Promoting the energy refurbishment of social housing: the KlimaKit model

P Penna 1, A Schweikofler 1, R Brozzi 1, C Marcher 1,2, D T Matt 1,2

1 Fraunhofer Italia Research, via Volta 13/A, 39100 Bolzano (BZ)
2 Free University of Bozen-Bolzano, piazza Università 5, 39100 Bolzano (BZ)

Abstract. Despite the well-known need of retrofitting the existing building stock and the availability of a wide range of energy efficient technologies, financial products and public incentives, the private as well as the public sector are struggling to invest in energy efficient solutions for buildings. Designers, companies, financiers, and energy suppliers follow their own profit, instead of creating synergies to fulfill what should be the final goal of a retrofitting project: the client’s satisfaction. The aim of this paper is to present the methodology developed, within the KlimaKit project [1], to support both the refurbishment process of the buildings belonging to the social housing association of the Autonomous Province of Bolzano and the energy refurbishment market of South Tyrol. The results presented in this paper are part of the ongoing research project “KlimaKit”, founded by operational programme European Fund for Regional Development of the Autonomous Province of Bolzano EFRD 2014-2020 – Investments in Growth and Employment.

1. Introduction

The reduction of the energy consumptions related to the existing building stock is an undeniable need. Even if this need is well-known and despite the availability of a wide range of energy efficient technologies and public incentives, the private as well as the public sector are struggling to invest in energy efficient solutions. Some of the main barriers identified are the high refurbishment costs, the lack of information [2], the uncertainty related to the investment payback period [3], the mistrust of stakeholders and the overwhelming possibilities offered by the market [4].

Given that the major part of the social housing was built before 1990, promoting the renovation of those buildings represents an opportunity for the public administration to reduce the energy consumption of building sector and to be an inspiring example for the private sector. For this reasons, several studies [5, 6, 7, 8] have been focused on the energy refurbishment of the social housing stock. The social housing association of the Autonomous Province of Bolzano (IPES – Instituto per l’Edilizia Sociale della Provincia Autonoma di Bolzano) is already involved in some important renovation processes, such as the European Sinfonia Project [9], which aims at testing urban-scale strategies for improving the energy efficiency of social housing stock [10, 11]. However, according with the data received from IPES (figure 1), most of their buildings still present high energy consumptions and need to be renovated. Since social housing buildings are characterised by a typological and technological homogeneity [5, 6], developing standardized solution seems to be a promising strategy to promote the energy refurbishment.
This approach can drive and foster the AEC and energy sector to collaborate in the development of integrated solutions for energy retrofit of residential buildings, simplifying the decision-making process and creating synergies among stakeholders. Furthermore, the creation of these packages of Energy Efficiency Measures (EEMs), developed basing on representative buildings of the social housing stock, can take advantage of synergies between different EEMs [2, 12]. Another aspect that should be considered is the cost-effectiveness of the packages of EEMs. It should be calculated using cost/benefit analysis [2, 13], evaluating the investment costs for retrofit and the expected energy savings [7]. Especially in the early stage of renovation projects, decision support tools can help in managing this complexity, improving the awareness of decision makers owners. The growing relevance of this tools is evident in literature from the increasing development of new tools [14, 15, 16, 17, 18, 19].

The aim of this paper is to present the methodology developed within the KlimaKit project [1], to support both the refurbishment process of the buildings belonging to IPES and the energy refurbishment market of South Tyrol. The paper is organized as follows. Section 2 draws the framework of South Tyrolean AEC sector, defining strengths and weakness of the regional market. In Section 3 it is described the methodology used to identify the possible solutions for promoting the retrofit project. Section 4 presents the standardized retrofit packages, i.e. integrated out-of-the-box solutions optimized for selected representative buildings, and the development of the decision support tool. The main results and the outputs of the decision support tool are described in Section 5. Section 6 concludes the paper with the main recommendations and the future avenues of the work.

2. State of the art
At European level, buildings and in particularly the housing sector accounts for 24.8% of the total energy consumption [20]. This percentage is equal to 26.1% in Italy, constituting approximately 25% of total CO₂ emissions [21]. The remaining components of energy consumption are related to transport (35.4%), industry (23.2%), services (13%), and agriculture (2.3%). The European Commission [22] has identified the construction sector as the one with the highest potential in terms of energy efficiency while the Intergovernmental Panel on Climate Change [23] has identified it as the sector with the greatest potential for reducing pollution, although several barriers persist [23]. In the EU 2020 strategy, ambitious targets have been set for energy consumption and climate change mitigation. These include the 20% reduction in greenhouse gas emissions compared to the 1990 levels. The current political measures of the 28 countries of the EU should have an energy renovation rate of the existing building stock of about 2.5% by 2020 and 5%-5.5% by 2030 [24]. However, the renovation rates of residential buildings still remain relatively low in several EU countries, about 0.5% and 2.5% per year according to the European Institute for Building Performance and to Fraunhofer Institute [25, 26]. A more recent study [27] confirms that the annual percentage of renovations is around 0.7% in Italy, at least 0.5% in Spain, Poland and Belgium, about 1% in the Netherlands and Lithuania, above 1.5% in Germany, France and Austria, with a peak close to 2.5% in Norway. At regional level in South Tyrol, the current renovation rate is approximately 1% (550 buildings per year) [28]. The objective for 2020 aims at increasing the overall amount of renovated buildings to 1,500 per year, namely equal to 2.5% of the existing housing stock.

Figure 1 – Energy consumption and number of buildings from the stock of IPES, Source: IPES

![Figure 1](image-url)
Table 1. Residential buildings by construction period (Source: ASTAT).

|      | 1918 | 1919-45 | 1946-60 | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-05 | 2006-05 | Total |
|------|------|---------|---------|---------|---------|---------|---------|---------|---------|-------|
|      | 15.666 | 4.914 | 9.030 | 11.695 | 11.403 | 9.492 | 10.970 | 6.155 | 6.319 | 85.644 |

The analysis on local residential buildings, carried out in the framework of KlimaKit project, indicates that approximately 50% of existing buildings have been built before 1970 (table 1), confirming the large potential in energy renovation. Considering this background, further research showed additional challenges and opportunities for stimulating the construction, financial and energy local sectors towards integrated high-quality fair-price solution. On the one hand, it emerges the need of stronger collaboration among stakeholders during the retrofit processes to improve the quality of the intervention (figure 2). On the other hand, the use of standardized out-of-the-box solutions for the building stock are perceived as more desirable to reduce the range of payback times (figure 3).

Figure 2 – Benefits of improved collaboration among stakeholders, Source: KlimaKit survey.

Figure 3 – Definition of “integrated retrofit package”, Source: KlimaKit survey.

3. Methodology to define suitable solutions for supporting the retrofit process

Starting from these findings, a series of four workshops were organized, in collaboration with Eurac Research, in order to define solutions supported and validated by the main stakeholders, such as local social housing associations (IPES), professionals, energy suppliers, Energy Service Companies and the local agency for public tender. The workshops aim at defining preliminary concepts, solutions’ requirements, potential applications in the regional context and validation of the proposed solutions. The outcomes of the workshops make it clear that to support the retrofit process is necessary to:

- Analyse the social housing building stock to define the most representative buildings;
- Define standardised out-of-the-box packages of EEMs that presents specific energy savings and certain level of indoor comfort;
- Evaluate the cost/benefit analysis of the defined EEMs packages to guarantee a pay-back time as close as possible to 10 years;
- Use the public incentives in order to reduce the payback period and increase the cost-effectiveness of the retrofit solutions;
- Support the decision makers in choosing the optimal out-of-the-box solutions for a building that has to be retrofitted.

4. Development

4.1. Reference buildings

IPES owns about 3500 accommodations in Merano that present similar building typology and construction technologies according to the construction period. Therefore, it was decided to identify a series of “reference buildings”, representative of the building heritage. The results of this analysis were detailed in one of the working phases of the project by Eurac Research [30].
Based on this assumption, five reference buildings were selected within the entire social housing stock of Merano for developing standardized out-of-the-box packages composed by different EEMs. The characteristics of the selected buildings were summarized on Table 2. The reference buildings considered for the definition of retrofit packages are the ones with poorest energy performance level (labelled E, F or G according to the CasaClima protocol [31]), in fact they should be the first ones to be renovated since they are the main responsible for high energy consumptions.

Table 2. Main characteristics of the selected reference buildings.

| ID | Building Typology       | Climatic zone | HDD | Construct. period | Nr. Flats |
|----|-------------------------|---------------|-----|-------------------|-----------|
| 1  | Small multi-family building | Terraced house | E   | 2894              | 1976-91   | 8        |
| 2  | Large multi-family building   | Apartment block | E   | 2894              | 1976-91   | 24       |
| 3  | Small multi-family building   | Apartment block | E   | 2894              | 1946-75   | 33       |
| 4  | Small multi-family building   | Multi-family house | E   | 2921              | 1976-91   | 16       |
| 5  | Small multi-family building   | Mixed         | F   | 3223              | 1976-91   | 10       |

a According to the Italian Classification.
b Heating Degree Day.

4.2. The retrofit packages: standardized out-of-the-box solutions

Based on the reference buildings, as well as the IPES’ needs, a set of five different standardized retrofit packages has been defined by Eurac Research [32]. For optimizing the synergies among different EEMs, the proposed solutions concern the improvement of the thermal envelope performance and the replacement of the technical system. The goal was not to develop new technologies, but to encourage companies and industries of the South Tyrolean building sector to identify, integrate and improve existing solutions. Each of the package is structured in three levels of energy performance, each of which are designed for accessing tax deductions or financial incentives at a national or regional level. These levels differ mostly in insulation thicknesses and characteristics of the windows’ system (double or triple glazing system with improved PVC-frame) and they present a thermal transmittance of building components and envelope air tightness set according to minimum requirements defined:

- Level 1: at national level for having access to tax deduction;
- Level 2: at regional level for accessing financial incentives;
- Level 3: for achieving Nearly Zero Energy Building (NZEB) target.

While the retrofit of the building envelope is the same, according to the performance level, for all the five packages, different solutions are considered for the technical system. As it is summarized below, the existing heat generator is replaced:

- “BASIC” – with a condensing boiler (only if the existing ones is obsolete);
- “FULL” – with a heat pump coupled with a radiant floor;
- “FLEXI” – with the connection to the district heating network;
- “NZEB” – with a heat pump coupled with a radiant floor and a photovoltaic system.

The fifth package refers to the case where it is not possible to retrofit the entire building, but just a single apartment with a non-centralized technical system:

- “SINGLE” – Replacement of windows, mechanical ventilation system, replacement of the existing boiler with a new ones coupled with a radiant floor.

4.3. Energy simulations and buildings’ database

The energy analysis, reported in this section, has been carried out by Eurac Research. The retrofit packages have been applied to the five selected reference building, for defining the impact of different
EEMs on the overall energy consumptions. The calculation of the energy performance has been evaluated by means of a dynamic simulation software, TRNSYS © [33]. The results have been collected in a database, which contains the pre- and post-retrofit information. For each building, most of the pre-retrofit information, such as year of construction, climate zone, floor area, roof typology, heating generation system typology etc., was collected from the architectural drawings provided by IPES and through the photo documentation. The energy consumption pre-retrofit has been calculated with TRNSYS, then energy model has been validated with the data from real energy consumptions. The impact of the retrofit packages has been evaluated in terms of energy savings and CO₂ emissions.

4.4. Retrofit investment costs
The costs for each EEM have been evaluated based on a regional costs’ database (Regional Price List of the autonomous Province of Bolzano). To automatically provide the investment costs for each package, an analysis tool was developed with MS Excel. This tool connects the necessary information of the building’s database, such as surfaces (i.e. windows, roof, floor, walls) or power of technical system, with the costs and, according to the reference building, it automatically provides the cost per square meter for each retrofit package, according to the performance level. The costs for retrofitting the envelope and the technical systems have been evaluated separately. Regarding the envelope, the following costs have been considered:

- External insulation of the walls with expanded polystyrene, scaffolding, removal and disposal of existing insulation (if older than 30 years);
- External insulation of the roof, according to the roof typologies (pitched roof, flat roof or ceiling toward unheated space), removal and disposal of existing insulation (if older than 30 years);
- External insulation of first deck toward unheated space with mineral wool, removal and disposal of existing insulation (if older than 30 years);
- Substitution of the windows system with double or triple glazing system with improved PVC-frame, including removal and disposal of the old ones.

The mechanical ventilations costs are evaluated based on the number of building units, considering an application of two mechanical ventilation for each ones. The costs for renovating the technical system has been evaluated according to power need for heating and domestic hot water and according to the chosen technical system, i.e. condensing boiler, heat pump coupled with radiant floor or connection to the district heating network. The technical system costs include the removal of the existing system, the mounting and putting into service of the new ones. The costs for the photovoltaic system have been estimated based on the installed peak power evaluated based on the reference building.

4.5. Economic analysis
The economic analysis of the defined retrofit packages has been calculated based on Net Present Value (NPV), according to the comparative framework methodology of cost-optimal level, proposed by the EU 244/2012 [34]. The NPV allows to evaluate different cash flows, occurring at a different time, by means of the discount rate. For the calculation of the NPV, the investment cost for retrofit, the annual energy costs (considering different energy carriers and rise rates of the energy prize across the time) and different public incentives for retrofits have been considered. Table 3 summarizes the data considered for the economic analysis. The maintenance and replacement costs and the residual value were not taken into account, because the purpose of the analysis was just the evaluation of the possibility to pay back the cost of retrofit interventions with the energy savings. The NPV has been calculated considering the investment costs as an outflow (with a negative value) and considering the amount of energy costs savings as an income (with a positive value). Therefore, the year when the NPV assumes a value equal to zero, corresponds to the time when the retrofit costs will be paid back with the energy savings. The economic analysis has been also integrated into the Excel tool for defining the investment costs. Therefore, for each reference building, according to the cost of each retrofit package and the energy savings reported in the database, it is possible to automatically evaluate the payback time.
Table 3. Data considered for the economic analysis.

| Data considered                  | Value       |
|----------------------------------|-------------|
| Natural gas cost                 | 0.08 €/kWh  |
| Electricity cost                 | 0.20 €/kWh  |
| District heating cost            | 0.11 €/kWh  |
| Annual rate of increase natural gas price | 2.0%       |
| Annual rate of increase electricity price | 3.2%       |
| Real interest rate               | 3.0%        |

This table includes:

- a Centro Tutela consumatori utenti Alto Adige (Situazione 31 marzo 2018).
- ARERA Autorità di Regolazione per Energia Reti e Ambiente.
- European Commission, [35].
- European Commission [34].

5. Results

Through the analysis of the impact of each standardized retrofit package on each reference building, it was possible to create an information database with the calculation results. Table 4 reports the data for the reference building nr. 2 (Large multifamily building). Looking at the payback time of the packages “Full” and “Nzeb”, it emerges the importance of using public incentives as means to increase the affordability of the retrofit. Answering a series of questions related to a specific building belonging to the local housing stock, the tool identifies the most similar reference building, recommending the most desirable retrofit packages. The identification of similar reference building is operated according to a series of drivers such as building typology, year of construction and climatic context. Finally, the tool provides a technical estimation of the intervention costs in the very first planning phases.

Table 4. Impact of the standardized retrofit packages on the reference building nr.2.

| Package | Level of performance | Reduction of energy costs [%] | Reduction of CO₂ equiv. emissions [%] | Retrofit costs for envelope [€/m²] | Retrofit costs for technical system [€/m²] | Payback time without incentives [years] |
|---------|---------------------|-------------------------------|---------------------------------------|-----------------------------------|------------------------------------------|----------------------------------------|
| BASIC   | L1                  | 50%                           | 50%                                   | €146.16                           | €2.90                                    | 15                                     |
|         | L2                  | 72%                           | 72%                                   | €166.79                           | €2.69                                    | 14                                     |
|         | L3                  | 72%                           | 78%                                   | €198.92                           | €35.72                                   | 18                                     |
| FULL    | L1                  | 61%                           | 94%                                   | €146.16                           | €172.35                                  | 26                                     |
|         | L2                  | 82%                           | 97%                                   | €166.79                           | €162.79                                  | 22                                     |
|         | L3                  | 77%                           | 97%                                   | €198.92                           | €181.48                                  | 26                                     |
| FLEXI   | L1                  | 59%                           | 89%                                   | €146.16                           | €3.61                                    | 15                                     |
|         | L2                  | 77%                           | 94%                                   | €166.79                           | €2.81                                    | 14                                     |
|         | L3                  | 75%                           | 94%                                   | €198.92                           | €35.28                                   | 18                                     |
| NZEB    | L1                  | 73%                           | 96%                                   | €146.16                           | €181.02                                  | 25                                     |
|         | L2                  | 88%                           | 98%                                   | €166.79                           | €168.96                                  | 22                                     |
|         | L3                  | 82%                           | 97%                                   | €198.92                           | €185.32                                  | 26                                     |

The questions concern:
- The general features of the building, such as location, year of construction, number of flats and floor, roof typology etc., which allows to identify the most similar reference building;
- The retrofit drivers (i.e. if the roof has been already insulated in the last 15 years or if the existing boiler has been already substituted) which allows to identify the EEMs that should be applied to the building envelope;
• Some information on technical system, such as energy carrier, efficiency label of the building envelope, surfaces available for PV panels etc.

This Analysis indicates for a generic building, which should be the most suitable retrofit package and the EEMs that should be applied. Furthermore, it provides a valid range of information regarding the expected energy savings (in terms of energy costs reduction), the CO₂ equivalent emissions, the retrofit costs for the envelope and for the technical system and, then, the payback time.

6. Conclusion
The paper presents some outcomes of the KlimaKit project. It describes the methodology developed for supporting the social housing association of the Autonomous Province of Bolzano in promoting a refurbishment project. What seems to be a promising strategy to support the refurbishment market of South Tyrol and to improve the collaboration among stakeholders involved in retrofit projects, is the identification of standardized out-of-the-box solutions. Those standardized package, consisting of a combination of different EEMs, are optimized for the social housing stock of Merano and they guarantee specific energy savings, access to the public incentives and, considering the investment costs, a certain payback time. For supporting the decision makers in choosing the optimal package for a building that has to be retrofitted, a decision-making tool has been developed. The tool has been realized with Excel so far, but it is planned to be developed as a free online tool. Considering that the combination of EEMs have been optimized for a specific context and the economic analysis is based on regional costs’ database, the results cannot be extended on a national or European level, but the developed approach can be used for other contexts and be applied on a larger scale.

7. Acknowledgements
This paper has been funded by the European Regional Development Fund ERDF 2014-2020 Südtirol/Alto Adige – Axis 1 Research and Innovation, with the project KlimaKit FESR1018 (CUP: B56J16001740001). The authors would like to thank IPES, the West Technical Office and the Arch. Othmar Neulichedl, as well as the Institute for Renewable Energy of Eurac Research.

References
[1] KlimaKit Project “Drive the change of the energy refurbishment market in South Tyrol. A strategy for social housing associations and public administration”, www.KlimaKit.it
[2] Almeida M, Ferreira M, 2018, Building and Environment 143 15-23
[3] International Energy Agency. 2010, Energy Efficiency Governance Handbook. France.
[4] Monteiro C S, Causone F, Cunha S, Pina A, Erba S, 2017, Energy Procedia, 134 442-451
[5] Davoli P, Belpoliti V, Boarin P, Calzolari M, 2014, Innovative methods for a sustainable retrofit of the existing building stock. A cross-path from social housing to the listed heritage, Techne Journal of technology for architecture and environment, 15073 181-198
[6] Belpoliti V, Bizzarri G, 2015, Energy and Buildings, 96 261-271
[7] Agliardi E, Cattani E, Ferrante A, 2018, Energy and Buildings, 161 1-9
[8] Koch C, Lutteman A, Small, Beautiful, Yet Difficult: Energy Plus Renovation in Small Social Housing Companies, proceedings of World Sustainable Built Environment Conference 2017 Hong Kong 5-7 June, 2017.
[9] European project “Sinfonia - Low Carbon Cities for Better Living” http://www.sinfonia-smartcities.eu/
[10] Toni M, Coccagna M, 2018, The role of IPES social housing in the EU Sinfonia Project for a “Bolzano Smart City”, Techne Journal of technology for architecture and environment, Special issue 01 134-140
[11] Della Valle N, Bisello A, Balest J, 2018, Energy and Buildings, 172 517-524
[12] Bolliger R, Ott W, Almeida M, 2017, Investigation Based on Calculations with Generic Buildings and Case Studies (Annex 56), University of Minho, Portugal, Available on line in http://www.iea-annex56.org/
[13] Jensen P A, Maslesa E, Berg B J, Thuesen G, 2018, *Building and Environment* 143 130-137
[14] Nielsen A N, Jensen R L, Larsen T S, Nissen S B, 2016, *Building and Environment* 143 165–181
[15] Malmgren L, Elfborg S, Mjörnell K, 2016, Development of a decision support tool for sustainable renovation – a case study, *Struct. Surv.* 34 (1) 3–11
[16] Jensen P A, Maslesa E, 2015, *Building and Environment* 92 1–9
[17] Nielsen A N, Larsen S T, Jensen L R, Niessen S B, Decision Making in the Pre-design Stage of Building Renovation Projects, *proceedings of World Sustainable Built Environment Conference 2017* Hong Kong 5-7 June, 2017.
[18] Dalla Mora T, Peron F, Romagnoni P, Almeida M, Ferreira M, 2018, *Energy and Buildings*, 167 200-215
[19] Gade N A, Larsen S T, Nissen B S, JensenL R, 2018, *Energy and Buildings*, 142 107-118
[20] Eurostat, 2014, Statistics explained. Finale Energy Consumption EU-28.
[21] Ministero dello Sviluppo Economico, 2016, Relazione annuale sull’efficienza energetica. Risultati conseguiti e obiettivi 2020.
[22] European Commission, 2006, Action Plan for Energy Efficiency: Realising the Potential, COM(2006) 545 final.
[23] Intergovernmental Panel on Climate Change, 2007, Climate Change 2007: Mitigation of climate change. *Summary for Policy-Makers*, 10 (5.4).
[24] D’Agostino D, Zangheri P, Castellazzi L, 2017. *Energies*, 10(1), 117
[25] Buildings Performance Institute Europe, 2011, Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings.
[26] Fraunhofer Institute, 2009, Study on Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries. *Final Report for the European Commission Directorate - General Energy and Transport*. Karlsruhe, Germany: Fraunhofer Institute for Systems and Innovation Research ISI.
[27] Zebra 2020, 2016, *Nearly Zero Energy Building Strategy 2020 - Strategies for a Nearly Zero-Energy Building Market Transition in the European Union*. D6. 2: Strategies for nZEB market transition on national level.
[28] Autonomous Province of Bolzano, Assessorato per ambiente ed energia, 2017, *Contributi per Favorire l'efficienza Energetica. Con impegno verso Klimaland* [conferenza stampa: 15 Febbraio 2017].
[29] Belleri A M, Di Pasquale C, Maturi L, 2017, Deliverable 3.1.1, Caratterizzazione di edifici di riferimento, driver per il miglioramento prestazionale e requisiti tecnici, *KlimaKit Project*
[30] Casaclima Energy Agency, 2017, Direttiva tecnica edifici esistenti e risanamento, settembre 2017, Bolzano
[31] Belleri A M, Di Pasquale C, Adami J, 2019, A framework for the technical evaluation of residential buildings’ energy retrofit, *to be published in proceedings of Rehva 13th HVAC World Congress*, 26–29 May 2019, Bucharest, Romania
[32] Solar Energy Laboratory, TRNSYS 17, TRNSYS. A transient system simulationprogram, 2012, [http://sel.me.wisc.edu/trnsys](http://sel.me.wisc.edu/trnsys)
[33] European Commission, 2012, Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU.
[34] European Commission, 2016, Report from the Commission to the European parliament, the council, the European economic and social committee and the committee of the regions - Energy prices and costs in Europe - *Com (2016) 769 – 30.11.2016*, Brussels