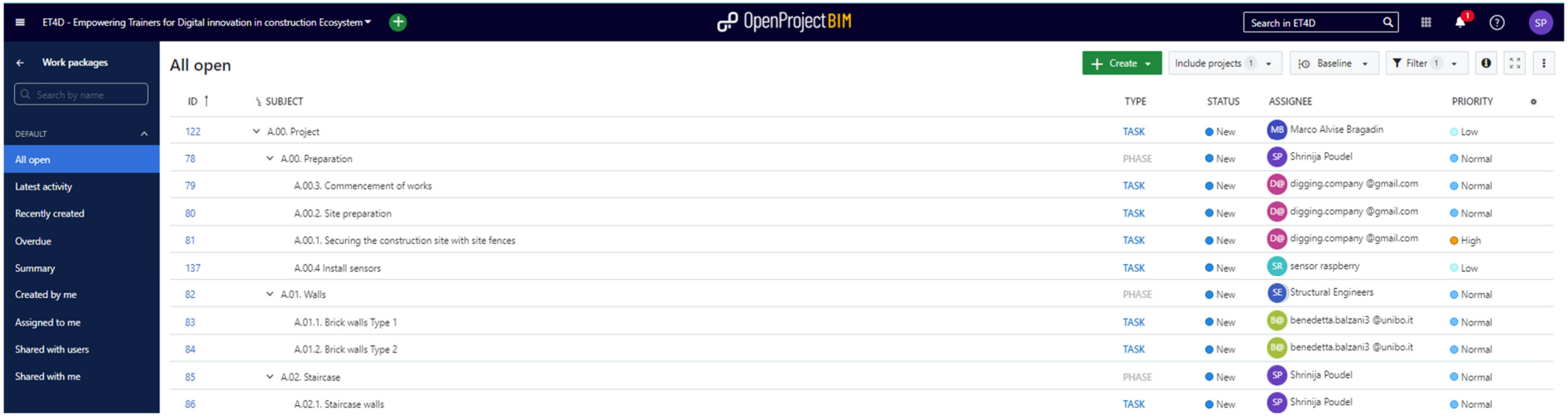


Work Packages-Work Breakdown Structure(WBS)

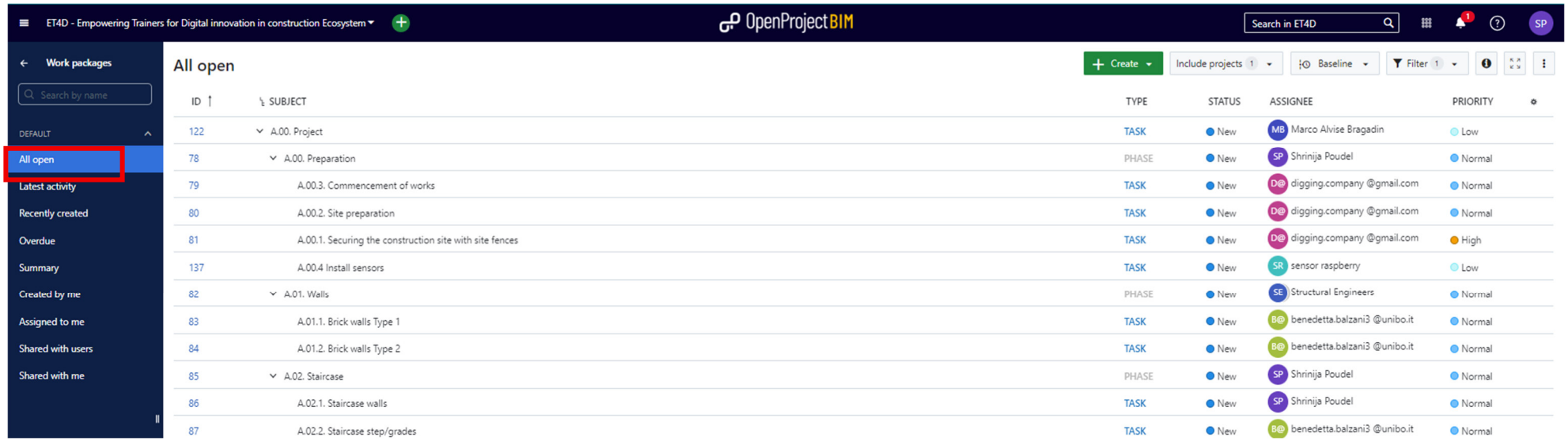
Work packages: this gives the list of all the work packages, it is basically the work break down structure of the project.



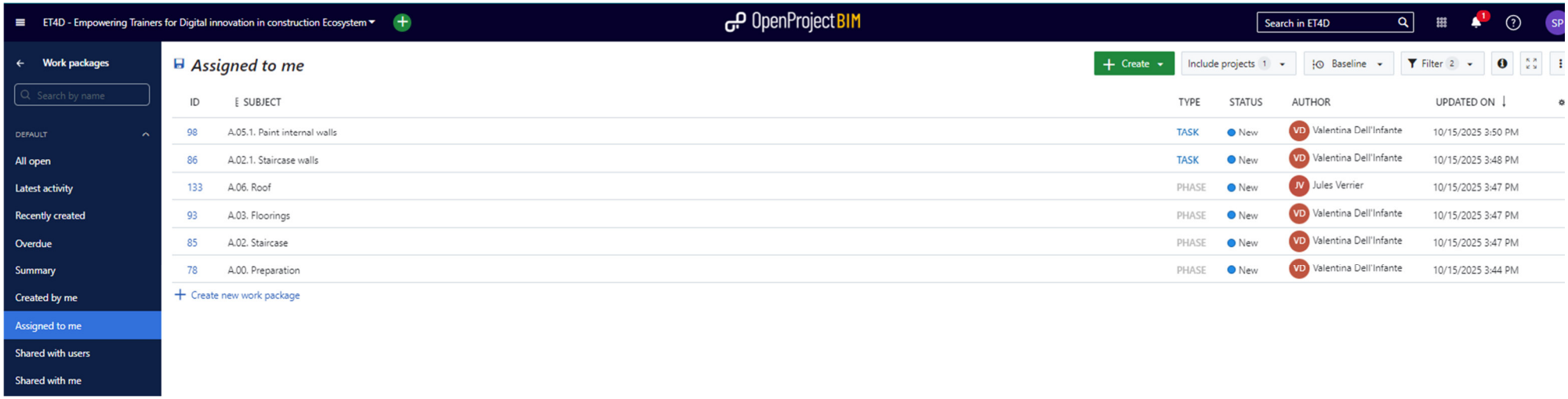
The tasks are categorised under different phases and listed in comprehendible manner. The status of tasks, phases, and priority level can be checked in a glace. The list of assignee provides with added layer of information that helps with clearly understanding the responsible authority to be contacted in case of an issue.



The users can conveniently get a list of tasks assigned to them.



The status of the task and person who assigned the task can be seen here.

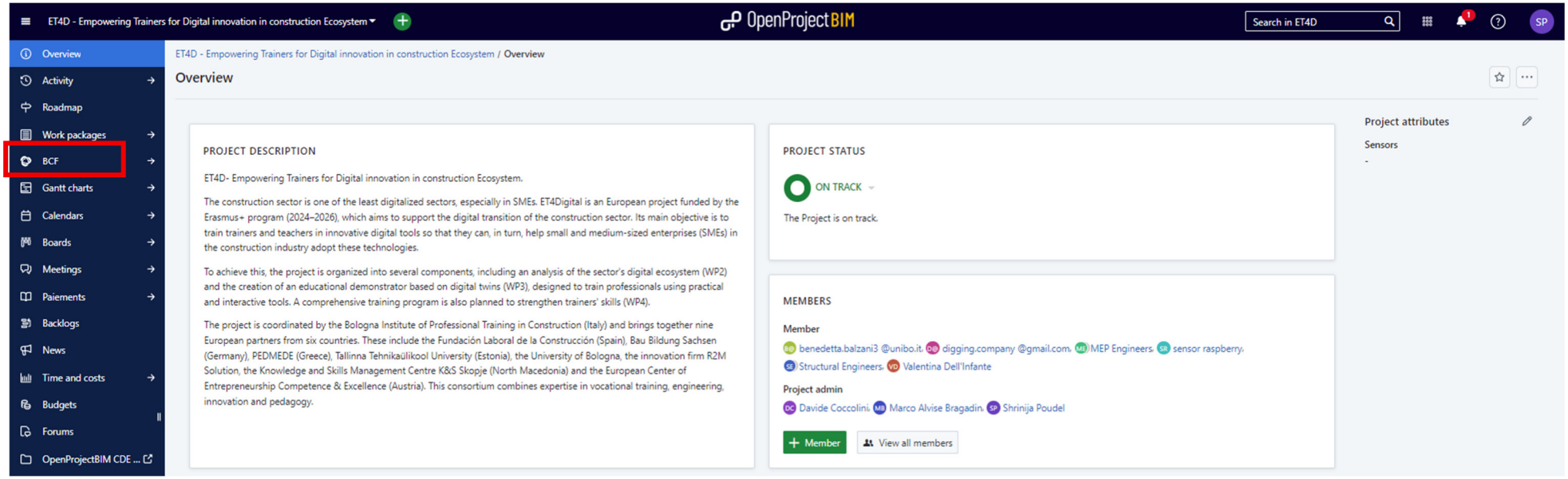


Click the back arrow to back to the project overview list, from where other parts of the project can be accessed.

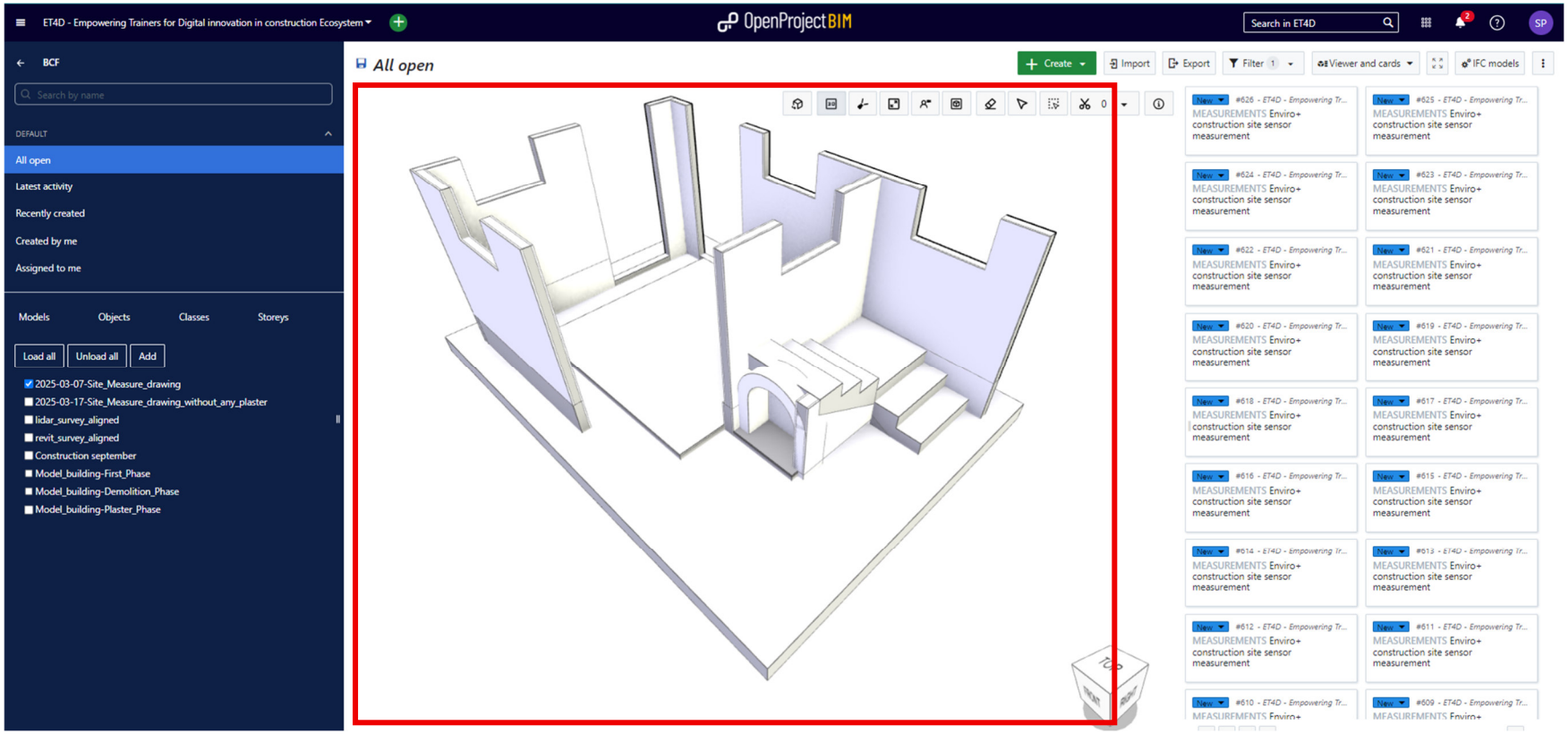


BIM Collaboration Format (BCF)

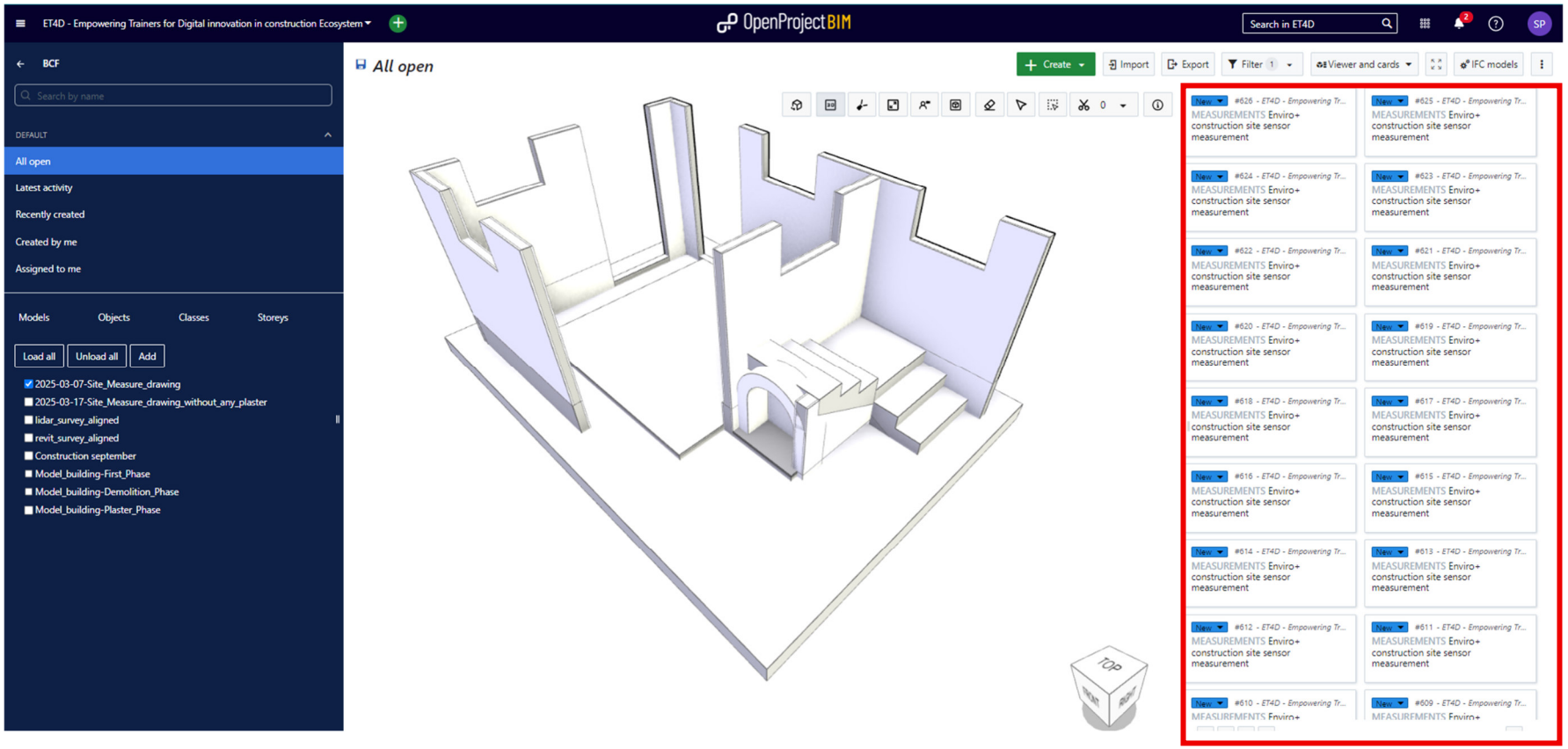
BIM Collaboration Format allows the user to view the BIM model of the project.



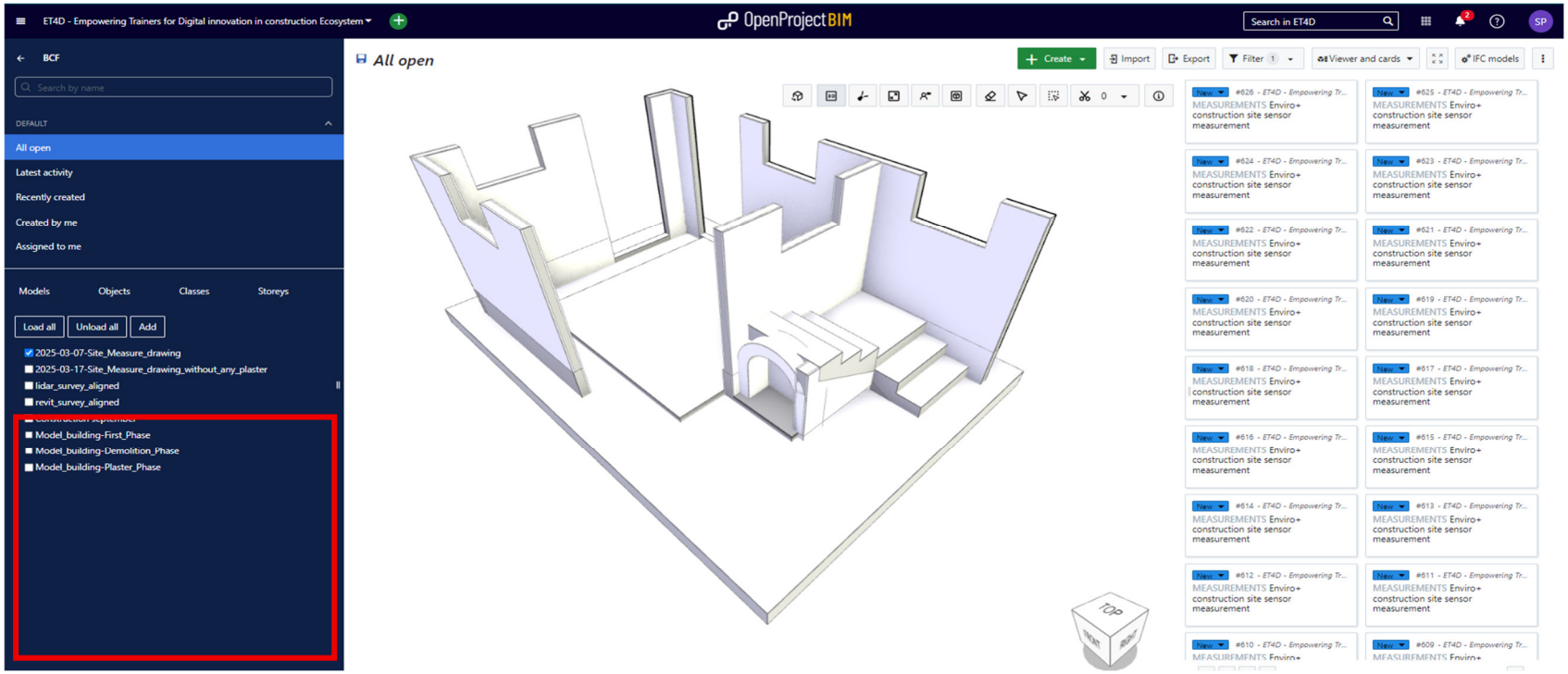
The main part of the window shows the BIM model that is/are selected.



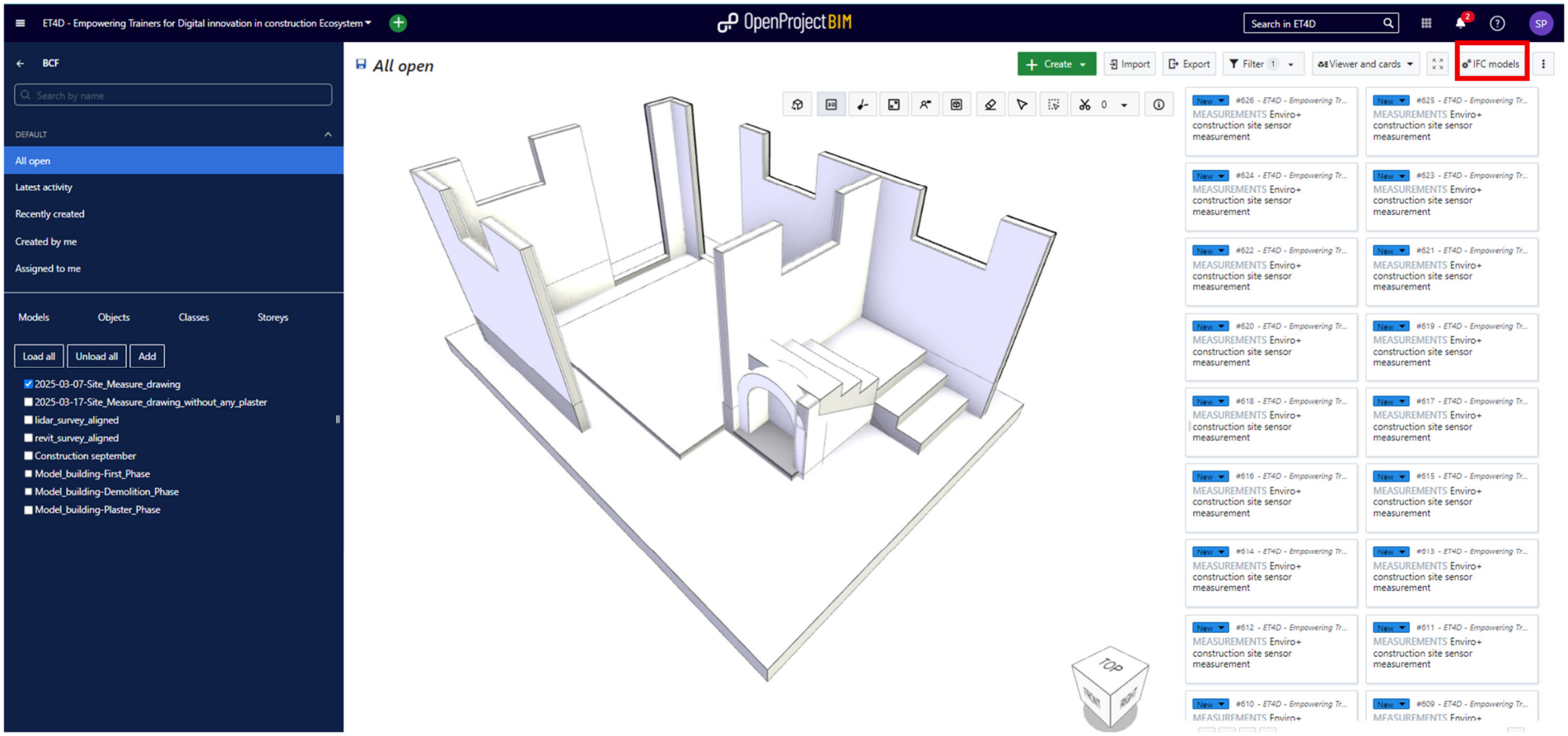
The right hand side of the BCF window can be filtered to show just the model or other information from the drop-down menu on the top.



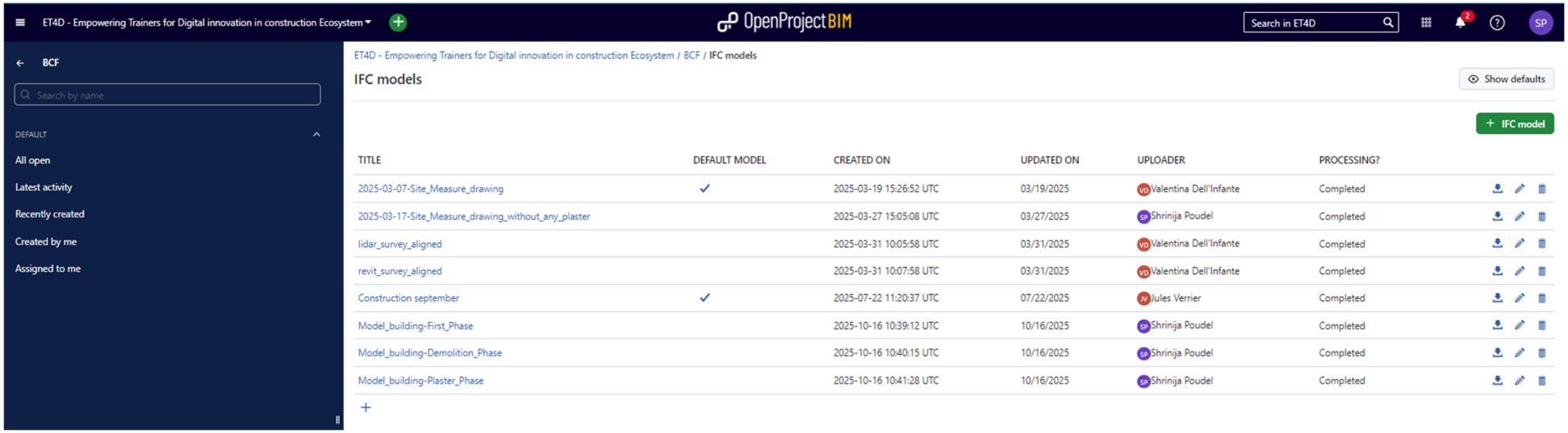
The list of available IFC models can be found on the left-hand side. The models can be checked or unchecked to view or hide the models respectively. Model objects, classes and storeys can also be viewed individually.



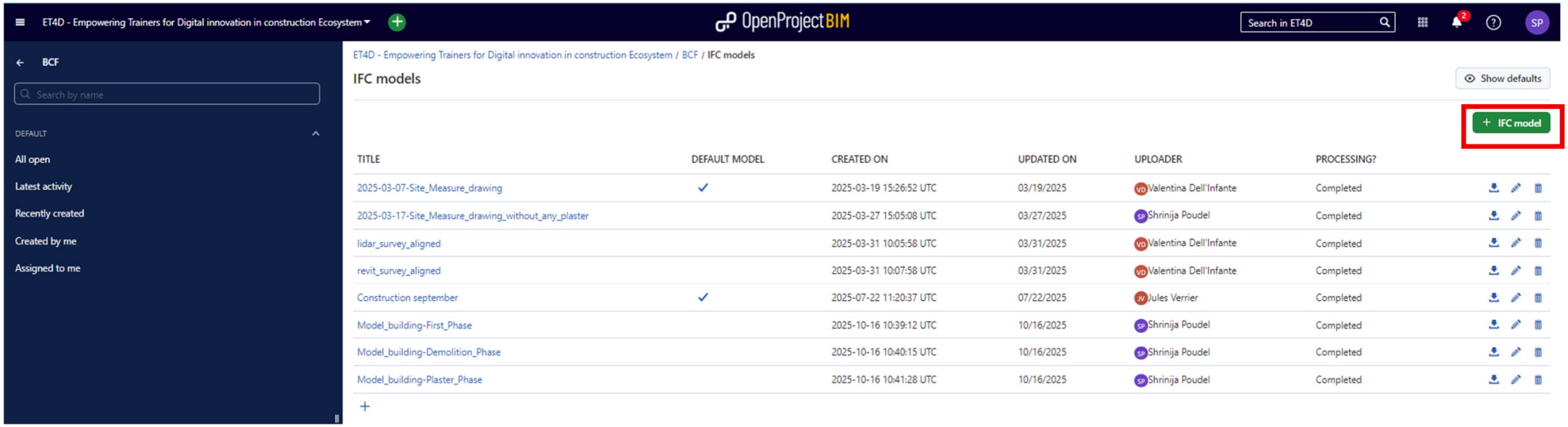
The list of all IFC models can be accessed by clicking on the right-hand top corner.



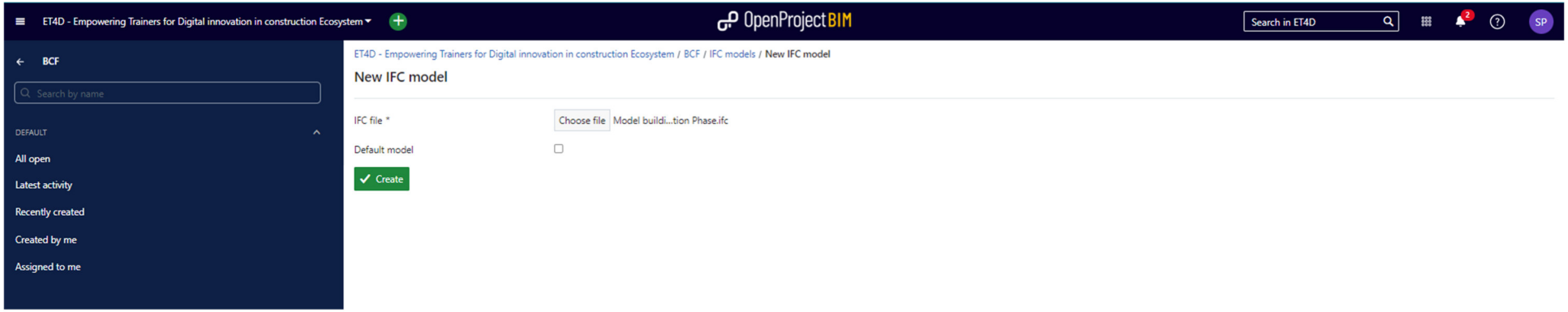
This window gives the details of the uploaded models, the models can be downloaded, edited or deleted, according to the permission granted to the user.



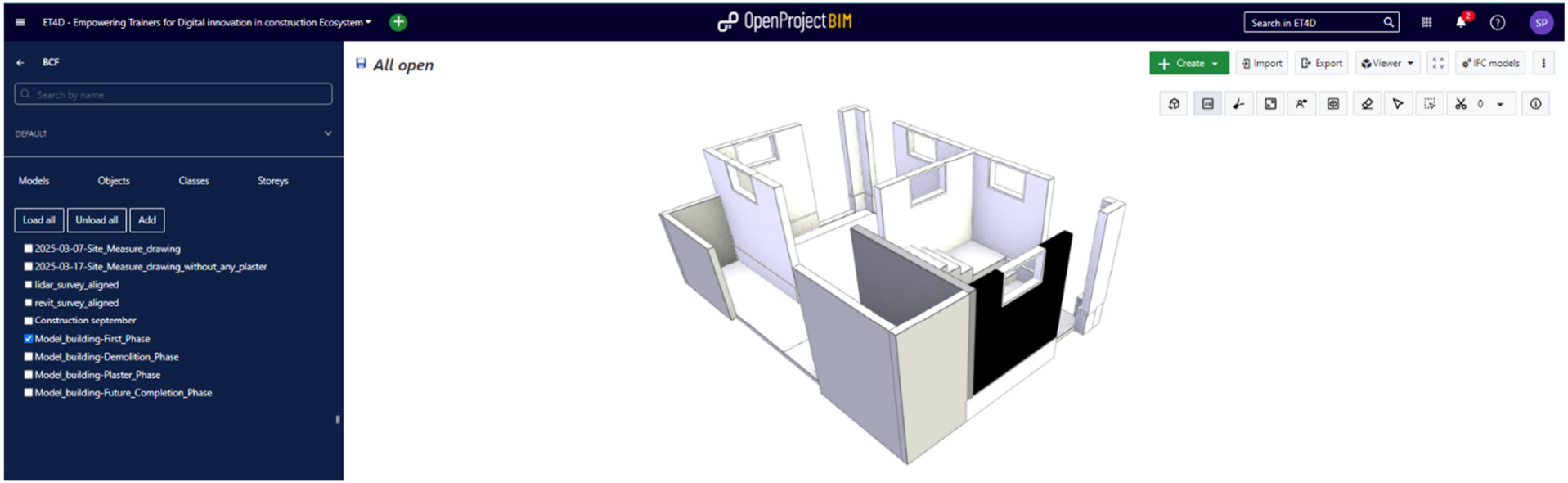
The green button on the top right corner allows to upload a new IFC model.

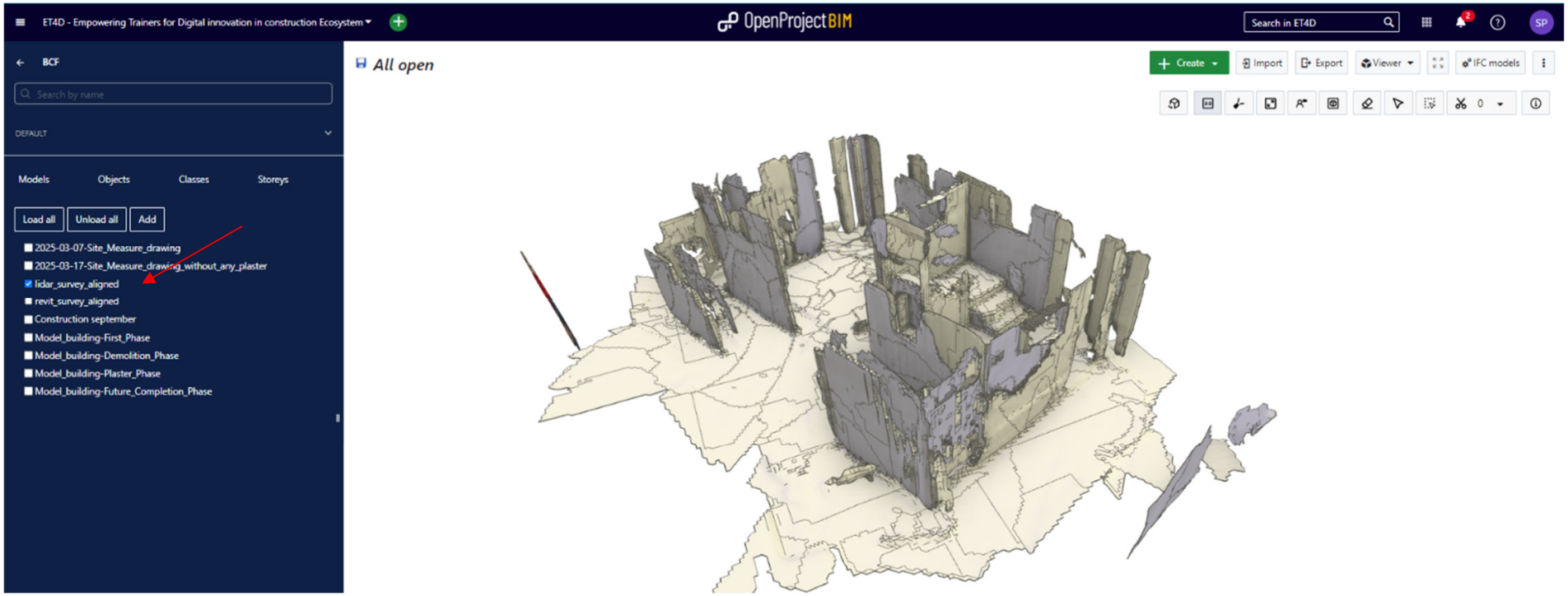


You can choose if the model is default model while uploading, or this can be changed later.

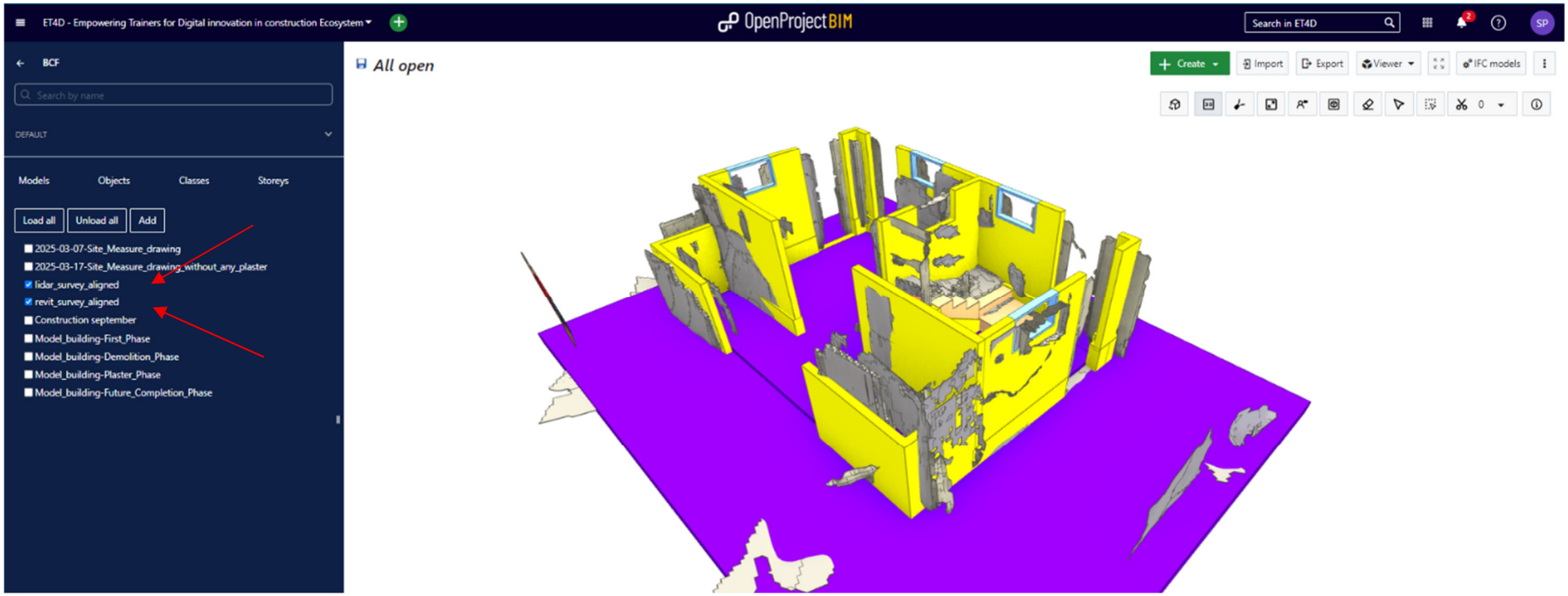


The models can be viewed individually...




ET4D - Empowering Trainers for Digital innovation in construction Ecosystem
OpenProjectBIM
Search in ET4D
BCF
Search by name
DEFAULT
Models
Objects
Classes
Storeys
Load all
Unload all
Add
2025-03-07-Site_Measure_drawing
2025-03-17-Site_Measure_drawing_without_any_plaster
lidar_survey_aligned
revit_survey_aligned
Construction september
Model_building-First_Phase
Model_building-Demolition_Phase
Model_building-Plaster_Phase
Model_building-Future_Completion_Phase
All open
Create
Import
Export
Viewer
IFC models

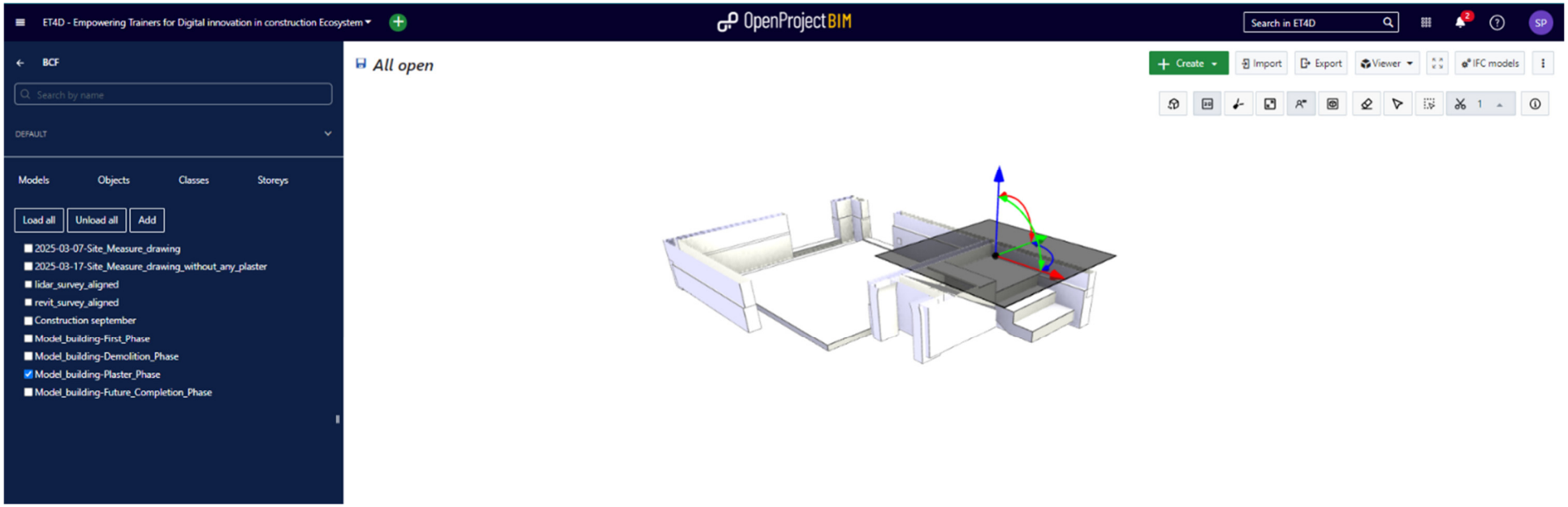
...or overlapped.



The buttons on the top right corner allow to view the 2D drawings, 3D, orthographic, or perspective views, and do various action like to view the model as a whole....

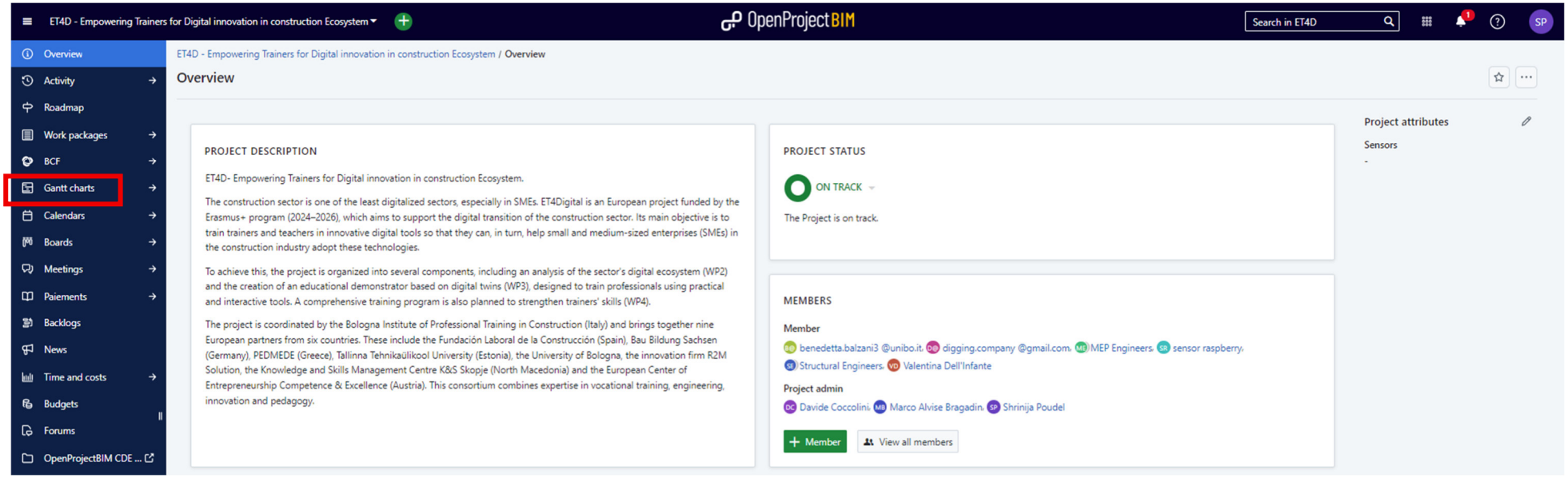


...or make sections and slices to get inside the buildings.

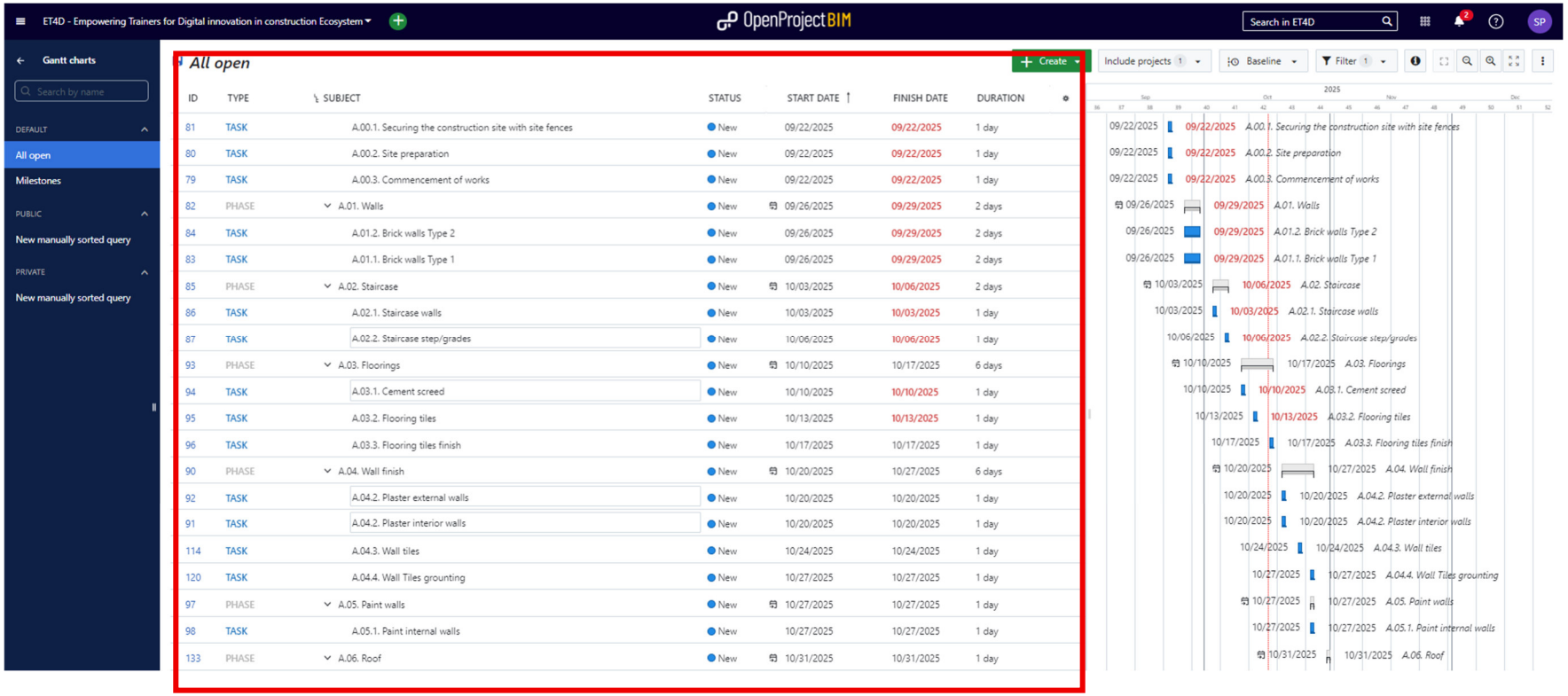


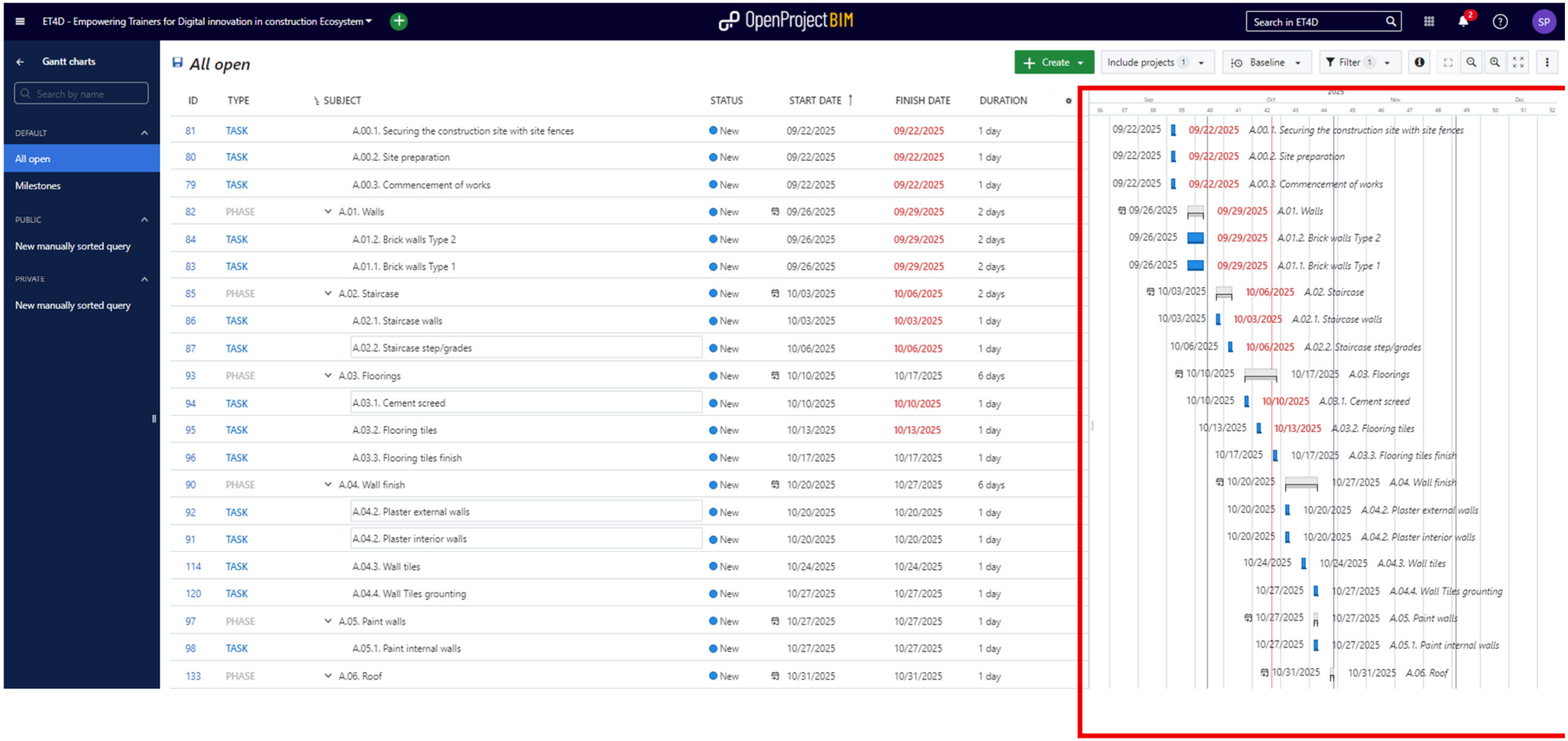
Gantt Charts

Next, we can have a look at the status and plan of the project in the Gantt Charts.

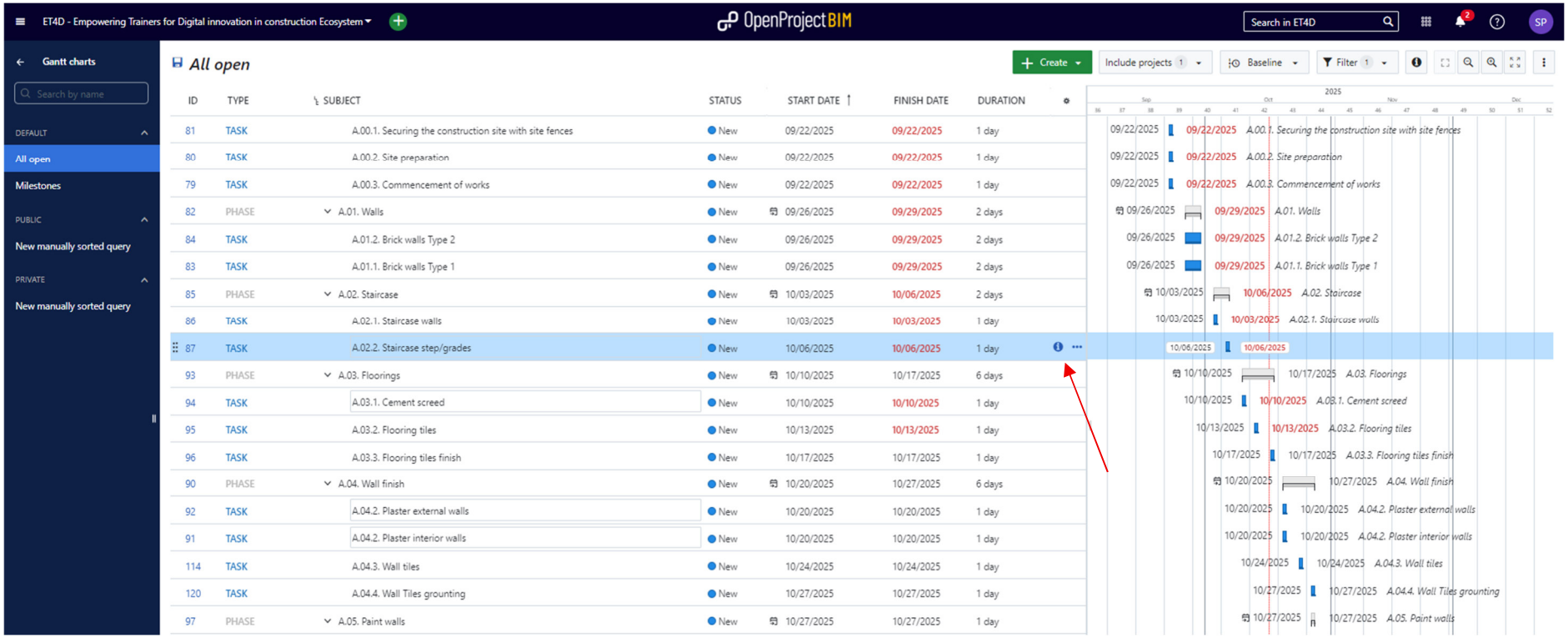


Here, the same information found in Work packages can be found, with addition of start and finish dates, predecessors and successors, along with the Gantt chart on the split left side of the screen.

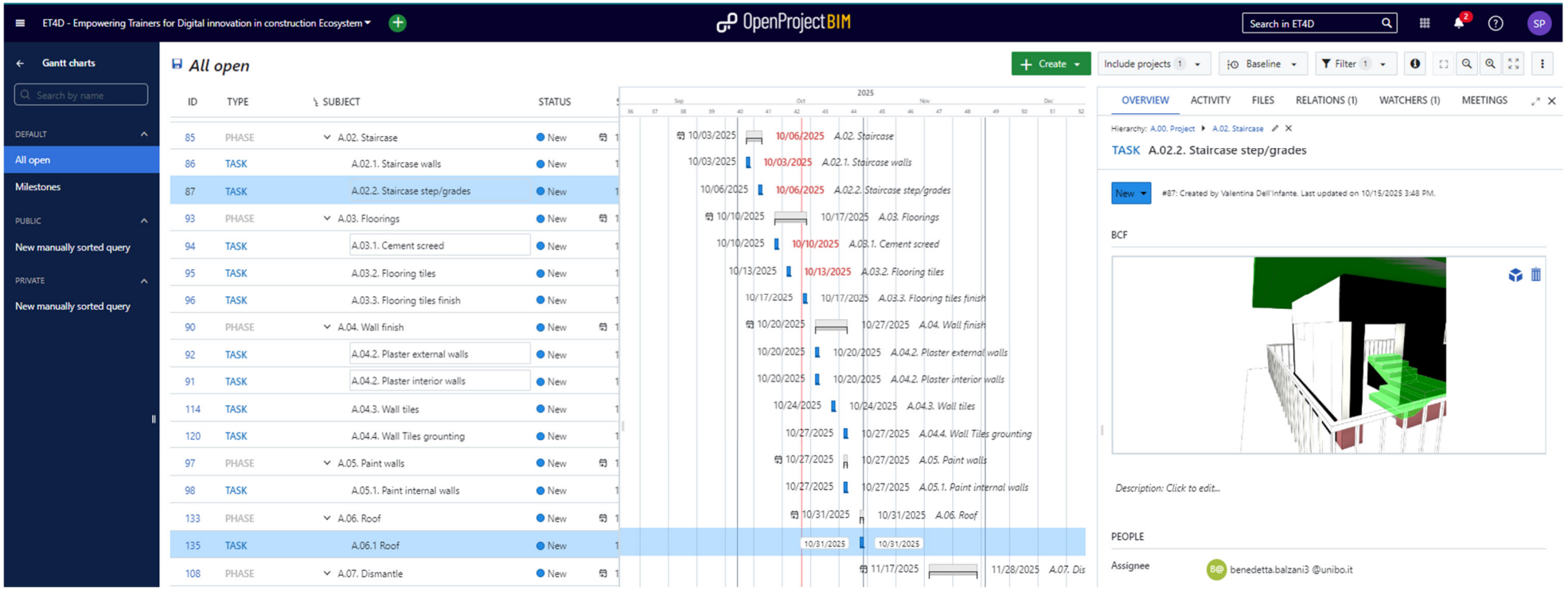



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OpenProjectBIM
Search in ET4D
Gantt charts
Search by name
DEFAULT
All open
Milestones
PUBLIC
New manually sorted query
PRIVATE
New manually sorted query
All open
Create
Include projects
Baseline
Filter
ID TYPE SUBJECT STATUS START DATE FINISH DATE DURATION
81 TASK A.00.1. Securing the construction site with site fences New 09/22/2025 09/22/2025 1 day
80 TASK A.00.2. Site preparation New 09/22/2025 09/22/2025 1 day
79 TASK A.00.3. Commencement of works New 09/22/2025 09/22/2025 1 day
82 PHASE A.01. Walls New 09/26/2025 09/29/2025 2 days
84 TASK A.01.2. Brick walls Type 2 New 09/26/2025 09/29/2025 2 days
83 TASK A.01.1. Brick walls Type 1 New 09/26/2025 09/29/2025 2 days
85 PHASE A.02. Staircase New 10/03/2025 10/06/2025 2 days
86 TASK A.02.1. Staircase walls New 10/03/2025 10/03/2025 1 day
87 TASK A.02.2. Staircase step/grades New 10/06/2025 10/06/2025 1 day
93 PHASE A.03. Floorings New 10/10/2025 10/17/2025 6 days
94 TASK A.03.1. Cement screed New 10/10/2025 10/10/2025 1 day
95 TASK A.03.2. Flooring tiles New 10/13/2025 10/13/2025 1 day
96 TASK A.03.3. Flooring tiles finish New 10/17/2025 10/17/2025 1 day
90 PHASE A.04. Wall finish New 10/20/2025 10/27/2025 6 days
92 TASK A.04.2. Plaster external walls New 10/20/2025 10/20/2025 1 day
91 TASK A.04.2. Plaster interior walls New 10/20/2025 10/20/2025 1 day
114 TASK A.04.3. Wall tiles New 10/24/2025 10/24/2025 1 day
120 TASK A.04.4. Wall Tiles grounting New 10/27/2025 10/27/2025 1 day
97 PHASE A.05. Paint walls New 10/27/2025 10/27/2025 1 day
98 TASK A.05.1. Paint internal walls New 10/27/2025 10/27/2025 1 day
133 PHASE A.06. Roof New 10/31/2025 10/31/2025 1 day

On clicking the i-information button....

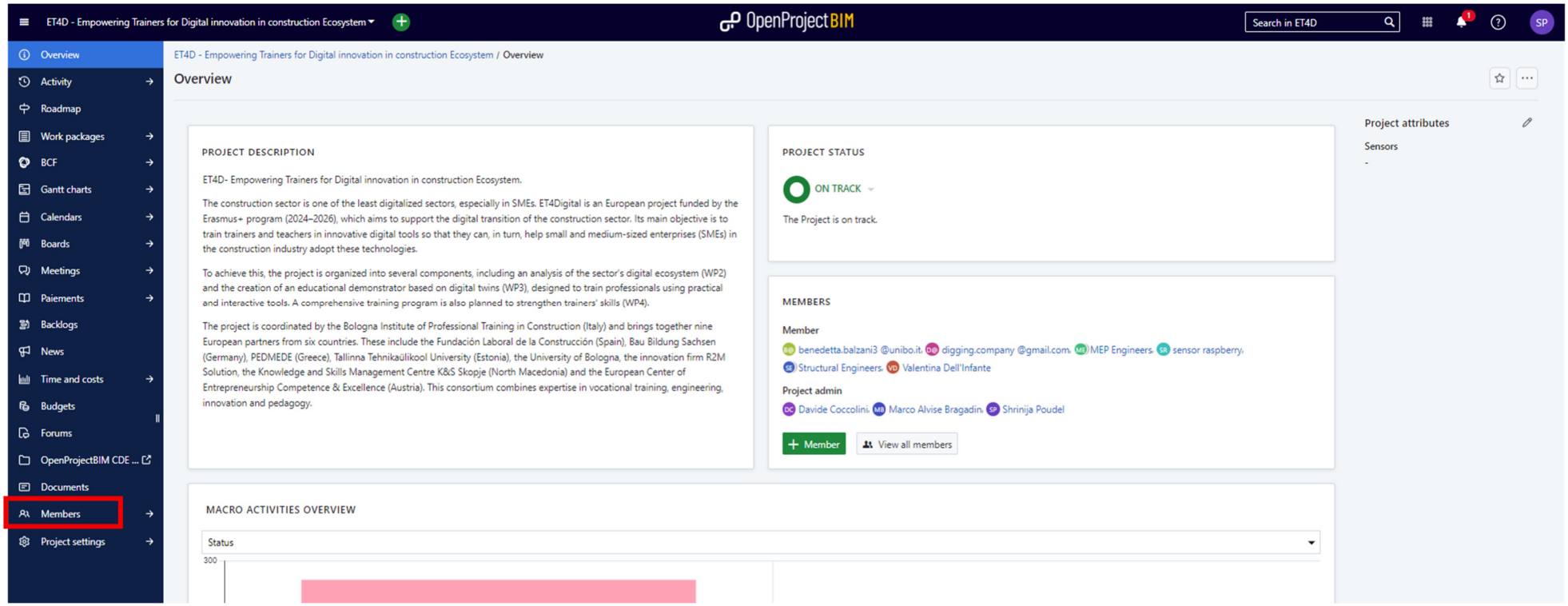


...3D model of the task can be viewed. This helps to clear up the doubt of which specific task the project schedule is mentioned for the specific user and time frame.

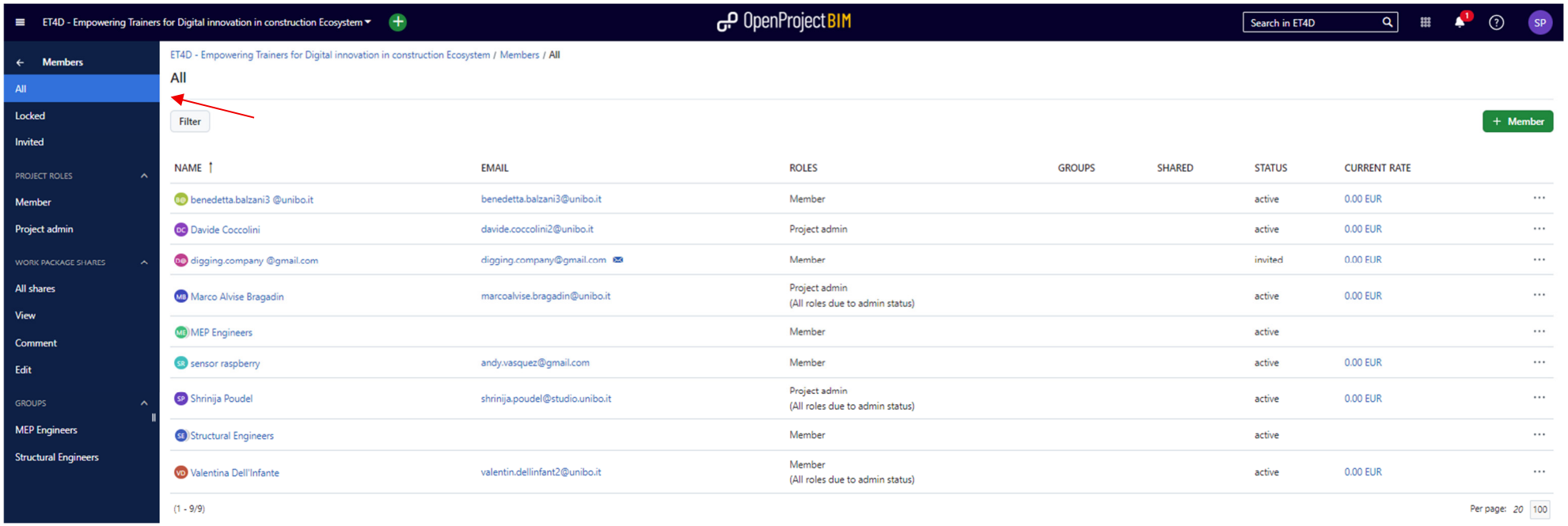


Members

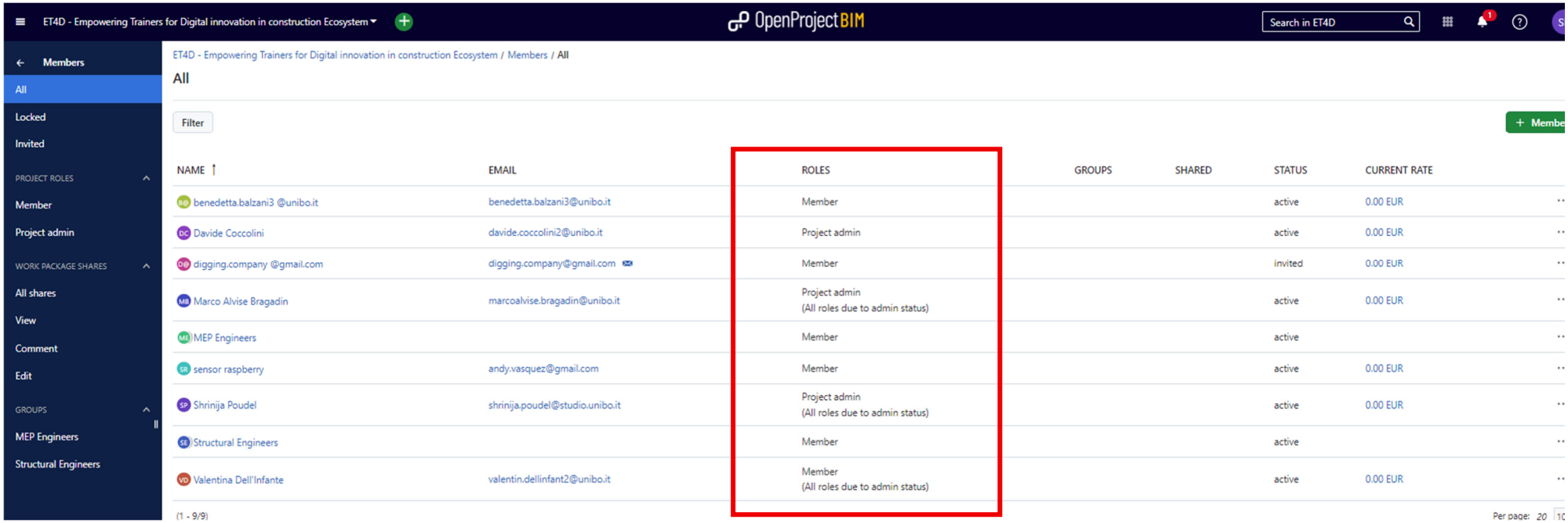
The Members-tab provides the list of all the members associated with the project.



The view list can be chosen according to the assigned groups or all.

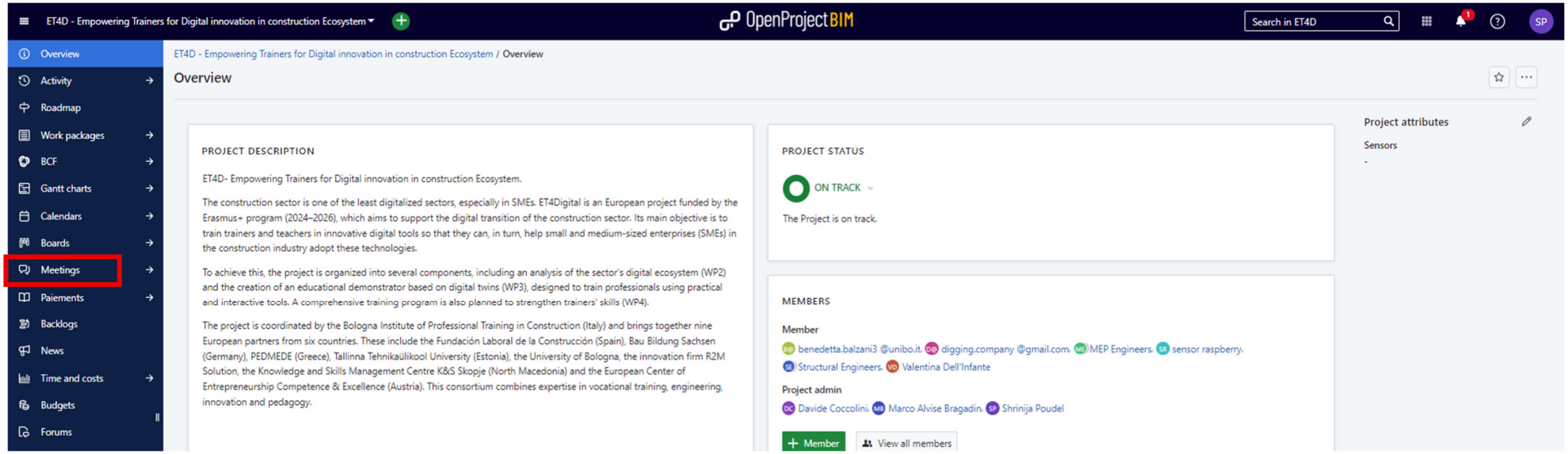


The roles of the members can be assigned and viewed in this tab and filtered to list accordingly as well.

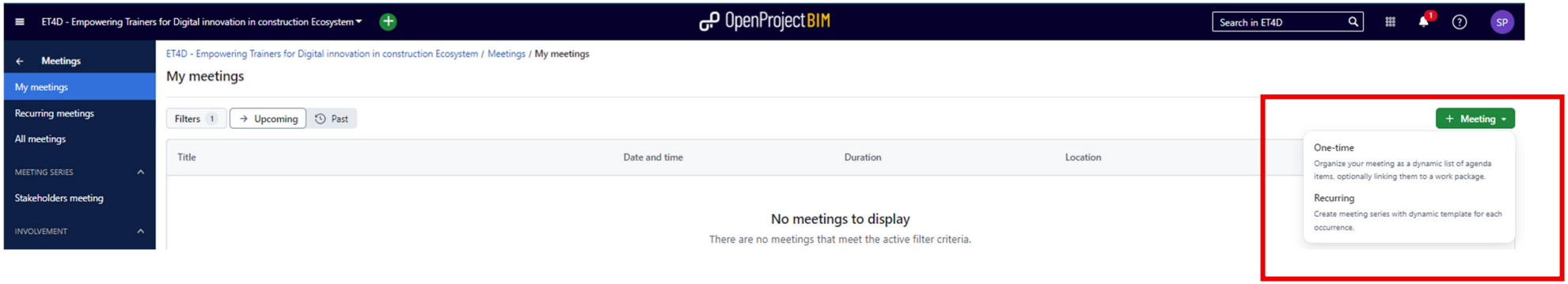


Meetings

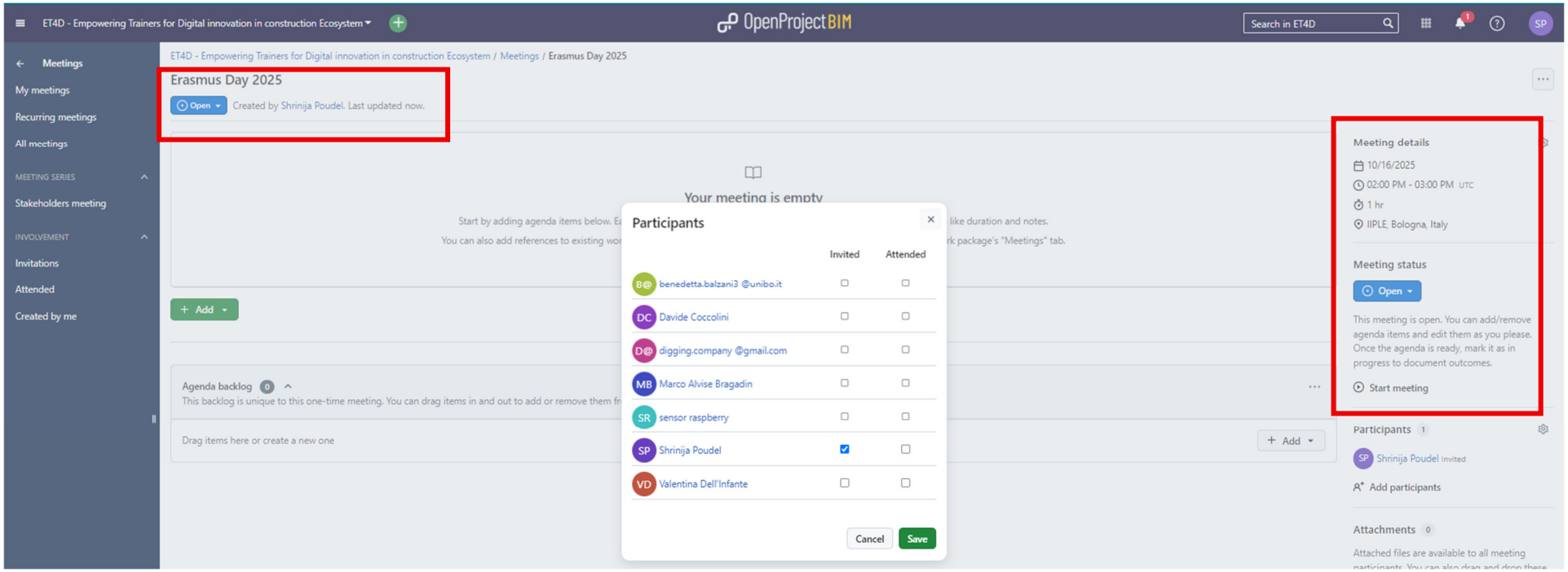
Meetings can be organized in the platform itself.



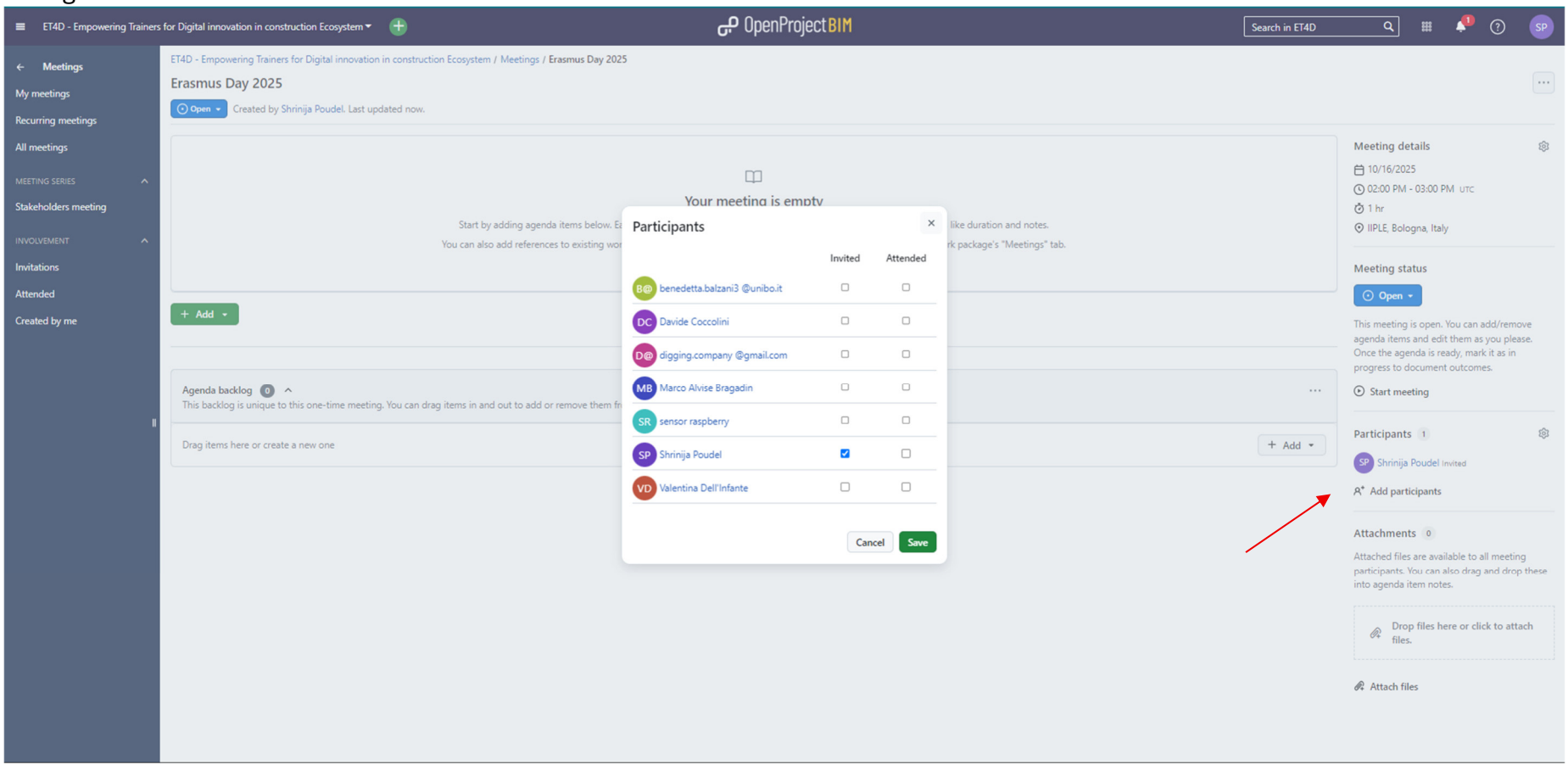
One time meeting can be organised, or a recurring meeting can be scheduled from the green button on the top right corner.



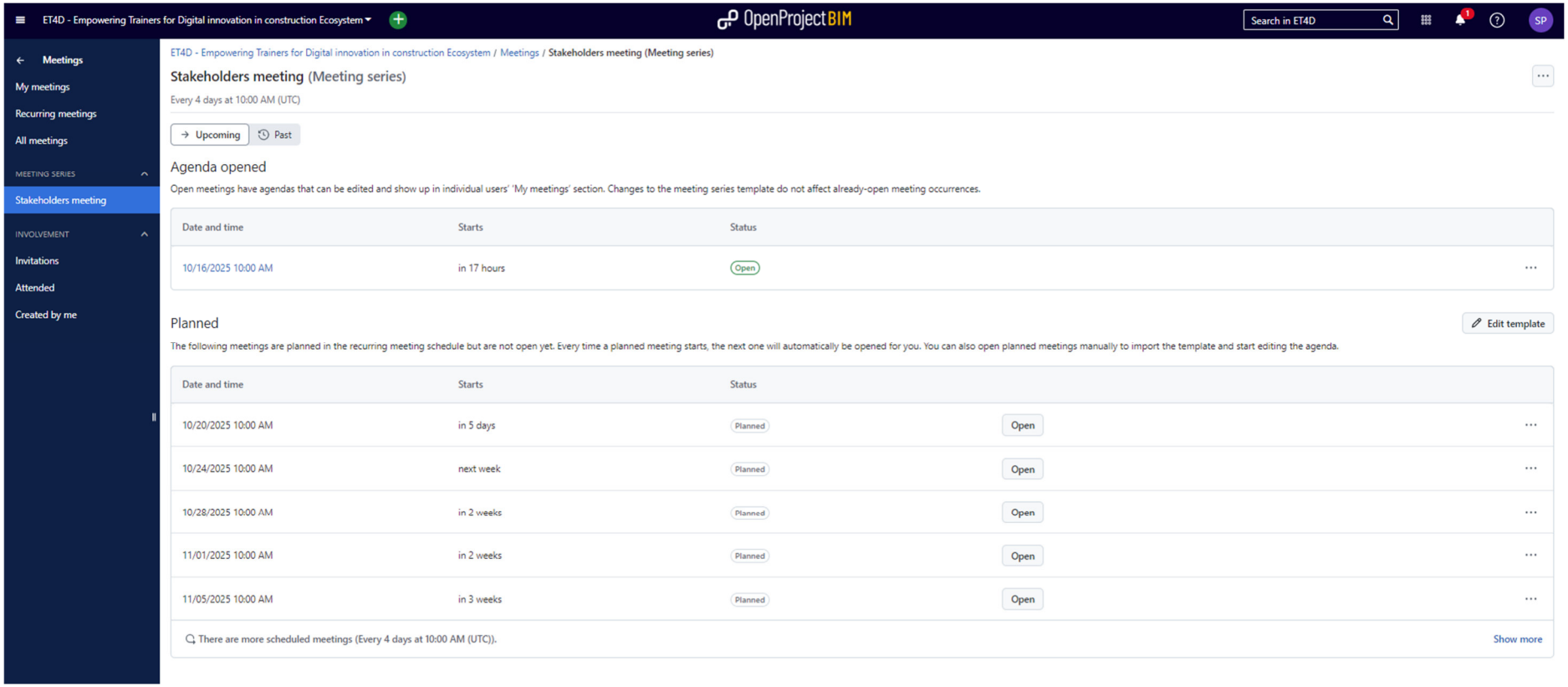
The meetings can be named, and the creator of the meeting is mentioned for the clarity of the event. The details of the meeting is shown in the right-hand side of the screen.



Participants can be added/selected by clicking the ‘add participant’ icon for the meeting from the list of members that appear in the dialogue box.

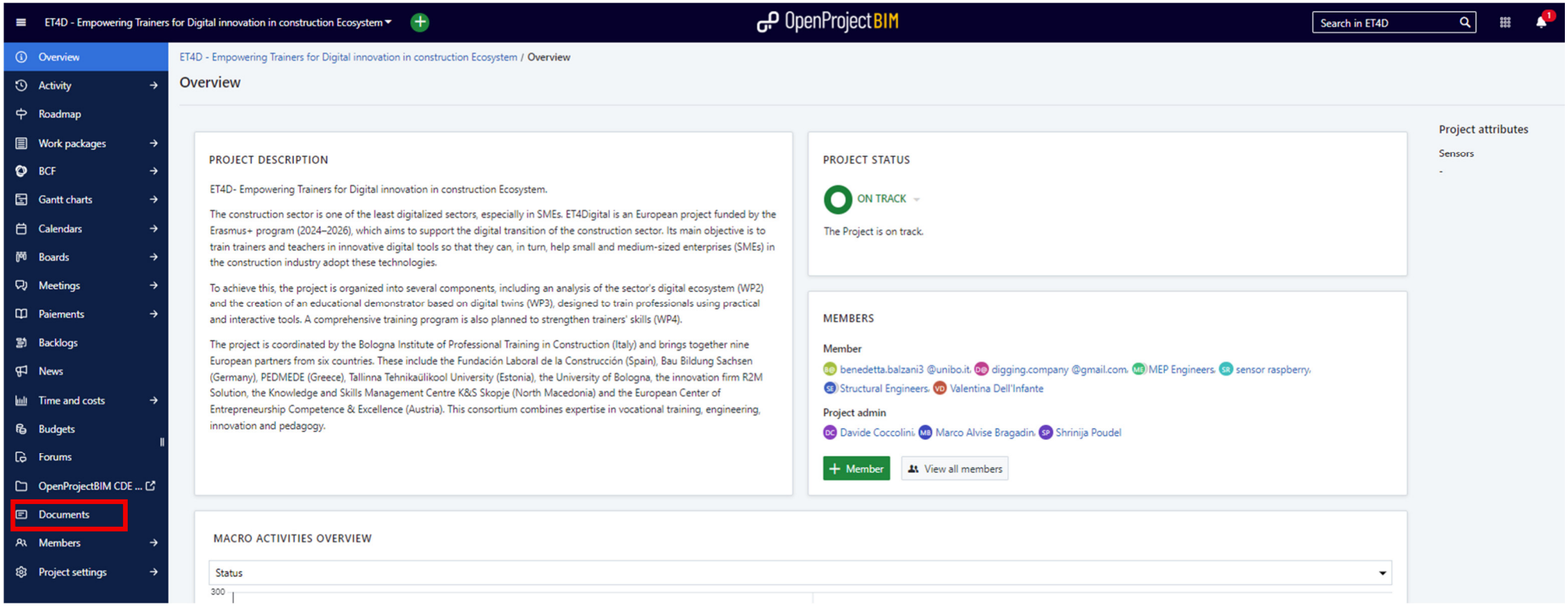


Recurring meeting like stakeholder or board meeting series can be scheduled beforehand and the status and updates can be accessed from tabs on the right-hand side of the screen

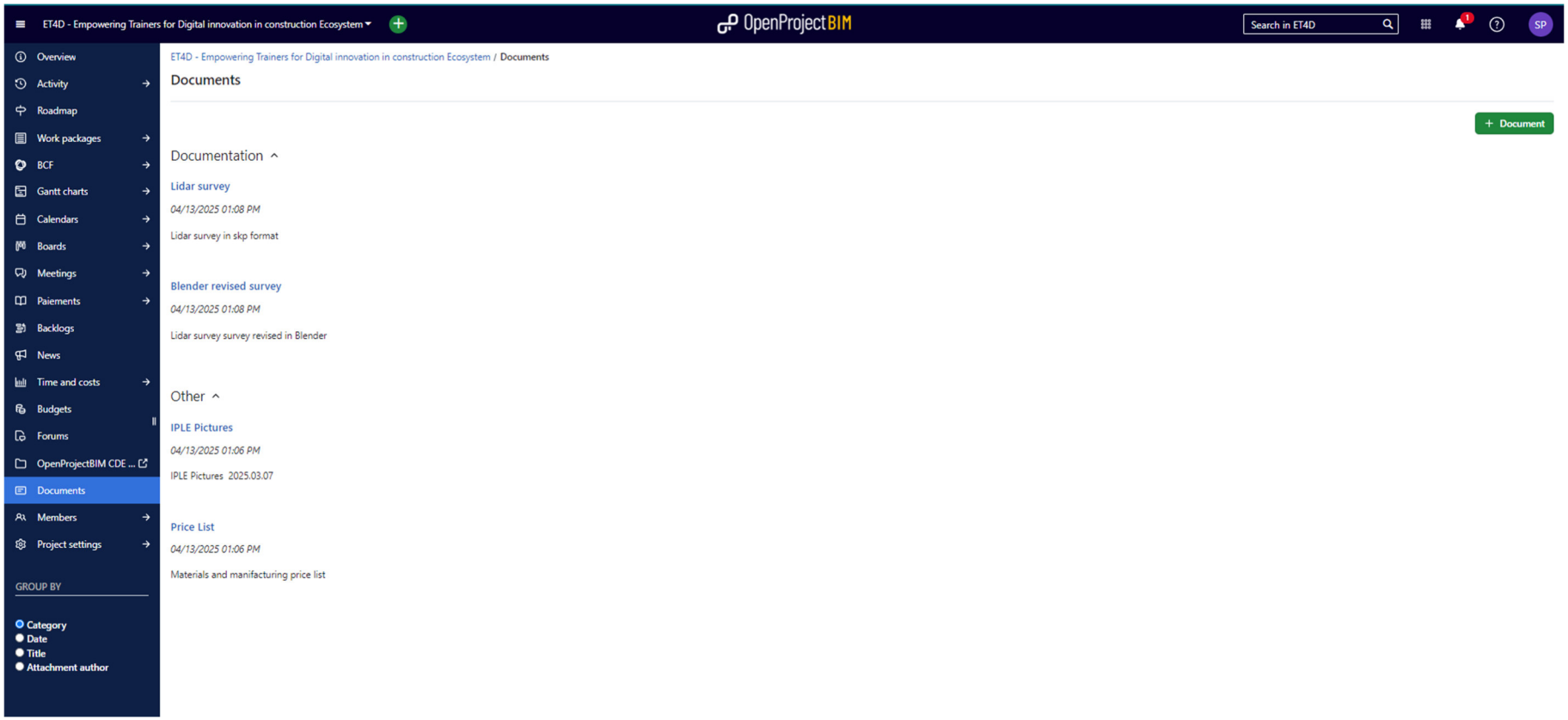


File Sharing

For file sharing, the document tab must be opened.

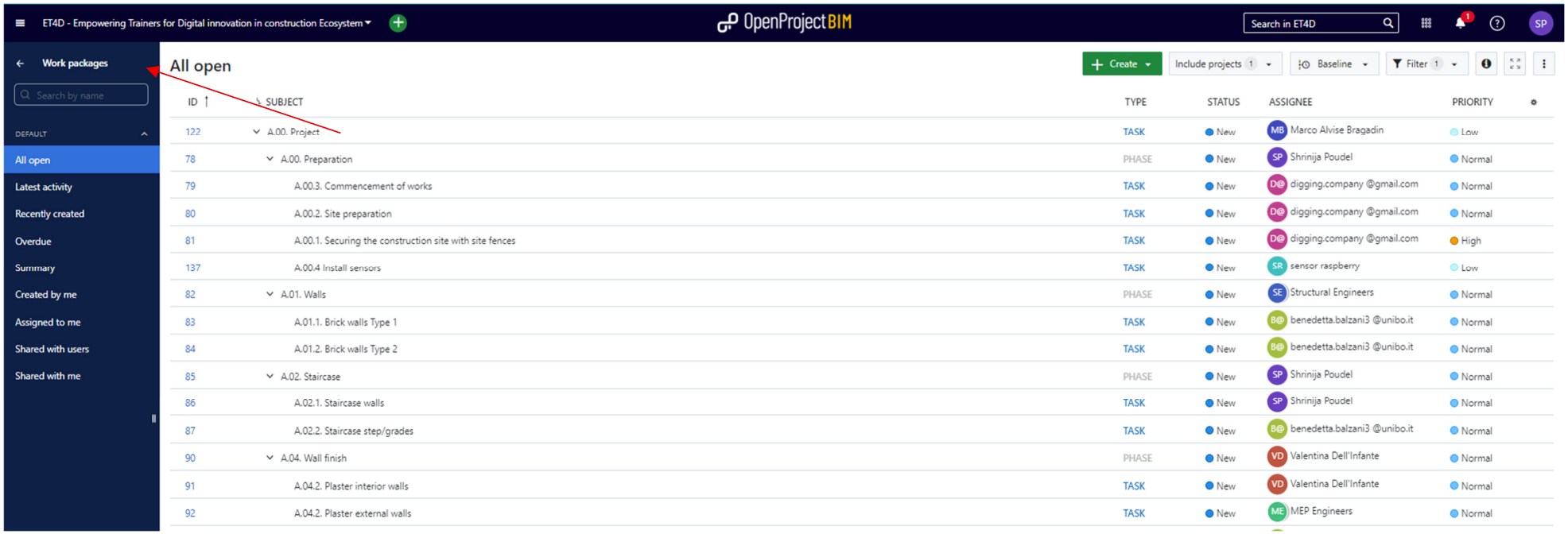


Any type of documents can be share among the members in this tab.



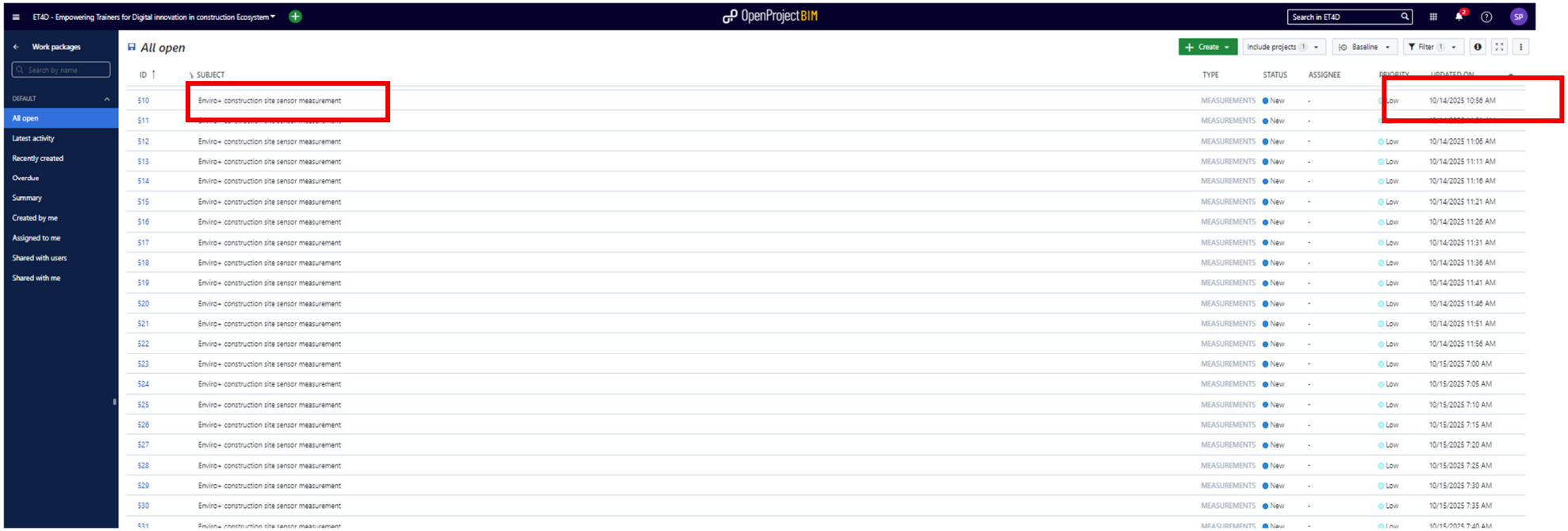
Sensor Reading

Sensor data can be accessed form the work package tab on the right-hand side menu then checking the ‘Latest activity’ tab for most recent sensor data.

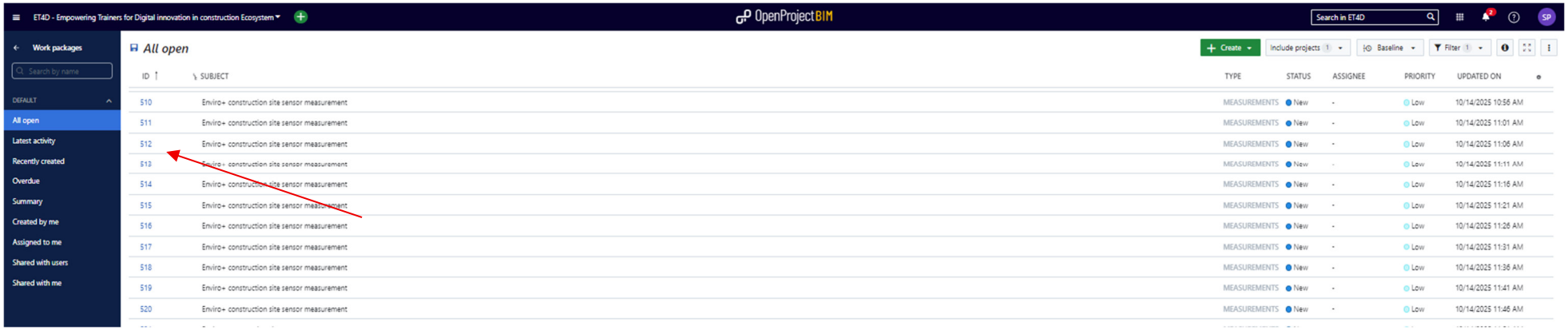



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OpenProjectBIM
Search in ET4D
Work packages
Search by name
DEFAULT
All open
Latest activity
Recently created
Overdue
Summary
Created by me
Assigned to me
Shared with users
Shared with me
All open
Create
Include projects
Baseline
Filter
ID
SUBJECT
TYPE
STATUS
ASSIGNEE
PRIORITY
122 A.00. Project TASK New Marco Alvise Bragadin Low
78 A.00. Preparation PHASE New Shrinija Poudel Normal
79 A.00.3. Commencement of works TASK New digging.company @gmail.com Normal
80 A.00.2. Site preparation TASK New digging.company @gmail.com Normal
81 A.00.1. Securing the construction site with site fences TASK New digging.company @gmail.com High
137 A.00.4 Install sensors TASK New sensor raspberry Low
82 A.01. Walls PHASE New Structural Engineers Normal
83 A.01.1. Brick walls Type 1 TASK New benedetta.balzani3 @unibo.it Normal
84 A.01.2. Brick walls Type 2 TASK New benedetta.balzani3 @unibo.it Normal
85 A.02. Staircase PHASE New Shrinija Poudel Normal
86 A.02.1. Staircase walls TASK New Shrinija Poudel Normal
87 A.02.2. Staircase step/grades TASK New benedetta.balzani3 @unibo.it Normal
90 A.04. Wall finish PHASE New Valentina Dell'Infante Normal
91 A.04.2. Plaster interior walls TASK New Valentina Dell'Infante Normal
92 A.04.2. Plaster external walls TASK New MEP Engineers Normal

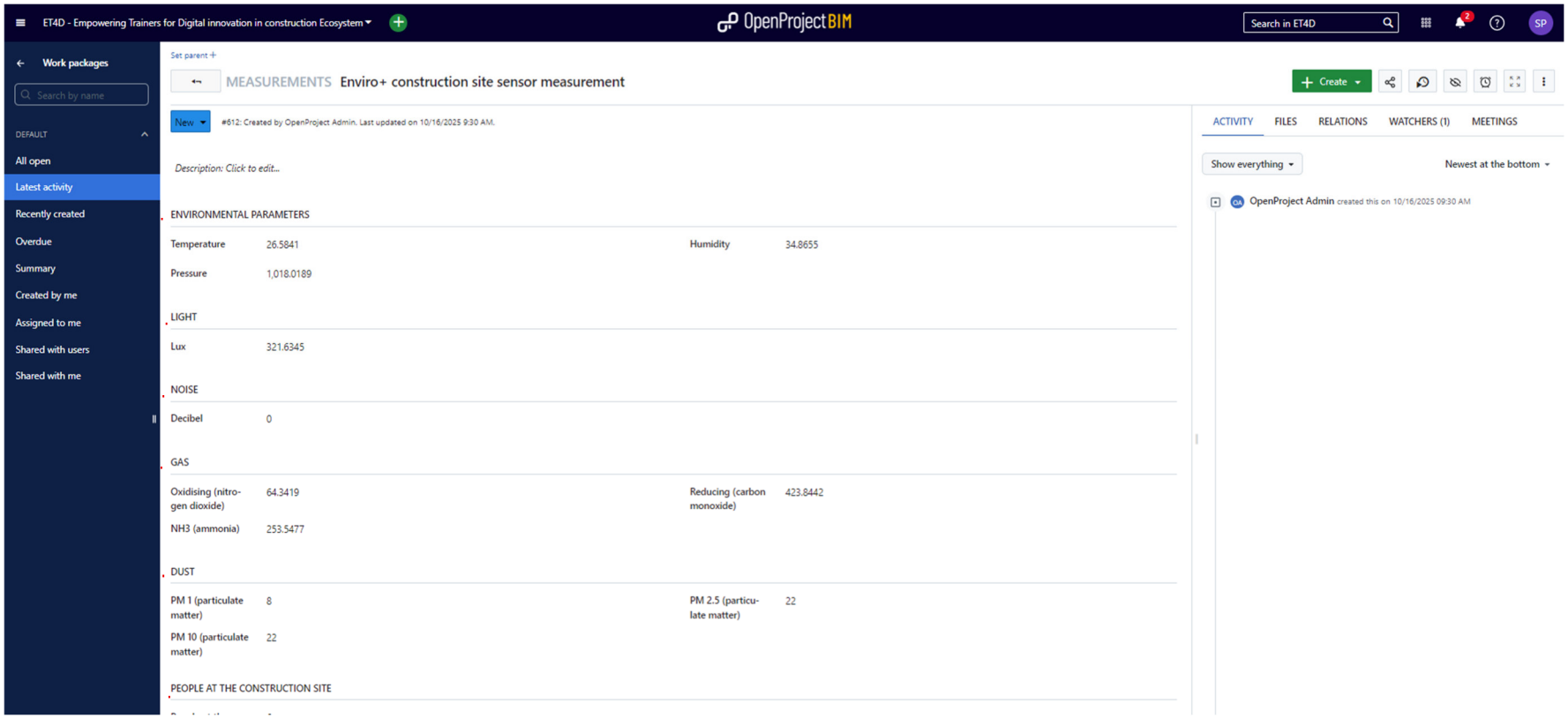
The readings form different sensors can have different names, so the data can be filtered clearly. They can be sorted as per readings or oft this case, as per the time stamp. X



These reading can be individually accessed for the detailed information, according to the time stamp, but for the graphs of the sensor data can be accessed from the dashboard in the overview panel.

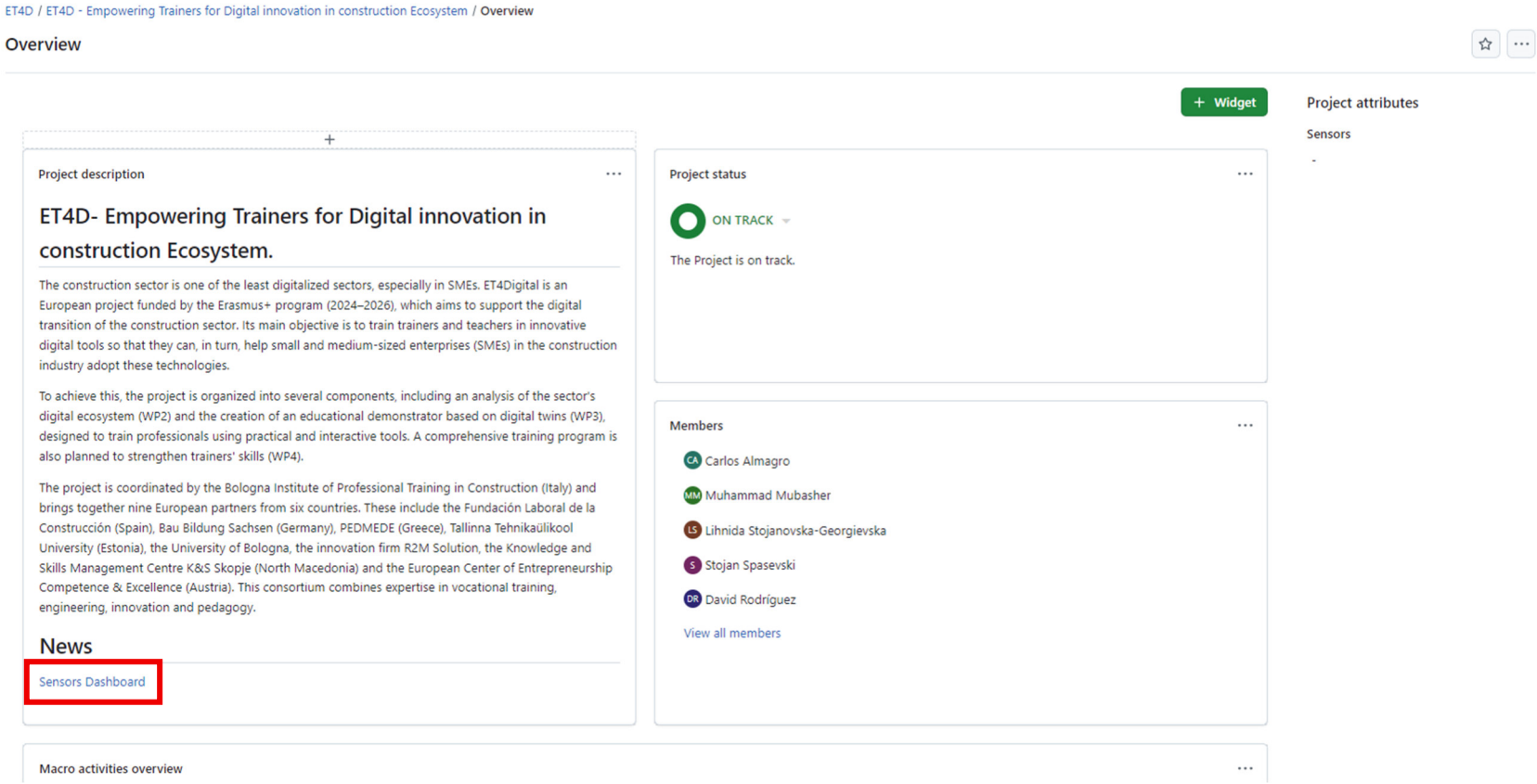


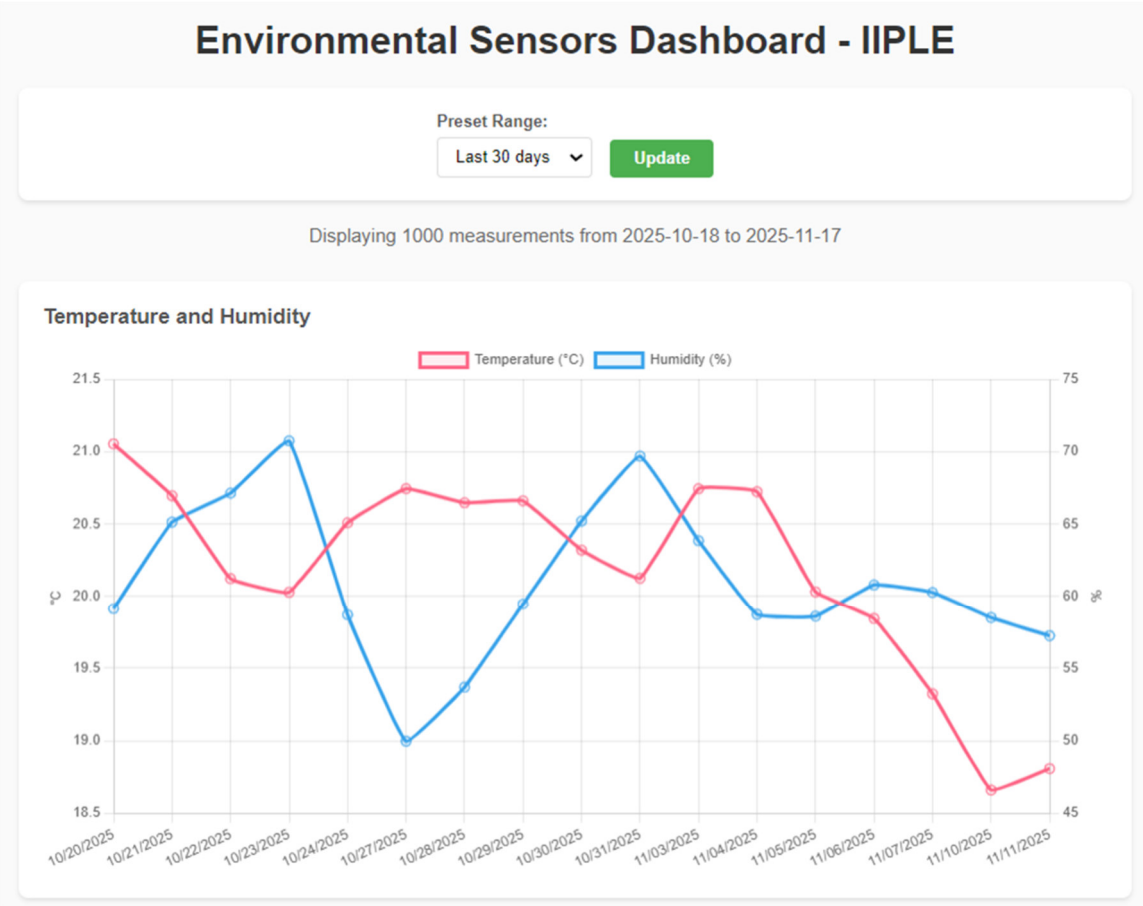
Environmental parameters like Temperature, Light, Noise, Gas, Dust and Number of people present in the site are read by the sensors currently in the site.

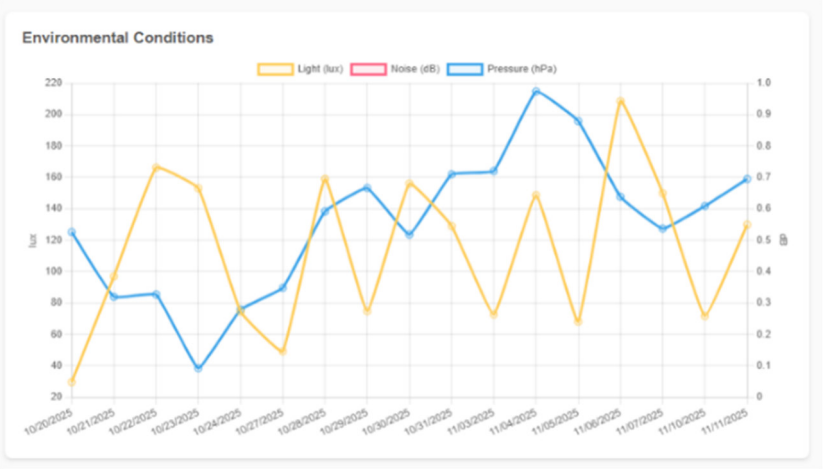


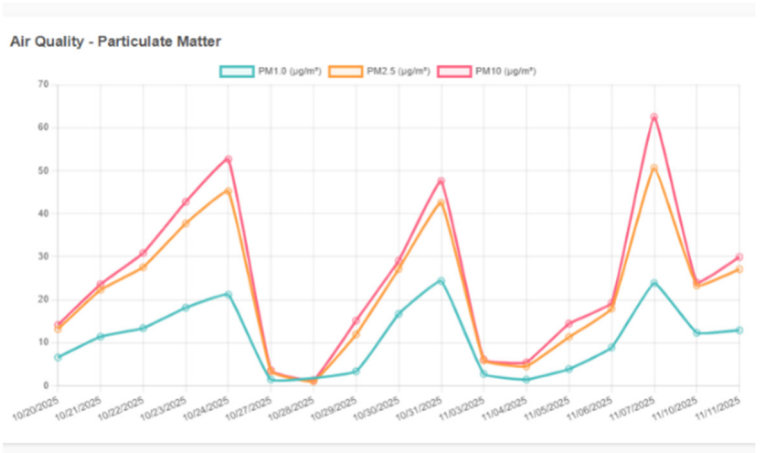
Sensors Reading- Sensor Dashboard

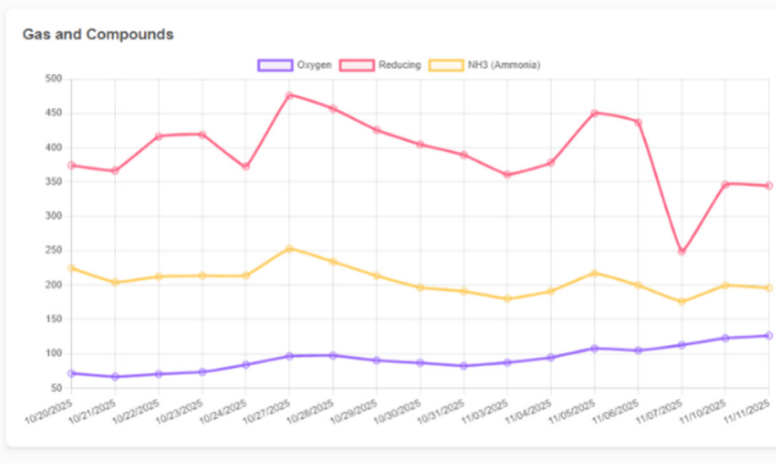
The graphs can be viewed from the Sensors Dashboard button in the overview panel.

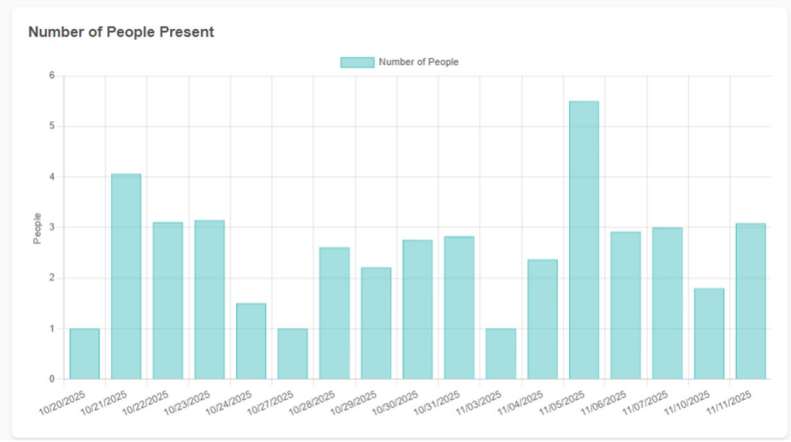



Environmental Sensors Dashboard - IIPLE
Preset Range:
Last 30 days
Update
Displaying 1000 measurements from 2025-10-18 to 2025-11-17
Temperature and Humidity
Temperature (°C)
Humidity (%)
21.5
21.0
20.5
20.0
19.5
19.0
18.5
°C
75
70
65
60
55
50
45
%
10/20/2025
10/21/2025
10/22/2025
10/23/2025
10/24/2025
10/27/2025
10/28/2025
10/29/2025
10/30/2025
10/31/2025
11/03/2025
11/04/2025
11/05/2025
11/06/2025
11/07/2025
11/10/2025
11/11/2025


Environmental Conditions
Light (lux)
Noise (dB)
Pressure (hPa)
lux
dB


Air Quality - Particulate Matter
PM1.0 (µg/m³)
PM2.5 (µg/m³)
PM10 (µg/m³)


Gas and Compounds
Oxygen
Reducing
NH3 (Ammonia)


Number of People Present
Number of People
People

The platform is very flexible and customisable for each project. Further information can be found in the official website of OpenProject; linked underneath.
https://www.openproject.org/collaboration-software-features/

ET4Digital

Empowering Trainers for Digital Innovation in the Construction Ecosystem

PROJECT no. 2024-1-IT01-KA220-VET-000249119

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