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DECISION-SUPPORT TOOL FOR PRIORITIZING RETROFITTING ACTIONS ON SOCIAL HOUSING STOCK IN ITALY

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Abstract. Housing is the main environmental impact generator (62 %) of the whole building sector, but it also has the greatest reduction potential. Enhancing its performance is thus crucial to sustainable development. Social Housing (SH) represents a critical asset within the residential segment, due to the recurrent investment shortage and several environmental, social, and economic related implications. In Italy, SH is held by around one hundred public agencies facing endemic resource constraints for both maintenance and retrofitting, which are limited further by a diffused lack of information regarding the conditions and features of the buildings they manage. In cooperation with an Italian SH agency (ACER Bologna), we developed a speedy tool to compare the technical and economic effects of different refurbishment scenarios on a case-by-case basis. This is not a tool to manage retrofitting works, as the many already available, but a means to help large housing managers overcome the intention-action gap that limit their capacity to properly prioritize interventions based on reliable information. The research focuses on the validation of the fast procedure for estimating the baseline energy scenario, arguing that the relatively small inaccuracies are irrelevant for the scope of the tool and are compensated for by the time saved.

Keywords: Retrofitting, social housing, decision-support tool, energy efficiency.

1. Introduction

The built environment is estimated to contribute 30 % of global greenhouse gas (GHG) emissions and 40 % of total energy final consumption [1]. Within it, the main generator of environmental impact is the residential sector (62 %), which accounts for 25 % of total final energy consumption, primarily due to the operational phase of buildings [2].

Large energy saving campaigns have therefore been launched globally, as well as actions to accomplish considerable emissions reductions in the Building and Construction Industry by 2050, based on new net-zero carbon buildings, deep renovations of existing ones, green energy supply, and low-emissions materials [3].

Households are estimated to have a reduction potential of 40 %, mainly due to the flexibility of their demand for energy and resources [4]. Extraordinary energy and carbon savings can be achieved in new constructions, downing up to 70 % reduced energy demand compared to traditional constructions. However, due to the slow turnover rate of the stock [5], the largest potential lies in retrofitting the existing asset. In fact, taking Europe as example, in forty years the vast majority (90 %) of the built environment will consist of buildings that are already in use today, with a large portion of them constructed before energy efficiency standards were introduced [6].

For this reason, in Europe, where the household sector was responsible for 26 % of final energy consumption in 2018 [7], several policies and measures to increase the building sustainability have been introduced, requiring a deep enhancement of their performance. The Energy Efficiency Directive 2012/27/EU (EED) [8] and the Energy Performance of Buildings Directive 2018/844/EC (EPDB III) [9] promote the energy efficiency improvement of both new and existing buildings stock, aimed at reducing 80–95 % of the building related GHG emissions by 2050. The recent EU Green Deal [10] also highlights the importance of renovating the stock in an energy and resource efficient way.

In spite of the huge effort EU has been spent in the last decades, likewise several other countries worldwide, enormous emissions reduction potential remains untapped due to persistent use of fossil fuel-based resources, lack of both effective energy-efficiency policies and investments in sustainable buildings [2]. According to UNEP, the main barriers preventing a higher pace in interventions for energy efficiency in housing are: economic/financial (e.g., high investment cost compared to energy saving return), due to hidden costs/benefit ratios (e.g., misleading perception of cost focussing on first cost rather than reduced operational costs, and split economic interest between owners and tenants – who spends the money is not who directly benefits from the intervention), market failures, behavioural and organizational obstacles, low level of awareness (e.g., lack of information provided on energy saving potential) and political/structural constraints (e.g., ownership fragmentation) [1].

These barriers especially affect the Social Housing (SH) stock that, despite representing a relatively small share of the whole residential built stock, is among the harder asset to renovate. This is mainly because of its poor baseline energy performance, socioeconomic fragility of users, peculiar tenure and management status, and availability of financial resource for the purpose.

In figures, SH accounts for more than 28 million dwellings and about 6 % of the total housing stock in OECD and non-OECD EU countries. In most European states it makes up 10 % of the whole residential sector, reaching up 20 % in some Northern EU countries [11].

Despite some differences across the members states, most of the current SH stock in EU has been built between 1960s and 1980s as public answer to housing needs of the working classes. In many cases, it consists of high rise residential blocks made by industrial construction systems and new building materials that have proved to be limited in durability (e.g. façades, joints, windows, roofs) and soon have showed severe technical deficiencies, in addition to their poor energy performance [12]. This not only results in high environmental impacts of the SH stock, but also affect the building operational costs, and in turn economic and health status of its final users. In fact, this has a strong impact on social housing tenants, most of whom are low-income and socially disadvantaged, thus highly exposed to the risk of energy poverty and the inability to access fair energy policies [13, 14].

Furthermore, technical obsolescence increases maintenance costs, which are already affected by the heterogeneity of the stock managed by each agency, often large in size but made up of very different assets in terms of age, size and state of conservation [15].

Regional and municipal authorities hold on average half of the SH stock in EU, while the rest is divided among non-profit, limited-profit or cooperative housing associations (15 %), national governments (14 %), for-profit providers (11 %) [16]. Almost all of them struggle with scarcity of resources and a lack of adequate knowledge of their assets. The combination of these impacts the capacity of agencies to effectively undertake renovation programs.

Hence, even though the huge effort of many countries in renovating their built park, a significant share of this stock still needs interventions and proper support tools. This is the case of most SHs, whose refurbishment and energy efficiency enhancement not only would contribute to reduce environmental impact, but also to lessen social fragility of tenants and improve the management effectiveness. This is the mission of the Housing Europe Network, which collects Public, Cooperative and non-profit agencies sharing the aim of "considering climate without pricing people" (i.e., retrofitting for lessening building's environmental impact while reducing operational costs) [15].

1.1. Social Housing stock in Italy

The SH stock in Italy is critical to manage and renovate, far more than in other EU countries with greater public housing share, larger resource availability and a wider variety of subjects operating within the sector in addition to public authorities.

In fact, the Italian SH stock accounted for less than 4 % of total residential asset in 2020 [16], it consisted of 836 000 dwellings hosting 2.2 billion inhabitants [17]. The historic shortage of these subsidised dwellings – which have been heavily reduced after a massive selling campaign started in the 1990s [18] – is largely inadequate to cover the demand, which national association for public housing [17] estimated to increase by 36 % (300 000 additional dwellings). As no financial resources are available for increasing the building offer, it becomes critical for owners and managers to handle their assets as efficiently as possible and to make them fully useable through intensive maintenance and retrofitting interventions.

The technological features of Italian SH are quite similar to those of other EU countries [19]: most of these buildings were built before the early energy regulation being enforced in 1976 [20]. This usually results in poor energy performances, mainly because of low thermal insulation levels and inefficient technical systems, heavily impacting both the tenants and owners' finances. This suggests that basic but effective interventions would greatly help, such as thermal insulation of envelopes, window replacement with higher-performing ones, and systems upgrading. However, the pace of refurbishment is very slow, and even decreased in recent years: 11 423 dwellings were deeply refurbished in 2014, while three years later (2017) the annual share was reduced to almost half (6 578 dwellings, that is less than 1 % of the whole stock) [15].

The main reason of this is that social housing agencies find it difficult to successfully retrofit their assets, owing to a lack of investment resources, insufficient information on the status of their properties, and tenure fragmentation [17]. In fact, while there are only 74 territorial agencies (originally, one in each province) managing the SH dwellings, they belong to different public owners (the agencies themselves, municipalities, other bodies) and they are often located within the same building together with some, if not dozens, of family property flats.

On the other hand, a lack of information on the status of the property risks misleading the agency in assigning priorities to the interventions: in contrast to what currently happens in the management of private real estates, the implementation of advanced information systems is still not widespread in the publicly owned buildings and often does not include an accurate survey of the physical state of the building. Without having properly organized information on buildings, whose lack is typically due to data retrieval costs, SH owners are often unable to implement appropriate management practices. As a result, the already limited resources allocated to social housing refurbishment and energy retrofitting are not optimised [21].

In addition to the difficulty of managing thousands of accommodations at a time, these agencies often deal with condominium buildings (resulting from the massive sale of the late 90s) which further hinder the possibility for many different owners to agree on renovations. Not to mention the resistance of tenants to accept planned actions due to a false perception of cost-benefits ratios or the presumed opposite interests of landlord and tenant [1, 6].

This clearly highlights how crucial it is for owners to carefully select properties to include in their frequent but limited maintenance or renovation programs. In this context, having quick and cheap pre-evaluation tools could be of great help for the owners themselves, in order to maximize the effectiveness of each initiative [19, 22, 23].

Several tools are currently available on the market with the aim of supporting the building retrofitting process. However, very few of them have been developed targeting SH and its peculiarities. Among those there is the free tool "Condomini+4.0", developed by the Italian national energy agency (ENEA) for multi-propriety buildings, which aims to assess their energy demand and seismic vulnerability and, on this basis, suggests a set of intervention to be implemented. The tool has been tested on six SH cases [23].

While the application "InvestImmo" directly targets the SH, having been developed by the regional housing association ALER Lombardia to survey its asset and detect maintenance priorities on 320 social dwellings [24]. Other similar applications have been developed at regional scale, but restricted in scope and extent, while very few implementations have been performed of tools for quick simulating the effect of maintenance and strategic retrofitting combined [21]. This is also because available tools for this purpose usually require detailed input data that SH managers hardly have on their vast assets.

Given that the inability to prioritize interventions based on reliable information, investigation and diagnostic activities represents a serious intention-action gap that limit agencies' operational capacity, it appears that a tool is required to assist them. On this premises, the paper presents a study aimed at developing a tool to support decision-making for retrofitting the SH stock in a timely but effective manner.

2. Method

The overall methodology can be broken down into four main steps, which almost match with the implementation flow of the tool:

(1.) determining a procedure to obtain quick and homogeneous pieces of information about the current energy behaviour of buildings within a certain stock (baseline scenario);

(2.) defining a set of suitable retrofitting actions based on the most recurrent interventions in SH;

(3.) estimating the benefit of those actions on the overall energy demand of the building;

(4.) calculating and comparing the cost-energy benefits ratios of different retrofitting options.

The overall procedure has been developed within a study called Integrated technologies for Smart buildings and PREdictive maintenance (InSPiRE, 09/2019-09/2021), supported by ACER together with the Emilia-Romagna region and carried under the umbrella of a broader cooperation between the Department of Architecture and the Interdepartmental Centre for Industrial Research (CIRI) of the University of Bologna.

The study worked on the more frequent retrofitting measures used within the observed stock over the last decade, resulting in the identification of a set of standard intervention schemes and their expected performance improvements. The detected ones have been grouped as follows:

(i) application of insulation layer on the building envelope;

(ii) application of insulation layer on horizontal closures, such as flat and sloping roofs; and

(iii) replacement of windows.

For each of them, two increasingly higher performance levels have been determined:

(i) **basic refurbishment**, by applying the most used measures to reach the minimum legal requirements regarding energy transmittance (U-value) of the building envelope elements; or

(ii) **advanced refurbishment**, by implementing the best available technologies to obtain high energy performance, or an improvement of about 30 % compared to the legal minimum requirements.

A standard cost of the intervention has then been associated to each. On this basis, the architecture of the digital tool has been completed with a section that compares different refurbishment scenarios on an iterative basis, resulting in user friendly visualisation.

The procedure and the general scope of the study are reported in [25, 26] while this paper is focused on reporting the implications of the first research phase and its validation on a sample pool of buildings belonging to ACER Bologna, which is the local agency for social housing that has funded the project. As SH agencies have often heterogeneous and inadequate data about the status of their assets, the first step was to find how they can get the necessary information timely and in reliable conditions, so to evaluate the baseline performances and rationalise interventions accordingly. To this end, the study identified three alternative ways to calculate a building status in terms of energy performance.

The first (a) is to analytically calculate – or just retrieve if already available to the manager – the overall building energy need (i.e., Energy Performance certificate – EP). This, in general, requires a thorough understanding of the building and its systems, as well

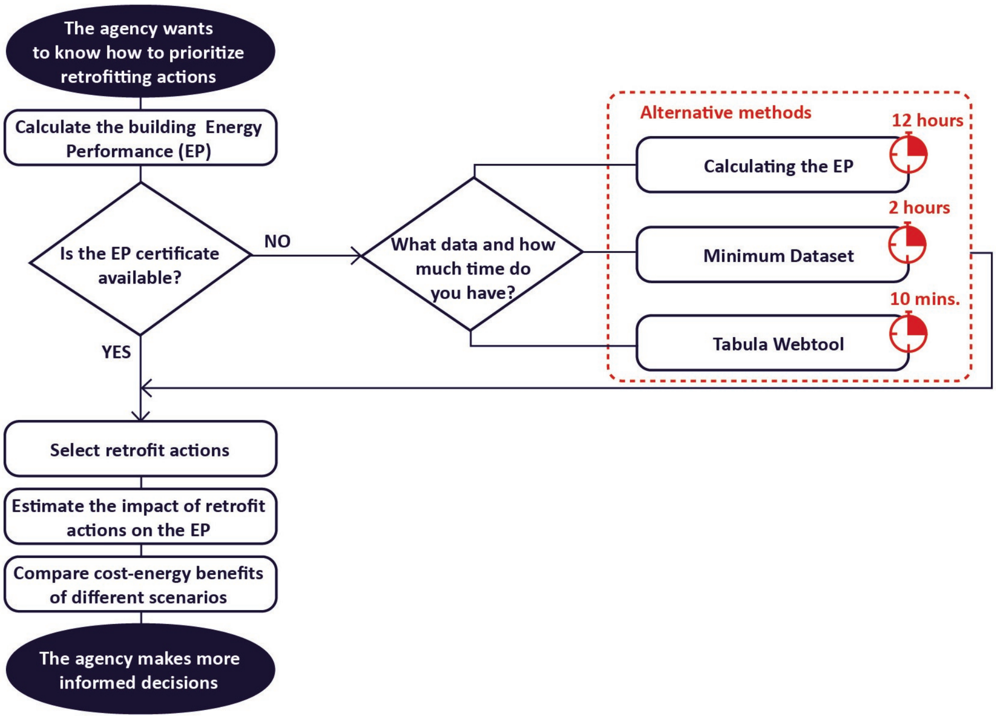

Figure 1. Implementation workflow of the tool.

as the capacity to operate specialist software with analytic data, or to hire an expert to do this job.

The second (b) is to access third-part well-diffused and recognised tools such as the Tabula WebTool [27] that assigns a building an energy performance class based on parametric data, according to the average consumption of buildings of similar type, location, and construction period. This procedure is especially useful when only cadastral data are available, and no specific knowledge is required to the user.

Then, the study identified a third option that is an intermediate way to be used when managers already have or can quickly retrieve a set of simple data. This is to prevent more detailed knowledge from being lost by merely applying solution (b). To this end, a Minimum Dataset (c) was defined, including those basic physical and technical features of the building required to perform the energy simulation (e.g., Building volume, Net floor area, Envelope surface, Envelope area to Volume ratio, and average Thermal transmittance of technical units).

However, when parametric and analytic data are used together, the risk of discrepancy arises, as well as the possibility of severe estimation mistakes. Therefore, in order to validate the results obtained from the speedy method (b) considering its accuracy to justify the potential approximation, a test on a group of buildings with available EPs has been performed by comparing the results and ensuring that their maximum deviations were acceptable to the scope. In particular, the *Non-renewable primary energy demand for heating and domestic hot water* ($EP_{gl,nren}$) was assumed as the most precise value to assign an energy class to a building. It is expressed in total energy used by the building per square meter of surface every year [kWh/m^2y].

If (b) is validated, it goes without saying that the intermediate way (c) is acceptable too. Then, the average time that is needed to collect information and complete the three procedures has been calculated in order to highlight the potentiality of the tool in saving time and resources while improving the prioritization process, thus in ranking buildings for renovation.

2.1. Application case study: ACER Bologna

As it happens to many other agencies in Italy, ACER Bologna runs a large asset (18 000 dwellings across 55 Municipalities) on which it has a scarce level of information. The datasets owned by ACER have been gathered during multiple campaigns over different time periods indeed and, therefore, it is very heterogeneous and frequently structured according to different criteria. As already mentioned, this prevents the Agency from having a thorough understanding of the condition of its asset and properly prioritizing, optimising, and implementing retrofitting interventions. Hence, after the methodology was developed, ACER explicitly suggested the tool to be validated on a sample pool of buildings belonging to its asset.

A first test was undertaken on six buildings for which the agency already had the EP certificate, with the scope of determining the suitability of the speedy method to calculate the baseline scenario. The buildings for the sample have been selected to be representative of the whole stock, balancing construction periods to cover different construction techniques and conservation status (from 1930s to 1990s). Then their

Building	Typology*	(a) EP $EP_{gl,nren}$ [kWh/m^{2}y]	(b) Tabula $EP_{gl,nren}$	Error (b − a)	Error [%]
1. Via F. Albani	1946–1960	211,55	218,2	6,65	3 %
2. Via P. Tibaldi	1921–1945	220,64	217,2	-3,44	-2 %
3. Via A. di Vincenzo	1946–1960	173,22	218,2	44,98	26 %
4. Via W. Goethe	1976–1990	125,94	174,1	48,16	38 %
5. Via A. Gandusio	1976–1990	195,89	174,1	-21,79	-11 %
6. Via Verne	1961–1975	221,29	211,9	-9,39	-4 %

* Building typology for TABULA requires the type of building, the period, and the climatic zone: since all these buildings are Apartment Block (AB), in climatic zone E, only the construction period is reported.

TABLE 1. Comparison of results from the validation phase.

EPs have been estimated by means of the Tabula Webtool and compared with the ones from EP certificates. Then, discrepancy between the two values have been calculated to assess the method reliability and accuracy level.

3. Results and discussion

The comparison between the results from the two methods applied on the 6 buildings from ACER sample pool is reported in Table 1. Errors range from 2 to 38 kWh/m^2 per year. For 4 buildings (2/3 of the sample) the EP from Tabula differs of less than 11 %, which is assumed as an acceptable error with relation to the scope and for buildings with an average energy demand of 215 kWh/m^2 per year, largely justified by time and effort savings. Two buildings presented a significative discrepancy (26 % and 38 %) that could not simply be explained as calculation errors. Thus, after a site visit emerged that they were involved in some interventions for improving accessibility (this not registered as retrofitting actions) which partially modified the building behaviour influencing the performance level. These circumstances confirmed the need for a more coherent and organised approach to data collection, but also the necessity for a speedy way to solve current discrepancies and proceed with renovation implementation consistently with urgency and according to funding availability.

Looking at the results of the process it can be easily observed that, assuming the heterogeneity of available knowledge and data, detailed pieces of information must be gathered before implementing the retrofitting process. At the same time, a comprehensive view of intervention priorities is required to schedule actions and possibly consider the logistic and management benefit of operating on narrowing buildings in the same plot. If a detailed level of information is to be achieved for the whole, the process would require a huge amount of time and resources, so impeding retrofitting until the overall picture is fully completed. This would be probably the worst option considering the urgency affecting some buildings and their living conditions. Otherwise, a more rapid but less precise approach could be considered. The proposed speedy methodology provides acceptable (tested) results in a quite short time. Compared to an average time of 12 hours (1.5 working days) for a detailed calculation of Energy Performance, only 10 minutes are required for the speedy estimation by Tabula. Thus, in the same time frame, the manager can obtain the baseline scenarios of around 72 buildings.

4. Conclusions

The outcome of this study is a speedy digital tool for detecting the baseline performance of a building (or a group of buildings) and then comparing the effects of different retrofitting actions based on criteria such as energy efficiency, intervention costs, or a combination of the two.

The paper focused on the need for SH agencies to have homogeneous information on the status and energy performances of their stock to start the retrofitting process and thus prioritize interventions effectively. On this basis, the idea was to investigate if less precise but more expeditious tools to calculate buildings EP, compared to traditional EP certificate procedure, were accurate enough to take adequate decisions. Two alternative methods were proposed (accessing Tabula Web Tool and measuring the EP by a Minimum dataset) and were proved to be quicker and easier to perform. Hence, a validation of their accuracy was performed and resulted that the maximum error is around 10 %. This can be considered acceptable for the scope of the tool, also considering the manager's abilities, knowledge, and time availability, rather than delegating the assessment to time-consuming and costly consultations of experts. The main novelty of the study lies in this point.

In addition, the fact of having heterogeneous data on the stock also allow to take advantage of mass economy mechanism. For example: if ACER found that three close buildings would require the thermal insulation of the envelope, the intervention could be planned to be undertaken simultaneously, reducing transportation cost and test of machineries installation like crane.

Moreover, the intermediate method to calculate energy performance allow the SH manager not to lose important information when available, representing an added value to accuracy of the tool. In the case of ACER Bologna, for example, about 20 % of dwellings had sufficient info to apply the Minimum Dataset calculation. Hence, the proposed approach may effectively support the decision-making process accelerating the expenditure rate according to a more finalised and priority-based way.

To conclude, despite the encouraging results, the method will certainly benefit from additional validations on a larger number of buildings in different situations. The tool's accuracy can be tested in other ACER Bologna buildings, but also a national campaign could be launched to this purpose now that considerable funds have been set for building retrofitting under the umbrella of Recovery Plan. In addition, the tool can be easily transferred in other countries since both Tabula WebTool and Energy Performance certificates are already in use, at least in the EU. This may lead to some changes to the tool, mainly concerning the energy retrofitting options and costs not the procedure for calculating the baseline scenario outlined in the paper.

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References

[1] G. Yamamoto, P. Graham. *Buildings and climate change. Summary for decision makers.* United Nations Environment Programme, Paris, 2009.

[2] IEA. Tracking buildings 2020, Paris, 2020. [2021-10-23]. https://www.iea.org/reports/tracking-buildings-2020

[3] GlobalABC/IEA/UNEP. *GlobalABC Roadmap for Buildings and Construction: Towards a zero-emission, efficient and resilient buildings and construction sector.* IEA, Paris, 2020.

[4] McKinsey & Company. Pathways to a low-carbon economy. Version 2 of the global greenhouse gas abate-ment cost curve, 2009.

[5] M. D. Levine, D. Ürge Vorsatz, K. Blok, et al. Residential and commercial buildings. In B. Metz, O. R. Davidson, P. R. Bosch, et al. (eds.), *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 387–446. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.

[6] BPIE. *Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings.* Buildings Performance Institute Europe, Brussels, 2011. http://www.bpie.eu/publication/europes-buildings-under-the-microscope/

[7] Eurostat statistic explained. [2021-03-23]. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households

[8] European Union. Energy Efficiency Directive (EED) 2018/2002/EU, 2018.

[9] European Commission. Energy Performance of Buildings Directive (EPBD III) 2018/844/EC, 2018.

[10] European Commission. The European Green Deal. COM(2019) 640 final, 2019.

[11] OECD. Social housing: A key part of past and future housing policy, Paris, 2020. [2021-10-10]. https://www.oecd.org/social/social-housing-policy-brief-2020.pdf

[12] M. Krapp, M. Vaché. Housing policies in the European Union, 2020.

[13] EPEE. European fuel poverty and energy efficiency, 2009. [2021-03-23]. http://www.fuelpoverty.org

[14] B. Boardman. Fuel poverty synthesis: Lessons learnt, actions needed. *Energy Policy* **49**:143–148, 2012. https://doi.org/10.1016/j.enpol.2012.02.035

[15] Housing Europe. The state of housing in Europe, 2021. [2022-10-11]. https://www.stateofhousing.eu

[16] OECD. Affordable housing database. [2021-09-06]. https://www.oecd.org/housing/data/affordable-housing-database/

[17] Federcasa. [2021-08-20]. https://www.federcasa.it/appello-di-federcasa-e-federcostruzioni-in-italia-servono-300mila-nuove-case-popolari/

[18] Censis. *Social Housing e agenzie pubbliche per la casa.* Dexia-Crediop, Roma, 2008.

[19] J. Aranda, I. Zabalza, A. Conserva, G. Millán. Analysis of energy efficiency measures and retrofitting solutions for social housing buildings in Spain as a way to mitigate energy poverty. *Sustainability* **9**(10):1869, 2017. https://doi.org/10.3390/su9101869

[20] Enea. *Rapporto Annuale Efficienza energetica (RAEE) 2016.* ENEA, Roma, 2016.

[21] P. Melis. *La valutazione della qualità globale degli edifici residenziali nella programmazione degli interventi di riqualificazione alla scala del patrimonio edilizio.* Ph.D. thesis, Università degli Studi di Cagliari, 2010.

[22] P. Tzortzopoulos, L. Ma, J. Soliman Junior, L. Koskela. Evaluating social housing retrofit options to support clients' decision making – SIMPLER BIM protocol. *Sustainability* **11**(9):2507, 2019. https://doi.org/10.3390/su11092507

[23] A. Amato, N. Calabrese, C. Lavinia, L. Volpe. Riqualificazione energetica del patrimonio immobiliare di edilizia residenziale pubblica. *Energia, Ambient e Innov,* (3):87–91, 2020. https://doi.org/10.12910/EAI2020-075

[24] ALER Notizie. Periodico dell'ALER di Bergamo, **4**(10), 2008. [2021-10-01]. http://www.alerbg.it/

[25] J. Gaspari, M. De Giglio, E. Antonini, V. Vodola. A GIS-based methodology for speedy energy efficiency mapping: A case study in Bologna. *Energies* **13**(9):2230, 2020. https://doi.org/10.3390/en13092230

[26] V. Vodola, E. Antonini, J. Gaspari, L. Marchi. A methodology for fast simulation of energy retrofitting scenarios of social building stock. In J. R. Littlewood, R. J. Howlett, L. C. Jain (eds.), *Sustainability in Energy and Buildings 2021*, pp. 147–157. Springer Singapore, Singapore, 2022. https://doi.org/10.1007/978-981-16-6269-0_13

[27] Tabula WebTool. [2021-03-20]. https://webtool.building-typology.eu/#bm