BEEM-UP

Building Energy Efficiency for Massive Market Uptake

SEVENTH FRAMEWORK PROGRAMME

BEEM-UP Building Energy Efficiency for Massive Market Uptake

BEEM-UP
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A message from the project coordinator

BEEM-UP aims to demonstrate the economic, technical and social feasibility of retrofitting to drastically reduce energy consumption in existing buildings. Our main goal is to get to a 75% reduction in heating energy demand in existing residential buildings under current market conditions.

Such ambitious objectives have to be faced in the scope of the reality of Europe, at global level, as a fuel dependant region, with an average of old residential building stock and with a geopolitical structure that is already making all EU members walk in the same direction.

The conditions under which the objectives of the project are demonstrated are different, depending on which topic we are considering. In relation to the economic feasibility of a deep retrofitting project, a long-term scope is a must. If we are going to face a reasonably high investment to achieve important savings in energy bills, the business case has to consider a long period of operation for the new retrofitted building. We are working on specific financial models to make it possible for future building owners with a special mention to the policy makers.

In relation to the technology, we are lucky to be working with BEEM-UP Partners who deal with top quality standards in refurbishment projects. The technological progress is always developing and we know that the technology is already available for most of the particular challenges to be accomplished.

Last but not least, the social factor also has to be considered. Tenant involvement is crucial to pave the ground for successful market uptake based on tenants request to have an energy efficient home.

Project Coordinator
Juan Ramón de las Cuevas Jiménez
ACCIONA Infraestructuras S.A.

Management summary

Through the refurbishment of a total of 339 dwellings in the Netherlands, France and Sweden, the BEEM-UP project (Building Energy Efficiency for Massive Market Uptake) goes beyond 75% heating energy demand reduction, demonstrating the economic, technical and social feasibility of retrofitting in social or public housing in the residential sector.

The multi-stakeholder approach applied in the whole process of refurbishment shows high potential for energy demand reduction in housing under current market conditions. The comprehensive analysis of technology measures results in solution packages that are radically different from those currently applied in the sector.

Preliminary project results show that optimal technology packages contain ICT based solutions and are considered a cost-effective measure for the energy demand reduction. Moreover, initial evaluation of the refurbishment process indicates that involvement of tenants in the retrofitting project results in lower costs of work execution as well as buildings better adjusted for households´ needs. Furthermore, tenants involved in the refurbishment are more conscious on their energy use.

Within this document the three BEEM-UP cases for deep energy refurbishment are presented, emphasising a multi-dimensional approach of passive (building envelope improvement), active (ICT and HVAC systems) and social measures (tenant involvement).






BEEM-UP project overview

The BEEM-UP project aims to demonstrate the economic, social and technical feasibility of retrofitting initiatives for drastically reducing the energy demand in existing residential buildings and lays the ground for massive market uptake.

BEEM-UP
Duration: 48 months
Start: January 2011
Total Cost: 7,7 M€
EU Contribution: 4,86 M€

BEEM-UP context

The urgency for Europe to transform into a low-carbon economy to meet climate and energy security targets is a fact.[1] Buildings account for 40% of the European energy consumption and for one third of the GHG (Green House Gasses)emissions. According to the Energy Performance of Building Directive, refurbishment of existing buildings must play an important role in achieving the ambitious objectives of a reduction of European energy consumption.[2] In particular, the status of the European residential building stock contains a tremendous potential for improvement.

Besides its environmental impact the built environment is also a central aspect of daily human life. People in industrialized countries spend about 90%[3] of their time in buildings. In emerging or developing countries, this percentage is also higher than 50%. It can therefore be assumed that buildings have a strong influence on individuals as well as the society they live in.

Building processes are also among the most cost intensive processes that we come into contact with. As for residential buildings, many people take 20 to 30 years, sometimes even more, to pay back their home loans.

BEEM-UP directly addresses the challenge of deep energy demand reduction in the residential sector on a European scale. The project focuses on multi-family residential buildings with a tenant rental structure, which is representative for almost 18% of the European housing stock. This specific scope allows for interchange of experience throughout the project and gives an enormous replication potential of best practises for refurbishment across European countries.

Main BEEM-UP objectives

- Demonstrate cost-effective high performance renovation of existing residential buildings
- Reduce heating energy demand by at least 75%, while ensuring a comfortable and healthy living environment
- Investigate the replication potential through the European housing stock

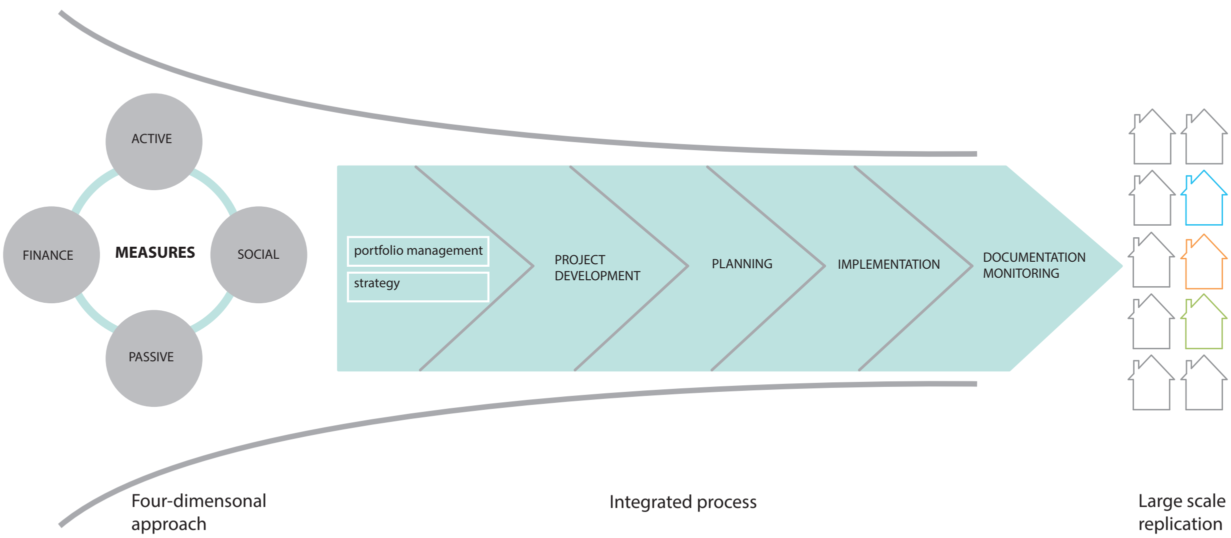
1 Communication from the Commission - Investing in the Development of Low Carbon Technologies (SET-Plan) – COM/2009/519
2 Energy Efficiency in Buildings –Transforming the Market, World Business Council for Sustainable Development, 2009
3 Höppe, P. Different aspects of assessing indoor and outdoor thermal comfort. Energy and Buildings 34 (2002)

BEEM-UP Methodology

The BEEM-UP project has developed and deployed a multidimensional methodology within the whole process of refurbishment where building owners, technology providers, construction companies and researchers collaborate to demonstrate successful methods for deep retrofit with the potential for large-scale replication.

The most adequate solutions for achieving drastic energy savings involves deployment of a four-dimensional approach of static (building envelope improvement), active (ICT and HVAC-systems), social (tenants involvement) and financial measures (innovative financing instruments), which go beyond 75% energy demand reduction.

The BEEM-UP project approach for energy retrofitting



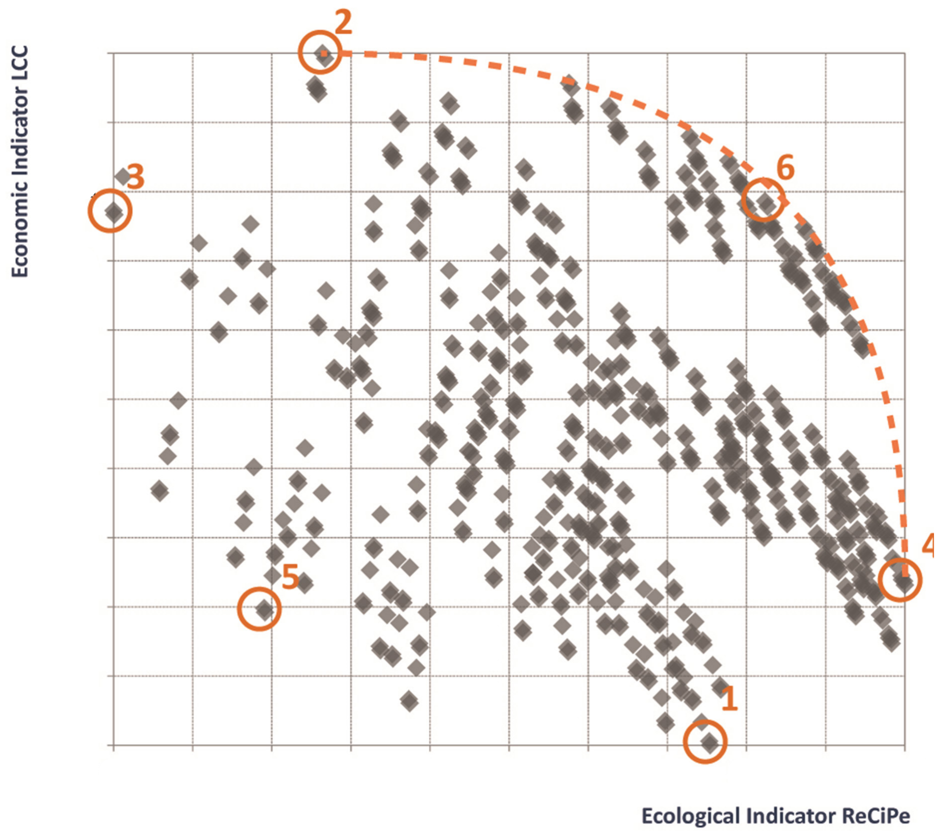
Holistic evaluation of the technology options

Considering its strong impact and interchange with environment, society and economy, the built environment is an excellent example of a sector that needs methodologies for a holistic evaluation covering all these fields, in order to get to sensible solutions for given situations. This clearly requires tools and approaches that assess all three aspects and evaluate the interchange between them.

Following the paradigm of weak sustainability, suitable solutions that achieve an optimal overall performance and ideally a minimum performance in all three pillars need to be identified. Most importantly, solutions for which superior alternatives exist for all three pillars should be avoided — only Pareto-optimal solutions should be considered and only those that achieve a minimum performance in all three dimensions of sustainability.

BEEM-UP addresses this need by evaluating the performance of a large number of possible refurbishment concepts and by assessing their environmental and economic performance from a lifetime perspective (from the generation of the building materials, the usage phase up to the deconstruction). The graphic below shows an example of such an assessment for the site in Paris.

Performance of all 729 concepts for the site in Paris/France according to ecological and economical indicators



BEEM-UP Pilot Sites

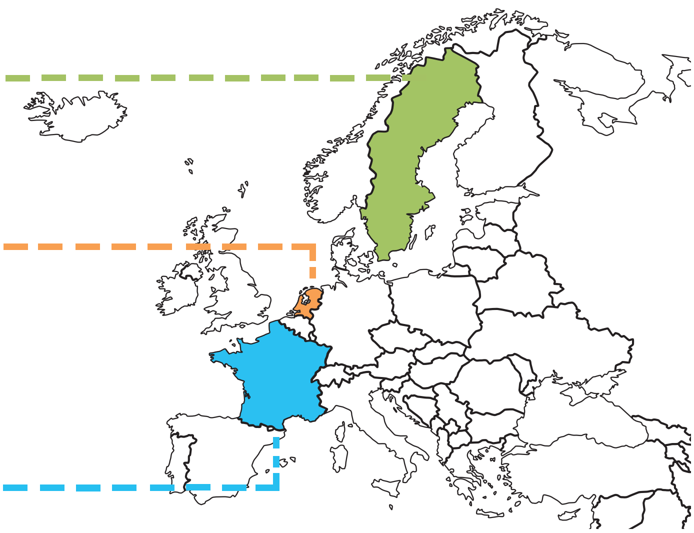
Within the BEEM-UP project 339 dwellings are being refurbished with high-energy efficiency standards in France, the Netherlands and Sweden.

The BEEM-UP consortium consists of best-in-class leading actors in different fields related to energy efficient retrofitting of residential buildings. BEEM-UP involves building owners with a total building stock over 150.000 dwellings, leading and highly innovative construction companies, major industry suppliers, excellent research organizations and consultancy firms.

ALINGSÅS Brogården
– 144 refurbished dwellings
– Built in the 1950s
– Owner: Alingsåshem

DELFT Van der Lelijstraat
– 108 refurbished dwellings
– Built in the 1970s
– Owner: Woonbron

PARIS Cotentin Falguière
– 87 refurbished dwellings
– Built in the 1950s
– Owner: ICF Habitat Novedis



Building owners

- icf Habitat Novedis
- alingsåshem
- woonbron

Industry suppliers

- BASF The Chemical Company
- SIEMENS
- Eneco
- ISA Intelligent Sensing Anywhere
- Mp

Research & consultancy

- ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich
- Bax & Willems Consulting Venturing
- nobatek
- Maastricht University
- Luwoge consult
- CHALMERS University of Technology
- SP
- Solintel
- ita Instituto Tecnológico de Aragón
- TU Delft Delft University of Technology

Construction companies

- SKANSKA
- acciona
- DURA VERMEER

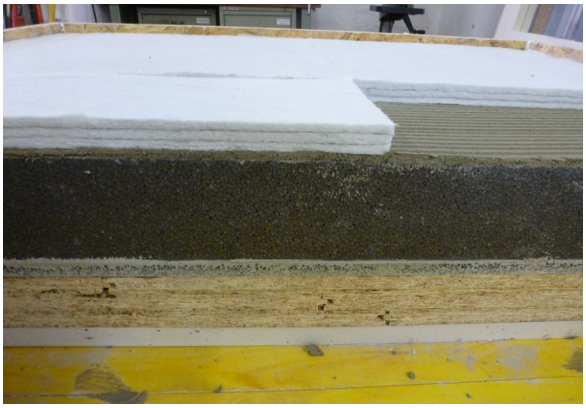
Technology innovation and tailoring for replication

High performance of a building envelope is one of the most important challenges of energy retrofitting. The BEEM-UP project addresses technical barriers of building insulation and air-tightness by developing and optimising specific technical solutions, suitable for massive market uptake in the residential sector. The tasks included adaptation and optimisation of roof, wall and floor insulation solutions for the building envelope to the specific building typology of the pilot sites.

All three building sites were analysed and discussed on their individual improvement potential of the energy performance of the building envelope.

All measures were evaluated by replication and innovation potential through an interdisciplinary team of architects and construction specialists with different backgrounds.

Factors taken into account in the evaluation of innovative insulation solutions:



Cross sectional cut of a mock-up – an aerogel board as a refurbishment solution for an existent ETIC System

- Performance
- Costs
- Integration in the wall structures
- Potential for mass application
- Global warming impact

A multilayer aerogel board developed by BASF was the most suitable insulation material for the Paris pilot site, where we faced a problem of limited space on the balconies. The board is thinner than standard EPS and has high fire resistance what perfectly answers the specific needs of the pilot. This solution can be used as a new exterior insulation system or as a repair system for damaged and already existent insulation systems.

Other solutions developed include a vacuum insulation glued and protected by a polyurethane sprayfoam coating. This innovation results in ultra thin and load bearing flooring and roofing insulation solutions.

Building envelope's part	Measure
Roof	Ameriglue® + Neopor®
Roof	Walltite® + recycling EPS
Wall	Aerogel coated Neopor®
Wall	Existent EIFS + Aerogel
Wall	PUEIFS
Wall	Ameriglue® + Aerogel internal
Wall	Aerogel+PC Minternal
Wall	Skanska mock-up 3rd Generation
Cellar ceiling	Walltite® + VIP
Ground slab	Ameriglue® + VIP
Ground slab	Skanska mock-up
Suspended floor	Walltite®

Innovative insulation materials developed and tested in the BEEM-UP project

Pilot site: Alingsås, Sweden

AB Alingsåshem is a municipal housing corporation in the municipality of Alingsås, Sweden. Alingsås has 38.000 inhabitants and is situated in the western part of the country, 45 km northeast of Gothenburg. Alingsåshem owns 3.400 dwellings, and builds approximately 50 new dwellings every year. The company's aim is to offer attractive, secure and pleasant housing with focus on individual needs and improved access for disabled and elderly people. Alingsåshem strives to contribute to the development of the sustainable society both in an economical and ecological as well as social point of view. This approach is included in every decision in the building processes. Today the company consists of 32 employees.

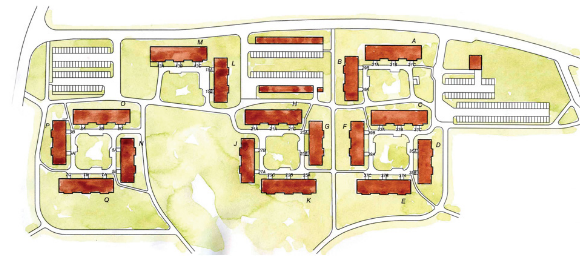
The Brogården area was built in 1971- 1973 as part of the Million Homes Program in Sweden. The period specific architecture means that the area is of cultural-historical interest for future generations. This is a specific value that it is Alingsåshems' task to manage.

Existing qualities of the buildings:

- Architecturally valuable buildings and a coherent area.
- Quiet area close to town centre and nature. Green, car free courts with playgrounds.
- All flats have balconies or a patio.
- District heating network from 98% renewable fuel.

Existing defects:

- Frost wedged façades need replacement, poor insulation.
- Electricity and plumbing systems in poor state, high use of domestic hot water (DHW).
- Discomfort due to draughty flats, thermal bridging.
- Poor soundproofing. Poor accessibility and little variation in flat sizes.
- Bathrooms, kitchens and common areas need renewal.



The residential area Brogården

Building before refurbishment

Technical characteristics of the Swedish buildings before refurbishment

	Brogården. Building year: 1971-1973. 144 dwellings, 8 blocks, 4 floors, 14860 m^2
Envelope	*Walls: (Curtain walls) Gypsum boards on non-loadbearing wooden studs, 95 mm insulation and façade bricks. To be demolished in its entirety. Basement: Cast-in-situ concrete walls without any insulation. Roof: 300 mm insulation on roof slab. Wooden rafters with props on roof slab*
Windows	*Single pane with supplementary aluminum sash and one additional pane (U value = 3.0)*
Heating	*District heating. Water carried heating with radiators*
Hot water	*District heating*
Ventilation system	*Mechanical exhaust with air intake through window vents*
ICT - (incl. smart meters)	*No individual measuring.*
Lighting	*Incandescent light fittings.*
Renewable energy source	*District heating is renewable to 98%*
Other energy saving	*None*

Sustainability is a major goal for national economies and also for housing companies. As a general definition of sustainability following objectives are taken into account: environmental, economic, and social quality.

Following the policy on environmental, economical and social sustainability, Alingsåshem decided on a major internal and external reconstruction using passive house technique. Measures done in the first completed house in Brogården during the first year show that the energy consumption connected to heating has been reduced with 89%.[4]

Buildings after refurbishment

Saving results for Alingsås buildings

KPI	Retrofitting plan	Status quo
∑ Primary Energy Demand	*45 kWh/(m²a)*	*163 kWh/(m²a)*
Saving space heat + DHW demand (PE energy)	*72%*	
Saving space heat demand (final energy)	*89%*	
Savings DHW (final energy)	*13%*	
Savings household electricity	*37%*	

Technical characteristics of the buildings after refurbishment

Envelope	*Walls: Previous wall is replaced by new wall with several layers of insulation and slotted steel studs. In total 440 mm insulation. Basement: 100 mm expanded polystyrene extends 1 meter below ground level. 100 mm drainage panel downwards to ground floor. Roof: 400 mm new.*
Windows	*NTriple pane window with insulated glass (U-value = 0,85)*
Heating	*Recovery system in combination with district heating*
Hot water	*District heating as before*
Ventilation system	*Balanced ventilation with heat recovery. Single unit serves entire building.*
ICT - (incl. smart meters)	*Electricity is measured individually; hot water is monitored remotely for each flat; heating is measured for each staircase.*
Lighting	*Low energy fittings. Low energy or halogen lighting and LED lighting in staircases.*
Renewable energy source	*District heating and PV on roof of 4 buildings*
Other energy saving	*The tenants receive energy-saving tips*

4 BEEM-UP uses an international methodology for calculating the energy demand reduction in the 3 pilot sites. The numbers can differ from locally calculated results.

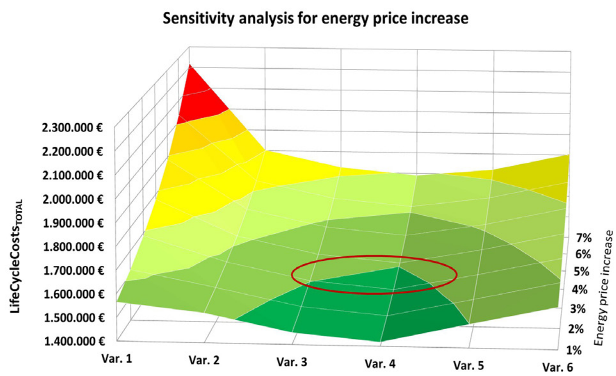
At the beginning of the refurbishment process all building components were evaluated and existing needs for maintenance and improvements were determined. The need for renovation of the brick façades of the building was one of the major starting points for the project development. There was also a strong focus on the energy demand reduction, maintenance and the need for functional improvements such as better accessibility for elderly and disabled people.

The space heat demand reduction has been estimated for all 6 scenarios, ranging from 41% for the maintenance scenario to up to 89% for variant 6.[5] For all the technology variants the highest investment component was related to the building envelope.

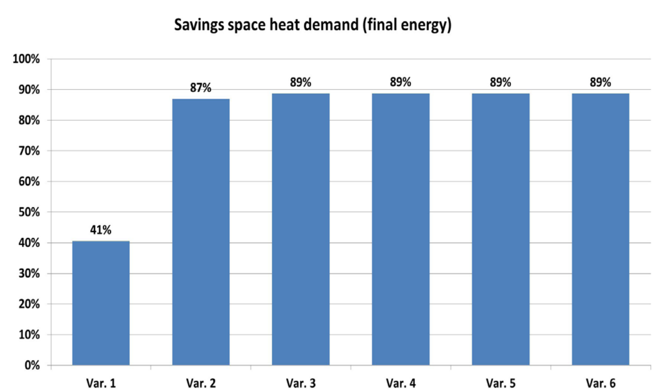
All the scenarios have been evaluated within the Life Cycle Cost approach, including the investment and operational costs (incl. energy and future maintenance) over its lifetime. This was calculated for different energy price increments. The greener the graph, the more economic a scenerio is. Variant 4 is in the long term the most economic scenario.

Variant Component	Var. 4 Alternative Pilot
External wall	Alternative pilot: Wall constr. with EPS core
External wall concrete	Pilot: attached façade (add.ins., partial demol)
Roof	Status quo
Upper ceiling	Pilot: 2 layer mineral wool
Floor slab common spaces	Maintenance
Floor slab apartments	Pilot B: PIR on floor slab
External wall perimeter	Pilot: perimeter insulation XPS
Ceiling cellar	Maintenance
Windows	Pilot triple glazing
Doors	New door
Ventilation	1:2 Pilot Central vent. + heat rec.
Heating + DHW	1.2: Pilot: district heat and central DHW
ICT	15,00%

The most optimal technology package for the Swedish pilot site



Scenarios for life cycle costs dependent on different energy price increases



Space heating demand savings

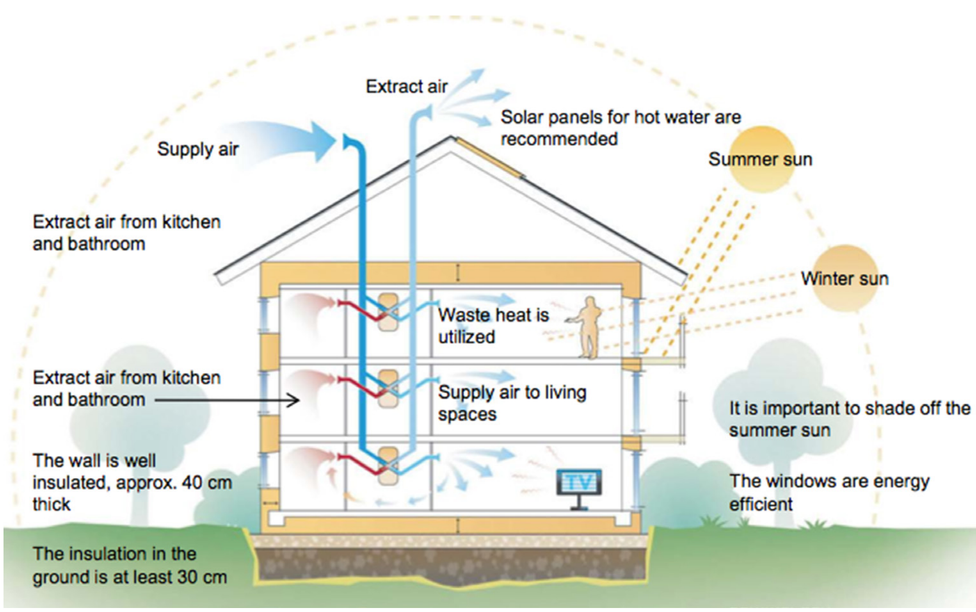
5 BEEM-UP uses an international methodology for calculating energy demand reduction in the three pilot sites. The numbers can differ from locally calculated results.

Brogården is classified by the municipality as an area with a conservation value. Because of this, the design and materials have been chosen to resemble those of the original building. The first house in the area has been renovated as an initial comprehensive pilot for energy efficient refurbishment towards passive house performance. For the final 8 houses, the aim is to bring this process up to scale, and develop cost-efficient solutions to make energy efficient refurbishment a viable alternative for the remaining housing stock.

The passive house technique means that the houses are very well insulated and only require a minimum of added heat. During most of the year the heat generated by the household equipment, light fittings and the tenants themselves is sufficient to keep the house warm. On the coldest days, a small district heated heating element in the exchanger is used to slightly preheat the incoming ventilation air. Renovation according to the passive house method puts demands on all stages in the building process, for example moisture must be kept from penetrating the building components.

In connection with the refurbishment with passive house technique, not only old brick walls but also all of the old curtain walls have been torn down. A completely new wall with 48 cm mineral wool insulation was erected against the existing concrete frame in the first house. Thanks to the technical development in methodology and design, as initiated by the skilled workers, the following houses have had 44 cm insulation but kept the same U-value.

Demolition work at Brogården; the original façade is taken down



Principles of Passive house technique. Source: ArtCon/Passivhuscentrum

In the Brogarden pilot site Skanska developed wall modules with high insulation properties which are constructed in a factory and mounted to the building on the construction site. Prefabrication of the modules result in increased efficiency of the construction process, improved rigidity of the wall structure and savings on materials. The work on the construction site is reduced, as the primary part of the wall is build under controlled conditions in a factory. Skanska already implements the BEEM-UP approach of prefabricated wall modules in its other re-furbishment projects in Sweden.

The new facade is build up from tiles mounted on horizontal support profiles, which gives a back-ventilated and damp proof construction. The tiles consist of a hard-burnt light yellow clinker stone or brick that aesthetically gives an impression similar to the original. The original indented balconies caused thermal bridges and draughts. Because of this they are replaced with externally mounted balconies with screens on the short sides and a roof even on the topmost balcony. All windows are in accordance with passive house standards and the ground slab has been supplementary insulated.

A sample of the new mock-up wall, which is prefabricated and transported to the construction site

On-going refurbishment

Crumbling brick façade before and the new tile facade after the refurbishment.

Social interaction is an important part of a deep energy refurbishment. For Alingsåshem it was especially crucial to make sure that everybody was “on board” for this massive change. The refurbishment is an emotional and complex issue, thus asking people direct questions could lead to misleading answers. Therefore, Alingsåshem relied on the household lifestyle profiles in order to find out what different groups of tenants really want in relation to their homes.

At the first stages of the refurbishment the tenants were only involved indirectly through their household lifestyle profiles and their service notifications. As a result Alingsåshem obtained information on how important different issues are to different tenants groups.

In the next stage Alingsåshem established a continuous dialogue with tenants all through the process by setting up open house meetings and by creating a newsletter.

Within the whole process of refurbishment tenants have had the opportunity to react to the progress in all stages of the project. Their feedback might not influence how the actual house is built but it has given Alingsåshem opportunities to adjust the shared spaces and some details in response to their comments.

The tenants were often invited to a discussion. The Swedish Union of Tenants contributed to a workshop where the tenants were involved to come up with ideas for how the defects could be redressed.

All the “first tenants” in the flats have had the opportunity to choose wallpapers and kitchen fittings. These are details in such a sizeable project, but it’s an important aspect for the tenants. Usually they make their choices when signing the contract – which is normally at least three months before they move in.

Architect Kerstin Nilsson shows the change in spatial dispositions for some tenants at an Open House in the show apartment.

After the execution of the whole refurbishment process, the monitoring system has been installed in Brogården. Whole facility monitoring and measuring is the primary method for the calculation of energy savings. In Brogården multiple innovative energy conservation measures have been used. Due to this fact, real consumption data are of particular importance for the project in order to precisely evaluate the technical solutions.

The monitoring plan for Brogården has been divided into three parts:

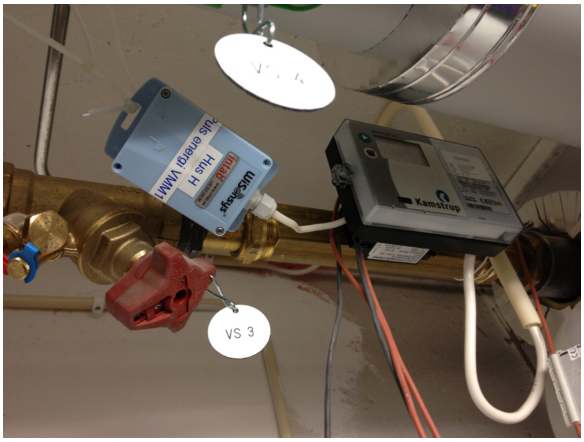
- Energy use for space heating, hot water, ventilation and electricity
- Outdoor climate parameters
- Indoor climate parameters

The electricity consumption is measured on an hourly basis from the local energy company (Alingsås Energy) for all apartments. The same is valid for the common electricity.

The space heating consumption is the sum of the recovered heat from the air handling unit and the heat produced by district heating. The heat supply from the district-heating network will be monitored for the whole building on an hourly basis.

The use of domestic hot water is determined in the same way as the heat supply from the district-heating network. Monitoring is done with existing meters installed by the local energy company and complementary meters that were installed to get more information.

Air quality will be measured through the concentration of CO_2 in some apartments. During the whole monitoring period the outdoor climate will also be monitored.



Flow meter installed by the energy company and connected to a pulse meter sending information to a base station

Meter for DHW in one apartment

Pilot site: Delft, the Netherlands

Woonbron is one of the largest social housing groups in the Netherlands. Its working area is the southern part of the Randstad (the metropolitan region of the Netherlands). Woonbron serves about 50,000 households and has five offices in Rotterdam, Delft and Dordrecht. Woonbron offers, in a coproducing role, housing and choices to a broad customer group in a healthy urban area that has different, but attractive, living styles. As an organisation Woonbron positions itself for its customers that are in need of good housing.

The BEEM-UP building site is located in the north west of Delft, approximately 2,5 km from the city centre. The group of buildings is called complex 5. The area has a specific identity and quality. The surrounding buildings share the typical Dutch brick façade as a remarkable architectural quality.

Before the retrofit the building owner formulated the following requirements:

Energy:
- Reduction of the energy consumption
- Improvement of the thermal envelope
- Avoidance of water condensation and reduction of thermal bridges
- Effective heat and DHW production

Functional and economical:
- High-performance windows
- Decentralized systems (HVAC) are preferred
- Cost effective measures
- Minimized impact (on tenants) due to construction work
- Simplicity, replication, rationality, effective building
  - Optimized solutions for replication
  - High planning and construction quality
  - Redress technical defects

A building from the Kuyperwijk Complex

Building before refurbishment

Technical characteristics of the Dutch buildings before refurbishment

	Kuyperwijk Complex 5: 80 apartments and 28 attached houses (7326 + 2355 m²)
Envelope	*Walls: no insulation but 4 cm air Basement: too humid 60 cm air Roof: no insulation*
Windows	*Only double glazing in the living room, aluminium frames over wood*
Heating	*Different types of old gas heaters. Not insulated distribution.*
Hot water	*No special measures*
Ventilation system	*Old mechanical ventilation*
ICT - energy management (incl. smart meters)	*None*
Lighting	*Incandescent light bulbs*
Renewable energy source	*None*
Other energy saving	*None*

The refurbishment has resulted in substantial energy demand reduction for space heating. According to calculations the improvements reached 77% depending on building type. Preliminary results show that most flats investigated after the retrofit reach Energy label A.

In Delft tenants had the possibility to choose a specific energy reduction refurbishment package according to their preferences. Measures, which were implemented upon a request from tenants, include: solar panel, floor insulation and home energy management with a feedback system.

Saving results for Delft buildings

KPI	Retrofitting plan	Status quo
∑ Primary Energy Demand	*99-251 kWh/(m²a)*	*380 kWh/(m²a)*
Saving space heat + DHW demand (PE energy)	*34-74%**	
Saving space heat demand (final energy)	*36-77%**	
Savings DHW (final energy)	*6-52%**	
Savings household electricity [4]	*28%*	

The building after refurbishment

Technical characteristics of the Dutch buildings after refurbishment.

Envelope	*Walls: 4,5 m2 K/W Basement/floor: 5,0 m2 K/W Roof: 4,0 m2 K/W*
Windows	*HR ++ windows with layer of metal foil. 1.6 times better insulation than double-glazing.*
Heating	*HR 107 boiler with use of solar panels on the houses. Insulated distribution.*
Hot water	*Water saving showers.*
Ventilation system	*Mechanical*
ICT - (incl. smart meters)	*Toon – Home Energy Management system. Real time electricity and gas consumption monitoring. Heating remote control.*
Lighting	
Renewable energy source	*Solar energy on roof for warm water and heating.*
Other energy saving	*Focus on tenant behavior and awareness-raising during and after retrofit is expected to lead to further reductions in energy consumption*

4 Increasing usage of energy savings light bulbs included (30%)
** Depending on tenant´s choice of measures*

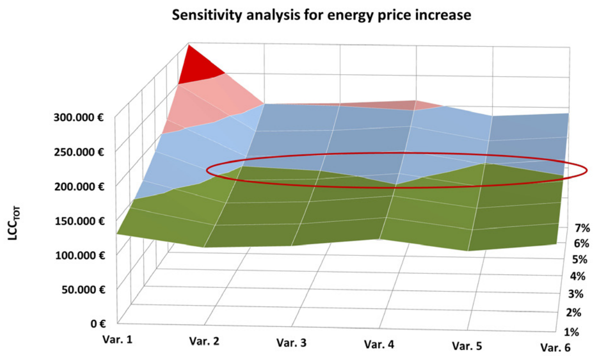
As a first step, all building components were evaluated and existing needs for maintenance and improvements were determined. The need for renovation of HVAC system and the existing windows of the building was one of the major starting points for the project development. Furthermore, the following needs for improvements have been identified: energy demand reduction with implementation of renewable energy, lowering maintenance costs and functional improvements.

An analysis of six scenarios has been performed. The space heat energy demand has been massively reduced for all 6 scenarios, ranging from 36% for the variant 1 up to 77% for the variant 6. Corresponding investment costs for retrofit components indicate the biggest share of investment spent on the building envelop.

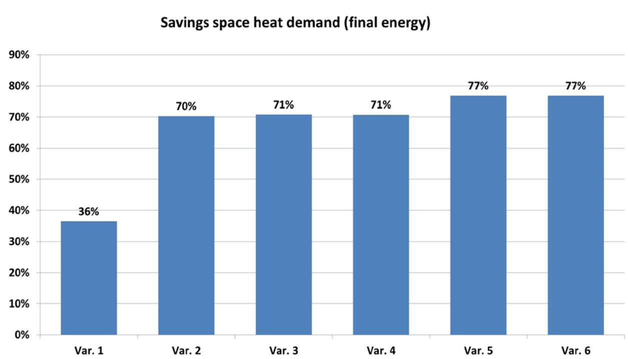
Life Cycle Cost analysis including the investment and operational costs (incl. energy and future maintenance) over its lifetime shows that all variants except the maintenance scenario are nearly equal from the point of view of economic optimality. Due to this reason, technology packages implemented in the pilot site slightly differ according to tenants' preferences. The greener the graph, the more economic the scenario is.

Variant Component	Var. 6 Alternative Pilot
External wall	Maintenance (hydrophobia-tion)
Loggia ceiling	Insulation +10 cm EPS
Loggia floor	Maintenance
Sus. floor	Reflective foil insulation
Ceiling entrance	10 cm EPS
Roof	Insulation between rafters 120 mm
Dividing wall	Status quo
Domer wall	Sandwich construction 100 mm EPS
Domer roof	Sandwich construction 150 mm EPS
Windows type 1 ori.wood / single glazing	Wood frame with HR ++ glass for type 1
Windows type 2 later alu frames single glazing	Wood frame with HR ++ glass for type 2
Windows type 2 later alu frames doubled glazing Win-dows type 2 later alu frames doubled glazing	Wood frame with HR ++ glass for type 3
Ventilation	1:2 Maintenance: window ventilation
Heating + DHW	1.4: Condencing boiler + solar
ICT	15,00%

Optimal technology package for the Dutch pilot site. Tenants can individually decide about floor insulation, boiler, solar panel and ICT system



Scenarios for life cycle costs dependent on different energy price increases

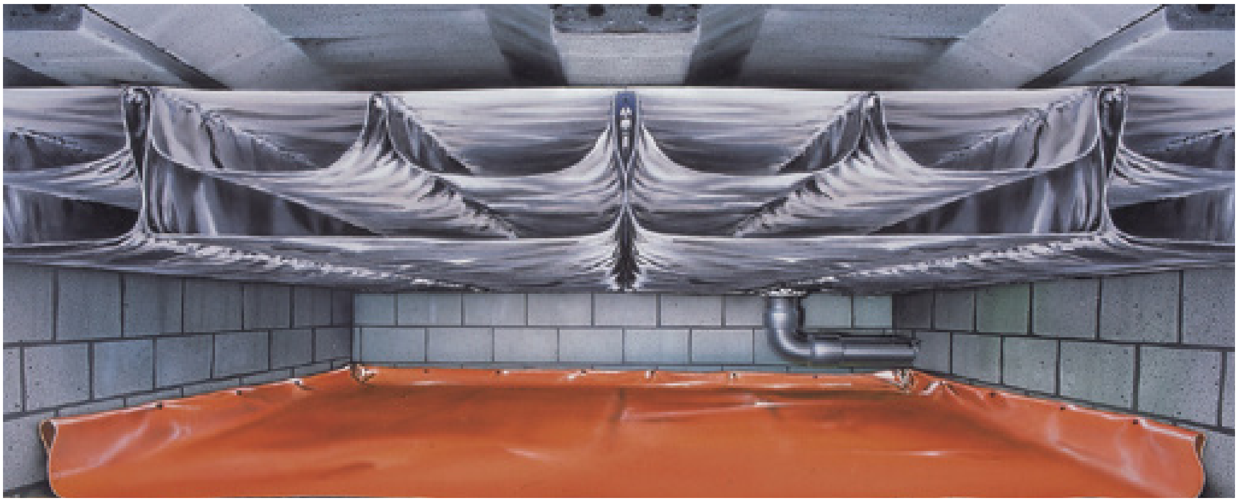


Space heating demand savings

In Delft, where the tenants stayed in the dwellings during the refurbishment, a complete house reconstruction was not necessary. As the existing wall structures were in a good state in this pilot site, only exterior measures were needed. The characteristic brick façades in Delft were cleaned and repaired, and a hydrophobisation was performed. Impregnation can, apart from the water protection, also improve the thermal performance of a cavity wall if bricks are kept drier and thus better insulating. At the same time, the architectural expression could be kept.

For suspended floors, exterior insulation could be applied even though the working space is limited. Height of the crawl space is only 0,8 m. For construction work from underneath the house a person has to work in a difficult environment. All options had to be in compliance with national Occupational Health and Safety Requirements. To decrease the extent of work in the crawl space, the Delft demonstrator chose a solution with layers of reflecting insulation foils hung up in closed sections between the joists from under the floor, with an additional vapour barrier on the ground. Pre-assembly evaluations show that a considerable improvement can be expected in terms of heat loss, thermal comfort and moisture conditions of the wooden floors.

Refurbishment works in Delft pilot site

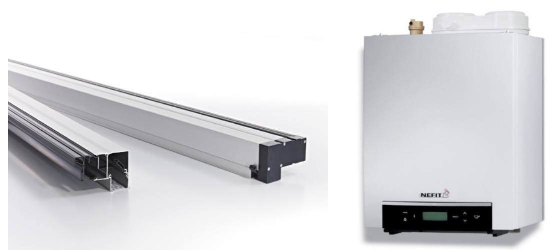


Reflective foil – the floor insulation. Source: www.apotheekengezondheid.nl

The pitched roofs of Delft were effectively insulated exteriorly using prefabricated modules of high performance insulation (graphite enhanced EPS). Element joints were sealed and the roofs were quickly completed with battens and roof tiles (tiles were reused where possible).

In Delft the solar heat system as well as condensing boilers have been offered to tenants. Households which wanted to have the system installed in their dwellings agreed to pay € 55 extra rent. Around 50% of dwellings from the BEEM-UP project have the system installed. Additionally, new double glazed windows classified as HR++ have been installed. HR++ glass windows are filled with Argon gas and have better characteristics than the normal insulating glazing. The insulation value (U-value) is less than 1.2 The new windows are equipped with ventilation openings.

Roof elements assembly



Ventilation openings for the windows (www.ventilatieroosters.nl)
Nefit Proline CW3 condensing boiler (www.kieskeurig.nl)

Solar system installed on the roofs of buildings in the Delft pilot site

In Delft a feedback group was used to develop (or check) a shared opinion on the improvements needed. The tenants feedback group assured that costs and measures are in line with households´ needs.

Open house sessions have been held in order for people to have the opportunity to inform themselves about the renovation plans, to hear explanations of the plans from the feedback group as well as having the possibility to ask questions. The open house events have resulted in identification of positive and active persons, who care about the neighbourhood and want to be involved in activities to improve the area.

An intense social program was launched after the retrofit of the roofs and walls. Elements of the social program are a questionnaire on energy behaviour and energy consumption, idea generating meetings to promote awareness and information on energy behaviour and do-it-your-self measures in the dwellings. This program is essential in promoting participation in as many free-selective energy saving measures as possible.

The promotion and awareness program involves meetings, education courses, information transfer and coaching. The goal is to find out which improved level of social interaction around energy issues can be developed and maintained afterwards. The questionnaire on behaviour and energy use is part of this program.

Dutch tenant-protection regulation demands that 70% of the tenants agree to a physical improvement of the houses in case the landlord wants to increase the rent, re-claiming costs for the improvement. This can lead to strong discussions if certain refurbishments are indeed an improvement or perhaps nothing more than regular maintenance. In this particular project these discussions were avoided by the mix of envelope-refurbishment without rent increase and other improvements at extra costs.

Woonbron arranged open house meetings for tenants in a vacant dwelling

Specific about the Delft site is the diversity in the refurbishment options to be implemented in the dwellings. This constitutes one of the most interesting points to be analyses during the monitoring and evaluation work.

Whole facility monitoring and measuring will be the primary method for the calculation of energy savings. The baseline period has been established through the means of energy bills. It allows getting a robust view of the energetic behaviour of the building before refurbishment.

Specific energy conservation measures are isolated and compared in order to obtain clear evidence on what specifically contributes to energy savings. Comparisons will be performed for the sample dwellings on the following criteria: new boiler installed or not, solar boiler or not, with/without use of Toon, ground insulation or not.

The assessment of the building performance is done on the following levels:

- Whole facility, i.e. the building, through gas bills analysis
- Intermediary scale, i.e. the dwelling, through the analysis of consumptions and comfort parameters for a representative set of dwellings
- Energy conservation measures scale, through the analysis of specific phenomena corresponding to particular energy conservation measures

A number of dwellings in Dutch pilot site have been equipped with the TOON system (feedback system combined with smart meters), which helps tenants to save energy and reduce the gas consumption. The system is equipped with an engaging, simple design and is easy to use. Additionally, tenants can control their heating remotely by a smartphone.

“Toon” home energy management system

Pilot site: Paris, France

ICF Habitat Novedis is a subsidiary of ICF Habitat, one of the major housing companies in France belonging to the French railway company SNCF. ICF Habitat Novedis invests, builds and maintains a 12 000 dwelling portfolio mainly intermediate, first and foremost dedicated to the French national railway company's workers and to every person whose income exceeds the income threshold of social housing recipients. Committed in an approach of value creation addressed to her customers, the society leads in the major French metropolitan areas a policy of development and active renovation of its portfolio.

The Paris building was constructed in the late 50's and is located in the central area of Paris close to the Montparnasse railway station. It is a district with many old buildings of historical importance; this means that the urban regulation is strict regarding architectural projects, which often have to be approved by the Architect of National Buildings.

The insulation level of the building envelope including negative effects of thermal bridges did lead to a reduced comfort and a high risk for condensing moisture and mould. It also caused a demand for a higher internal temperature and increased energy consumption. The energy consumption was even reinforced by the flawed collective floor heating system. In some dwellings it was replaced by simple electrical heaters. Finally, the windows of the building were not functioning correctly, which caused increased infiltration during the heating period.

The building has undergone a light refurbishment in 1993 (outer insulation, double glazed windows, boilers), but it needed a major upgrade in order to make it fit with the standards expected by ICF Habitat Novedis tenants with consideration of the BEEM-UP targets. The internal organisation of dwellings was not well adapted to the actual market (small rooms) and had to be restructured.

The need for renovation of HVAC system and the existing windows of the building was one of the major starting points for the project development. Other technical and functional improvements as well as energy demand reduction were needed.

Paris building before the renovation

Technical characteristics of the French buildings before refurbishment

	Building year: 1959. 87 dwellings, 7 floors, 4352 m²
Envelope	*Walls street side: concrete + 2 cm sandwich insulation. Walls back side: concrete + 2 cm sandwich insulation + 8 cm ETICS. Basement: concrete. Roof: concrete + 5 cm insulation*
Windows	*PVC double glazing, 20 years old*
Heating	*2 collective gas boiler*
Hot water	*Individual electric boilers have been installed in 1993. Originally hot water was provided by a collective boiler located on the roof.*
Ventilation system	*Natural ventilation grids in the kitchen, bathroom and toilets (apparently no ventilation problems)*
ICT - (incl. smart meters)	*None*
Lighting	*Regular incandescent light bulbs*
Renewable energy source	*None*
Other energy saving	*None*

The refurbishment of the building in Paris started in April 2013. According to the planning, the whole process of refurbishment will be finished by March 2014. The technology package chosen for the retrofit indicates high-energy efficiency; going beyond the BEEM-UP target with an estimated energy demand reduction for space heating of 84%. After refurbishment the building will not be only energy efficient, but also the overall functionality will be enhanced. Some of the dwellings will be connected into duplexes in order to answer current households needs.

Graphical simulation of the building after the refurbishment

Saving results for Paris buildings

KPI	Retrofitting plan	Status quo
∑ Primary Energy Demand	*77 kWh/(m²a)*	*338 kWh/(m²a)*
Saving space heat + DHW demand (PE energy)	*77%*	
Saving space heat demand (final energy)	*82%*	
Savings DHW (final energy)	*71%*	
Savings household electricity [5]	*62%*	

Technical characteristics of the Paris buildings after refurbishment

Envelope	*Walls street side: + 20cm ETICS EPS λ032 Walls back side : New 20cm EPS ETICS λ032 Basement: + 10 cm insulation EPS λ032 below ceiling Roof: New 10cm insulation PUR λ024 on ceiling*
Windows	*New PVC double glazing, U= 1,5 W/m².K*
Heating	*New condensing boilers for heating and warm water*
Hot water	*Focus on tenant behaviour and awareness-raising during and after retrofit is expected to lead to further reductions in energy consumption.*
Ventilation system	*New controlled mechanical ventilation*
ICT - (incl. smart meters)	*Cost optimal control solutions (from individual solutions like chronostat, radiator zone control, meter data for individual billing, to full home automation). Exact optimum will be defined during integration with total system and specific simulation.*
Lighting	*All public spaces will be fitted with low-energy light systems. All tenants en-couraged to switch to low-energy lighting.*
Renewable energy source	*Focus on tenant behaviour and awareness-raising during and after retrofit is expected to lead to further reductions in energy consumption.*

5 Increasing usage of energy savings light bulbs included (30%)

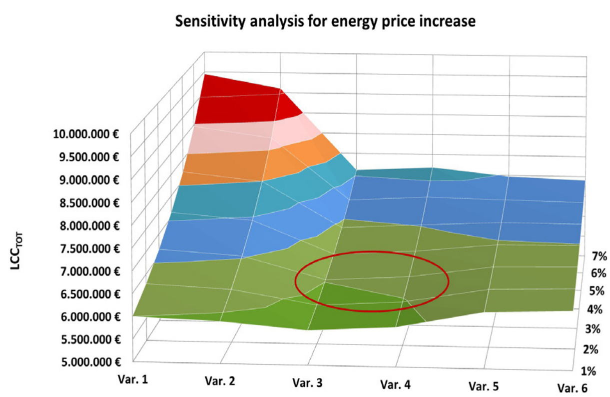
During the planning of refurbishment, six technical scenarios for retrofit have been identified. For all the scenarios the building envelope is optimized which influence the heat demand and required performance of the HVAC system.

Within all scenarios the space heating demand is reduced significantly, ranging from 50% for the variant 1 up to 92% for the variant 6. In case of the Paris building, the biggest share of investment is related to installation of the HVAC system.

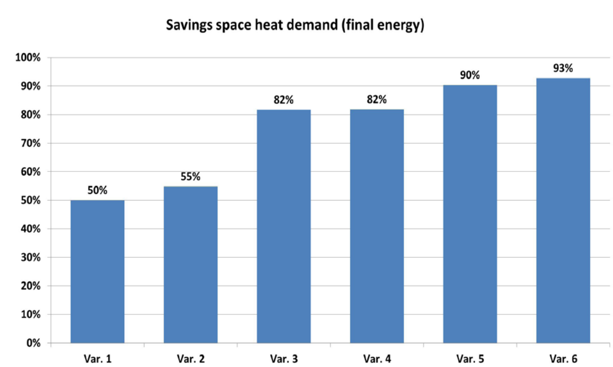
All the technology packages have been evaluated using the Life Cycle Cost approach, including the investment and operational costs (including energy and future maintenance) over its lifetime. According to the analysis the technology package, nr. 3 has been found to be the most economically optimal (it has the lowest life cycle cost).

Variant **Component**	**Var. 3** **Alternative Pilot**
Flat roof	24 cm PUR (non-ventilated)
Roof terrace	16 cm PUR 025 (non-ventilated)
Ceiling cellar	Ceiling insulation 20 cm EPS
External wall front	Front EIFS Neopor 20 cm
External wall yard	YARD EIFS EPS 20 cm
External wall passage	Passage EIFS EPS 10 cm
External wall ground floor	EIFS Mineral wool 20 cm
External wall penthouse	Ph. EIFS EPS 20 cm
Ceiling passage	Passage EIFS EPS 10 cm
Windows front	Wooden frames, PVC double glz ins. layer
Windows yard	Wooden frames, PVC double glz ins. layer
Windows front balconies	Balc. Wooden frames PVC double glz ins. layer
Ventilation	1.2: Exhaust air
Heating + DHW	1.5: H: Cert. cond. boiler W: central + waste water
ICT	11,00%

The most effective technology package for the Paris building site



Scenarios for life cycle costs dependent on different energy price increases



Space heating demand savings

The work carried in the French pilot site includes:

The building envelope
- Thermal insulation
- Façade restoration
- Roof and terraces
- Replacement of windows

Outdoor areas
- Courtyards and parking lots

Common areas
- Lobbies, hallways and technical rooms

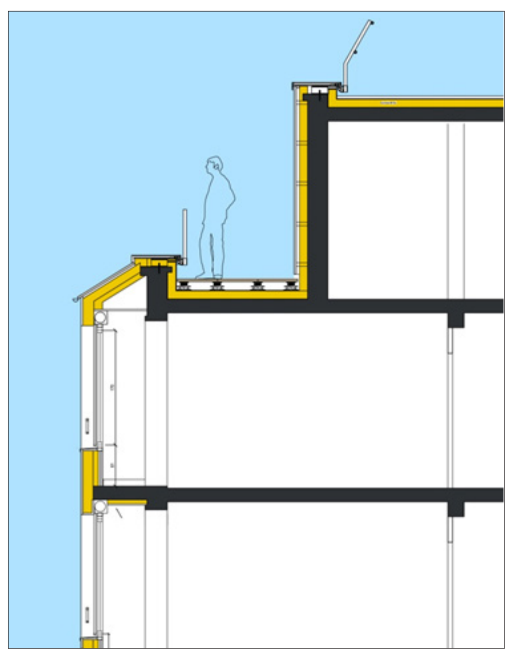
Common amenities
- Ventilation
- Collective heating and hot water

Housing units
- The restructured dwellings
- Heating and sanitary equipment
- Electricity

Back facade before the refurbishment

The external wall on the front is a double leaf concrete wall construction with a 20 mm EPS insulation core. All measures have to fit with the window installation in avoidance of thermal bridges and moisture. Each solution with an additional insulation layer needs space and should be integrated in an appropriate façade concept.

Construction work on the back facade of the building



External insulation layer

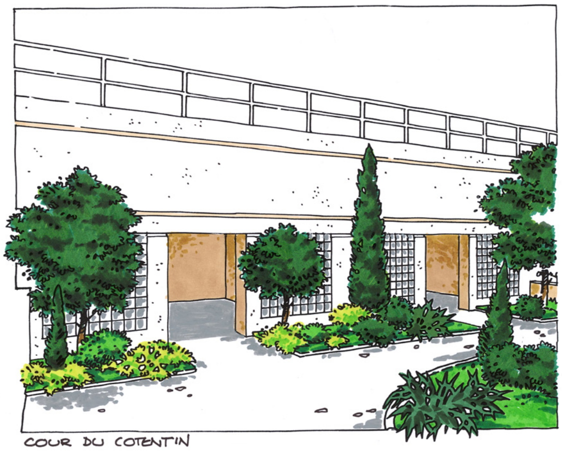
On the balconies ICF decided to use an innovative insulation material developed by BASF - Aerogel boards. The material has a very good insulation performance and it is much thinner than EPS. Thanks to its properties ICF was able to save extra room on the balconies, which have very limited space. The solution substantially raised the quality of dwellings, keeping balconies accessible for tenants.

Show-case apartment after the refurbishment

Within the renovation also the outdoor areas will be changed. The green spaces will be reorganised, thus more accessible and friendly for the tenants. The parking areas for two-wheelers will be renovated and green roofs will be built on the garages.

Old individual boilers have been replaced by a collective high-efficient DHW system.

In the basement a heat recovery of wastewater system Biofluides has been installed. Grey water is used to pre-heat cold water, which improves an overall system efficiency and saves energy. In order to place the system of hot water tanks, the storage room had to be created from six existing cellars.



Common courtyards

Heat recovery from grey water

ICF Novedis decided to involve tenants within the whole process of refurbishment in order to make them accept the work more easily. Observations of the Paris pilot indicate that people who are engaged in the refurbishment are more aware of environmental issues and consequently contribute to the successful accomplishment of the project.

The main methods used during the pre-retrofit phase have been:

- Employment of new person in charge of tenant interaction
- Individual interviews about occupation of the dwellings, assessment of housing, use of common. spaces of the building and interest in the environment (72 dwellings interviewed among 87)
- Letters to all tenants informing about forthcoming renovation plans
- 2 Meetings where general information about the retrofit project is shared
- Questionnaire about the technical state of the building
- 2 Workshops on specific topics (energy consumption commitment and renovation of outdoor spaces)

During the work period:

- A showcase apartment presented to tenants at the beginning of the refurbishment
- The house keeper used as a communication channel
- Information website informing about the work schedule
- One person from the construction company (BREZILLON) dedicated to tenants interaction

Most tenants did not have to move out during the retrofitting work. There have been individual meetings to inform them of the schedule of work. Some tenants have been moved temporarily because they work at the National Railway Company during the night and sleep during the day.

The only tenants to be moved to another location are those affected by the creation of duplexes on the two top floors. For them, solutions have been found to re-house them in ICF patrimony in Paris. The building owner takes up on all expenses related to the moving. Dialogue with these tenants started early in the process in order to prepare them for a smooth move.

Communication brochure for the Paris building

Information meeting with tenants

Whole facility monitoring and measuring will be the primary method for the calculation of energy savings. The baseline period has been established through the means of energy bills. It allows getting a robust view of the energetic behaviour of the building before refurbishment. It is important that within the monitoring system specific energy conservation measures are isolated and compared. For that purpose, the Biofluides system based on grey water heat extraction will be specifically monitored. Punctual measurements such as blower door tests, infrared thermography associated with global heating consumption and comfort analysis will be performed to assess the façade refurbishment. The acoustic insulation improvement will be assessed through punctual acoustic tests.

The assessment of the building performance is done according to the following indicators:

- Final energy consumption
  – For the whole building through a gas bill analysis (for evaluating the whole heating consumptions before and after refurbishment)
  – Per apartment through the analysis of consumptions parameters for a representative set of dwellings.
  – Per applications (heating, DHW, light, appliances)

- Comfort level through the analysis of comfort parameters for a representative set of dwellings
- Specific analysis (heating response per flat)
- A preliminary instrumentation was installed on the site for the monitoring of the baseline period. A wireless technology using the sensors shown on Figure 6 was selected.

For the period after refurbishment the SYNCO LIVING system from SIEMENS, installed in the monitored dwellings, will be used to provide information on comfort conditions and consumption.

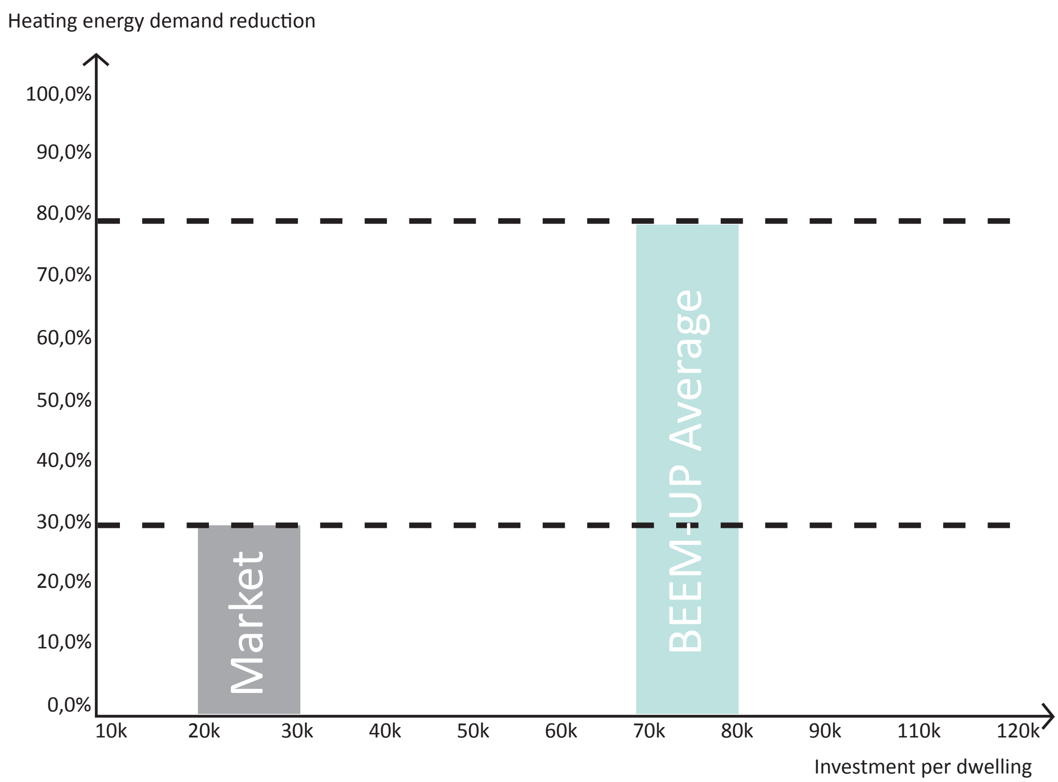
A panel of SYNCO LIVING system from SIEMENS

Market Replication

The current state of technology allows for achieving more than 80% energy demand reduction in refurbishment of residential buildings. However, the investment costs for deep energy refurbishment seem to be beyond current financial capacities of social or public housing companies on a large scale. R&D and demonstration projects related to energy retrofitting provide a good source of lessons-learnt and give valuable insights into optimization of the ratio-energy demand reduction vs. investment costs. Despite a substantial progress within the best practice for energy retrofitting, there is a considerable large gap existing between the financial capacity of social housing companies and the required investment costs for deep energy refurbishments.

In order to address replication strategies of deep energy refurbishment in the residential sector, BEEM-UP aims to analyse the current market practices for refurbishment of social and public housing companies.

BEEM-UP provides viable insights in the optimisation of investment in energy refurbishment. Furthermore, mapping of innovative financial instruments will lead to recommendations on how the available technology and financing options would change future investment decisions in terms of quality of buildings being renovated on a large scale in Europe.



Current market vs. conditions for deep retrofitting

Conclusions

BEEM-UP identifies the best practices within the whole process of refurbishment. The lessons-learnt have a high potential impact on optimization of investments in retrofitting. The preliminary conclusions and recommendations are listed below within forth categories of a refurbishment process.

Housing stock management

Conclusion	Recommendations
Housing Corporations need a strategic refurbishment programme (setting objectives) and investment plan to guide decision-making at building level.	• To accelerate uptake and promote best practices, there should be more regional exchange of experience in low-energy housing. • EU/member states need central databases on energy performance certificates/benchmarking (long term investigations).

Project development and planning

Conclusion	Recommendations
Each refurbishment project should start with the holistic technical analysis of the building and involve a broad consideration of the specific site conditions (scanning opportunities).	• Establish a multidisciplinary team + (external) expertise/designers responsible for the project development. • Consider critical conditions/requirement/goals related to the building (national building regulations, financial incitements, legislation, building traditions, local/cultural aspects) as well as indoor environment (moisture, health, acoustic problems, air tightness, ventilation). • Involve tenants in the development process and make sure that the building meets their needs.

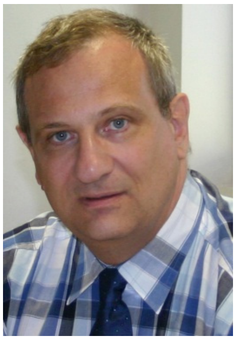
Implementations

Conclusion	Recommendations
During the work execution strong focus needs to be put on testing, quality assurance and improvement identifications.	• Apply stepwise approach or use a pilot house/flat in order to test and verify the technical solutions • Listen to people who work on the construction site. They are aware of possible improvements, thus have a high impact on the project efficiency. • Collaborate closely with a construction company in order to have a good understanding of project´s goals. • Introduce quality assurance procedures. • Involve the tenants. On-going interaction makes the tenants feel "seen" and implement small adjustments if needed.

Documenation and monitoring

Recommendations	Conclusion
Include deployment of ICT solutions within your refurbishment.	• Monitoring data is of crucial importance for energy retrofitting. Quantified data shows the expected and real performance of a building after a refurbishment. Moreover, reliable data allow for spotting errors in a construction and thus help to establish suitable refurbishment plans. • Monitoring encourages tenants to save energy and water. • Requires a low investment, ICT application is considered the best cost effective energy measure possible.

Interviews



Dr Luc Bourdeau
E2BA Secretary General of E2BA (Energy Efficient Buildings Association)

"Renovating the European stock of residential buildings is critical if we want to decarbonise the European economy by 2050, reducing its CO2 emissions by at least 80% and its energy consumption by as much as 50%. But as the replacement rate of the existing stock is very small (1-2% per year), acceleration is urgently needed. Developing, testing, and demonstrating through projects such as BEEM-UP is essential. Systemic, cost-effective, mass-customised, high-performing and minimally invasive building retrofitting solutions are needed in order to multiply the yearly energy efficient and high quality renovation rate with tangible benefits for users at least by 2.5 by 2020."

Claire Roumet
Secretary General of CECODHAS Housing Europe

"CECODHAS Housing Europe as the European Federation of Public, Cooperative and Social Housing recognises the importance of energy efficiency in residential buildings. Affordable housing consisting of 12% of the European housing stock is well positioned to lead a massive transformation of the built environment into high-energy efficiency standards and our members, through the POWER HOUSE nearly Zero Energy Challenge project, are committed to design strategies towards nearly-Zero housing stock. However best practices and replicable methods for cost-effective energy retrofitting need to be identified. While involving different stakeholders within a whole process of refurbishment, the BEEM-UP project demonstrates an innovative and effective approach for the deep energy retrofitting which can trigger the renovation rate of residential housing in Europe."

Susanne Sjöblom
Concept Manager Miljonhemmet, Skanska Sweden

"Very high competence in energy efficient retrofitting is a part of the Skanska objective to be a leader in green construction. The BEEM-UP collaboration involves the opportunity of international knowledge and experience sharing, enhancing our competence within this field."

www.beem-up.eu

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BEEM-UP

SEVENTH FRAMEWORK PROGRAMME

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