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*Published Version:*
Investigating the Role of Occupant Behavior in Design Energy Poverty Strategies. Insights from Energy Simulation Results / Santangelo, Angela; Tondelli, Simona; Yan, Da. - ELETTRONICO. - (2021), pp. 255419.525-255419.537. [10.1007/978-3-030-57332-4_37]

*Availability:*
This version is available at: https://hdl.handle.net/11585/818208 since: 2021-04-07

*Published:*
DOI: http://doi.org/10.1007/978-3-030-57332-4_37

# Investigating the Role of Occupant Behavior in Design Energy Poverty Strategies. Insights from Energy Simulation Results

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**Abstract** Energy poverty is very much interlinked with housing stock characteristics in terms of energy performance. Energy-led building renovation within the social housing stock combines the energy-saving goal with social and economic co-benefits (e.g., poverty alleviation and health improvements), thus contributing to facing stigmatization, social segregation and energy poverty, particularly prevalent in the social housing sector. However, to design renovation strategies aimed at achieving multi-benefits rather than just improving the buildings energy performance still remains a challenge, and considerations concerning energy poverty alleviation are far from being embedded. To the aim of this investigation, building energy renovation is believed to be a key opportunity to roll-out a comprehensive urban regeneration strategy with the goal of tackling energy poverty. However, at the same time, it is important to acknowledge that the gap between expected and actual energy consumption in buildings is highly dependent upon the human factor. Indeed, energy saving is not only a matter of technology, but it is influenced by the use by and the behavior of occupants. The overall aim of the paper is to provide an insight into building energy simulation and occupant behavior modeling as tools to support policymakers in making decisions on which strategies to apply to energy poverty through improvement of energy efficiency of public housing stock. To do so, this contribution investigates the impact of occupant behavior to reduce energy consumption at the household level. The Italian public housing sector is taken as a reference. A multi-family public housing building is assumed as a case study. Three dwellings with different sizes and exposures are considered, having three different occupancy patterns in turn. The results show to what extent the heating loads are influenced by occupant behavior and dwelling characteristics. The results are then discussed to form a basis for exploring how and to what extent housing policies and energy-led regeneration strategies can contribute to addressing energy poverty.

**Keywords:** Occupant behavior, Energy behavior, Energy poverty, Public housing, Building renovation

# 1 Introduction

According to the Italian Statistic Bureau (ISTAT 2014), in Italy there are 14.5 million buildings, and more than 84% of them are residential buildings. Approximately half of the housing stock consists of apartments in multi-family buildings, a figure that is higher particularly in metropolitan areas, where this share reaches 85.5% of the total housing stock (ISTAT 2014). However, Italian multi-family buildings are rather small and low-rise, with high surface area-to-volume ratios, resulting in very likely high thermal dispersions. Commenting on the quality of the Italian building stock, it is quite old and not adequately refurbished. More than 75% of households live in buildings built before 1990[1] (ISTAT 2010), with low efficiency rates, high maintenance costs for the owners and high energy costs for the households.

Propriety fragmentation, low awareness of homeowners of energy efficiency improvements and benefits and the low skills of multi-family building managers can be considered among the main barriers to buildings retrofitting and, thus, to energy-led urban regeneration. Energy efficiency renovation rates have been positive but negligible, namely an annual average of 0.5%. Nevertheless, the potential for improving building energy performance is still substantial, particularly in the field of public housing (Copiello 2015), where the housing stock is generally characterized by increasing age and poor energy efficiency. In this situation, more than a half of the public housing stock, about 500,000 public dwellings, belong to the three lowest EU energy labels, where households spend more than 10% of their income on energy costs (Federcasa 2015).

Conversely, the renovation of the social housing stock has not only an energy-saving purpose, but it also enhances the role of energy efficiency in combination with the social and economic co-benefits (e.g., poverty alleviation and health improvements), thus contributing to avoiding stigmatization and social segregation and to reducing energy poverty.

However, as pointed out by an increasing number of scholars from various disciplines (Janda 2009; Feng et al. 2016; Della Valle et al. 2018), an improvement in energy efficiency does not automatically lead to the expected energy savings; this is due to the fact that the occupants are the ones who use energy in the buildings. In fact, energy savings through behavioral factors can be as high as those from technological ones (Lopes et al. 2012), thus giving the occupants the possibility either to reinforce the savings from energy efficiency measures or to waste them. Behavior is more likely to be deliberately considered and changed when a discontinuity occurs in the household context (Huebner et al. 2013). Therefore, building renovation programs offer a key opportunity to involve households to convince them to reconsider their consumption practices (Santangelo et al. 2018).

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[1] In 1990 the first Italian energy efficiency regulation was adopted, although it was limited only to providing prescriptions for the heating systems in new residential buildings.

Better energy performance of the housing stock can have a significant reduction in the amount of energy bills and can contribute to alleviating energy poverty. Nevertheless, as just framed, building characteristics alone do not explain the energy consumption, and energy behavior and practices should be taken into account, too. Energy- efficient technologies, together with awareness of energy behavior and information on how to reduce the energy consumption, have the potential to alleviate energy poverty. Nevertheless, as noted by Ürge-Vorsatz and Tirado Herrero (2012), due to a number of barriers (i.e., relatively long payback times, restricted access to credit, a lack of appropriate financing schemes, low awareness of decision-makers about the alternatives and split incentives between tenants and owners), greater efficiency is not often usually achieved in spite of the corresponding larger societal benefits. Smart metering, a growing priority of EU energy policy, holds the potential to combat energy poverty to some extent, although it also requires careful considerations of the role of user behavior (Darby 2012).

Low-carbon urban and regional development policies also proffer significant opportunities for energy poverty reduction. In Europe, the Covenant of Mayors currently requires the signatory municipalities to commit not only to take action on mitigating climate change and adapting, but also on alleviating energy poverty. There- fore, due to the great number of Italian municipalities being part of the Covenant of Mayors initiative, how to tackle energy poverty can be considered a predominant challenge of Italian cities, despite the fact that competences and awareness concerning how to deal with this issue are still limited. In addition to this, it is worth noting that public housing, social housing and housing policies have always been studied as issues contributing to achieve sustainability in cities. Therefore, demonstrating—first in the public housing stock even before the rest of the housing stock—the relevance of household energy behavior to effectively reduce energy consumption in buildings and, in turn, to contribute to the reduction of energy poverty, is the focus of this research.

The aim of this paper is to provide an insight on building energy simulation and occupant behavior modeling as powerful tools to support policymakers and planners in setting strategies to address energy poverty while improving energy efficiency. The Italian public housing sector is taken as a reference to investigate to what extent understanding the human factor can contribute to alleviating energy poverty. To do so, this research investigates the impact of occupant behavior to reduce energy consumption at the household level.

## *1.1 The Italian Public Housing Stock*

In the European context, Italy emerges as one of the countries where social housing is less developed, and, more generally, public expenditure for housing is lower: Only 0.1% of total social expenditure is devoted to housing, less than 1% of the total expenditure of EU-28 (Eurostat 2018). Less than 4% of all households live in social housing dwellings, with the public sector having almost the exclusive role in providing social housing. Therefore, Italian social housing can be almost totally identified with public housing.

Today, Italian public housing is managed by public housing providers, either at the regional or municipality level, depending on the regional legislation. Renting is by far the most prevalent tenure (i.e., almost 95% of the total dwellings) (Nomisma 2016). However, assisted home-ownership has always been part of public housing schemes through various forms of leasing contracts (Baldini and Poggio 2014). At the end of 2013, the total available stock accounted for about 805,000 housing units; however, only 86% was properly allocated, 5% less than in 2004, resulting in an increasing share both in the number of squatters and in the number of vacant dwellings due to insufficient maintenance conditions. Fifty-five percent of public housing tenants pay less than 100 euros per month, while the rate of households paying a rent higher than 300 euros is only about 7% (Nomisma 2016). 45% of the total public housing stock is located in the 12 largest urban areas, where higher housing demand is concentrated. Access to the Italian public housing is related to one's income level, and the selection criteria for economic and social needs are tight. The stock is allocated on the basis of availability and size in relation to the household composition. However, low- income households may experience significant differences in energy expenditures depending on the energy efficiency of their dwellings, having in turn consequences on energy poverty and causing both horizontal and vertical inequality (Santangelo and Tondelli 2017). The turnover rate of social tenants is extremely low, and most of the occupants tend to remain in public housing for their entire lives, regardless of improvements in their economic and social conditions and changes in the household size. This propensity for stability, together with the reduction in the construction of new dwellings, explains the progressive aging of occupants. Elderly people, in fact, are the main beneficiaries, with more than 44% of household heads being 65-years old or older, while the share reaches 28% for those 75-years old or older (Nomisma 2016). These figures are significantly higher in the public housing stock than in the residential sector as a whole, where the share of household heads 65-years old or older and 75-years old or older decreasing, respectively, to 35 and 19% (ISTAT 2012). Although housing needs have constantly increased, both in terms of affordability and quality of the housing stock, and despite the fact that about 650,000 households across the entire country are subscribed to waiting lists to access public housing (Federcasa 2015), the public housing sector has continued to shrink since the 1990s. The lack of constant resources to be used to manage, maintain, and refurbish the existing stock and for the creation of new housing stock, together with cuts in public investments and the privatization plans for public housing stock, are only some of the structural issues that affect the public housing sector (Almadori and Fregolent 2020). The traditional rent-setting model raises, as well, financial sustainability issues. It operates by setting a rent to cover costs and subsequently to discount it according to the tenants' income. All the aforementioned issues result in a public housing model that is far from being sustainable.

# 2 Methodology and Assumptions

## 2.1 Methodology

A multi-family public housing building in Bologna, the capital city of Emilia-Romagna Region, is assumed as a case study to estimate the influence of three dimensions linked to occupant behavior—management of the thermostat, management of the heating system and variation of building characteristics—on energy heating consumption. The reference building is a ten-story building[2] (ground floor on *pilotis*) built in 1976, with five staircases and 92 housing units. Each story hosts from 6 to 11 housing units, while their sizes vary from 65 $m^2$ for the smallest housing unit—kitchen, living room, bedroom, bathroom, and corridor—to 116 $m^2$ for the largest ones—kitchen, living room, four bedrooms, two bathrooms, and corridor. The total heating consumption for the year 2011 was measured as 552,864 kWh. The high level of heating consumption was mainly due to the poorly insulated building materials and the lack of thermostats that would enable the occupants to regulate the temperature according to their presence and needs.

A building performance simulation tool was applied to investigate the impact of behavior and to build scenarios to inform decision-makers. The case study is modeled using the dynamic building simulation program DeST (Yan et al. 2008; Zhang et al. 2008). The model[3] was previously applied by Santangelo et al. (2018) to investigate the impact of the human factor in energy consumption at building scale and to build scenarios to support decision-makers regarding design renovation strategies to apply to the public housing sector.

## 2.2 Basic Assumptions

The reference building has a centralized heating system which operates for 14 h per day during the reference period (i.e., from the 15th of October to the 15th of April, according to E climatic zone[4]), from 6 to 9 am, and from 11 am to 10 pm. Since the measured consumption refers to 2011, the Bologna meteorological data of the entire 2011 are used for the analysis of the heating consumption. When it comes to internal gains, since the Italian average household size is 2.4 persons (ISTAT 2015), the number of people assumed for each housing unit in the model is the statistical number rounded up to three people.

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[2] Although this type of building has a higher density than the average Italian housing stock—characterized by small and low-rise multi-family buildings—it represents well the public housing stock, which from the 1960s has been the result of ad hoc urban planning instruments named *"Piani per l'Edilizia Economica e Popolare (PEEP)"*.

[3] Further details on the model and its validation are described in Santangelo et al. (2018).

[4] According to the legislative decree 412/93, the Italian municipalities are divided into six climatic zones (i.e., from A to F) based on the energy consumption needed to maintain a comfortable temperature inside the building equalling to 20 °C. The degree-day is the unit used to assign a climatic zone to each municipality. It is the sum, extended to all days in a conventional annual heating period, of positive differences between interior temperature (conventionally fixed at 20°C) and the mean daily external temperature. Degree-day for E climatic zone varies from over 2100–3000.

The thermal characteristic values of main building elements have been considered as representative of the residential buildings built between 1960s and 1980s in Italy, particularly in the public housing sector where the majority of the stock was built of a combination of precast and construction materials with poor thermal properties. Window surfaces are larger than the average for similar buildings, and windows have aluminum frames with single pane of glass, resulting in a high heat-dissipating factor.

Due to the unavailability of actual occupancy data, three different occupancy preferences (OPs) have been considered in order to take into the account variety in occupancy patterns. Each OP is representative of the number of hours that households decide to spend at home with the heating system on and the thermostat at the highest preferred temperature. OP1 considers tenants setting the heating system at the preferred temperature for 14 h per day (from 6 to 9 am and from 11 am to 10 pm), which decreases to 11 h per day for OP2 and eight hours per day for OP3.

Two extreme cases have been taking as a reference. In the first case called “no control,” the central heating system of the reference building is turned on for 14 h per day and occupants are not allowed to switch on/off the heating system, while they may choose the temperature set-point and the time to spend with their preferred set-point, among the 14 h that the system is on. They choose to adopt an “energy intensive behavior,” with the temperature set at 22 °C in all the rooms for the maximum number of hours defined by the occupancy preferences. In the second case called “full control, dual set-point,” households decide to switch off the heating system when away from home and not to use some of the rooms (e.g., bedrooms during the day), in accordance with the assigned occupancy reference. In addition, they adopt “energy-saving behavior,” setting the temperature to 20 °C when the heating system is operating, and the rooms are occupied.

These two cases were simulated according to three different building characteristics. “No retrofit” applies when no physical intervention to the building elements is foreseen. “Limited retrofit” foresees the replacement of the single-glass windows with double-glass windows and the insulation of the roof. “Total retrofit” is the deepest level of retrofit considered, when all the external elements are renovated, and the building is completely retrofitted. The heat transmission values (U) considered are the minimum requirements for the renovation of the existing buildings in the municipality of Bologna, according to the regional regulation (Regione Emilia-Romagna 2015).

The building energy simulations and occupant behavior model previously presented and already applied by Santangelo et al. (2018) to get results on energy behavior at building scale, provide also significant results at dwelling scale. These results involving dwellings with different characteristics have not been studied before; therefore, they are taken into consideration in this research to give a novel contribution about the role of occupant behavior in tackling energy poverty, an issue that has recently received attention also from other scholars (Kearns et al. 2019; Della Valle 2019).

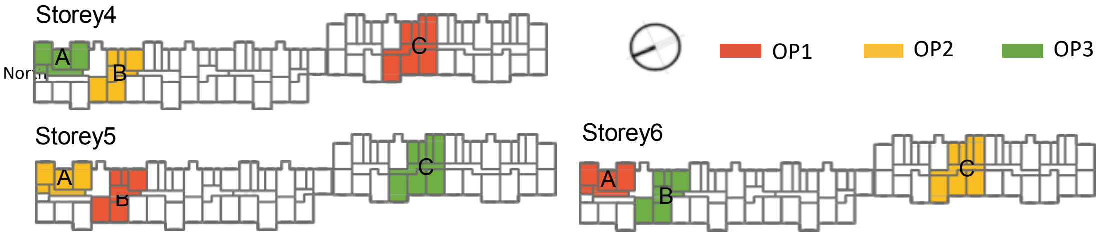

**Fig. 1** Housing units and occupancy preferences distribution. *Source* author's elaboration.

Three levels of renovation have been considered to check whether the variations among the dwelling occupancy and types of dwelling remain stable or not as the energy efficiency of the dwelling changes.

Three different dwelling sizes have been considered. They are located in mid-stories (i.e., fourth, fifth, and sixth stories) to limit the influences of the heating loads due to the poor thermal properties of floors and roofs. Housing unit A is the smallest among the ones considered: The total net size is 65 $m^2$ with one bedroom, kitchen, living room, bathroom, and a corridor. It faces north and east at the building corner, with two external walls, and one of the internal walls next to the building staircase. The occupancy preference is foreseen to vary among the different stories, and therefore, OP1 is assigned to housing unit A at story 6 and OP2 at story 5, while it is OP3 at story 4 (Fig. 1). Housing unit B is located on the opposite side of the staircase: It is 79 $m^2$ in area, and it has two bedrooms, kitchen, living room, bathroom, and a corridor. The kitchen and one of the bedrooms face east, while the living room and the other bedroom face west. OP1 is allocated to housing unit B at story 5, OP2 at story 4 and OP2 at story 6. The final dwelling considered, housing unit C, has an area of 99 $m^2$, with one more bathroom and bedroom than housing unit B. It is an internal unit with only two external walls facing east and west, while internal walls border on the one side the staircase and on the other side a specular housing unit.

## 3 Results

Table 1 shows the heating load simulation results according to the different housing units and different occupancy preferences, also taking into consideration the building retrofit level. Similarly to what resulted from the investigation at building scale (Santangelo et al. 2018), the analysis at dwelling scale confirms that the more energy efficient the dwelling is, the greater is the share of the energy consumption that occupant behavior can affect: up to 52% of energy reduction for housing unit B with occupancy preference OP3 (i.e., "back home in the afternoon" with the heating system at the maximum preferred temperature for 8 h per day) in the case of total retrofit. However, the no-retrofit scenario shows the highest potential for occupants to decrease the dwelling heating load in absolute terms: up to 818 kWh/year of reduction for housing unit A with OP3 by adopting an energy saver behavior, with full control and a dual set-point.

**Table 1** Heating load simulations related to types of dwelling and occupancy preferences (OPs) for the three levels of renovations.

| | No control (Case 1) | | Full control, dual set-point (Case 2) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | OP1 (14 h) | | OP2 (11 h) | | OP3 (8 h) | |
| | kWh/y | kWh/m$^2$y | kWh/y | kWh/m$^2$y | kWh/y | kWh/m$^2$y | kWh/y | kWh/m$^2$y |
| No Retrofit | | | −11–14% | | −12–15% | | −17–21% | |
| Housing unit A | 4244 | 65.3 | 3779 | 58.1 | 3748 | 57.7 | 3426 | 52.7 |
| Housing unit B | 3667 | 46.4 | 3167 | 40.1 | 3120 | 39.5 | 2891 | 36.6 |
| Housing unit C | 4709 | 47.6 | 4184 | 42.3 | 4157 | 42.0 | 3896 | 39.4 |
| Limited Retrofit | | | −15–23% | | −16–24% | | −23–29% | |
| Housing unit A | 2241 | 34.5 | 1912 | 29.4 | 1886 | 29.0 | 1715 | 26.4 |
| Housing unit B | 1036 | 13.1 | 794 | 10.1 | 786 | 9.9 | 739 | 9.4 |
| Housing unit C | 1558 | 15.7 | 1252 | 12.6 | 1213 | 12.3 | 1135 | 11.5 |
| Total Retrofit | | | −31–51% | | −35–51% | | −39–52% | |
| Housing unit A | 356 | 5.5 | 247 | 3.8 | 232 | 3.6 | 217 | 3.3 |
| Housing unit B | 305 | 3.9 | 148 | 1.9 | 148 | 1.9 | 146 | 1.8 |
| Housing unit C | 311 | 3.1 | 208 | 2.1 | 200 | 2.0 | 178 | 1.8 |

As expected, results also show that the higher the exposure to external conditions due to the location at the building corner, the higher is the heating load per square meter yearly. In fact, housing unit A can require more energy than larger dwellings such as housing units B and C, with the same building- component thermal proprieties, but located in a more favorable position within the building. In case of a limited retrofit, the simulated heating load for housing unit A is 2.2 times higher than the one for housing unit B, and 2.6 times more than the one for housing unit C.

The occupancy preferences play also a role in the definition of the dwelling energy demand. Regardless of the retrofit level of the dwelling, there is a common tendency for an energy demand decrease as the number of hours the heating system is operating decreases. Taking into account Case 2, where households adopt an energy saver behavior compared to Case 1, results show that, in the case where no retrofit occurs, the energy reduction is in the range of 11–14% for OP1, 12–15% for OP2, and 17–21% for OP3, depending on the housing unit considered. Energy savings increase as the energy efficiency of dwellings increases. Therefore, they are in the range of 15–23% for OP1, 16–24% for OP2, and 23–29% for OP3 when the limited retrofit occurs; and 31–51% for OP1, 35–51% for OP2, and 39–52% for OP3 when the dwellings are totally retrofitted. However, for all the three retrofit levels and all the dwellings considered, less time spent at home with the heating system on generates higher energy savings.

When it comes to the rebound effect identification, the investigation at dwelling level shows that it can be even higher than the one identified with heating load simulations at building level as presented in Santangelo et al. (2018). In fact, if occupants just decide to change the thermostat from 20 °C in the day-zone and 18 °C in bedrooms when occupied to 22 °C in all rooms for the maximum working hours of the heating system (i.e., from Case 2 to Case 1), then the consumption increases, and the rebound effect reaches up to 23%, 29% and 27%, respectively, for limited retrofits of housing unit A, B, and C. When the total retrofit occurs, the rebound effect can increase further up to 39%, 52%, and 43%, respectively, for housing unit A, B, and C, in comparison with the expected consumption after the renovation.

## 4 Discussion

Occupant behavior modeling is an effective tool to make explicit the impact of the human factor on the energy saving potential. It also enables quantifying the impact of the rebound effect in case of a building retrofit, as well as the impact of "green behavior" (Ben and Steemers 2014) when positive behavioral changes occurs. The findings at dwelling level show that impact of occupant behavior can reach up to 52% of energy savings for the case study considered. As for the analysis at building scale (Santangelo et al. 2018), this impact increases as the retrofit level increases in terms of percentage on the total heating consumption, while the energy savings due to behavior change decreases as the retrofit level increases. Despite that the results are not surprising, they deserve to be outlined since they show variance in the energy saving potential of different households living in different dwellings. Therefore, it is of key importance to understand a household's saving potential in relation to the dwelling characteristics they lived in and to avoid "blaming the victim" (Stevenson and Leaman 2010), especially in the public housing sector where the random allocation of dwellings generates inequalities in energy costs and energy poverty conditions. Indeed, considering three different dwellings that have in turn different occupancy preferences (OPs) shows that, income and energy poverty conditions being equal, people living in public housing units experience differences in energy demands and, therefore, in energy bills. This is evident not only for households living in dwellings located in buildings with different characteristics, but also for those living in the same multi-family building but on different floors and in different apartments.

Due to the fact that public housing is allocated according to the income level and the house- hold size, but not the housing unit characteristics, and the social rent is calculated mainly according to the income rather than the energy efficiency of the dwellings, inequalities among low-income families might be exacerbated. Therefore, strategies addressing energy poverty should take into account the challenges linked to the allocation system and the rent calculation system.

When limited resources are available, investing in tackling behavior change through information provision and education, rather than building retrofit, has resulted in a convenient strategy to implement energy efficiency while addressing energy poverty. However, as soon as other funds become available, it is important to combine informative and feedback strategies with the renovation of the building. While the former affects the energy consumption and, in turn, energy poverty, the latter has the potential to lead to higher energy savings. Especially for those dwellings located on the first or top floor, any retrofit could improve the household energy poverty situation considerably more than in the other cases, while the influence of the household behavior might be more limited. The combination of informative strategies and retrofit solutions should be considered the most favorable option, one the one hand, to maximize energy saving and on the other hand to avoid overestimations of the saving potential of retrofitting solutions due to underestimations of the occupant behavior impact (Santangelo and Tondelli 2018). Moreover, the combination of such measures is expected to reduce both the gap between expected and actual heating consumption and the rebound effect. However, as pointed out by Della Valle (2019), these measures implicitly rely on the rational choice model of decision making, while extensive evidence has shown that the capacity to make rational decisions depends on situational factors that should be studied by applying behavioral economics. In addition to this, it should be noted that, although the rebound effect—as the offset of the beneficial effects of energy retrofitting—increases when the energy efficiency of buildings increase, the building retrofit may alone reduce the energy savings gained thanks to a greener behavior due to the higher impact of retrofit solutions on energy saving compared to the ones addressing behavior only.

Even more than the Jevons' paradox (Alcott 2005) explaining the rise of quantity demanded although the promotion of different types of measures should result in higher energy efficiency and saving, it is actually the prebound effect that is the one more closely linked to energy poverty. It can be framed as households using less energy than foreseen due to an energy poverty condition and low awareness of the use of energy efficient technology. The prebound effect can to some extent explain the reason why public housing providers are reluctant to implement behavior change strategies, or to involve Energy Service Companies (ESCo) in the renovation of the public housing stock, since there is a limited knowledge on how to deal with people experiencing energy poverty conditions. To this aim, more effort has to be invested to show that the prebound effect and energy poverty condition are interlinked with housing policies and housing-welfare strategies. In fact, in order to both ensure equality among public housing tenants, and to tackle energy poverty, housing policies cannot be seen as apart from the energy performance of the housing stock.

Other measures related to the housing sphere (e.g., rent re-calculation according to the energy demand of the housing unit), as well as involving health, education or transport services should be considered. Any single solution cannot address a multi-faceted issue such as energy poverty.

## 5 Conclusions and Policy Implications

This research has contributed to show that occupant behavior is worth being investigated when it comes to energy poverty. In the case of the Italian public housing sector—which is allocated to low-income households matching certain characteristics—when the income and family size are equal, households living in dwellings with different physical and thermal characteristics experience differences in energy bills. This situation creates inequalities that can lead to the exacerbation of energy poverty conditions, and, therefore, they need to be taken into account by municipalities.

Energy poverty policies should embed household behavior in their considerations as a driver to alleviate the energy poverty conditions, in particular, in the absence or scarcity of structural policies. Among the types of policy instruments widely used in Europe to tackle energy poverty (Kyprianou et al. 2019), energy savings measures—including energy efficiency and renewable energy sources—and information provision should both include references and specific measures to address behavior and mitigate energy poverty.

The extreme fragmentation of the housing demand, the increasing energy poverty of tenants living in public buildings, the overall decline of public spending on the housing sector and the aging of the building stock are only some of the elements describing the Italian housing issue that need to be tackled when structuring strategies to alleviate energy poverty. New conceptual and methodological advancements are needed in order to tackle the housing issue, where the provision of information, awareness raising and new skills can be the drivers not only of the renovation of the public housing stock, but also for a new housing policy based on providing housing as a service, rather than just an asset.

Embedding the energy poverty issue into the ones driving the decision to renovate the housing stock can enhance social sustainability and livability in cities. Urban planning and energy-led regeneration strategies are increasingly seeking criteria to renovate the existing housing stock, where the energy saving is only one of the benefits that cities aim at achieving. The Covenant of Mayor is certainly pushing the transition of cities toward agents for the reduction of energy poverty. However, more research in the field of urban policies and urban planning is needed in order to understand how to integrate energy poverty measures into the city planning systems.

**Acknowledgements** The authors of this paper received funding from the EU–China “IRES-8” Mobility Project under EU Contract Number No. ICI+ /2014/347-910. The contents reflect only the authors’ view, and the European Union is not liable for any use that may be made of the information contained therein.

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