Analysis of the most optimal technical solutions – BEEM-UP toolkit

Process and Methodology

A specific focus of the BEEM-UP project is the development of a methodology to find and implement the most effective modernization concepts.

To find the most important applicable indicators for the refurbishment projects, the spectrum of existing Key Performance Indicators (KPI) of the labelling systems DGNB, LEED and BREEAM (ecologic, economic and socio-cultural aspects) were discussed in several workshops. These were then evaluated by the housing companies and other stakeholders against the background of different professional or national specializations and adapted to the project requirements.
The indicators were then included in a BEEM-UP toolkit which was especially developed for holistically assessing and comparing refurbishment projects in different countries and climate zones. It takes following aspects into account:

- Environmental aspects (Energy demand, emissions, grey energy, impact on nature)
- Economic balances (Life cycle costs - including cost for energy, investment, current and future maintenance, etc.)
- Social aspects (Summer / Winter Comfort and tenant involvement feedback)

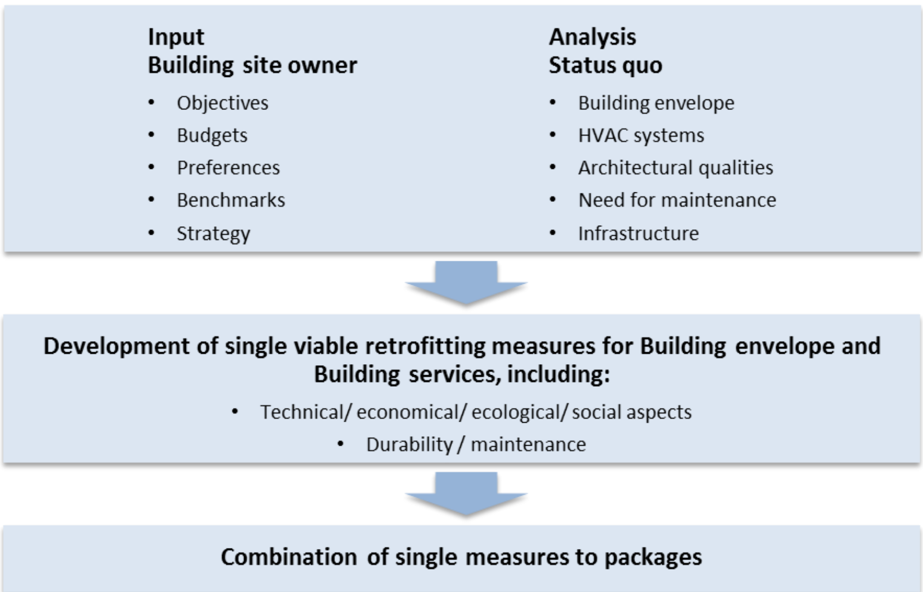

Figure 1 Process of variants development

The first step of the applied procedure is an analysis of the building status quo and clarification of general requirements given by the housing company. In step two, single measures are developed and evaluated with the BEEM-UP toolkit, which gives indications of their impacts in terms of economy, ecology and comfort. The single measures need to be compiled to complete retrofitting scenarios. Scenario 1 is always the "anyway" or maintenance scenario. The maintenance scenario is important for an economical comparison

and feeds in KPIs like cost of saved energy and other and represents the package of measures with the lowest investment costs.
Compiling single measures has to be done very carefully. Especially the inter-dependences between the thermal envelope and the HVAC system needed special attention. As an improved thermal envelope reduces the heat load of the building, the HVAC systems need to take this into account.

The BEEM-UP toolkit is evaluating the performance of a large number of possible refurbishment concepts (up to 10 000) by assessing their environmental and economic performance from a lifetime perspective (production, construction, operation and maintenance during 40 years of lifetime). This automated process leads to optimized results.

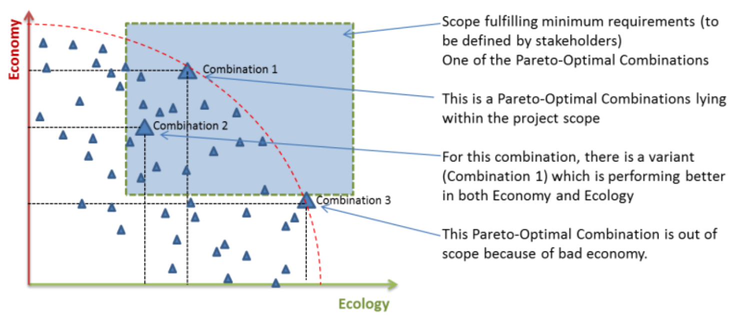

Figure 2 Performance of different concepts according to ecological and economic indicators, evaluation of comfort for selected concepts. Identifying pareto-optimal solutions for the sites by the combination of possible single measures, helps to exclude concepts that are less efficient than others. (Source: Luwoge consult)

To visualize a large number of scenarios in order to improve the comprehension of the complexity of the building and the interdependence of different measures on economical, ecological and social sustainability can give the building owner a good basis of decision.

To tackle specific problems in refurbishment projects, the construction sites were assessed for innovation potential (Wall, roof and ceiling situations were specially addressed). In different workshops, architects, engineers, site owners, designers and craftsmen developed innovative ideas. The most promising improvements were then built and tested and then evaluated using the BEEM-UP toolkit. Where outperforming the standard practice, detailed construction guidance was developed for the actual building sites.

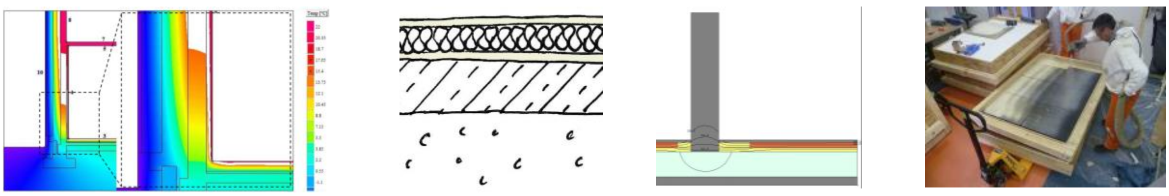

Figure 3 Process of developing innovative system solutions (problem detecting, idea, evaluation, testing)
Depending on technology readiness levels, costs and applicability to the actual situations these then could be implemented into the pilot sites.

Results for the 3 pilot sites (showing examples of how the methodology was applied)

The methodology developed helped to find the most appropriate solutions for all building sites. By offering multiple optimized variants, the refurbishment concepts go beyond standard practice. The general goal of reducing the energy demand by 75% was defining a threshold for all building sites and lead to eco-efficient refurbishment scenarios. For each building site, six cost-efficient variants were then assessed and compared in detail to show a variety of solutions (including maintenance only).

Paris

In Paris six cost-effective variants showed a huge potential for energy savings.

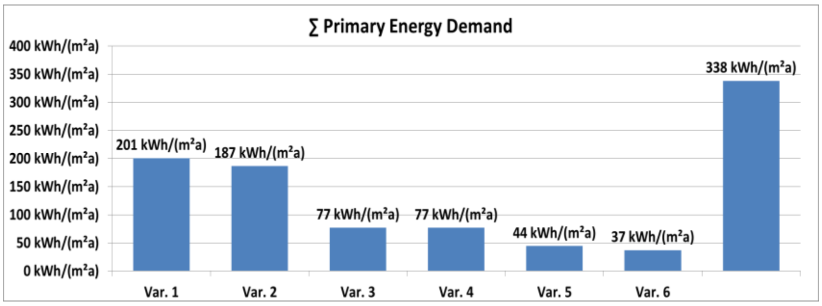

Figure 4 Assessment of the primary energy demand of the different variants and the Status quo (last column)
Variant 1 is the maintenance scenario which contents measures that have to be done because of system failure or legislation, followed by the variants with increasing energy performance.

As the overall project goals were to save at least 75% of energy, variants 3 to 6 were taken into consideration and taking into account economic aspects.

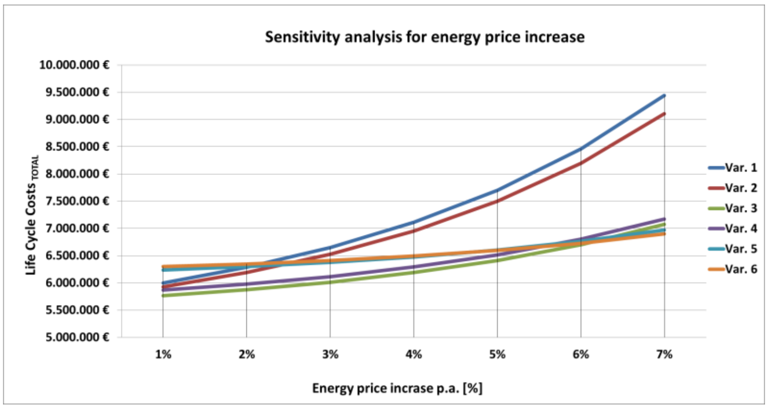

Figure 5 The sensitivity analysis is showing the Life Cycle Costs of the variants taking into account different energy price increase rates (excl. inflation). For all scenarios with energy price increases under 6%, Variant 3 is the most economic variant. Variant 1 (the maintenance scenario) is the least economic variant for energy price increases of over 2.2%.
The Pareto-Optimization showed very similar results for the variants.

From the graphic above, variant 3 was chosen by the housing company. For Paris, several of the innovative solutions were interesting, amongst other, the space saving Aerogel insulation was implemented as well as a grey water heat recovery system and an ICT feedback solution for tenant involvement.

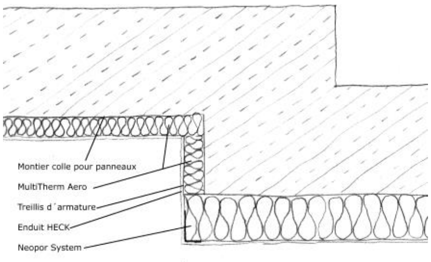

Figure 6+7 By installing an ultra-thin Aerogel insulation EIFS, the depths of the balconies will still allow to actually use the balconies with minimal loss of space. The system is the first of this kind to be installed in France.

Overall, the best performance could be achieved by assessing all relevant Key Performance Indicators, offering a wide range of possible solutions and setting preferences for this site.

Brogården

Six cost-effective feasible variants show a huge energy demand reduction potential for the refurbishment project, with Var.1 being the maintenance scenario enabling the lowest savings.

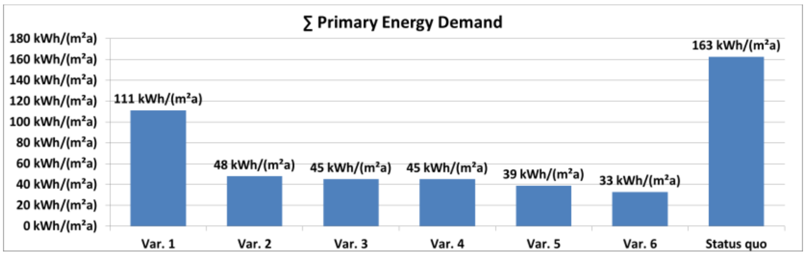

Figure 8 The primary energy demand is showing huge saving potentials especially for the variants 2 to 6. Considering economic, ecologic and social aspects of all variants, Variant 4 was chosen by the housing company.

A special focus was laid on the social indicators like room comfort, accessibility and dwelling usability as the housing company´s main goal was to improve quality of life of their tenants. Therefore intense tenant involvement activities were going on like active groups or the possibility to use of the showroom apartment as a communal space.

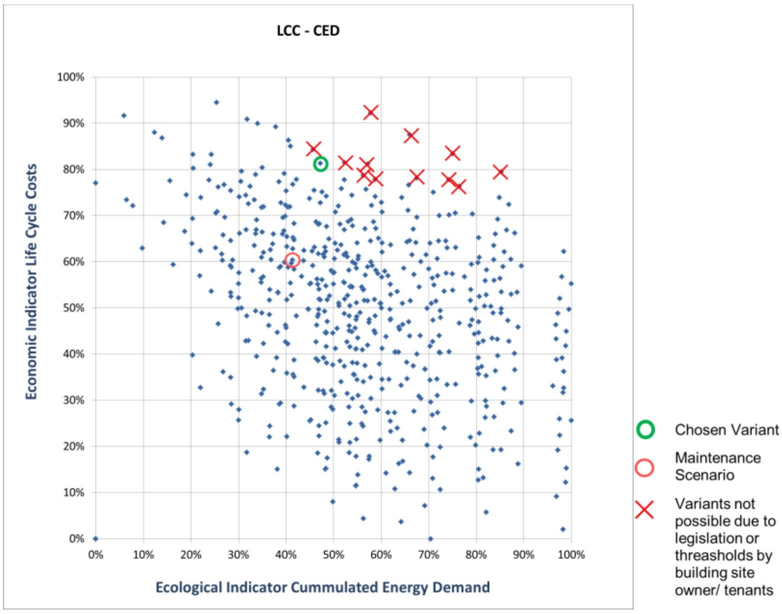

Figure 9 Pareto-Optimization of a wide range of possible variant. At the axes 100% are always marking the best possible result for the Life Cycle Costs respectively Cumulated Energy Demand.
The chosen variant was only theoretically outperformed in both by variants that were not possible because of legislation. As the tenant involvement was a crucial part for the Brogarden building site development, also indoor environment and comfort were important topics for which at an earlier stage thresholds were developed. This was done in close cooperation between the building site owner, the construction company, the tenants, the planers and evaluators.

The wide range of possible solutions and their visualisation helped the refurbishment team in Brogarden to find the best fitting solutions having in mind also all of their former set KPIs and individual refurbishment goals.

In terms of innovations, prefabricated wall elements with grey EPS cores were developed and implemented to guarantee best Life Cycle Costs and Eco Efficiency as well as room comfort. Amongst others, as well an ultra-thin flooring system and an ICT solution were constructed.

Delft

For Delft six of the most economic scenarios (Var. 1 is the maintenance scenario) were evaluated in detail and presented to the tenants.

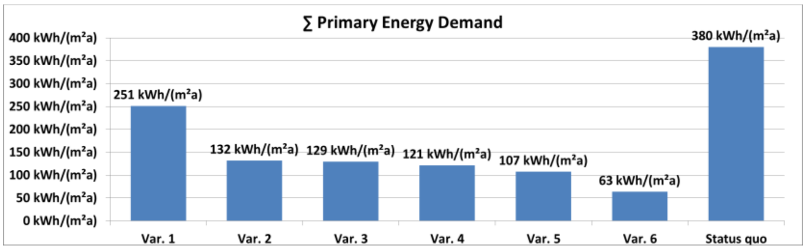

Figure x Although the energy savings of the different variants are very different, they are all economically viable. The chosen approach of advanced tenant involvement is emphasizing especially the social aspects of refurbishment.

The housing company described the measures and involved costs comprehensively to their tenants. Then these decided which measures they want to have for their dwellings. Therefore, except of the maintenance variants, all developed variants for the buildings are performing well in terms of economy as only these variants would be chosen by the tenants.

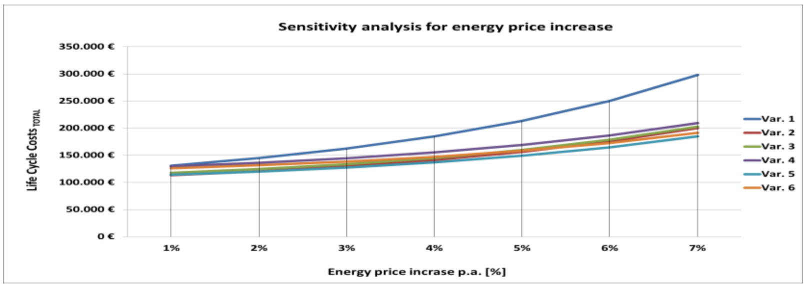

Figure x All of the combined variants are outperforming the maintenance scenario for the buildings for all energy price increase scenarios. The maintenance scenario is the minimum solution to be done (because of system/element failure or because of regulations).

As the tenants were responsible for the chosen refurbishment concept, a wide range of possible combinations was realized.

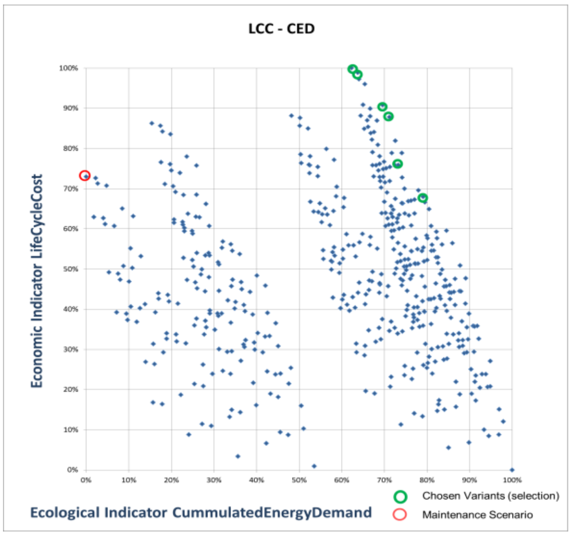

Figure x The proposed variants are all situated at the Pareto-optimal zone of the graph. The tenants can therefore decide where they put their own preferences (economic or ecologic). Additionally, they can take into account social indicators like construction time for the measures or room comfort after installation. It is also possible to decide step by step for the single measures – depending on experiences of neighbours.

In many of the buildings an ICT feedback system has been installed to help the tenants save energy. The experience with this is so far very good. Most of the building envelope innovations developed for the Delft buildings´ problems are not yet at a technology readiness level to be implemented immediately. However, as a step by step approach is considered, the innovations may be implemented at a later time when they are ready for the market.

How can the methodology be used for other projects

Focussing on the most important indicators helped to find overall environmental friendly and cost-efficient solutions which were also performing well in terms of socio-cultural aspects. It resulted important to take into account long term implications of different retrofitting alternatives. A practical assessment tool helped to make decisions within three main sustainability dimensions (social, economic and environmental), provided transparency for the decision makers (housing companies, etc.) and helped them to set preferences.

While most refurbishment projects still focus on investment costs only, it became clear that Life Cycle Cost considerations should become more important. Therefore, in many countries the legislation needs alternations as it is often not possible for investors to cover additional upfront costs for energy-efficient solutions through the resulting energy savings, which the tenants cash in. Alternative rent concepts (i.e. warm rent models) or Energy Performance Contracting may help to solve this issue as well as absolute transparency of future maintenance and energy costs for tenants (when searching a dwelling).

As considerations to eco-efficiency will probably rise in importance during the years to come, it makes sense to include indicators of grey energy and impacts on the environment into the assessment. For almost all of the refurbishment materials it was proven with the calculations that these are saving far more energy during their useful life than was needed to produce them. EPDs help to compare products and can give first indications about their eco-efficiency.

Of the socio-cultural aspects not all indicators are measurable (i.e. accessibility, construction traditions...). However, including a (simplified operative temperatures) winter comfort calculations into the energy performance calculations is an easy way to find out which measures offer a healthy indoor environment. The temperatures of the surfaces should not differ more than 3-5 K from the indoor temperature. Then, the risks of draft (through convection) and of condensation is minimised. Also the overheating frequency can be calculated and compared for different variants.