SUSTAIN

cluSter bUilding SmarT reAdiness INdicators

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Table of Contents

List of Tables

Executive Summary

The Deliverable's primary purpose is to define and offer a framework of existing tools and solutions in energy-efficient buildings.
The first part summarizes some of the most disruptive tools developed in several European projects. The second part offers a cross-section of the European entrepreneurial reality and innovative dynamism in the construction field, starting from an analysis of the strategies developed within some European Innovation Hubs.
Finally, the Deliverable presents a proposal for an analysis questionnaire prepared to probe the innovation response of the entrepreneurial ecosystems of the various members of the consortium. The questionnaire will be disseminated during the project's second quarter. It will provide the basis for developing the bases of technical assistance to the SMEs for adopting innovative solutions in the sector.

1. Introduction

The construction industry is very important to the EU economy. The sector provides 18 million direct jobs and contributes to about 9% of the EU's GDP. It also creates new jobs, drives economic growth, and provides solutions for social, climate and energy challenges. However, it is also responsible for around 40 % of greenhouse gas emissions, uses more than 50 % of the raw materials extracted from the Earth, and generates around one third, in volume, of all waste produced in the EU. The building industry, either residential or commercial, is reported to contribute the most to global energy consumption. Furthermore, it's estimated that 75% of the existing building stock in the European Union is inefficient in terms of energy use. However, yearly renovation rates are incredibly low (0.4–1.2%) and existing building energy-oriented refurbishment progress work is typically regarded as insufficient[1]. In order to increase the energy efficiency of buildings, fund building rehabilitation investments, and implement smart, energy-efficient technology in the building industry across Europe, actions and interventions must be accelerated. Additionally, it should be mentioned that the building industry produces a significant volume of waste which, in turn, creates a sizable environmental impact. EU-funded research has developed know-how and tools to help the construction sector embrace the circular economy and increase the reuse, reconfiguration and recycling of products, materials, components and buildings.

Through the €806.9 billion Recovery and Resilience Facility (RRF)[2], which aims to help Europe recover from the pandemic and future-proof its economy and society, the European Union also hopes to achieve its Green Deal target of climate neutrality by 2050[3]. In fact, at least 37% of spending in the national plans funded by the RRF must relate to climate goals[4]. Much of that, in turn, is going to construction and infrastructure projects. In the effort to build a truly climate-friendly, circular economy, where waste and carbon emissions are minimized or eliminated, building and renovation methods are crucial. Prefabrication, for example, can enhance efficiency and build speed, while minimizing waste. Across the board in Europe, governments are making use of this funding to enable the Green transition.

Renovating energy-inefficient buildings is crucial if Europe is to reduce its carbon footprint. That is why an EU-funded project is making renovations faster and easier, helping homes to save energy - for the benefit of the general public and the planet. For most people, the idea of renovating their home can be a daunting prospect. Building renovations have long been associated with stress, delays and spiraling costs. Their poor reputation is one reason why the renovation rate across Europe is so low – less than 1 % of EU buildings are refurbished every year. However, renovating both residential and non-residential buildings will be crucial if Europe is to reduce its carbon footprint. At present, three-quarters of the EU's building stock is energy-inefficient, which means homes and workplaces are the bloc's biggest single energy consumer, responsible for 40 % of primary energy consumption and 36 % of CO_2 emissions.[5]

To establish a future sustainable society, the building sector must move towards energy-efficient technologies in the building industry. In order to maximize the energy-efficient control of Technical Building Systems (TBS) and enable interaction with their inhabitants and the energy grids throughout the daily operation, smart buildings incorporate cutting-edge information and communication technology (ICT)-based solutions. As a result, the use of smart technologies is intended to enable the creation of healthier and more comfortable buildings that adapt to the needs of both users and the energy grid while lowering energy usage and carbon impacts. The future energy systems, which are expected to include a greater proportion of renewable energy, improve local green energy storage, and estimate maintenance requirements automatically.

Digital transformation can improve the level of innovation of green technology in all productive sectors. In this sense, digital technologies will create transformative changes in the construction sector. In this work, some so-called champions of innovation are examined in two CLUSTERS of the consortium, Greentech and CEEC. In the first part, we want to analyze how these subjects frame the future by combining a range of digital technologies and trends, such as big data, the internet of things, automation and the blockchain, to transform construction into a sustainable and energy-efficient key. Drawing on a study based on interviews with construction professionals in Spain and Latvia, this document presents emerging innovations for the sustainable transformation of the sector.

[1] https://commission.europa.eu/news/focus-energy-efficiency-buildings-2020-02-17_en
[2] https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en
[3] https://climate.ec.europa.eu/eu-action/european-green-deal_en
[4] https://ec.europa.eu/commission/presscorner/detail/it/qanda_21_481
[5] https://ec.europa.eu/research-and-innovation/en/projects/success-stories/all/home-improvements-planet

1.1 WP2 Innovation

The main objectives of WP2 are: 1) Innovation in building capacity for strategic autonomy in the building construction domain; 2) Adopt processes and technologies to reinforce transformation into a greener and more digital economy; 3) Identify innovative existing solutions; 4) Support SMEs for adopting innovative solutions; 5) Offer technical assistance to SMEs; 6) Offer digital tools for enhanced SRI estimation.
In particular, in T2.1 an identification of the existing tools and solutions in the field of energy-efficient buildings will take place. Ideas and concepts that have already been presented in several other projects, and have managed to further demonstrate parts or combinations of the above in real-life pilots will be investigated. In T2.2 business process innovations will be introduced in order to support SMEs to adopt the innovative solutions that were identified in T2.1. During this task, there will take place recommendations and support to SMEs for getting familiar with the innovative tools that are relevant to the building sector and include them in their business process in order to involve also new systems and methods for improving organizational performance. Finally, Task 2.3 will provide customized support through the offering of technical assistance to SMEs and industries for adopting the new proposed solutions (including the SRI assessment innovative digital tool, and other relevant digital tools for answering building stock actors' needs in terms of efficient construction planning, operational energy performance monitoring and management, flexibility utilization etc. Moreover, there will take place some networking and best practices exchange events in all the participating countries (at least one per country, Greece, Latvia, and Spain).

1.2 Structure of the Deliverable

The deliverable D2.1 New-to-firm products and/or services in the industrial ecosystem/s is structured according to the following sections.

- Section 1 contains the introduction of the deliverable, the structure and the objectives of the deliverable and the innovation that work package two offers on behalf of the project SUSTAIN.
- Section 2 outlines a list of existing tools and solution from construction of energy efficient buildings.
- Section 3 underlines the conclusion of the Deliverable.

2. An identification list of existing tools and solutions from construction of energy efficient buildings

In this section a list of exiting tools and solutions in the field of energy efficient buildings is described. The information is organized in the following tables for 9 main categories of tools based on BIM, 3D printing tools, 3D scanning tools, Augmented reality tools, IoT tools, energy monitoring tools, data management and collection tools and tools based on robotics. At the last subsection, tools from the project EUhubs4Data are presented in detail.

New technologies are drastically changing the world of construction and the way professionals and businesses work, bringing about what is commonly known as the digital transformation of the building.
Among the most advanced technologies already available in the construction industry are the following.

2.1 Tools based on BIM

BIM software – the use of BIM offers better interdisciplinary collaboration based on the 3D model. Every professional can add their piece to the same model instead of splitting it into multiple versions of a 2D drawing. This way, the model evolves gradually, streamlining the process and increasing efficiency. BIM also aids in troubleshooting the design and planning stages of a project by automating interference detection and providing a complete picture of the project.

BIM is one of the most powerful digital tools that benefit every stage of a building's life cycle.

Digital construction can take many forms:

- simple tools that simplify communication and reduce the need to travel (messaging or video conferencing tools);
- automation of production processes;
- cloud-based computing and storage systems;
- software applications for use in both delivery and facility management.

More advanced technologies accompany these processes:

- unmanned aerial vehicles for scanning or job site inspections;
- 3D and 4D printing;
- robotics and artificial intelligence (AI).

The combination of all these new technologies falls into the broad category of digital construction. In the construction sector, digital technologies have also enabled new ways of working, especially in the BIM field, with the facilitation of a highly collaborative approach.

In the first category (BIM tools) six BIM sub tools are included and some examples of their implementation in business cases are described.

Table 1. Tools based on BIM

No.	Name of the tool	Category	Application of innovation	Business cases	Description of impact
1.1	BIM	Digitalisation	BIM is the foundation of digital transformation in the architecture, engineering,	BIM is actively used in EU construction market. Companies from questionnaire using BIM: MB Betons (Latvia) www.mbbetons.lc	Building Information Modelling (BIM) is a concept which has arisen to address the management and interoperability of the data exchanged between different computer aided tools employed at different stages the

			and construction (AEC) industry [6]	SIA Arcers (Latvia) www.arcers.lv SIA JEO (Latvia) https://www.joe-latvija.lv	BLC, including design, construction, commissioning, operation, refurbishment and demolition. BIM therefore plays a key role in all aspects of energy management across the BLC (Building Life Cycle). It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations.[7]
1.2	BIM-Speed.	Digitalisation	BIM-SPEED aims to address this challenge by developing a combination of methodologies and tools with one central information source at its core: the Building Information Model (BIM), a digital representation of a building. This model will be the catalyst for a smarter, more efficient, method of deep renovation for the residential building sector**.**	Malko Tarnovo, Bulgaria. During the BIM-SPEED project will be demonstrated new tools supporting the as-built data acquisition, the energy behaviour of the building, and will be approached new solutions for exterior renovation of buildings with façade's walls by prefabricated elements by reinforced concrete. More in reference link.[8]	40% - of the annual energy consumption and 36% of annual CO_2 emissions can be attributed to buildings.
1.3	Encore-BIM Cloud Platform	Digitalisation	Providing effective and affordable BIM tools that cover the whole renovation life-cycle (from data collection to project execution, and commissioning /delivery).[9]	BIM Equity is full BIM consultancy company focusing on providing the best BIM services to the Danish and International market. LAURENTIA TECHNOLOGIES is a technology-based start-up founded in 2014 that provides	From the software industry perspective, given that renovation projects account for 57% of all construction activity, creating a specific solution that supports and accelerates the overall buildings renovation process, and obtains effective energy savings.**[9]**

[6] Cordis,https://cordis.europa.eu/project/id/637162
[7] ECSO (2019), Supporting the digitalisation of construction and SMEs.
[8] BIM Speed , https://www.bim-speed.eu/en/demonstration-cases#1
[9] Encore, https://encorebim.eu/about/

				services in two separate areas: nanotechnology and BIM technology.[9]	
1.4	BIM4EEB	Digitalisation	BIM based fast toolkit for efficient renovation of residential buildngs[10]	Finland: The Finnish demonstration site has two main renovation objectives. The primary objective is an energy upgrade. BIM4EEB tools will be used to compare different upgrade options, such as heat recovery, geothermal heating, and demand-based ventilation. The secondary objective is to ensure a good indoor climate. The climate will be controlled by various sensors, like temperature, CO_2 and humidity sensors.[10]	BIM4EEB targets the reduction of least 20% of renovation time, 15% the average renovation cost, 10% of net primary energy use for a typical residential apartment and a reduction from 3 to 1.5 working days required for a deep energy audit.[10]
1.5	Bimmer	Digitalisation	Design and develop an ICT-enabled Renovation 4.0 toolkit comprising tools for Architecture, Engineering & Construction (AEC)[11]	Multi-family Residential Building. The main objective of the renovation measures that will take place, is an improvement of the energy class, from G to C. And other projects[11]	Reduction of the renovation working time of at least 15-20% compared to current practices with the baseline defined in the proposal. Acceleration of the market uptake across Europe, by speeding-up industrial exploitation, in particular amongst constructing/ renovations companies with a target of 50% of their renovation business based on BIM.[11]
1.6	BIM4Ren	Digitalisation	BIM4REN is developing a set of easy-to-use tools & services in the same common Open Environment for an agile, adaptable and fast renovation	• Paris: Residential (Social Housing). Scan2BIM with Snapkin for Geometry Adquisition • San Sebastian: Residential (Private)HeatP	Through a single entry point, the BIM4Ren One Stop Access Platform (OSAP), users will have access to innovative tools to guide them in the creation of a renovation project.[12]

[10] Bim4ee, bhttps://www.bim4eeb-project.eu/demo-cases.html
[11] Bimerr, https://bimerr.eu

			process that can be used in real, everyday projects.[12]	URE / FDD HVAC Characteristics. And other.[12]	
1.7	Arise	Digitalisation	Project supports the upskilling of the design and construction professionals on the topics of energy efficient buildings and BIM processes.[13]	Abruzzo Region Alliance Villes Emploi Balance & Result and more.[13]	ARISE's global goal is to revolutionize the learning process by changing both delivery and recognition of sustainable energy skills in the construction sector. The new system of training and recognition of skills will be valid across the EU, thus increasing the spread of skilled workforce in the building market.[13]
1.9	BEMServer	BEMS	Enables building stakeholders to construct a flexible and secure BEMS using an open-source platform.	https://www.bemserver.org/	Building managers are able to install apps that address their particular needs because of BEMServer's ability to distribute services.

2.2 Tools based on 3D Printing

3D printing as a construction technology can potentially change the sourcing of materials. For prefabrication, materials for a project can be printed, transported to the construction site, and immediately ready for use. This allows you to obtain materials quickly and simplify the building process. 3D printing will enable materials to be printed directly on-site, reducing waste and further saving on transport and storage costs;

In the second category, 3D printing tools are described in terms of their applications in the construction sector.

Table 2. Tools based on 3D printing

No.	Name	Category	Application of Innovation	Business cases	Description of impact
2.1	3D Printing	Digitalisation	Additive manufacturing (hereinafter, 3D Printing) is the process of creating an object by adding layers of material (e.g. plastic, metal or concrete) upon	Pilot projects on the use of 3D printing for an entire building have taken place (e.g. ETH in Zurich, Switzerland) , 3D-printed pedestrian bridge in Madrid, Spain) [14]	The role of 3D Printing occurs primarily in the construction phase, contributing to an overall construction cost reduction by using more time-efficient and material-efficient machines [15], thus also reducing the final amount of construction waste,

[12] Bim4ren, https://bim4ren.eu
[13] Arise, https://www.ariseproject.eu/
[15] Construction Review Online. 7 Advantages of using a 3D printer in construction projects. https://constructionreviewonline.com/2020/04/7- advantages-of-using-a-3d-printer-in-construction-projects/

			one another under the control of a computer using a Computer-Aided Design (CAD) or BIM file to guide the 3D printer's nozzle[14].		particularly if used to produce modular elements. 3D- printed elements benefit from the characteristics of the material they are built from and are proven to be more durable, thanks to the way materials are produced and assembled[16].
2.2	3D construction printing (3DCP)	Digitalisation	3D construction printing (3DCP) - relies on extrusion of cement-based composites – whether this is a mortar with fine aggregates or concrete with large aggregates.	PERI builds the first 3D-printed residental building in Germany [17]	With 3DCP, the printing process can be configured to minimize material usage. By cutting down the need for raw materials, 3DCP can significantly reduce the large environmental footprint associated with construction activities and concrete fabrication.[18]

- In the third category, 3D scanning and some of its applications in the construction sector are presented. In the fourth category, some augmented reality sub tools are described.
- In the fifth category the digital twins applications and sub tools are summarized
- In the sixth category the drone technologies and tools used in construction are presented.

2.3 Tools based on 3D Scanning

Table 3. Tools based on 3D Scanning

No.	Name	Category	Application of Innovation	Business cases	Description of impact
3.1	3D Scanning	Digitalisation	3D scanning is the process of creating a 3D model of a real-world object or building by scanning it from all possible angles.	3D Scanning to preserve Europe's wooden built heritage[19] Italian start-up Gexcel, in cooperation with the European JRC, has developed a backpack equipped with a 3D scanner for rapid mapping of indoor and outdoor	Depending on the 3D scanner used (i.e. if it is equipped with a GPS device), the data points gathered can also include topographic data of the scanned buildings. This process can be used in the construction sector to create 3D models of existing buildings and infrastructures for which there is no digital information. The 3D data

[14]Construction Review Online. 7 Advantages of using a 3D printer in construction projects. https://constructionreviewonline.com/2020/04/7- advantages-of-using-a-3d-printer-in-construction-projects/
[16] Giatec Scientific. How 3D Printing has transformed the Construction Industry. https://www.giatecscientific.com/education/8-ways-that-3d- printing-has-transformed-the-construction-industry/
[17] Peri group. https://www.peri.com/en/company/press-releases/peri-builds-the-first-3d-printed-residential-building-in-germany.html
[18] G. De Schutter, K. Lesage, V. Mechtcherine, V.N. Nerella, G. Habert, I. Agusti-Juan Vision of 3D printing with concrete — technical, economic and environmental potentials Cem. Concr. Res., SI : Digital concrete, 112 (2018), pp. 25-36,
[19] European Commission. Preserving Wooden Heritage. Methods for monitoring wooden structures: 3D laser scanner survey and application of BIM systems on point cloud models. https://cordis.europa.eu/project/id/746215

				sites [20] COWI has developed a 3D-scanner that can create 3D models of existing infrastructure such as tunnels. 3D scanners were used for the renovation of social housing in the Netherlands (Energiesprong project). This allowed producing 3D drawings of the existing buildings which were used later for the prefabrication of the renovation kits.[21]	captured by the scanners is then incorporated in BIM models or Digital Twins for further elaboration and use with the information already available. [22]
3.2	Digital Deconstruction (DDC) - 3D Scanning tool solution	Digitalisation	By linking the digital system to innovative Building Information Model techniques, a cycle is created between design, construction and demolition. Scarce resources are reused in this way and will drastically reduce the huge CO2 emissions of the construction industry.	3D scanning Hof Ter Laken (B) before demolition works 3D scanning Vilogia (Fr)[23]	The project aims to develop an innovative digital decision support system, integrating various digital tools (3D scanning, Building Information Modelling, a digital materials & buildings database, blockchain technology) that helps to define the most sustainable and economical deconstruction and reuse strategy for building.

2.4 Tools based on Augmented Reality

Artificial intelligence (AI) can help improve the construction sector at all stages, from planning to work on site. The first real-world applications of AI in the construction industry have demonstrated the potential to increase labor productivity by up to 40% while saving more than 10% of the budget. For example, machine learning is used at the

[20] Gexcel. HERON. https://gexcel.it/en/solutions/heron-mobile-mapping
[21] COWI (2018), 3D models of infrastructure will soon be a prerequisite for maintenance work. https://www.cowi.com/insights/3d-models-of-infrastructure-will-soon-be-a-prerequisite-for-maintenance-work
[22] Li, L.; Xiangyan, C.; He, Q.; Sun, J.; Jia, B.; Dong, X. (2019). A new 3D laser-scanning and GPS combined measurement system. Comptes Rendus Geoscience 351(7): 508-516.
[23] NWE Europe. https://www.nweurope.eu/projects/project-search/digital-deconstruction/#tab-4

design stage to identify potential interferences related to design variations. In this regard, software has been developed that can perform automatic compliance checks of all kinds of rules and interferences without direct human control. On the other hand, deep learning can be used during the construction phase to predict cost overruns based on factors such as project size, contract type, and the skill level of project managers. Additionally, AI can be used to assess structural damage or monitor structural health.

Table 4. Tools based on Augmented Reality

No.	Name	Category	Application of Innovation	Business cases	Description of impact
4.1	Augmented reality	Digitalisation	Virtual and Augmented Reality (VR/AR) is a technological innovation that incorporates virtual elements into real surroundings or directly by visualising the whole environment.	EU-funded CSETIR acronym for Construction Safety with Education and Training using Immersive Reality.[24]	VR/AR in construction makes it possible to combine digital architectural models with the physical reality of a construction site, or to directly visualise the final outcome of a project even before construction works have started. [25] In the construction sector, VR/AR can be used to simulate real world situations and scenarios, and, consequently, it has a wide range of applications in several phases of a building lifecycle, in particular in the design, planning, construction, and management phases.[26]
4.2	Augmented reality - Artwin solution	Digitalisation	ARtwin is set on providing the European Industry and Construction 4.0 ecosystem with a sovereign ARCloud platform that meets their ever-growing needs for increased productivity, improved product quality as well as reduced time and cost.[27]	Pilots in the SIEMENS factories and an EIFFAGE construction sites.[28]	Artwin provides an accurate and robust 3D registration for any AR device in large-scale and dynamic environments, reduction of the difference between the physical and digital world by continuously maintaining the Digital Twin/BIM model based on vision sensors available in the factory or on construction sites and display of complex 3D augmentations on any AR device by remotely rendering them in the cloud with ultra-low-latency. [28]
4.3	IsZEB assistAR	Augmented Reality	Integrated support system	https://iszeb.gr/isZEB-hub	IsZEB assistAR help technicians/engineers, by

[24] CSETIR. http://csetir.civil.auth.gr/
[25] ESub Construction Software, 7 uses in 2020 for Augmented reality in Construction. https://esub.com/blog/7-uses-in-2020-for-augmented-reality- in-construction/
[26] European Commission, JRC Science for Policy Report.
[27] Artwin, https://artwin-project.eu/index.php/concept-objectives/
[28] Cordis. https://cordis.europa.eu/project/id/856994/reporting

			for technicians with Augmented Reality technologies, for more efficient work execution.		using Augmented Reality technologies for on-site assistance in performing tasks with kinematic visual instructions directly on the physical object of the task.

2.5 Tools based on IoT

The new era of digitalization creates new opportunities to boost energy efficiency in the built environment, as well as human health and productivity. One of these prospects to lower energy needs and meet sustainable development objectives is the Internet of Things.

Table 5. Tools based on IoT

No.	Name	Category	Application of Innovation	Business cases	Description of impact
5.1	IoT	Digitalisation	Internet of Things (IoT) is the concept of connecting to the internet household appliances, devices, sensors, vehicles, etc. thus allowing for communication, remote control, exchange of data, etc.	IoT is an emerging technology in the construction sector and its application is still primarily in the R&D phase (i.e. it is not industrialized yet. IoT has a low adoption rate in the EU when compared to, for example, the USA, with only around one-fourth (26%)[29] of European companies starting to use this technology, against a 40% average in the USA. https://digital-strategy.ec.europa.eu/en/policies/internet-things-policy	During the construction phase, IoT can be used by project managers and site supervisors to monitor workers' safety by using a system of connected sensors to ensure that they are not exposed to hazardous substances or to situations of physical danger [30]
5.2	domOS	Digitalisation	Provides open, secure, multi-service Internet of Things (IoT) ecosystem for smart buildings.[31]	EDF Energy Neogrid tech. Oiken[31]	Improving the energy efficiency of existing buildings can and should be achieved through deep renovation. In comparison, smart technologies can increase the efficiency and flexibility of buildings in a shorter term

[29] European Investment Bank (2019). Investment Survey 2019
[30] Allerin (2019). Transforming the Construction industry with IoT. https://www.allerin.com/blog/transforming-the-construction-industry-with-iot
[31] Domos, https://www.domos-project.eu

					and with much fewer investments.[31]
5.3	BEYOND H2020	Digitalisation	BEYOND H2020 project is a reference big data platform implementation and AI analytics toolkit toward innovative data sharing-driven energy service ecosystems for the building sector and beyond.[32]	BEYOND H2020 project is a reference big data platform implementation and AI analytics toolkit toward innovative data sharing-driven energy service ecosystems for the building sector and beyond.[32]	Soution develops and offers a big data platform and a set of technologies that allow a data consumer to search, find and utilize data generated by buildings (data owners).[32]
5.4	BIGG	Digitalisation	Application of big data technologies and data analytic techniques for the complete buildings life-cycle of more than 4000 buildings in 6 large-scale pilot test-beds.[32]	CSTB Cordia domX[32] and more in homepage.	Significant and measurable contribution to standardisation of European buildings data.[32]
5.5	InterConnect	Digitalisation	Gathers 50 European entities to develop and demonstrate advanced solutions for connecting and converging digital homes and buildings with the electricity sector.[33]	Greece: 200 houses equipped with real-time power meters. Convert 70 households into smart-homes by equipping them with advanced end-to-end technological solutions offered by GRIDNET (50 houses) and COSMOTE (20 houses), including IoT gateways, sensors and power meters.[33]	InterConnect will allow a digitalization of homes, buildings and electric grids based on an Internet of Things (IoT) architecture.[33]
5.6	Sato	Digitalisation	Cloud-based platform that can perform self-assessment and optimization of energy-consuming devices in a building.[34]	The project includes eight pilots in three climate regions.	Integrated cloud-based data management and computing platform to control IoT devices at the building level.SRI-based building smartness assessment and user engagement.

[32] Beyond, https://beyond-h2020.eu
[33]InterConnect https://interconnectproject.eu/about/
[34] Sato Project, https://www.sato-project.eu

2.6 Tools based on Energy Monitoring

In order to optimize savings and take energy management decisions, tools related to energy monitoring give consumers information about their use habits.

Table 6. Tools based on energy monitoring

No.	Name	Category	Application of Innovation	Business cases	Description of impact
6.1	Build in wood	Construction	Optimized and cost-effective wood construction methods	The city of Copenhagen is officially one of seven Early Adopter Cities of the Build-in-Wood project[35]	Developing a sustainable and innovative wood value chain for the construction of multi-storey wood buildings.[35]
6.2	Re4	Construction	Prefabricated energy-efficient building.	http://www.re4.eu/partners Used: https://www.acciona.com https://www.creaghconcrete.co.uk	The overarching purpose is to develop an RE4-prefabricated energy-efficient building concept that can be easily assembled and disassembled for future reuse, containing up to 65% in weight of recycled materials from CDW (ranging from 50% for the medium replacement of the mineral fraction, up to 65% for insulating panels and concrete products with medium mineral replacement coupled with the geopolymer binder). The reusable structures will range from 15-20% for existing buildings to 80-90% for the RE4-prefabricated building concept.
6.3	RES4BUILD	Renewable Energies	Decarbonising the energy consumption in buildings by developing integrated renewable energy-based solutions that are tailored to the needs and requirements of users and installers.[36]	MartiniPlaza in Groningen is amongst the top event centres in the Netherlands with a large theatre, exhibition space, basketball arena, conference rooms and more. RES4BUILD is collaborating with the MartiniPlaza and its	

[35] Build in wood . https://www.build-in-wood.eu
[36] Res4build , https://res4build.eu

				stakeholders, including the Municipality of Groningen, on a long-term vision for the complex aiming at net-zero emissions, as well as a short-term package to achieve low-emission objectives.[36]	
6.4	Dreeam	Technology packages	Multi-building renovation solution	Within the replication programme, BaxCo has supported the municipal housing management company in Jelgava, Latvia to develop the organizations' long-term investment planning approach. Similar in Riga and other EU cities. [37]	The project demonstrates a multi-building and single owner renovation approach that can achieve a 75% reduction of total energy demand.[37]
6.5	Gelclad	Production	Production of innovative facade systems/panels based on nanoinsulation in eco-innovative skin frame.[38]	Partners : JUB.eu https://www.activeaerogels.com/corporate/about-us/	The foreseen impacts of the novel GELCLAD will be 20% lower embodied energy and carbon than traditional oil-based panels, attain more than 40% reduction of energy savings due to GELCLAD refurbishment, reduce costs of 40% over traditional façade thanks to single panel systems, less installation and maintenance expenses while providing functional building envelope solutions for a life span over 50 years.[39]
6.6	Iceberg	Digitalisation	Circular economy in the building industry through the development of innovative circular reverse	Solutions demonstrated (at TRL7) through 6 case studies across different	Circular value chain: from end-of-life building materials (EBM) to new building products prepared for circularity, resource-efficiency and containing 30wt% to 100wt%

[37] Dreeam, https://dreeam.eu
[38] Gelclad. https://www.gelclad.eu
[39]Corbis EU. https://cordis.europa.eu/project/id/723425

			logistics' tools and high-value secondary raw materials production technologies.[40]	locations in Europe (Finland, The Netherlands, Belgium, UK, Spain/France and Turkey)	of high-purity (>92%) recycled content.
6.7	IsZEB hub	Informative platform	Contains three innovative services, IsZEB Certify, IsZEB Charge and IsZEb ARassist	https://iszeb.gr/isZEB-hub	All-in-One informative platform: IsZEB tools cover a variety of sectors Personalized solutions: most suitable services according to business needs.
6.7.1	IsZEB Certify	Software Package	An innovative software package issuing certificates based on European & Greek standards and methodologies	https://iszeb.gr/iszeb-certify	IsZEB Certify offers an easy to use and friendly design environment. EPCs issuance accompanied with a complete technical report, including calculations, plans, results' diagrammatic presentation and benchmarking analysis of buildings' energy performance between the current situation and the proposed improvement scenarios. It also supports the use of information from BIM models.
6.8	Be-plato	Investments optimizer	Analyzes your investments and Renewable Energy System installation projects.	https://re-cognition-project.eu/2020/11/05/be-plato-building-energy-plant-planning-tool/	Utilizing this green technology would assist decrease reliance on fossil fuels and enhance the use of renewable energy sources, which would minimize emissions of CO_2.
6.10	Smart-Ready-Go!@	SRI	A web tool for evaluating the SRI of buildings.	https://www.euphyia-tech.com/	The tool aims to grow into a well-know application for the evaluation of a building's intelligence.

2.7 Tools based on Data Management and Collection

Applications for data management and collection – using applications directly on tablets and smartphones allows for excellent real-time communication and the ability to work from anywhere. In particular, data collection apps help professionals and companies to collect data directly on-site faster and more accurately. Integrating this type of technology into current processes is simple. It requires a minimal initial investment while offering essential benefits, including significant time savings and reduction of data entry errors, improved workflows, use of any digital device, and safety. Data collection apps can facilitate everything from daily equipment inspections to incident reporting to a comprehensive workplace safety analysis;

[40] Iceberg, https://iceberg-project.eu

Table 7. Tools based on data management and collection

No.	Name	Category	Application of Innovation	Business cases	Description of impact
7.1	Digital Twins	Digitalisation	A Digital Twin is the real-time digital representation of the physical building or infrastructure[41]	https://sphere-project.eu Better scheduling forecast by 20%; Better allocation of resources and optimization of equipment usage; Reduced number of accidents on construction sites; Reduction of costs on constructions projects by 20%.[42] Technology uses cases: Port of Antwerp, Belgium.[43] 3D-Printed bridge, the Netherlands.[44]	A Digital Twin provides construction companies with real-time data on the development of their assets, devices and products during creation and also enables predictions on workforce, material and costs. With Digital Twins companies can avoid over-allocation and proactively predict resource needs on construction sites, thus avoiding the need to move resources over long distances and improving time management[45]
7.2	Digital Twins - Sphere Project	Digitalisation	Solution adapt the innovative Integrated design and delivery solutions (IDDS) as a general implementation framework to be more inclusive by incorporating the knowledge of the operational stakeholders based on the experience gathered by the future Digital Twins Environments.[46]	Finland- Large factory building in Joensuu region in Eastern Finland, including factory and office spaces. ITALY-The demo site is located in San Salvo (Abruzzo region) is under renovation.[46]	Implementation will provide advanced technology to improve, and drastically reduce, the time and costs needed to assess, design, manage the construction process, etc.[46]
7.3	Digital Twins - Cogito solution	Digitalisation	COGITO project introduces a real-time digital representation (twin) of a construction project, using methods to ensure	Metro Network Extension (Copenhagen-Denmark)- Copenhagen Metro Network Extension as the first real validation site for full experimentation with	COGITO aims to materialise the digitalisation benefits for the construction industry by harmonising Digital Twins with the Building Information Model concept and to establish a digital Construction 4.0 tool-box.[47]

[41] LIST, Digital Twin. https://www.list.lu/en/institute/strategic-priorities/digital-twin/
[42] Cordis. https://cordis.europa.eu/programme/id/H2020_LC-EEB-08-2020
[43] Port of Antwerp. www.portofantwerp.com/en/
[44] Industryeurope, World's first 3D printed steel bridge with Digital Twin Tech. https://industryeurope.com/world-s-first-3d-printed-steel-bridge- with-digital-twin-tech/
[45] IntellectSoft, Advance imaging Algorithms for Digital Twin Reconstruction.
[46]Sphere Project, https://sphere-project.eu

			interoperability among the different components and technologies constituting the digital twin ecosystem, following the lean construction principles[47]	the COGITO tools. High Speed Railway Station (Murcia-Spain)-The second construction project for the validation phase is the Underground Station construction and adaptation of the current railway corridor for the implementation of High-Speed services, making it compatible with the other types of traffic.[47]	

2.8 Tools based on Robotics

Table 8. Tools based on Robotics

No.	Name	Category	Application of Innovation	Business cases	Description of impact
8.1	Drones	Digitalisation	Drones are aerial vehicles equipped with high-resolution cameras and other scanning equipment.	German company h-aero has developed drones that can be used to scan, stock-take and inspect tunnels, power plants, and other sites [48] The benefits of drones in Construction[49] Drammen railway station-The map, updated each time surveyed with a drone, shows a visual timeline of data that's inarguable, leading to a significant	Drones can provide live streaming videos and photos, which can be further elaborated through dedicated software to create 3D models, for instance, for BIM use. This also allows for reality-capture solutions and real- time comparison between planned and implemented solutions[51] In the context of construction, drones are used by an increasing number of European construction companies (around 21%[52]), with the utilisation being equally distributed across large-scale companies and SMEs[53]

[47] Cogito, https://cogito-project.eu
[48] H-aero. https://h-aero.com/en/
[49] DroneDeploy, Trends Report 2018
[51] ECSO (2019). Integrating digital innovations in the construction sector.
[52] European Investment Bank (2019). Investment Survey 2019.
[53] ECSO (2019). Integrating digital innovations in the construction sector.

				reduction in disputes across the project.[50]	
8.2	Sensors	Digitalisation	Sensors are electronic devices that offer the possibility to collect data and monitor the performance of individual types of information.	Companies from questionnaire using Sensors: MB Betons (Latvia) With concrete curing sensors, its possible to speed up construction schedules. Such IoT-enabled devices provide monitoring of concrete's maturity via temperature probes and then transmit real-time data to the cloud. You have to embed the sensors in concrete during casting for tracking its curing. That allows managers to plan further construction work accurately.	Sensors can be used by architects and project managers to monitor the environment of construction sites[54] (e.g. humidity level, presence of gasses, etc.) and detect local variations in material strength or work integrity, as well as to keep monitoring the buildings once they have been completed (e.g. long-term health of concrete). Sensors are also being increasingly integrated onto heritage sites or infrastructure, such as bridges, and used to monitor their conditions, in order to undertake timely interventions as soon as a potential issue is detected or foreseen.
8.3	Robotics	Digitalisation	The scope of robotics in construction is broad, encompassing the majority of the stages of construction, from initial construction to its operation and maintenance, to the eventual dismantling and recycling.	Exoskeletons are expected to have the fastest increase is their development compared to other technologies. Hephaestus ,EU Project: https://www.hephaestus-project.eu have developed a cable-driven robot as part of the project. A prototype is being tested in central Spain.	Robots are devices that execute specific operations (i.e. lay tiles, lift objects, etc.), either autonomously (i.e. under pre-determined reiterative instructions) or under an operator's direct control. The use of robots on construction sites is still very limited, and the market adoption is at the infancy stage, but the robotics production market is predicted to grow steadily over the next few years.
8.4	Robotics - Bots2rec	Digitalisation	Automated removal of asbestos contamination.	Bots2rec EU project -automated removal of asbestos contamination.[55]	Asbestos (a naturally occurring mineral forming thin fibrous crystals) was widely used for construction materials, due to its beneficial physical properties

[50] Construction Technology https://www.constructiontechnology.media/news/construction-surveying-new-software-and-drones/8018399.article
[54] Constructionblog (2020). Sensors in Construction. https://constructionblog.autodesk.com/sensors-in-construction/
[55] Bots2rec , https://www.bots2rec.eu

					and low price. Today, asbestos dust is known to be hazardous for humans and for this reason millions of flats and buildings have to be refurbished to remove the hazardous asbestos. A task which is putting humans at danger and is very inefficient without robotic solutions.[55]

2.9 Tools based on Smart Applications

Applications are considered “smart” when data-driven, practical insights are included into the user experience. Insights are presented in apps as features that help users carry out desired actions or tasks more effectively.

Table 9. Tools based on Smart Applications

9.1	IsZEB Charge	e-mobility	IsZEB Charge is an integrated solution that combines the conversion of electrical chargers into smart interoperable units with their remote monitoring and control, via a relevant online platform or with the use of an application for smart devices.	https://iszeb.gr/iszeb-charge	With IsZEB Charge App, Electric Vehicle drivers gain access to an interactive map of the charge point locations, availability status, charge point information, pre-booking and easy payment solutions.

2.10 EUHubs4Data Tools

Within the phase of identifying the innovative tools most present on the market in Europe, research was developed starting from the information elaborated by the European Federation of data-based Innovation Centers. The EU-funded project EUHubs4Data created a European federation of data innovation hubs based on existing key players in this sector and linking with data incubators and platforms, networks of SMEs, AI communities, skills and training, and open data repositories. The European Federation of data-based Innovation Centers is now a European reference body for data-driven innovation and experimentation, fostering collaboration between data-driven initiatives in Europe, federating solutions in a global common catalog of data services and sharing data in a context cross-border and cross-sectoral. The federation is composed of relevant European initiatives experts on data-driven innovation that will support your organization in digital transformation.

The following table shows examples of innovative data-driven tool development selected to be part of the EUHubs4Data program and the SMEs behind them. These represent relevant examples of fostering data-driven cross-border innovation and experimentation in Europe. The companies that have developed the following tools represent some of the most innovative models of innovation development in the energy sector and construction applications.

Table 10. EUHubs4Data tools

No.	Name of project	Category	Application of innovation	Innovation example	Description of impact
10.1	Produtech dih, energy- and context-related dataset of a smart building	Digitalisation tool	BIM is the foundation of digital transformation in the architecture, engineering, and construction (AEC) industry	Dataset concerning 4 years of data with 10-second readings of a smart building. The data collected regards energy measurements of the building, where consumption is divided by electrical sockets, ceiling lights, and air conditioner units. The dataset includes data from a 7.5 kW peak photovoltaic installation. The dataset also includes contextual data regarding several parameters such as temperatures, presence, and lighting.	● Access to a sustainable supercomputing and BigData infrastructure ● Access to Virtual Machine resources ● Technical Support to create knowledge in data science and artificial intelligence ● Technical Support in managing and deploying data science infrastructures, development and testing of hardware, and software applied research focused in CPS and IoT
10.2	Air4s, ai & data based applications for optimisation of smart grids and smart buildings	Digitalisation tool	Data, AI & Technology, Proof-of-Concep	Access and technical support to specific own platforms based on Artificial Intelligence and data processing for the development of smart energy solutions applied to smart grids or smart buildings.	● Data-based solutions for real-time management of demand and reduction of energy consumption in smart buildings, analysis of weak points from the point of view of energy consumption and their potential to increase energy savings, create sustainable building strategies and maximize the use of local and distributed generation.
10.3	ECIPA HUB, consultancy and training for digitalisation	Building Information Modelling	BIM data, Thermographic inspection data	Local Digital Innovation Ecosystem building initiatives; Training services (Consultancy and training on Data for Energy Efficiency; Waste Traceability; Building Information Modelling;	● Online training courses about the BIM as a tool to monitor energy efficiency of a building through IoT applications for building sustainable automation ● Consultancy services, as an Energy Service Company (ESCo), for Energy Communities design and data monitoring for better performances ● Trend watching and identification of

					opportunities.
10.4	GEM-RETAIL 2.0 ADVANCED GENIUS ENERGY MANAGER FOR RETAIL SHOPS	Artificial Intelligence (AI) models and advanced analytics	integrate EUH4D's big data services in a commercial tool, that would be extensively improved to handle much larger and more heterogeneous data sources, which in turn could allows us to make a qualitative steps in our embedded AI models for the efficient management of energy consumption and environmental quality metrics.	GEM-Retail 2.0 aim at designing and developing a plug-and-play, affordable and innovative product to effectively monitor, analyze and control thousands of shops.	• objective of the GEM-Retail 2.0 project is to study, test and eventually adopt a series of big-data analysis tools, thanks to the resources offered by the EUH4D data services, to allow our product to grow in accordance with our envisaged commercial plan and effectively support two orders of magnitude more edge nodes than it currently does. • GEM-Retail 2.0 is a plug-and-play solution that allows to collect and process data related to energy and environmental KPIs, offering a new solution to reduce energy consumption, improve air quality and point out the most critical stores.

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3. Conclusions

BIM is more and more utilized in the construction sector, thanks to the important benefits it brings in terms of cost-saving, better cooperation among stakeholders, and, more generally, improved project performance.
To fulfill T2.1 we have gathered information from open resources and analyzed 32 innovative solutions for greener construction and included 15 of them in the report as the most relevant.
Innovative solutions stand for digitalization and automatization, building monitoring tools, ICT (also cloud-based solutions), renovation solutions, prefabricated element production (drywalls, foam panels), 3D printing, energy performance monitoring tools (also saving), bio-material usage, BIM and energy storage solutions. Digitalization in the construction sector can bring significant opportunities for the whole value chain not only by improving existing practices, but also by integrating disruptive technologies and tools that can lead to new processes, business models, materials, and solutions. In sum, digital technologies can help the sector build better, and tackle several issues, including labor shortages, labor productivity, waste and greenhouse gas emissions, and health and social challenges. data acquisition technologies, namely sensors, IoT, and 3D scanning, are the starting point for the digitalization of the construction sector, as they provide most of the data necessary to build and develop the digital construction ecosystem.
The analysis developed during the first part of WP2 offers a vision of the panorama of innovative tools in the European context of the construction sector. The partners involved in the work package know how fundamental it is to probe the response of the entrepreneurial fabric of each productive ecosystem involved in SUSTAIN.
In this sense, intending to deepen the topics covered in D2.1, the partners worked on a questionnaire of questions to present to companies active in the construction sector. With this questionnaire, the consortium expects to receive direct information regarding the response and the state of the art of the adoption of innovative tools by Small and Medium Enterprises (Annex A). The consortium will further elaborate on this information capital in D2.2, providing the basis for the further development of WP3.

ANNEX A: Questionnaire for adoption of innovative tools by SMEs in building construction field

Content

The data collected will be used exclusively for the project, processed and disclosed only in an integrated manner in the sector's interest.

You can indicate your interest in a more in-depth interview and a technological audit on technological innovation. Thanks for your collaboration.

QUESTIONNAIRE

Name and Surname _____ Position: _____ email: _____

SECTION 1: TECHNOLOGY AND INNOVATION

1.1 - Considering some current technological trends, which do you think are most interesting for your company? (tick one or more topics)

Digital innovation: adoption of new digital and IT tools (e.g. BIM, IFC, …) ☐

New technologies: use of new materials, new machinery, new systems that enable new processes ☐

Home automation / control / sensors ☐

New business models (activities, resources and key partners, value proposition, customers, …) ☐

Perception of value by the market: product/service quality, methodologies and processing techniques, increase in consumer awareness (e.g. constitution of an intermediary trust instrument) ☐

1.2 - On which topics/technologies is your company already active? (choose one or more options)

Energy efficiency ☐

Environmentally friendly materials and products ☐

Innovative materials and products ☐

Innovative processing techniques ☐

Tools/software for acquiring, viewing and analysing images ☐

Industry 4.0 and digitization (New equipment, machinery, technologies, …) ☐

1.3.-Could Your company specify technologies (tools and solutions) used in Your projects regarding energy-efficient buildings and renovation projects at the moment?

1.4 - What are the topics of technological innovation in the near future that you consider important for your company?

1.5 - Is your company interested in participating in working groups on the subject of technologies?

1.6 - In which areas does your company deem it appropriate to invest in the next two years? (choose one or more options)

Product or service technological innovations ☐

Personalization, efficiency, specialization ☐

New technologies applied to machinery, equipment, software ☐

Opening up to new markets ☐

Digital Transformation ☐

Business models/Communication/marketing/sales network ☐

Staff skills ☐

Other (specify):

1.7 Other comments, recommendations and experience sharing from Your company regarding tools and solutions in the field of energy efficient building industry.

1.8. Any negative experience with energy-efficient innovations? If so, please provide examples.

1.9. Can You name partners Your company cooperates with in terms of receiving innovations for energy-efficient tools and solutions?

1.10. Is there any specific legal regulations that slow down the implementation of innovations? Our opposite.

1.11 Other comments, recommendations and experience sharing from Your company regarding tools and solutions in the field of energy efficient building industry.

SECTION 2: OPERATING STRUCTURE OF THE COMPANY

2.1 - Company number of employees: ACTIVITY SECTOR Company type
2.2 - Are there members/owners under 40 in the company?
2.3 - Turnover last year:
decrease ☐
stable ☐
increase ☐

SECTION 3: RESEARCH AND DEVELOPMENT

3.1 - Does the company carry out or has it carried out in the last two years Research and Development activities on topics of technological innovation? Yes No
IF:
3.1a - Making use of internal skills (specify which: owner/partners, technical department, ...) ☐
3.1a bis - Number of internal personnel dedicated to R&D (also specify educational qualification: diploma, degree, master, doctorate...
3.1 b - Making use of external expertise (professionals, research institutions, universities, consultancy firms) ☐

3.2 - Has the company ever hired researchers?
Yes ☐
No ☐
3.3 - Does the company make use of external training institutions?

(If yes, specify training areas of the last two years)
Yes ☐
No ☐

3.4 - Does the company carry out internal training activities?
(If yes, specify training areas of the last two years)
Yes ☐
No ☐

3.5 - Has the company developed patents and/or specific industrial technologies? (If yes, specify scope)
Yes ☐
No ☐

3.6 - Has the company ever used third-party patents (universities, research centres, companies, start-ups)? (If yes, specify scope)
Yes ☐
No ☐

3.7 - Has the company ever made use of public funding for Research and Development? (If yes, specify which, e.g. MIUR, European Funds, ...)
Yes ☐
No ☐

Request/expression of interest for Technological Audit?