SIRCULAR

DELIVERABLE D3.3:

Process and Methodology Toolset WP3

Date of document

28/11/2025

Deliverable Version: **D3.3, V2.1**

Dissemination Level: Public

Deliverable Lead: Hellenic Passive House Institute

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

OVERVIEW	
Project Acronym	SIRCULAR
Project Title	Sustainable and Integrated people centRiC solUtions for buiLding decArbonisation and ciRcularity.
Project Coordinator	RINA-C
Project Duration	42 months
Deliverable Title	Process and Methodology Toolset
Deliverable No.	D3.3
Dissemination Level	**Public**
Work Package	**WP3: SIRCULAR technologies development for sustainable construction and renovation**
Deliverable Lead	Hellenic Passive House Institute (HPHI)
Lead Authors	Evgenia Melachroinou (HPHI); Mariza Gkadri (HPHI),
Main Contributor Authors	Simone Schiller (ZRSA); Margherita Fabbri (RINA-C); Marta Rivarola (RINA-C); Cristina Vaccarella (RINA-C); Jairis Arleen Alvarez Truillo (RINA-); Dimitris Pallantzas (NTUA); Natascha Steiner (KIT); Felix Dingeldein (KIT)
Other Contributors	ZRSA, KIT, RINA-C, NTUA, CARTIF
Due date	**30/11/2025**
Submission date	**28/11/2025**
Peer Reviewers	José L. Hernández García (CARTIF); Eva París Sánchez (AHC); Marta Arrufi Franch (AHC)

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Table of Contents

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Table of Tables

Table of Figures

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Abbreviations and Acronyms

Table 1 Acronyms of D3.3.

ACRONYM	DESCRIPTION
HPHI	Hellenic Passive House Institute
SME	Small-Medium Enterprises
NGO	Non-profit organization
CDW	Construction and Demolition Waste
PESTEL	Political, economic, social, technological, legal and environmental
PHPP	Passive House Package Planning
BIM	Building Information Modeling
CAD	Computer Aided Design
MEP systems	Mechanical, Electrical and Plumbing systems
BPS	Building Performance Simulation
DHW	Domestic Hot Water
MVHR	Mechanical Ventilation with Heat Recovery
IDF	Intermediate Data Format
EDA	Electronic Design Automation
TFA	Treated Floor Area
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
DGNB	German Sustainable Building Council
NURBS	Non-Uniform Rational B-Splines
IDA ICE	IDA Indoor Climate and Energy
DXF/DWG	Drawing Exchange Format/ Drawing
IoT	Internet of Things

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Disclaimer

Funded by the European Union. The content of this deliverable reflects the authors' views. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Background: About the SIRCULAR project

SIRCULAR is coordinated by RINA-C and combines the expertise of 22 partners from six European countries, including universities, SMEs, NGOs, and industries. During the next three-and-a-half-years, SIRCULAR will transform the building sector into a circular and sustainable industry, aligned with the Built4People partnership principles.

We will test and demonstrate innovative technologies and services across four regional clusters: initially in Estonia and Spain, followed by Germany and Greece. These clusters will engage construction companies, housing companies, universities, and local administrative entities, focusing on buildings owned or occupied by vulnerable population groups, in line with the SIRCULAR just and affordable transition approach.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Executive Summary

The SIRCULAR D3.3 deliverable presents the context, challenges, methodology, and implications of developing the ArchBuilder tool, which is focusing on bridging the gap between design and construction, while elevating circularity and accelerating buildings decarbonization. The report's core aims to bridge collaboration and information gaps among design and construction stakeholders, minimizing delays, miscommunication, and inefficiencies that typically escalate project costs and environmental impacts. It draws context from stakeholder experiences—primarily in Greece but extrapolated across Europe—emphasizing the need for methodologies adaptable to various building uses, typologies, climates, and legislative frames.

In reviewing the status quo, the deliverable outlines persistent challenges such as fragmented communication, regulatory complexity, slow digital tool uptake, labour and material shortages, and construction failures observed in both Germany and Greece. Divergence between design intention and construction reality often results from poorly defined responsibilities, insufficiently integrated project management systems, and slow, multilateral information exchanges.

To address these shortcomings, the ArchBuilder methodology is introduced as a comprehensive, cyclical workflow spanning initial energy studies, material and implementation detailing, on-site supervision, quality assurance, and feedback loops. This approach strongly integrates feedback at every stage, demanding clear documentation practices, defined roles, and shared digital repositories to ensure that as-built realities match design intent. First implemented as an Excel-based platform, but able to be upgraded to an online tool with more features, the tool itself features interconnected modules for project overview, insulation, thermal bridges, airtightness, MVHR/HVAC systems, task scheduling, and stakeholder coordination. The methodology was tested and refined through cases involving new construction and renovations in Greece, each providing evidence that streamlined information flows and clarity in execution significantly improve project outcomes and manage construction costs. Every building which is not targeting to be PEB (Positive Energy Building) [1] in the cost optimal way is considered as another wasted opportunity. ArchBuilder methodology and toolset is aiming to bridge the biggest gap in construction sector which is communication and collaboration between stakeholders. Moreover, by setting specific numerical targets, the project will retain its compass, which is crucial for the final result. BIM methodology is aiming to bridge the gap between

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

designers and engineers, while ArchBuilder methodology is aiming to bridge the gap between everyone, therefore there are plenty of tools that can be incorporated to this methodology according to the project's needs.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

1. Introduction

The following deliverable is a report that analyses the involvement of design and construction stakeholders in a project and highlights the gap that occurs among them. The analysis that enabled the creation of the first version of the ArchBuilder tool during the period of February 2025 till November 2025 and involves the previous experience of the SIRUCLAR consortium. The topic revolves around the problems that occur when one or more entities are involved in the construction process for a new-built or renovated building. Having Greece as a starting point and trying to expand to a European level (by studying the challenges and the available tools in the construction sector in Germany), this document aspires to provide a general image of the current state of the construction methodology and solutions through the ArchBuilder tool. The main challenge here is to be as inclusive as possible for buildings with different uses, typology, climate and legislation framework, and integrate in the process as many of the available tools as possible that are used in the construction sector at a European level to achieve optimum energy performance. The starting point of the ArchBuilder tool is based on the Greek construction scene and aims to satisfy the needs of the European construction needs in the future.

1.1 Objectives of the Deliverable

The deliverable has the following main objectives:

- Identify the main problems among the collaboration of different partners in the construction process (energy design, implementation and construction phase).
- Inform different stakeholders involved in the different phases of the construction (energy design, implementation and construction) about the problems encountered during them, even those without specialized experience, such as owners, housing associations etc.
- Provide solutions integrated into the SIRCULAR tool aiming to minimize the delays, management and communication problems during construction; ArchBuilder's first version architecture.

The target audience of the report is people working in the design, the implementation or the construction phase of a building project or in the management of a project like this. The general

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

ambition is to minimize the loss of shared necessary information among stakeholders that is transferred as cost. The methodology described in Chapter 5 is the medium to achieve that.

1.2 Structure of the Document

The structure of the document is the following:

- Chapter 1: Contemporary challenges in the design and the construction process
- Chapter 2: Specific challenges per country
    - 2.1 Challenges in Germany
    - 2.2 Challenges in Greece
- Chapter 3: Tools in the design process
- Chapter 4: Tools in the construction process
- Chapter 5: Definition of ArchBuilder's methodology
- Chapter 6: Examples leading to the ArchBuilder methodology
    - Design phase
    - Implementation phase
    - Construction phase
- Chapter 7: Architecture of the tool

In the first chapter, the current background information revolving around the design and the construction processes and the challenges faced is presented. It is important to understand the challenges that the ArchBuilder tool aims to face.

In the second chapter, the document aims to report on the specific challenges that are faced in each country where the SIRCULAR project has a virtual demonstrator. Focus will be given on the challenges among the different collaborators of a project, the timeline and the legislative limitations that apply to each country.

In the third chapter, an analysis of the existing tools, their possibilities and their purpose in the standard followed design practices is presented, mentioning the advantages and the disadvantages of each design tool. Among the design tools are also known tools developed during other European projects, not only commercial widely used tools.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

In the fourth chapter, an analysis of the existing tools, their possibilities and their purpose in the followed standard construction practices is offered, including which are the receivers of the result of each document. In this part of the document, there are also included known tools developed during other European projects.

In the fifth chapter, the methodology which aims to be applied in the ArchBuilder tool is described. Special details will be given to the different phases of the progress of a building, the design, the implementation and the construction and how each of them are interlinked.

In the sixth chapter, a justification of the selected methodology will be provided through the presentation of different selected previous projects.

Finally, in the seventh chapter, the architecture of the ArchBuilder tool will be described based on the principles of the ArchBuilder methodology of the fifth chapter.

The contribution of each partner on the deliverable is presented in table 1.

Table 2 Contribution per partner in D3.3.

Partners	Specific contribution
HPHI	Contemporary challenges in the design and the construction process, Challenges in Greece, Digital tools for design and construction, Definition of ArchBuilder's methodology, Examples leading to the ArchBuilder methodology, Architecture of the ArchBuilder tool, Necessary Supporting material for the ArchBuilder tool
RINA-C	Digital tools for design and construction
KIT	Challenges in Germany, Digital tools for design and construction

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

ZRSA	Challenges in Germany, Digital tools for design and construction

1.3 Relation to Project Documents

There is not a direct connection between a specific deliverable of the SIRCULAR project, besides the second version of the deliverable that will be submitted on M30 of the project. However, there are observations that could add to the work of the deliverables **D6.2** Sandbox Validation and Performance Report and lessons learnt) and **D6.3** Policy innovation and certification and standardization recommendations). This document will indirectly provide suggestions for future implementations and policies that can facilitate sustainable and circular practices in the construction sector.

Furthermore, there is not a direct link to the Spanish and Estonian pilot as well. However, the methodology can be exploited as a strategy by them in Work Package 4 and therefore at the deliverables **D4.2**

Another highlight is that the ArchBuilder is not officially part of a deliverable at the SIRCULAR project. At the moment of the submission of D3.3, there is a draft version of the tool and at the time of the second submission of an initial version of the tool will be finalized. Part of the deliverable submitted in M30 will be the description of the current state of the ArchBuilder tool.

1.4 Overall Approach

This deliverable was created based on the following approach. It is a mixture of previous experience of the different partners involved and of the attempt to translate the experience into an actual tool. The structure of the deliverable starts with the observations gathered, an extended presentation of the existing tools, and proceeds with the documentation of a methodology that could face the existing pathologies. Lastly, after the methodology is well defined, the architecture of the tool that could apply it is presented.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

2. Contemporary challenges in the design and the construction process

While the construction industry continues to account for one-third of the total waste generation and, the resulting buildings, the biggest energy consumer globally, there is a heightened demand for building stock due to the global population increase [2]. To be able to achieve the UN Sustainable Development Goals, further development in the current design and construction practices are expected to optimize the construction process and building performance. To be able to reach the solution, in this chapter, the first step is to define the underlying causes of the poor building performance that are rooted in the management of the design and construction information. The ultimate goal is to provide a methodology that will be used by the ArchBuilder tool to minimize the gap between the design and the construction.

Various solutions have been developed targeting the minimization of waste that spans all stages of the project's whole life cycle. There is a wide bibliography that identifies the barriers that decelerate the minimization of waste and result in poor energy performance globally. It has also been observed that different challenges apply to different countries. At a project level, CDW has significant consequences for profitability and productivity.

Another important aspect that creates problems in the different parts of the design, the implementation and the construction, is the diffusion of the information. The usual steps include the cooperation of many different teams that must exchange studies, negotiate and collaborate to offer the desirable result. A typical team includes:

- Architecture team
- Structural team
- Energy and mechanical engineering team
- Construction team
- Inspector/Certifier team

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

These entities are tasked to follow the desires of the responsible decision maker (public or private entity) and the satisfaction of the user. In the document, for reasons of facilitation, the involved members of the project will be called “project team” and the decision makers, the “clients”. The need to meet the requirements of the project team and the client without a properly established common platform of communication, faces therefore all the aforementioned hurdles of a new construction or a renovation project, that can lead to costly modifications for the client and the environment. A common platform would enable the project team to solve all the miscommunications, update all the project members simultaneously and give the opportunity for immediate action on management issues.

A platform like this would also permit to identify gaps in overambitious designs that usually end up contradicting the budget constraints of the project in the overall picture. There could be a necessity to create implementation studies and avoid costly adjustments during the execution, since there would be the necessary time to manage more realistic early cost estimations and maintain the timeline and financial control during the project.

It is worth noting that many examples have been realized to face the issues described. Many digital tools, Building Information Modeling (BIM) and smart systems promise enhanced efficiency. However, adoption is slow due to high initial costs and resistance to change.

2.1 Chapter 2: Specific challenges per country

Different problems appear in different countries as different structures are involved during the realization of a new construction or renovation project. To be able to test the proposed methodology a description of the specific challenges will be provided for two different countries, Germany and Greece, where the two virtual demos are located.

2.1.1 Specific challenges in Germany

A significant decline in construction and issued building permits, caused by high costs and interest rates, has been creating major unrest within Germany’s construction sector in the last few years. The industry currently faces exceptional challenges, as these weaker economic conditions coincide with the urgent need to transform towards more sustainable practices reducing emissions, minimising

Co-funded by the European Union

SIRCULAR has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

waste, and optimising resource efficiency. While virtually all sectors of the economy are under pressure to decarbonise, the construction industry in Germany bears a particularly heavy environmental burden. Compared to other European countries, the building sector in Germany accounts for a disproportionately high share of total energy consumption and greenhouse gas emissions. While EU-wide the building sector accounts for 36% of CO_2 emissions [3] and 35% of waste [4], in Germany the figure reaches 40% of national emissions [5] and 55% of national waste [6]. These numbers show that the construction sector needs to catch up in Germany's efforts to mitigate climate change and protect biodiversity.

At the same time, the sector's transformation is hindered by one of the most rigid and complex regulatory frameworks in the European Union. As a consequence, planning and construction processes are often lengthy and costly. Innovative and sustainable construction methods are particularly affected by this development. Although many projects start with strong sustainability goals, these are often sacrificed as budget limitations arise. Nevertheless, there are promising developments offering new opportunities.

One such initiative is the introduction of the so-called *Building Class E*, with "E" standing for *einfach* (simple) or *experimentell* (experimental). The German DIN standardisation framework plays an important role in ensuring quality and safety in the construction sector. However, current standards often do not differentiate clearly between those ensuring essential aspects such as safety and durability, and those defining comfort features, such as increasingly high requirements for sound insulation or a large number of power outlets. While such comfort standards are not always essential to achieve a functional and high-quality building, failing to meet them has in the past exposed architects to legal liability for defective planning. As a result, building designs have become increasingly complex, further driving up costs and causing disproportionate resource consumption. The introduction of *Building Class E* could counteract this development by offering clients an option to select a simplified regulatory framework as the contractual basis for their projects. Unfortunately, the formal adoption of *Building Class E* could not be completed as planned during the last legislative period due to early federal elections, but the preparatory steps taken have laid a solid groundwork for its forthcoming adoption.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

The challenges outlined above apply not only to new construction but also, and perhaps even more urgently, to existing buildings. The existing building stock currently represents the greatest environmental burden in the construction sector: a low renovation rate and a large number of poorly insulated buildings contribute significantly to emissions. At the same time, existing buildings represent an immense resource and opportunity. In 2022, nearly 2 million apartments in Germany stood vacant [6]. While not all of these are currently ready for immediate use - and factors such as urban-rural dynamics and demographic developments must be considered - this high number nonetheless highlights the potential of the existing building stock. Through innovative approaches, repurposing and retrofitting can make a significant contribution to the transformation of the construction sector. By making better use of these structures, the construction demand (currently estimated at 320.000 housing units alone per year [6]) could be significantly reduced, along with the associated emissions.

Furthermore, with approximately 52 billion tons of materials embedded in existing buildings in Germany [7], the building stock represents a substantial reservoir not only for housing but also for material resources. The vast majority of the anthropogenic stock is attributed to the construction sector. Alone, 55 percent of the stock is contained in residential and non-residential buildings [7]. This anthropogenic stock includes valuable materials such as metals, minerals, timber, and other reusable components. To fully exploit this potential, new processes and routines must be established to efficiently recover and reuse these resources rather than directing them to waste.

While several pilot projects are already underway, circular construction still needs to be significantly scaled up to demonstrate the reuse of reclaimed materials in both renovations and new construction, and to fully realise its potential. The urgency of this transition becomes evident when considering that approximately 10 million tonnes of reclaimed wood are currently incinerated annually in Germany, releasing around 15 million tonnes of CO_2 instead of being reused [8], a clear indication of untapped potential within the existing material cycle. Scaling up circular construction will demand collaboration across building authorities, industry and research, establishing approaches for material reuse and driving the transition to a circular building economy.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

2.1.2 Specific challenges in Greece

The biggest challenge in Greece regarding building's energy efficiency and thermal comfort is the absence of numbers. Energy Performance Certificates are issued in letters (A, B, C etc.), but the majority are misleading. This is the result of inevitable divergences from the original study and no systematic post-construction verification In many cases, there is no systematic post-construction verification. The EPC reflects the study and not the reality. There is a huge lack in monitoring crucial indicators, such as temperature, relative humidity, CO_2 concentration and consumption. During the construction/renovation there is not even a single numerical test for the building (i.e., blower door test, infrared imaging etc.). A recent study in Cyprus (with a directly analogous legislative framework and climate to Greece), found deviations of up to 377% in the cooling energy measured versus calculated, underlining the lack of validity of the 'letter' grade certificates as a real proxy for performance [9].

This leads to a bigger challenge, which is the differentiation between the working groups, such as Architects, Civil Engineers, Technicians, etc., who are "forced" by the lack of guidance by the system, to act independently without any interest about the next steps of the project (design to selection of materials to construction). Consequently, all the above are causing significant issues on the final "product" which is the building. The Greek construction system has historically been characterized by weak institutional frameworks, low digitalization, and a lack of centralized technical guidance. The sector is mostly consisted by small and medium-sized enterprises, which often lack the resources to invest in coordinated project management systems. The absence of a unified system for technical specifications and pricing, as well as the slow implementation of digital tools like Building Information Modelling (BIM), further hinders effective collaboration among professionals [10].

Subsidy programs funded by EU for building renovation do not have a clear scope and often prioritise quantity over quality, by minimising funding per m^2 and maximizing building units [11]. This leads to soft renovation measures, without targeting specific goals, which often leads to problem creation than problem solving. When windows are replaced with more energy-efficient and airtight models through subsidized programs, but the building lacks adequate ventilation, moisture can accumulate. This insufficient airflow often leads to condensation and mold growth inside the building, posing health risks and damaging the structure. Proper ventilation must be ensured to prevent these problems when

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

upgrading windows. This reflects the essential cause-effect relationship clearly and emphasizes the importance of a holistic approach in building construction/renovation such as Passivhaus.

Simultaneously, the rapid expansion of construction activity, after the pandemic recovery, has significantly affected the labor shortages. Large-scale projects including the Hellinikon redevelopment, Europe's largest development project [12] and other major infrastructure initiatives have identified labor shortages as a principal limiting factor in project delivery timelines and cost control. The shortage of skilled personnel is compounded by demographic trends, with many workers who departed Greece during the financial crisis remaining abroad [13]. As a result, Greece presents an inability to ensure adequate training and retention of qualified personnel, directly limiting the implementation of large-scale retrofit and renovation programmes that are essential for meeting climate and housing objectives.

Although the ArchBuilder methodology does not have immediate connection to the CDW, proper communication and reporting can help track the waste or reduce it. Greece faces challenges in adopting circular economy principles within its construction sector while dealing with a vacant building crisis. These issues highlight systemic inefficiencies in resource management, regulatory enforcement, and urban planning that require comprehensive solutions. Limited pre-demolition audits and enforcement gaps worsen progress [14]. Skilled labor shortages make even more difficult circular practice adoption. Integrated policy measures such as landfill taxes and incentives for reuse and green procurement are vital [15].

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

3. Tools in the design process

To accelerate the transformation of the construction sector, planners increasingly rely on advanced design tools to support the complex processes involved. Currently, several software programs serve this purpose. In this chapter, an analysis of the available tools used for building energy modeling will be presented. This analysis aims to describe the available design tools to highlight the results and the interconnections among various software used, which the Arch Builder methodology and tool users should keep in mind.

The selection of the programs is based on the usage of them during the existing processes in the design. Among them are the following.

- 3D modeling programs
- Passive House Package Planning (PHPP)
- DesignPH
- EnergyPlus
- IDA ICE
- HONEYBEE

3.1 3D modeling programs

Among the relatively recent technological advancements is the introduction of Building Information Modeling (BIM) and 3D modeling software for construction. The digital transformation has enabled a more efficient construction lifecycle by increasing the speed of the design process and the visualization of the result. In general, 3D modeling enables better visualization and communication, design and planning, clash detection, cost estimation, construction sequencing and scheduling, facility management, risk mitigation and stakeholder engagement.

Architectural BIM (Building Information Modelling) programs play a central role in today's design practices, as they must consolidate all available information from a growing number of disciplines and store it in a structured, accessible way. Most other tools revolve around these central BIM models. In Germany, Graphisoft's **ArchiCAD** and ComputerWorks' **Vectorworks** are widely used examples.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

To move forward with the presentation of the functionalities of specific programs, it is helpful to distinguish the differences between 3D Computer Aided Design (CAD) Modeling and BIM. They are presented in table 2.

Table 3 Difference of features between 3D CAD Modeling and BIM.

Features	3D CAD Modeling	BIM
Purpose	Creation of 3D models of objects and structures	Integration of 3D geometry with intelligent data to support the entire building lifecycle
Representation	Mostly geometric shapes and visual representation	Both geometric and non-geometric information
Collaboration	Limited collaboration with other users, usually individual designers	Enables collaboration among different stakeholders through the project lifecycle
Data integration	Visual representation with limited data integration	Possible integration of data sources with interoperability features
Life Cycle Management	Main focus design and visualization	Follows the entire building lifecycle
Change Management	Change requires manual updates	Dynamic change management
Quantities and Cost Estimation	Limited capability for automated quantity calculations and cost estimation	Ability to automate quantity take-offs, cost estimation and analysis due to embedded data in the model
Parametric Modeling	Parametric modeling for design flexibility	Extensive use of parametric modeling, allowing for intelligent, rule-based design changes
Visualization	Visualizing the physical appearance of the design	Provides enhanced visualization, including 3D walkthroughs and simulations, with added information for decision-making
Regulatory Compliance	May require separate documentation for regulatory compliance	Facilitates compliance documentation through embedded data

A few challenges remain important to highlight regarding the current usage of BIM Methodology. First, maintaining and updating BIM models requires a significant investment of time. In theory, this effort is offset later through the efficient generation of results, tables, and documentation. In practice,

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

however, many offices struggle with this, as every building design is highly specific and often demands bespoke solutions. Secondly, many architects and designers lack formal training in working with BIM models. As a result, they may use these programmes inefficiently or rely on support from specialised BIM managers. And third, some design solutions, particularly for the retrofitting of existing buildings, are still difficult to fully represent in BIM due to limitations in functionality and practical usability. Consequently, in addition to fostering training for architects, the software itself must also continue being refined.

Despite these challenges, integrated BIM models hold enormous potential during the entire design process. In the long term, they can allow planners to integrate structural analyses and building physics, rapidly generate life cycle assessments (LCAs), life cycle cost calculations (LCCs), and energy simulations, provided that seamless data exchange allows the integration of other planning disciplines. Currently, specialised software tools are often used in parallel, for example **Hottgenroth** software for energy simulations and the preparation of energy performance certificates (EPC), **eLCA** for life cycle assessments, and dedicated **tools published by the DGNB** (German Sustainable Building Council) for LCA/LCC calculations and circularity indices in Germany. The results are iteratively fed into the design workflow, so accurate maintenance of data is crucial. Coordination gaps must be avoided, as they can lead to inaccuracies, and any adjustments must be made individually in each program once exported.

Looking ahead, BIM models could also integrate circularity aspects. Ideally, they would contain detailed information on all materials and building components, allowing for easier assessment of reuse potential at the point of disassembly - essentially supporting the creation of a digital building passport, or **Gebäuderessourcenpass**, as defined by the DGNB in Germany. Such documents are becoming increasingly important and, in some cases, mandatory. Several digital platforms for building documentation and optimisation - such as **Concular**, **Madaster**, **EPEA's Circularity Design Toolkit**, and the **Urban Mining Index** - have already started aligning their systems accordingly [16]. These tools are also being developed to ensure compatibility with upcoming federal and EU initiatives, including the planned digital resource passport for buildings.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

By linking BIM systems with specialized tools for circularity, energy, LCA/LCC and other aspects, planners can fully leverage integrated digital workflows. This combined approach has the potential to significantly advance circular and sustainable construction.

In the following subchapter, the capabilities of the most-used programs are presented. All of them can be used either for 3D CAD modeling or BIM.

3.1.1 Revit

In Table 4, information about the capabilities, the benefits and the purpose in construction for Revit are presented [17].

Table 4. Capabilities, benefits and purpose in construction for Revit.

Capabilities	Benefits	Purpose in construction
Create detailed architectural designs, visualizing spaces, creating floor plans, and generating construction documents	Digital 3D model of a building, providing a detailed representation of its physical structure and components	Improves project stakeholder communication, facilitates efficient design changes, detects clashes early, ensures data accuracy, and contributes to cost and time savings by improving collaboration
Model and analyze the structural components of a building, designing and simulating the behavior of various structural elements	Streamlines collaboration among architects, engineers, and construction professionals, ensuring consistency and reducing errors	
Design and coordination of Mechanical, Electrical and Plumbing (MEP) systems, enabling professionals to model and analyze the components of a building	Parametric design capabilities enable the creation of relationships between model elements, enhancing flexibility and efficiency in the design process	
Project management, construction sequencing, and coordination, assisting in visualizing the		

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

construction process and identifying potential issues before they occur on-site		

3.1.2 SketchUp

In Table 5, information about the capabilities, the benefits and the purpose in construction for SketchUp are presented [18].

Table 5 Capabilities, benefits and purpose in construction for SketchUp.

Capabilities	Benefits	Purpose in construction
Creation of 3D models of buildings and visualizing spaces, allowing architects to communicate design concepts to clients	Intuitive and user-friendly interface	3D modelling software for construction, facilitating conceptual design and visualization. It facilitates collaboration, quick iteration, and aids client presentations
Model and visualize interior spaces, including furniture, fixtures, and other elements	Versatile for architectural, interior design, urban planning, and landscape architecture	
Creation of 3D models of cities or urban areas, to evaluate the impact of new developments on the existing environment	3D Warehouse for pre-built models, integration with other software, and real-time visualization	
A platform for visualizing the layout and elements of the landscape		

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

3.1.3 Rhino 7

In Table 6, information about the capabilities, the benefits and the purpose in construction for Rhino 7 are presented [19].

Table 6. Capabilities, benefits and purpose in construction for Rhino 7.

Capabilities	Benefits	Purpose in construction
Widely used in architectural design for creating detailed 3D models of buildings and structures	Non-Uniform Rational B-Splines (NURBS) for accurate and flexible 3D modelling	Rhino's NURBS-based modelling allows for precise representation of architectural and structural elements, enabling complex building models. Its real-time rendering capabilities facilitate architectural design presentation
	Supports various file formats, enhancing interoperability with other design and engineering software	
	A robust plugin ecosystem to extend capabilities and includes real-time rendering for visualising designs with realistic lighting and materials	

3.1.4 ArchiCAD

In Table 7, information about the capabilities, the benefits and the purpose in construction for ArchiCAD are presented [20].

Table 7. Capabilities, benefits and purpose in construction for ArchiCAD.

Capabilities	Benefits	Purpose in construction
Creation of detailed 3D models of buildings and structures, as well as	A powerful BIM software for creating virtual building models with detailed	Construction software that streamlines the design process, reduces errors, and

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

model entire cityscapes for urban planning purposes	information about materials and components	enhances efficiency due to its accurate BIM capabilities
Creation of detailed interior models, including furniture and lighting	Facilitate collaboration among architects, engineers, and stakeholders, allowing multiple team members to work on the same project simultaneously	
Generation of detailed construction documentation, including floor plans, sections, and elevations, aiding in the construction process and ensuring accurate implementation of the design	Integration of architectural design, structural engineering, and MEP systems for efficient coordination	
Efficient and intuitive BIM software on the market, allowing users to focus on designing great buildings	Advanced 3D visualization capabilities and the creation of parametric components for realistic renderings and flexible design adjustments	

3.2 Energy analysis

Besides the creation of the 3D model, there are various plugins or separate programs that permit the import of a 3D model to reach conclusions related to the energy performance of the building and the thermal comfort of the user. Among the most popular is Energy Plus in collaboration with HONEYBEE, DesignPH, IDA-ICE.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

3.2.1 Passive House Package Planning (PHPP)

PHPP is an easy-to-use planning tool for energy efficiency for the use of architects and planning experts. The reliability of the calculation results and ease of use of this planning tool has already been experienced by several thousand users.

The PHPP based on Excel was introduced for the first time in 1998 and has been continually further developed ever since. Calculation sheets for space heating balances (annual and monthly methods), and for heat distribution and supply, as well as for electricity and primary energy demand, constitute the main features of this tool. Essential modules were successively supplemented for the practical planning of energy efficient projects throughout the world, including the calculation of the characteristic values of windows, shading, heating load and summer behavior, cooling and dehumidification demand, ventilation for large objects and non-residential buildings, consideration for renewable energy sources, and EnerPHit certification (retrofitting of existing buildings). The PHPP is continually being validated and extended based on measured values and new research findings.

In the context of accompanying scientific research in several objects, measured results were compared with the calculated results. During the process, a high correlation could be demonstrated between the demand calculated using PHPP and the consumption ascertained through scientific monitoring projects. With careful planning of building efficiency, there will be no performance gaps.

The tried and tested Passive House Planning Package provides reliable results for the following:

- Heating demand per year [kWh/(m²a)] and maximum heating load [W/m²].
- Cooling demand per year [kWh/(m²a)] and maximum cooling load [W/m²] (in case of active cooling).
- Summer comfort in case of passive cooling: frequency of overheating [%].
- Demand for renewable primary energy (PER) per year and primary energy demand (PE) of all energy services in the entire building [kWh/(m²a)].
- Assessment of the annual renewable energy gains [kWh/(m²ground a)].

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

PHPP utilizes the calculation methods from ISO 13790:2008 (and its European equivalent EN 832) for its quasi-static energy balance, which determines heating and cooling demands. However, PHPP also incorporates adjustments based on validation with real-world Passive Houses and uses procedures derived from other ISO standards, such as ISO 6946 for U-values and ISO 10077 for window thermal characteristics [21].

Among the positives aspects of this software are the following:

- Energy balance calculation in the common Excel format.
- Easy and direct data input, in a flexible way where required.
- Validated result accuracy.
- Verification for Passive House buildings and EnerPHit retrofits.
- Detailed manual with tips for energy efficiency.
- Interface for import/export of data from/into other programs.
- Can be combined with the 3D tool designPH (plugin for SketchUp).

3.2.2 EnergyPlus

EnergyPlus is a whole building energy simulation program developed by the U.S. Department of Energy, designed to model the energy consumption of buildings for heating, cooling, ventilation, lighting, plug and process loads, and water use [22] .

Table 8. Input, output and purpose in construction for EnergyPlus.

Capabilities	Benefits	Purpose in construction
Widely used whole-building energy simulation program for modeling thermal dynamics, heating, cooling, ventilation, lighting, and water use in buildings.	Integrated, simultaneous solution of thermal zone conditions and HVAC system response without assuming the HVAC system can always meet zone loads, enabling accurate modeling of un-conditioned and under-conditioned spaces.	Enables precise prediction of building energy consumption and thermal performance across design phases, from conceptual design through post-occupancy evaluation, supporting code compliance and certification.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Advanced heat balance-based method calculating surface temperatures, convective and radiant effects, thermal comfort, and condensation analysis; supports component-based HVAC modeling with flexible system configurations.	Sub-hourly, user-definable time steps for accurate modeling of systems with fast dynamics; combined heat and mass transfer accounting for inter-zone air movement and moisture migration.	Supports building load calculations, equipment sizing optimization, atmospheric pollution predictions (CO_2, NOx, SOx, particulate matter), and integration with advanced control strategies including Energy Management System (EMS) scripting and model predictive control (MPC).
Modular, open-source architecture developed by U.S. Department of Energy; extensive third-party interface ecosystem (OpenStudio, DesignBuilder, IFAC HVAC) and Functional Mockup Interface (FMI) support for co-simulation.	Free, cross-platform software (Windows, MacOS, Linux) with standard and user-customizable output reports at multiple time resolutions (annual to sub-hourly) and energy source multiplier calculations.	Provides comprehensive building retrofit and operational optimization capabilities through comparison of design alternatives, evaluation of passive strategies, investigation of equipment undersizing impacts, and post-occupancy performance verification against predicted models.
Integrates loads, systems, and plants simultaneously where system and plant output directly impact thermal response rather than sequential calculation; supports parametric analysis and optimization workflows.	Enables early-stage design decision-making with validated simulation paradigm based on ASHRAE heat-balance methodology and extensive test suite with weather data for 550+ global locations.	

3.2.3 IDA – ICE

IDA Indoor Climate and Energy (IDA ICE) is a Building performance simulation software. IDA ICE is a simulation application for the multi-zonal and dynamic study of indoor climate phenomena, as well as energy use. The implemented models are state-of-the-art; many studies show that simulation results and measured data compare well [23].

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Table 9. Input, output and purpose in construction for IDA – ICE.

Input	Output	Purpose in construction
IDA ICE supports IFC BIM models generated by tools such as ArchiCAD, Revit, MagiCAD, and others.	IDA ICE output includes tables, charts, reports and plots. 3D visualizations (both stills and animations) show geometry, solar shadings, color coded input data as well as results.	The primary purpose of IDA ICE in construction is to simulate and optimize a building's indoor climate and energy performance throughout the year, supporting more sustainable, comfortable, and energy-efficient building design and operation
Geometry and shading on site can also be imported from SketchUp, Rhino or other geometry tools. Solar influx is evaluated through windows (also internal) with full 3D accounting for the local shading situation. Climate files like EnergyPlus weather files or ASHRAE climate files, can be downloaded and installed. The table-based input structure allows full interoperability with MS Excel and comparable software.	Predefined output files and reports cover •Zone heat and energy balances: solar radiation, occupants, equipment, lights, mechanical ventilation, heating and cooling devices, air leakage, thermal bridge losses and surface transmission. •Control signals: window opening and shading, signals for secondary and primary systems. •Building occupancy: for each zone or the whole building. •Heat and mass transfer: detailed heat fluxes of surfaces and air streams.	

3.2.4 Edilclima

Edilclima covers needs such as energy calculation according to major Italian and European standards, detailed and customized analysis of energy performance, while also supporting integrated and multidisciplinary design [24]. Some of the previous tools are also compatible with specific standards,

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

such as EnergyPlus with ASHRAE for example. Ediclima is mentioned in this section, even if it has similar features to the other design tools. The mention of this design tool aims to highlight the fact that different country specific software exists. Similarly in Greece there is the TEE-KENAK software which some engineers use to issue energy certificates and the electronic building identity card. The ArchBuilder tool will have to comply with the requirements of all these tools. The presentation of TEE KENAK is omitted because PHPP use the same standard, ISO 13790.

Among its critical aspects is the inability to integrate BIM software other than Autodesk Revit. It prioritizes Italian regulations and has difficulty in applying to non-Italian projects. This showcases the critical aspects that appear in multiple design software throughout Europe, where connection only with other software and main compliance with local regulations are the rule. The input, the output and the purpose in construction is presented in Table 10.

Table 10. Input, output and purpose in construction for Edilclima.

Input	Output	Purpose in construction
IFC BIM files from major design tools (e.g. Revit, ArchiCAD, MagicCAD)	Automated detailed reports: monthly/seasonal energy needs by zone and subsystem	Provides centralised and integrated management of all activities related to energy efficiency; facilitates compliance with current regulations; optimises energy design through integration with BIM tools; simplifies the production of documentation required for tax deductions and certifications
Manual tabular input or enhanced graphical input for building geometry (walls, windows, thermal bridges)	- Heat load calculations (EN 12831) - Heating and cooling needs (UNI/TS 11300-1) - Primary energy for heating, cooling, and domestic hot water - Renewable energy contributions (thermal solar, PV, biomass) - Energy use for lighting (EN 15193)	
Climate data, including custom weather files		
User behaviour profiles, indoor/outdoor climate, plant system data		
DXF/DWG background images for accurate geometry tracing	Tabular and visual results for envelope losses/gains, service-specific consumption, and system efficiencies	

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

4. Tools in the construction process

Following the design phase, the construction process equally relies on specialised software to ensure quality, efficiency, and real-time coordination on-site. In this chapter, an analysis of the available tools used for the organization of the various involved members in the construction process is presented. Similarly with chapter 5, this analysis aims to identify the functionalities used of the presented programs and incorporate features that are going to satisfy them in the Arch Builder.

To cover the gap in the market, particular emphasis has been placed on the transition between design and construction. Scheduling programs, which are already relevant during planning, become even more critical during execution - **OmniPlan** is one example. Other tools, such as **ORCA** or **ProjektPro**, integrate tendering, contracting, invoicing, and change management into a single platform. Platforms for exchanging plans, like **Planfred**, provide a shared hub where the latest plan versions are always accessible and traceable across all indices. QR codes printed on plans allow on-site teams to verify whether a plan reflects the current version or if updates have occurred. Together, these tools help track progress and identify potential bottlenecks.

On-site, a key example of construction-focused software is **PlanRadar**, which enables teams to monitor and document defects, tasks and changes directly and in real time. PlanRadar is a cloud-based construction management platform designed to streamline project documentation, communication, and task management for construction and real estate professionals. It acts as a central digital hub for all project-related information, significantly improving efficiency and reducing errors in construction processes (more about the tool in Table 11) [25]. By offering visual documentation, automatic reporting, and instant updates, PlanRadar improves communication between contractors, site managers, and design teams, ensuring efficient problem-solving.

Table 11. Input, output and purpose in construction for PlanRadar

Input	Output	Purpose in construction

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Digital drawings, BIM models, floor plans, blueprints	Customizable, exportable reports (progress, defect logs, handover checklists)	• Assign, track, and resolve defects or quality issues via tickets linked to exact plan locations
Photos, geotags, and voice notes from mobile devices or tablets	Real-time dashboards and analytics for project status, deadlines, and compliance	• Share real-time updates and documentation between office and field teams
Custom forms, inspection checklists, and daily site logs	Documentation audit trails and version histories for approvals and changes	• Reduce paperwork, prevent data loss, and ensure version control in project documentation
Project schedules, task lists, and resource assignments	Centralized, searchable project documentation archive	• Facilitate inspections, progress monitoring, and compliance reporting directly on-site
Comments, mark-ups, and defect tickets attached directly to plans	Notifications for assigned tasks, outstanding issues, and completed actions	• Integrate with BIM/CAD systems and fit established construction workflows with minimal training needs

During construction, revision planning must not be overlooked. Inevitably, some decisions need to be made at short notice on-site. Promptly recording this information ensures that valuable data is not lost during the fast-paced construction phase. This applies not only to revision planning, but also to other documentation tools. Accurate and up-to-date information is one of the most valuable assets for promoting more sustainable resource management in the future.

Among the available methodologies and tools to optimize construction, the Lean Construction methodology exists with the goal of optimizing the management of construction projects [26]. The main objective of this methodology is to eliminate or reduce activities that do not add value to the project and optimize those that do [27]. The intention of Lean Construction to eliminate non-value activities and optimize logistics to reduce costs and meet delivery deadlines efficiently is also an indirect objective of the ArchBuilder's methodology. Among the Lean techniques that could be used to optimize the Archbuilder's tool structure are Value stream maps [28], Root cause analysis [29], Kanban Boards [30], Last-minute planning events [31] and Just-in-time delivery [33]. The joint

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

adoption of BIM and Lean Construction seems promising for the future of construction [34]. Among the difficulties encountered during the implementation of Lean construction, similarly with BIM, are the need for cultural change [35], the lack of knowledge and experience [36], and the need for collaboration among stakeholders [37].

However, one problem that remains is the usage of the tools for all the members involved. The high level of complexity, correlations and necessary communication cannot be satisfied with simple tools. At the same time, not all members have access or familiarity with the same tools.

The features of the most used project management in construction are selectively presented. Among them are the following;

- Monday
- ClickUp
- Millent
- Trello

It is worth mentioning that these applications have been developed to improve coordination in building construction projects. And all of them include features that target one of the main challenges as the ArchBuilder methodology, effective communication and collaboration between architects, engineers, contractors and project managers.

Monday.com, ClickUp, Millient, and Trello can facilitate construction management by streamlining project tracking, team collaboration, and workflow automation across all project phases. These platforms help construction managers coordinate tasks, monitor resource allocation, and maintain clear communication among dispersed teams, significantly reducing project delays and administrative overhead.

4.1 Monday.com

Monday.com provides dynamic boards for tracking tasks, deadlines, and project milestones, offering visualization tools like Gantt charts and Kanban boards suited for construction schedules. The platform supports resource management, portfolio tracking, and automated workflows, helping site managers oversee responsibilities and adapt rapidly to project changes. Integration with common tools (Slack,

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Google Drive) ensures relevant updates are accessible to boost decision-making speed. Its user-friendly interface makes onboarding easy, but the cost can rise with team expansion and the platform lacks advanced custom reporting for highly complex needs [38].

4.2 ClickUp

ClickUp consolidates project, document, and communication tools in one workspace, making it suitable for managing design documents, site instructions, and progress updates. Teams can assign tasks, collaborate via chats and whiteboards, and visualize the project's status through interactive dashboards. ClickUp's customizable features help construction professionals plan, track, and adapt rapidly across phases, but its limitation to iOS and macOS environments can restrict accessibility for some construction operations [39].

4.3 Milient

Milient serves as a comprehensive project management system that extends beyond basic tracking, by including features like timekeeping, invoicing, quality control, and resource planning. This makes it especially valuable for architecture and engineering firms in construction who need integrated budget management, invoicing, and risk assessments alongside project workflow management. Centralizing these processes helps ensure that both quality and budget are constantly controlled throughout the construction cycle [40].

4.4 Trello

Trello uses a Kanban board approach, enabling construction teams to organize tasks, monitor progress, and adapt workflows visually. Simple scheduling and assignment, coupled with integration into platforms like Slack, Gmail, and Dropbox, promote real-time collaboration and documentation sharing. While Trello is ideal for smaller-scale projects or early-stage planning, it can lack the advanced reporting and resource allocation tools found in more complex solutions [41].

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

4.5 Summary of management tools

While the management tools mentioned can satisfy some needs of a construction team, they continue to lack the link between the design team and the implementation study. They mainly focus on task tracking, scheduling and collaboration. Simultaneously, they do not sufficiently cover areas such as regulatory compliance, real-time visibility and safety oversight. At the same time, software focusing on construction may exist in-house, such as the construction tool of RINA. Its main purpose is to coordinate and monitor on-site renovation logistics and operations, while reducing waste and rework by digitalizing construction workflows. A program like this requires sensor and data infrastructure, operated by a member of the working team, who should update the rest of the members. Its functionality is useful once the inputs and the outputs are communicated correctly. At the moment there is not one single available solution that bridges the information gap.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

5. Definition of ArchBuilder's methodology

To minimize the errors that occur from the gap between the design and construction phase, a flow methodology is developed on this chapter to eliminate it. This methodology aims to reduce environmentally and financially costly errors, ensuring optimal building energy performance.

The idea is to follow a stepwise approach from design study through implementation and construction stages, with integrated feedback loops and supporting features. The following flow will be cyclical and multidisciplinary, while/by integrating energy modeling, implementation, quality assurance, and feedback driven by both informational and team roles.

This methodology's starting point is the initiation of modeling from the engineering teams. Thus, it omits the part of the offers between the client and the project teams, to the reach of an agreement between the parties involved, excluding all contracts negotiations. Also, after the delivery of the construction site there are some steps that are considered optional if the project does not include quality assurance procedures. In Figure 1, there is a concept image of the first schematic representation.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

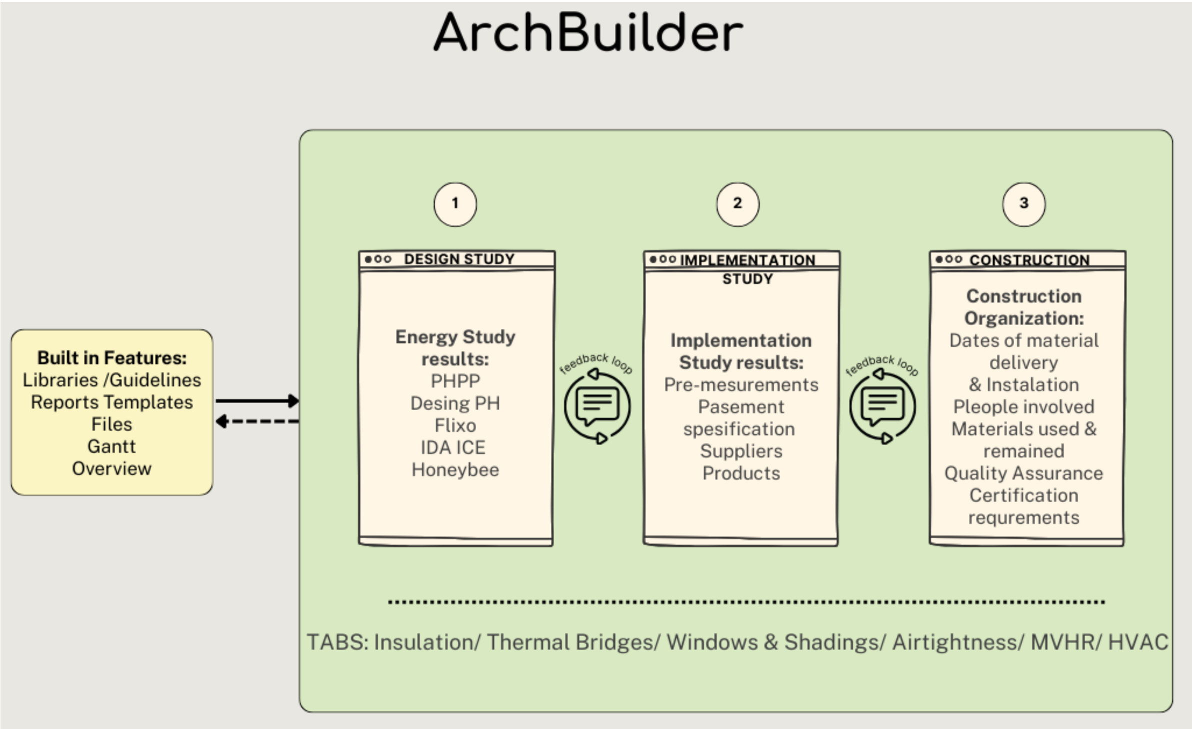


Figure 1 Schematic representation of the ArchBuilder methodology.

The project decision tree aims to follow the flowchart, starting from the activation of a new project, then the initial energy study, the implementation study and the selection of materials moving to site supervision, and construction details and quality assurance activities reaching its certification, if it is applicable.

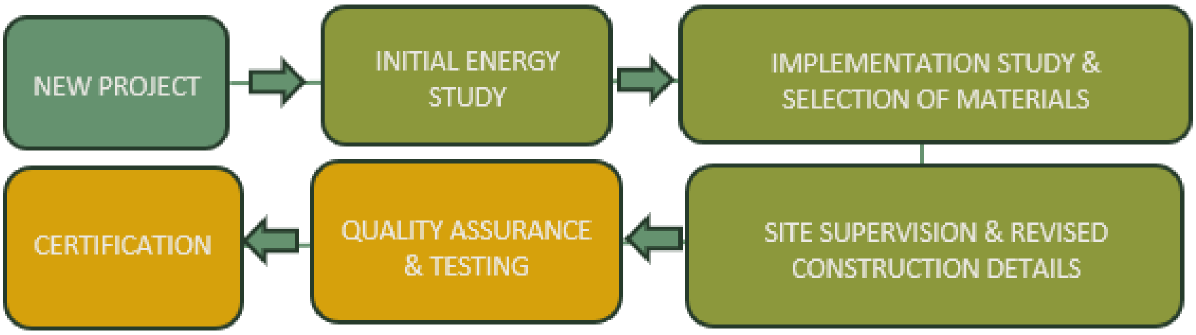


Figure 2. Flowchart of the main steps in the ArchBuilder methodology

It is also important to highlight that, in this methodology, a big part of the total budget of the project is not included. The arrangements between the client and the project team are expected to be well-

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

defined financially before the usage of the tool. In this methodology, the only financial parameter that is examined is the minimization of materials/systems cost for the client during the implementation phase. The reason why the budget is not separately mentioned inside the steps of the methodology is because it is part of the implementation work, where different offers are assessed, and part of the construction organization, where the final decision is being made. Goal of the tool is not to find the best financial offer or visualize the benefit from successful communication. The objective is to be the medium that reduces the costs that are provoked due to miscommunication and delays that appear between the different stakeholders of the project.

In Figure 2, it is depicted how the information flows in the ArchBuilder methodology. Beginning from the Plans (BIM or not), the first step is to start with the **Energy Study** with the available data from the architects' team. Among the tools that are being used in this phase are PHPP, Design PH, IDA ICE, flixo, Honeybee, WUFI. The selection of the tools is a choice of the modeling team based on the particularities of the project. The results from the design study should also be transferred to the **Life-Cycle Analysis (LCA)** and **Life Cycle Cost analysis (LCC).**

After completing the **Energy Study**, the modeling team forwards the results to the next responsible modeling team, that sometimes are the same and proceeds with the **Implementation Study**. In this step of the methodology technical details of the building's thermal envelope and HVAC are included. By delivering the implementation requirements to the person that must apply them, the third stage began, **Implementation and Guidelines.**

To initialize the **Implementation and Guidelines** another input is necessary, so as to provide the materials to support the implementation, such as reports, implementation videos, good practices and the available materials in the market. Once the selection of materials is completed, the flow in the form of feedback should move backwards to the modeling teams that realised the energy, implementation and LCA/LCC studies to update their data and provide the necessary warnings to the involved members.

Once the materials and the way they are going to be combined with each other to form the building system are selected, the **On-Site Implementation** starts. The site supervisor is constantly in contact with the construction team, feeding one another with photos, videos and quality checks to overview

Co-funded by
the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

the progress on site. Simultaneously, the site supervisor is responsible for transferring the progress information with the certifier and the quality assurance team to receive feedback. **On-Site Implementation** and **Quality Assurance**, steps 4 and 5 of the methodology, usually overlap each other since some stages of the construction are completed while others continue. Step 5 is almost exclusively the responsibility of the site supervisor. Once the first commissioning of the envelope, the HVAC system, the BDT and MVHR are completed, this step is considered done.

Moving to step 6, **Internet of Things (IoT) and Sensors** is optional to verify the results of the design studies of a project. By observing the electrical consumptions (either by energy bill analysis or by monitoring devices) and monitoring the indicators of thermal comfort (temperature, relative humidity, CO_2 concentration) that can be provided further consultation to the user to educate them further about energy saving alternatives (usage of the shading-heating/cooling/mechanical ventilation systems) and setting points optimization of the systems to correspond with the needs of the building is conducted.

As it is indicated in Table 3, the necessary inputs to initiate each step of the methodology are clear Usually, this is the common simple sequence followed intuitively. However, what is usually omitted to be referenced is the constant back and forth due to practical problems. In Table 4, there is an effort to predict all the possible interactions that lead backwards in this methodology. The backwards flow is defined as "feedback", while the forward flow as "information".

Table 12 Necessary inputs to feed the Arch Builder methodology.

FEED THE ARCBUILDER TOOL	
INPUT	**FEEDING STEP**
Building Plans	Step 1: Energy study
Energy study results	Step 2: Implementation study
Technical details for envelope, HVAC	Step 2: Implementation study
Implementation study report	Step 3: Implementation & Guidelines
LCA/LCC reports	Step 3: Implementation & Guidelines
Selected materials	Step 3: Implementation & Guidelines

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Good practices of materials' application	Step 3: Implementation & Guidelines
Implementation guidelines for specific project	Step 4: On-Site Implementation
Photos-Videos on-site	Step 4: On-Site Implementation
Quality checks, certification of products	Step 4: On-Site Implementation
Commissioning of Envelope, HVAC and MVHR	Step 5: Quality assurance
Blower Door Test results	Step 5: Quality assurance
Electrical bill analysis or Monitoring consumptions	Step 6: IoT Sensors
Thermal comfort report	Step 6: IoT Sensors
Educational material to users	Step 6: IoT Sensors
Monitoring report	Step 1: Energy study

It is important to highlight that even though these forward and backward flows of information are between specific teams, they should be reported to the involved stakeholders in order that the receiver can trace the origin of the information and communicate directly with the person responsible.

Table 13 Summary of the expected direction flows

INFORMATION DIRECTION FLOW			
INFORMATION/FILE	**FROM**	**TO**	**FLOW CATEGORY**
Building Plans	Architect team	Energy modeling team	INFORMATION
Energy study	Energy modeling team	Implementation modeling team	INFORMATION
Energy study	Energy modeling team	LCA/LCC team	INFORMATION
LCA/LCC results	LCA/LCC team	Site supervisor	INFORMATION
Implementation study	Implementation modeling team	Site supervisor	INFORMATION
Selected materials	Site supervisor	Energy modeling team	FEEDBACK
Selected materials	Site supervisor	Implementation modeling team	FEEDBACK

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Selected materials	Site supervisor	LCA/LCC team	FEEDBACK
Photos, videos, quality assurance results	Construction team, Site supervisor	Certifier	INFORMATION
Observations on site	Certifier	Construction	FEEDBACK
IoT results	Monitoring team	Quality assurance	FEEDBACK
IoT results	Monitoring team	Energy modeling team	INFORMATION
Commissioning	Energy modeling team	Monitoring team	FEEDBACK

In the general image of the methodology the ArchBuilder (Figure 2), all the interaction between the different steps that were described already are depicted schematically. More details about what is included in each step are analyzed in the following subchapters.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

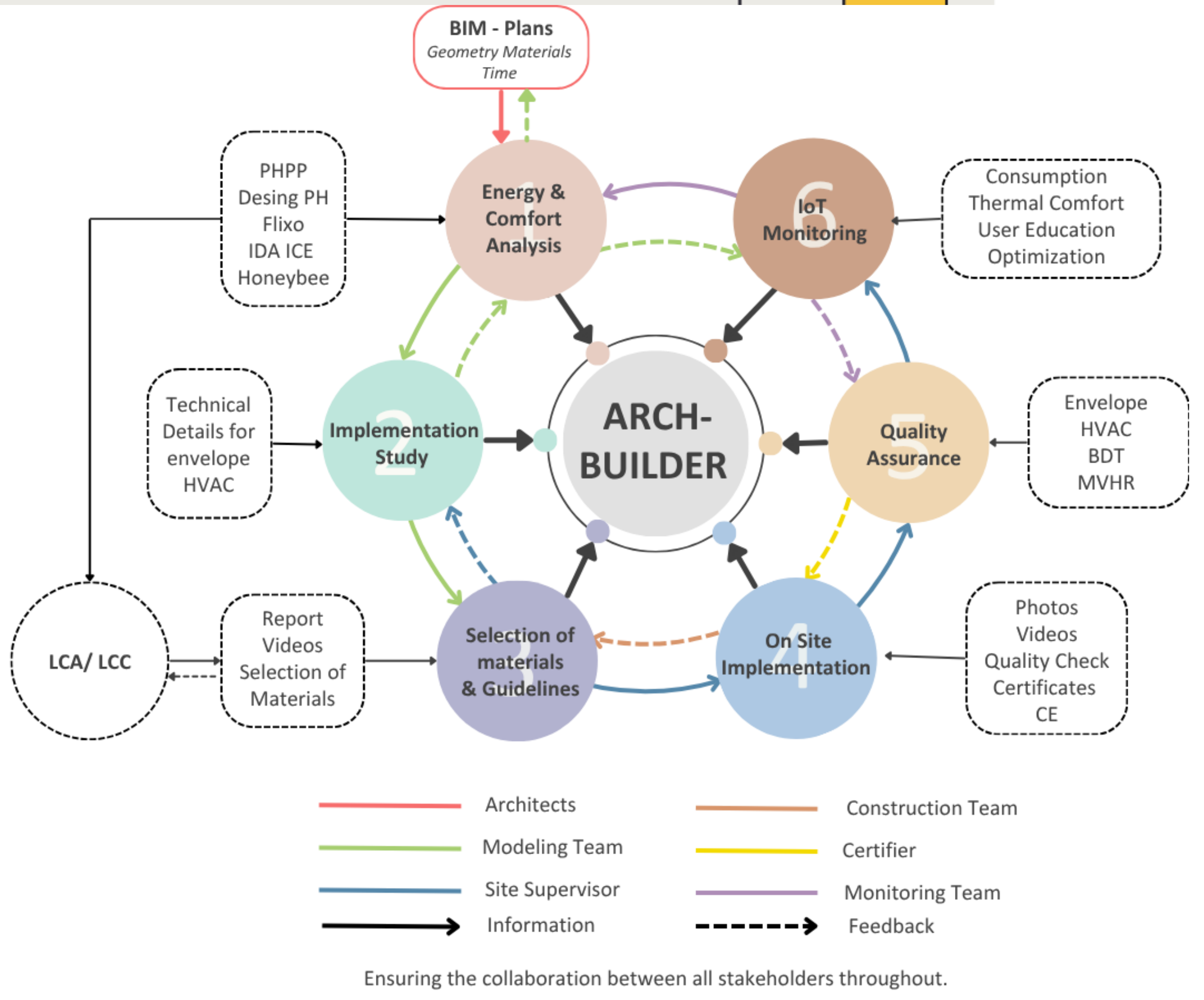


Figure 3 Image of the general methodology followed by the ArchBuilder tool

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

5.1 New project

Focusing on the energy design of the building, the beginning of a new project can have various points of initiation. The four most common ones encountered in the market:

- A new construction without initial architectural plans
- A new construction with initial architectural plans that require adaptations to optimize the energy performance of the building
- A renovation project without major limitations in the possible interventions
- A renovation project with significant limitations in the possible interventions

Different scenarios require different strategies. But, in order to proceed with the strategy, the first step is to assign clear roles and responsibilities among the collaborators. Among different working groups there are two possible cases:

- One compact team with an architect, a civil engineer and a mechanical engineer.
- Individual professional (architect, civil and mechanical engineer, energy consultant) that collaborate with each other for a specific project.

Due to the interconnecting working tasks of each professional, all the members involved should be aware of the total team for transparency but also for functional reasons to be able to locate the responsible contact or project manager.

5.2 Initial study focused on energy parameters

There are two points of initiation whether there are existing plans or not. If there are no available plans, for example for a new construction, the best solution for is the architect and the energy consultant of the project to cooperate closely to minimize back and forth and to find their common approach regarding important aspects of the building, including:

- Type of thermal envelope
- Selected systems
- Shading
- Ventilation
- Integration of Renewable Energy Solution

Co-funded by
the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Considering the initial studies' step completed, the following tasks must be realized with the following sequence:

- The full definition of the thermal envelope;
- The definition of an autonomous or central HVAC system and the possible positions;
- Identification of thermal bridges and alternatives to optimize energy performance;
- The definition of HVAC system solutions for heating, cooling, domestic hot water (DHW) and mechanical ventilation with heat recovery (MVHR) system;
- The creation of the permits study for submission to the respective regulatory body;
- The creation of the final design reports for distribution to the client and the implementation study responsible.

The initial design study focuses on energy parameters, since one of the goals is to achieve optimum building energy performance. Besides the tool, the users of ArchBuilder are expected and encouraged to use all the other available tools. If other tools are used, it is advised to report this activity shortly to update the involved members.

5.3 Implementation study & selection of materials

Based on the design requirements to achieve specific energy demand and desirable thermal conditions, the following tasks sequence is proposed to be completed:

- Identify necessary construction details with critical points to create the implementation study or at least the requirements of the installation practices;
- Premeasurement of the materials quantities;
- Request of offers for the systems based on the design requirements;
- Assessment of the concentrated offers;
- Identification of the final characteristics of selected materials;
- Communication with the designer or/and certifier to verify the selected materials;
- Update of the design studies to match the properties of the selected materials to control the result;
- Identify the materials of the airtightness layer of the thermal envelope based on the building system;
- Creation of the implementation design for heating, cooling, DHW and shading systems;

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

- Creation of the necessary permits to proceed to construction site based on the identified actions of the implementation studies.

5.4 Site supervision and revised construction details

In this step of construction, the focus is shifted towards the site. The supervisors are called to visit the site to check that the implementation studies are followed.

If there are deviations from the implementation design, the supervisor and the people who created the implementation studies should remain in contact. While ideally the implementation studies and the site's supervision are two separate phases, realistically these are overlapping due to unexpected events, dependence from materials and delivery dates, available stock and clients' priorities (time, cost, quality of the result). As highlighted in the available bibliography, the project management triangle (Figure 3) [42] emphasizes the constraints of the project. It summarizes the following statements:

- The quality of work is constrained by the project's budget, deadlines and scope
- The project manager can trade between constraints.
- Changes in one constraint necessitate changes in others to compensate, otherwise quality will suffer.

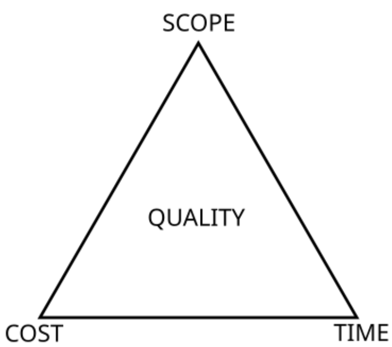


Figure 4 The project management triangle

To ensure the desirable energy performance, which is the main scope of this methodology, special focus on these points of the construction should be given:

- Inspection during the materials' delivery
- Insulation installation
- Windows installation

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

- Application of airtight materials
- Installation of heating, cooling, MVHR and DHW systems
- Installation of shading systems
- Report on supervision observations
- Concentration of technical documentation of the installed materials and systems

Lastly, every change, in relation to the initial designs, must be communicated to the designer, while and beforehand (at the first stage "new project"), there should have been defined an appointed person to update the plans. The common practice usually does not include the production of the as-built plans. However, it has been observed that in cases where a certification or a quality assurance process is not mandatory, the client or the project team permits discounts or changes which influence the final performance, resulting in the digital depiction not accurately representing the actual building.

5.5 After construction management

Although the steps after the completion of the construction are not immediately connected with the gap between design and construction, they are part of this problem's solution. Certification processes and quality assurance measures, such as Blower Door test, infrared imaging, bill analysis and monitoring, are not actively contributing to the alignment of the design and the construction. However, they can push the realization of the necessary steps as they act as control mechanisms and milestones. The quality assurance measures evidently check if the installation of the materials and systems has been done according to the requirements. But additional time and equipment may be needed. If the steps of the previous phases are performed adequately, it can be verified whether there is an actual gap between design and construction. Since it is not part of this version of the ArchBuilder, steps for specific protocols, sensor specification and threshold values for different building typologies are omitted.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

6. Chapter 6: Examples leading to the ArchBuilder methodology

Using as a base previous experience from other projects, mainly focusing on residential buildings, the methodology described in chapter 5 has emerged. To justify the selection of certain decisions on the Architecture of Tool in Chapter 7, examples from the design, the implementation and the construction phase will be presented.

In the following examples, there is a representation of specific phases of each project which shows both good and failed actions. Summing up all these examples, this deliverable is creating a universal methodology applicable in every building which minimizes the performance gap, while creating a holistic approach involving every stakeholder.

6.1 Design phase

Two study cases are selected with different typologies. The common element is that all of them refer to residential buildings, located in Greece but with differences in buildings characteristics.

6.1.1 Multifamily building in the center of Athens

Project Description:

This project involved designing a modern multi-family residence in central Athens. The collaboration included an architecture office, a consulting office, and an investor intending to sell the properties. The design integrated Passivhaus principles while minimizing construction costs.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

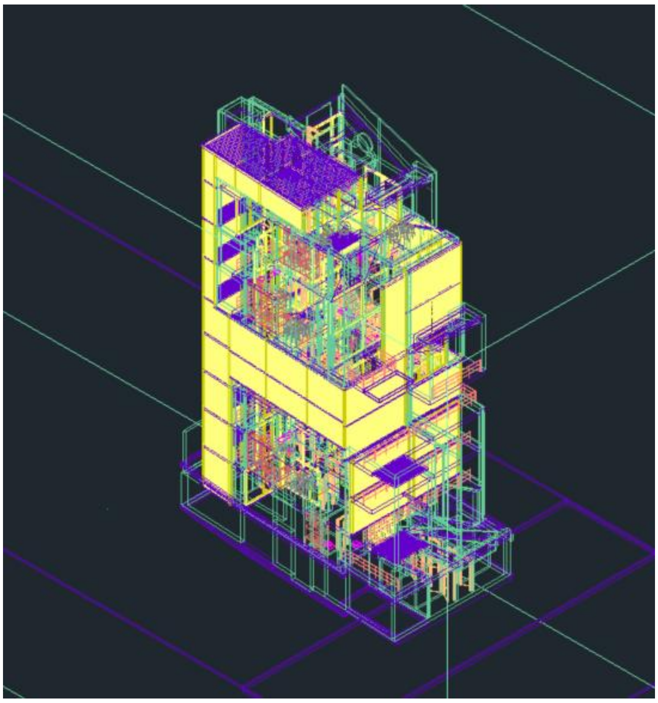


Figure 5 Snapshot of CAD 3D model of study case 1, HPHI copyright.

Figure 6 Render image of study case 1, HPHI copyright.

Technical Description:

The design phase included architectural and structural components. Multiple professionals collaborated, including architects, structural and mechanical engineers, energy consultants, permission engineers, and project managers. Challenges included varied software usage and detail levels, limited BIM adoption, and diverse file formats such as IDF. Coordination was maintained via a common repository, meetings, and emails.

Worked Well:

- Effective collaboration among multiple disciplines.
- Information sufficiently transferred to implementation.
- Use of a common repository for file sharing.

Failures / Lessons Learned:

- Lack of uniform software and design detail standards.
- Time-consuming coordination meetings.
- Communication overload leading to information retrieval difficulties over time.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

6.1.2 Block of touristic apartments in Greek island

Project Description:

A design for a block of five apartments on a Greek island, involving architects, project managers, energy consultants, and constructors.

Technical Description:

Lack of well-defined responsibilities delayed information flow. Design adjustments required approvals not only by architects but also by interior designers unfamiliar with Passivhaus needs. Mechanical ventilation design had to be adapted accordingly.

Worked Well:

- Verification of needs for direct information flows.
- Collaborative design adjustments involving multiple disciplines.

Failures / Lessons Learned:

- Unclear partner responsibilities causing unclear communication.
- Disrupted workflow due to incomplete initial conditions coverage.
- Time loss through re-design and adjustment.

6.2 Implementation phase

Two case studies were selected that showcase successful examples of implementation studies and demonstrate their importance in the proper selection and ordering of materials, the simplification of complex construction details, and the provision of a clear guide during the construction phase.

6.2.1 Single family house in Greek island, Greece

Project Description:

Renovation of an old, mold-affected single-family house to Passivhaus standards, complying with rigid island architectural guidelines.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Figure 7 Before and after the renovation of the house in a Greek island.

Technical Description:

Implementation studies focused on airtightness, thermal bridges, and material sequencing. Coordination among architects, energy consultants, contractors, and owners was essential. Detailed construction drawings and shared PDFs enabled effective communication.

Worked Well:

- Clear definition of materials and installation methods.
- Iterative vapor study and expert review.
- Back-and-forth communication using shared comments in PDFs (Figure 7).

Failures / Lessons Learned:

- Complex coordination requiring a common communication platform.
- Market availability influenced material selection.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

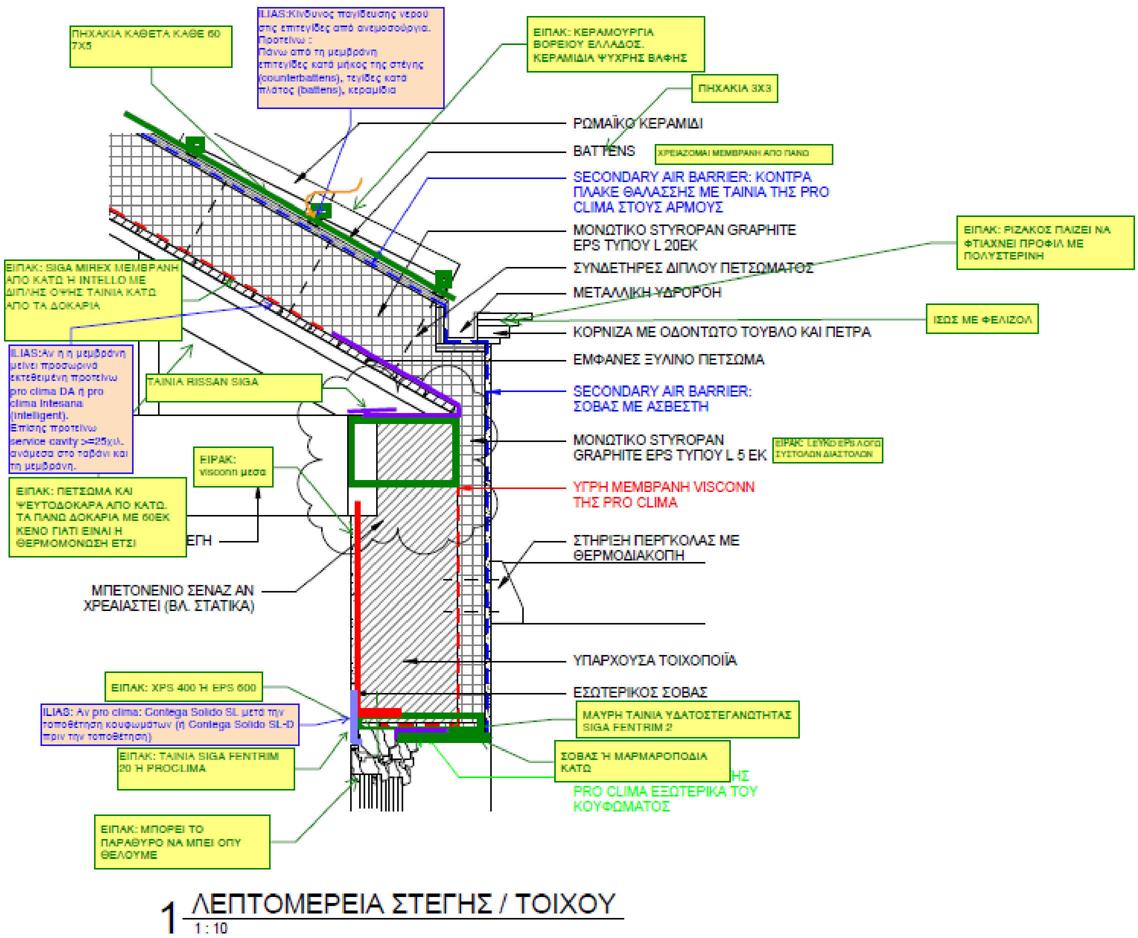


Figure 8 Construction detail of the roof-to-wall connection, and back and forth communication between the team members

6.2.2 Luxury House in a Greek island

Project Description:

New luxury house construction with a 152 m² treated floor area featuring advanced mechanical ventilation installation.

Technical Description:

2D plans and a detailed 3D model were created for ventilation unit and piping placement. Model facilitated component selection, routing clarity, and guided construction.

Worked Well:

- Accurate spatial coordination and component selection.
- Visualization tool increased owner engagement and construction accuracy.
- Approximately 90% implementation accuracy reduced on-site issues and waste (see Figure 9 and 10).

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Failures / Lessons Learned:

- No significant failures reported; well-planned construction phase demonstrated value of detailed modeling.

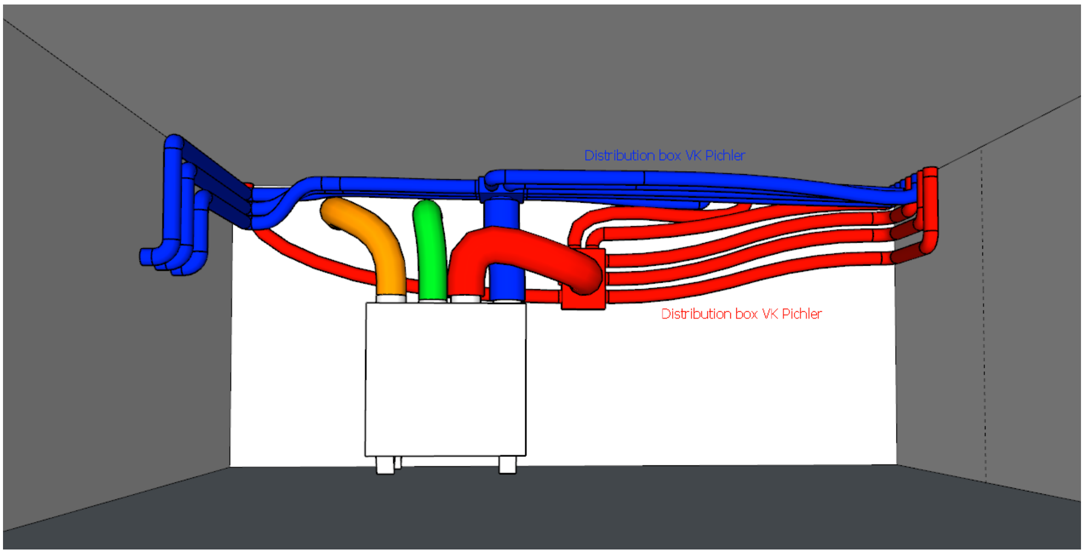


Figure 9 3D model of mechanical ventilation unit and piping installation in a luxury house in Paros, Greece.

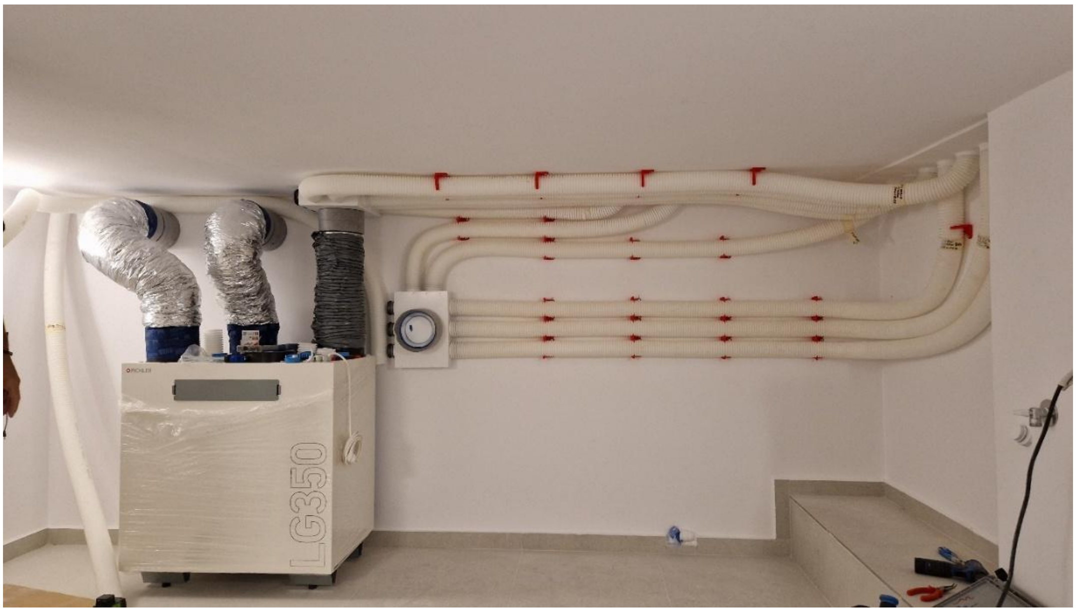


Figure 10 Final installation of mechanical ventilation unit and piping in a luxury house in Paros, Greece.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

6.3 Construction phase

In this chapter, some examples of construction organization are analyzed. It is known that the more hours spent in the office on design and implementation studies, the fewer problems occur on the construction site.

6.3.1 Detached house in Neo Heraklion, Attica, Greece.

Project Description:

New single-family house construction (120 m^2) started in 2024 with expected completion within 2025.

Technical Description:

Implementation study was skipped for economic reasons (decision of the client). Different professionals managed architectural and engineering designs, with many construction details unresolved at design stage.

Worked Well:

- Meticulous construction management and close collaboration mitigated some risks.

Failures / Lessons Learned:

- Significant gap between design and actual construction.
- Budget and timeline exceeded due to late decisions and numerous modifications.
- Additional rework and personnel needed due to incomplete early planning.
- Absence of implementation study resulted in setbacks commonly encountered in construction.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

7. Architecture of the tool

Having a description of the methodology that could bridge the gap between design and construction in Chapter 6, the implementation of the methodology to the architecture of the tool is followed. Back-end and front-end code will not be developed to host the tool to a platform or in a web environment until it reaches a satisfactory level of development. Thus, it was decided that the first version of the tool will be developed in an excel environment.

It is reminded that the tool aims to connect all stakeholders through every step of the construction focusing only on energy and comfort design.

Following the classic worksheet structure, the interface layer of the file includes 9 visible sheets that correspond to the following topics:

- Instructions
- Overview
- GANTT
- Contact list
- Insulation
- Thermal bridges
- Windows & Shadings
- Airtightness
- MVHR & HVAC

In this document that aims to be submitted by the end of November 2025, the last updated version of the tool is presented. So, a description of the structure and functionality of the last updated version until November of each sheet is presented.

- The tab ***"Instructions"*** clearly describe the suggested way to fill in the document to take advantage of its use.
- The tab ***"Overview"*** includes the inserted general information by the user. The information inserted there will be transferred automatically to feed the other sheets if they are related thematically. In this sheet, there will be also presented the outputs from the other tabs that are important to understand the general image of the building.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

- The tab ***"GANTT"*** is going to transfer the timeline that it is inserted from the other tabs to provide a visualization of the whole project from the beginning of the design phase until the end of the construction phase. No input information will be necessary from the user in this sheet
- The tab ***"Contact list"*** is the sheet that includes all the involved members of the project reported starting from the owners, the engineers, the suppliers to the technicians and other project managers involved. From this sheet, the rest excel sheets will be fed (apart from "the instructions") so the appointed person filling in each tab is obvious.
- The tab of ***"Insulation"*** aims to provide information about the important thermal characteristics of the building envelope. In this excel sheet, critical points due to the particularities of each envelope are going to be inserted, why they are considered risky and their mitigation measures. There is a feature to enable limited communication between different individuals who are collaborating in the fill in the ArchBuilder Tool. This feature aims to support communication between the different phases. There are three sections dedicated to design, implementation and construction phases, respectively, requesting information input to provide a clear summary of the thermal envelope areas.
- The tab of ***"Thermal bridges"*** is the second sheet that is related to the thermal envelope. Since the part of thermal bridges in conventional constructions is not usually treated sufficiently to minimize thermal losses, it was deemed necessary to have a specific section dedicated to it. Following the same structure as the "Insulation" sheet, there are three different sections dedicated to the three phases. The goal is to provide an overview of the total thermal bridges of the building and their position, if the thermal bridges were estimated or calculated during the project and if additional measures to minimize the losses were designed/implemented/constructed. The same feature to ensure sufficient communication is added as well as to the sheets of "Windows & Shadings", "Airtightness" and "MVHR & HVAC".
- The tab of ***"Windows & Shadings"*** aims to create a summary of the characteristics of the windows and their placement, orientation, size and thermal characteristics to understand how shielded the house is from the external conditions and how it takes advantage of the possible solar gains. Again, the information gathered is a summary of the total openings of the building and if there are multiple typologies, selectively, the ones that represent the three typical openings of a building are inserted; a typical window, a typical door and a typica balcony door at least. Regarding the respective types of openings, the selected shading systems are

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

expected to be inserted as well as the dynamic analysis for the shading reduced factors in case it has been performed.

- The tab of ***"Airtightness"*** aims to give a general image of the airtightness of the building and define which one is the selected airtightness layer. In some cases, there are special materials and systems (tapes, membranes, boxes) applied to ensure high airtight standards are met, besides the standard practices in a construction, such as plaster, that accidentally improve the airtightness level of a building. To get a typical image of the planning, the available variety of materials and the applied ones, general information are requested to be able to define approximately the expected air changes per hour so an experienced professional from the building can see the progress and the actual situation of the airtightness of a building in a new construction or in a renovation and the differences from the designed to the delivered building. Goal of this tab is to give special attention to users of this tool in countries in Southern and Eastern Europe, where airtightness practices are not obligatory from the national standards and to track it.
- Lastly, the tab ***"MVHR & HVAC"*** includes all the information for the non-passive measures that help with the coverage of the heating and cooling demand.

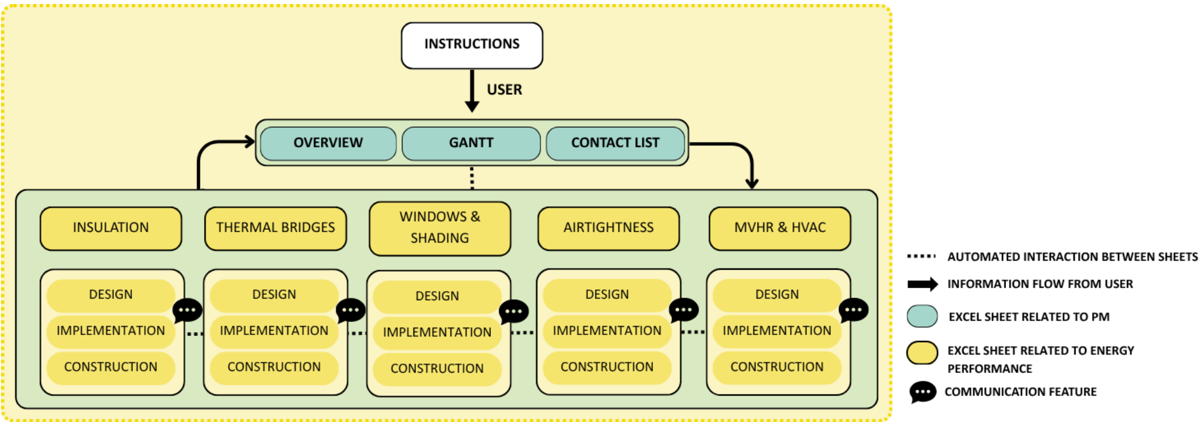


Figure 11. Overview of the architecture in the excel file.

In the next deliverable of M30, the final structure will be presented as well as the final conclusions and the necessary supporting materials to be functional. At this deliverable, the technical specifications for data exchange will not be presented.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

8. Conclusions

To summarize, conclusions derived from the total document are presented. Starting from the challenges, the main identified problem is systemic, the breakdown in information management across the construction lifecycle. The lack of standardized mechanisms for continuous data synchronization between design, implementation and construction phases permits professionals to operate isolated with conflicting incentives. The cost of miscommunication translates into incomplete implementation studies, expensive site-work, multiple modification in design and performance deviations. The document establishes that this challenge is not a unique case, but that manifests itself in various environments.

Different countries require different tools (Greece benefits from simpler systems with lower barrier to entry; Germany's regulatory complexity demands more sophisticated compliance tracking), but all require common protocols for how information flows between phases.

The available tool exhibits a mismatch between capabilities and implementation barriers. BIM technology possesses the theoretical capacity to integrate lifecycle information (geometry, materials, cost, circularity indices, energy performance) yet adoption remains limited due to high initial investment and training requirements, inconsistent workflows across professional disciplines, and lack of seamless interoperability between specialized tools. Engineers rely on parallel software (EnergyPlus, PHPP, IDA-ICE, DGNB) with manual data transfers between programs, introducing coordination gaps and transcription errors. At the same time, construction management platforms (Monday.com, ClickUp, Milient, Trello) excel at task tracking and timeline visualization but fail at design-construction integration.

The workflow of ArchBuilder methodology represents a shift from linear to cyclical thinking. Rather than optimizing each phase independently, the methodology enforces continuous feedback loops where each phase's outputs become the next phase's constraints. The critical innovation is explicit phase-gating and role definition: every participant knows exactly which information they must fill in and how that information flows downstream. This transforms construction from an exercise in damage control into an exercise in coordinated optimization.

The decision to implement the initial version of the ArchBuilder tool in Excel is strategic: it prioritizes accessibility, allowing professionals with basic digital literacy to use the tool without requiring BIM expertise or expensive software licenses. The modular structure (Insulation, Thermal Bridges,

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Windows & Shadings, Airtightness, MVHR & HVAC) enables country-specific adaptation and integration with existing regional software ecosystems, such as Edilclima for Italy, TEE-KENAK for Greece, while maintaining methodological consistency.

The Excel structure reflects an information hierarchy where sheets feed technical modules. The critical feature is the communication infrastructure embedded within technical sheets. This addresses the deliverable's core finding: **communication is not the absence of talking but the absence of structured repositories where decisions and their rationales are documented persistently and searchable.**

The document's ultimate contribution is establishing that the construction sector's productivity problem is not only a technology problem; it is an institutional coordination problem that technology can help solve but cannot solve alone. ArchBuilder succeeds or fails based on commitment to the discipline of structured communication and role clarity. This represents an inversion of current practice: instead of assuming better software will automatically improve outcomes, ArchBuilder assumes that process discipline makes even simple software effective, while poor process makes sophisticated software (BIM) waste resources on data entry and conflict resolution rather than value creation.

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

9. References

[1] Ala-Juusela, M.; Rehman, H.U.; Hukkalainen, M.; Tuerk, A.; Trumbic, T.; Llorente, J.; Claes, S.; Tsitsanis, S.; Latanis, K.; Maas, E. (2020). D1.1 PEB as Enabler for Consumer Centred Clean Energy Transition: Shared Definition and Concept (Deliverable 1.1 of H2020-870157 EXCESS project). Retrieved from https://positive-energy-buildings.eu/

[2] Ferriz-Papi, J.A.; Lee, A.; Alhawamdeh, M. Examining the Challenges for Circular Economy Implementation in Construction and Demolition Waste Management: A Comprehensive Review Using Systematic Methods. Buildings 2024, 14, 1237. https://doi.org/10.3390/buildings14051237.

[3] European Commission, "Buildings and construction," *Single Market, Industry, Entrepreneurship and SMEs*, 2024. [Online]. Available: https://single-market-economy.ec.europa.eu/industry/sustainability/buildings-and-construction_en. [Accessed: Oct. 20, 2025].

[4] Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), *Umweltfußabdruck von Gebäuden in Deutschland*, 2020. [Online]. Available: https://www.bbsr.bund.de/BBSR/DE/veroeffentlichungen/bbsr-online/2020/bbsr-online-17-2020-dl.pdf?__blob=publicationFile&v=3. [Accessed: Oct. 27, 2025].

[5] Federal Statistical Office of Germany (Destatis), "Pressemitteilung Nr. 261," *Destatis*, Jun. 2021. [Online]. Available: https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/06/PD21_261_321.html. [Accessed: Oct. 27, 2025].

[6] Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), *Analysen Kompakt 05/2025: Zentrale Ergebnisse der BBSR-Wohnungsbedarfsprognose. Neubaubedarfe in Deutschland bis 2030*, 2025. [Online]. Available: https://www.bbsr.bund.de/BBSR/DE/veroeffentlichungen/analysen-kompakt/2025/ak-05-2025-dl.pdf?__blob=publicationFile&v=2. [Accessed: Oct. 27, 2025].

[7] Federal Environment Agency (Umweltbundesamt), "Das anthropogene Lager," *Umweltbundesamt*, May 11, 2022. [Online]. Available: https://www.umweltbundesamt.de/themen/abfall-ressourcen/abfallwirtschaft/urban-mining/das-anthropogene-lager. [Accessed: Oct. 27, 2025].

[8]German Environment Agency (UBA), "Altholz – Verwertung und Produktion in Deutschland," 2015. [Online]. Available: https://www.umweltbundesamt.de/altholz#verwertung-und-produktion-in-deutschland. [Accessed: Oct. 27, 2025].

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

[9] Academia.edu. A Comparative Study on Discrepancies in Residential Building Energy Performance Certification in a Mediterranean Context. October 27, 2025,from https://www.academia.edu/125278819/

[10] G. Maniatis, A. Mavropoulos, F. Stroubakou, and N. Vettas, "Trends, Challenges and Prospects of Construction in Greece," Foundation for Economic and Industrial Research (IOBE), Athens, Greece, Jun. 2025. [Online]. Available: https://iobe.gr/docs/research/en/RES_05_F_24062025_REP_EN.pdf

[11] Renovate Europe. (2024). National Initiatives: Greece. Retrieved October 28, 2025 from https://www.renovate-europe.eu/national-initiatives/greece/

[12] The Ellinikon. About Us: The Ellinikon. Retrieved October 28, 2025 from https://theellinikon.com.gr/en/about-us/the-ellinikon/

[13] German Sustainable Building Council (DGNB). (2025). Building Resource Passport. Retrieved January 13, 2025, from https://www.dgnb.de/en/sustainable-building/circular-building/building-resource-passport

[14] Eurostat, "GDP and main components - current prices," Eurostat Data Browser, [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/tps00177/default/table?lang=en. [Accessed: 05-Nov-2025].

[15] European Environment Agency, "Greece - Municipal Waste Management Country Profile," May 2022.

[16] Solomon, "Every Minute, a Building in Europe is Demolished," Oct. 2025.

[17] Autodesk. Revit Features. Retrieved October 28, 2025, from https://www.autodesk.com/products/revit/features

[18] Trimble SketchUp. Benefits of SketchUp. Retrieved October 28, 2025, from https://sketchup.trimble.com/en/benefits-of-sketchup

[19] Rhino 3D. Version 7. Retrieved October 28, 2025 from https://www.rhino3d.com/7/

[20] Graphisoft. ArchiCAD: Plans and Products. Retrieved from https://www.graphisoft.com/plans-and-products/archicad/

Co-funded by
the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

[21] Passive House Institute. Passive House Package Planning (PHPP). Retrieved October 28, 2025, from https://passivehouse.com/04_phpp/04_phpp.htm

[22] U.S. Department of Energy. EnergyPlus. Retrieved October 28, 2025, from https://energyplus.net/

[23] EQUA. IDA Indoor Climate and Energy (IDA ICE). Retrieved October 28, 2025 from https://www.equa.se/en/ida-ice

[24] Edilclima. Edilclima Software. Retrieved October 28, 2025 from https://en.edilclima.it/

[25] "Construction and real estate management software - PlanRadar." [Online]. Available: https://www.planradar.com/. [Accessed: 19-Nov-2025].

[26] Nguyen P, Akhavian R (2019) Synergistic Effect of Integrated Project Delivery, Lean Construction, and Building Information Modeling on Project Performance Measures: A Quantitative and Qualitative Analysis. Advances in Civil Engineering 2019:1–9. https://doi.org/10.1155/2019/1267048

[27] Bajjou MS, Chafi A (2020) Lean construction and simulation for performance improvement: a case study of reinforcement process. Int J Productivity and Performance Management, ahead-of-p(ahead-of-print). https://doi.org/10.1108/IJPPM-06-2019-0309

[28] Ramani PV, KSD, L. K. L. (2021) Application of lean in construction using value stream mapping. Eng Constr Archit Manag 28(1):216–228. https://doi.org/10.1108/ECAM-12-2018-0572

[29] Enshassi A, Saleh N, Mohamed S (2021) Barriers to the application of lean construction techniques concerning safety improvement in construction projects. Int J Constr Manag 21(10):1044–1060. https://doi.org/10.1080/15623599.2019.1602583

[30] Schimanski CP, Pasetti Monizza G, Marcher C, Matt DT (2021) Development of a BIM-based production planning and control system for Lean Construction through advancement and integration of existing management techniques. Frontiers of Engineering Management 8(3):429–441. https://doi.org/10.1007/s42524-020-0105-5

[31] Hampson I (1999) Lean Production and the Toyota Production System Or, the Case of the Forgoften Production Concepts. Econ Ind Democr 20(3):369–391. https://doi.org/10.1177/0143831X99203003

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

[32] Si T, Li HX, Hosseini MR, Ji Y, Liu C (2020) A Solution to Just-in-Time Delivery for Off-Site Construction: A Conceptual Model. Construction Research Congress 2020:345–353. https://doi.org/10.1061/9780784482865.037

[33] Schimanski CP, Pasetti Monizza G, Marcher C, Matt DT (2021) Development of a BIM-based production planning and control system for Lean Construction through advancement and integration of existing management techniques. Frontiers of Engineering Management 8(3):429–441. https://doi.org/10.1007/s42524-020-0105-5

[34] Evans M, Farrell P (2023) A strategic framework managing challenges of integrating lean construction and integrated project delivery on construction megaprojects, towards global integrated delivery transformative initiatives in multinational organisations. Journal of Engineering, Design and Technology 21(2):376–416. https://doi.org/10.1108/JEDT-08-2021-0402

[35] Awad T, Guardiola J, Fraíz D (2021) Sustainable Construction: Improving Productivity through Lean Construction. Sustainability 13(24):13877. https://doi.org/10.3390/su132413877

[36] Sepasgozar SME, Hui FKP, Shirowzhan S, Foroozanfar M, Yang L, Aye L (2020) Lean Practices Using Building Information Modeling (BIM) and Digital Twinning for Sustainable Construction. Sustainability 13(1):161. https://doi.org/10.3390/su13010161

[37] Tafazzoli M, Mousavi E, Kermanshachi S (2020) Opportunities and Challenges of Green-Lean: An Integrated System for Sustainable Construction. Sustainability 12(11):4460. https://doi.org/10.3390/su12114460

[38] monday.com. Project Management Platform. Retrieved October 28, 2025 from https://monday.com/

[39] ClickUp. Project Management and Collaboration Platform. Retrieved October 28, 2025 https://clickup.com/

[40] Millient. Project Management Software. Retrieved October 28, 2025 https://www.milientsoftware.com/

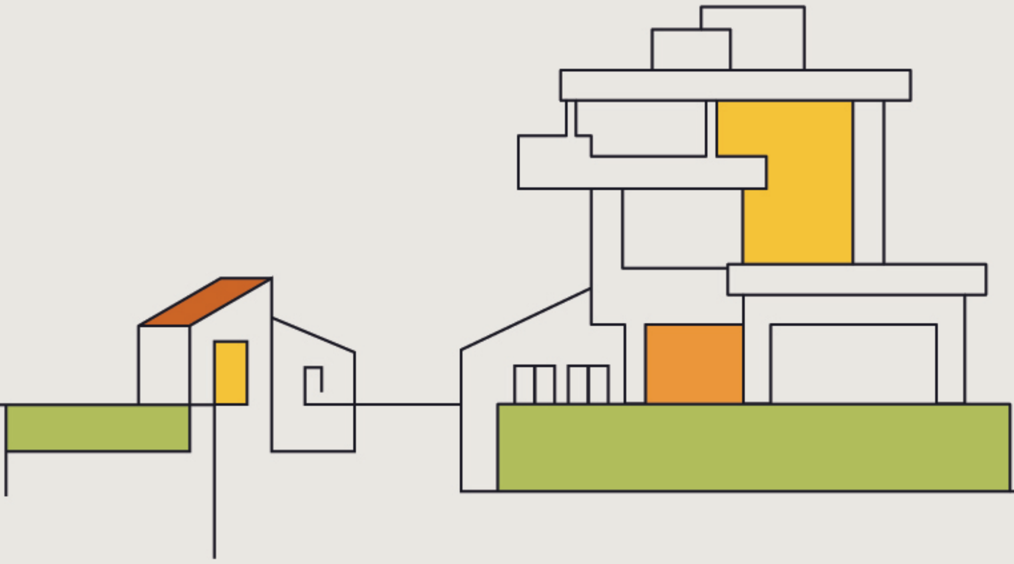
[41] Trello. Kanban Board Project Management. Retrieved October 28, 2025 https://trello.com/

[42] Atkinson, R. (1999). Project Management: Cost, Time and Quality, Two Best Guesses and a Phenomenon, It's Time to Accept Other Success Criteria. *International Journal of Project Management*, 17(6), 337–342. https://doi.org/10.1016/S0263-7863(98)00069-6

Co-funded by the European Union

SIRCULAR has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101147412. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

www.sircularproject.eu



@SircularProject

@SIRCULAR Project