D7.2: Prototypical implementation – Part 1

COST REDUCTION AND MARKET ACCELERATION FOR VIABLE NEARLY ZERO-ENERGY BUILDINGS

Effective processes, robust solutions, new business models and reliable life cycle costs, supporting user engagement and investors' confidence towards net zero balance.

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D7.2: Prototypical implementation – Part 1

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FOREWORD

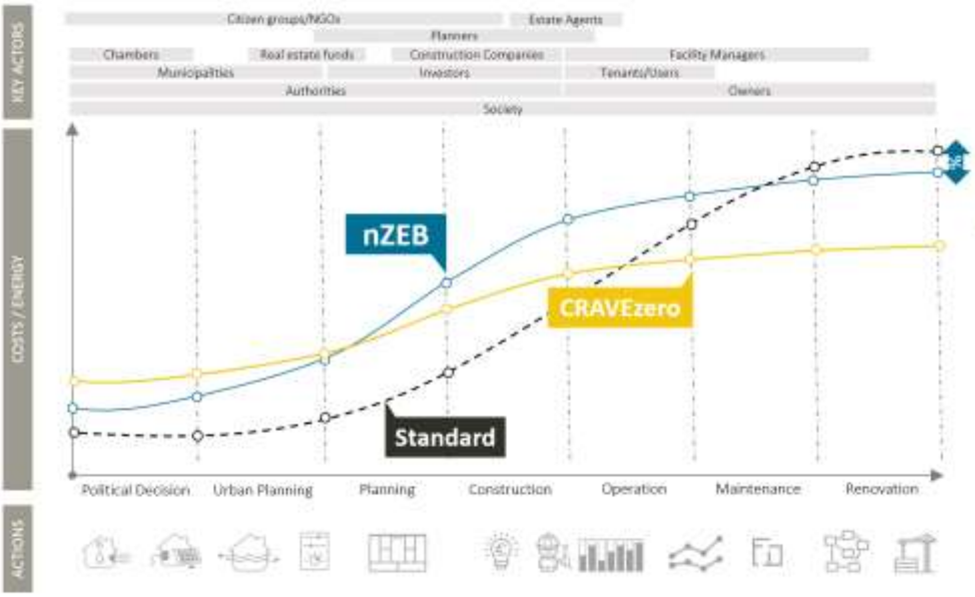

Figure 1: CRAVEzero approach for cost reductions in the life cycle of nZEBs.

Cost optimal and nearly zero-energy performance levels are principles initiated by the European Union's (EU) Energy Performance of Buildings Directive, which was recast in 2010 and amended 2018 [3]. These will be significant drivers in the construction sector in the next few years because all new buildings in the EU from 2021 onwards are expected to be nearly zero-energy buildings (nZEB). While realised nZEBs have clearly shown that nearly zero-energy target could be achieved using existing technologies and practices, most experts agree that a broad-scale shift towards nearly zero-energy buildings requires significant adjustments to prevailing building market structures. Cost-effective integration of efficient solution sets and renewable energy systems, that go along with the development, manufacturing and construction industry processes, as well as with planning, design, and procurement procedures, are the major challenges.

This report summarises the outcomes of the work package prototypical implementation of the CRAVEzero project. The project partners ATP Sustain, Bouygues Construction, Köhler & Meinzer, Skanska, Moretti and 3i have applied the "CRAVEzero methodologies" to six ongoing projects, in order to optimize their design workflow and to achieve efficient nZEBs, taking the whole life cycle of the projects into consideration. In this way, the CRAVEzero approach can demonstrate the results of its application and the replication potential for planning and construction of low LCC nZEBs. This deliverable covers the first two out of the six prototypical implementations carried out within the CRAVEzero project.

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EXECUTIVE SUMMARY

The objective of work package 7 is to provide the methodological framework for the implementation of the CRAVEzero approach. The idea is to collect all the methodologies and approaches developed within the project and then to test them, implementing those methodologies to case studies/ongoing project developments by the project partners: ATP sustain, Bouygues, Skanska, Moretti, 3i and Köhler & Meinzer.

This deliverable builds upon the methodologies as published in the CRAVEzero pinboard (http://pinboard.cravezero.eu/) and Deliverable 7.1: "CRAVEzero pinboard", which is devoted to the pinboard description. The aim is to provide the user with all necessary information, online and downloadable tools and databases to develop specific business models (BM) and technology sets for low Life Cycle Cost (LCC) nZEBs, suitable for different building types in different climate regions.

The first part of this deliverable provides an overview of the main features characterizing the CRAVEzero approach for realizing nZEBs. The second part presents the results of the application on the design process of two case studies, called "prototypical implementations", with a direct feedback on the applicability of the developed methodologies, a validation of the approach and an assessmept of the impact of the approach on the design and results.

In this regards, it is important to underline that CRAVEzero's primary goal is to identify and eliminate the extra costs for nZEBs, related to processes, technologies, building operation, and to promote innovative business models taking into account the cost-effectiveness for all the stakeholders during the life cycle of the building.

For the purposes of a practical implementation, the proposed CRAVEzero methodology, which aims at achieving those targets, can be divided into eight majors steps:

1. Define energy and related project goals.
2. Define actions to reach the goals and track them throughout the life cycle.
3. Create win-win situations for all stakeholder.
4. Select optimal nZEB technical solution sets.
5. Do life cycle cost analysis and variants.
6. Quantify co-benefits for nZEBs.
7. Learn from frontrunners and avoid pitfalls and bottlenecks.
8. Bring all together in the business case for nZEBs.

Each step can be easily implemented with the support of one or more of the tools available on the pinboard:

- **Business Model Repository and Canvas:** It offers the possibility to browse through existing business models or to create new ones. The business model repository collects 60 existing nZEB business models, where the life cycle phases are indicated. It is also possible to create a business model from scratch with the Business Model Canvas creator.
- **Case-study dashboard – Frontrunner buildings:** Within the dashboard, users can add and remove data, change visualization types, and apply filters. The idea of this interactive dashboard is to allow users of the pinboard to dig into the data, discover insights and look for optimal solutions that can also be applied for their nZEB developments.
- **Process Map:** The Process Map is a process tool that enables the project team to integrate additional tasks and actions for achieving the nZEB standard into their own planning, construction and execution routine.
- **Life Cycle Tracker Tool and process management**: An excel tool was developed, which is intended to provide assistance to consider the relevant aspects and actions of individual planning phases in the realization of nZEBs.
- **Life cycle cost tool:** A tool for the LCC calculation was developed and it is available in two versions: a complete version with all functionalities and freedom to customize and a

reduced online version, which permits to do a preliminary LCC calculation.

As mentioned before, the project partners (in this case Moretti and 3i) applied a set of tools and methodologies to two case studies as "prototypical implementation". These two cases have a peculiar feature: they do not represent specific projects, but more general building models: for 3i the case is a novel flexible living building model, called "DoppioUno", while in the case of Moretti, it is a prefabricated house that can be easily replicated by the company.

DoppioUno - 3i

The structure chosen is a residential tower with seven stories and a basement. The main feature of this building is its design for flexibility. In fact, each floor has the possibility to adopt different interior layouts according to the evolution of the user needs, ranging from the studio flat to the four-room apartment. In this way, DoppioUno is adaptable over time and can meet different demands.

The analysed building is a new construction, designed by different engineering and architecture sectors of the 3i group. The aim is to compare the life cycle costs of a nZEB with a standard building in the current real estate stock of northern Italy and to carry out a preliminary quantitative analysis of the DoppioUno business model.

Targeted building performaces are: reduction of energy cost influence for the user of the BM DoppioUno, high production of energy from renewable sources, low purchase costs for the buyer, and economic sustainability for the company.

Currently, buildings constructed with the current standard, besides a lower envelope quality, have only a limited production of renewable energy, while a solar system and a photovoltaic system supplying a high amount of the energy needs are installed on the roof of the DoppioUno building. In addition, compared to the standard building, it integrates an advanced control and automation system for all the installed services.

The objective of implementing the LCC methodology, as developed within CRAVEzero, consists in quantifying the costs of the entire life cycle of a new nZEB, compared to a building of the same volume but with construction features and thermal systems typical of the current real estate park in northern Italy.

The performed calculation, considering a life span of 40 years, shows a LCC of the DoppioUno nZEB of € 8,107,555 €, which is 14 % higher than the standard building. However, the initial investment costs for the nZEB were 33 % higher than the standard building, during the life cycle the cost gap decreased due to the reduced energy consumption, despite the higher maintenance costs.

The implementation of life cycle costing was the first fundamental step for the quantitative analysis of the feasibility of the business model DoppioUno. The main advantages of applying this methodology are:

- Availability in a single instrument - all the costs that must be incurred to design, build and operate a building.
- Possibility to compare the incidence of each cost item at the end of life, and consequently to carry out interventions and design choices for their reduction.
- Possibility to compare different design choices from an economic point of view throughout the life cycle.
- Mapping of all costs that must be incurred for the design and construction of a building allowing not to leave out cost items in the economic evaluation of the work.

However, the implementation of the methodology requires a relevant expenditure in terms of time during the design phase of the building, however this allows to transform this cost into a future added value.

A further implemented methodology is the CRAVEzero Business model canvas. This methodology conducted in the preliminary development of the business model, backs up the LCC analysis, aiming at analysing key parameters and deepening the business model structure and features. The main objective achieved through the application of the methodology was the qualitative and quantitative definition of the key points, costs and revenues for the new business model. Furthermore, the database analysis of existing business models enables to compare the new model with the current market proposals.

Casa More Franchino - Moretti

The second case study is the model of a prefabricated house developed by Moretti called 'Casa More'.

In particular, the application to a single family house of one storey has been analysed, with prefabricated concrete panels and wooden roof, which combine structural and thermal performance, located in the northern of Italy. For this prototypical implementation, two methodologies have been selected: LCC analysis and process map. The objective was to define a standard methodology to be integrated in the company's workflow and applied to future projects.

Having completed the construction phase of the building, a comparison was carried out, using the LCC tool, between two variants, keeping the same characteristics for the building envelope:

- Variant A: the HVAC system configuration as planned in the design phase,
- Variant B: the HVAC system implemented in the construction phase.

Both cases have similar initial investment cost, due to the construction cost, which represents the largest cost share. However, the operating costs in the variant B are higher, due to the greater demand for primary energy. Another interesting result is about the different impact of the maintenance phase. The same amount is reached at the end of the considered period, but it is clear that the maintenance costs grow much faster in the variant B. This difference is due to the the number of systems selected and the simplified solution installed in the first place. Based on these results, the LCC tool can be a very useful application to be introduced in the company's methodology in order to evaluate with the client the best configuration taking into account a large time frame. In fact, one of the main advantages is being able to analyse, already in the preliminary stage, how different solutions can affect the costs during and after the construction. In this way the company will have reliable arguments to lead the client to choose the best solution for his/her needs, looking at the whole life cycle of the building and not only at the early investment.

Moreover, Moretti is involved in planning and construction phases and has an in-house approach that guides all the stakeholders during the process. Company's process map is structured in eight steps, each phase identifies the activities to carry out, the main actors involved with the RACI scheme (Responsible, Accountable, Consulted, Informed), the scheduled time to complete the activities. Each phase can be further detailed and elaborated, if needed. Although Moretti's process map is a tested and useful guideline throughout all phases for involved stakeholders, this process is not aimed to new nZEBs , but to Moretti's core activity, custom prefabricated houses. Therefore it is interesting to integrate CRAVEzero tools in Moretti's workflow.

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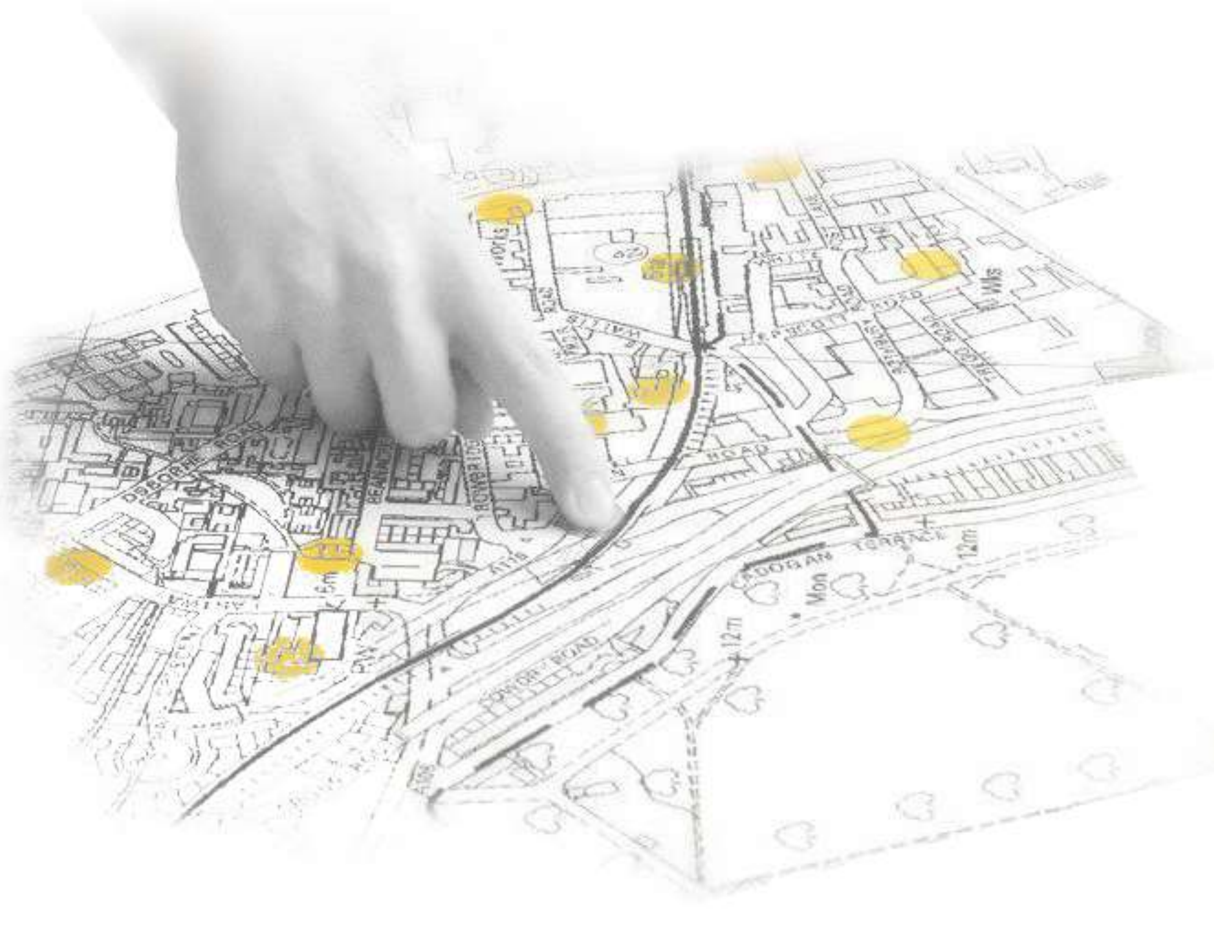
CHAPTER 1

CRAVEZERO METHODOLOGY



1.CRAVEZERO METHODOLOGY

1.1. INTRODUCTION

The objective of work package 7 is to provide the methodological framework for the implementation of the CRAVEzero approach. The idea is to collect all the methodologies and approaches developed within the project and then to test them, implement those methodologies to case studies/ongoing project developments by the project partners: ATP sustain, Bouygues, Skanska, Moretti, 3i and Köhler & Meinzer. In this way, the CRAVEzero approach can demonstrate the results of its application and the replication potential for planning and construction of low LCC nZEBs.

This deliverable builds upon the methodologies as published in the CRAVEzero pinboard (http://pinboard.cravezero.eu/) and Deliverable 7.1, which is devoted to the description of the pinboard and its functionalities.
The CRAVEzero pinboard is a structured framework, which collects and organizes all major methodologies, results and tools developed along the project activities to build reliable and viable low life cycle cost nZEBs. The pinboard makes these results available as an interactive support web tool for most of the involved stakeholders such as developers, designers, advisors, general contractors, suppliers/sub-contractors, investors and financiers. It permits the organization of data and information in a user-friendly visual way. The aim is to provide the user with all necessary information, online and downloadable tools and databases to develop specific business models and technology sets for low LCC nZEBs, suitable for different building types in different climate regions.

Deliverable 7.2 is devoted to the first application of CRAVEzero methodology. The objective is to test and display how the CRAVEzero approach has been implemented in two ongoing planning/construction processes provided by the project partners, the so-called "prototypical implementations". Four more of these "prototypical implementations" are described in deliverable 7.3. In the first part, this deliverable provides an overview on the main features of the pinboard tools and describes the meaning of applying CRAVEzero on a real case. The second part is focused on the practical application on two case studies. The two cases represent replicable building paradigms: the first one "DoppioUno" represents the model of flexible building, able to adapt its configuration to the evolution of the needs of the users throughout the life span. The second one is a single family house constructed with a prefabricated structure realized by Moretti, that followed the entire process from the design to the construction of the building elements towards the installation and operation. This house represents one of the products that the company Moretti sells on the market, thus represent a replicable model to be fine-tuned and further implemented for new buildings.

1.2. METHODOLOGY DESCRIPTION

CRAVEzero's primary goal is to identify and eliminate the nZEBs extra costs, related to processes, technologies, building operation, and to promote innovative business models, which create win-win situations and cost-effectiveness for all the involved stakeholders. The main targets pursued in the project can be summarized as follows:

- The reduction of construction-related costs compared to the current cost of a new conventional building that meets current building regulations.
- The nearly zero (or beyond) energy consumption (including on-site or nearby

renewable energy sources) and nearly zero impact of materials used over the whole life cycle.

- The co-benefits such as increased real estate value and working environment quality.
- The cost-effectiveness of the investment from a business model point of view.

To achieve those targets, a methodology has been developed and proposed within CRAVEzero project. This methodology can be divided into eight major steps (Figure 2):

Figure 2. The eight major steps of the CRAVEzero methodology.

1. Define energy and related project goals.
2. Define actions to reach the goals and track them throughout the life cycle.
3. Create win-win situations for all stakeholder.
4. Select optimal nZEB technical solution sets.
5. Do life cycle cost analysis and variants.
6. Quantify co-benefits for nZEBs.
7. Learn from frontrunners and avoid pitfalls and bottlenecks.
8. Bring all together in the business case for nZEBs.

Define energy and cost-related project goals

It is important to clearly define energy consumption and life cycle cost goals for the project in the first step. This step lays the foundation for defining key actions needed to achieve those goals, avoiding pitfalls and bottlenecks.

Define actions to reach the goals and track them throughout the life cycle

Considering the complexity to reach nZEB-target with cost-optimal solutions for all the different stakeholders, multiple actions are required. However, these are usually missing in standard planning processes. Therefore, it is important to promote a shared, interdisciplinary understanding of the complexity of nZEB planning processes for all involved stakeholders. A well-organized and transparent process is a key issue of achieving the goal of cost-optimal and sustainable nZEBs throughout the entire life cycle. The CRAVEzero consortium, which provided its experience in the area of holistic project management with a focus on integral building planning of nZEBs, defined how key performance parameters, to achieve successful nZEBs, should be prioritized and can be tracked along the whole life cycle process. Additional advantages of this approach are:

- Risk reduction.
- Speed-up of construction and delivery.
- Control over costs and energy performance.
- Foster integrative design and make optimal use of team members’ expertise.
- Establishment of measurable success criteria.

Deliverable D3.1: "Guideline I: nZEB processes" and D3.2: "Optimized nZEB process map" are dedicated to this step.

Create win-win situations for all stakeholders

A win-win situation for the involved stakeholders needs to be created to push and support the nZEB market uptake. To do that a win-win situation has to be translated into a business model.

Business models are usually based on cooperative strategies, where different stakeholders bundle their expertise to create positive outcomes for all processes, creating synergies and 'win-win' situations. Already existing and new examples for 'Win-win-win' nZEB business models have been analyzed during CRAEzero project, showing advantages to different types of stakeholders, for example, planners, developers, construction companies and users, while positively contributing to the environment and society. More information can be found in deliverable D5.1: "Typology canvas of business models" and D5.2: "Report describing nZEB business models".

Select optimal nZEB technical solution sets

To realize cost-efficient nZEBs for all stakeholders throughout the life cycle, knowledge about the most important technologies sets as well as possible cost developments of these technologies is essential.

Development of comprehensive solution-sets based on key industrialized components and renewable energy systems and its cost-effective integration in the design and construction process are major challenges. CRAVEzero approach has identified technical and life cycle cost reduction potentials for each nZEB technology set in order to define robust solution sets based on industrialized multifunctional building components, easy and flexible to produce, install, and maintain. Deliverable D4.1: "Guideline II: nZEB technologies" and D4.2: "Optimized nZEBsolution sets" deal with this step of the methodology.

Do life cycle cost analysis and variants

According to the ISO 15686-5:2008 [6], the life cycle costing of a building is the net present value, that is the sum of the discounted costs and revenue streams during the phases of the selected period of the life cycle. The life cycle phases generally included in the assessment are the cost for the initial investment (design and construction), the cost for operation and maintenance and the end-of-life residual value.

The implementation of LCC in the design phase allows moving the focus away from the initial investment perspective, including operation, maintenance and end-of-life stages as well. The advantages are that this methodology gives transparency on the operational phase of a building, awareness of total costs and the possibility to adjust these total costs already in the design phase. This approach leads to better determine the optimal solution-set from a cost-effectiveness point of view over a selected life cycle. As indicated in Heralova (2014) [4], the greatest benefit of LCC can be obtained in the initial phase of a construction project since it provides an appraisal function and allows:

- Balancing the cost of ownership and occupation, analyzing initial investment and running cost
- Assessing risk and costs connected to maintenance and replacement due to failure
- Supporting decisions which consider sustainability.

Furthermore, LCC calculation can be adopted to compare building variants, alternative technology sets or mutually replaceable design alternatives as well. This approach allows selecting the most cost-effective solution undertaking financial options evaluation. In this way LCC analysis becomes a tool which supports the decision making process. This is illustrated in deliverable D2.2: "Report on the EU implementation of nZEB".

Quantify co-benefits for nZEBs

It is essential to quantify the added value associated with green buildings and its impact on life cycle costs. Co-benefits such as increased productivity, improved health, publicity value, higher renting opportunities, reduced employee turnover and reduced absenteeism need to be quantified. The objective is to present new business advantages and opportunities to potential investors, going beyond technical performance analysis [1]. Deliverable D6.4: "Framework for co-benefit analysis" covers the co-benefit analysis.

Learn from frontrunners and avoid pitfalls and bottlenecks
Cost and construction time overrun for nearly-zero and plus energy buildings, due to unclear requirements, unclear processes and the lack of knowledge about these technologies. CRAVEzero project showcase frontrunner nZEB projects which have been realized in a cost-efficient way, so that pitfalls and bottlenecks can be avoided in future projects. Deliverable D6.1: "Parametric models for buildings and building clusters" analyses frontrunner buildings.

Bring all together in the business case for nZEBs
The goal was to develop an effective methodology to achieve the best conditions towards cost optimal nZEBs, exploring the concept of integrating nZEB technologies and business models in the whole planning, construction and operation process. The evaluation and generation of enhanced and innovative business models are also part of the study of nZEBs. In order to generate new business models, it is necessary to identify what types of different business models already exist in the markets and what makes them successful or inconsistent (Deliverable D5.3: "Database of all fund services and business models" and D5.4: "Guideline III: nZEB Businessmodels").

1.3. CRAVEZERO TOOLS: THE PINBOARD

The above-mentioned methodology steps and the outcomes of its development along the CRAVEzero project have been collected and condensated into the so-called 'pinboard'. The pinboard can be considered the backbone of CRAVEzero project, allowing changing the approach for the design and construction of new nZEBs through the solutions, ideas and tools developed. A brief overview of the pinboard's main features is required to better understand the prototypical implementations carried out by project partners (see Deliverable D7.1 for a complete description of the pinboard).

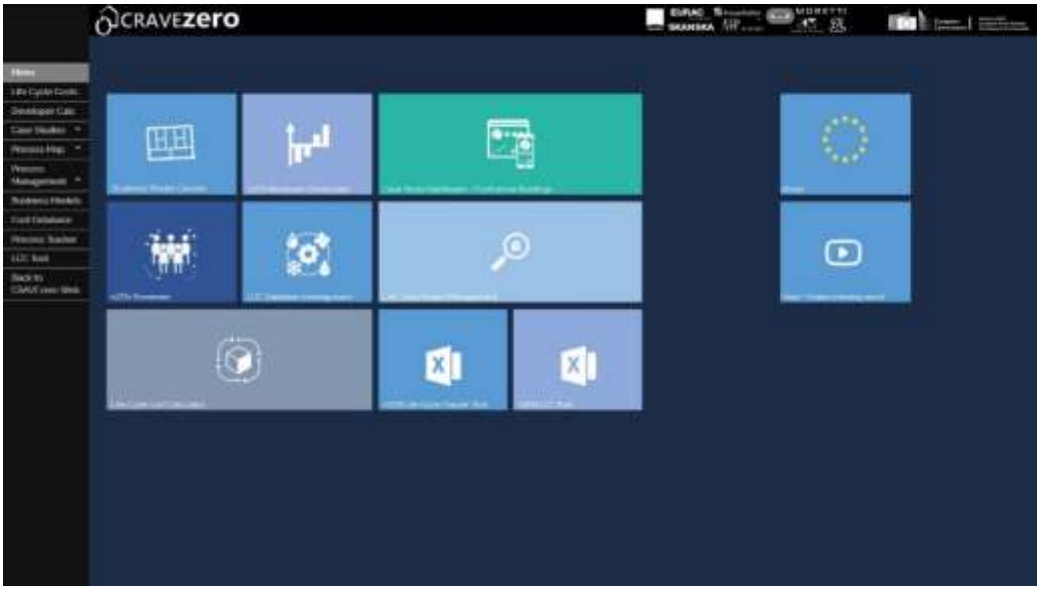


Figure 3: Pinboard landing page on CRAVEzero website (cravezero.eu).

Business Model Canvas

The business model canvas is a tool which helps to understand a business model in a straightforward, structured way. It offers the possibility to browse through existing business models or to create new ones. The business model repository collects 60 existing nZEB business models, where the life cycle phases are indicated. The information of each business model is displayed according to the Osterwalder Business Model Canvas structure: It is a visual chart with elements describing a company's or product's value proposition, infrastructure, customers, and finances.
It is also possible to create a business model from scratch thanks to the Business Model Canvas creator. This is a lean startup template for developing new or documenting your existing nZEB business models.

Case-study dashboard – Frontrunner buildings

The idea of this interactive dashboard is to allow users of the pinboard to dig into the data and discover insights and look for optimal solutions that can also be applied for their nZEB developments. The web-report is highly interactive and highly customizable. Within the dashboard, users can add and remove data, change visualization types, and apply filters.

Process Map

The Process Map is a process tool that enables the project team to integrate additional tasks and actions for achieving the nZEB standard into their own planning, construction and execution routine. It gives an initial overview of the complexity and the possibilities of influencing the planning and construction process in order to develop an nZEB. In the interactive process map, stakeholders are able to display individual “nZEB specific action items” (To Do's) or alternatively to see which tasks other project participants have, in order to achieve a nZEB. The whole process is divided into the following planning and construction steps: urban planning; planning; building construction; utilization; end-of-life. In addition, action items and bottlenecks can be displayed for the following stakeholders: owner / user; municipalities; integrated planning team; construction companies.

Life Cycle Tracker tool and Process Management

CRAVEzero Life Cycle Tracker is an easy to customize electronic document that can be adapted to the specific needs of any practice, team or project. It organises the process of briefing, designing, constructing, maintain-ing, operating and using building projects into a number of key stages. It gives details of the tasks and outputs required at each stage, which may vary or overlap to suit specific project requirements. It is a downloadable spreadsheet, in Microsoft Excel format, containing customizable tables allowing easy creation of the project roles, design responsibility matrix and multidisciplinary schedules of services.

CRAVEzero Life Process Management tool is an online tool which allows tracking and managing an nZEB Project Throughout the whole life cycle.

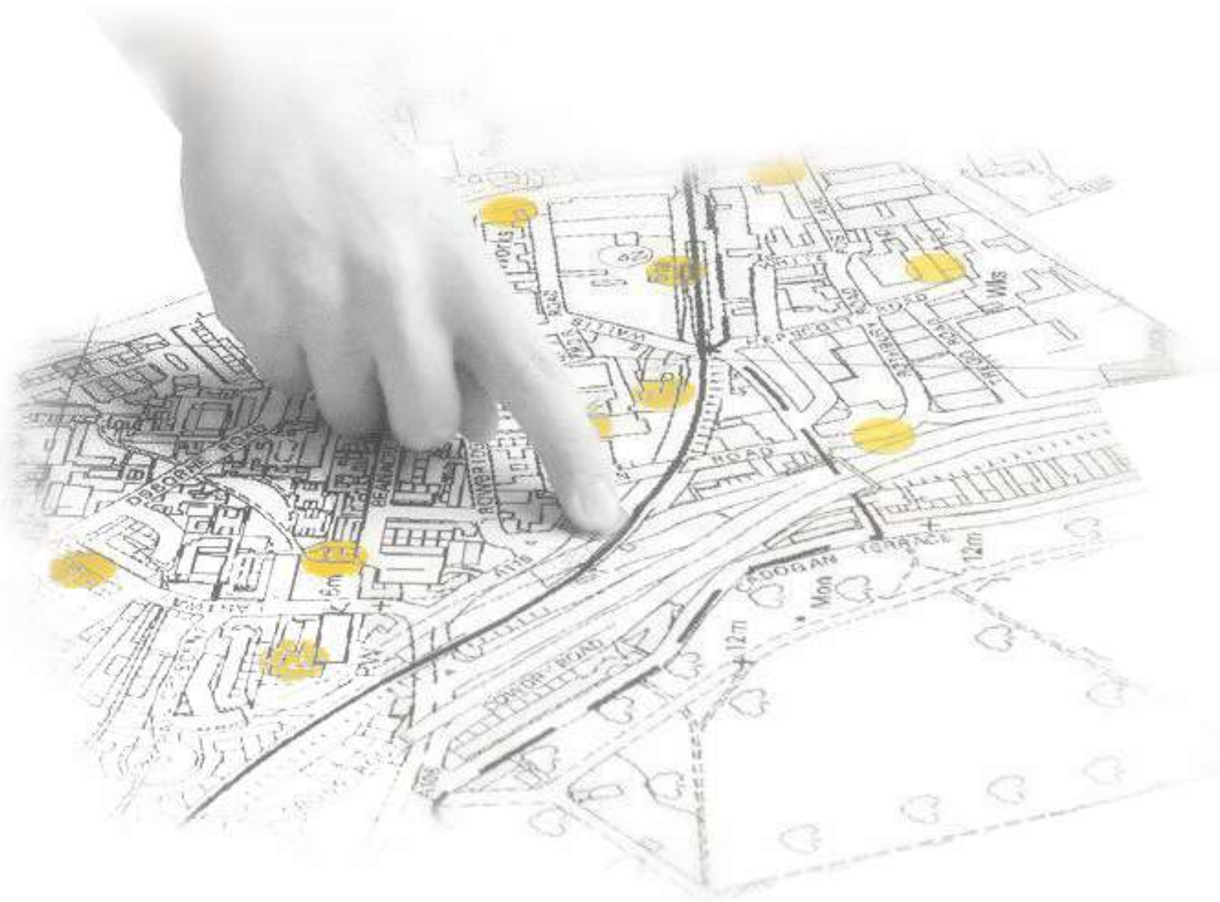
Life-cycle cost tool

A tool for the life cycle cost calculation was developed and it is available in two versions: a complete version with all functionalities and freedom to customize and a reduced online version, which permits to do, a preliminary LCC calculation.

The data collection, within the tool, is organized following as a base reference the LCC structure introduced by the standard ISO 15686-5:2017 [6]. Furthermore, the source used to structure the construction costs is the European Code of Measurement, elaborated by the European Committee of the Construction Economists. Regarding the analysis of maintenance costs of Heating, ventilation, and air conditioning (HVAC) systems, this is based on standard values from EN 15459:2018 [7], which provides yearly maintenance costs for each element, including operation, repair, and service, as a percentage of the initial construction cost. Lifespan for system replacement is also provided by the norm. According to the ISO 15686-5:2017 the LCC analysis includes the processes from point 2 to 5, and it deals with the activities connected with the design, construction and operation of the building. End-of-life costs have not been implemented in the tool yet. The Whole Life Cost (WLC) includes also the non-construction cost (e.g. cost of land, enabling activities) and the needed fees for allowing the set-up of the building from the technical and administrative point of view.

CHAPTER 2

IMPLEMENTATION PHASE I



2.IMPLEMENTATION PHASE I

In this implementation phase the project partners 3i engineering and Moretti have applied the methodologies and the tools, developed within CRAVEzero project, to two building models. In the first case for the design and comparison of the solutions and related business model for the concept of a flexible building, able to adapt its features to the needs of the users. In the second case for testing the decision-making process followed by the company Moretti for evaluating the configurations of the prefabricated building. The overall targets pursued in the realization of these so-called "prototypical implementations" are defined as follows:

- The reduction of construction-related costs compared to the current cost of a new conventional building that meets current building regulations.
- The nearly zero (or beyond) energy consumption (including on-site or nearby renewable energy sources) and nearly zero impact of materials used over the whole life cycle.
- The co-benefits in terms of real estate and architectural value (increasing living experience and building functionality).

CRAVEzero project aims at fostering these goals through the application of the developed approach in these prototypical implementations, which will provide a feedback on its validity and impact on the planning process and the obtained results. The idea is on the one hand to support the design and decision process, on the other hand to provide planners with the tools which can help them to convince involved stakeholders on the investment effectiveness and the high replication potential of the CRAVEzero approach.

Table 1: Overview of the case studies and adopted methodologies.

	3i	Moretti
Typology	Residential tower	Single family house
Net floor area	2,249 m²	125 m²
Methodology 1	LCC	LCC
Methodology 2	Business model canvas	Process map
Phase of implementation	Design	Design
Advantages	- LCC: Comparison between different design choices and cost mapping. - BM canvas: simple and quick parameters definition that build a nZEB BM.	- LCC: as support to decision making process. - Process map: focus on nZEB standard.
Disadvantages	- LCC: Time expenditure. - Business model canvas: Snapshot of the BM is taken without a forecast over time.	- LCC: difficult access to complete cost data in design phase. - Process map: do not replace the company process map completely.

3.CASE STUDY: DOPPIOUNO – 3I

3.1. GENERAL DESCRIPTION

Brief description / main features
Precast component, flexible, compact and modular, heat pump supported by a condensing boiler, photovoltaics (PV), air handling unit (AHU).

Energy concept: nZEB.

Table 2: General project information.

General project information	
Project name	DoppioUno
Location	Alessandria, Italy
Planning team	Davide Torriglia, Mirco Balachia, Marta Boschetto, Fausto Daquarti, Igor Cavallero
Architect	Gianluca Gualco
Building owner	Not defined
Net floor area	2,249 m^2
Construction date	-
Building typology	Residential tower with seven stories and a basement
Current status	Design phase

3.2. GOALS DEFINITION

Main goals and the priorities of the design
The building has been designed in order to reach: reduced investment cost (cost-effectiveness), affordability for users (purchasing power), low energy consumption.

Main constraints for the design
The main driver for the design is to limit as much as possible the construction cost, in order to enhance the convenience for the investors, constructors and for the users.

Main characteristics of the building

The walls are designed in XLAM[1] wood and are insulated with 12 cm of rock wool.

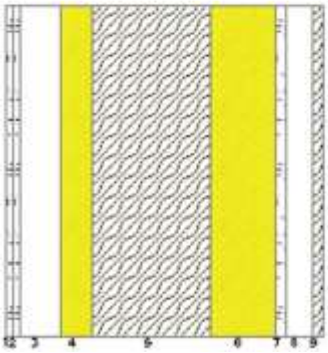


Figure 4. Building walls characteristics.

The flat roofs and the ground floors are characterized by the same construction typologies described for the vertical walls (XLAM wooden panels).

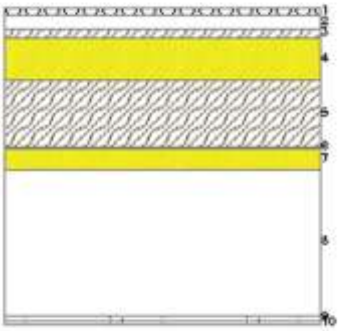


Figure 5. Building roofs/floors characteristics.

Table 3: Building envelope/structure DoppioUno

Building envelope	
U-value opaque components	0.172 W/m²K
U-value window	1.04 W/m²K (g=0.342)
Air tightness	Class 4 according to UNI EN 12207
Shading	Automatic outside(?) solar shading systems regulated through the Building Management System (BMS)

Table 4: HVAC systems and RES DoppioUno

Building services	
Heating	Centralized reversible heat pump + condensing boiler with thermal storage / Radiant panels
Domestic Hot Water (DHW)	Solar panels + Centralized reversible heat pump + condensing boiler with thermal storage
Ventilation	High efficiency heat recovery AHU
Cooling	Centralized heat pump with thermal storage
Others	LED lighting, BMS
RES	42 kW PV

[1] Cross Laminated Timber.

Targeted performances

The prototypical implementation aims to the reduction of energy costs for the user of the DoppioUno business model, high production of energy from renewable sources on-site, low purchase costs for the buyer, economic sustainability for the construction company.

Selected business model(s)

In order to foster the intervention of the investors, a business model for lowering cost of the construction (investment) was selected, increasing the affordability for the users; fostering savings in terms of building costs, energy consumption, and maintenance thanks to typological study, used technology , design and installation of building services.

Selected reference case

In order to apply the DoppioUno business model, a reference building was adopted, a multi-family house defined by the italian national standards (DM 26/06/2015[2]). The same geometry and building features was applied, and adapted the design according to the variants described in the following.

Variants

- Evaluation of the influence of the photovoltaic system in the nZEB Life Cycle Costing, comparison of operating costs at the end of the life cycle between the nZEB DoppioUno building and a traditional standard building with construction features and energy systems typical in the current Italian real estate market.
- Comparison between living in DoppioUno flexible dwelling and traditional building from the user's point of view.

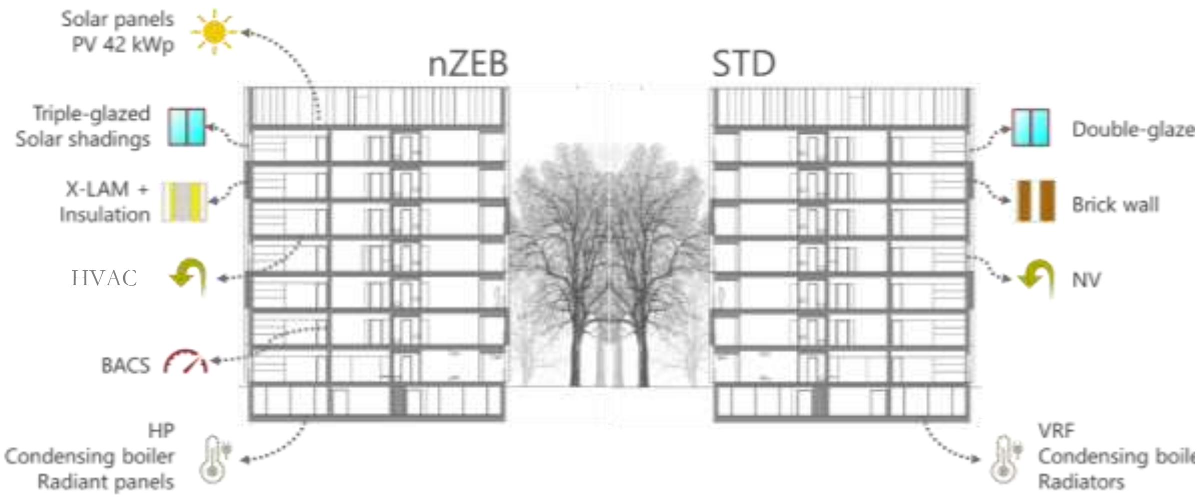


Figure 6. DoppioUno building (on the left - nZEB) and reference standard building (on the right – STD)[3].

Preliminary design

The structure chosen is the residential multi-family house as a tower with seven stories (+ basement). This typology is ideal in responding to the project requirements and is the most appropriate to the context in terms of land use and approach to the

[2] The decree of June 26, 2015 of the Minister of Economic Development defines the application of the methodologies for calculating building energy performances and the definition of minimum requirements.

[3] List of abbreviations: BACS: Building Automation and Control Systems; NV: Natural Ventilation; VRF: Variable Refrigerant Flow

landscape. It successfully addresses the typical conditions found in high intensity urban, peri-urban, and extra-urban areas. It provides residential models that - despite their complexity - feature a high quality of environment and of urban design.

The main purpose of the project is to provide desirable living conditions for all the tenants. The green spaces occupy the transition areas between the buildings and the outer limits of the land plot. The towers are characterised by wide loggias and external cladding panels that ensure ideal shielding from the sun and provide agility and vitality to the building aspects. The general layout is rational and symmetric and was designed in order to ensure the maximal level of use flexibility and reversibility in the interior spaces.

A number of different interior layouts are possible, ranging from the studio flat to the four-room apartment. DoppioUno is adaptable over time and can meet different demands. It can become a residential condominium for a variety of tenant types, a student hall of residence, or a block of serviced flats.

The tower extends over seven floors above ground and a basement. The basement will accommodate service rooms and storage spaces. On the ground floor, besides the spacious entry hall, there are some units that can also be used as workshops, offices, or multi-purpose common rooms. Possible uses include: laundry and drying room, social space, bicycle and pushchair room, library, etc. The vertical distribution is concentrated in a hub with a staircase and lift.

Figure 7. Section of the building DoppioUno.

The apartments are located in the upper part, up to a maximum of eight dwellings per floor. The layout of the apartments is functional, with living and sleeping areas always separated, and an open-plan kitchen. Each floor opens up at its four corners and gives way to wide loggias with large floor-to-ceiling windows that allow the optimal amount of natural light in and offer a pleasant view on the outside. The dwellings can be arranged according to several possible layouts. In fact, they were also designed to be combined if so desired into two-room or four-room apartments. Structure and installations are rationally designed to be functional. All utilities are located in the central hub, including electricity, water, heating, mechanical ventilation. Bathrooms and kitchens are vertically aligned across all stories.

The ceiling height in the flat is 2.7 m across all areas, apart from parts where it is slightly lowered to 2.4 m to accommodate wiring and piping. The layout of the floor plans designed allows great flexibility. The apartments can be combined or split in different moments of their life cycle, thanks to predesigned linking passageways. A total of five different types have been devised, with a wide offer including one, two, three, and four-room apartments.

Figure 8. Interior layout and possible configurations for DoppioUno BM.

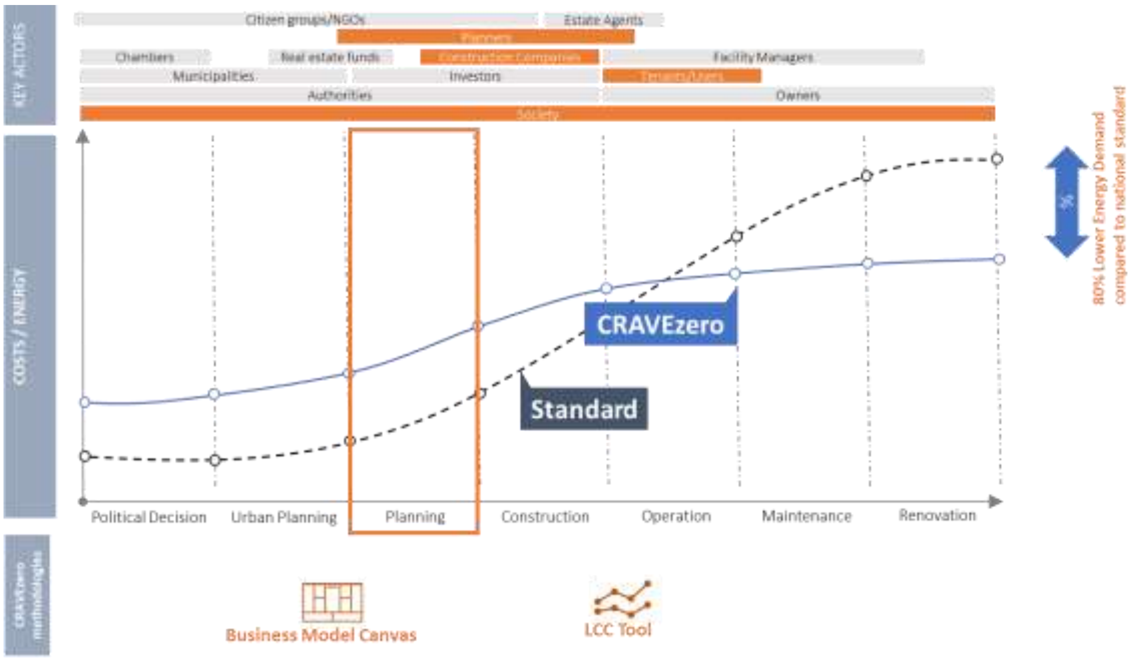
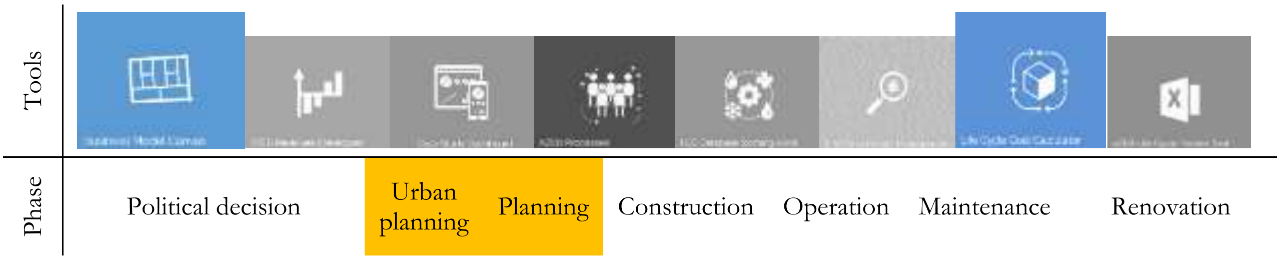


Figure 9. Graphical representation of the prototypical implementation most relevant features – 3i.

3.3. PROTOTYPICAL IMPLEMENTATION OF 3I PROJECT



3.3.1. DOCUMENTATION: LIFE CYCLE COST ANALYSIS

The LCC tool was chosen to be implemented within 3i Group design process.

The analysed building is a new construction, designed by the different engineering and architecture sectors of the 3i group. The implementation aims to compare the life cycle costs of an nZEB to a standard building in the current real estate park of the northern Italy and to carry out a preliminary quantitative analysis of the DoppioUno business model.

Each sector of the 3i Group proceeded to develop the part related to the area of competence (i.e. architecture and technical systems) by periodically sharing the progress of the work in scheduled meetings. During the elaboration of the project (architectural, structural, electrical, thermal and fireproof), metric calculations were drawn up based on the design work carried out. The metric calculations of each engineering sector include the costs for the construction of the designed building. In this case, such costs constitute the database for the implementation of the life cycle cost analysis of the building, in addition to the energy characteristics of the envelope and of the building's systems. Edilclima software[4] was used for the thermal modelling of the building in order to assess the energy performance. Edilclima summarizes all the information related to the energy characteristics of the building components and services and provides a complete overview of the technologies installed.

General project information

One of the main issues of the analysis, is to collect a comprehensive data set for the life cycle cost evaluation. To cope the issue, several meetings within the working teams were necessary, in order to merge the information of the different competence areas and to implement it in the tool.

The data collection started from the inputs for the "Project information" sheet of the CRAVEzero LCC tool, which contains generic data on the geometric and thermal characteristics of the building. The information required in this spreadsheet was derived from the extrapolation of the results of the thermal modelling and from the architectural project. Figure 10 shows an extract of the general information required by the LCC tool. In this section, in addition to the surfaces and the volumes of the heated and unheated areas, the data of the thermal envelope and the installed building services are collected: in particular, for each energy vector, the energy requirements upstream of each energy system were determined through thermal modelling.

[4] EC700 software supports the calculation of the energy performance of buildings according to the methods defined in UNI/TS 11300-5 technical specification, considering all energy services: heating, cooling, domestic hot water, ventilation, lighting, energy needs of escalators and elevators.

Figure 10: Extract from "Project information" section of the LCC tool.

The analysed building is a new construction located in Alessandria (Italy) that allows the implementation of the DoppioUno business model: this building complies with the energy requirements of the nZEB of the DM 26/06/2015[5], in which the very low energy requirement is covered to a considerable extent by renewable energy sources (DoppioUno building). Furthermore, all the assessments were also carried out for a standard building with the same geometric dimensions and geographical location but with construction characteristics typical of the Italian real estate assets (Standard building). As shown in the following table, the buildings analysed have the same geometry, while different thermal features (i.e. average U-values for glazing and opaque surfaces). In addition, the standard building has no renewable energy sources installed.

Table 5. Geometric and construction characteristics of the buildings analysed.

Parameter description	DoppioUno building	Standard building
Heated areas		
Gross floor area [m^2]	2,627	2,627
Net floor area [m^2]	2,249	2,249
Gross volume [m^3]	9,319	9,319
Net volume [m^3]	6,407	6,407
Unheated areas		
Gross floor area [m^2]	831	831.24
Net floor area [m^2]	751	751
Gross volume [m^3]	2,949	2,949
Net volume [m^3]	2,138	2,138
Energy calculation parameters		
Glazing area [m^2]	682.08	682.08
Opaque surface [m^2]	2,918	2,918
Shape factor S/V	0.39	0.39
Average U-value opaque components [W/m^{2}K]	0.17	0.98
Average U-value glazing components [W/m^{2}K]	1.04	4.35
PV installed capacity [kWp]	42.2	-

[5] This decree defines the application of the methodology for calculating the energy performance of buildings, including the use of renewable sources, as well as the minimum requirements regarding the energy performance of buildings and real estate units.

As regards building services (Table 6), the differences between DoppioUno and the standard building are mainly related to the type of technology installed. The following table clarifies the types of systems installed in both buildings for air conditioning, heating, domestic hot water production and room ventilation. As previously mentioned, the standard building does not have systems for the production of renewable energy, while a solar system and a photovoltaic system are installed on the roof of the DoppioUno building. In addition, compared to the standard building, DoppioUno has a control and automation system for all the installed services.

Table 6. Technologies installed in both analysed buildings for each service.

Services	DoppioUno building	Standard building
Heating system	Centralized reversible heat pump + condensing boiler with thermal storage / Radiant floor	Condensing boiler with thermal storage / Radiators
DHW production	Solar panels + Centralised reversible heat pump + condensing boiler with thermal storage	Condensing boiler with thermal storage
Cooling system	Centralized heat pump with thermal storage	Single unit air conditioning systems (VRF[6])
Mechanical ventilation system	High efficiency AHU with heat recovery	Natural ventilation

The following tables present the input data in LCC tool for the "Building energy consumption and production" section: energy requirements for each energy source/supplying energy system are collected.

Table 7. DoppioUno building energy requirements input data.

DOPPIOUNO BUILDING					
SYSTEM	Technology	Energy source	Energy cost €/kWh	Specific energy consumption kWh/m²a	Annual energy consumed kWh
HEATING SYSTEM 1	Heat pump	National Electricity-Mix	0.250	13.63	30,653
HEATING SYSTEM 2	Condensing boiler	Natural Gas	0.103	11.52	25,910
COOLING SYSTEM 1	Heat pump	National Electricity-Mix	0.250	8.90	20,010
DHW SYSTEM 1	Heat pump	National Electricity-Mix	0.250	1.43	3,216
DHW SYSTEM 2	Condensing boiler	Natural Gas	0.103	0.37	836
PV PRODUCTION		Electricity from Photovoltaics	0.250	-	25,743

[6] Variable refrigerant flow (VRF) is an air-conditioning system configuration where there is one outdoor condensing unit and multiple indoor units.

Table 8. Standard building energy requirements input data.

STANDARD BUILDING					
System	Technology	Energy source	Energy cost €/kWh	Specific energy consumption kWh/m²a	Annual energy consumed kWh
Heating system 1	Condensing boiler	Natural Gas	0.103	195.82	440,442
Cooling system 1	VRF single unit	National Electricity-Mix	0.250	12.03	27,058
DHW system 2	Condensing boiler	Natural Gas	0.103	4.55	10,229
PV production		Electricity from Photovoltaics	0.250	-	-

WLC and construction cost

Once all the information regarding the project in general has been entered in the "Project information" sheet (Figure 10) of the LCC tool, the inventory of the WLC (Whole Life Cost) and construction costs was collected. During the design and the simultaneous cost assessment, the data required by the "WLC" and "Construction cost" sheets of the LCC tool were entered: the extract of the tool presented below allows to detail all the costs of the building elements, services, renewable energy sources, other installations and equipment and site external works.

A	Building elements		Building elements tot.	3.716.772 €
A1	Roofs			163.182 €
A1.01	Flat roof			
A1.02	Pitched roof – Ceiling next to air (outside)			
A2	Ceilings			0 €
A2.01	Ceiling next to unheated area			
A2.02	Ceiling next to ground (outside)			
A3	Floors			64.544 €
A3.01	Floor next to ground (outside)			
A3.02	Floor next to air (outside)			
A3.03	Floor next to unheated area (like garage)	m²		
A4	Walls			684.380 €
A4.01	External wall			
A4.02	Wall next to unheated area (garage...)			
A4.03	Wall next to ground (outside)			
A5	Windows			403.829 €
A6	Shading Systems			105.228 €
A7	External Doors			0 €
A8	Internal elements (next to heated areas)			1.493.727 €
A8.1	Internal partition			
A8.2	Internal floor/ceiling			
A8.3	Internal door			
A9	Structural elements			626.446 €
A9.01	Foundations			
A9.02	Raising structure			
A10	Other elements			175.415 €
A10.01	Balcony			
A10.02	Banisters			
A10.03	Chimney			
A10.04	Stair			
A10.05	Lift			
A10.06	Other			
	BUILDING SERVICES		Building services tot.	984.227 €
B1	Heating System			275.145 €
B1.01	Heating system 1			
B1.02	Heating system 2			
B2	DHW production			115.219 €
B3	Cooling system			67.381 €
B3.01	Cooling system 1			
B4	Mechanical ventilation system			210.545 €
B5	Electric			190.927 €
B6	Hydraulic system / Plumber			125.009 €
	RES		RES tot.	93.160 €
C1	Photovoltaic system			64.170 €
C1	Photovoltaic system			0 €
C1	Photovoltaic system			0 €
C2	Solar thermal system			28.990 €
C3	Other on-site electricity generation systems from RES (e.g. eolic etc.)			0 €
D	OTHER INSTALLATIONS AND EQUIPMENTS		Other installation and equipments tot.	897.630 €
D1				
E	SITE AND EXTERNAL WORKS		Site and external work tot.	137.880 €
E1				
E01.01	Garden, plants			
E01.02	External Installations			

Figure 11: Extract from "Construction cost" section of LCC tool.

Table 9. WLC and construction costs inventory for the analysed buildings.

	LCC tool reference	Category	Elements	DoppioUno €	Standard building €
WLC		ENABLING COSTS	Site clearance	125,000	
			Demolition	325,000	
		DESIGN COST	Technological design	110,000	42,000
			Urban plan	12,000	12,000
			Geological plan	8,000	8,000
			Seismic and structural design	70,000	38,000
			Acoustic design	11,000	
			Analysis of the construction cost	25,000	17,000
			Fire safety prevention plan	12,000	12,000
			Building site management	80,000	80,000
			Security and safety plan	60,000	60,000
			Energy performance evaluation and certification	11,500	
Building elements	A1.01	ROOFS	Flat roof	163,192	74,729
	A3.03	FLOORS	Floor next to unheated area (like garage)	64,544	68,341
	A4.01	WALLS	External wall	684,300	217,637
	A5	WINDOWS	Windows	403,920	222,624
	A6	SHADING SYSTEMS	Shading Systems	105,228	29,230
	A8.1	INTERNAL ELEMENTS	Internal partition	389,186	280,725
	A8.2		Internal floor/ceiling	968,159	469,272
	A8.3		Internal door	136,382	136,382
	A9.01	STRUCTURAL ELEMENTS	Foundations	626,446	626,446
	A9.02		Raising structure		242,600
	A10.01	OTHER ELEMENTS	Balcony	27,120	27,120
	A10.04		Stair	41,469	41,469
	A10.05		Lift	64,234	64,234
	A10.06		Other	42,592	42,592
Building services	B1	HEATING SYSTEM	Heating system 1	275,145	187,918
	B1.01	DHW PRODUCTION	DHW production	115,219	115,219
	B1.02	COOLING SYSTEM	Cooling system	67,381	72,000
	B2	MECHANICAL VENTILATION SYSTEM	Mechanical ventilation system	210,545	
	B3	ELECTRIC	Electric	190,927	198,127
	B4	HYDRAULIC SYSTEM	Hydraulic system / Plumber	125,009	125,009
RES	C1	PV	Photovoltaic system	64,170	
	C2	SOLAR	Solar thermal system	28,990	
Others	D1	BMS	Building automation, measuring, management systems	377,832	
	D2	FSS	Fire and security systems	28,422	28,422
	D3	FURNITURE	Furniture	491,376	491,376
Site/external works	E01.01	GARDEN	Garden, plans	75,000	75,000
	E01.02	EXTERNAL INSTALLATIONS	External lighting	62,080	62,080

The cost inventories included in the LCC tool for the nZEB DoppioUno designed by 3i Group and for the Standard building are shown below. The data reported in the table below are the summary of numerous cost items that define the metric calculations (structural, thermal, electrical and fire prevention) elaborated on the basis of the nZEB project. Also for the standard building, metric calculations have been prepared for each sector, not referring to a specific project but based on experience and data provided by the Piedmont Region's price list. In the table there is a specific reference to the items of the data collection sheets of the LCC tool. In particular, in the "WLC" sheet all the data were collected that do not specifically concern the construction of the building, such as the costs for cleaning the site and the possible demolition of existing complexes, and all design costs.

For DoppioUno case, costs have been introduced for the arrangement of the site, since it was supposed to build it in an already urbanized area by demolishing an existing building, while for the standard building such costs are neglected.

The "Construction cost" data collection sheet includes all the costs for the construction of the building divided into:

- Building elements (structural elements such as foundations and pillars, roofing, external and internal walls, floors, windows, shielding systems, stairs, elevators, balconies, etc.).
- Services (heating systems, domestic hot water, plumbing, electricity, cooling, controlled mechanical ventilation, etc.).
- Other equipment and installations (systems control and automation systems, fire prevention system, interior furnishings, etc.).
- External site works (garden, external lighting).

The cost of the fire prevention system has been provided for both buildings, like that for all external installations (garden and lighting). In addition, the costs for the interior furnishings of the apartments are considered. This cost represents a significant contribution to be taken ino account, because DoppioUno business model requires a certain versatility of the internal ambient with a specific design of the interior furnishings and a relative cost forecast. In order not to compromise the comparison between the buildings analysed, since the "furniture" cost item is not very interesting in the study undertaken, not affecting the operating costs of the building, the same internal furnishing costs were also considered for the standard property.

Results

Once all the cost data that determine the life cycle of the buildings analysed have been collected, excluding the end of life phase from the calculation, the LCC tool allows to view the following results. Considering a life span of 40 years, the Life Cycle Cost of the DoppioUno nZEB is 8,107,555, 14 % higher than the standard building. However, the initial investment costs for DoppioUno were 33 % higher than the standard building, during the life cycle the cost gap decreased thanks to the reduced energy consumption, despite the higher maintenance costs. In fact, DoppioUno building presents a greater number of systems characterized by higher complexity, thus also the maintenance is more expensive.

The energy costs for the nZEB after 40 years are equal to 487,863, 70 % lower than the standard building where the energy costs are 1,647,198.

The table below collects some results extract from the LCC tool, in particular, the absolute values and the specific costs in /m² (of heated surface) are shown for the nZEB with and without the contribution of photovoltaics and for the standard building. It is important to underline that the contribution from RES is accounted for as a reduction in the energy cost of the entire life cycle (calculated as the balance between energy consumed and produced).

With the photovoltaic contribution, the energy costs of the nZEB are further reduced from 487,863 to 295,681 after 40 years, i.e. 82 % lower than in the standard case.

Table 10. LCC results in and in /m² for the analysed buildings.

	DoppioUno with PV		DoppioUno without PV		Standard building	
	€	€/m²	€	€/m²	€	€/m²
Non-construction cost	450,000		450,000			
Executive design	399,500	177.6	399,500	177.6	269,000	119.6
Investment cost	6,228,369	2,769.1	6,228,369	2,769.1	4,167,552	1,852.9
Construction	5,828,869	2,591.5	5,828,869	2,591.5	3,898,552	1,733.3
Building elements	3,716,772	1,652.5	3,716,772	1,652.5	2,543,401	1,130.8
Building services	984,227	437.6	984,227	437.6	698,274	310.5
RES	93,160	41.4	93,160	41.4	0	0.0
Other	1,034,710	460.0	1,034,710	460.0	656,878	292.0
Operation and Maintenance Costs	1,960,496	871.6	2,152,678	957.1	2,786,437	1,238.9
Energy consumed	487,863	216.9	487,863	216.9	1,647,198	732.3
Energy produced	192,181	85.4				
Net energy consumed	295,681	131.5	487,863	216.9	1,647,198	732.3
Maintenance	1,664,815	740.2	1,664,815	740.2	1,139,239	506.5

The figures below show an overview of the LCC calculated considering a period of 40 years for the buildings analysed, with a breakdown of the cost for each phase. The graph below underlines the high initial investment cost for the nZEB and how the energy costs (Operation in the graph) remain reduced compared to this investment and to the high maintenance costs.

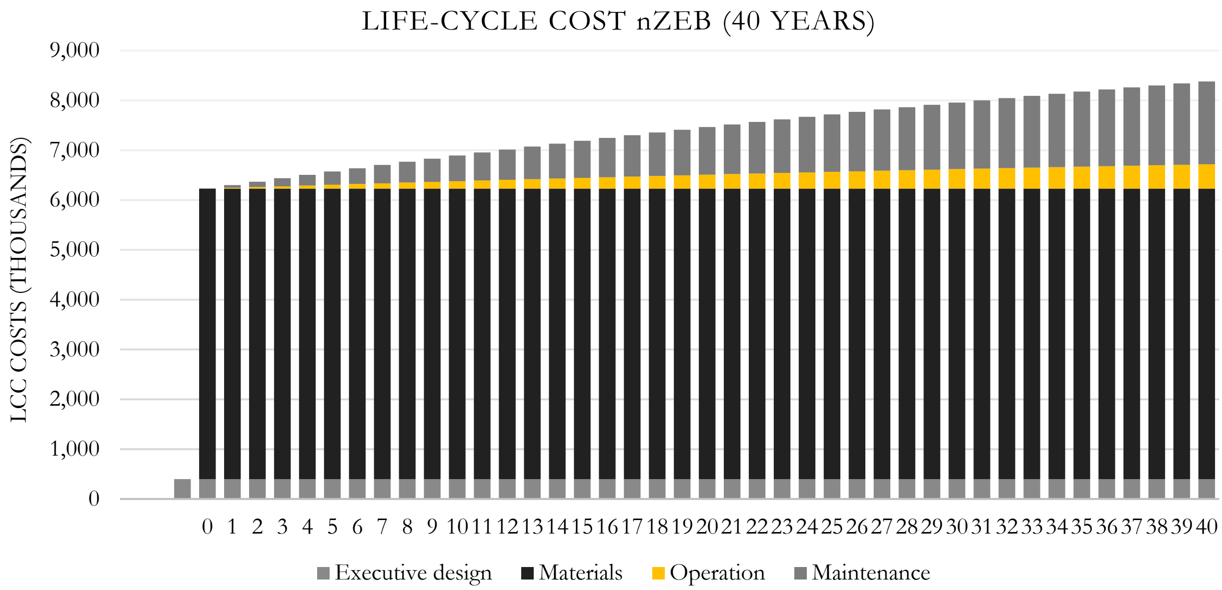


Figure 12. Life cycle cost of the nZEB without PV.

The installation of the photovoltaic system allows to reduce the consumed energy, the figure below shows the accumulated costs broken down into the various items for the period of time analysed (40 years).

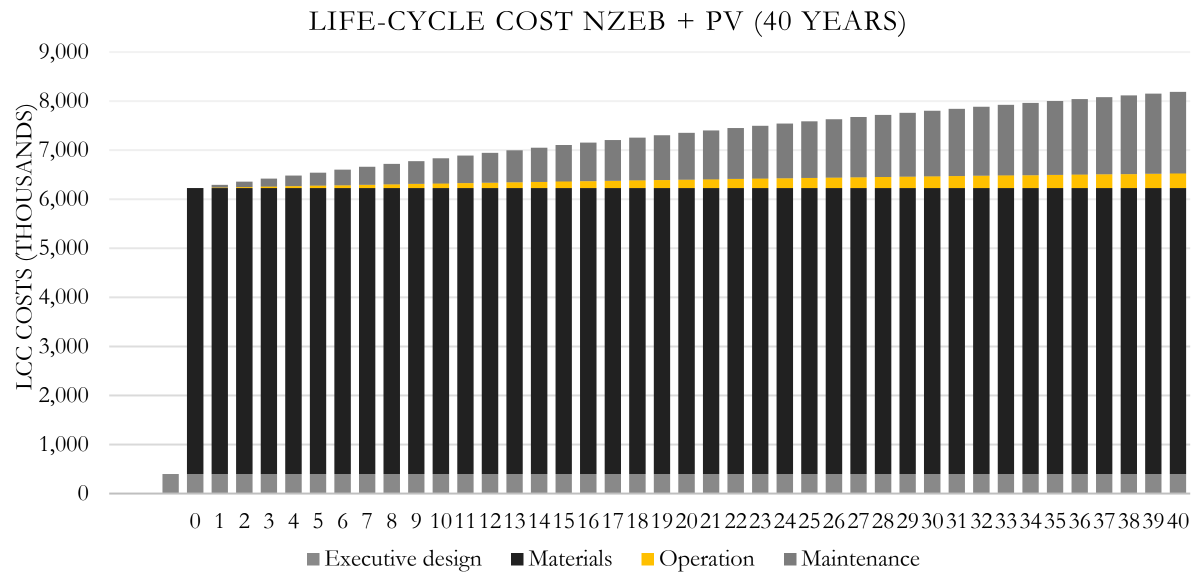


Figure 13. Life cycle cost of the nZEB with PV.

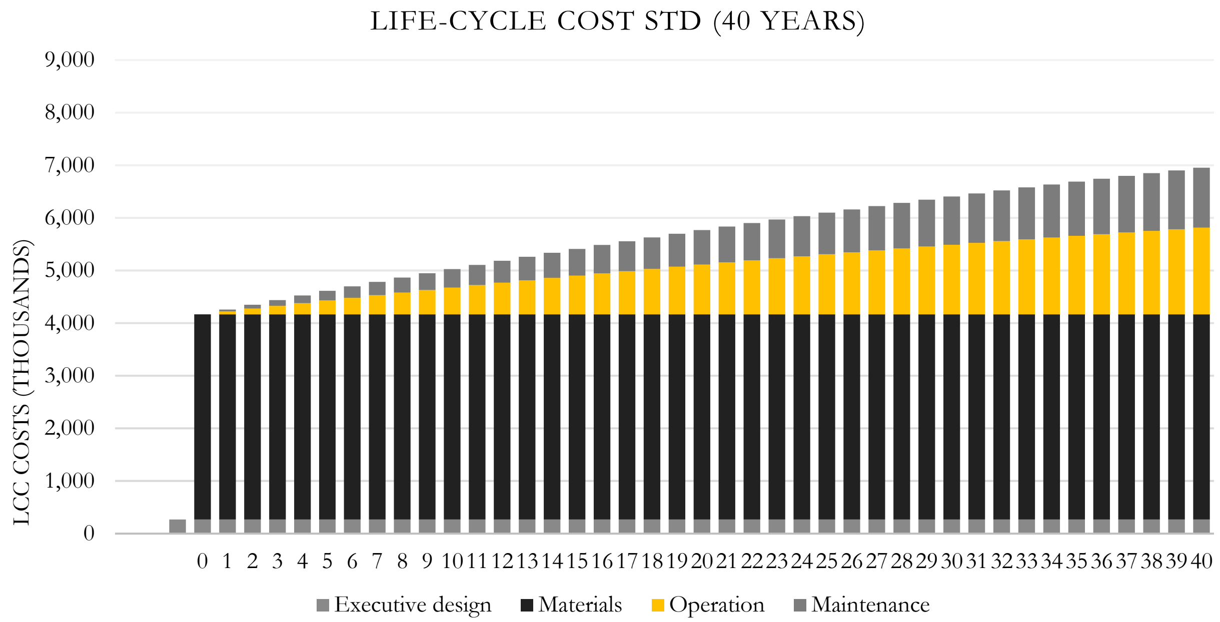


Figure 14. Life cycle cost of the standard building.

For the standard building the initial investment costs are lower, around 4M against the 6M of the nZEB, however, in the following years the operating costs increase very quickly, reaching 7M after 40 years (+ 66.9 % compared to the initial investment). For the nZEB without PV (photovoltaic) the increase in costs compared to the initial investment is +34.6 %, while in the case with PV the increase in costs is equal to +31.5 % after 40 years. So, at a first glance, a standard building seems to be the most economical solution; since the design and construction phase lead to lower costs. However, this entails higher follow-up costs. On the other hand, DoppioUno shows greater efforts in the first planning phase, but this allows to optimize the following processes. In the subsequent life stages

(reuse and recycling), not analysed in this study, it is plausible that the costs related to the nZEB will become lower than the standard building, reaching an approximately equal cycle cost value at the end of life.
The costs for the construction of the building structure constitute the majority of the costs, especially for the nZEB, the second cost-value item in the case of the nZEB is represented by maintenance costs, while for the standard building it consists in the energy consumed. The "Other" item includes the costs for internal furnishings, for the fire-fighting system and for building automation.

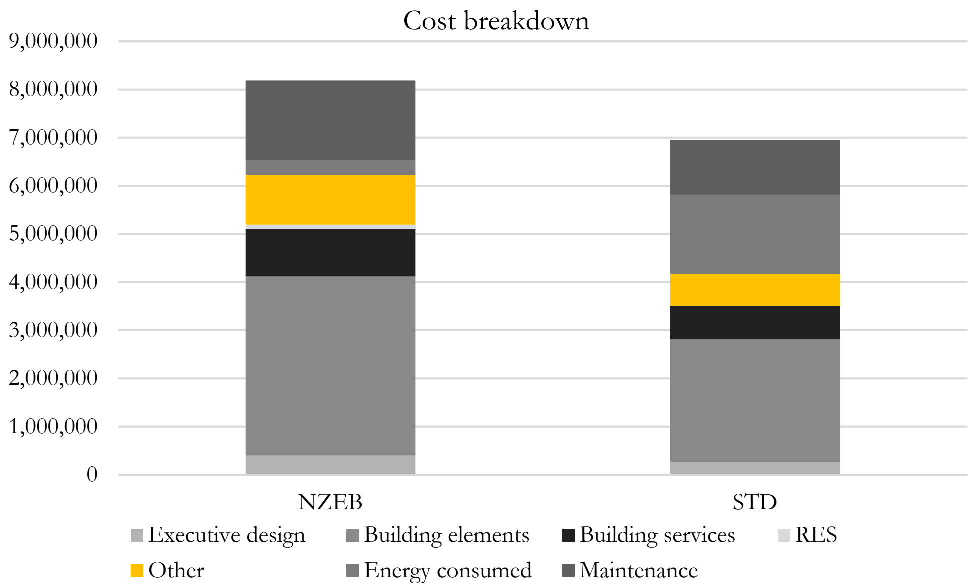


Figure 15. Life cycle cost breakdown for DoppioUno and standard building.

3.3.2. DISCUSSION

Phase of implementation
The CRAVEzero methodology was implemented in the preliminary design phase of an nZEB, in order to compare different variants.

Boundaries of application
The methodology has been applied to a single building, in order to evaluate the life cycle costs of different design solutions. In particular, the process has been considered from the general planning, considering also the urbanization costs, towards the building operation and maintenance.

If a similar methodology is already integrated in the standard workflow, which are the main differences between the two methodologies?
The described methodology is not integrated in the usual company work process. However, 3i plans to insert this design approach after this first pilot project. In fact, the company foresees a feasible replication of the approach, since the advantages (i.e. possibility to improve the decision-making process and the more detailed information that can be shown to the investors)are more coordinated by a project manager.

Goals from the application of the methodology
The objectives of implementing the methodology consist in quantifying the costs of the entire life cycle of a new nZEB (i.e. DoppioUno), compared to a building of the same volume but with construction features and thermal systems typical of the current real estate park in northern Italy. The comparison of the life cycle costs of the buildings analysed allows to highlight to a customer, the economic convenience compared to the purchase of an nZEB

compared to a standard building. The implementation of life cycle costing was the first fundamental step for the quantitative analysis of the feasibility of the BM DoppioUno. The final goal of the implementation is, therefore, to make nZEBs more competitive on the real estate market, through the construction of new business models.

Difficulties and critical points of the implemented features

There were no particular difficulties in applying the methodology because the tool is very intuitive and the definitions of the required parameters are well explained and clear. The only difficulties encountered relate to the availability of construction material and installation costs, as the planned building is made of wood: for this reason, as this structure is not used frequently, the cost assessment of the wooden structures was carried out with the support of Moretti SPA.

Furthermore, the definition of the energy cost, especially the long-term prediction, was quite critical, and affected by several uncertainties (climate conditions, cost of energy, user behaviour).

Advantages of the applied methodology

The main advantages identified by 3i of applying this methodology are the following:

- Availability in a single instrument all the costs that must be incurred to design, build and operate a building.
- Possibility to compare the incidence of each cost item at the end of life, and consequently to carry out interventions and design choices for their reduction.
- Possibility to compare different design choices from an economic point of view throughout the life cycle.
- Mapping of all costs that must be incurred for the design and construction of a building allowing not to leave out cost items in the economic evaluation of the work.

Disadvantages of the applied methodology

The implementation of the methodology requires a greater expenditure in terms of time during the design phase of the building, with a dedicated person working on it. However, this allows to transform this cost into a future added value for the project.

How easy is the methodology to be implemented in the normal workflow?

The application of CRAVEzero methodology changed the 3i usual design process. First of all, the normal design process has been modified because the planned building is the basis for the construction of a new business model, therefore there is no a real client/owner. In fact, this is a project for the development of a new innovative business model, therefore all the procedural phases which involved the customer interaction have not been considered. Apart from this, the subsequent project phases have been modified above all for the evaluation of costs and for the coordination of the activity. In fact, the standard design process of the 3i Group, which involves different engineering sectors, is normally structured in this way:

- Preliminary architectural design and structural modelling.
- Thermal modeling of the building and verification of energy requirements (DM 26/06/2015), installation of renewable sources (Legislative Decree 3/03/2011 n°28[7]) and compliance with the Minimum Environmental Criteria for public buildings (DM 11/10/2017[8]).
- Preliminary thermal design.
- Preliminary electrical and fire prevention design.
- Cost evaluation and elaboration of the estimate metric calculations.

[7] Decree for the promotion of the use of energy from renewable sources.

[8] Decree addressing minimum environmental criteria for the assignment of design and works services for the new construction, renovation and maintenance of public buildings.

All these design phases intersect temporally and are normally coordinated by the respective sector manager. Furthermore, meetings are scheduled on a specific time, based on the works planning, in which the progress of each technical sector design and the problems encountered are shared. The main objectives of the meetings are the definition of short-term objectives and strategies for solving problems.

The cost assessment phase in the usual 3i design process always took place at the end of all the preliminary design phases, with the adoption of the LCC tool the cost plan was implemented simultaneously with the technical design. Therefore, the LCC tool made it possible to collect a large amount of information on the costs of the entire project and its subsequent operational phase. The LCC tool allowed 3i Group not to limit the analysis of costs only to the construction phase , but to broaden the view also on the operational phase and the future disposal of the building: in this way it was possible to evaluate from the preliminary design, not only what are the most convenient choices in the immediate term, but over a wider time period, in order to provide a holistic picture of the building system.

The implementation of the LCC tool also changed the standard coordination of activities. In fact, in the standard process flow the coordination of the sectors is carried out by a sector manager, who interfaces with the others during the meetings to follow the progress of the project. With the introduction of the life cycle costing methodology, it was necessary to coordinate the activities of all the technical sectors through a project manager, who knew all the details of the project and planned the work.

Target/s achieved

By implementing the life cycle tool in the design process, it was easy to make comparisons between the life cycle cost of an nZEB and a standard building typical of the current Italian real estate park. In this way, the cost differences between the two buildings at all stages of the life cycle were highlighted quantitatively. This made it possible to quantitatively develop the DoppioUno business model, highlighting the added value of the business model compared to the current life cycle of a standard building and a typical user.

Another important result achieved was the assessment of the energy impact of the photovoltaic system, which assumes great strategic importance in reducing operating costs: at the end of its life, the impact of energy expenditure on the total costs of the building is equal to 5.8 % without photovoltaics, considering the energy production from this renewable source it drops to 3.6 %.

How satisfied are you with the results obtained

3i is very satisfied with the results obtained also because it was possible to carry out a benchmarking analysis with the data collected in the deliverable “D2.2: Spreadsheet with LCCs” for European case studies already built. Therefore, in addition to achieving a life cycle cost analysis result for our designed building, it was possible to relate each cost category to the real values of the case studies collected in the previous deliverable.

Lessons learnt

Through the implementation of the methodology, 3i was able to understand the importance of analysing the cost of the life cycle of buildings and how design choices can influence the functioning of the structure. The cost of energy and the use of renewable sources play a fundamental role in the end-of-life cost balance. The choice of construction materials is also not trivial and it would be interesting to evaluate their economic impact for disposal and recycling, compared to the investment cost and energy performance.

From the point of view of internal processes, the implementation of the methodology has allowed 3i to work in a more precise and organized way, without neglecting any cost item for the design and construction of the building. Furthermore, it was possible to understand how a transversal organization of the project and of the different skills had advantages, both for solving problems and respecting deadlines.

Which part of the CRAVEzero methodology will be further implemented within the company?

The energy retrofit of apartment buildings is a service recently implemented in 3i Group. Hence, there is a need to structure this service and standardize the design and construction processes. For this reason, 3i would like to use the Life Cycle Tracker tool in the future in order to determine a process map and have a management tool. Also on standard nZEB design processes it would be very interesting to implement the CRAVEzero methodology, especially the standardization and optimization of processes through the use of the Life Cycle Tracker tool.

3.3.3. DOCUMENTATION: BUSINESS MODEL CANVAS

Starting from the results of the Life Cycle Costing described in the previous section, the business model called "DoppioUno" was qualitatively and quantitatively analysed. The focus was to assess the construction of a low-cost sustainable building in which the internal layout and technological systems can be easily adapted in order to change over time, during a person's life. In particular, the “Business Model Canvas” (see Figure 16) tool was implemented. This tool was used by the CRAVEzero team to highlight relationships and similarities between the existing BMs concerning nZEBs in the deliverable “D5.2: Existing nZEB business models”. This approach allows 3i to focus on the main points for the development of a business model, including: value proposition, customer segment, customer relationship, activities and capabilities, strengths and key factors, costs, revenues, maturity, placement along the value chain of nZEBs.

The standardized profile was built for the new BM DoppioUno designed by 3i Group. Through the creation of the profile it was possible: to define more in detail the key points of the new business model, to relate the parameters described with the current business models on the European market and from this analysis, to make a preliminary estimation of costs and revenues for a construction company and for the occupants. The standardized profile built for the DoppioUno business model is presented below, with some additional considerations of the BM DoppioUno with respect to existing business models. The following sections describe the business model canvas of a company implementing the DoppioUno business model.

Figure 16. CRAVEzero Business Model Canvas.

Value proposition

DoppioUno combines low cost of the construction (investment) and affordability for the prospective users (purchasing power) and build flexible and reversible residential towers. Typological study, technology and design of the utility installations allow for conspicuous savings in terms of building costs, energy consumption, and maintenance. These design and technological solutions also ensure that the interior layout of the units is flexible and able to accommodate different use requirements, and heterogeneous dwelling types.

Customer Relationships

In order to get in touch with customers, the company provides a detailed website. References of previous projects and all services offered by the company are shown on the website. Personal assistance, a customer service reachable via telephone hotline as well as internet and the offer of maintenance services helps to create a long-term customer relationship.

Customer Segment

The offer is wide spread. Students, city users, single-income families, young couples, singles, senior citizens and expatriates represent segments that are not properly addressed by the current property market, and this prevents them from finding the right housing solution. DoppioUno responds well to their needs.

Activities and Capabilities

The service portfolio includes the provision of all the necessary information for customers, consultancy, construction and its supervision as well as optional financing subsidies, maintenance service and customer support.

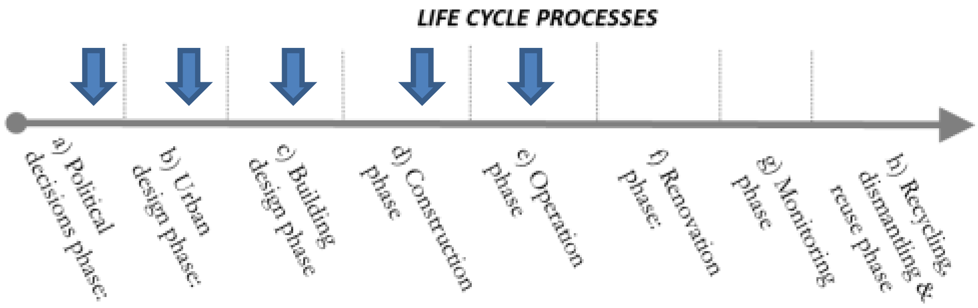


Figure 17. Life cycle processes targeted by BM DoppioUno.

Revenues

The company offers dwellings with different layouts, ranging from the studio flat to the four-room apartment. Moreover, additional revenue streams are foreseen for financial consultancy, interior furnishing or maintenance service.

Costs

The most important costs are represented by building materials, followed by personnel expenditures for the construction phase, consultancy, maintenance and customer support.

Strengths and key factors

Tha main identified strengths are:

- Flexibile and customisable dwellings
- Low cost of investment compared to standard nZEBs and affordability
- Environmental, social and economic sustainability

Maturity

It can be considered in the startup phase.

Placement along value chain of nZEBs

Figure 18. DoppioUno concept.

From the profile, it emerges that the value proposal of the BM DoppioUno is in line with the key success characteristics highlighted for the existing BMs, such as sustainability, comfort/innovation and cost reduction (investment and operating costs). Also the customer segment (building owners), which DoppioUno addresses, is the main reference sector of the existing BM. In fact, in Italy, the segment of the residential market continues to lead the ranking of investments in energy efficiency with 53 % of the total investments made in 2017 [5]. The same report shows that 80 % of investments in energy efficiency can be associated with retrofit interventions, while only 20 % is dedicated to new buildings. The long term return on investment represents a barrier to the implementation of interventions for 80 % of operators. Even for the construction of the nZEB, despite the important benefits in terms of consumption, it is clear that the return on investment represents a barrier for many investors. The DoppioUno business model has as main objective the reduction of the investment costs of the nZEBs, through the creation of modular real estate units that adapt over time along the life cycle of the occupant and the provision of a service for obtaining of state incentives and funding.

DoppioUno also aims to create a lasting and trust relationship with the customer, a very important element for the development of large investments in the energy efficiency market, as highlighted in the overview of existing business models. Furthermore, the DoppioUno business model could be concretely constructed in order to define a BM package to create a more efficient innovative BM capable of covering multiple phases of the building's life cycle through collaboration of different stakeholders and skills. In fact, many phases of the building's life cycle are currently covered by a low number of existing BM.

Design and engineering are usually the most common activities in the supply of value proposals related to nZEB. Also in the BM DoppioUno engineering and design are fundamental for the construction of the building and the business model. Furthermore, customer service, communication and intermediation are important activities, which are part of the value chain of the BM DoppioUno. These activities, together with the maintenance and management of the building, could be carried out by permanent partners specialized in the aforementioned services. In this way, all the activities would not be internalized in a single company, but could be outsourced to multiple companies that have specific skills connected with a single business model, thus creating a BM package. For example, the construction company could have a design studio organized internally, in order to make the construction processes of the structure simpler and leaner, highlighting any problems related to the construction phase from the beginning.

Finally, a quantitative analysis was carried out on the BM DoppioUno in order to make a preliminary estimate of the cost flows for the construction company and the owner of the property, highlighting the advantages and disadvantages of this new proposal.

Company side quantitative analysis

The estimate of the design and construction costs of the nZEB DoppioUno building was made through the use of the LCC tool. First, the quantitative analysis starts from the business point of view by examining two cases:

- CASE 1: demolition of an existing inhabited building
- CASE 2: demolition of an existing disused building

In the first case, the owners of a building who intend to energetically redevelop their property by demolishing and building a new one with the same shape: in this case access to the tax deduction incentive in Italy (ecobonus) allows to recover up to 75 % of the expense for the renovation in 10 years, provided that the new construction has a volume equal to or less than the previous building to be renovated. In the second case, the company that autonomously decides to redevelop an area with a disused building: the total costs that the company has to sustain increase due to the purchase of the unused urbanized land valued at 125 /m^2 (brown field value in the table below). In both cases two conditions were considered:

- Condition A: Access to the eco-bonus
- Condition B: Without eco-bonus

Access to the eco-bonus for building owners (Case 1) is simpler, while in Case 2 the company, to use the incentive, deductible only for natural persons, must necessarily have sold the housing unit. For this reason, in the second case, access to the tax deduction is more complicated.

The following table shows the achievable costs and revenues. The costs deal with: the land purchase (only in Case 1) and the cleaning of the site, the demolition of the existing building, the design and construction of the new building. As regards revenues, in Condition A, the value of the deduction considered is equal to 75 % of the restructuring cost (therefore, in Case 2 the restructuring cost is calculated net of the brown field value). In order to receive the tax deduction immediately and not in a deferred period of 10 years, in both cases it was assumed to sell the tax credit at 67 % (through the mechanism of the tax credit assignment). In this way, the cost of the building in condition A is reduced to 2,203,862 in case 1: dividing this total cost by the number of housing units gives a value of 46.914 per apartment. This cost was margined by 30 % to obtain a final company profit of 661,159, i.e. 9.9 % of the total costs initially incurred (revenues are given by the sum between the sale value of the deduction and the sale cost of an apartment multiplied by 48 housing units). In case 2 the cost of the building is higher because the costs for the acquisition of the site are included: in this case, since the sale cost per apartment should be kept equal to case 1, the business profit is lower (6.5 %).

Table 11. DoppioUno BM costs and revenues for company.

COSTS	**1. Existing inhabited building** €	**2. Existing disused building** €
Brown field	0	225,000
Non construction costs (site clearance, demolition)	450,000	450,000
Building design	399,500	399,500
Construction costs	5,828,869	5,828,869
Total cost design + construction	6,228,369	6,228,369
TOTAL COST NEW BUILDING	6,678,369	6,678,369
TOTAL COSTS FOR COMPANY	6,678,369	6,903,369
REVENUES		
A) Eco-bonus (75%)	5,008,777	5,008,777
A) Sale value deductions (67%)	4,474,507	4,474,507
A) Building cost net of deductions	2,203,862	2,428,862
A) Single apartment cost with deductions	45,914	50,601

A) Single apartment selling cost with deductions with business profit (30% - 15.2%)	59,688	59,688
B) Single apartment cost without deductions	139,133	143,820
B) Single apartment selling cost without deductions with business profit (9% - 5.1%)	151,655	151,655
A) TOTAL COMPANY REVENUES – WITH ECOBONUS	7,339,528	7,339,528
B) TOTAL COMPANY REVENUES – WITHOUT ECOBONUS	7,279,422	7,279,422
A) BUSINESS PROFIT WITH ECOBONUS (9.9% - 6.3%)	**661,159**	**436,159**
B) BUSINESS PROFIT WITHOUT ECOBONUS (9% - 5.4%)	**601,053**	**376,053**

In condition B (without access to the eco-bonus) the cost of sale per housing unit (given by the ratio between the total company cost value and the number of housing units) is clearly higher, considering a company profit of 9 % in case 1, it is equal to 5.4 % in case 2.

The following figure graphically represents the costs and revenues for the most convenient case 1, in conditions A (access to deductions) and in conditions B (without tax deductions).

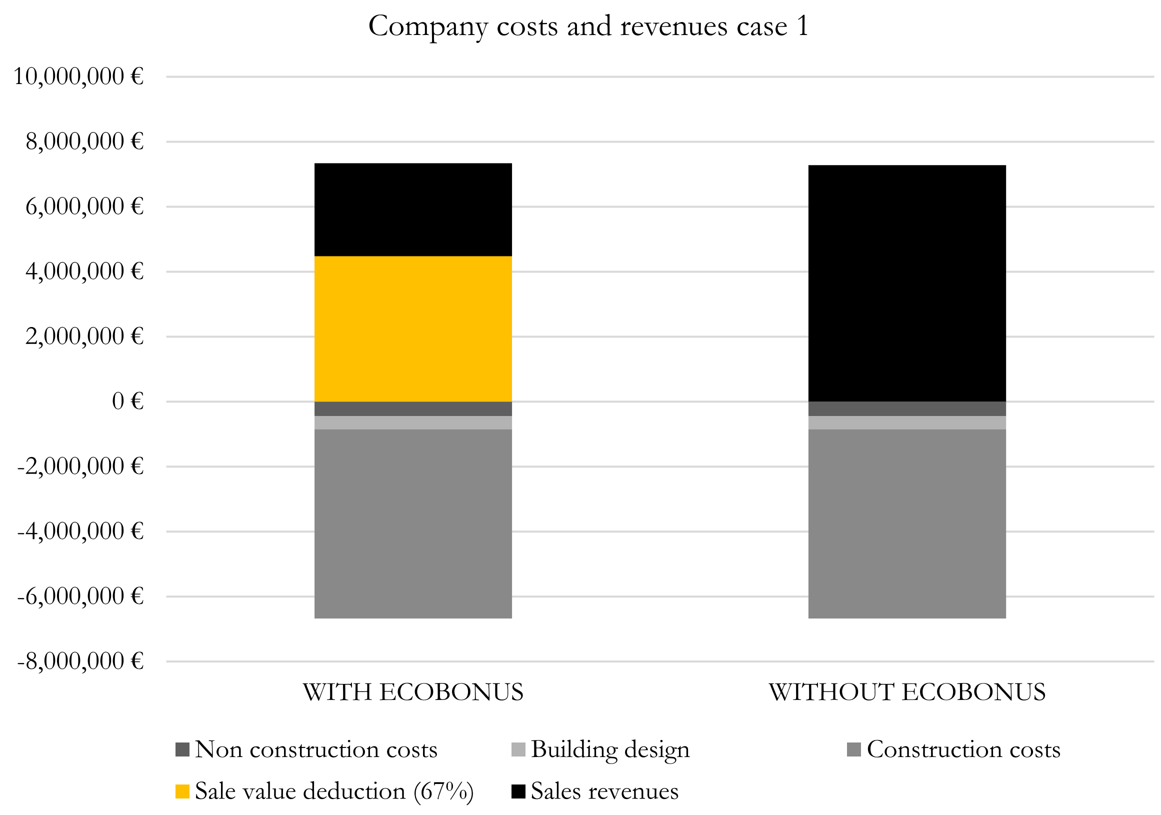


Figure 19: Breakdown of costs and revenues case 1 (Condition A and B).

The figure below shows the case 2 break even point for the company (in case 1 the company does not have to sell the apartments, because the buyers are the owners of the property), which consists of the minimum number of housing units to be sold so that the costs are repaid by the revenues (costs = revenues). For condition A, the minimum number of apartments for sale is equal to 41 units, since the mechanism of the tax credit assignment allowed the company to immediately repay 4,474,507 €, for condition B, however, the minimum number of sales is equal to 46 units.

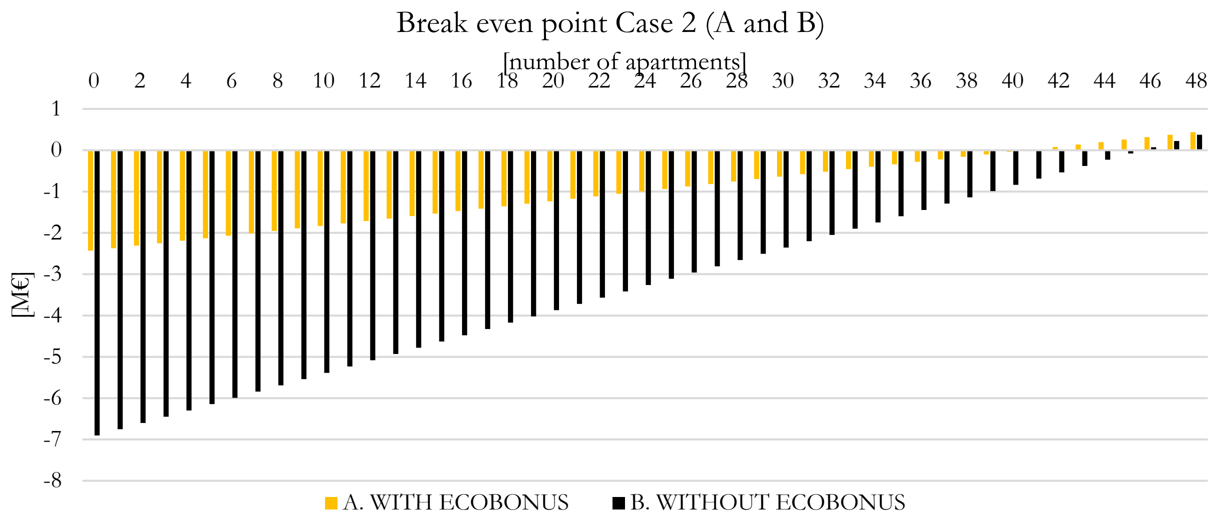


Figure 20: Company break even point.

Occupant side quantitative analysis

Analysed the point of view of the company, in this section, a preliminary quantitative estimation on the costs and operating feasibility of the DoppioUno BM for an occupant/buyer was developed. The two cases compared are shown schematically in the figure below.

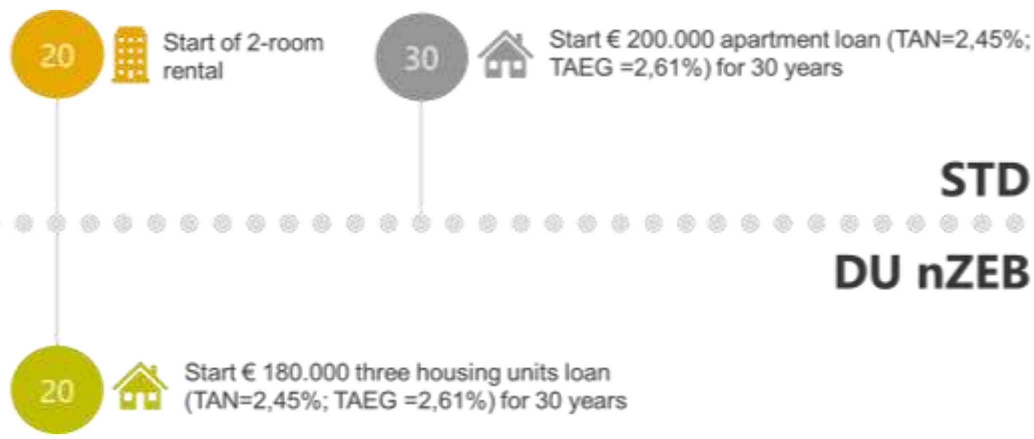


Figure 21: Occupant life cycle for standard and DoppioUno case.

The standard case is represented by the life cycle of a person who lives between 20 and 30 years in a rented two-room apartment (monthly cost of 400[9]) and, subsequently, decides to buy a larger apartment for 200.000 with a 100 % of the property value bank loan through the Italian incentive "Prima Casa Consap Guarantee Fund"[10].

[9] Value based on the average rental price of furnished two-room apartments located in Alessandria (Italy) of about 50-60 €/m^2.

[10] Consap = Public Insurance Services Dealer. In Italy, Consap is the manager of the Fund, recently refinanced with the "Growth Decree" (art. 19, DL 30 April 2019 n. 34), which provides for the granting of first demand guarantees on loans, with a maximum amount of 250,000 €, for the purchase also with restructuring interventions, provided that with an increase in energy efficiency, of real estate units located on the national territory to be used as the principal home for the borrower.

Using an online banking simulator[11], the fixed rate monthly mortgage payment (TAN[12] and TAEG[13] in Figure 21) was calculated for 30 years. Energy costs refer to the energy needs of the standard building typical of the 1970s Italian real estate (calculated with the LCC tool). In the DoppioUno case, at the age of 20, the occupant, instead of renting a two-room apartment, buys three furnished housing units of the nZEB through the same guarantee fund previously cited, with a 100 % mortgage of the property value for 30 years. Also in this case, the same interest rates were used. The main difference is that, instead of occupying all the purchased housing units, two of these are rented to third parties, becoming a revenue for the inhabitant. The energy costs of the nZEB DoppioUno building are very limited: This is a key and determining factor in ensuring that the final monthly cash flow, considering costs and revenues, is positive up to the owner's 30 years of life.

During the life of the inhabitant the necessities change, and having more space needed, it was assumed that the owner occupies:

- from 30 to 35 years two units,
- from 35 to 55 years three units,
- from 55 to 70 years two units and
- from 70 to 80 one unit.

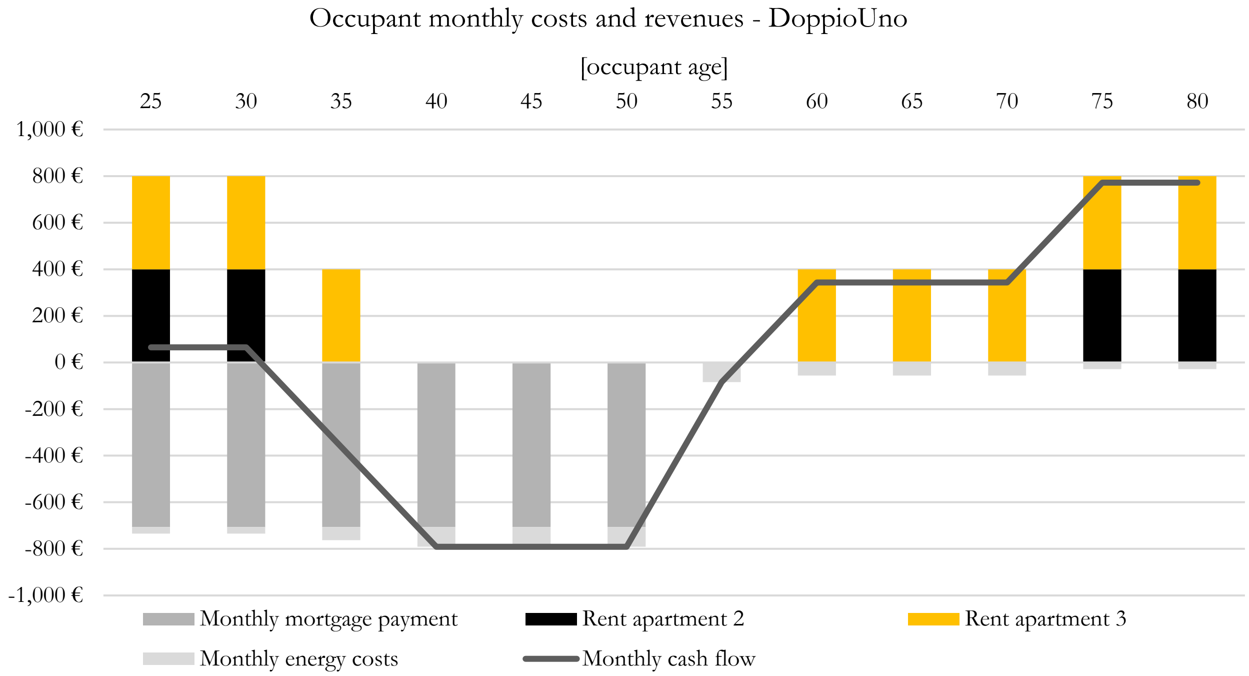


Figure 22: Occupant monthly costs and revenues – DoppioUno condition A.

The cost of selling a property unit in the simulation shown is 59,688 (Table 11, condition A of the previous section), therefore, the cost of selling three furnished property units of usable surface equal to 120 m² is 179,063.8 (rounded to 180,000).

Figure 19 graphically shows the monthly cash flow for the BM DoubleUno from the owner's point of view. In figure 19, the time period refers to the age of the occupant, it can be noted that:

- From 20 to 30 years the total cash flow is positive, characterized by the income from the leases of units 2 and 3 and the limited energy costs;
- From 30 to 55 years the total cash flow is negative, but still sustainable by an average two-income family (the maximum monthly cost in this period of time is 791 /month);

[11] https://www.intesasanpaolo.com/it/persone-e-famiglie/prodotti/tool/calcolo-mutuo.html

[12] Italian abbreviation for nominal interest rate.

[13] Italian abbreviation for annual percentage rate of charge.

- From 55 to 80 the cash flow is always positive.

The following graph relates the cash flows calculated for the buildings analysed, highlighting the energy contribution: in fact, not considering the energy costs, the cash flows for the standard and DoppioUno apartments are very similar in the period from 30 to 50 years (range in which total expenses are maximum). By inserting the energy expenditure in the total cash flow, it can be seen that for the standard apartment the costs increase by 34.6 % (-274 /month) in the period from 30 to 50 years.

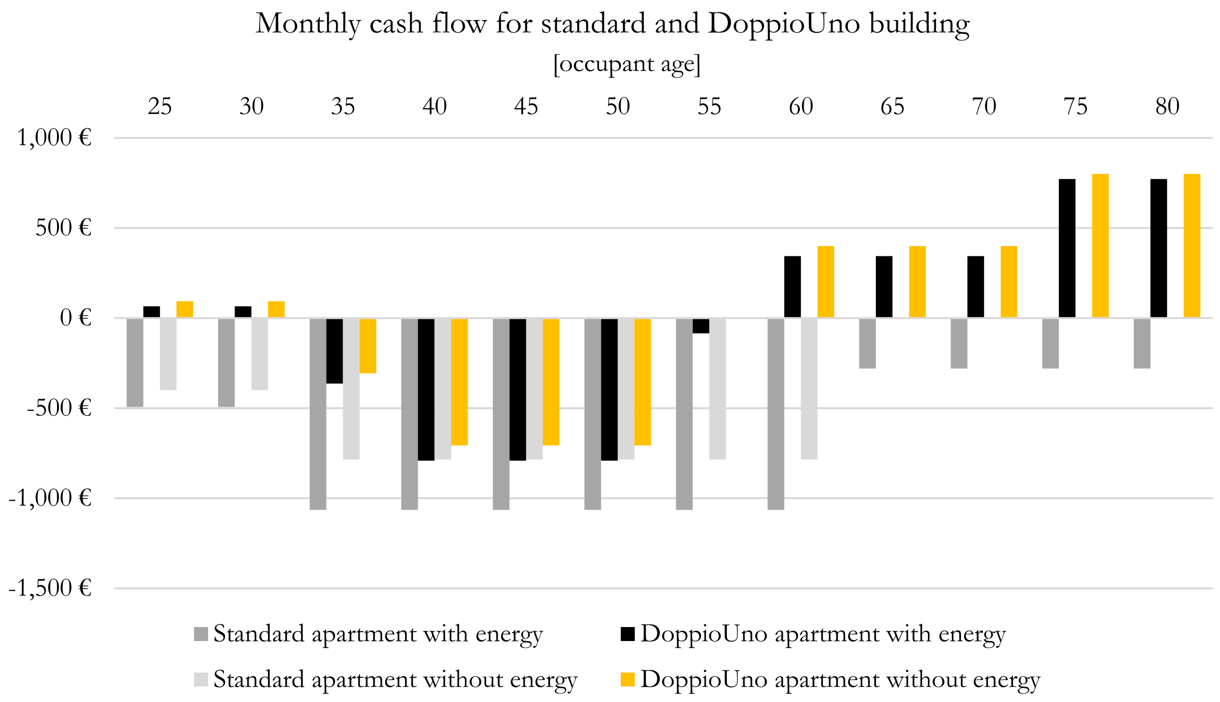


Figure 23: Monthly cash flow comparison between standard and DoppioUno building.

Finally, the cumulative cost flows were calculated for both cases analysed. The cumulative of the cost flows shows that the DoppioUno model, compared to the traditional case, is much convenient in terms of cost: at the age of 80, the occupant of the traditional apartment will have spent around 500,000, while the inhabitant of the DoppioUno apartment only 7,000. Therefore, for the inhabitant, the DoppioUno model, compared to the traditional case, is much more convenient in terms of cost and less subject to the influence of energy costs (Figure 23).

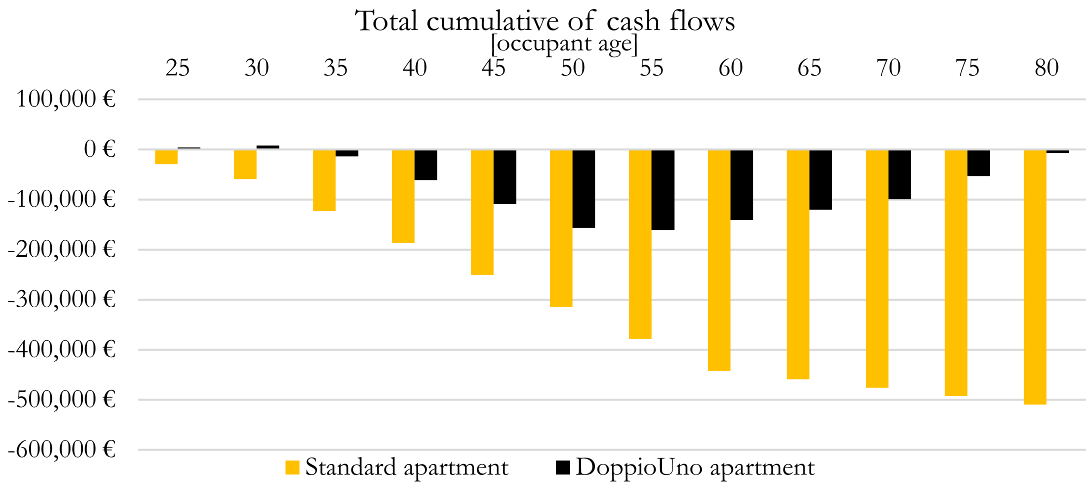


Figure 24: Cumulative of cash flows for standard and DoppioUno apartment.

3.3.4. DISCUSSION

This Section reports the feedback for the practical application of the CRAVEzero methodologies in the development process of a nZEB, carried out by 3i.

Phase of implementation

The methodology has been implemented during the preliminary development of the business model, in order to predict the economic feasibility of the company and occupant side.

Boundaries of application

In the nZEB value chain, the boundaries of the implementation of the company-side methodology are the building design and construction company. In fact, building management and maintenance services were not considered in the quantification of the business model. The BM could, however, combine the union of different skills to cover multiple phases of the building's life cycle. Occupant side: the methodology was applied over a large part of its life (from 30 to 80 years) considering the purchase of three residential units inside the DoppioUno building.

If a similar methodology is already integrated in the standard company workflow, which are the main differences between the two methodologies?

There is currently no standardized methodology in 3i for defining new business models. As in many European realities, business models for traditional activities are based on experience, while innovative business models are developed preliminarily to verify the feasibility and is subsequently applied on a pilot project. Through a standardized methodology, the 3i group was able to analyse key parameters and deepen the functioning of the business model. In this way, from the beginning, the weaknesses were also highlighted: in fact, the application of the BM Canvas allowed a greater knowledge of the new BM, anticipating the resolution of any problems and critical issues to the phase prior to the implementation of the pilot project. For example, it was possible to highlight how access to the eco-bonus is a fundamental aspect to keep the purchase costs of real estate units reduced and to ensure that the business model is economically sustainable for the occupant.

Goals from the application of the methodology

The main objective achieved through the application of the methodology was the definition, also quantitatively, of the key points, costs and revenues for the new business model. The compilation of the standardized profile made it possible to compare the new model with the current market proposals, thanks to the overview of the existing business models collected by the Cravezero team in the previous Deliverable 5.2: "Existing nZEB business models". Through the collection of existing BM and their consultation it is possible to build a BM package by developing the new model on the company side to connect other services related to the building's life cycle, such as maintenance and management.

The application of the method has also made it possible to verify the sustainability of the business model, both at a social level for the occupant, because it allows access to the real estate market for segments with low purchasing power that currently do not find an offer suitable for their needs (single income families, young couples, students, older people); both economically, because it allows to keep the purchase costs of the real estate unit reduced. In addition, 3i Group was able to verify the consistency of the value proposition for the customer and the company, in order to guarantee that the offer for the occupant corresponds to the product that the company has made. Correspondence is guaranteed by the prospect for the company to design and build the nZEB making profits, and by the possibility for the occupant to purchase new, comfortable and nZEB apartments at low cost.

Difficulties and critical points of the implemented features

The difficulties encountered in applying the methodology on a new business model relate precisely to the definition of all aspects of the business model, in order not to overlook important points that could compromise its functioning. There were no particular difficulties in applying the methodology itself.

Advantages of the applied methodology

The advantages derived from the application of the methodology concern the simple and quick definition of parameters that manage to determine a complete picture of the factors and key points that build the business model. Furthermore, the definition of the same parameters allows comparison with the current proposals on the market and to draw inspiration from them for the creation of more innovative and efficient business model packages. The strength of the methodology lies in having created a collection of BMs on the nZEB at a European level that did not exist before: in this way, companies can learn about the current overview of the market and get ideas for their technological innovation.

Disadvantages of the applied methodology

A disadvantage of the methodology itself is the fact that a snapshot of the BM is taken without a forecast over time, in fact, the possible risk factors that could compromise the functioning of the BM are not highlighted. In the case of DoppioUno, in fact, possible threats could be the repeal of incentives for the energy requalification of buildings or the increase in interest rates on bank loans.

How easy is the methodology to be implemented in the normal workflow?

Certainly the implementation of the BM Canvas methodology would be very advantageous for 3i, above all because today the services in the energy sector change very frequently, also in relation to territorial legislation. Business models have to adapt easily to changes and market demands. In the preliminary formulation phase of the model, the implementation of the methodology would require more time and resources, but would allow to obtain a clearer and more complete idea of the mechanism and to evaluate specific variants in greater detail. Therefore, for 3i the implementation would require greater efforts especially in the early stages, probably also through the inclusion of a figure dedicated to the evolution of business models, but this would certainly allow to waste resources in the subsequent stages of pilot projects realization. Obviously, the use of resources and time strongly depends on the level of in-depth study of the BM that you want to carry out, especially at a quantitative level.

Target/s achieved

The results achieved can be summarized in the following points:

- Greater knowledge and deepening of the new business model

- Identification of weaknesses that could compromise the models, especially through quantitative analysis
- Comparison with standardized parameters of the new BM with current market proposals
- Greater awareness of the importance of a standardized, punctual and structured analysis even in the simplest projects

How satisfied are you with the results obtained

3i is very satisfied with the implementation of the methodology because it has allowed us to know the importance of using a standardized and effective methodology for evaluating business models. The introduction of the methodology could make business models more efficient and innovative with the aim of using them in the development of the corporate strategy.

Lessons learnt

Through the implementation of the CRAVEzero methodology 3i has expanded our knowledge on the current market proposals for nZEBs, understood what are the critical points that hinder the spread of nZEB on the market and what are the tools to accelerate their diffusion. It was clear how fundamental is to build innovative and more efficient business models that combine different stakeholders and skills to provide a complete service throughout the entire life cycle of the building. This allows to create a more stable and lasting relationship with the customer, a fundamental aspect to overcome the barrier imposed by the high investments that characterize the nZEBs. In fact, credibility is a key aspect in the development of the energy efficiency market as highlighted by the study of FIRE[14]. Furthermore, we were able to understand what are the advantages both in economic terms and in terms of comfort for the DoppioUno business model compared to the traditional case for the user and the company.

Which part of the CRAVEzero methodology will be further implemented within the company?

For 3i Group it would be very interesting to implement a pilot project of the DoppioUno business model, structuring lasting relationships with partners in order to provide a more complete service from design to management of the building. Therefore, in the future, a business model package could be built based on elementary BM of different stakeholders. This would mean using the current overview of existing BMs in order to achieve the actual purpose for which it was created, that is, the construction of innovative and efficient BM packages capable of covering multiple phases of the nZEBs life cycle.

Table 12. Upcoming nZEB projects – 3i.

	Project	Location	Building use / Typology	Client
1	Villaggio Alessandria	Alessandria	Residential – Block of flats	Owners
2	Tortona 1	Tortona	Residential - Block of flats	Owners
3	Tortona 2	Tortona	Residential - Block of flats	Owners
4	Via Napoli	Alessandria	Residential - Block of flats	Owners
5	Voghera 1	Voghera	Residential - Block of flats	Owners
6	AMAG2020	Alessandria	Office building	Multi utility Company

Table 12 displays the building projects that are in 3i's pipeline. These projects are mainly refurbishments, since this is 3i's core business at the moment this report is written, therefore not directly related to the case study here illustrated. However, the flexibility of CRAVEzero methodology can be easily adapted. For instance, a LCC analysis can be performed analysing the the building before the refurbishment as the base case and the building after the refurbishment as a variant.

[14] FIRE (Italian Federation for the Rational Use of Energy): proposals for the development of energy efficiency in Italy, Tools for face the great challenges of the energy market.

4.CASE STUDY CASA MORE FRANCHINO – MORETTI

4.1. GENERAL DESCRIPTION

Brief description / main features

The case study adopted for this analysis is the model of a single family house on one storey, with prefabricated concrete panels and wooden roof, which combines structural and thermal performance, located in northern Italy.

Energy concept

The envelope has been designed to reach the passive house standard. Regarding the building systems, one single AHU with heat recovery, heating/cooling and DHW has been chosen.

Table 13: General project information Casa More Franchino.

General project information	
Project name	Casa More Franchino
Location	Pavia, Italy
Planning team	Moretti More
Architect	Valentina Moretti
Building owner	Franchino Carlo
Net floor area	125 m²
Construction date	2019
Building typology	Single family house on one floor
Current status	Construction, delivery

Figure 25. Casa More Franchino floor plan.

4.2. GOALS DEFINITION

Main goals and the priorities of the design
The pursued goal was to combine the aesthetic value of the design with a simple, straightforward and efficient energy concept and system for heating and cooling.

Main constraints for the design
There were no major constraints except to optimize the selected system, introducing an accurate calculation of the heating and DHW demand of the house.

Focus on the application of CRAVEzero approach
In order to evaluate the adoption of CRAVEzero methodologies in the company workflow for the application in future projects, the analysis focused on LCC analysis and process map.

Currently Moretti is not applying Life Cycle Cost analysis in the usual business, while there is already an internal process map for the management of the design and construction of a building, but it is not focused on nZEBs.

The investigation has been carried out after the conclusion of the building construction, for analyzing the actual operation in comparison to different design variants that can be applied in further prefabricated houses.

Main characteristics of the building
The main feature of Moretti system applied for the construction of the case study are the concrete precast components with structural and insulating high performance. In Table 13, the main thermal properties of the building are reported.

Table 14: Building characteristics Casa More Franchino.

Parameter	Value
U-Value Wall	0.17 W/m²K
U-Value Roof	0.16 W/m²K
U-Value Floor	0.15 W/m²K
U-Value Window	0.6 W/m²K (g =0.35)
Air tightness	n50<0.91
PV	4 kW PV

No shading systems have been implemented thanks to the arcades which shield the large south-facing windows. However, the client requested motorized blackout curtains in the bedrooms and in the living room. The performance target is to reach an annual primary energy demand lower than 30 kWh/m²a.

4.3. PROTOTYPICAL IMPLEMENTATION OF MORETTI PROJECT

4.3.1. DOCUMENTATION: LIFE CYCLE COST ANALYSIS

Introduction

LCC analysis was introduced for the first time in the company design workflow for the case of a residential prefabricated house. This project has already been finished and delivered to the client, for this reason complete and definitive costs of the building are available for an accurate LCC analysis.

The project analyzed is a single-family house 160 m^2 of one floor, located in the north of Italy. The house has been designed with an envelope made of prefabricated concrete panels and a roof built in wood sandwich panels. The elements have been delivered on site already insulated and preassembled. This mixed structure combines a high structural and thermal performance with an easy assembly.

Nevertheless, using prefabricated elements has some constraints in terms of layers and dimensions allowed for the panels. For this reason an integrated design is crucial: the right balance between architectural design, structural and thermal performance needs to be found, and the LCC can be a criteria for improving the decision-making.

General project information

The building has been realized for a family with two kids. They got to know Moretti through a web search while they were looking for a partner able to design and build an innovative and performing prefabricated concrete house. The building has been finished at the end of 2019 after around four months of construction and one year and a half from the first meeting.

The client has chosen to build an ex-novo house after evaluating the possibility of renovating an old existing farmhouse already exinting on the site. This first hypothesis was rejected due to the uncertainty of the final costs and the construction time.

The client's conditions were thus very clear from the beginning: Moretti had to guarantee a well-designed project with a fixed budget and time schedule. The project goals were, on the one hand, to achieve the best design (taking in consideration the rural context) and, on the other hand, to optimize building's dimensions and the internal space, limiting the costs. The offer presented to the client was very detailed but one of the most sensitive topics for the agreement was the efficiency of the building in terms of energy consumption.

Figure 26. Pictures from the contruction site.

General Project Information / Energy Costs

(CRAVEzero cost Spreadsheet based on ISO 15686 and EconCalc - for internal use only)

LEGEND

Cell to be filled-in with input values	Cell to be filled-in with text, comments and references	Automatic calculation

PROJECT DATA

Name	Casa Franchino	
Nation/Region/city	Italia	
Location	Rosasco (PV)	
Author	Moretti	
Building Use/Typology	Apartment house	
Construction year	2'019	
Variants	Hide_Variant_1	Hide_Variant_2

BUILDING SURFACES AND VOLUMES

Gross floor area (GFA)	159	m^2
Net floor area (NFA)	125	m^2
Gross volume	669	m^3
Net volume	413	m^3

UNHEATED AREAS

Gross floor area (GFA)		m^2
Net floor area (NFA)		m^2
Gross volume		m^3
Net volume		m^3

OTHER AREAS

Balconies, terraces, winter gardens, porches...	33	m^2
	Description	
Other surfaces		m^2

Figure 27. LCC tool – General information sheet part 1 from Casa More Franchino.

DATA RELATED TO ENERGY CALCULATION TOOLS		
Treated floor area (ex: PHPP)	125	m²
Glazing area	40	m²
Total thermal envelope	618	m²
Window to wall ratio	0.07	-
Opaque surface	578	m²
Shape factor S/V	0.92	-
Average U-value opaque components	0.16	W/(m²K)
Average U-value glazing components	0.63	W/(m²K)
Average heat recovery efficiency	0.85	%
Air tightness	0.91	1/h
PV installed capacity	4000.00	Wp

Figure 28. LCC tool – General information sheet part 2 – values from Casa More Franchino.

According to the client's request both, client and company, decided to invest in a high performance energy house. Moretti calculated in detail the energy requirements of the building using Passive House Planning Package (PHPP) software.

The company could present to the client different solutions for the heating/cooling system, without being able to evaluate the benefit on the entire life cycle though. In fact, at the time of the building design the company did not have any tool able to display reliable data on the economic benefits of building an nZEB house taking into consideration the whole life cycle of the building.

Consequently, the choice of the technological system was taken based on economic evaluations focused only on the initial investment for the construction, as it was not possible to evaluate an economic scenario taking into account a wider time frame.

Only after an additional calculation of the real performance of the envelope with PHPP tool, the technology was changed and simplified adopting a simple mechanical ventilation (i.e "current building"). Thanks to the high performance of the envelope and the low heating demand, one single compact unit with heat pump (HP), AHU and DHW has been selected, combined with air distribution in the ceiling. In the part of LCC tool dedicated to building energy consumption a unique value was inserted in the heating system cell, comprehensive of all energy requirements for different uses (see Figure 29).

On the other hand, during the contract phase, the building was designed with an underfloor heating and cooling system, powered by a heat pump and supported by mechanical ventilation with a dehumidification system (i.e. "variant").

BUILDING ENERGY CONSUMPTION AND PRODUCTION	Technology	Energy source	Energy cost	Specific energy consumption	Annual energy consumed
			€/kWh	kWh/m²	kWh
Heating system 1	NILAIR	National Electricity-Mix	0.180	44.80	5'600
Heating system 2		...	0.000		0
Cooling system 1		...	0.000		0
Cooling system 2		...	0.000		0
Domestic hot water (DHW) system 1		...	0.000		0
Domestic hot water (DHW) system 2		...	0.000		0
Household elt. + aux.		...	0.000		0
PV production		Electricity from Photovoltaics	0.000		

Figure 29. LCC tool – Building energy consumption and production - Casa More Franchino.

Life cycle costing

Having completed the construction phase of the building, Moretti compared, using the LCC tool, the difference between the current HVAC system installed in the building and a variant, keeping the same characteristics of the building. First, data about building energy consumption had to be modified, since in the variant case (right column in Figure 31) the system appears oversized compared to the building's thermal energy needs:

	Energy source	Energy cost	Specific energy consumption	Annual energy consumed
		l/kWh	kWh/m²	kWh
Heating system 1	National Electricity-Mix	0.180	49.13	6'141
Heating system 2	...	0.000		0
Cooling system 1	National Electricity-Mix	0.180	12.30	1'538
Cooling system 2	...	0.000		0
Domestic hot water (DHW) system 1	National Electricity-Mix	0.180	25.71	3'214
Domestic hot water (DHW) system 2	...	0.000		0
Household elt. + aux.	...	0.000		0
PV production	Electricity from Photovoltaics	0.000		

Figure 30. Energy consumption data - Casa More Franchino.

In the WLC sheet of the tool, the same non-construction and design costs as for the base case are considered. In the construction cost sheet the differences regarding construction cost of the current project and the variant have been identified. Figure 31 reports the cost data comparison for building services, the main difference is how the costs are splitted and the total amount for the variant is 2,300 higher.

CURRENT			VARIANT		
B	BUILDING SERVICES		B	BUILDING SERVICES	
B1	Heating System	0	B1	Heating System	0
B1.01	Heating system 1	0	B1.01	Heating system 1	18'200
B1.02	Heating system 2	0	B1.02	Heating system 2	0
B2	DHW production	0	B2	DHW production	0
B3	Cooling system	0	B3	Cooling system	700
B4	Mechanical ventilation sys	33'100	B4	Mechanical ventilation sys	16'500
B5	Electric	13'624	B5	Electric	13'624
B6	Hydraulic system / Plumbe	5'140	B6	Hydraulic system / Plumbe	5'140
		51'864			54'164

Figure 31. Contruction cost comparison for building services: current building vs. variant.

	Current building				Variant building			
WHOLE LIFE-CYCLE COST	615'426	€	-	€/m²	670'973	€	5'368	€/m²
Non-construction cost	21'000	€		€/m²	21'000	€		€/m²
Design	39'152	€	313	€/m²	39'152	€	313	€/m²
Preliminary design	4'524	€	36	€/m²	4'524	€	36	€/m²
Definitive design	15'300	€	122	€/m²	15'300	€	122	€/m²
Executive design	19'328	€	155	€/m²	19'328	€	155	€/m²
Building site	-	€	-	€/m²	-	€	-	€/m²
LIFE-CYCLE COST	594'426	€	4'755	€/m²	649'973	€	5'200	€/m²
Investment cost	393'239	€	3'146	€/m²	395'539	€	3'164	€/m²
Operation and maintenance cost	201'187	€	1'609	€/m²	254'433	€	2'035	€/m²
Construction	354'087	€	2'833	€/m²	356'387	€	2'851	€/m²
Materials	354'087	€	2'833	€/m²	356'387	€	2'851	€/m²
Building elements	232'183	€	1'857	€/m²	232'183	€	1'857	€/m²
Building services	51'864	€	415	€/m²	54'164	€	433	€/m²
RES	-	€	-	€/m²	-	€	-	€/m²
Other	70'040	€	560	€/m²	70'040	€	560	€/m²
Labor	-	€	-	€/m²	-	€	-	€/m²
Building elements	-	€	-	€/m²	-	€	-	€/m²
Building services	-	€	-	€/m²	-	€	-	€/m²
RES	-	€	-	€/m²	-	€	-	€/m²
Other	-	€	-	€/m²	-	€	-	€/m²
Operation and Maintenance Costs	201'187	€	1'609	€/m²	254'433	€	2'035	€/m²
Energy consumed	27'574	€	221	€/m²	53'635	€	429	€/m²
Energy produced	-	€	-	€/m²	-	€	-	€/m²
Net energy consumed	27'574	€	221	€/m²	53'635	€	429	€/m²
Maintenance	173'612	€	1'389	€/m²	200'799	€	1'606	€/m²
Indicators								
DC/LCC	10%				10%			
CC/LCC	90%				90%			
LC/LCC	0%				0%			
OC/LCC	51%				64%			
Energy consumed	5'600	kWh	45	kWh/m	10'893	kWh	87	kWh/m²
Building elements costs	232'183	€		€/m²	232'183	€		€/m²
Building elements costs/CC	66%				65%			
Building envelope costs	171'557	€	1'372	€/m²	171'557	€	1'372	€/m²
Building structure costs	20'579	€	165	€/m²	20'579	€	165	€/m²
HVAC costs	33'100	€	265	€/m²	35'400	€	283	€/m²
PV installed capacity	4'000	Wp	32	€/m²	4'000	Wp	32	€/m²
Building services	51'864	€	415	€/m²	54'164	€	433	€/m²
RES	-	€	-	€/m²	-	€	-	€/m²
Maintenance/Investment	44%				51%			
RES/LCC	0%				0%			
Usable to gross floor surface ratio	1				1			

Figure 29. LCC tool – "Results" sheet - Casa More Franchino.

Analysing the same results organized in the tables available by the LCC tool, a better insight on the comparison between the two solutions can be achieved. Figure 32 shows the relative impact of the different costs along the life cycle of the building (considering a period of 40 years): the highest cost share is the construction cost, which accounts for 60 % of the total LCC.

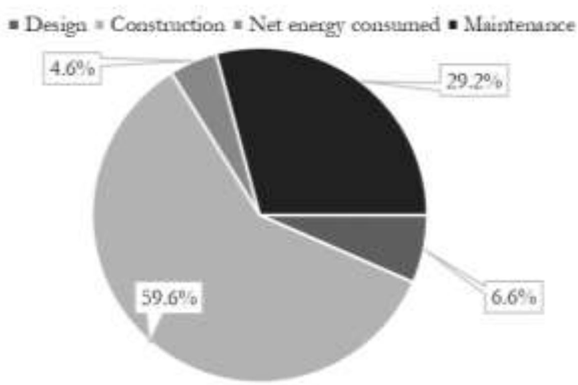


Figure 32. LCC breakdown – current building.

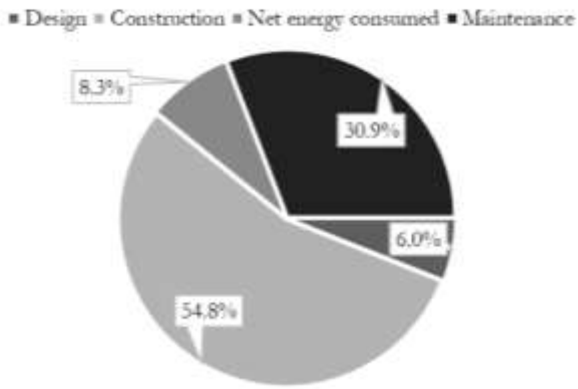


Figure 33. LCC breakdown – variant building.

Figure 34 and Figure 35 display an overview of the LCC calculated considering a period of 40 years for the building, with a breakdown of the cost for each phase for the two projects.

CURRENT BUILDING

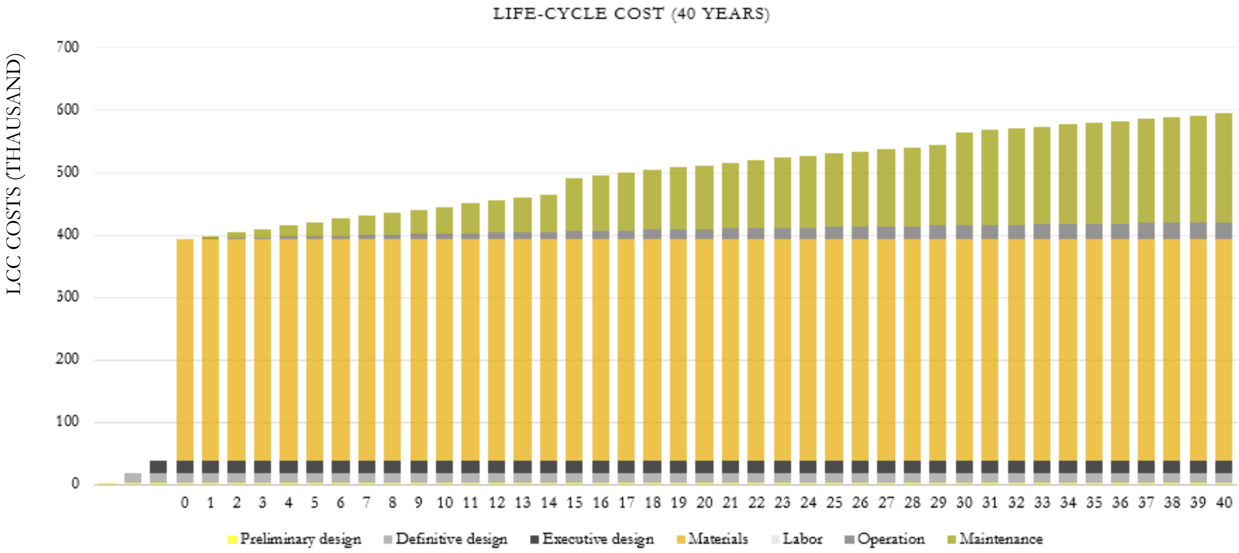


Figure 34. Yearly LCC (40 years) – Current building of Casa More Franchino.

VARIANT BUILDING

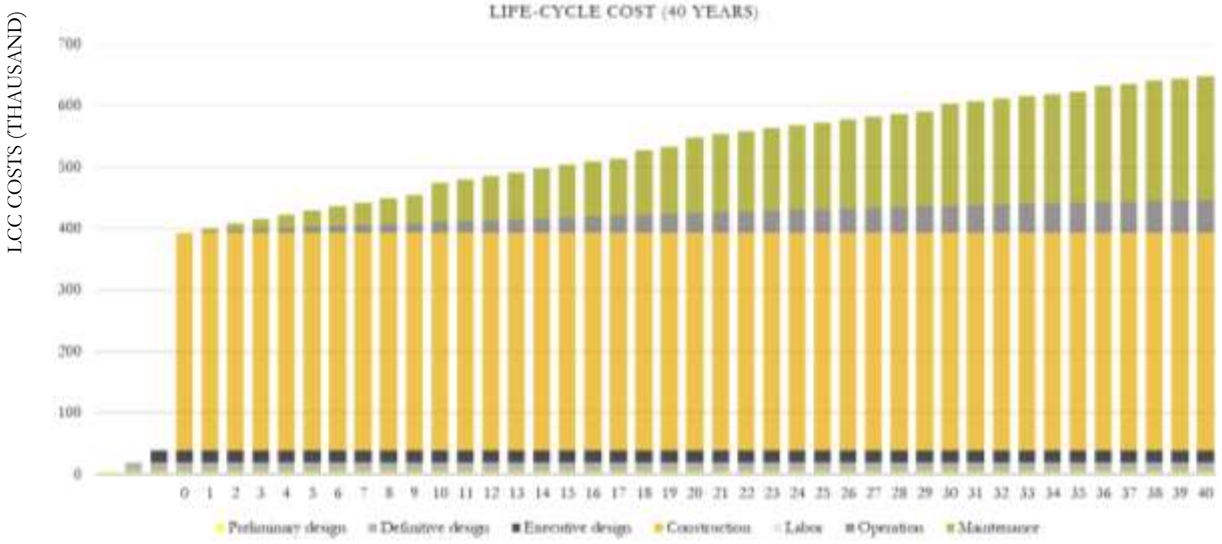


Figure 35. Yearly LCC (40 years) – Variant building of Casa More Franchino.

The graphs show that both cases have similar initial investment cost, due to the construction cost, which represents the largest cost share.
However, the operating costs in the variant analyzed are higher, due to the greater demand for primary energy.
Another interesting result is the different impact of the maintenance phase. The same amount is reached at the end of the considered period, but it is clear that the maintenance costs grow much faster in the variant building. This difference is due to the the number of systems selected in the building variant and the simplified solution installed in the first place.

Based on these results, Moretti thinks, that the LCC tool can be a very useful application to be introduced in our company in order to evaluate with the client the best configuration taking into account a wider time frame.
Being able to analyse, already in the very preliminary stage, how different solutions can affect the costs during and after the construction, the company will have reliable motivations to lead the client in choosing the best solution for his/ her needs.
Since Moretti produces industrialized technologies, the construction phase is quite strict and during planning phase fix constraints need to be respected. Therefore, the implementation of this LCC tool in the organization process will be feasible and effective. The next step for a fruitful implementation would be to insert the specification of the company estimation sheet (applied for invoices and cost provisions) in the LCC tool, to be able to evaluate different scenarios, only modifying the characteristics of the investigated solution.
Moretti would start from this prototypical case to extend the methodology to the technology of prefabricated houses they produce. It will become a useful tool to analyse different scenarios and also to make more effective the decision-making process of the client, highlighting the the impact of a different choice, looking at the whole building life cycle and not only at the early-stage investment.

Figure 36. Construction site.

4.3.2. DISCUSSION

Phase of implementation
Although the analyzed building has been completed and delivered to the client, this implementation has been carried out as if being back at the design phase, by comparing two different variants.

Boundaries of application
The methodology has been applied during the design phase of the HVAC system for a single family house of 125 m^2.

If a similar methodology is already integrated in the standard workflow, which are the main differences between the two methodologies?
Currently Moretti does not implement LCC methodology in the company workflow for design and construction.

Goals from the application of the methodology
The main objective of this implementation was to test and introduce in the company design approach a methodology for performance evaluation of the building and LCC analysis in the early stage of the project. Moretti decided to start from this real prothotypical case to extend the methodology to our technology of prefabricated houses. It will become a useful tool to analyze different scenarios and also to highlight to the client the impact of different alternatives, looking on a wider perspective.

Difficulties and critical points of the implemented features
The main difficulty for applying the LCC evaluation is related to the data collection. In fact, the information required by the construction cost sheet is very detailed, it could be difficult to have access to all this costs in a early stage of the project. In future projects parametric costs can be adopted in the first place, detailing those cost during the project prosecution.

Advantages of the applied methodology Thanks to this methodology it is possible to clarify to the customer in a more concrete, reliable and understandable way, the differences between the designed variants.
How easy is the methodology to be implemented in the normal workflow?

At the moment, Moretti does not have tools for this type of analysis, so CRAVEzero LCC is easy to implement and indeed welcome. Furthermore, implementing this tool in the company's workflow is quite easy, thanks to the standardised process applied for the prefabricated construction technology.

Target/s achieved - How satisfied are you with the results obtained
This analysis confirms with quantitative results the qualitative decision-making applied during the design of the analysed building. For this reason this methodology can help to be more effective and reliable with the client because it provides concrete results to support design choices.

Lessons learnt
The first result obtained by applying the tool showed that the most relevant cost share during the life cycle of a building is due to the construction costs. Furthermore, Moretti prefabricated technology, being an industrialized system, does not leave great flexibility in terms of the energy performance of the envelope, and now after some experience, the right balance between performance and technology constraints was found.

So two different building services systems were compared: one more traditional but oversized compared to the heating and DHW demand of the building and one simpler, but not so commonly adopted and therefore apparently less reliable in terms of comfort. The results confirm our choice, because it reduces operating and maintenance costs.

4.3.3. DOCUMENTATION: PROCESS MAP

In the framework of the prototypical implementation, Moretti adopted a second approach introduced by the project, i.e. the CRAVEzero process map together with the life cycle project management and nZEB life cycle tracker tool. The objective is to compare them to Moretti's standard workflow and possibly integrate them.

Comparison between CRAVEzero and Moretti process map
Moretti is involved in planning and construction phases, having its own process that guides all the stakeholders during the process.

Moretti process map is structured in eight steps, each phase identifies the activities to carry out, the main actors involved with the RACI scheme (Responsible, Accountable, Consulted, Informed), the scheduled time to complete the activities. Each phase can be further detailed and elaborated, if needed.

Although Moretti process map is a tested and useful guideline throughout all phases for involved stakeholders to follow the right steps at the right time, this process is not focused on new nZEBs. Thus it is interesting to integrate the additional features introduced by CRAVEzeroin the Moretti workflow.

Furthermore, Moretti process is easily replicable and aims to keep the same approach in every project, finding the right level of integration between our existing process map and the CRAVEzero process map.

Moretti thinks that the integration between CRAVEzero tool and their standard building process will help to reduce risks, to speed up the process in the design phase, to guarantee cost and energy performance.

The next part of the report is going to highlight the best features found in theCRAVEzero tool to be implemented in Moretti's own tool, to track along the process, the key performance parameters to achieve successful nZEBs.

The aim of CRAVEzero tools is to provide an operative methodology to ensure a quality workflow to achieve the best solutions for cost optimal new nZEBs. Accordingly, the process map is very well structured because the whole process is organized and splitted in clear different phases. For this reason every stakeholder can focus in a efficient way on the action he/ she is involved in.

Another useful feature is the stakeholder-relation in CRAVEzero life cycle tracker. Often Moretti focuses on some decisions in a wrong way, not considering all the stakeholders which will be involved to reach a defined goal. Consequently, in case of a late involvement, the risk to have additional review loops to the project or, worse, to miss the goal. These tools help to make sure to take the right decisions at the right time and considering all points of view.

Life cycle tracker application

The application of the life cycle tracker at Moretti case study, takes into account the constraints represented by the specific contruction technology: the wall composition, constructive elements nodes, prefabricated elements.

So the focus was on these elements to understand if the process usually followed is efficient and exhaustive.

In the action view filtering by importance, appears that the most important issue is the details about heat bridges, so more attention on these details should be paid during planning and construction phases.

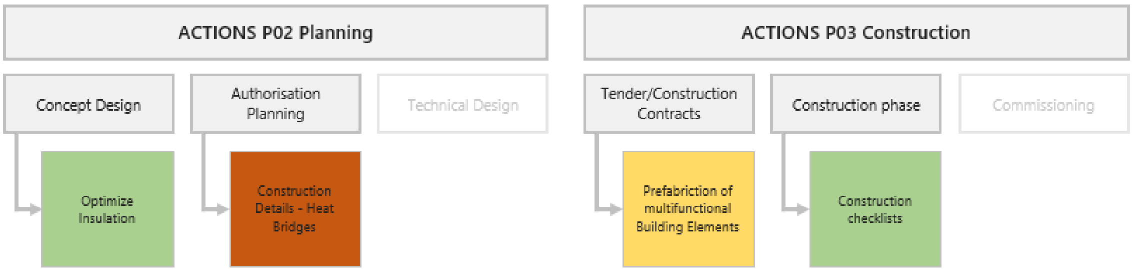


Figure 37. Life cycle tracker – Actions related to planning and construction.

In the action description appears that it has influence on other actions in the planning (2.3 Improve window to wall ratio, 2.21 BIM system), construction (3.6 thermography infrared, 3.8 eliminate heat bridges) and operation phases (4.7 system test procedures) as displayed in Figure 40.

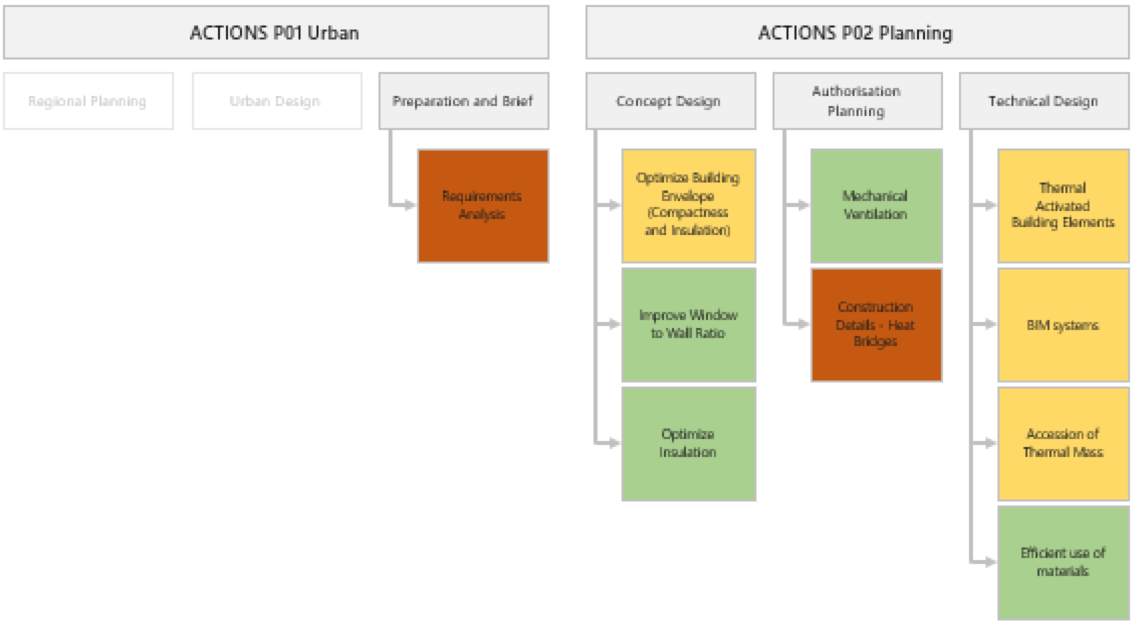


Figure 38. Life cycle tracker – Actions related to whole life cycle part 1.

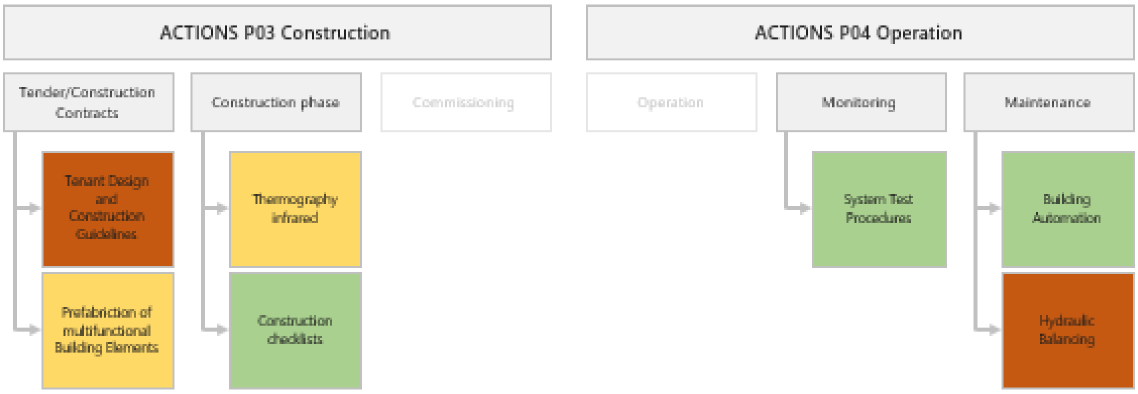
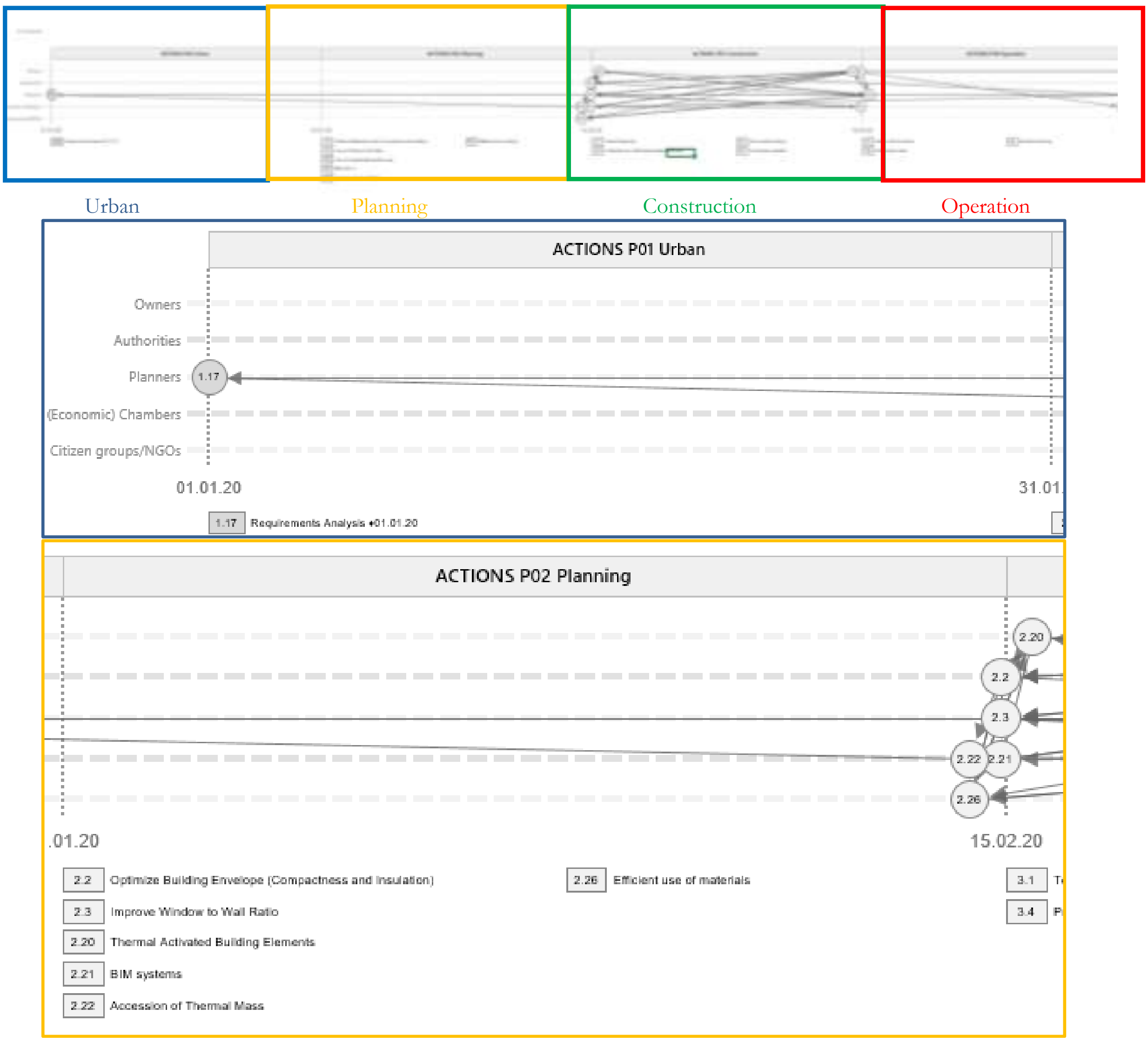


Figure 39. Life cycle tracker – Actions related to whole life cycle part 2.

For all the actions selected, the stakeholders involved are principally planners and construction company. Moretti, as general contractor, integrates both these functions, which can lead to an efficient workflow.



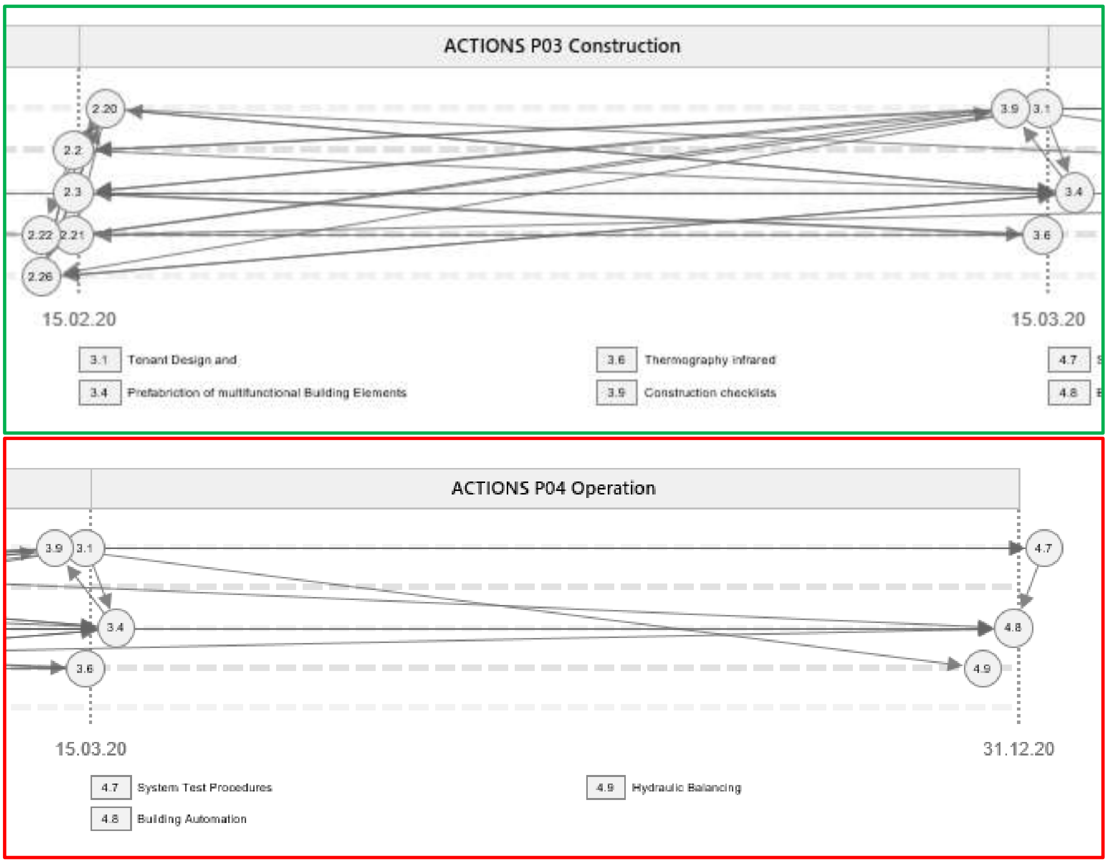


Figure 40. Life cycle tracker – actions correlation.

Planning and construction phases are crucial for the project success: by applying an integral planning strategy Moretti chooses the combination of materials and technologies for the building industry and subsequently execution on site is also very important.

The integration of planning and construction allows to reach more ambitioned targets, this requires that the actors of planning and construction need to work in an exchanging way.

For the same reason the Process Tracker allows to see different dependencies between actions which helps to prepare questions and plan meetings, minimizing conflicting objectives between different chosen actions and speed up processes.

Considering the importance and the complexity to reach the nZEB standard in a cost-optimal way for all the different stakeholders during the process, multiple actions are required.

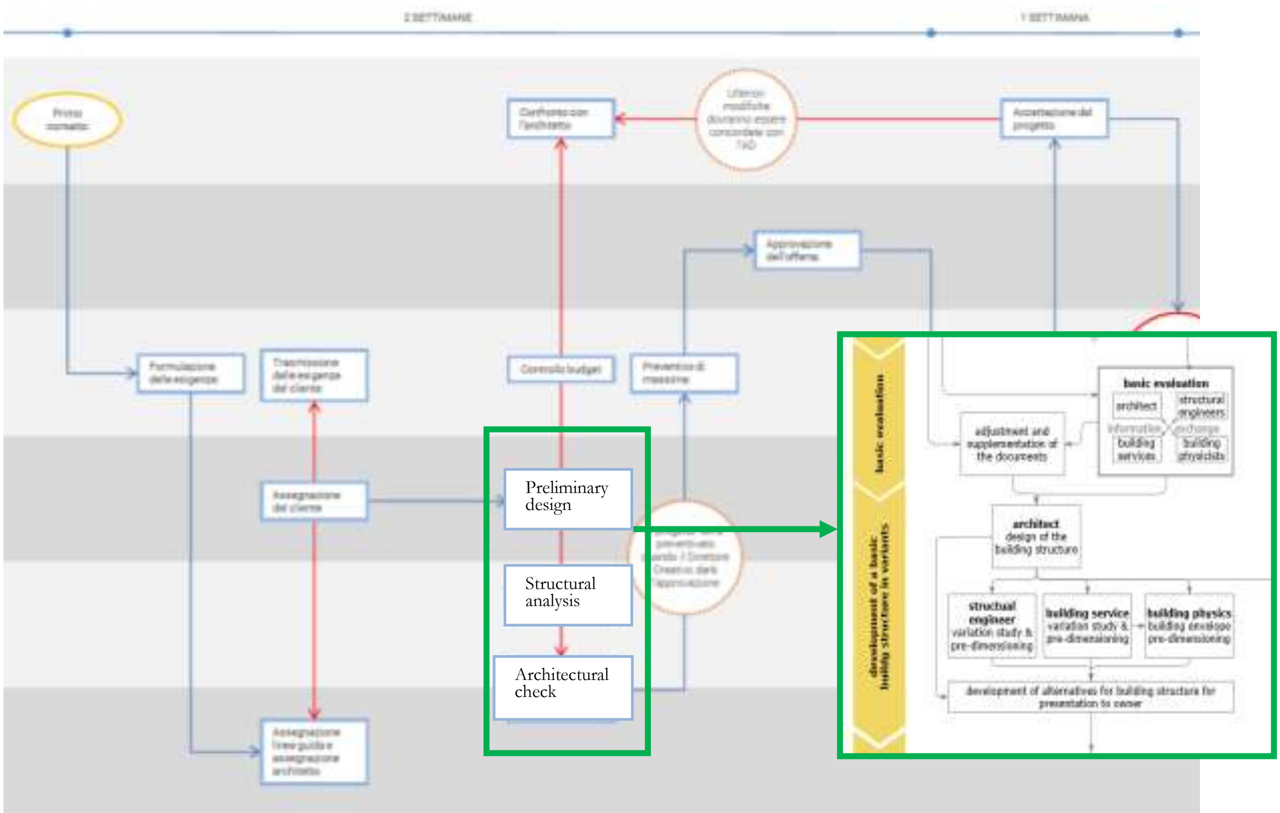


Figure 41. Moretti process map in comparison with CRAVEzero one.

During the concept design, also critical pitfalls and bottlenecks, which may affect the project goals, need to be identified. As a general contractor Moretti has an advantage to apply this approach because coordinates the design of different building aspects and also the construction itself.

During the authorization planning Moretti usually put different knowledge together. Interdisciplinary work is crucial in this part of the process. Only a simultaneous and interdisciplinary project team can apply an integral design method, which makes it possible to compare variants and to select the concept which is in line with the client's requests and the targeted values.

During technical design, the verification of the goals of the project is defined in detail. At design stage if the phases described in CRAVEzero process map are followed, strategies to skip pitfalls and bottlenecks can be found.

The integration of the process map with actions is a useful check-list to verify whether every task has been tackled at the right moment. Main bottlenecks usually found in Moretti process among the ones highlighted in CRAVEzero process map are the following:

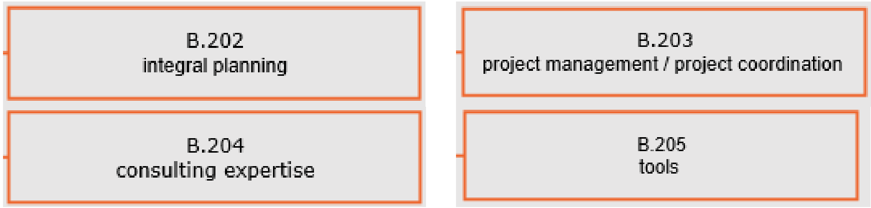


Figure 42. Main bottlenecks.

Collaboration between different experts and designers have to be carried out in a very early stage of the planning process and not only during the emission of technical design.

To reach an aware decision, it is important to advice the client about all aspects concerning the building life cycle. The introduction of CRAVEzero approach during the decision process could be useful.

Concerning the construction phase Moretti has the advantage that use of prefabricated systems and the displacement of the workings as much as possible outside the building site is a winning strategy to achieve a lean construction process. Off-site construction reduces on-site work, allowing reorganization of technologies and process with an improved efficiency and quality. The reliability of the products, the traceability of the components, their programmable maintenance as well as the reduction of the energy costs are decisive aspects for off-site construction.

The construction process displayed in CRAVEzero Process map does not haverelevant differences compared to Moretti's one, however it is interesting how pitfalls and bottlenecks that can endanger deadlines, budgets and quality of the nZEB project are highlighted.

Another interesting feature is the display of required goals and co-benefits. Besides the optimisation criteria and thus the benefits that can be directly assessed from the economic point of view, there are also different co-benefits for the each stakeholder, which often cannot be assessed directly in monetary terms but important as well in the process.

As a result of the analysis performed in this implementation, Moretti believes that the tested tools developed within the CRAVEzero project can be well integrated and give the added value in the case of nZEB.

4.3.4. DISCUSSION

Phase of implementation: the analysed building has been already completed and delivered to the client. However, the present implementation has been conducted, going back to the design phase.

Boundaries of application: The building is a single family house, of 125 m² on one floor. The envelope of the building is made by concrete prefab panels, which combine structural and thermal performances.

If a similar methodology is already integrated in the standard workflow, which are the main differences between the two methodologies? Moretti has its own process map, from planning phase to construction. Nevertheless Moretti's process is not focused on nZEBs.

Advantages of the applied methodology: CRAVEzero focus on nZEBs, complemets Moretti's lack on how to reach the nZEB standard in a cost-optimal.

Difficulties and critical points of the implemented features: the main difficulty found using life cycle tracker tool is that it contains a lot of actions and if multiple are selected at the same time, the stakeholder-relation could become confused. It is better to find a criteria to select group of actions.

Disadvantages of the applied methodology: CRAVEzero process map cannot replace the company's specific one. It has to work in parallel.

How easy is the methodology to be implemented in the normal workflow? Easy applicable to usual workflow as a support to Moretti's process map.

How satisfied are you with the results obtained: useful results have been obtained which can help Moretti to improve our performance.

Table 15. Upcoming nZEB projects – Moretti SpA.

	Project	Location	Building use / Typology	Client
1	Casa More Zanetti	Pianezzo	Residential Single-family house	Zanetti Manuel
2	Casa More Costa	Travagliato	Residential Single-family house	Costa Giorgio
3	Casa More Scaratti	Concesio	Residential Single-family house	Scaratti Francesca
4	Casa More Zanini	Grezzana	Residential Single-family house	Zanini Tommaso
5	Casa More Brambilla	Casteggio	Residential Single-family house	Sig. Brambilla
6	Casa More Boldrini	Rimini	Residential Single-family house	Boldrini Marco

Table 15 displays the building projects that are in Moretti's pipeline. The replicability of the analysed case study, which represents one of the products that Moretti company sells on the market, will permit to fine-tune and further implement CRAVEzero methodology to these upcoming nZEBs.

5.CONCLUSIONS

Life cycle costing

In this first implementation phase the life cycle costing approach has been adopted and tested in both cases during the design phase. The first consideration is that this methodology allows moving the focus away from the initial investment perspective, including in the analysis operation and maintenance as well. Some of the advantages, confirmed in the prototypical implementations, are that gives transparency on the operational phase of a building, awareness of total costs for both designer and client and the possibility to adjust these total costs already in the design phase.
This approach helps to achieve a design which balances initial capital cost and future running costs. This leads to identify opportunities for a better cost-effectiveness, for example selection of components with a longer service life or reduced maintenance needs. [4] underlines the above-indicated benefits of LCC implementation in the initial phase of a construction project, since it provides an appraisal function and allows:

- To balance the cost of ownership and occupation, analysing initial investment and running cost,
- To assess risk and costs connected to maintenance and replacement due to failure and,
- To support decisions which consider sustainability.

As reported by both partners, 3i and Moretti, this approach entails some difficulties too:

- Availability and reliability of input data already in the design phase of a building.
- Input parameters require to make assumptions and simplifications. For example for the estimation of maintenance costs.
- Uncertainties on boudary conditions such as economic parameters (interest rate, inflation energy cost, etc.).

Another characteristic of LCC analysis highlighted in this first implementation phase is the variants comparison function. Moretti has analysed the LCC of two technology sets, 3i compared its case study with a standard building. This approach allows to undertake financial options evaluation, being in this way a tool which supports the decision making process.
Detailed design requires final selection of materials, components and technologies. For example the LCC analysis can be applied to the selection between an active technology with a lower investment cost and a passive technology which requires a higher initial investment (planning effort) but has a reduced maintenance cost.

Business model canvas

Similar statements reported by [5] in the case of zero carbon buildings can be applied to nZEB market since, also this case, the unstable and ambiguous political, legislative and economic challenges such an harmonized legislation among member states, a clear financing scheme and the high initial investments required, strongly determine the slow uptake of nZEBs. Furthermore, social-cultural challenges, such as customers' awareness and behaviors, and the fragmented structure of the construction industry, have to be taken into account as well. For these reasons innovative business models together with innovative processes can help to tackle those challenges.

3i project shows how the development of a new nZEB project requires the definition of a corresponding business model. Its definition, which deals with all the innovative characteristics of a nZEB, aims at creating synergies and a win-win situation for the involved stakeholders. Therefore it is key aspect to foster nZEB market uptake.
It was pointed out that the application of the BM Canvas allowed a deeper knowledge of the new BM, in that thanks to this approach it is possible to tackle problems and critical issues anticipating the

implementation of the pilot project. Furthermore, it is recognized that another key methodology feature is the BMs database on the nZEB at a European level. This feature allows to draw a comparison with the current proposals on the market and tto take inspiration from them.

The performed analysis on the DoppioUno business model thanks to the CRAVEzero approach led to a deeper understanding of the new business model, to the identification of weaknesses in an early stage, and to combine different stakeholders and skills to provide a complete service throughout the entire life cycle of the building.

Process analysis

Planners, general contractors and construction companies generally have their internal processes in order to guarantee product quality to the client. Nevertheless, as stated before, nZEB market presents numerous challegess as it did not reach a maturity yet. The "CRAVEzero Process Map" is a process tool which is dedicated to nZEBs, enabling the project team to integrate in its design process additional tasks and actions for achieving the nZEB standard in the most straightforward and cost-efficient way.

Moretti company represents an example of the implementation target pursued within CRAVEzero project, because the company already implements in the workflow its own process map which is meant to optimize and structure the planning process. However the complexity of nZEB requires a dedicated approach, which the CRAVEzero process map provides, supporting and integrating company’s own process map.

6.REFERENCES

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