BEEM-UP Building Energy Efficiency for Massive market Uptake: Methodology, Calculations and Results

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Other partners of the BEEM-UP consortium

Abstract

The EU funded project BEEM-UP will demonstrate the economic, social and technical feasibility of retrofitting initiatives, drastically reducing the energy consumption in existing buildings, and lay the ground for massive market uptake. BEEM-UP involves the building owners at 3 sites in France, Sweden and the Netherlands to implement an innovative approach to go beyond a 75% reduction in space heat energy consumption, in addition to reducing the total energy consumption. Ambitious energy reduction will be demonstrated as the most attractive alternative for retrofitting.

In integrated design the building owners, industry, designers and energy experts collaborate around the building to reach a higher performance and be more adapted to the tenant needs than if just plugging in separate solutions. New concepts will be identified that can be replicated in further retrofit projects. An ambitious monitoring programme to demonstrate the reduction in energy consumption will accompany the whole process. This technical monitoring will be complemented with a social monitoring, focusing on the acceptance of the occupant.

A whole programme is designated to involve the occupants in the retrofit. ICT systems (smart metering and building control) will encourage and support energy savings.

The main challenge is to turn energy reduction in existing buildings into standard option on the market. Going beyond pure demonstration, BEEM-UP will be develop and exploitation plan based on green value, actively disseminate across Europe, and interact with stakeholders, to create a solid demand for energy reductions by building owners, and make BEEM-UP a model for future retrofits. Before 2020, all retrofit projects in Europe will target ambitious energy reductions: not because it is “compulsory and good”, but because it is the most attractive alternative.

This paper is concentrating on the methodology of assessment, the calculations and the expected results for ecological, economic and social aspects.

Keywords: EU funded research project, pilot projects, assessment method, calculation results, economy, ecology, social aspects.

Methodology

Process of the project

A specific focus of the project is the development of a methodology to find the most effective modernization concepts. Within this wide field of different aspects and criterions a coherent process needed to be found and to applied. Therefore the focus was set on the assessment of possible modernization scenarios. The process of developing variants for the three sites involved all stakeholders and is to last during the whole planning, construction and post construction time. The methodology describes applicable key performance indicators of three dimensions, which were verified and discussed within the interdisciplinary team against the background of different professional or national specializations.

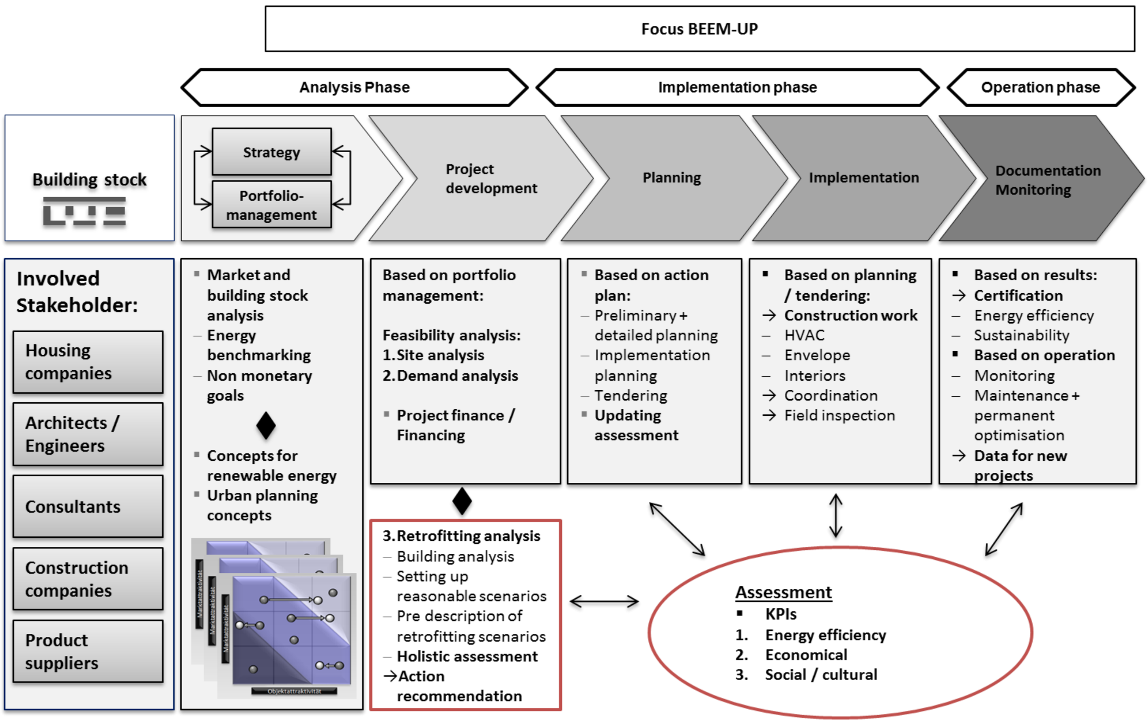


Figure 1 BEEM-UP – Scope for assessment – process and involved stakeholders

Energy demand calculation: Passive House Planning Package

To calculate the energy demand the passive house planning package (PHPP) was chosen. The calculation tool enables the consideration of many different aspects. A very detailed calculation is possible. Adaptions are possible, all calculations steps are transparent.

At an early stage of the project a replicable holistic methodology was developed[1]. Main focus of this methodology is the development of a holistic assessment approach for all three sites.

Figure 2 shows the procedure of applied scenario development. The first step is an analysis of the building status quo and clarification of general requirements given by the housing company.

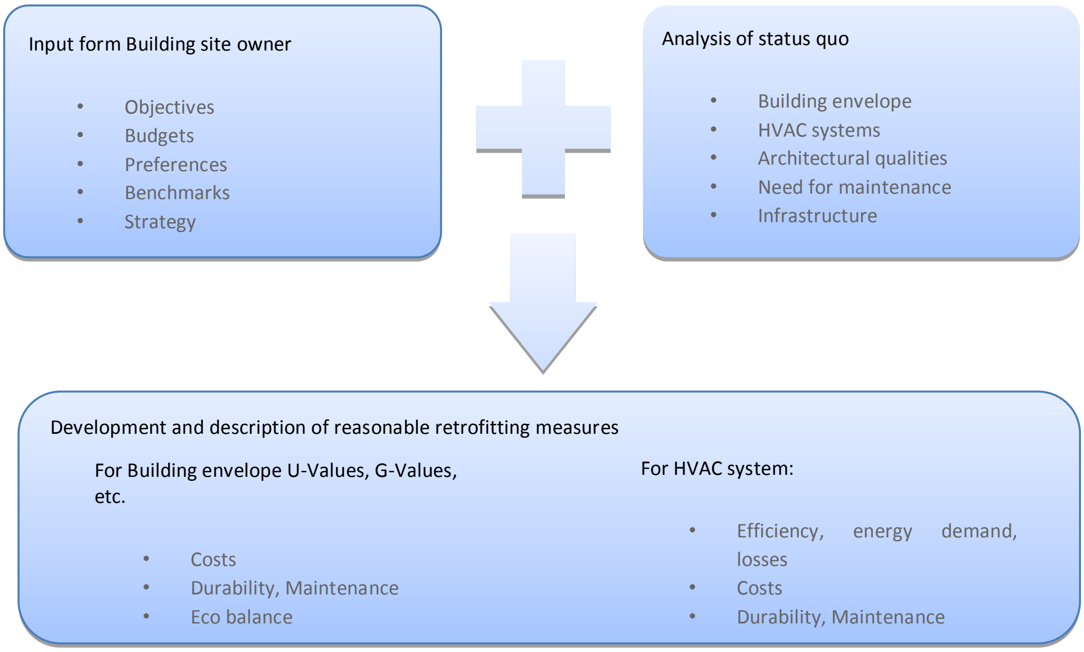


Figure 2 Development of reasonable measures (source LUWOCO)

This data are inserted in the PHPP and additional calculation tools. The measures need to be compiled to complete retrofitting scenarios.

Scenario 1 is always the “anyway” or maintenance scenario. Maintenance costs are important for an economical comparison and feed in KPIs like cost of saved energy and other. For certain calculations it needed to distinguish between costs for maintenance, extra costs and additional costs for energy efficiency.

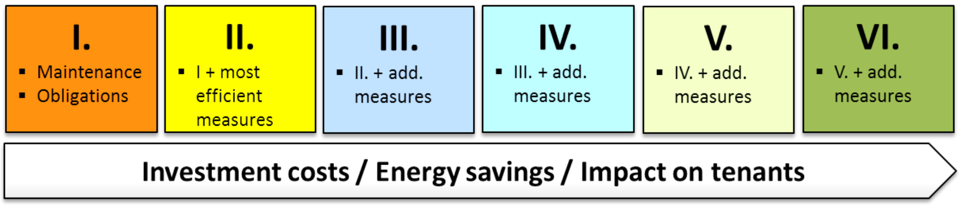


Figure 3 Spectrum of scenarios development for each building site

Compiling single measures should be done very carefully. Especially the inter-dependences between the thermal envelope and the HVAC system need a lot of attention. An improved thermal envelope reduces the heat load of the building. The HVAC system can become less complex (lower investment costs for radiators, boilers, pipes, etc.).

[1] ETH Zürich, Chalmers University, LUWOCO and involved partners

Combination of measures is an iterative process. For all sites six scenarios were developed and compared.

The assessment takes following aspects into account:

- Environmental (Energy demand/ CED/ IPCC 100, includes an appropriate LCA)
- Economic balances (LCC - including cost for energy, investment, current and future maintenance, etc./ - with optional aspects like rent increase potential, specific loans and value increase)
- Social (Comfort)
  Social aspects are mainly evaluated during workshop discussions and integrated in the ex-ante selection of measures.

A practical stakeholder oriented approach appropriate for each building site was chosen. Included costs are estimated costs for all sites in Euro[2].

Paris

Status quo analysis, General Information

The building is located in the centre of Paris, 800 m from Montparnasse train station, at the corner of Rue du Cotentin and Rue Falguière. The building is oriented to North and South on rue du Cotentin, East and West on rue Falguière. All dwellings have small balconies, 7th floor dwellings have a large terrace with a view of Paris. The surrounding buildings have similar heights.

ICF Novedis: Immobilière des Chemins de Fer (Housing Company of the Railways) is SNCF's subsidiary in charge of rental housing. With a housing stock of 96.000 dwellings, it is one of the major housing companies in France.

Figure 4 Photo with front elevation, excerpt floor plan

As a first step, all building components were evaluated and existing needs for maintenance and improvements were determined. Need for improvements are for the energy demand, maintenance and demands for functional improvements. The need for renovation of HVAC system and the existing windows of the building is one of the major starting points for the project development.

[2] Also Swedish construction costs were calculated in Euro, differences to specific project costs after project completion will appear, construction cost estimations bases on empirical values (mainly of LUWOGE consult) and were reviewed from involved project partners. Within the comprehensive scenarios comparison, some

The insulation level of the building envelope including negative effects of thermal bridges does lead to a reduced comfort and a high risk for condensing moisture and mould. It also causes a demand of a higher internal temperature and increased energy consumption. The windows of the building are not functioning correctly[3] and are causing increased infiltration during the heating period.

The majority of defects are technical defects and improvements within a retrofitting are possible. It should be generated a Win-win situation between maintenance and the improvement of the energy performance.

Six cost effective scenarios

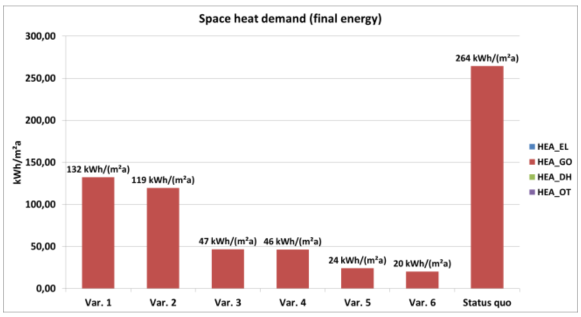
The variants were developed including all stakeholders and according to the common methodology.

Table 1 Detailed measures of all six scenarios

Variant Component	Var. 1 Maintenance	Var. 2 Improve	Var. 3 II + New front	Var. 4 High performance insulation	Var. 5 III + heat recovery	Var. 6 Maximum
Flat roof	Maintenance, 12 cm PUR (not ventilated)	16 cm PUR (non-ventilated)	24 cm PUR (non-ventilated)	24 cm PUR (non-ventilated)	24 cm PUR (non-ventilated)	24 cm PUR (non-ventilated)
Roof terrace	Maintenance	12cm PUR 025 (non-ventilated)	16cm PUR 025 (non-ventilated)	16cm PUR 025 (non-ventilated)	16cm PUR 025 (non-ventilated)	16cm PUR 025 (non-ventilated)
Ceiling cellar	Status quo	Maintenance	Spray insulation 15cm	Ceiling insulation 20cm EPS	Ceiling insulation 20cm EPS	Ceiling insulation 20cm EPS
External wall front	Maintenance	Maintenance	Front EIFS EPS 20cm	Front EIFS Aerogel 10cm	Front EIFS EPS 20cm	Front EIFS EPS 20cm
External wall yard	Maintenance: Yard EIFS EPS 15cm	Maintenance: Yard EIFS EPS 15cm	Yard EIFS EPS 20cm	Yard EIFS EPS 20cm	Yard EIFS EPS 20cm	Yard EIFS EPS 20cm
External wall passage	Passage maintenance	Passage maintenance	Passage EIFS EPS 10cm	Passage EIFS EPS 10cm	Passage EIFS EPS 10cm	Passage EIFS EPS 10cm
External wall ground floor	Maintenance	Maintenance	RDC curtain wall 14cm EPS	EIFS Aerogel 10cm	RDC curtain wall 14cm PUR	RDC curtain wall 14cm PUR
External wall penthouse	Maintenance	Maintenance	Ph. EIFS EPS 20cm	Ph. EIFS EPS 20cm	Ph. EIFS EPS 20cm	Ph. EIFS EPS 10cm
Ceiling passage	Maintenance	Maintenance	Passage EIFS EPS 10cm	Passage EIFS EPS 10cm	Passage EIFS EPS 10cm	Passage EIFS EPS 10cm
Windows front	Maintenace (PVC double glz.)	Maintenace (PVC double glz.)	PVC double glz. ins. layer	PVC double glz. ins. layer	PVC double glz. ins. layer	PVC triple glz. ins. layer
Windows yard	Maintenance (new PVC double glz.)	Maintenance (new PVC double glz.)	PVC double glz. ins. layer	PVC double glz. ins. layer	PVC double glz. ins. layer	PVC triple glz. ins. layer
Windows front balconies	Maintenance (new PVC double glz.)	Maintenance (new PVC double glz.)	Balc. PVC double glz. ins. layer	Balc. PVC double glz. ins. layer	Balc. PVC double glz. ins. layer	Balc. PVC triple glz. ins. layer
Ventilation	1.2: Exh.air	1.2: Exh.air	1.2: Exh.air	1.2: Exh.air	1.3: Exh. + supply air central	1.3: Exh. + supply air central
Heating + DHW	1.2: H: Cent. cond. boiler W:decent.elec.	1.2: H: Cent. cond. boiler W:decent.elec.	1.5: H: Cent. cond. boiler W:central + waste water	1.5: H: Cent. cond. boiler W:central + waste water	1.5: H: Cent. cond. boiler W:central + waste water	1.5: H: Cent. cond. boiler W:central + waste water
ICT	0,00%	0,00%	11,00%	11,00%	11,00%	11,00%

Results

The space heat demand is being reduced massively for all 6 scenarios, ranging from 50% for the maintenance scenario to up to 92% for variant 6. Variants 3 + 4 are already saving very much energy.



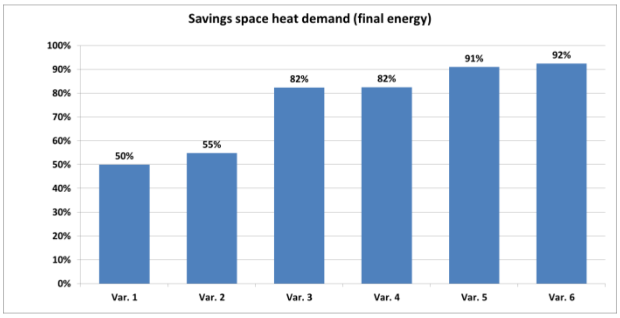


Figure 6 Space heat demands and space heat savings (final energy)

[3] Defect builders hardware and poor installation

Costs and savings for all scenarios

Highest investment costs are needed for the HVAC system. Figure 7 shows the investment costs for all building components. Scenario 1 serves as maintenance scenario. The difference between maintenance costs and investment costs of scenario 2 – 6 are additional costs for investment in energy saving measures.

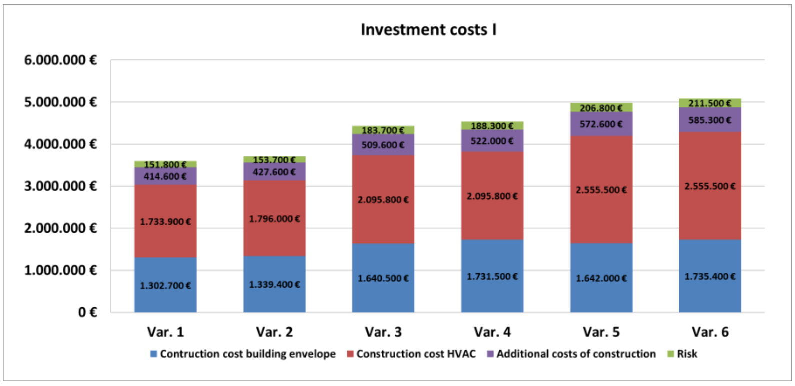


Figure 7 Investment costs

Sensitivity analysis for Life cycle costs

The life cycle costs of a building are the investment costs and operational costs (incl. energy and future maintenance) over its life time. As energy costs are dependent on market prices, this graph is showing different scenarios. Var.3 and Var. 4 are in the long term the most economic variants.

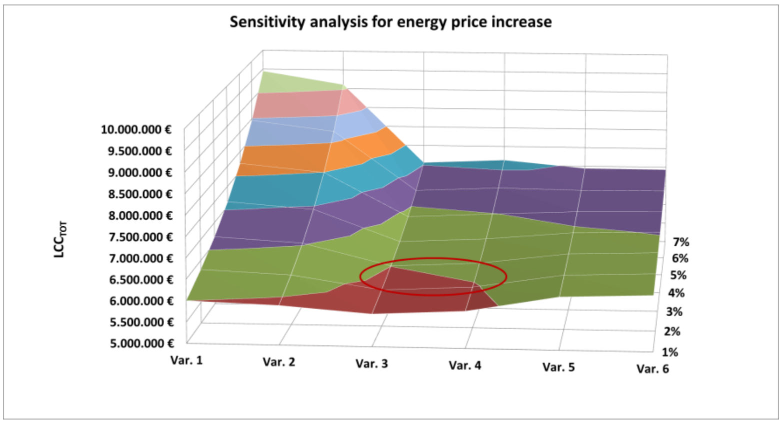


Figure 8 Scenarios for life cycle costs dependent on different energy price increases.

Eco efficiency

The six scenarios were assessed in different aspects regarding eco efficiency. Additionally to the assessment of total values, a trade-off assessment was carried out. It shows the Variants in the context of both, economic evaluation and eco efficiency. Variants 3 to 6 show good eco efficiency, with Var. 3 and 4 showing better economic results, and Var. 5 and 6 showing better eco efficiency.

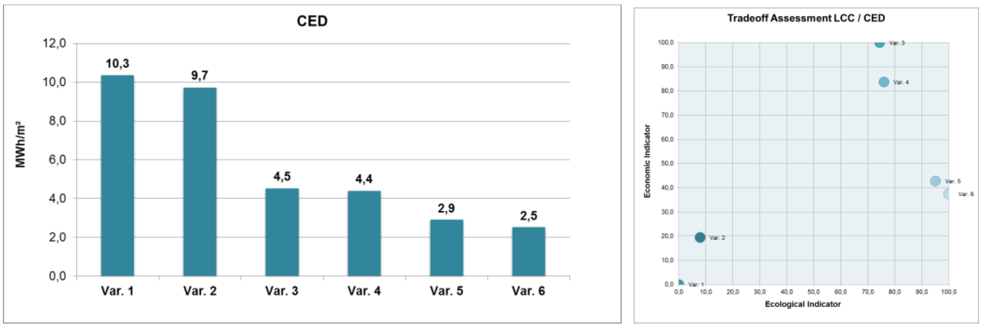


Figure 9 Cumulated energy demand for the six scenarios

Comfort

As measurable social indicators, the thermal comfort of the dwellings was assessed. Variants 3 to 6 show good results in terms of comfort.

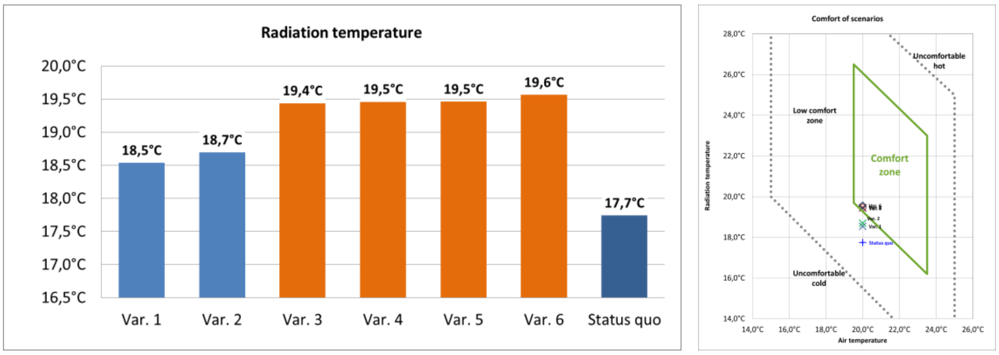


Figure 11 Temperatures in comparison and assessment of temperatures inside the building

Delft

Status quo analysis, General Information

The relevant building site is located in the north west of Delft. All buildings show specific similarities like brick facades, pitched roofs, porches, etc. Window reveals are relatively small.

Woonbron: Woonbron is one of the top 5 social housing groups in the Netherlands. Since 2006, Woonbron has its own sustainability policy. The main target is a reduction in CO_2 emissions of 3% a year. The association of Dutch housing associations has a target of 2% reduction on national gas yearly.

Three different building types exist (A, B, C).

Figure 12 Site plan – with in BEEM-UP involved Buildings, facades and floor plans of the 3 types

As a first step, all building components were evaluated and existing needs for maintenance and improvements were determined. Need for improvements are for the energy demand, maintenance and demands for functional improvements. The need for renovation of HVAC system and the existing windows of the building is one of the major starting points for the project development.

Six cost effective scenarios

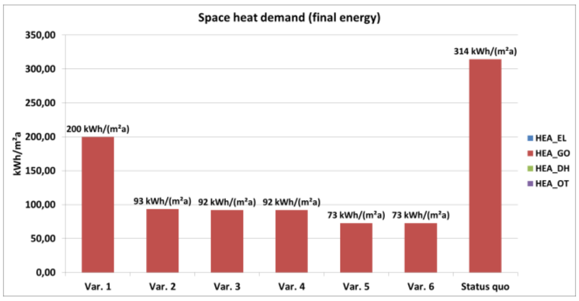
The variants were developed including all stakeholders and according to the common methodology.

Table 2 Detailed measures of all six scenarios

Variant Component	Var. 1 Maintenance	Var. 2 Improved envelope	Var. 3 Improved envelope+boiler	Var. 4 I. e.+boiler+solar	Var. 5 I. e.+boiler+floor	Var. 6 I. e.+boiler+fl.+solar
External wall	Maintenance (hydrophobation)	Maintenance (hydrophobation)	Maintenance (hydrophobation)	Maintenance (hydrophobation)	Maintenance (hydrophobation)	Maintenance (hydrophobation)
Loggia ceiling	Maintenance	Insulation +10cm EPS	Insulation +10cm EPS	Insulation +10cm EPS	Insulation +10cm EPS	Insulation +10cm EPS
Loggia floor	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance
Sus. floor	Maintenance	Maintenance	Maintenance	Maintenance	Reflective foil insulation	Reflective foil insulation
Ceiling entrance	Maintenance	10cm EPS	10cm EPS	10cm EPS	10cm EPS	10cm EPS
Roof	Maintenance	Insulation between rafters 120mm	Insulation between rafters 120mm	Insulation between rafters 120mm	Insulation between rafters 120mm	Insulation between rafters 120mm
Dividing wall	Status quo	Status quo	Status quo	Status quo	Status quo	Status quo
Dormer Wall	Sandwich construction 100mm EPS	Sandwich construction 100mm EPS	Sandwich construction 100mm EPS	Sandwich construction 100mm EPS	Sandwich construction 100mm EPS	Sandwich construction 100mm EPS
Dormer roof	Sandwich construction 150mm EPS	Sandwich construction 150mm EPS	Sandwich construction 150mm EPS	Sandwich construction 150mm EPS	Sandwich construction 150mm EPS	Sandwich construction 150mm EPS
Win. type 1 ori. wood / single glz.	Wood frame with HR ++ glass for type 1	Wood frame with HR ++ glass for type 1	Wood frame with HR ++ glass for type 1	Wood frame with HR ++ glass for type 1	Wood frame with HR ++ glass for type 1	Wood frame with HR ++ glass for type 1
Windows Type 2 later alu frames single glazing	Wood frame with HR ++ glass for type 2	Wood frame with HR ++ glass for type 2	Wood frame with HR ++ glass for type 2	Wood frame with HR ++ glass for type 2	Wood frame with HR ++ glass for type 2	Wood frame with HR ++ glass for type 2
Windows Type 3 later alu frames double glazing	Wood frame with HR ++ glass for type 3	Wood frame with HR ++ glass for type 3	Wood frame with HR ++ glass for type 3	Wood frame with HR ++ glass for type 3	Wood frame with HR ++ glass for type 3	Wood frame with HR ++ glass for type 3
Ventilation	1.2: Maintenance: window ventilation	1.2: Maintenance: window ventilation	1.2: Maintenance: window ventilation	1.2: Maintenance: window ventilation	1.2: Maintenance: window ventilation	1.2: Maintenance: window ventilation
Heating + DHW	1.2: Maintenance existing boiler	1.2: Maintenance existing boiler	1.3: Condensing boiler	1.4: Condensing boiler + solar	1.3: Condensing boiler	1.4: Condensing boiler + solar
ICT	0,00%	15,00%	15,00%	15,00%	15,00%	15,00%

Results

The space heat demand is being reduced massively for all 6 scenarios, ranging from 36% for the maintenance scenario to up to 77% for variant 6.



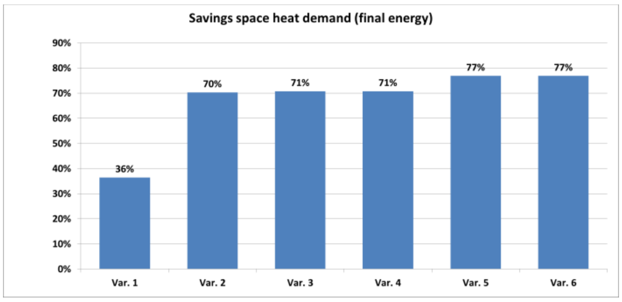


Figure 13 Space heat demands and space heat savings (final energy)

Costs and savings for all scenarios

The largest share of the investment costs are needed for the building envelope. The chart below shows the investment costs for all building components (including additional costs). Scenario 1 serves as maintenance scenario. The difference between maintenance costs and investment costs of scenario 2 – 6 are additional costs for investment in energy saving measures.

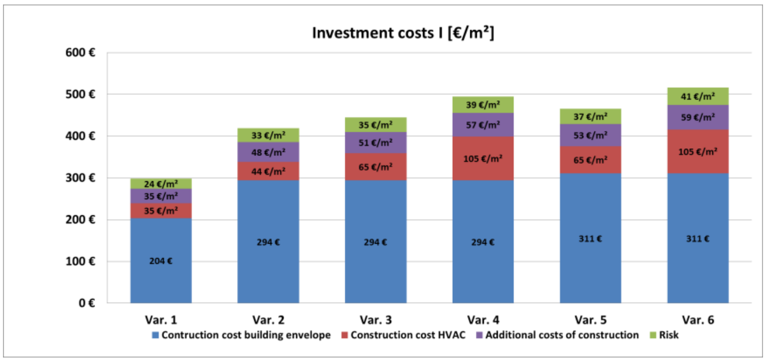


Figure 14 Investment costs

Sensitivity analysis for Life cycle costs

The life cycle costs of a building are the investment costs and operational costs (incl. energy and future maintenance) over its life time. As energy costs are dependent on market prices, this graph is showing different scenarios. Here, all variants except the maintenance scenario (Var.1) are nearly equally economic. The focus can be on other factors like social or environmental factors.

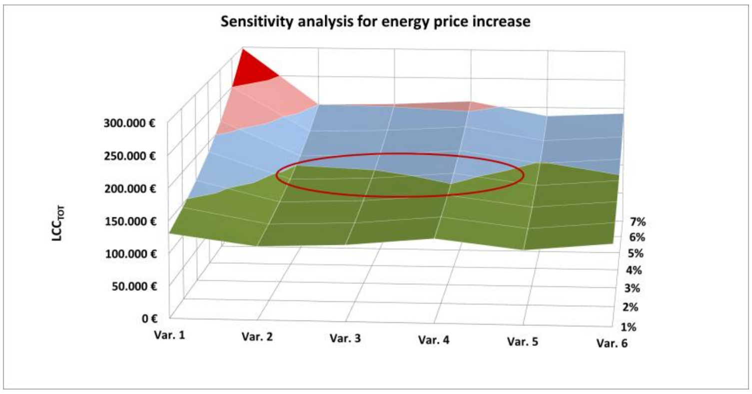


Figure 15 Scenarios for life cycle costs dependent on different energy price increases.

Eco Efficiency

The six scenarios were assessed in different aspects regarding eco efficiency. Additionally to the assessment of total values, a trade-off assessment was carried out. It shows the Variants in the context of both, economic evaluation and eco efficiency.

Variants 2 to 6 show good eco efficiency, with Var. 5 showing best results in both, economic evaluation and eco efficiency.

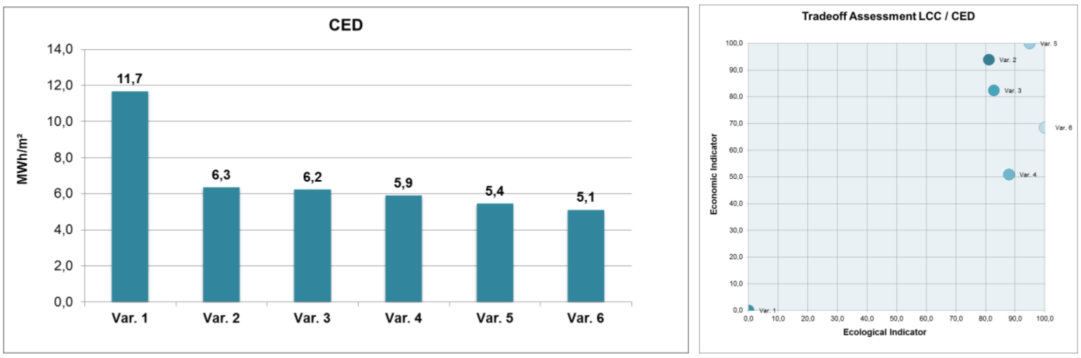


Figure 16 Cumulated energy demand for the six scenarios

Comfort

As measurable social indicators, the thermal comfort of the dwellings was assessed. As the possibilities for wall insulation were limited due to the wall construction method, all Variants are showing results that are only in the low comfort zone, but still in comparison to the current status quo of the building, all variants are increasing internal comfort massively. Variants 2 to 6 show well acceptable results.

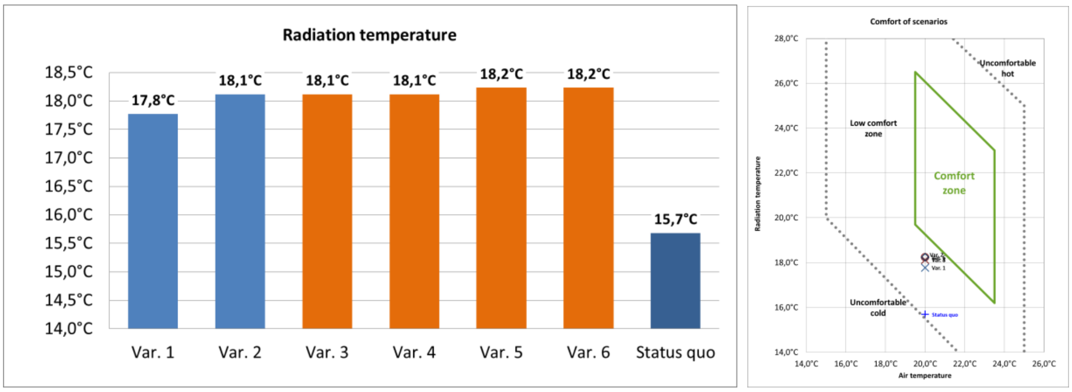


Figure 17 Temperatures in comparison and assessment of temperatures inside the building

Brogården

Status quo analysis, General Information

The Buildings were built in 1973 as part of the Million Homes Program in Sweden. The area comprises a total of 300 flats, divided into 16 building with 2-4 floors. Each flat has a balcony or patio.

The buildings show several defects with a need for maintenance and refurbishment. Therefore a retrofitting concept was carried out. The general concept started with discriminating specific qualities and defects of the involved building stock and general requirements were set.

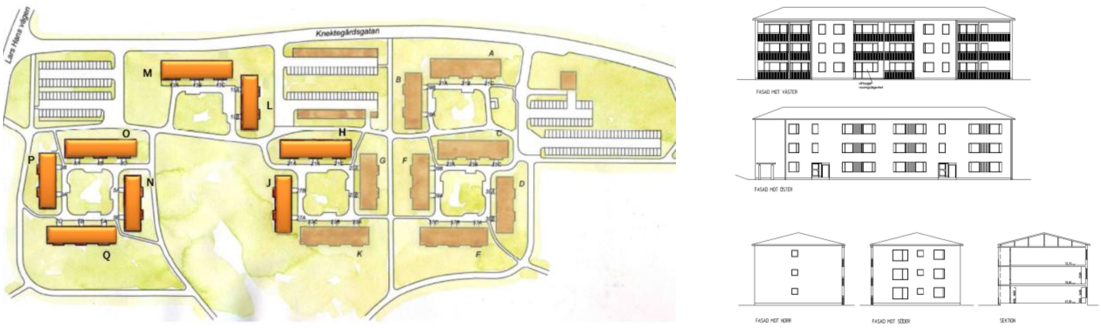


Figure 18site plan – with in BEEM-UP involved buildings, elevations

As a first step, all building components were evaluated and existing needs for maintenance and improvements were determined. Need for improvements are for the energy demand, maintenance and demands for functional improvements. The need for renovation of the Brick facades of the building was one of the major starting points for the project development.

Maintenance costs for the damaged brick façade are difficult to estimate. Many aspects need to be clarified[4] (moisture of the brick leaf, remaining load capacity of the façade, condition of the internal insulation, mould)

Within the decision making process, related risks need to be evaluated and have to be taken into account.

Six cost effective scenarios

For all scenarios the building envelope is highly optimized. This leads to a low annual heat demand and reduced load. Investment costs for the HVAC system can be reduced drastically.

Table 3 Detailed measures of all six scenarios

Variant Component	Var. 1 Maintenance	Var. 2 Improve	Var. 3 Pilot	Var. 4 Alternative pilot	Var. 5 Pilot + grey water	Var. 6 Pilot + photovoltaic
External wall	Maintenance	EIFS: add. insul., no demolition	Pilot: Lightweight constr. wall MW	Alternative pilote: Wall constr. with EPS core	Pilot: Lightweight constr. wall MW	Pilot: Lightweight constr. wall MW
External wall concrete	Maintenance	EFIS (add. insul., partial demol.)	Pilot: attached façade (add. ins., partial demol.)	Pilot: attached façade (add. ins., partial demol.)	Pilot: attached façade (add. ins., partial demol.)	Pilot: attached façade (add. ins., partial demol.)
Roof	Status quo	Status quo	Status quo	Status quo	Status quo	Status quo
Upper ceiling	Maintenance	Insulation on upper ceiling EPS 300mm	Pilot: 2 layer mineral wool	Pilot: 2 layer mineral wool	Pilot: 2 layer mineral wool	Pilot: 2 layer mineral wool
Floor slab common spaces	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance
Floor slab appartments	Maintenance	Pilot B: PIR on floor slab	Pilot B: PIR on floor slab	Pilot B: PIR on floor slab	Pilot B: PIR on floor slab	Pilot B: PIR on floor slab
External wall perimeter	Maintenance	Pilot: perimeter insulation XPS	Pilot: perimeter insulation XPS	Pilot: perimeter insulation XPS	Pilot: perimeter insulation XPS	Pilot: perimeter insulation XPS
Ceiling cellar	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance
Windows	Maintenance	Pilot: triple glazing	Pilot: triple glazing	Pilot: triple glazing	Pilot: triple glazing	Pilot: triple glazing
Doors	Maintenance	New door	New door	New door	New door	New door
Ventilation	1.3: Maintenance: exhaust air system	1.2: Pilot: Central vent. + heat rec.	1.2: Pilot: Central vent. + heat rec.	1.2: Pilot: Central vent. + heat rec.	1.2: Pilot: Central vent. + heat rec.	1.2: Pilot: Central vent. + heat rec.
Heating + DHW	1.4: Maintenance: District heat +cent. DHW (normal heat load)	1.4: Maintenance: District heat +cent. DHW (normal heat load)	1.2: Pilot: district heat and central DHW	1.2: Pilot: district heat and central DHW	1.6: Pilote: 1.2 + Greywater	1.3: Pilote: 1.2 + PV
ICT	0,00%	15,00%	15,00%	15,00%	15,00%	15,00%

[4] Very important questions for further detailing crucial

Results

The space heat demand is being reduced massively for all 6 scenarios, ranging from 41% for the maintenance scenario to up to 89% for variant 6.

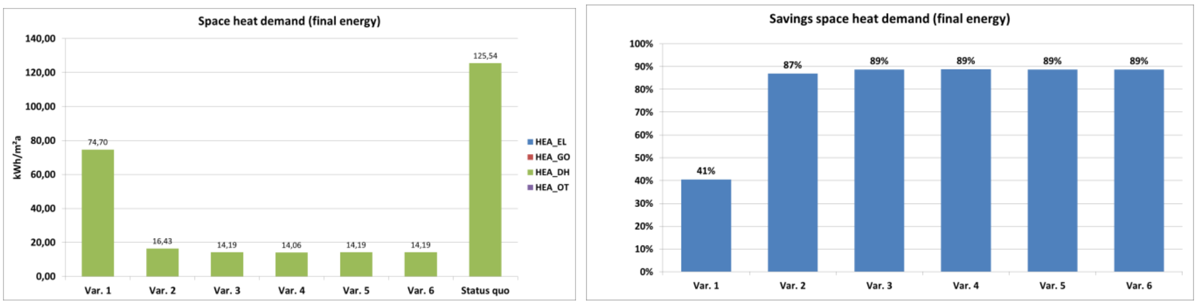


Figure 19 Space heat demands and space heat savings (final energy)

Costs and savings for all scenarios

Highest investment costs are needed for the building envelope. Figure 20 shows the investment costs for all building components. Scenario 1 serves as maintenance scenario. The difference between maintenance costs and investment costs of scenario 2 – 6 are additional costs for investment in energy saving measures.

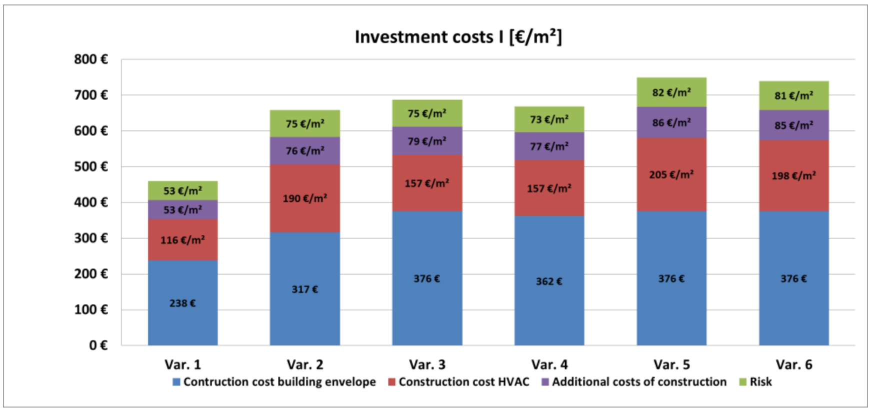


Figure 20 Investment costs

Sensitivity analysis for Life cycle costs

The life cycle costs of a building are the investment costs and operational costs (incl. energy and future maintenance) over its life time. As energy costs are dependent on market prices, this graph is showing different scenarios. Var.3 and Var. 4 are in the long term the most economic variants for various energy price developments.

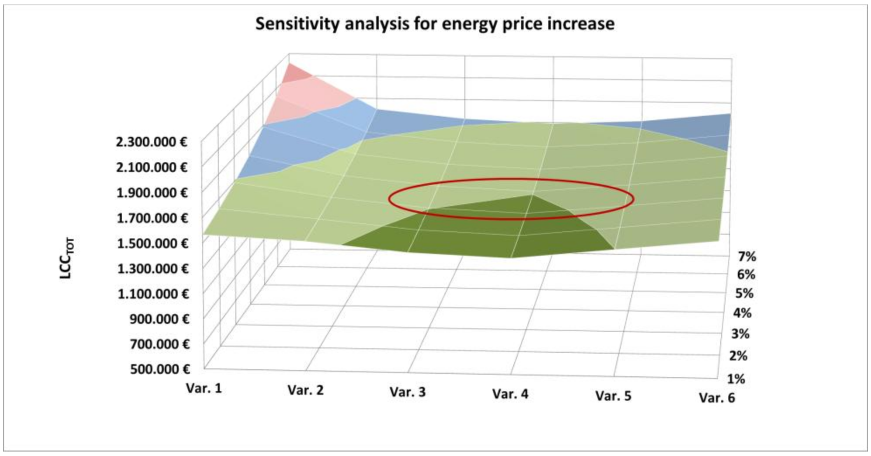


Figure 21 Scenarios for life cycle costs dependent on different energy price increases.

Eco efficiency

The six scenarios were assessed in different aspects regarding eco efficiency. Additionally to the assessment of total values, a trade-off assessment was carried out. It shows the Variants in the context of both, economic evaluation and eco efficiency.

It was not possible to assess Variant 6 in all aspects, so it was taken out of the assessment.

All variants except the maintenance scenario show good results in eco efficiency with variants 3 and 4 being the most economic ones.

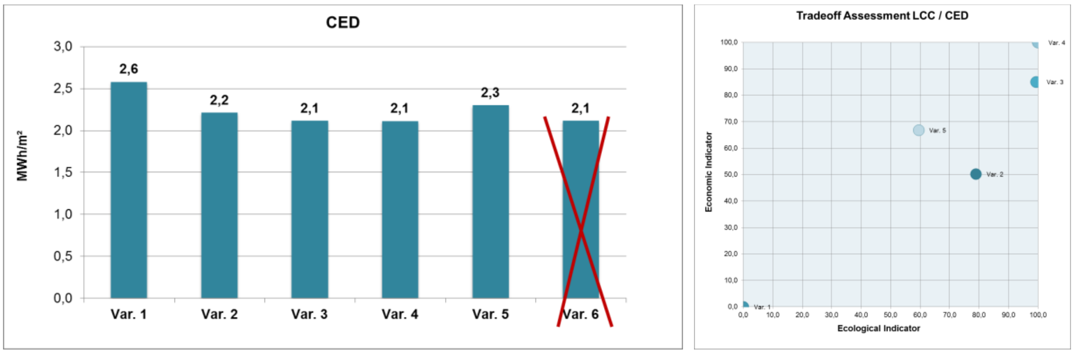


Figure 22 Cumulated energy demand for the six scenarios

Comfort

As measurable social indicators, the thermal comfort of the dwellings was assessed. All Variants and even the status quo show temperatures well in the comfort zone. Only for air temperatures below 20°C the status quo may result in lower comfort.

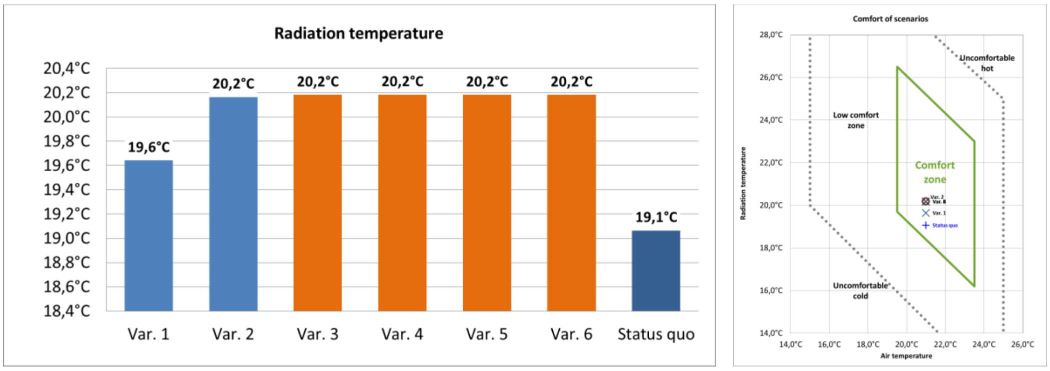


Figure 23 Temperatures in comparison and assessment of temperatures inside the building

List of references:

[Janson, 2010]   Janson, Passive houses in Sweden (2010)