



4RinEU

Reliable models for deep renovation

RENOVATE DEEP AND RENOVATE FAST



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723829

Project information

Title: Robust and Reliable technology concepts and business models for triggering deep Renovation and residential Buildings in the EU (4RinEU)

EC Grant Agreement Number: No 723829

Duration: October 2016 to June 2021 (57 months)

Coordinator: Eurac Research (IT)

Project Partners: SINTEF (NO), ADERMA (IT), TRECODOME (NL), AIGUASOL (ES), G&M (DE), THERMICS (IT), IES (UK), ACCIONA (ES), BOLIGBYGG (NO), WOONZORG (NL), AHC (ES), R2M (IT), TECNOZENITH (IT)

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4RinEU is a project funded by the European Commission under the Horizon 2020 Programme and has been running for five years from 2016 to 2021.

Project Partners



Early Adopters



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ENERGY EFFICIENT CITIES AND NEIGHBOURHOODS?

All states in the UN have adopted the 17 sustainability goals in the Agenda for Sustainable Development for 2030. The European Union is committed to increasing energy efficiency and improving the quality of life, health and well-being of its citizens.

To achieve these goals, buildings need to be healthier and more efficient, and this needs to happen now.

We cannot wait for the current renovation rate of 1% per year to transform 75% of the buildings in the EU that are energy inefficient.

The 4RinEU project presents prefabricated solutions and tailor-made renovation packages to overcome barriers and increase deep renovation rates. We invite all building owners to put them to use for a sustainable future.

3 GOOD HEALTH AND WELL-BEING



Improved indoor environment quality and health by balanced ventilation, heat recovery and accommodated cooling.

7 AFFORDABLE AND CLEAN ENERGY



Renewable and clean energy by photovoltaic and solar thermal.

11 SUSTAINABLE CITIES AND COMMUNITIES



Prefabrication as a measure for increased deep-renovation rates of energy-efficient buildings.

13 CLIMATE ACTION



Reduced energy use and CO₂ emissions by increased insulation, airtightness and heat recovery.

Background image credits: SINTEF

MANAGING THE RISKS OF DEEP RENOVATION OR DOING NOTHING

Experienced buildings owners know very well that building refurbishment is a risky business that can go wrong in more ways than it can go right. However, doing nothing with your buildings has serious risks like falling market value, accelerating degradation and end users complaining, refusing to pay rent, or moving out. Healthy and energy-efficient buildings are more attractive to own!

A thorough assessment of existing construction, its condition and performance will be a great aid in identifying maintenance needs and emerging malfunctions, as well as the possibilities for deep renovation. It is key to successful risk management.

A broadly assembled group can be very useful both in identifying risks and finding solutions. The building users will probably be closer to the building process than normal, and their positive involvement will reduce risks.

The technologies and methods developed within 4RinEU are designed to reduce process risks by helping owners to assess potential and select suitable renovation packages.



FURTHER READING

Risk Assessment Guidance

This report describes risk management in deep renovation projects using the technologies and methods developed in 4RinEU.

The report is prepared for professional owners or managers of dwellings but can hopefully also be of use to building surveyors, designers and contractors as well as less professional building owners.



4RINEU TIP

Close control of the existing condition is important!



Photo credits: Boligbygg

THE RISKS OF ONLY DOING STANDARD RENOVATION

Maintenance and superficial renovation can prevent degradation from accelerating, and keep buildings appearing acceptable. However, they rarely contribute to raising the performance of the building to current standards. Energy bills, the indoor environmental quality and comfort stay more or less as they are.

Since normal maintenance and light renovation have their costs both in terms of money, workload and user disturbance, a superficial renovation can often be regarded as a lost opportunity to improve performance. The money invested cannot be uninvested and does not really reduce the costs of future deep renovation. So, when money is invested in superficial renovation, it can be seen as a gamble that the value of energy efficiency, comfort and air quality will not increase significantly in coming decades.

Sometimes deep renovation can be done in steps, but only if it is carefully planned to avoid technological or financial lock-in.

Higher initial investments required to achieve attractive, energy-efficient and energy-producing buildings through a deep renovation may turn out to be a less risky long-term strategy.



4RINEU TIP

Light or standard renovation can block future possibilities for deep renovation for energy efficient and more healthy solutions.



Photo credits: Boligbygg

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Standard renovation has for a long time often been “light renovation”. This is often renovation of the cladding or the façade with just some extra insulation. Windows have been changed to an improved, acceptable U value, but not to an ambitious level. Upgrading to balanced ventilation is often not included.

Yearly budgets and disturbing tenants are two main barriers.

- Boligbygg / Demo owner Norway



Image credits: agNOVA architects

“

Why spend double the money to achieve 3 times the advantages?

We always have to choose to invest a lot in one project or to share resources among multiple buildings.

At Marienheuveld in the Netherlands, 64 apartments have been renovated to standard level. 15 apartments have been renovated with 4RinEU prefabricated elements to ambitious level. This gives a good opportunity for comparison.

- Woonzorg Nederland / Demo owner The Netherlands

RENOVATION PACKAGES TAILORED TO FIT DIFFERENT NEEDS THROUGHOUT EUROPE

RENOVATION PACKAGES ACCORDING TO EXISTING BUILDING TYPES

The renovation packages are developed for residential buildings. The impact has been assessed for single family houses, small two-floor apartment buildings and larger multifamily houses.



TERRACED HOUSE
88 m²



APARTMENT BLOCK
1,330 m²



SINGLE-FAMILY HOUSE
228 m²



MULTI-FAMILY HOUSE
3,456 m²

TAILORED TO DIFFERENT GEOCLUSTERS

The 4RinEU project has developed and demonstrated deep renovation packages suitable for different geoclusters represented by the demo counties Spain, the Netherlands and Norway, as well as the early adopter countries UK, Poland and Hungary. Differences in climate and typical existing building performance are taken into account.



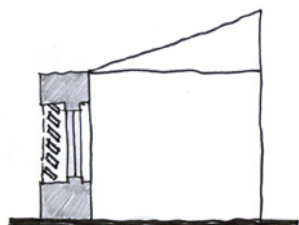
4RINEU TECHNOLOGIES

Advanced and robust prefabricated solutions are one key element for easier and faster implementation on site with low occupant disturbance.

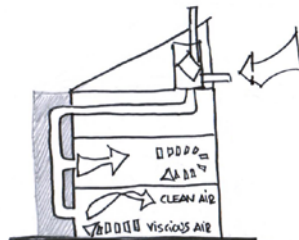
New technologies have been developed and tested in the project. Performance, production process and technological risks have been addressed to minimize

failures, a close-to-market approach with high replication potential and confidence for building owners.

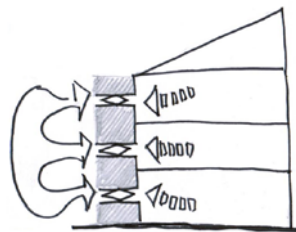
ADVANCED PREFABRICATED ELEMENTS WITH INTEGRATED TECHNOLOGY



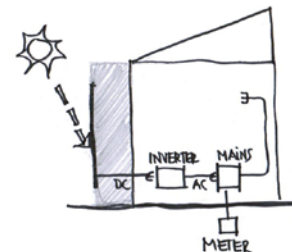
**INTEGRATED SOLAR
SHADING**



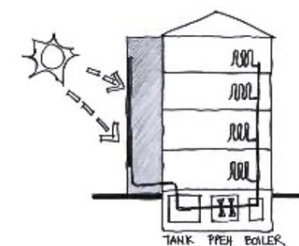
**INTEGRATED
VENTILATION DUCTS**
for balanced ventilation



**INTEGRATED
VENTILATION MACHINES**
connected to windows



**INTEGRATED
PHOTOVOLTAIC**
or solar collectors



ENERGY HUB



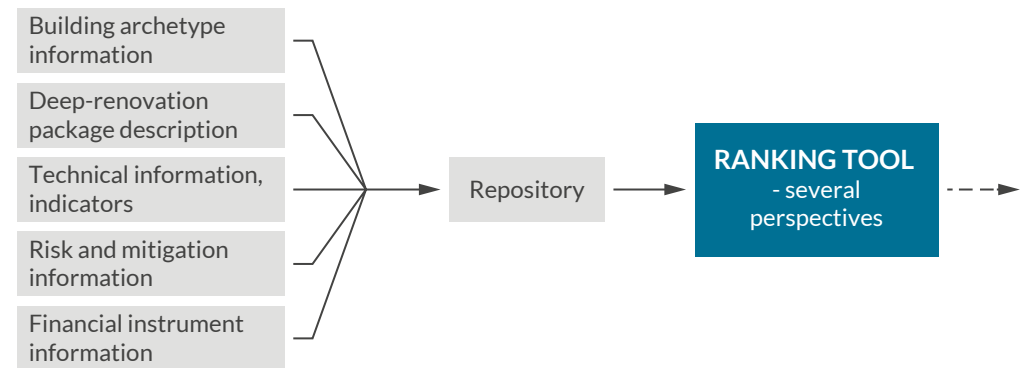
SMART CEILING FAN
with advanced control for
energy efficient cooling

Credits: hand-drawn illustrations by Linda Toledo

4RINEU RANKING TOOL PROTOTYPE

Finding suitable renovation package depends not only on location and existing conditions. Different building owners have different priorities, resources and constraints. While the budget may be the major limitation in one project, environmental goals or improved indoor comfort are emphasised in another.

To ease and assist the decision-making process for building owners, the 4RinEU project has developed a ranking tool prototype to suggest optimal deep-renovation packages tailored to specific needs and preferences.



Case selection

Geocluster & reference country
Building archetype

Northern (Norway)
Single family

User priorities for areas of interest

Economic issues
Energy
Environment
Building site management
Comfort & Indoor Air Quality

KPI of interest

Total investment cost [€]
Heating demand [kWh/m2/y]
CO2 emissions heating [kg/y]
Time on building site [hours]
pmv_zone2_CatII [hours/year]

User specifications for construction process

Cladding type
Mounting system
Removal of old facade cladding
Anchoring type for prefabricated facade
Roof insulation type
Distance from building site

Ventilated facade with facade panels
Scaffolding + crane
Yes
Facade mounted
Normal insulation
50 - 250 km

Single family

Multi family

Check building features

Run analysis

Result details

Risk management

Financial instruments

Results overview

Combined score (max = 10; low values = good)

Percentage	Pre-no
0.077	
0.154	
0.308	
0.077	
0.385	

Combined score

Economics

Energy

Environment

The building owner prioritizes between five areas of interest:

- budget
- energy
- environment
- building site management
- indoor environmental quality

with a number of associated indicators.

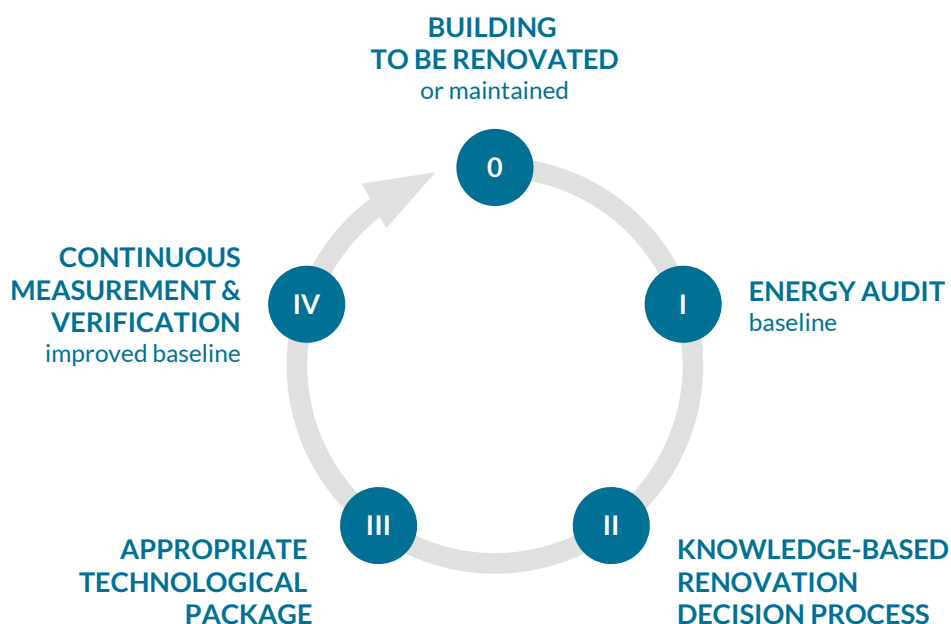
The tool selects the five deep-renovation packages for the country in question and the building types that have the best combined score over all packages. These scores will be displayed together with recommended technologies, indicator values, risk management advice and pointers to suitable financial instruments.

Screenshot of the 4RinEU Ranking Tool prototype. Tool credits: SINTEF

GUIDANCE FOR A SUCCESSFUL RENOVATION PROCESS

The 4RinEU project also includes guidance and several other tools for a successful deep-renovation process. It is a data-driven and performance-based circular path from one deep renovation to the next.

The 4RinEU deep-renovation approach includes 5 steps from the first diagnosis of building needs to the final assessment of actually achieved results to provide a new positioning on the real-estate market.



PHASE 0: BUILDING TO BE RENOVATED (OR MAINTAINED)

The aim of this phase is to decide whether a building needs to be renovated (or maintained).

PHASE I: ENERGY AUDIT

The aim of this phase is to perform an energy audit to create an existing baseline. It is recommended to perform an energy audit to assess the current annual energy consumption and CO₂ emissions of the existing building.

PHASE II: KNOWLEDGE-BASED RENOVATION DECISION

The aim of this phase is to take the knowledge-based renovation decisions. It is recommended to rely on modelling and building-energy simulation. At this stage, design energy demand and CO₂ emissions are set, together with optional comfort calculations.

PHASE III: APPROPRIATE TECHNOLOGICAL PACKAGES

The aim of this phase is to install the appropriate technological package, such as a prefabricated multifunctional timber façade and a smart ceiling fan.

PHASE IV: MEASUREMENT & VERIFICATION

The aim of this phase is to measure and verify to acquire a new (improved) baseline. In this stage, it is recommended to perform an energy audit to assess the (new) current annual energy consumption and CO₂ emissions of the renovated building.

4RINEU DEMO BUILDINGS

NOT A STANDARD RENOVATION, ONLY STANDARD BUILDINGS

Tailor-made deep-renovation packages have been demonstrated in three publicly owned multifamily buildings. They were initially up for normal renovation. Choosing advanced prefabricated elements resulted in a different building process with early decision making as well as extra renovation measures including the use of renewables.

EXPECTATIONS

Compared to a standard renovation the 4RinEU goal is a 60% reduction in energy use, a 50% reduction in renovation time by using prefabrication, BIM and Lean construction management and a 15% reduction of costs during the building's life cycle compared to standard renovation, as well as improved indoor climate.

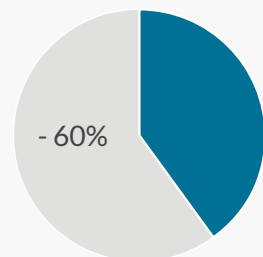
EARLY INVESTIGATIONS ARE IMPORTANT

To achieve this, mapping the existing situation and limitations are of great importance.

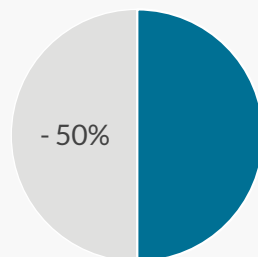
Pre-monitoring energy performance, investigating the construction condition, construction details, hazardous materials, load bearing capacity as well as scanning the building pipes, cables and penetrations are important. Terms like compactness of the existing building, slab on ground and cavities can be challenging for overall energy measures. Airtightness details for the renovated building should be in focus, also below ground level.

Early investigations secure a solid baseline. It is important to set and track the impact of the renovation measures and secure a good decision-making process towards the goals.

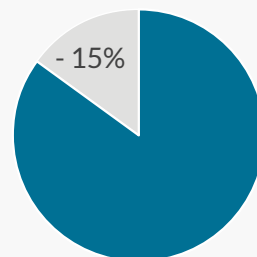
ENERGY USE
of the renovated building



RENOVATION TIME
by using prefabrication, BIM and lean construction



RENOVATION COSTS
in the building life cycle



Norwegian demo building



OSLO | HAUGERUDSENERET

- 2 storey building from the 1970s
- 8 apartments
- Wooden construction
- Natural ventilation
- Energy label F
- Electrical heating, separate DHW
- Assisted living publicly owned by Boligbygg

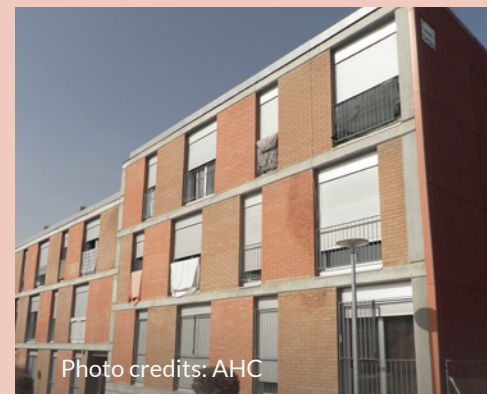
Dutch demo building



SOEST | MARIËNHEUVEL

- 4 storey brick building from 1980
- Low insulation of cavity walls and thermal bridges
- Mechanical exhaust ventilation
- Centralized boilers for heating and DHW
- Energy label D
- Elderly welfare housing
- Private ownership, Woonzorg Nederland

Spanish demo building



BELLPUIG | LA VALL 9

- Two attached blocks from 2009
- Pilar framed concrete construction
- 15 apartments to be renovated
- Low-quality insulation and thermal bridges
- Natural ventilation, no cooling
- Energy label E
- Heating by electricity and butane gas
- Social housing publicly owned by AHC

Before / After renovation



RENOVATION PACKAGE

The initial need was for a façade renovation, improved ventilation and thermal comfort. Minimal tenant disturbance was highly emphasized, solved through renovation from the outside so that tenants could stay put. The renovation package consisted of prefabricated elements with high-standard insulation, new windows, and new foundations (wall U value $0.13 \text{ W/m}^2\text{K}$, window $0.8 \text{ W/m}^2\text{K}$). PV panels were integrated on the south façade and supply air ducts integrated on the north façade. A prefabricated technical room allows for space for air handling units with heat recovery and other technical equipment. The environmental profile was also important to the owner.

RENOVATION PROCESS

Early involvement of the element producer in the design team was important to ensure suitability for production, transportation and mounting of elements, and a close to market solution. A PV expert was subcontracted. Early investigation of the existing building revealed load-bearing problems, and elements were mounted on a new foundation. No damage or moisture problems were discovered, details for new and existing construction were checked to not add problems in the future.

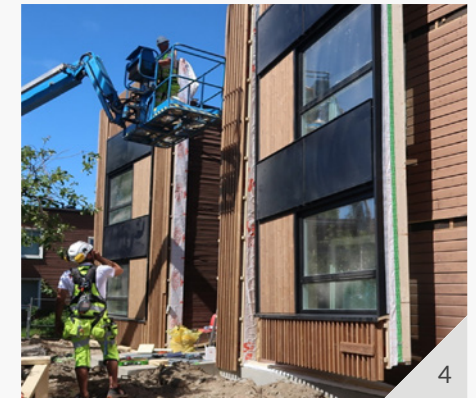
Use of BIM and digital process

Tolerances and safe installation were important issues. The old building was scanned, transformed to design BIM, then to production BIM. The producer was also responsible for transporting and mounting the elements to ensure transfer of knowledge.

Façade construction



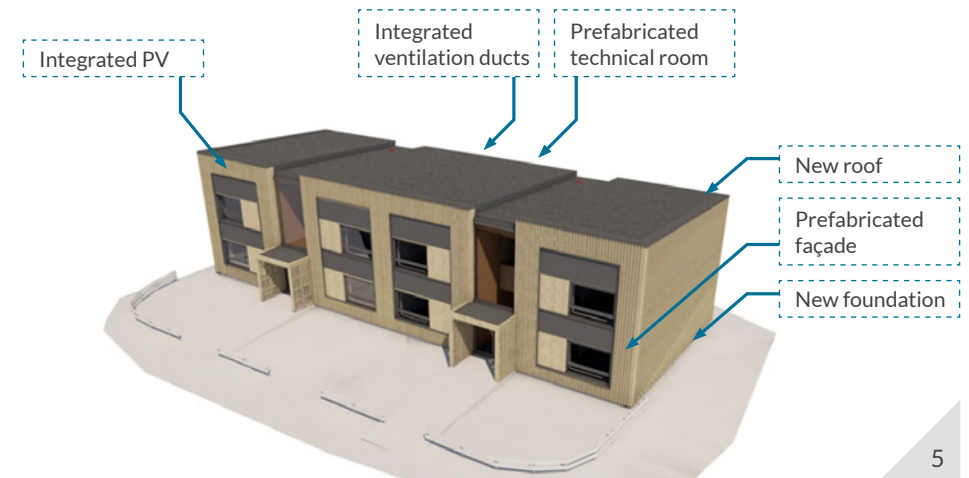
Façade installation



LESSONS LEARNED

Successful installation of elements by crane, 2 weeks, total 8 weeks on site. Energy label F to B. Blower door test showed that construction details also

below ground can be critical, as well as monitoring the penetration of pipes etc.



Before / After renovation



RENOVATION PACKAGE

15 apartments with a 4RinEU deep renovation package. Using prefabricated wall elements anchored to the existing brick wall. Filled with cellulose fibre insulation for environmental reasons. Fully glazed window frames and triple glazing included in prefabricated elements. Integrated shading and decentral heat recovery ventilation under the window in living rooms in 4RinEU apartments.

136 apartments renovated to regular label B renovation using cavity wall, roof and floor insulation, new glazing and exhaust ventilation.

RENOVATION PROCESS

The building owner managed the renovation process and reported to their tenants. The design team consisted of architects and their consultants, supported by 4RinEU partners. A main contractor was selected for the standard and deep renovation of Mariënhorst and Mariënhuvel. A local manufacturer designed, produced and mounted the prefabricated façade elements in 15 apartments. Use of scaffolding was needed primarily for the standard roof renovation work, and was also used during the mounting of the prefab elements.

Façade construction



Façade installation



LESSONS LEARNED

2 weeks for mounting elements, 24 days with construction work, 5 months on site because the standard roof renovation was scheduled in a separate workflow and due to some months stoppage for Covid. Tenants could stay put with most impact during the prefab façade mounting.

Deep renovation took longer in design and preparation but was fast and short on site compared to standard renovation. No technical surprises and failures during renovation. Good expectation management is needed between a general contractor and a prefab element mounting company working on the same renovation site.

Energy label D was improved to B for the standard renovation and to A for 4RinEU Package.

The net heat demand was reduced from 108 kWh/m² before to 70 kWh/m² for the standard renovation and 20 kWh/m² for the deep renovation. Desired airtightness of n50 = 1,5 was achieved.



Before / After renovation



RENOVATION PACKAGE

The main goals were to increase tenants' thermal comfort and reduce energy costs. Low tenant disturbance was also important.

The renovation 4RinEU Package was installed on 209 m² on the east façade. Prefabricated elements (PMF), with high insulation, including timber balconies with integrated solar shading, 10 PV panels as external cladding and ducts for the new ventilation units with heat recovery placed inside. The wall U value was improved to 0.16 W/m², and on the balconies to 1.4 W/m².

Simultaneously other conventional actions were previewed in the building to reduce 60% of the primary non-renewal energy demand.

RENOVATION PROCESS

First, a local multidisciplinary team prepared the executive project for the renovation. They adapted the 4RinEU PMF façade design to the local context, the block typology, the local regulations, etc. Then a public tender was opened for the construction work with a closed budget.

Finally, while some actions were executed on site, the PMF was manufactured off-site. The manufacturer made a 3D model to send the dimensions of the pieces automatically to the cutting machine. Then the elements were assembled. The installation by crane took 1 week for outside work. The inside finishing tasks took 4 weeks.

Façade construction



Façade installation

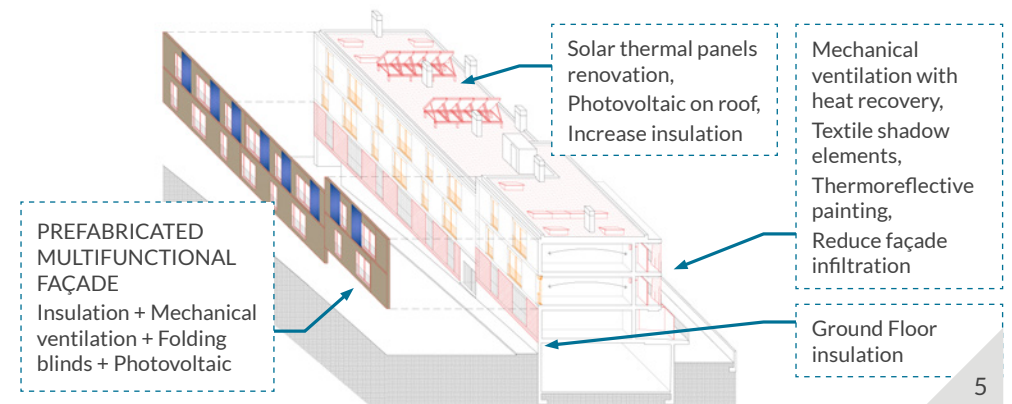


LESSONS LEARNED

It is important to measure the existing façade well before prefabrication of the elements. To install a connection layer between the PMF and the existing façade, guarantees airtightness and absorbs the irregularities of the support surface. Also, check the airtightness of the

components integrated, like balconies, PV, ducts.

As a conclusion, the PMF façade is suitable for buildings with flat façades and good accessibility. Especially if high levels of insulation are needed or it integrates active solutions.



FINANCIAL STRATEGY

AMBITIOUS RENOVATION LEVEL AND PREFABRICATION IS MORE COSTLY

Deep renovation to a high energy standard including renewable energy sources is in general more costly than a standard renovation, so too is using prefabrication. So where can you find the extra money and motivation?

FINANCIAL INSTRUMENTS

Wanting a deep renovation and financing it can be two different things. Several financial instruments are available, depending on country and factors like type of ownership, energy-saving potential and often depend on technology rather than addressing deep renovation, and for sure it is a quickly changing matter. Identified instruments are mostly funds and subsidies that often support but are not large enough to really influence the decision-making process. Future developments like taxation that favours reuse or legal instruments will have a stronger effect.

ROLLING BUDGET AS AN ENABLER

A challenge revealed by the demos is a yearly budget; a deadline in December can result in unfortunate decisions. An allocation over a three year rolling budget can easily support larger and favourable investments and avoid smaller light renovations.



FURTHER READING

Regional adaptable financial instruments

This report gives a comprehensive summary of the financial instruments available that support deep renovation of existing residential buildings at a European level, with in-depth insights into available instruments in Norway, the Netherlands, Spain, Poland, Hungary, the UK and Ireland. It gives a good snapshot of the current state of funding schemes for deep renovation of buildings in these European countries.

THE TENANTS

One of the main barriers to deep renovation for a building owner is the tenants. A lot of extra work and money is needed to organise moving the tenants, and intermediate accommodation represents a considerable cost. Prefabrication implies that tenants can stay put, with minimal disturbance and accommodation costs saved.

PREFABRICATION AS AN ENABLER

Prefabricated elements can provide extra space where it is lacking, like space for pipes, ventilation supply ductwork and room for HVAC equipment. Integrated photovoltaics in walls enable valuable roof space for roof gardens or other purposes. Integrating technical installations in prefabricated elements saves costs compared to traditional on-site installation.

LIGHT RIG AND SHORT TIME ON SITE

Prefabrication implies shorter time on site. In the 4RinEU demos time on site was less than half that of a standard renovation. This means lower tenant disturbance as well as lower site-management costs. Prefabrication allows for a light rig, including less scaffolding and minimal waste. Prefabrication is more costly, but the rig costs are more or less included. A light rig can easily save costs.

LOW FAILURE RATE

Using prefabrication normally implies using BIM and Lean processes. This can secure good tolerances, coordination between players, avoids failure, and addresses challenges on site at an early stage. Failure costs money, both in the building process and the operational phase.

ENERGY SAVINGS AND PRODUCTION

Energy-efficient buildings with renewable energy sources both save and produce energy for the building. However, this is rarely the main contribution to an attractive net present value.

ENERGY EFFICIENT BUILDINGS ARE ATTRACTIVE TO OWN AND LIVE IN

Factors like environmental profile, reputation and attractive appearance can provide strong motivation and market value. Private owners can often benefit from a higher rent. This is not always the case for public buildings such as for the Oslo demo; rents follow regulation restrictions and can only be adjusted as a delayed averaged market price for similar apartments. Nevertheless, it meets the owners' environmental goals, increases comfort and indoor climate for the tenants and clearly makes the building attractive.

FURTHER READING



BUSINESS MODELS

- ✓ Risk Assessment Guidance
- ✓ Cost-effectiveness rating system
- ✓ Historical buildings
- ✓ Replication potential
- ✓ Regional adaptable financial instruments



OTHER RELEVANT DOCUMENTS

- ✓ Building archetypes and deep renovation technology
- ✓ Deep Renovation packages tailored to geoclusters
- ✓ Deep Renovation design and user-motivation
- ✓ 4RinEU management to implement deep renovation
- ✓ Concept design and performance targets for the demos
- ✓ 4RinEU Deep Renovation packages in the demos
- ✓ Potential renovation rate of a building typology
- ✓ Building Deep Renovation guidelines



Satisfied end users watching elements being mounted. Photo credits: Boligbygg



SUCCESS?

The tenants were applauding and watching the process from a front row position!



The element producers' handling of the tenants together with good information from the building owner's representative was a key success factor for a smooth installation process.

- Boligbygg / Demo owner Norway

IMPRINT

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Picture on the booklet cover

Credits: Boligbygg

All other pictures

Credits indicated in the image caption

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No **723829**