Energy Poverty Zero

Deliverable

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Work Package 2

Deliverable D2.2 – Presentation of the retrofit solutions

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I. Preliminary information

A. Executive Summary

The European Union (EU) is actively pursuing its climate neutrality goals by 2050, emphasizing decarbonization in the building sector. Central to these efforts is the adoption of innovative renovation approaches like the EnergieSprong model, which leverages industrialized prefabricated solutions to achieve scalable and effective building refurbishments. This model is designed to meet energy performance standards while also being cost-effective and minimally disruptive, particularly benefitting low-income households.

Overall, the adoption of the EnergieSprong model and the deployment of prefabricated retrofit solutions represent a significant step towards achieving the EU's ambitious building sector decarbonization targets, supporting the broader Renovation Wave strategy. By focusing on scalability, cost-effectiveness, and improved living standards, these efforts align with the EU's climate neutrality objectives and support the transformation of Europe's building stock into a more sustainable and resilient infrastructure.

In this direction, the Energy Poverty Zero project, aligned with the EnergieSprong Global Alliance movement, adapts this model to different EU countries, including France, Italy, and the Netherlands. Within this framework, the specific work of WP2 enables municipalities and users to assess renovation potential at the neighbourhood level using an advanced analysis tool, namely the EP-0 ICT tool, presented as a first version in D2.3. This tool starts from an analysis of the current performance of buildings according to their typology and year of construction, and it helps identify scenarios for energy-efficient retrofits, delivering information regarding the type of solutions to be implemented, costs, and environmental impact.

Task 2.3 of the project, which leads the elaboration of D2.2, aims to develop a comprehensive repository of prefabricated retrofit solutions to be, in a second developing phase, showcased in the tool. These solutions target energy efficiency improvements, seismic resilience, and occupants' comfort. By qualifying this mix of industrialized retrofit options that support the improvement of building's energy efficiency, the project supports the development of efficient and low-disruption renovation strategies. These solutions are intended to be integrated into the EP-0 ICT tool by August 2025, facilitating the choice of technical elements by the user, to support the energetic and environmental enhancement of buildings.

This deliverable document outlines several key sections, including an overview of the EnergieSprong model and its process and business model, the benefits of adopting such an approach (e.g., enhanced energy performance, occupant engagement, seismic safety,

decarbonization, and sustainability), a classification of the solutions, and a repository of these solutions.

The *Presentation of the retrofit solutions* deliverable (D2.2) under the Energy Poverty Zero project outlines innovative, prefabricated retrofit solutions aiming to meet EU energy efficiency and decarbonization targets. These solutions, based on the EnergieSprong model, are designed for efficiency, minimal on-site disruption, and scalability. They focus on enhancing energy performance, seismic resilience, and comfort, making large-scale retrofits viable, especially for low-income households. The deliverable also introduces a repository of retrofit solutions for the EP-0 ICT tool, categorizing options by technical elements and features like energy efficiency, environmental impact, and seismic resilience. This repository will be integrated into the tool's final version in August 2025, allowing users to evaluate suitable solutions for their buildings.

B. Grant Agreement Expectations

According to the grant agreement, this D2.2 deliverable must provide a detailed presentation, in a Word document, of the different retrofit solutions selected by the consortium for implementation in the EP-0 ICT tool.

This tool is designed to define scenarios, characterize buildings, and link the suitable prefabricated renovation solutions for users to choose from. These prefabricated solutions have significant potential for cost-effective deep energy retrofits, particularly benefiting low-income residents.

As a first step, the tool will categorize buildings based on their architectural features and construction years to establish a baseline, and identify energy improvement needs. Once categorized, the tool will propose retrofit scenarios characterized by general retrofit packages.

In the second phase of the project, the most suitable solutions identified in this deliverable will be included as a repository in the tool, in its final version expected in August 2025 (M34). At this stage, each solution's main characteristics, including structural features and installation needs, compatibility, renewable energy capabilities, thermal properties and other comfort benefits, installation costs, time of installation, and environmental impact, will be integrated in the tool. This is crucial in order to allow everyone to evaluate the adaptation of the solutions to the buildings and to elect them for possible renovation projects.

A comprehensive cost analysis module, being developed in D2.4 and integrated by the tool's final version, will complete the analysis and be available for users to assess the financial implications of the renovation interventions. To make these renovation options accessible to

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private owners, the team will explore financing options, in WP4, D4.3. The financing tool will incorporate subsidies and incentives to accommodate users' individual financial capacities, ensuring the affordability and feasibility of renovation projects and the implementation of chosen solutions.

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II. Deliverable

A. The context

1. European Union energy and decarbonization targets

The European Union (EU) has established ambitious decarbonization targets with a strong focus on the building sector, which is essential for achieving climate neutrality by 2050. The European Green Deal highlights the necessity of comprehensive renovations to enhance energy efficiency and reduce emissions in buildings. This effort is supported by the "Renovation Wave" strategy, which seeks to double the annual rate of energy renovations in buildings by 2030. This initiative aims not only to cut emissions but also to create green jobs and improve living standards across Europe[1, 2].

Under the 2030 climate and energy framework, the EU aims to reduce net greenhouse gas emissions by at least 55% from 1990 levels. Significant improvements in building energy performance are crucial for meeting these targets, given that buildings represent a large share of the EU's energy consumption and CO^2 emissions[3].

Despite these efforts, the progress in decarbonizing the building sector has been slower than needed. The EU Buildings Climate Tracker indicates that the current pace of building decarbonization is insufficient to meet the 2050 climate neutrality goals. The index shows that between 2015 and 2019, the progress was only a fraction of what is required, suggesting a need for accelerated and deeper renovations[1].

To address these challenges, the EU has implemented key legislative measures, such as the Energy Performance of Buildings Directive (EPBD), which sets minimum energy performance standards and encourages deep renovations. Additionally, funding from initiatives like the Horizon Europe program and the Recovery and Resilience Facility supports these efforts by promoting research, innovation, and the scaling up of renovation activities[3, 4].

In conclusion, while the EU has established a robust framework and ambitious targets for decarbonizing buildings, the pace and depth of current efforts need significant enhancement

[1] https://www.bpie.eu/publication/eu-buildings-climate-tracker-urgency-to-close-the-buildings-decarbonisation-gap/
[2] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en
[3] https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2030-climate-targets_en
[4] https://www.mckinsey.com/capabilities/sustainability/our-insights/how-the-european-union-could-achieve-net-zero-emissions-at-net-zero-cost

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to align with the 2050 climate neutrality objectives. Various barriers subsist towards the achievement of the set targets, which can be grouped into three main categories: i) Information, which covers how communication and education can raise awareness to encourage energy renovation; ii) b) Finance, which deals with the economic aspects of renovation, including subsidies; iii) Process, which encompasses the physical and social context, decision-making, and regulation[5].

2. The existing building stock: enhancing its value and meeting the challenges of the transition towards large-scale, industrialized renovation

The city of tomorrow depends on housing renovation. The city of tomorrow will mainly be the city of today, but it will have evolved to accommodate 70% of the world's population by 2050. And with 400,000 new homes being built every year in France, out of a total housing stock of 37 million, the housing stock of 2050 will mainly be made up of existing homes. These homes are ageing, uncomfortable, thermal flats where fuel poverty reigns and is increasing every day (11.7% of households in 2018). Housing that is incompatible with national targets for combating climate change. Housing that needs to be renovated. But if we are to meet our energy and climate objectives, the crux of the matter will be our ability to transform the quantity and quality of our existing buildings in a sustainable way, with the aim of achieving energy sobriety.

The building and public works sector must reinvent itself to better meet the challenges of transition. This delay means that we need to think collectively about new ways of doing things to massively increase renovation. However, it has to be said that the building sector is struggling to innovate in this area. With only 0.1% of the construction industry's turnover devoted to R&D (compared with an average of 2% for industry), the sector is lagging behind in terms of quality, productivity gains and digitisation. Yet it is through the industrialisation and standardisation of ambitious, high-quality and desirable solutions that we will succeed in achieving our energy transition objectives. Faced with the emergence of international players with substantial financial resources (Google, Katerra, Amazon, etc.) in this market sector, we need to convince the entire ecosystem to support the players in the French economic fabric in making the transition to embracing digital, LEAN and off-site thinking to rework their renovation offerings.

[5] Bjørneboe M, Svendsen S, Heller A, Initiatives for the energy renovation of single-family houses in Denmark evaluated on the basis of barriers and motivators, Energy and Buildings, Volume 167, 2018, Pages 347-358.

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This long-awaited transition also requires a change of vision. With public finances under pressure, the choice is no longer between carrying out a lot of unambitious renovations or supporting a few very ambitious ones. We need to take a third path: that of undertaking a lot of highly ambitious but less expensive renovations to combat fuel poverty.

EnergieSprong, and industrialized prefabricated processes in general, represents a collective innovation process designed to address this challenge through a refurbishment approach that, by design, is intended to meet the necessary scalability and performance requirements. A market still in its early stages, which will find its key growth drivers not only in technological advancements but also in appropriate market conditions: sufficient volumes of adequate demand, sustainable economic and financial models, suitable procurement frameworks, and an adequate regulatory framework.

3. Relation with other activities: the EP-0 project and WP2

The overall goal of the project is to support and boost large-scale renovation projects by adopting an industrialized prefabricated approach. The project raises and embraces the EnergieSprong Global Alliance movement, and its declinations in the different EU countries, especially the ones mentioned in the project (i.e., France, Italy, the Netherlands).

Within the project, WP2 aims at enabling municipalities to assess the potential for renovating housing using an industrialized approach through a neighbourhood-level analysis tool. In this direction, prefabricated industrialized solutions hold significant promise for cost-effective deep energy retrofits, particularly benefiting low-income residents.

As part of *Task 2.3,* this deliverable aims to build a repository of the prefabricated retrofit solutions that can support a quick, low-disruptive, and efficient buildings' retrofit, targeting energetic and seismic issues, and enhancing occupants' comfort and well-being. As conceptualized in Figure 1, the solutions hereby presented are meant to be integrated in the EP-0 ICT tool by its final version in Month 34/August 2025, as a repository provided to the user in order to select the best option to achieve the energetic and environmental improvements of selected buildings to be refurbished. The development of this repository also includes the insights and experience from EnergieSprong, in particular the Italian and French movements, which in their guidelines are publicly contributing valuable information from conducted case studies and from cooperation with manufacturers and technology providers.

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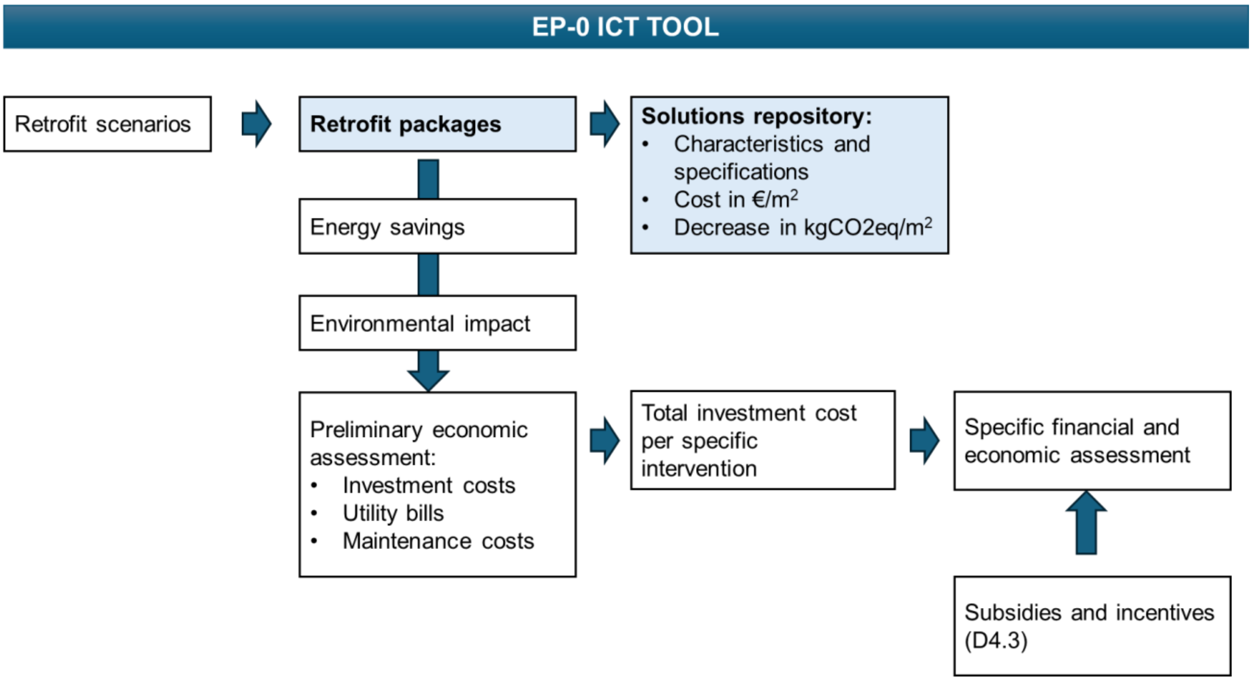

Figure 1. Conceptualization of repository of solutions' integration in the EP-0 ICT tool final development.

This document consists of the following sections: i) the EnergieSprong model: process and business model; ii) benefits: occupants' engagement, energetic, seismic, decarbonization, timeline, circular economy and sustainability; iii) classification of categories of solutions; iv) repository of solutions.

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B. The EnergieSprong model: process and challenges

The EnergieSprong refurbishment process is a comprehensive method that integrates digital technologies to optimize the building retrofit process from analysis to the end of the building's life cycle. A key focus of the approach is on **prefabricated retrofit solutions**, which play a central role in improving efficiency, reducing costs, and ensuring long-term performance.

Depending on the type of solution to integrate, the process can entail several phases:

1. **Analysis and design**: the building is evaluated and a feasibility study is conducted. Especially for the installation of envelope elements, can be beneficial to create a digital model of the building. Building Information Modeling (BIM) can be also used to integrate all architectural, structural, and energy aspects, including energy and seismic simulations.
2. **Manufacture**: drawings are elaborated for offsite prefabrication, for designing and manufacturing the solution elements. Prefabricated elements are manufactured offsite, allowing for greater control over quality and production efficiency, which then optimizes the logistics and construction phases.
3. **Construction and installation**: the prefabricated components are installed onsite, speeding up the construction process and reducing disruptions typically associated with traditional building methods.
4. **Use and Management**: monitoring and management continue throughout the overall operational stage of the building. A Digital Twin can support ongoing maintenance and management of the refurbished building.
5. **End of life and dismantling**: the disassembly, reuse and recycling of materials from the prefabricated elements are evaluated for the building's eventual end of life.

As also highlighted in D2.4, and strictly connected with the technological solutions, the economic and financial feasibility of an intervention is one of the biggest challenges, also when it comes to large buildings' stocks like the ones owned by public administrations. Undertaking a large retrofitting campaign can be hugely affected by the lack of capital availability and the upfront cost of the retrofit, as well as uncertainties related to investments, long payback periods, negative net present value, or the impossibility of undertaking a loan. Particularly with **prefabricated solutions**, the economic and financial feasibility of retrofitting, is one of the main challenges. Although initial costs for prefabrication may be higher due to the need for advanced digital planning and production, economies of scale can drastically reduce costs over time. Prefabricated elements, being one of the most significant expenses in the retrofit process, benefit from industrial production, which leads to cost reductions proportional to the

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volume of production. **Economies of scale** are further enhanced by supply chain optimizations, reducing subcontracting costs and capitalizing on aggregated demand within similar building clusters. This approach ensures that as prefabricated solutions are scaled, both production efficiency and overall cost-effectiveness improve.

Moreover, the prefabricated retrofit approach generates numerous **additional benefits**, including better environmental, social, and economic outcomes compared to traditional methods. These offsite solutions, which have been successfully implemented in Europe, provide not only lower costs but also improved product quality, better building performance, and long-term sustainability. The aim is to develop a market that recognizes and values these benefits, ultimately enabling deeper, more impactful renovations.

C. The multiple benefits of an industrialized approach

Retrofitting existing buildings leads commonly to various types of benefits, direct and secondary (or indirect) ones. Direct benefits are the ones strictly resulting in energy and GHG emissions savings, whether indirect benefits entail a wider concept, both at users and societal level, and multiple dimensions, i.e., comfort and wellbeing, economic, environmental and social[6] (Table 1).

Table 1. Co-benefits of retrofitted buildings and high-performance buildings. From: Pistore et al., 2023 [9]

Comfort and wellbeing	**Economic**
The indirect effects associated with this category directly impact the building's occupants, influencing their comfort, convenience, health, perceptions, adaptation, and interactions with the building and its systems. This category includes factors such as thermal comfort, acoustic comfort, visual comfort, indoor air quality, health improvements,	Economic indirect impacts regard both individual households and the broader community are affected. At the household level, the economic benefits include reduced energy bills, lower maintenance costs, an increase in the building's value (which facilitates easier selling or renting), and enhanced productivity (especially related to smart working). At the community level, the

[6] Pistore, L., Tintinaglia, F., Pernetti, R., Stivanello, P., Pasut, W. Indirect Effects of High-Performance Buildings at Household and Community Level: A Systematic Literature Review. Energies 2023, 16, 2499.

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increased usable space, ease of use, safety, and climate change resilience.	economic impacts primarily involve decreased energy costs and the creation of new business opportunities.
Environmental In the environmental sphere, the positive impacts on society include reduced atmospheric pollution, less construction and demolition waste, protection of environmental resources (such as ecosystems and biodiversity), and mitigation of climate change.	**Social** Social impacts extend beyond individuals or families to affect entire communities globally. Key aspects include the reduction in mortality and morbidity rates, the mitigation of urban heat islands, enhanced energy security, improved building aesthetics contributing to neighbourhood enhancement.

Aside from these benefits, which, due to the difficulty of the task, are still often not quantified and consequently neglected, other additional benefits can result from the application of an industrialized retrofit process. The EnergieSprong movement is working to create a market where the benefits produced can be acknowledged and appreciated by all parties involved, from stakeholders involved in the design process, to the final buildings' occupants, and at different individual and community levels. This effort aims to expand the economic opportunities for more extensive and impactful renovations that benefit both people and the environment.

From the macro-areas outlined in Table 1, Table 2 details more specific benefits focusing on the ones specifically coming from industrialized prefabricated solutions, which target various stakeholders such as tenants, companies, builders, and communities. These benefits span multiple levels of impact, including components, projects, sectors, and the environment. The aim is to raise awareness of the full range of advantages this approach offers, going beyond direct financial gains.

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Table 2. Additional benefits resulting from industrialized off-site retrofit interventions. Adapted and integrated from: EnergieSprong Italy "Guida alla progettazione EnergieSprong", translated and adapted

Macro - Category	Additional Benefit	Description
Economic	Reduced intervention time	Utilizing offsite technologies can reduce construction time by up to 45%, depending on the project's industrialization level and organization.
	Reduction in intervention costs	Prefabricated panels may be more expensive, but shorter timelines reduce indirect costs, leading to overall lower project expenses.
	Economies of scale	Increased renovations lead to decreased unit costs for industrialized components due to factors like production scaling and learning curves, not found in traditional methods.
	Increased productivity	Factory-based production improves productivity, addressing shortages of specialized labor in the market.
	Reduction in maintenance costs	Prefabrication results in fewer unforeseen failures, thus lowering unexpected and extraordinary maintenance costs over the building's lifecycle.
	Reduction in design changes	Offsite production requires detailed upfront design, reducing the risk of changes during construction, preventing delays and additional costs.
	Reduction in financial burdens	Improved certainty in project timelines and costs reduces financial risk and exposure for stakeholders.

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	Increase in property value	Energy efficiency upgrades, improved aesthetics, comfort, durability, extended lifespan, and seismic upgrades increase the overall property value.
	Reduction in insurance costs	Higher quality from industrial processes, combined with performance monitoring and scheduled maintenance, lowers risk and consequently insurance premiums.
Environmental	Reduction of environmental impact	Lower CO2 emissions from optimized production, renewable energy usage, minimized materials, and waste recycling, contributing to NZEB status and enhancing urban air quality.
Social	Ensuring continuous occupancy and reducing inconvenience for tenants/users	No need for scaffolding reduces construction time and disruption, avoiding the need to relocate residents during the renovation process.
	Reduction in energy poverty	The improved energy profile of the building reduces energy costs for occupants, providing better comfort and improved health.
	Enhanced safety and health for workers	Factory-based production allows for safer working conditions by reducing tasks at heights and implementing standardized processes in controlled environments.
	New jobs creation	Training of skilled labour for the design, production, installation, and management of processes using prefabricated solutions.

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Comfort and Wellbeing	Improved quality of work	Offsite solutions deliver higher-quality components compared to traditional on-site construction, ensuring durability and extending the lifespan of the building's elements.
	Optimization of design	Standardized, modular, and certified components streamline both the design and construction process, enhancing cost-effectiveness and efficiency.
	Reduction in insurance costs	The industrial-grade quality and consistent monitoring result in reduced risks and lower insurance premiums.
	Ensuring continuous occupancy and reducing inconvenience for tenants/users	No need for scaffolding reduces construction time and disruption, avoiding the need to relocate residents during the renovation process.
	Improved quality of life	Improved indoor environmental quality for buildings' occupants

As with traditional building retrofits, some benefits of this approach are not yet widely recognized. Transforming these into measurable, monetary value will require comprehensive research and a shift in market and stakeholder perspectives. A key challenge in the open innovation process is determining how different stakeholders can effectively identify, measure, and validate the diverse benefits provided by various EnergieSprong business models.

Given the goals of this document, **it is clear that industrialized technical solutions are pivotal in realizing a wide array of both direct and indirect benefits**. These include improvements in energy efficiency (such as upgrading a building's energy label), reductions in environmental impact (e.g., lower CO_2 emissions), economic advantages (such as economies of scale, reduced maintenance costs, and increased property value). Additionally,

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these solutions enhance occupant well-being, providing greater energy security, comfort, and minimizing disruption during the retrofit process.

Not only energy: decarbonization, circularity, time, and anti-seismic aspects

When talking about deep retrofit of buildings, and considering the EU targets issued by the European Commission, it is clear that the first analysis brings our mind to energy effectively. However, as above explained, other multiple benefits are crucial and must be taken into account for an holistic consideration of deep industrialized interventions, towards a comprehensive integration into business models. Hereafter, three focus paragraphs are proposed, addressing more specifically the themes of decarbonization, time, and anti-seismic requirements (this latter very important in the Italian context of the project). These paragraphs build upon some case studies provided by EnergieSprong Italy[7].

[7] EnergieSprong Italy, "Guida alla progettazione EnergieSprong" by EDERA.
Available at: https://www.energiesprong.it/documenti/

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Focus: industrialized off-site technologies towards the decarbonization, a case study

According to the study conducted by Politecnico di Milano and EnergieSprong Italy, the preliminary carbon footprint analysis for the energy and seismic retrofit of a two-story residential building in Brescia, Italy, **reveals a significant 55% reduction in emissions during production and assembly using offsite solutions compared to traditional methods.** Four scenarios were assessed: no renovation, traditional on-site renovation, offsite X-LAM panels with rock wool insulation (the chosen solution), and offsite panels with biogenic cork insulation. Key findings include:

- A nearly 55% reduction in greenhouse gas emissions from offsite solutions.
- A CO_2-equivalent payback period of 3 years, 4 years quicker than traditional methods.
- A 75% reduction in carbon emissions from 2022 to 2050 compared to no renovation.
- An overall CO_2-equivalent saving of 13%.

Substituting rock wool with cork insulation could further reduce the carbon footprint by an additional 5%. **These results highlight the environmental advantages of offsite solutions, promoting faster decarbonization in the construction sector.**

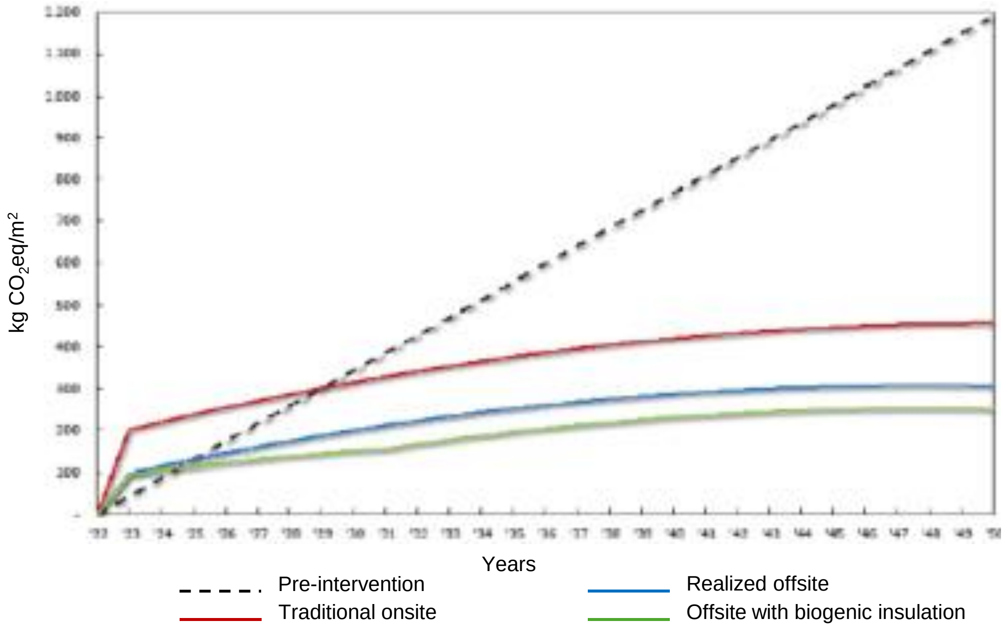

Figure 2. Life-cicle carbon footprint for the different evaluated scenarios. From: EnergieSprong Italy "Guida alla progettazione EnergieSprong" by EDERA, translated and adapted

Focus: circularity and Design for Disassembly

The industrialized prefabricated allows to employ the **"Layered Design"** which involves separating and replacing building components with different lifespans. This design strategy enables **the use of more durable elements while facilitating the replacement of those with shorter lifespans. It enhances the potential for reuse, regeneration, and recycling, minimizing waste and resource consumption, and reducing environmental impacts. This approach also avoids the need for entirely new construction.**

By structuring building systems with independent layers, each with its own lifespan, the model allows for the repair, replacement, relocation, or adaptation of individual elements without affecting the entire building or infrastructure. **This reduces technological and functional obsolescence and increases the building's flexibility and longevity.**

Examples of circular design applied at various building scales include **Design for Disassembly, ease of maintenance, flexibility, and adaptability.** In the context of EnergieSprong interventions, this layered design approach is particularly effective for retrofitting existing buildings. The focus is mainly on upgrading the Skin and Services layers to enhance energy efficiency and reduce carbon emissions. If seismic improvements are necessary, the interventions extend to the Structure and Skin layers as well. **This method optimizes retrofit operations by allowing targeted and independent upgrades, ensuring more sustainable and adaptable building solutions.**

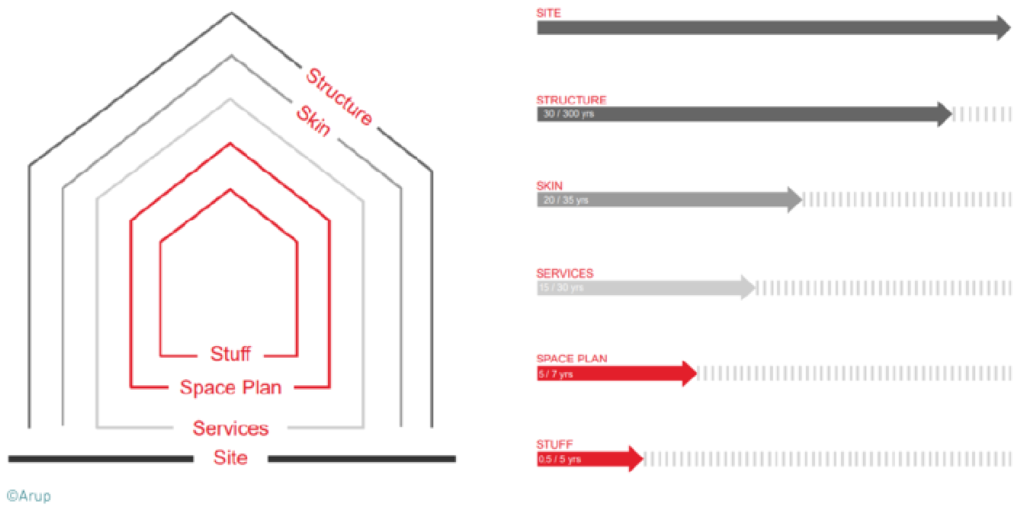

Figure 3. Design for Disassembly scheme. From: EnergieSprong Italy "Guida alla progettazione EnergieSprong" by EDERA. ©Arup

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Focus: reduction of on-site construction time and extension of the design and production phases

Offsite construction solutions offer considerable time savings by **shifting much of the production to the factory, thus significantly reducing on-site construction time**. This method requires a more detailed design phase, including a comprehensive analysis of the existing building's conditions. Although this preliminary phase may extend the timeline, it reduces setup and teardown activities, as scaffolding is not needed. **The approach minimizes disruptions for tenants by concentrating work on external distribution and limiting on-site activities** to tasks like replacing system terminals, removing existing windows, and updating the internal frame with new panels and potentially Controlled Mechanical Ventilation (CMV).

Additionally, if climate control systems are installed on the roof, this can further streamline the process by facilitating quicker handling of equipment without extensive disassembly. **Overall, offsite construction can cut on-site construction time by over 45% and total process time by 20% to 40%, depending on the degree of prefabrication employed.**

In the future, increasing the level of prefabrication could further reduce on-site activities by utilizing increasingly integrated systems (such as panels and coverings), while still maintaining a high standard of design quality.

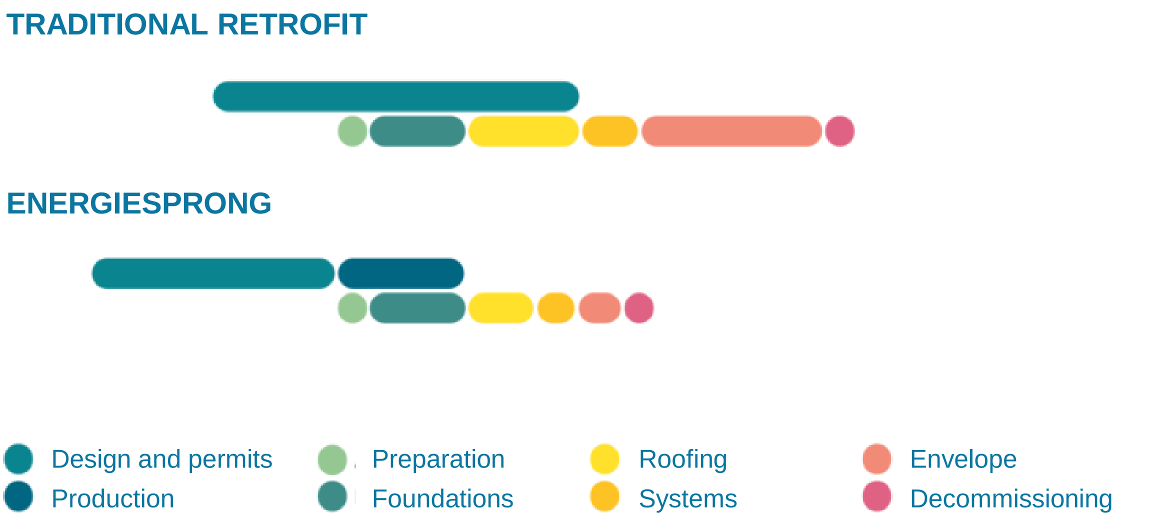

Figure 4. Comparison of timeline between traditional retrofit and EnergieSprong approach. From: EnergieSprong Italy "Guida alla progettazione EnergieSprong" by EDERA, translated

Focus: anti-seismic integration

Seismic risk in Italy is a major issue because of its location in a seismically active area. The level of risk differs throughout the country. Central and southern Italy are classified as high-risk zones due to their proximity to active fault lines. Although northern Italy experiences fewer significant earthquakes than the central and southern regions, it remains vulnerable, albeit generally at lower intensities. Overall, **seismic risk in Italy profoundly affects building practices, urban planning and design**.

In this context, EnergieSprong interventions in Italy focus **on integrating energy retrofitting with seismic performance upgrades through a single prefabricated**. These facade panels are specifically designed to enhance the structural strength and seismic resilience of buildings, effectively redistributing forces to the ground and improving overall seismic safety. The process involves detailed BIM surveying, documentation analysis, seismic risk assessment, and strategic planning, which also enables architectural and aesthetic improvements. Upgrading both primary and secondary structures provides long-term investment protection, particularly in regions prone to significant earthquakes, **preserving both occupant safety and property value**. The investment required for seismic improvements is generally returned through increased property value. Additionally, **tax incentives, even if partial, can make these retrofitting projects more financially attractive.**

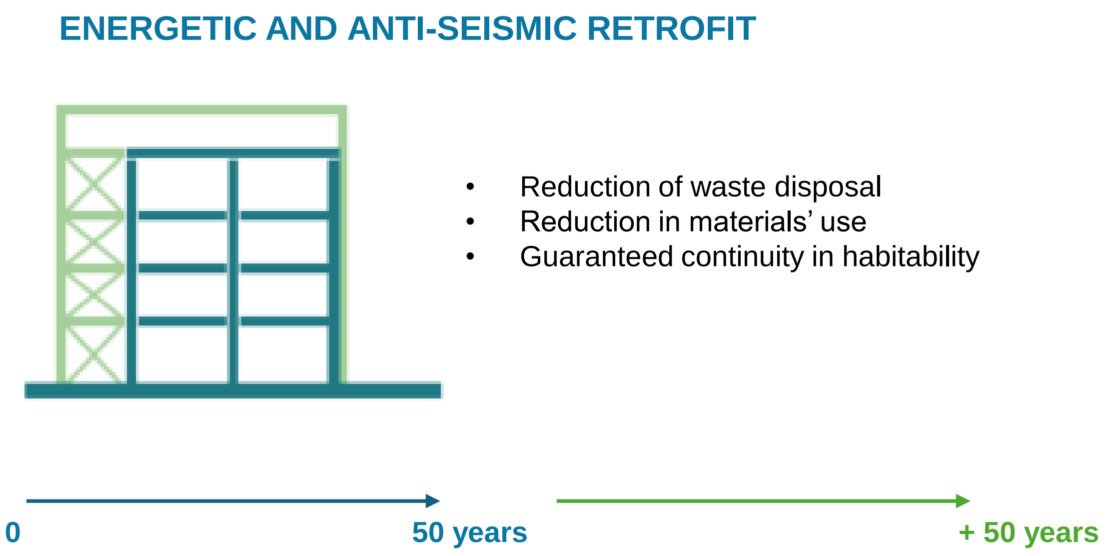

Figure 5. Energetic and anti-seismic requalification benefits. From: EnergieSprong Italy "Guida alla progettazione EnergieSprong" by EDERA, translated and adapted

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D. Classification of solutions into technical elements groups

The development of a reference framework for off-site renovation is essential to standardise practices, guarantee high levels of quality and sustainability, and meet today's environmental and economic challenges by incorporating the latest technological and industrial advances. Having a repository of existing types of off-site renovation solutions enables social landlords to respond effectively and sustainably to the current challenges facing the building sector. This helps them to choose the best practices for improving residents' quality of life, while actively contributing to the environmental transition and reducing the carbon footprint of the building stock.

Understand

The change in practices in the renovation sector, in favour of off-site manufacturing and mass production, is a major development. Its deployment must be accompanied by a gradual build-up of skills among all the players involved, in order to guarantee a collective understanding of the issues and the solutions available, and to ensure rich and constructive exchanges during the project development phases.

Choose

Building owners often manage a large number of buildings of varying types. A solutions repository standardises approaches and simplifies decision-making by providing a clear view of the options available for different types of building and renovation situations. This makes it easier to choose the solutions best suited to each specific context, while guaranteeing faster, more efficient implementation.

Implement

One of the main advantages of off-site renovation is that it facilitates the deployment phases. This is based on a detailed understanding of the project's challenges and an informed choice of solutions. But implementing these projects also requires inter-actor coordination, united around a common language and a clear direction. It is for this reason that the requirements relating to the implementation of offsite solutions, which must be discussed collectively, are set out throughout these guidelines.

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This deliverable is accompanied by a public report that aims at developing those ideas and bring a common understanding of the off-site retrofit approach. It comes, with a classification of the key technical elements that fit into industrialized offsite solutions, evaluated based on their technological capabilities and their potential for integration within the overall design process, and grouped into categories:

- **Thermal envelop:** Improving the buildings envelop and its efficiency using façade and roofing solutions
    - **Integrated facades:** solutions that combine various façade components into a unified unit for efficient installation and performance.
    - **Roofs:** prefabricated roof systems designed to streamline installation and enhance building efficiency.
    - **Low floor:** insulation of low floors to limit thermal bridges and heat loss
- **Energy systems:** offsite-manufactured building systems, including mechanical, electrical, and plumbing systems, designed for easy incorporation into the overall building structure.
- **Improvement of buildings and living comfort:**
    - **Accessibility:** installation of outdoor lifts and other prefabricated improvements
    - **Comfort and safety:** pre-assembled balcony and loggia units that can be integrated into building facades with minimal on-site modification, and interior solutions for bathrooms and kitchens
    - **Space creation:** Prefabricated structural extensions to densify the use of land

This classification has allowed the creation of a repository of solutions, represented by the category classification and renovation framework, which describe the overall characteristics of each up-mentioned categories, and the repository of product sheet that describes the technical specifications for existing or upcoming industrial solutions. The first part is attached to this document in Annex A “Off-site renovation framework”, and the second part is attached in Annex B “REPOSITORY OF EXISTING SOLUTIONS: solution sheets”.

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III. Discussion and Conclusions

The adoption of prefabricated, industrialized retrofit solutions presents a highly effective and scalable approach to meeting the European Union's decarbonization and energy efficiency targets for the building sector. Through the EnergieSprong model, which integrates offsite production, deep energy retrofits can be achieved **efficiently, with minimal disruption to occupants.** This approach can be an essential strategy for renovating Europe's aging building stock and aligns with the EU's 2050 climate neutrality goals. The key advantage of this model is its ability to provide **multiple benefits beyond energy efficiency**. The prefabricated solutions **improve energy, thermal and acoustic performance, enhance seismic resilience, and reduce on-site construction time** by up to 45%, lowering construction site costs. Additionally, the industrialized approach ensures high-quality, durable building components, benefiting both property owners and occupants. These solutions offer **minimal disruption during installation, making them ideal for large-scale retrofits, especially in residential areas with most vulnerable communities.**

Despite the promising potential, **several challenges remain**, including **financing**. The economic feasibility of large-scale prefabricated retrofitting is still hampered by the high initial investment required for advanced digital planning and production. Although economies of scale can mitigate these costs over time, the lack of immediate capital availability remains a barrier. The project recognizes this issue, as addressed by other tasks and working packages, and proposes integrating financial tools and schemes, such as subsidies and incentives, to ensure affordability. Future phases of the project will require the identification of more robust **funding mechanisms to support widespread adoption**, alongside the integration of a **financial tool for financial and economic analysis** in the ICT tool under development.

Another key challenge relates to **market readiness**. The building sector, particularly in Europe, has been slow to adopt digital technologies and industrialized construction methods, as the traditional construction sector lags in innovation and research and development. This situation calls for a paradigm shift in how construction and renovation projects are approached, with a **greater emphasis on digitalization, LEAN methodologies, and off-site manufacturing** to achieve the necessary scale and efficiency. Additionally, establishing a standardized classification system for prefabricated solutions, as proposed in this deliverable, represents a step forward in ensuring that stakeholders across the construction value chain—from manufacturers to end users— can collaborate more effectively.

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This deliverable, after an introduction of the prefabricated retrofit process and its benefits, outlines a repository of retrofit solutions, classified into categories according to their main use and scope.

In **ANNEX A**, categories are presented, within a wider renovation framework based on work carried out in France and Italy as part of the EnergieSprong approach, and thanks to feedback from numerous renovation projects that have already been completed or are currently underway, have made it possible to classify the diversity of industrial products on the European market in an effective and standardised way. **ANNEX B** collects specific solution sheets which aim to list as many product sheets and their technical characteristics as possible. When available, additional information and products will be constantly added to as the project progresses, thanks to feedback from the companies with which discussions are underway, and also thanks to the listing processes set up on the various partners' websites, or deployed during events bringing together these players.

These solutions are designed for rapid installation and high performance. By optimizing both the design and production phases, this approach ensures that **energy retrofits are not only faster and less expensive but also contribute to long-term environmental sustainability**. The repository of solutions will be **integrated into the EP-0 ICT tool** and updated with potential future integrations for additional solutions, providing users with actual recommendations for energy-efficient renovations, **helping municipalities and homeowners to evaluate suitable solutions** based on their needs, preferences, and building's characteristics.

Additionally, the integration -when provided by manufacturers- of **decarbonization and anti-seismic** insights ensures that the retrofits address broader environmental and safety challenges. Case studies above cited, such as those conducted by EnergieSprong in Italy, show significant reductions in carbon emissions and costs when using offsite prefabrication compared to traditional methods. The focus on **circularity**, particularly through Design for Disassembly, promotes **future adaptability and material reuse**, enhancing the sustainability of retrofitted buildings.

In conclusion, the prefabricated retrofit solutions presented in this deliverable offer a comprehensive, scalable, and sustainable path forward for building renovations across Europe. By focusing on energy efficiency, seismic safety, and occupant well-being, these solutions support the EU's broader goals of reducing carbon emissions, tackling energy poverty, and improving the quality of life for residents. As the repository of solutions continues

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to be refined and integrated into the EP-0 ICT tool towards its final version, the potential for large-scale, efficient renovations becomes even more attainable.

IV. Annexes

- **ANNEX A.** Off-site renovation framework
- **ANNEX B.** Repository of existing solutions: solution sheets

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