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HOLISTIC STRATEGIES FOR THE RETROFIT TO ACHIEVE ENERGY-EFFICIENT RESIDENTIAL BUILDINGS

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ABSTRACT

Today`s challenge in the retrofitting sector is the realization of building retrofits that considers a holistic approach under the pressure of cost-optimization and energy-efficiency goals.

The paper presents experiences of energy-efficient retrofit with highly industrialised renovation methods, which have been investigated and analysed at the demo projects realized in the FP7 project E2ReBuild `Industrial Energy Efficient Retrofitting of Resident Buildings in Cold Climates` (www.e2rebuild.com). A bottom-up methodology provided an insight in the development and decision-making of the retrofit strategies during planning and realization. The analysis was divided into an ecological, an economic and a social part. While the ecological part focused on the reduction of delivered and primary energy demand, the economic part showed the owners' approach on investment, rent increases and the expected further component and service life of renewed parts. The social part highlighted the owners' efforts to keep the residents' expenses for rent and energy low and to improve the living quality of the apartments and the entire surrounding area. Each demo project was characterized by different objectives and motivations, but all of them aimed at increasing the energy-efficiency.

Keywords: Energy-efficiency; Retrofit strategies; Residential Buildings; Demo Projects;

1 INTRODUCTION

Today`s challenge in the retrofitting sector is the realization of building retrofits that consider ecological and social aspects under the pressure of cost-optimization and climate policy goals. The design and implementation of strategies is determined by limited room for manoeuvring in terms of investment and the pressure to save energy. The residents as users are rarely integrated in the decision process, the options for improvements are hardly ever considered and the potential of added values at the same costs is most likely not used. Hence, the research on «Holistic Strategies for Retrofit» of the E2ReBuild Workpackage «Innovation in Planning and Design» aimed at providing new decision criteria away from the traditional paths. It focused on creating an in-depth understanding of the requirements for successful retrofitting that ensured energy-efficiency and high user acceptance.

1.1. Methodology

The seven E2ReBuild demo projects realized in different European countries were taken in order to analyse the applied retrofit strategies. Additionally the results of the previous evaluation of the *Collaboration Models* [2] were included. Following a bottom-up methodology, each demo project was evaluated according to its economic, ecological and social sub-strategy. Relevant key facts and figures were collected in questionnaires by demo project contact persons. Know-how and experience were exchanged and discussed in interviews, roundtables, site-visits, face-to-face and web meetings with actors and stakeholders. This information provided an in-depth understanding of the respective retrofitting «reality».

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1.2. Definitions

The definition of *Holistic strategies* applies the idea of *holism* to *strategic* actions for building retrofit. *Holistic* refers to the ancient Greek term *holos (whole)*[2] that provides the basis for its understanding as a comprehensive approach and does not only address the integration of a variety of (cross-sectorial) disciplines in construction processes. Moreover, it is an attitude to understand and to coordinate complex processes across different disciplines without separating them into isolated parts.

A *Strategy* (ancient Greek *strategōs* composed by *stratos* «army» and *ago* «leading»)[3] addresses the design of long-sighted and target-oriented action chains: *«A Strategy is a long term plan of action designed to achieve a particular goal, most often `winning`. A Strategy is differentiated from tactics or immediate actions with resources at hand by its nature of being extensively premeditated, and often practically rehearsed. Strategies are used to make the problem easier to understand and solve.»*[2]

2 APPLIED STRATEGIES

The analysis of the E2ReBuild demo projects provided different approaches in view of holistic strategies in building retrofit. It is not to judge whether one or the other was better. It is to understand the complex nature of how strategies were designed and how decisions were made.

2.1. Economic strategies

The analysis of the economic strategies showed, that despite the experimental character, financial limitations dominated the design of the retrofit strategies. Particularly, in projects with strong social housing affiliation (Voiron, Halmstad[4], Roosendaal and London) the retrofit strategies were strongly «designed to costs», considering reasonable rent increases and avoiding changes in the residents' structure through increased retrofit.

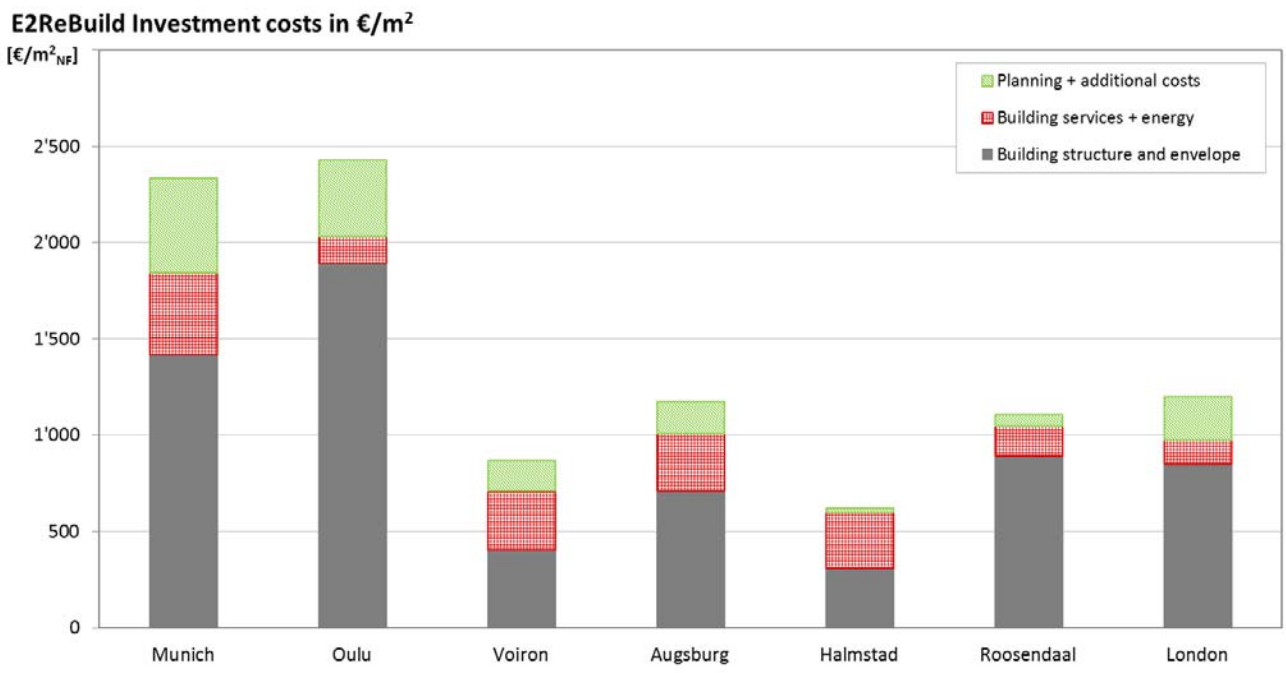


Figure 1. Investment costs in € per m^2 (rentable) net floor area. Source: E2ReBuild.

Limited budgets and limited options for rent increase presented good arguments for shortcuts in the retrofit strategy. Either measures inside the apartments (renewal of kitchens, bathrooms, etc.) or

2 www.de.wikipedia.org/wiki/Holismus; Download 19.02.2013; 17:41.

3 www.websters-online-dictionary.org/definitions/strategy#Wikipedia; Download 19.02.2013; 17:28.

4 The term «social housing» does not exist in Sweden. But the situation at the demo building in Halmstad was comparable with social housing conditions in the other countries.

on the outside (new envelope, exchange of windows) could not be realized, or the applied retrofit technology had to be changed entirely (Voiron).

2.1.1. Economic analysis

In the analysis of the economic strategy a detailed cost break down was carried out by a current standard asset oriented methodology. Thereby the costs for measures were structured into the categories:

- **Maintenance:** Measures to maintain the should-be-state or to repair weaknesses and damages in order to recover the should-be-state.
- **Energy improvements:** Measures to improve the energy performance of the building (improvement of the envelope, new and efficient building service systems, etc.)
- **Modernization:** Measures to improve the should-be-state which were not energy related (new kitchen, bathroom, barrier-free access, improved access, etc.)

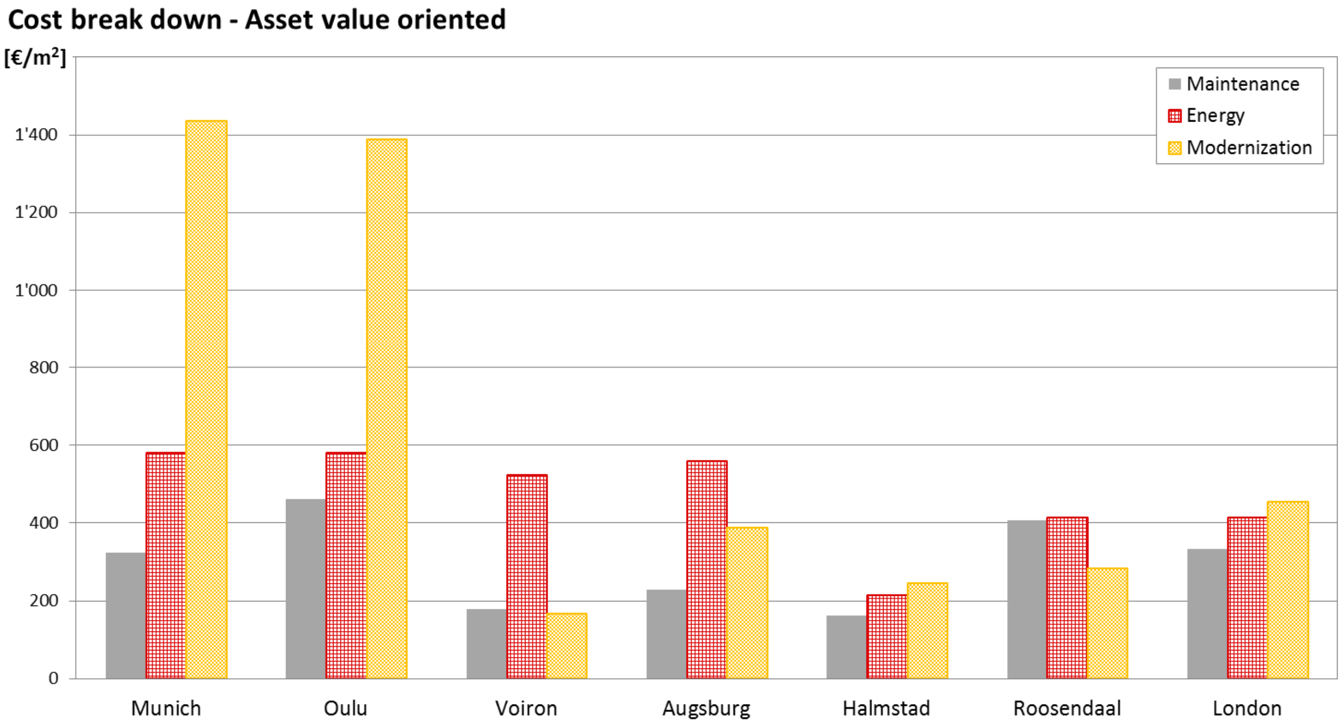


Figure 2. Cost break down asset value oriented structured according to the categories «Maintenance – Energy – Modernization». Incl. relevant VAT. Source: E2ReBuild.

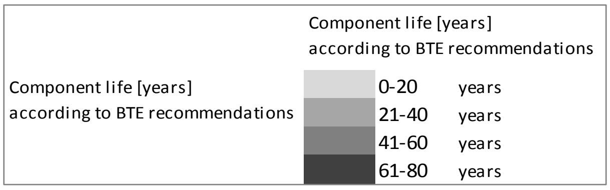
2.1.2. In-depth evaluation of the economic decision basis and findings

Most likely the decisions were based on simple amortization calculations. Within these traditionally applied cost break down methods (Figure 2) that focused on mere technical or constructive renovation aspects, the impact on sustainability or gained added values could not be identified.

Therefore a new cost break down approach was discussed: The main issue was to evaluate the investment costs according to their contribution to sustainability as a stable long-term added value. In this approach the costs for measures were structured into the categories:

- **Building**: Measures to maintain the functionality and usability of the building, e.g.: conversion of floor plan layout, access routes, public areas and renewal of kitchen, bathroom and internal fabrics (tiles, flooring, doors).
- **Envelope**: Measures to improve the thermal building envelope (e.g. prefabricated elements, insulation), windows, shutters, sun shading devices, cladding and balconies.
- **Services**: Measures related to HVAC systems; power supply, plumbing, security, fire protection systems, lighting, elevators and lifts, etc.

In addition, the component life time of the retrofitted parts and components was identified according to the *BTE* recommendations[5]. The figures for all major components were aggregated in bars showing the further component life in years with different grey levels (see legend on the right side). Figure 3 - 5 show the (retrofitting) investment costs in the categories «Building», «Envelope» and «Services» compared to the further component life time achieved by this respective retrofitting investment.



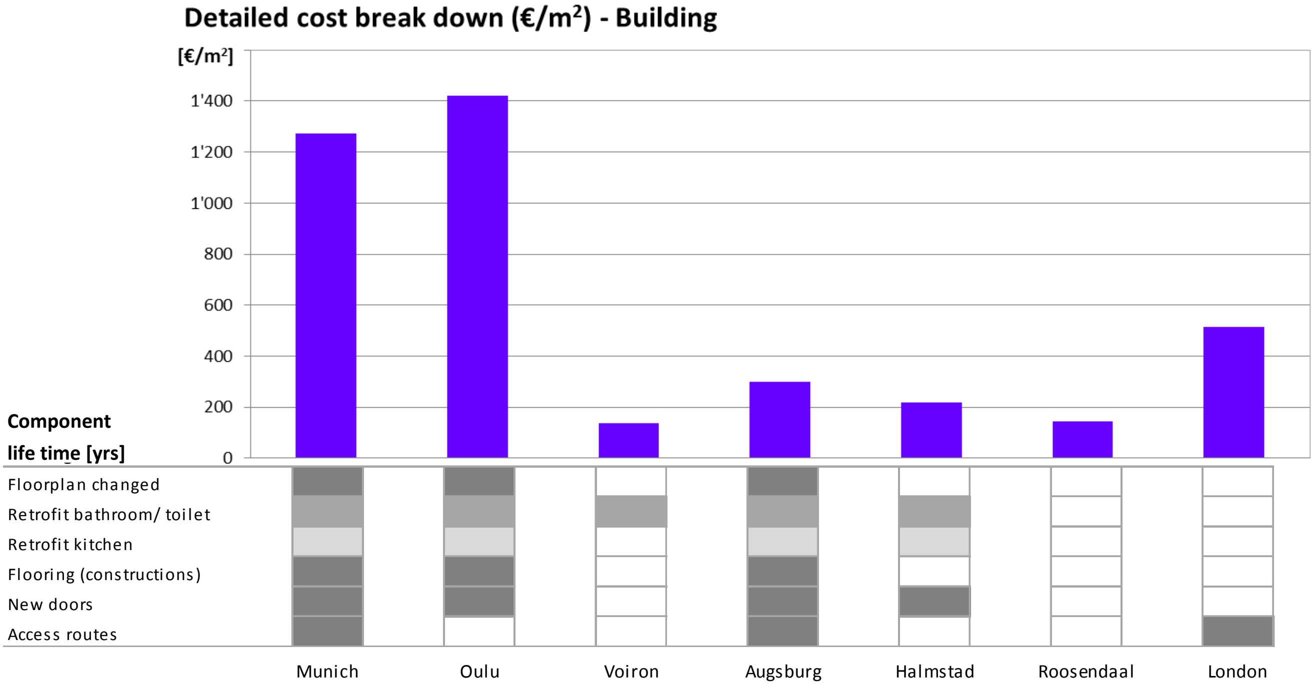
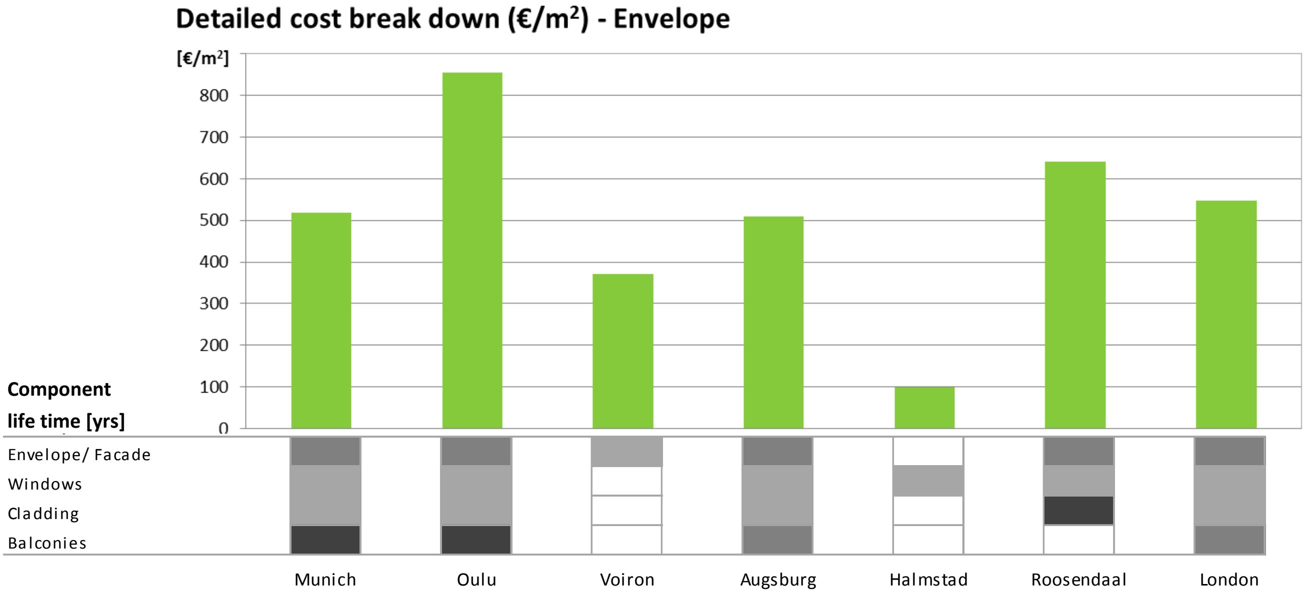


Figure 3. Investment costs for the category «Building» compared to the further component life after the retrofit. Source: E2ReBuild.



5 Recommendations of the German Experts`s Association «BTE». This source provides not only an isolated expectation; moreover it gives an overview on expectations of various sources for service life. [3]

Figure 4. Investment costs for the category «Envelope» compared to the further component life after the retrofit. Source: E2ReBuild.

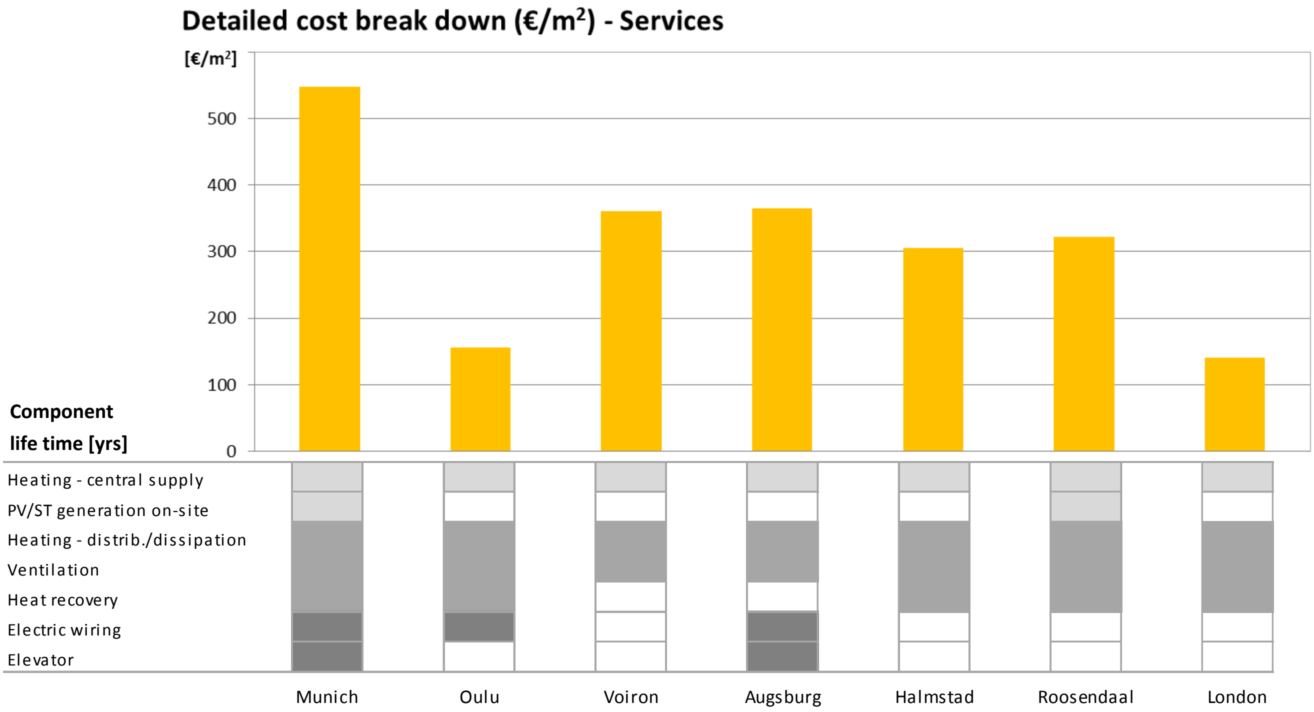


Figure 5. Investment costs for the category «Services» compared to the further component life after the retrofit. Source: E2ReBuild.

This in-depth evaluation (Figure 3 - 5) showed that investments for measures in the «Building» itself or the «Envelope» supported three times higher further component life times (0/20 yrs.→ 41-60 yrs.) than measures in «Services».

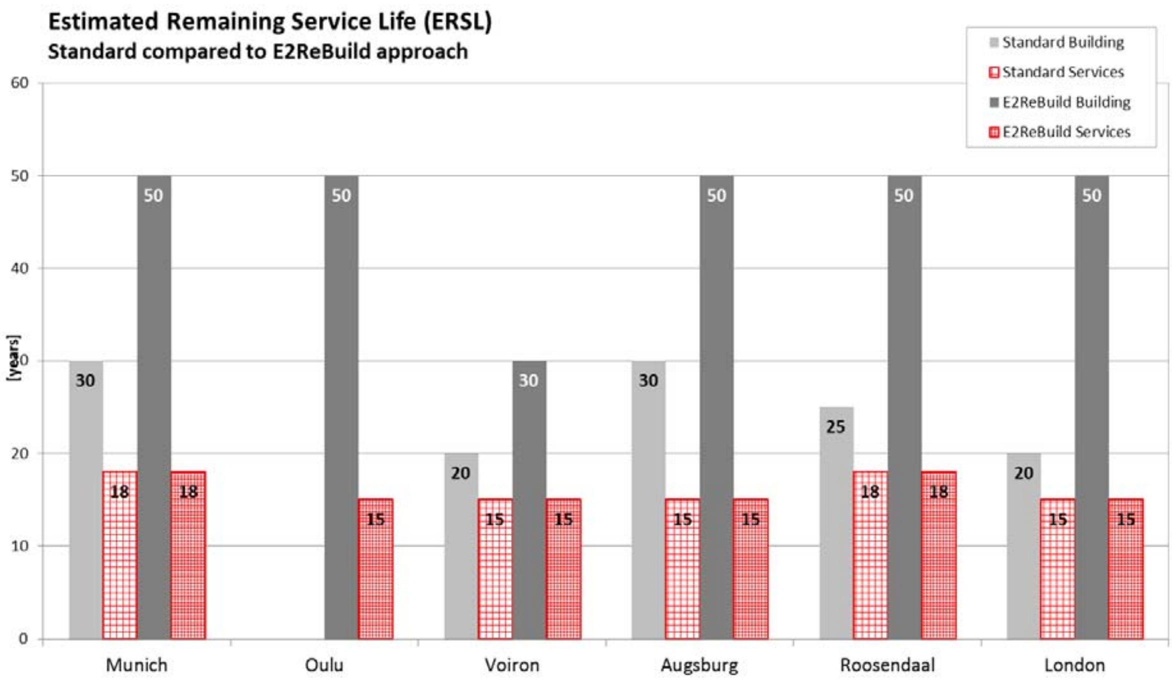


Figure 6. *ERSL* estimated by the building owners and experts for their usually applied standard retrofits compared to the E2ReBuild standard. Source: E2ReBuild.

The experts and demo building owners also stated their own expectations on the *Estimated Further Service Life (ERSL)*[6] of the retrofitted parts due to the higher standard applied (Figure 6). While the *ERSL* of the service technologies was expected to be renewed in shorter periods (15-18 yrs.), nearly all experts and stakeholders extended the *ERSL* for the «Building» from 20-30 years up to 50 years, except for Voiron – due to unchanged windows and the installation of a standard insulation system. However, these results gave an idea of the possible reduction of retrofit cycles by higher than usually applied standards.

2.2. Social strategies

All E2ReBuild demo projects showed a very high awareness of social aspects in the retrofit strategy itself and for the process of implementation.

2.2.1. Social analysis

The analysis of the social strategy showed the effort to provide affordable housing with low rent increases (~13 to 19%) which were compensated with reduced energy costs (~ -62 to -73%) – see Figure 7. This focus on affordable housing for residents was considered to be very important. Only the demo in Munich transformed the apartments from a low[7] to a very high standard with significantly increased rents (+70.5%). This was possible because the former tenants were relocated and new ones came in. But the unoccupied situation enabled a deep retrofit with significantly reduced energy costs. Nevertheless the increase of the apartment and living quality in the area caused a final monthly expense for living (12.85 €/m²) that was not affordable for the former residents.

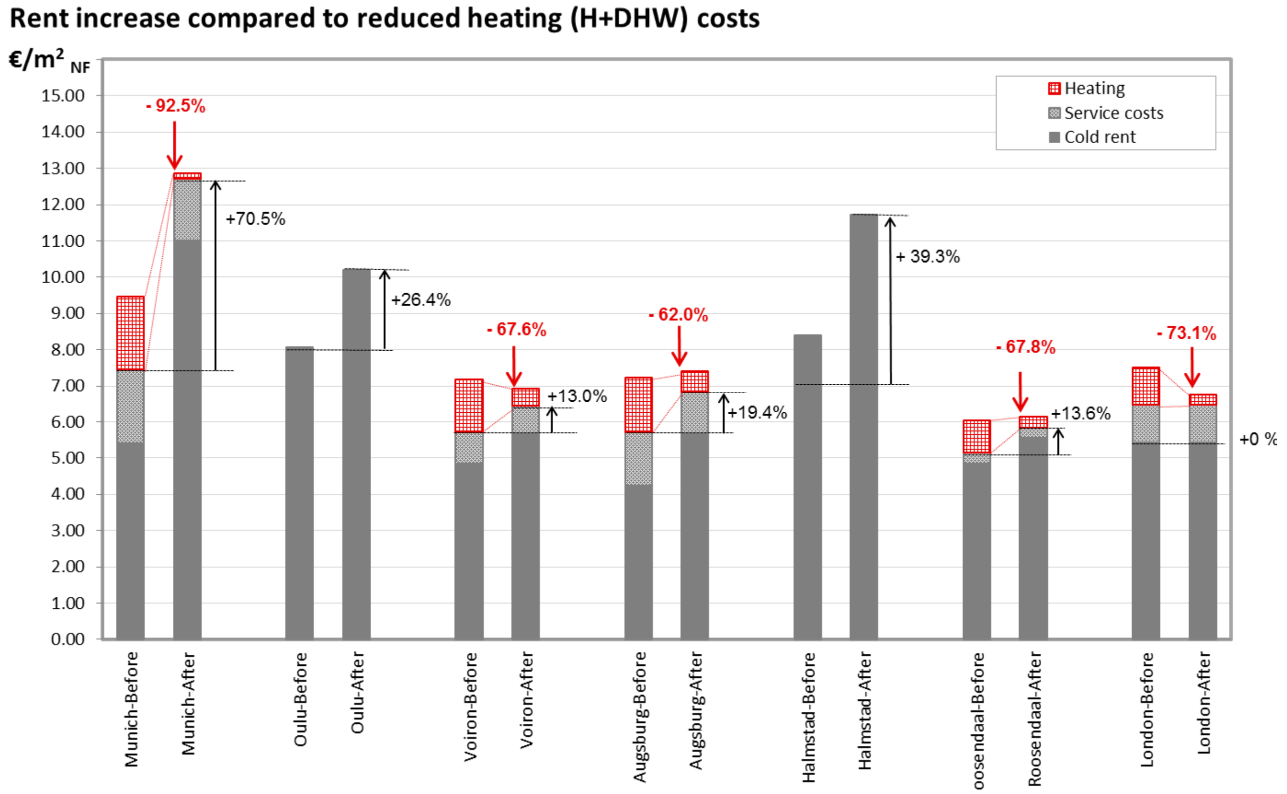


Figure 7. Monthly expenses of residents for rent and heating before and after retrofit. Rental figures in m²/ (rentable) net floor area incl. VAT. Source: E2ReBuild.

2.2.2. In-depth evaluation of the social strategy and findings

The perspective on the single building was to provide affordable rent levels. But all housing owners focused on high occupancy rates and long-term leasing agreements. Therefore a wider perspective

[6] The ERSL indicates the number of years of serviceable life time of the building components or building services until they reach a state that would need major retrofit.

[7] At the time of renovation the existing buildings had no longer a bonding for social housing; but the actual standard was very low (single heating units in the apartments, too small bathrooms with DHW, etc.)

was needed: Certainly residents remain in their apartments as long as they can afford to stay there, but the area has to be attractive (infrastructure) and safe (low crime rates and no social decline) as well. In order to support stabilization of entire areas, some of the owners (demo Augsburg, Munich, Voiron and Roosendaal) saw the city as an important alley and practiced a close cooperation with the city administration in order to adjust their retrofit strategies with the development plans of the city. For example, in Roosendaal the policy of the retrofitting strategy could be called «a whole district approach». It was designed on the motivation: *«How can* we *provide solutions?».*

Figure 8. Demo Roosendaal. The former monotonous appearance was changed by a «whole district approach» considering structural changes (a better apartment mix) and a selective design of the houses. Source: Trecodome.

Many added values could be gained from the close cooperation with the city:

- A concerted renewal of the infrastructure and the street layout.
- A higher attractiveness of the area with a better mixture of different apartment sizes.
- An upgraded residential area with new structural and visual identity.

Not only the physical achievements, but also the «soft factors» of retrofitting were very important. All interviewed actors stated that information to and communication with residents was the key issue for successful retrofit. All demos emphasized the importance of good communication in order to avoid or to overcome worries among tenants. Establishing a personal communication culture enabled a relation where trust supported a smoother retrofit process and a higher level of acceptance. This helped to get the necessary quota of tenants' agreements for the retrofit and led to a high rate of satisfaction afterwards.

Figure 9. In the «weekly open desk» in Voiron planners, site managers and tenants came together to discuss upcoming problems.

Figure 10. Significant lower heating costs and reasonable rent increases enabled tenants to remain in their apartments (Picture: Lattke)

A high level of user acceptance supported frictionless retrofit process chains, especially on-site. The E2ReBuild demos showed that residents tolerated disturbances to a greater extent, accepted worse conditions and raised less claims, if they felt well informed, taken seriously and part of the decision and retrofit process. Hence, fewer compensation measures were needed and work on-site could be processed smoothly with less interference.

Summing up the experiences, E2ReBuild showed that the social conditions in a residential area influenced significantly the development and design of the retrofit strategy. The existing structural conditions of the building structures were always challenging, but various social situations caused financial constraints for the retrofitting strategy that limited necessary measures in the field of energy-efficiency. In consequence, it was not easy to develop a strategy that met the ambitious energy-efficiency standards. The strategies varied from the fight against fuel poverty and the provision of healthy and affordable housing to strategies with a careful balance of moderate rent increases for improved apartment or living standards.

2.3. Ecological strategies

Basically the ecological strategies should address contributions to climate protection targets such as reducing *Delivered* and *Primary Energy* and improving resource-efficiency by the use of recycling-friendly and easy-to-dismantle constructions.

2.3.1. Ecological analysis

Mainly the focus in the E2ReBuild demo projects was to reduce energy demand in terms of the *Delivered Energy.*

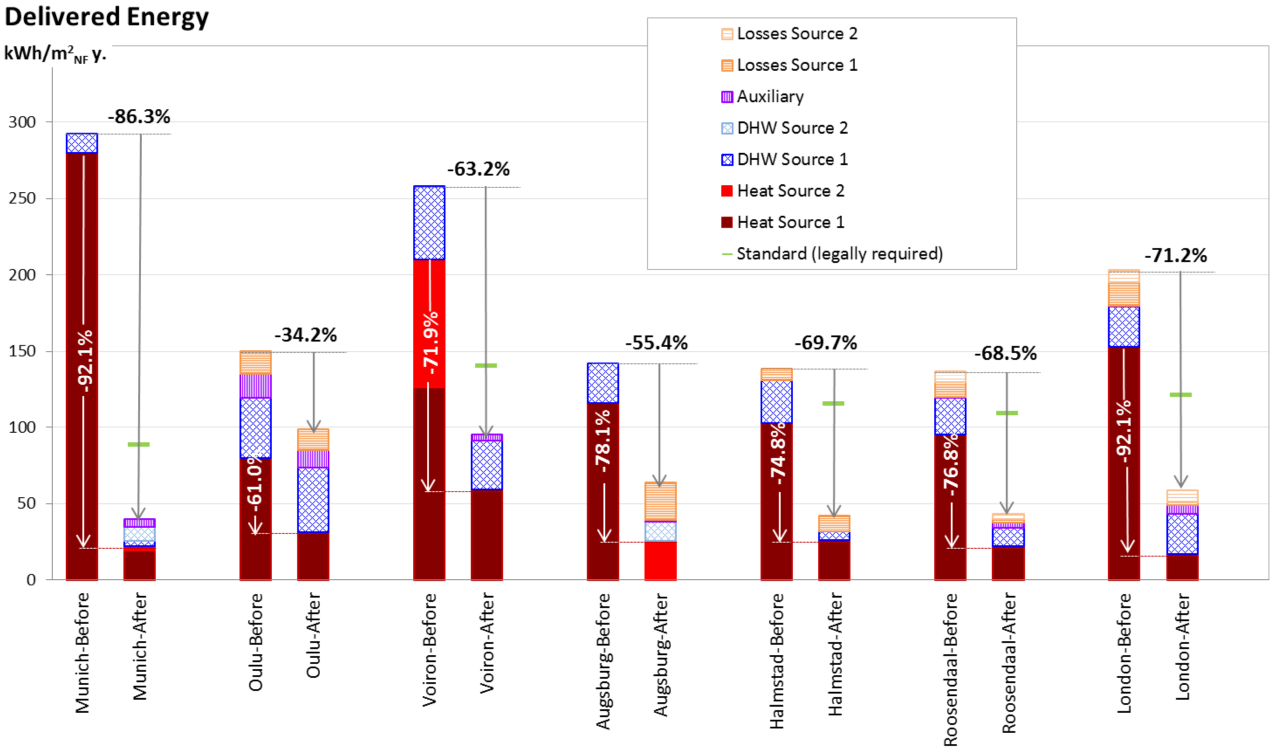


Figure 11. Reduction of the *Delivered Energy* before and after the retrofit. Source: E2ReBuild.

The effectiveness of retrofit measures in terms of reducing energy use for space heating and DHW was a key issue as it reduced the monthly energy costs for residents. A comparison of the figures for the *Delivered Energy* showed a -60 to -86% reduction for the space heating and DHW (Figure 11). The reduction of the demo in Oulu was lower due to climatic reasons, the existing cavity wall (with a very good U-value) and the already very good energy performance of the existing building. Therefore the reduction of the *Delivered Energy* was lower (-34%), but the reduction of the mere space heating was in a good range (-61%) compared to the other demos (-74 to -92%).The energy performance limits required by the national building codes (green horizontal dashes in Figure 11) were seen as not ambitious enough compared to technically possible standards. All demo projects aimed at a much better performance than legally required. Especially the calculated reduction of the space heating demand was possible by about -92% for Munich and London and -71% to -78% for Voiron, Augsburg, Halmstad and Roosendaal.

2.3.2. In-depth evaluation of the ecological strategy and findings

The analysis on the reduction of the *Delivered Energy* showed the direct benefits for residents (lower energy costs), but this did not demonstrate the effectiveness of the retrofit measures in terms of a future resource-efficient building operation. This would actually demonstrate the environmental impact of the applied retrofitting strategy.

Therefore in a further step the reduction of the *Primary Energy* was evaluated in two different approaches: by using conversion factors from a common European approach and from nationally or regionally applied figures. First, the common European approach enabled the comparison of different projects by using the same conversion factors. This was carried out by using the EN 15603:2008 Table E1, Annex E.[8]

	[kWh PE / kWh Source]		[kWh PE / kWh Source]
Electricity (UCTE Mix)	3.31	Wood shavings	1.06
Natural gas	1.36	Local-/District heating	1.3
Timber	1.09		

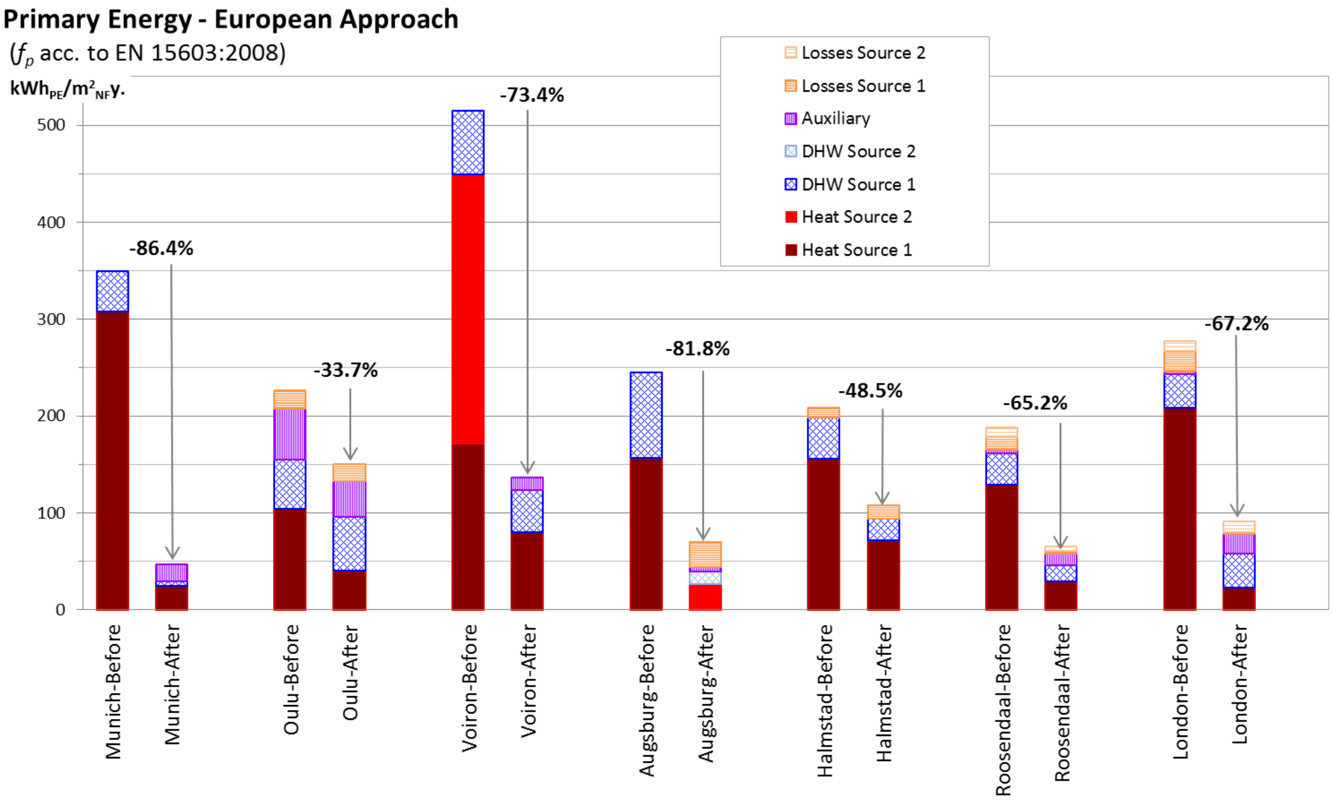


Figure 12. Reduction of *Primary Energy* based on conversion factors acc. to the EN 15603:2008. Source: E2ReBuild.

This evaluation showed significant reductions in the *Primary Energy* (Figure 12). Nearly all demos were able to achieve reductions of about -65 to -86%. The low reduction of Oulu (-33%) was caused by the already good energy performance before retrofit (the same reason as within the *Delivered Energy*). The reason for the modest reduction of the Halmstad demo (-48%) was the focus of the retrofit on lowering energy costs instead of decreasing *Primary Energy*.

[8] The prEN15603:2013 is going to be published, new conversion factors were not yet available at the time of the analysis.

As the *EPBD* refers to national primary energy factors and renewable energy sources on-site, a second approach was applied: a *Primary Energy* evaluation according to regionally or nationally used conversion factors. For example: The use of district heating (based on local resources such as waste heat) or renewable energy sources on-site would provide resource-oriented energy concepts and should be recognized as value in the design of holistic retrofit strategies. Therefore this evaluation focused on how the demo projects adopted their retrofit strategy to locally available and renewable energy sources. Following conversion factors were used for this evaluation:

		fp [kWh PE / kWh Source]
Germany (Munich) Source: *DIN V 18599/1 2007* and specific factor for DH – District Heating Munich	Electricity Timber DH (Munich)	2.6 0.2 0.35
Finland (Oulu) Source: *Government Decree 9/2013*	Electricity District Heating	1.7 0.7
France (Voiron) Source: *Thermal regulation RT 2012*	Electricity Gas	2.58 1
Germany (Augsburg) Source: *DIN V 18599/1 2007*	Electricity Gas Wood pellets	2.6 1.1 0.2
Sweden (Halmstad) Source: *SOU 2008:25* and *Lokala miljövärden 2012*	Electricity DH (Halmstad)	1.5 0.17
The Netherlands (Roosendaal) Source: *NEN7120*	Electricity Gas	2.6 1.0
United Kingdom (London) Source: *SAP 2012*	Electricity Gas	2.56 1.026

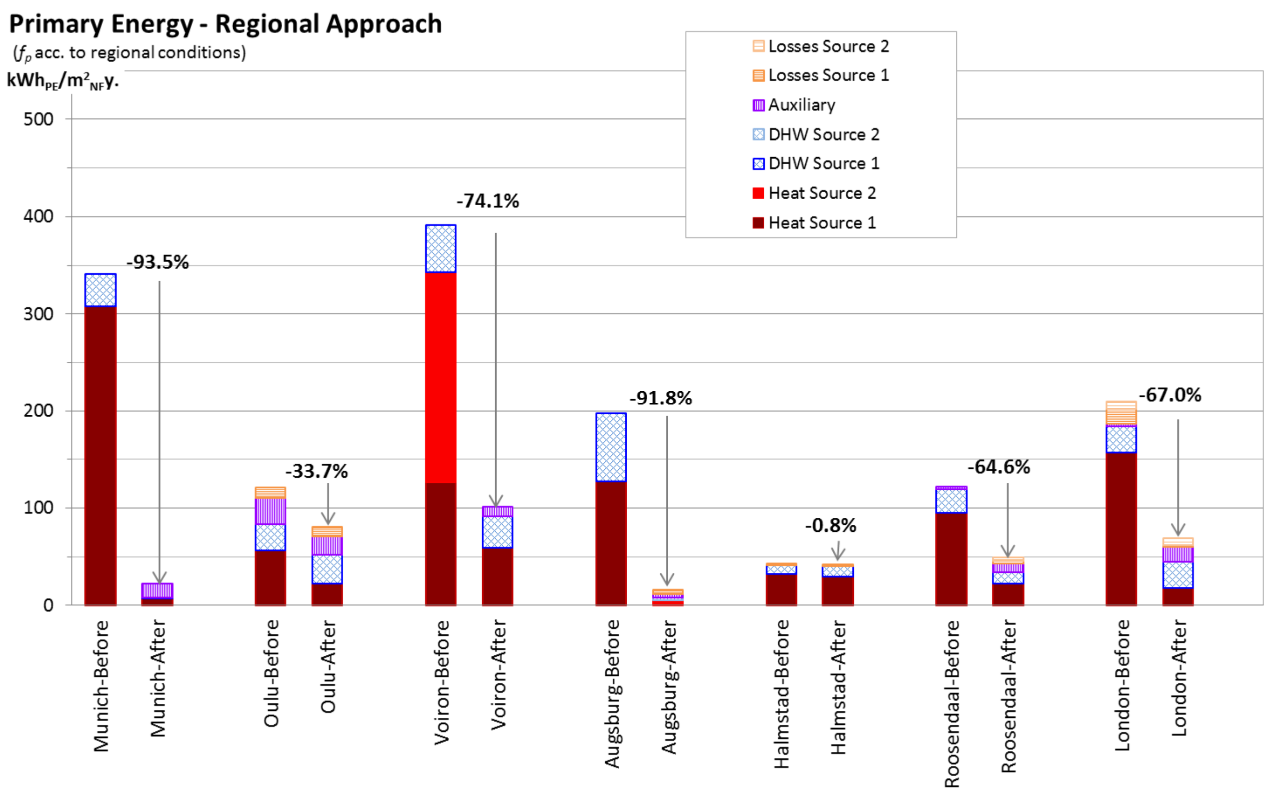


Figure 13. Reduction of *Primary Energy* based on regionally used conversion factors. Source: E2ReBuild.

In almost all demos the reduction of the *Primary Energy Demand* (based on regionally used conversion factors - Figure 13) was better (up to 93% reduction) than the *Primary Energy Demand* acc. to the European approach (Figure 12) with «only» - up to a 86% reduction. Oulu showed the same performance as in the European approach (-33%) and in Halmstad the goal to reduce energy costs instead of energy demand was obvious again. The reduction of *Primary Energy* according to regional conversion factors was nearly zero (-0.8%). The reason was the low primary energy factor in Sweden for electricity – this energy source remained the same after the retrofit.

3 RESULTS

Holistic strategies towards energy-efficient building retrofit

However, the evaluation of the E2ReBuild projects disclosed the added value of better higher ecological and social performance standards: Strategies with these higher standards were able to extend the expectation of the *Estimated Remaining Building Service Life (ERSL)* significantly, improved long-term attractiveness of the entire area and thus increased the economic feasibility of the retrofit strategy. What was surprising was the fact that owners prioritized the economic goals at the beginning – in particular stabilized or improved asset value and decreased energy costs in order to provide affordable housing. After the retrofit, the achieved ecological achievements, such as increased energy-efficiency or reduced *Primary Energy* were seen as «added value» of the retrofit strategy.

However, limited budgets and limited options for rent increase delivered arguments for shortcuts in the retrofit strategy. Either measures inside the apartments (renewal of kitchens, bathrooms, etc.) or on the outside (new envelope, exchange of windows) could not be realized. In one demo project (Voiron) even the retrofit technology had to be changed entirely (no industrialized technologies).

In the field of social strategies, participatory processes could be a puzzle piece in future to improve user acceptance. The discussions with the residents fostered acceptance of solutions on a collective and on an individual level. Currently, this is rarely practiced. Even more, the prevailing attitude declared tenants as immature to understand the complexity of a building renovation and its technical and financial frame conditions and impacts. In such traditional approaches, social strategies are reduced to providing affordable healthy housing and getting the necessary tenants` agreement. New, participatory approaches would understand the participation as a learning process to balance conflicting interests in order to achieve long-term, trust-based relationships empowering people to shape their own living environment. Such approaches would include social learning processes and generate identification and responsibility for the built environment.

The results of E2ReBuild showed that the reduction of the *Primary Energy* could be achieved by different approaches: either at the level of the *Delivered Energy* by reducing demand and losses or at the level of *Primary Energy* by the use of renewable energy sources that were locally available However, the biggest impact could be achieved by a combination of both reduction measures and changes to renewable energy sources.

Motivation and decision criteria

The arguments of the building owners leading to decisions in retrofitting were always based on serious feasibility considerations. Every measure was proved and evaluated according to the respective investment and its amortization. Even though the arguments for higher energy-efficiency standards and added values were numerous, every project needed a special starting point or trigger to initiate the actual retrofitting action. The decision to leave traditional ways of retrofit was important, but it needed a special external trigger that initiated this step towards energy-efficiency and innovative retrofitting technologies.

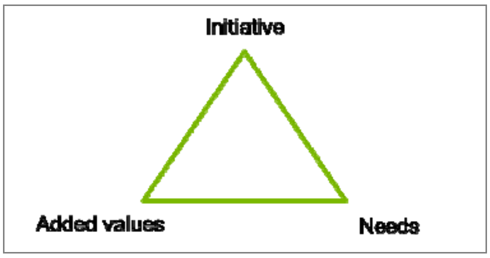


Figure 14. The «realization triangle». The need of building retrofit and the mere knowledge on added values is not sufficient to start a building retrofit - it is essential to have a trigger for the initiative.

The evaluation in E2ReBuild showed clearly that the added values of performance targets beyond usual standards were more or less known to all stakeholders, but this awareness and the mere knowledge of added values did not initiate the actual implementation. Only if the «realization triangle» is completed a retrofitting action can actually be started (Figure 14).

Nevertheless, all demo stakeholders stated that the E2ReBuild project was a trigger to initiate the respective demo project. The collaboration with housing associations facing similar problems and the opportunity to participate in a European research project were seen as an opportunity to leave traditional paths.

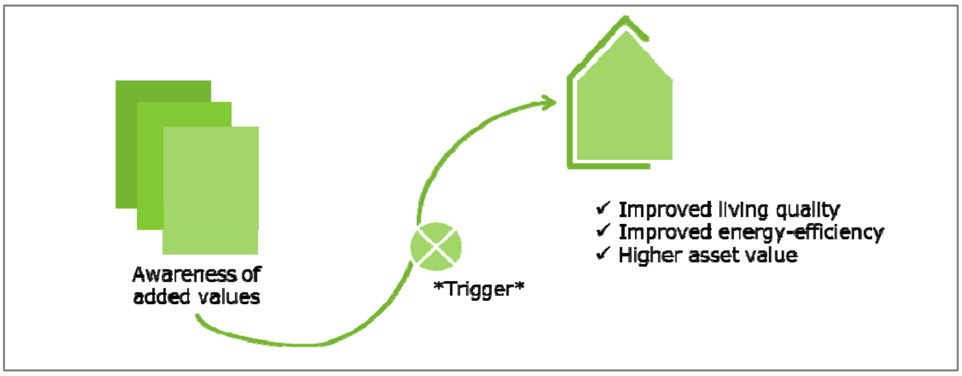


Figure 15. The trigger for implementation: the awareness of added values did not lead to the implementation of the respective measures. The actual realization needed a trigger to start and continue the retrofit on higher levels.

4 CONCLUSIONS

Summing up the experiences after the evaluation of the E2ReBuild demos a holistic strategy for retrofit was defined as ` *a long term plan for a building retrofit that is achieved by far-sighted design of retrofit measures considering the building structure and the related social, economic and ecological frame conditions and impacts*.` Thus a holistic strategy addresses the process of the development of the strategy and the relevant framings more than the solution itself.

ACKNOWLEDGEMENTS

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