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Energy behaviour-driven strategies for the effective renovation of the public housing stock

Presentata da: Ing. Angela Santangelo

Coordinatore Dottorato
Prof. Arch. Annalisa Trentin

Supervisore
Prof. Ing. Simona Tondelli

Co-supervisore
Prof. Arch. Annarita Ferrante

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Abstract

ENGLISH ABSTRACT

Energy efficiency through building renovation and urban regeneration is a major challenge both in EU and in the Italian context, where building renovation can be considered as one of the strategies to achieve city regeneration, due to the fact that the built environment is embedded in all the four categories of urban features (i.e. physical, functional, geographical, socio-economic) or subsystems influencing energy consumption and CO_2 emissions, as classified by scholars investigating the multidimensional relationship between cities and energy consumption in urban planning studies.

Despite the effort in promoting lower energy consumption in buildings, the visionary energy efficiency goals set at EU level are far to be met both for new and renovated buildings. The gap between expected and actual energy consumption, together with the impact of occupant behaviour on building energy use, have been increasingly studied by scholars. Occupant behaviour has been found to be crucial in actual energy consumption, accounting for as much as 50% of the variance in heating consumption. Indeed, energy savings through behavioural factors can be as high as those from technological ones, thus giving to the occupants the possibility either to reinforce the savings from energy efficiency measures, or to waste them. Building regulations on energy consumption are formulated based on building and system characteristics and they make assumptions of occupant behaviour paradigm as static and deterministic, ignoring the fact that, during the operational phase, are people who use energy, not the building as such.

The overall aim of the research is to contribute promoting urban regeneration through the energy renovation of residential buildings. The goal is to show, on the one side, the relevance of the occupant behaviour, at present seldomly included in the consideration of the measures to be adopted to renovate the buildings; on the other side, the relationship among stakeholders involved in the renovation process, in order to suggest new measures to improve the effectiveness of the process. The specific aim is to assess the impact of household energy behaviour on energy-related policies and practices tailored at reducing the energy consumption and at increasing the energy efficiency of buildings. The outcomes shall support decision-makers, planners and stakeholders to design and implement energy policy instruments and strategies to regenerate the existing built environment, with a focus on the residential sector.

Despite the size of the public housing stock in Italy, which account for only 3.7% of the total housing stock, due to the favourable situation of public housing providers, having an exclusive role in building management, and similar regional regulations and procedures to comply with, the public housing sector is considered as the case study for this research. When it comes to building renovation, demonstrating the relevance of including measures to tackle household energy behaviour prior in public buildings than in the other housing stock is believe to lead to a multiplier effect, also considering that about half of the total Italian housing stock consists of multi-family buildings, by far the most building typology used for public housing stock, and they urgently need to be renovated.

The general approach of this research tries to combine the review of the current state of scientific literature of the thematic field with the practical application and evaluation of a case study experience.

A multi-method approach to data collection is used, applying both qualitative research methods such as content analysis and surveys, and quantitative research methods such as statistical analysis, sensitivity analysis and simulation tools to assess the energy consumption-related human factor and to determine multiple scenarios to support decision-makers towards the implementation of effective strategies.
Chapter 2, 3 and 5 make an extensive use of literature review as main methods to investigate energy behaviour models in all the most relevant disciplines dealing with behavioural studies, the policy frameworks, the determinants of household energy behaviour, the strategies to promote behavioural change and the main characteristics of the Italian public housing stock in terms of roles and responsibilities. Chapter 4 presents two micro-level approaches to the topic, applying, on the one side, quantitative research methods as statistical analysis on the census data, and on the other side, qualitative research method for the analysis of the questionnaires resulting from the survey. Chapter 6 applies building energy simulation to investigate the impact of behaviour and to build scenarios to inform decision-makers, while in Chapter 7 a multi-criteria decision-making tool is adopted to make evidence of the behaviour-related improvements in the framework of housing renovation strategies, and to then suggest new solutions to improve them.

ABSTRACT IN ITALIANO

L'efficienza energetica attraverso la riqualificazione degli edifici e la rigenerazione urbana può essere considerata tra le sfide più importanti del presente, sia in ambito europeo che nel contesto italiano. La riqualificazione del costruito si può infatti considerare come una delle strategie per mettere in pratica la rigenerazione delle città, dal momento che l'ambiente costruito è incorporato in tutte e quattro le categorie che classificano le caratteristiche urbane (fisiche, funzionali, geografiche, socio-economiche) o sottosistemi, che influenzano il consumo di energia e le emissioni di CO_2, come evidenziato da studi urbanistici sulla relazione multidimensionale tra città e consumo di energia.
Nonostante gli sforzi per promuovere un minore consumo di energia negli edifici, gli ambiziosi obiettivi di efficienza energetica stabiliti a livello UE sono al momento inattesi, sia per quanto riguarda l'efficienza di nuovi edifici, sia per la riqualificazione degli esistenti. Il divario tra consumo energetico atteso e reale, insieme all'impatto del comportamento degli occupanti sull'uso dell'energia negli edifici, sono due temi di crescente interesse. Studi dimostrano come il comportamento degli occupanti sia cruciale nel determinare i livelli di consumo energetico, rappresentando fino al 50% della varianza nel caso del riscaldamento invernale. Il risparmio energetico legato al comportamento può essere significativo quanto quello derivante dalla tecnologia, dando così agli occupanti l'opportunità di rafforzare i risparmi dalle misure di efficienza energetica o di sprecarli. Le norme sul consumo energetico degli edifici richiedono prestazioni basate sulle caratteristiche costruttive e impiantistiche, ipotizzando il comportamento degli utenti come statico e deterministico, ignorando di fatto che, durante la fase operativa, sono le persone a consumare effettivamente energia.
L'obiettivo generale della ricerca è quello di contribuire alla promozione di processi efficienti di rigenerazione urbana attraverso il retrofit degli edifici residenziali. L'obiettivo è mostrare, da un lato, la rilevanza del comportamento degli occupanti, attualmente raramente incluso nelle considerazioni sulle misure da adottare per la riqualificazione degli edifici; d'altra parte, la relazione tra gli attori coinvolti nel processo di riqualificazione, al fine di suggerire nuove misure per migliorarne l'efficacia. L'obiettivo

specifico è quindi quello di valutare l'impatto del comportamento energetico delle famiglie sulle politiche e le pratiche energetiche per ridurre il consumo di energia e aumentare l'efficienza energetica degli edifici. I risultati sono pensati per supportare i decisori, i pianificatori e le parti interessate a progettare e attuare strumenti e strategie per rigenerare l'ambiente costruito, con particolare attenzione al settore residenziale.

Nonostante le esigue dimensioni dello stock abitativo pubblico (circa il 3,7% del totale degli alloggi), caratteristiche irripetibili quali la proprietà unica degli alloggi, la natura pubblica del soggetto gestore e le analogie tra le normative e procedure regionali, fanno si che il settore dell'edilizia residenziale pubblica (ERP) sia assunto come caso di studio privilegiato per questa ricerca. Dimostrare l'importanza di includere le misure per affrontare il comportamento energetico delle famiglie nelle strategie e pratiche di riqualificazione, prima negli edifici pubblici che negli altri alloggi di proprietà privata, può portare ad un effetto moltiplicatore, anche considerando che la metà circa delle abitazioni italiane è costituita da edifici plurifamiliari, di gran lunga la tipologia edilizia più utilizzata per l'ERP, ed è un patrimonio che necessita urgentemente di essere rinnovato.

L'approccio generale di questa ricerca mira a combinare l'analisi della letteratura esistente con l'applicazione pratica e la valutazione di un caso di studio. La raccolta dei dati è effettuata applicando sia metodi di ricerca qualitativi che metodi di ricerca quantitativi come analisi statistiche, analisi della sensibilità e strumenti di simulazione per valutare il fattore umano relativo al consumo di energia e per determinare molteplici scenari per supportare i decisori locali nell'attuazione di strategie efficaci.

I capitoli 2 e 3 e 5 fanno ampio uso della revisione della letteratura esistente come principale metodo per studiare rispettivamente: i modelli di comportamento energetico secondo le principali discipline e le determinanti del comportamento (capitolo 3); le strategie esistenti per incentivare un cambio di paradigma nel comportamento, secondo diversi livelli territoriali di governance (capitolo 2); e le principali caratteristiche del patrimonio immobiliare italiano in termini di ruoli e responsabilità (capitolo 5). Il capitolo 4 presenta due diversi approcci di micro-livello all'argomento, utilizzando sia metodi di ricerca quantitativi come le analisi statistiche sui dati statistici, che metodi di ricerca qualitativa per l'analisi dei questionari. Il capitolo 6 applica la simulazione energetica degli edifici allo studio dell'impatto del comportamento al fine di costruire scenari per supportare i decisori locali nelle loro scelte. Infine, nel capitolo 7 vengono illustrati i risultati di un'analisi multi-criterio per determinare l'impatto degli utenti sulle strategie per il risparmio energetico, per arrivare a formulare nuove proposte per considerare il comportamento degli utenti come una misura determinante per l'effettiva riduzione dei consumi energetici in ambito residenziale e per restituire qualità alle città.

Glossary

Building renovation

Actions to retrofit, restore, rehabilitate, and renovate the existing stock, aiming at improving the energy efficiency of the buildings.

Consumer behaviour

Set of activities that prospective customers undertake in searching, selecting, valuing, assessing, supplying and using of products and services in order to satisfy their needs and desires. It is a process which includes the issues that influence the consumer before, during and after a purchase or action. To the aim of the dissertation, consumer behaviour, user behaviour and occupant behaviour have been used indifferently.

Energy behaviour

All human actions that affect the way that fuels (e.g. electricity, gas, petroleum) are used to achieve desired services, including the acquisition or disposal of energy-related technologies and materials, the ways in which are used, and the mental processes related to these actions.

Energy poverty

Energy poverty, also known as fuel poverty, is often defined as a situation where households cannot access to and afford adequate level of heating or other required energy services to meet their basic needs, or they cannot afford other necessary goods due to the high utility costs. It is a growing phenomenon in European Union, with more than 150 million people with more of 10% of their annual income spent on energy services.

Energy Service Company (ESCo)

For-profit or non-profit organisation specialised in providing a range of energy services to their clients. It promotes energy efficiency and water consumption reduction on the premises of their customers. The building occupants then benefit from the energy savings and pay a fee to the ESCo (e.g. usually a higher energy bill than actual consumption, but still lower than the one prior renovation) for the whole payback period.

Occupant behaviour

Observable actions or reactions of a person in response to external or internal stimuli, or respectively actions or reactions of a person to adapt to ambient environmental conditions such as temperature, indoor air quality or sunlight.

Policy instrument

Tool used by government/public authorities in local, national or international context to pursue a desired outcome. Throughout the dissertation it is used to refer to different tools (e.g. energy policy or strategy, urban planning tool, building regulation tool, informational campaign).

Prebound effect

Households using less energy than foreseen due to energy poverty condition and low awareness of energy efficiency technology use.

Pro-environmental behaviour

Intentional behaviour that harms the environment as little as possible, or reduces the environmental impact relative to comparable behaviours.

Prosumer

Active energy consumer who both consumes and produces energy from microgeneration.

Public housing

Housing stock publicly owned for households whose needs are not met by the market and where there are rules for allocating housing to benefiting households, paying a rent far below the market one. Throughout the dissertation, it is considered as a subset of the social housing.

Rebound effect

Increase in household energy consumption as a consequence of paying less attention to the energy-related behaviour after the energy measures implementation, since there is a general belief that the increase of energy efficiency in buildings should automatically be translated into a decrease of consumption, no matter the level of usage and behaviour.

Social housing

Throughout the dissertation, it is considered as an asset mostly coincident with the public housing, for households whose needs are not met by the market and where there are rules for allocating housing to benefiting households, paying a rent far below the market one. To clarify the ambiguity around the Italian terms for public housing *(Edilizia Residenziale Pubblica)* and for social housing *(Edilizia Residenziale Sociale)* is out of the scope of this research, which considers the term social housing with the meaning generally recognised at EU level.

Urban regeneration

Urban regeneration is considered throughout the dissertation as a set of regeneration actions, policies and processes with a city, district or neighbourhood scale addressing interrelated technical, spatial and socio-economic issues towards the reduction of environmental impact, mitigation of environmental risk and improvement of environmental quality of urban systems, lifestyles and assets.

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1. Introduction

ENGLISH ABSTRACT

Energy efficiency through building renovation and urban regeneration is a major challenge both in EU and in the Italian context, where building renovation can be considered as one of the strategies to achieve city regeneration, due to the fact that the built environment is embedded in all subsystems influencing energy consumption and CO_2 emissions. Despite the effort in promoting lower energy consumption in buildings, the visionary energy efficiency goals set at EU level are far to be met. One of the causes explaining this gap is occupant behaviour, that has been found to be crucial in actual energy consumption, since energy savings through behavioural factors are as high as those from technological ones. The overall aim of the research is to contribute at promoting effective urban regeneration processes through energy renovation of residential buildings. The specific aim of the dissertation is twofold: on the one hand, to demonstrate to what extent understanding the impact of the human factor on energy efficiency can enhance the effectiveness of housing renovation policies; on the other hand, to show how adopting an urban policy perspective of occupant behaviour topic can bring new knowledge on the role policy-makers should play to support behavioural change towards a more sustainable energy consumption paradigm. The general approach of this research tries to combine the review of the current state of scientific literature of the thematic field with the practical application and evaluation of a case study experience.

ABSTRACT IN ITALIANO

L'efficienza energetica attraverso la riqualificazione degli edifici e la rigenerazione urbana può essere considerata tra le sfide più importanti del presente, sia in ambito europeo che nel contesto italiano. La riqualificazione del costruito si può infatti considerare come una delle strategie per mettere in pratica la rigenerazione delle città, dal momento che l'ambiente costruito è incorporato in tutte le caratteristiche urbane che influenzano il consumo di energia e le emissioni di CO_2. Nonostante gli sforzi per promuovere un minore consumo di energia negli edifici, gli ambiziosi obiettivi di efficienza energetica fissati a livello UE sono al momento inattesi. Una delle ragioni di questo divario è il comportamento degli utenti, che è stato dimostrato essere significativo nel determinare gli effettivi consumi energetici tanto quanto la componente tecnologica.

L'obiettivo generale della ricerca è quello di contribuire alla promozione di processi efficienti di rigenerazione urbana attraverso il retrofit degli edifici residenziali. L'obiettivo specifico è duplice: da un lato, dimostrare la rilevanza dell'impatto del fattore umano sull'efficienza energetica; dall'altro, dimostrare come il punto di vista delle politiche urbane sulla tematica del comportamento degli occupanti possa portare ad una nuova conoscenza sul ruolo dei responsabili politici nel supportare un cambio nel comportamento energetico degli utenti, verso un paradigma di consumo maggiormente sostenibile. L'approccio generale di questa ricerca mira a combinare l'analisi della letteratura esistente con l'applicazione pratica e la valutazione di un caso di studio.

Nowadays, the urban environment is considered to be a key player in the management of climate change related issues. Urban sprawl, over-consumption of energy, release of CO_2 emissions, deployment of natural resources, dependency from fossil fuels and waste production are among the main concerns of public authorities managing the public goods, increasingly looking for more effective ways to implement sustainable development without deploying the natural resources.
In terms of size, cities occupy only 2% of the world's land (Timothy 2003). However, in terms of climate impact, they are responsible of a far bigger footprint. Cities consume over two-thirds of the world's energy and account for more than 70% of global CO_2 emissions. When it comes to Europe, hosting more than 75% of the European population, cities have a prominent role in the mitigation and adaptation processes to climate change. Therefore, improving energy efficiency in all sectors has been a major concern in the European context.
In order to pursue together social, economic and environmental goals, energy-related issues should be embedded within the urban planning process (Gargiulo and Russo 2018). Local authorities, responsible for implementing urban planning tools and strategies, are the one able to lead to the urban transformations required to face climate change and energy efficiency challenges (La Greca and Martinico 2016; La Greca and Tira 2017). To this aim, innovative spatial and urban planning methods and procedures are required, as well as new approaches and instruments must be elaborated to shift from the building scale to the urban and territorial ones (Zanon and Verones 2013; Tira et al 2017).

Besides being a multi-scale issue, facing energy and climate challenges is a horizontal priority for different sectors and societal domains (Papa et al. 2016). Among them, the key role of the building sector has been clearly recognised in energy consumption and environmental impact. Worldwide, the residential sector consumes an amount of energy that varies between 16% and 50% of the total, depending on the country (Filippidou et al. 2016). In the European Union, buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions. The residential sector, with the 75% of the total energy consumption in buildings, is an important target area for energy reduction. There is a considerable potential for energy savings in heating and cooling that remains largely untapped. Today, at global level, heating and cooling in buildings and industry account for approximately 40% of final energy consumption — which is a larger share than transportation (27%) (IEA 2017).

Thanks to the energy performance regulations at EU level and at country level, residential buildings have incrementally improved in terms of their energy efficiency during the last decade. In particular, looking at the residential sector, the improvement has mainly been achieved thanks to the construction of new and more efficient buildings. So far, technology innovation, buildings and construction research and development sectors have focused on passive and low to zero energy housing. However, about 75% of the residential buildings that will constitute the European housing stock in 2050 have already been built today (Visscher et al. 2016), therefore, the renovation[1] of the existing housing stock is a fundamental step in the path to achieve the EU targets.

The urgency to renovate the existing buildings is also embedded in the new EU Directive 2018/844 amending Directive 2010/31/EU on the Energy Performance of Buildings (EPBD) and Directive 2012/27/EU on Energy Efficiency (EED), requiring Member States to establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, facilitating the cost-effective transformation of existing stock into nearly zero-energy buildings (European Commission 2018).

While the EPBD sets minimum energy performance requirements for all the buildings that undergo major renovations, Article 5 of the EED sets a binding renovation target for public buildings and imposes related obligations. It also stresses that governments shall undertake an exemplary role in the energy retrofit of their building stock. Article 5 of the EED stipulates that, for each Member State, 3% of the total floor area of heated and/or cooled buildings owned and occupied by central government should be renovated each year to meet at least the minimum energy performance requirements. However, renovation monitoring system is poor and, so far, there are no data to assess if 3% has been reached. Hence, how to boost the renovation of existing building stock and monitor the actual energy savings still represent major challenges.

[1] Similarly to Meijer et al. (Meijer et al. 2009), for the purpose of this work, the term *renovation* is used throughout the research investigation to take into account actions to retrofit, restore, rehabilitate, and renovate the existing housing stock, aiming at improving the energy efficiency of the residential buildings.

1.1 Problem definition

With 70% of Europe's 2050 housing stock already built, urban regeneration represents the key strategy to cope with the increasing demand of integrating sustainability principles in everyday life. Energy can be considered to be a prominent driver to address urban regeneration (Gargiulo and Lombardi 2016).

Due to the multiple and often divergent interests that characterise the urban environment, to be effectively implemented, urban regeneration requires the adoption of a multilevel governance approach. Multilevel governance has been analysed by Bulkeley and Betsill (2005) in terms of environmental and climate change governance as a possible interpretation of the changing relationships between institutional levels. The involvement of the private sector in the realisation of certain planning goals is strongly related to a very common trend characterised by governments that become less active regulators, and instead turn into facilitators of new developments that are preferably realized by the market (Verones 2013). Nevertheless, when it comes to residential buildings, the fragmentation of housing properties – typical of South-East Europe countries – represents a critical obstacle to the implementation and scalability of regeneration practices. Therefore, social housing associations with their large stock portfolios, either individually or in partnership with others, are the best playground to implement urban regeneration[2] strategies embedding household energy behaviour, both combining interventions to the open space and the built environment.

Despite the effort in promoting lower energy consumption in buildings, the visionary energy efficiency goals set at EU level are far to be met (Steemers and Yun 2009; Majcen et al. 2013; Yan et al. 2015; van den Brom et al. 2018) also for new buildings designed to be energy efficient, either residential buildings, or other buildings.

The gap between expected and actual energy consumption, together with the impact of occupant behaviour on building energy use have been increasingly studied by scholars, as investigated by D'Oca et al. (2018) for the timeframe 2005-2016. Guerra-Santin (2010) found

[2] Coherently with Urbact II programme (Czischke et al. 2015), this work refers to the term urban regeneration as a set of regeneration actions, policies and processes within a city addressing interrelated technical, spatial and socio-economic issues towards the reduction of environmental impact, mitigation of environmental risk and improvement of environmental quality of urban systems, lifestyles and assets.

that the actual energy consumption for heating is half of the expected use in dwellings with low energy efficiency, and the actual energy use is even higher than the one expected in very energy efficient houses. Other researchers have shown that occupants can use three or more times as much energy for heating as their neighbours living in dwellings with similar characteristics (Steemers and Yun 2009; Gram-Hanssen 2010). Majcen et al. (2016) found that the occupant behaviour is crucial in actual energy consumption, accounting for as much as 50% of the variance in heating consumption. Indeed, energy savings through behavioural factors can be as high as those from technological ones (Lopes et al. 2012), thus giving to the occupants the possibility either to reinforce the savings from energy efficiency measures, or to waste them.

Building regulations on energy consumption are formulated basing on building and heating, ventilation and air conditioning (HVAC) system characteristics, and make assumptions of occupant behaviour paradigm as static (Bedir 2017) and deterministic, ignoring the fact that, during the operational phase, they are people who use energy, not the building as such. Thus, building simulation models and energy renovation strategies need to be based on more realistic assumptions to take into account energy behaviour as a dynamic and stochastic variable.

Due to the large share of residential energy use in buildings, most of the research on energy behaviour has been essentially focused on the housing sector. Comfort preferences can vary across households and even across people in the same household. The control of indoor conditions (e.g. ventilation, temperature) could have a strong effect on the interaction between the household and the dwelling. Variations in preferences for comfort and indoor conditions have also been shown to depend on household characteristics and other socio-demographic variables, influencing energy consumption via differences in motivation and attitudes towards energy and environmental conservation. The relation among behavioural determinants is believed to be a key point in the formulation of policies and strategies to lower energy consumption through behavioural change.

Another key issue concerns the monitoring of energy improvements. The difficulty to quantify behaviour has contributed to limit the integration of the human factor in energy efficiency policies and building renovation strategies, with a consequent overconfidence in technology.

The above framed problems make explicit the urgency to tackle household energy behaviour as a prominent issue to effectively achieve the renovation and lower consumption of residential buildings. Many disciplines – from sociology, anthropology, psychology and economy, to building automation, data science, architecture and urban planning – can take part to suggest how to better incorporate the human factor in their core research topics.

The specific aim of the dissertation is twofold: on the one hand, to demonstrate to what extent understanding the impact of the human factor on energy efficiency can enhance the effectiveness of housing renovation policies; on the other hand, to show how adopting an urban policy perspective of occupant behaviour topic can bring new knowledge on the role policy-makers should play to support behavioural change towards a more sustainable energy consumption paradigm. This requires long term involvement of every stakeholder, including the final users, in developing policy, measures, technologies, and monitoring schemes.

1.1.1 A focus on Italy and on public housing

Increasing the rate at which existing buildings are renovated to at least 2% for private sector and 3% for public sector per year until 2030 is a key objective of the EU's Resource Efficiency agenda. However, figures for Italy resulted from a study commissioned by the European Parliament (Artola et al. 2016) show a current renovation rate below 1% of the total building stock, which confirms the data of the Buildings Performance Institute Europe (BPIE 2013).

Energy efficiency through building renovation and urban regeneration is a major challenge both in EU and in the Italian context, where building renovation can be considered as one of the strategies to achieve city regeneration, due to the fact that the built environment is embedded in all the four categories of urban features (i.e. physical, functional, geographical, socio-economic features) (Gargiulo and Russo 2017, 2018) or subsystems (Papa et al. 1995), influencing energy consumption and CO_2 emissions, as classified by scholars investigating the multidimensional relationship between cities and energy consumption.

In 2013, household energy consumption accounted for nearly 25% of the total Italian energy consumption (ENEA 2015). A significant amount of it – around the 70% – was due to space heating (Odyssee-Mure 2015). In the same year, the overall energy costs accounted for 42 billion euro, with an average cost of 1,635 euro per household (ISTAT 2014).

When it comes to the housing stock tenure, home ownership is by far the most common tenure in Italy, with more than 72% of households who own their houses (Pittini et al. 2017). Social rental housing accounts for 3.7% of the total housing stock (Pittini et al. 2017). The great majority refers to public housing for rent, managed by more than 100 public housing associations, which are responsible for the allocation and maintenance, while the dwellings are mainly owned by the municipalities, and they have to comply with regional norms and regulations. Housing cooperatives and most recently foundations have also been involved in social rental housing provision. So far, regulations and incentive schemes have failed to encourage home-owners to undertake deep renovation, in particular in case of multi-dwelling buildings where the propriety is fragmented and the decision to renovate has to be agreed among all the owners. While in the owner-occupied sector cost-savings are expected somehow to be the main stimulus for building energy-efficient renovation, the interventions within the social housing stock not only have an energy-saving value, but also enhance the role of energy efficiency in combination with the social and economic co-benefits (e.g. poverty alleviation, health improvements), thus contributing to avoid stigmatisation, social segregation and to reduce fuel poverty (Santangelo and Tondelli 2017a).

The involvement of Energy Service Companies (ESCos) for the energy renovation of the housing stock through the sign of an Energy Performance Contract (EPC) has been experimented in the Italian public housing context (Santangelo and Tondelli 2017a), due to the lack of public funds, that push public authorities to increasingly look for building public-private partnerships to renovate their building stock. The ESCos provide to the public housing providers and the municipality the technical and financial services needed for energy efficiency projects (i.e. implement a customised energy service package, consisting of – among others – planning, building, operation and maintenance). However, the uncertainness related to the occupant behaviour has limited this application, since the payback period is strongly related to the consumption patterns (Proli et al. 2016; Santangelo and Tondelli 2017a), and long payback periods make the investments unattractive. In addition, ethic issues have raised when the model is applied to the public housing sector (Santangelo and Tondelli 2017b), since the allocation of dwellings to low-income occupants is currently not taking into account the energy demand of the dwellings.

Despite the limited size of the public stock, due to the favourable situation of public housing providers having an exclusive role in public housing stock management, and the similarities in the regional regulations and procedures among providers, the public housing sector is selected as a case study for this research. Moreover, it has been chosen as the building typology is representative not only of the Italian public residential stock, but also of the Italian housing sector in general, considering that about half of the total housing stock consists of apartments. Due to the high percentage of housing units in multi-family buildings, the analysis of the impact of occupant behaviour for the reference building, as described in Chapter 6, can lead to a wide replicability of the method to more than a half of the Italian housing stock.

Public housing, social housing and housing policies have always been studied by urban planning as ways to achieve sustainability in cities. Demonstrating, prior in public buildings than in the other housing stock, the relations among stakeholders to implement energy renovation, and the relevance of household energy behaviour to effectively reduce energy consumption in buildings, could lead to a multiplier effect. Behaviour is more likely to be deliberately considered and changed when a discontinuity occurs in the household context (Huebner et al. 2013). Therefore, building renovation programmes are the key opportunity to involve households in order to make them reconsidering their consumption practices. However, pro-environmental behaviour is likely to be considered if information and education measures come from credible, trustworthy sources. Thus, the impact of the renovation programmes is closely linked to the relationship between tenants and housing providers.

1.2 Aim of the study

The overall aim of the research is to contribute to the discussion about urban regeneration enhancement through the energy renovation of residential buildings. The goal is to show, on the one side, the relevance of the occupant behaviour, at present seldomly included in the consideration of the measures to be adopted to renovate the buildings; on the other side, it addresses the relationship among stakeholders involved in the renovation process, in order to suggest improvements to increase the process effectiveness.

On the one hand, energy transition takes place on a local level and needs to involve individuals. Looking at the present situation in the realisation of energy projects on a community level (i.e. tenants of public housing buildings), it can be stated that, in the majority of cases, the projects are not integrated into a holistic development strategy. Small- and medium-sized communities often do not follow their own energy development plan but commonly outsource energy supply to external investors and regional or over-regional ESCos (Sager-Klauss 2016). On the other hand, long-term transition processes are well located at the level of urban planning, because by tradition urban planning is focused on the long-term development and not on short-term profit. The aim of this research is, therefore, also to show the role of urban planning in combining multiple approaches that reflect the different discipline methods and priorities, and in translating them into processes able to increase urban quality and liveability.

The specific aim is to assess the impact of the household energy behaviour on energy-related policies and practices tailored at reducing the energy consumption and increase energy efficiency of buildings. The outcomes shall support decision-makers, planners and stakeholders to design and implement energy policy instruments and strategies to regenerate the existing built environment, with a focus on the residential sector, in order to increase urban resilience, quality of urban spaces and quality of life. This requires a better understanding of the complex interactions within actors at local level, and stakeholders to act as learning organisations. The public housing sector is considered, as it is believed to have a leading role in demonstrating the feasibility and benefits of urban regeneration strategies.

1.3 Research questions

In this section, the overall research question is formulated in order to structure the work and to provide different directions for the following chapters. The main research question is stated in the following box:

To what extent understanding the impact of the human factor on energy efficiency can enhance the effectiveness of housing renovation policies?

To frame the possible answer to the overall question, this section introduces the three main research questions and seven sub-questions that have been defined for this study.

The relations between research questions and chapters are presented in Figure 1.1.

Research question 1:

To what extent are both energy behaviour and the role of household energy consumers embedded in current international and EU strategies, energy policies, urban planning policies and other policy instruments addressing energy renovation of the building stock, at different territorial levels?

Sub-questions:

a) Is there any relation between energy renovation, public buildings and user behaviour in the current policy instruments at EU level and at national, regional and local level for Italy?

b) How many approaches are there to understand household energy behaviour and which is the one that suits more for dealing with user behaviour in urban planning?

Research question 2:

How to identify the determinants of occupant behaviour and energy consumption, to understand which are the best strategies to promote pro-environmental behaviour?

Sub-questions:

c) Which are the determinants of energy behaviour in residential sector for heating consumption?

d) Is there any added value in promoting behavioural change at community level rather than at household level?

e) How does public housing sector can have a role in showcasing the path for increasing the renovation rate of residential buildings while addressing awareness on behaviour?

Research question 3:

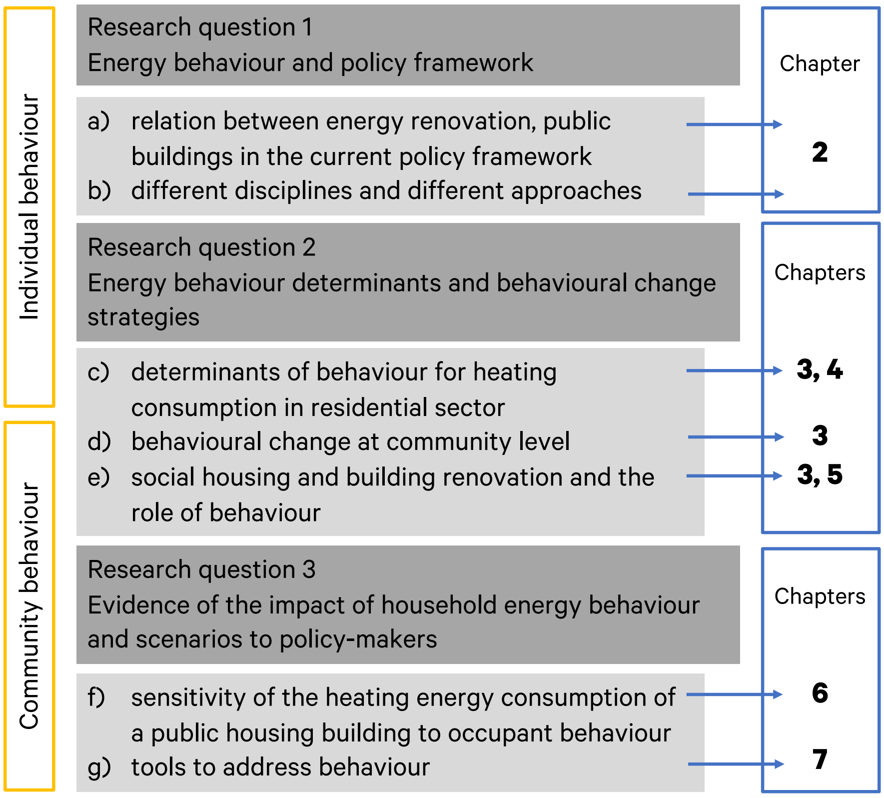
How to make evidence of the impact of household energy behaviour and provide scenarios to support policy-makers in taking decision on the renovation of buildings?

Sub-questions:

f) What is the sensitivity of the heating energy consumption of a public housing building to occupant behaviour?

g) Which tools can be provided to policy-makers to assess user behaviour impact and to promote effective renovation strategies?

Figure 1.1: Relation between research questions and chapters



Source: author's elaboration

1.4 Research approach and methodology

The general approach of this research tries to combine the review of the current state of scientific literature of the thematic field with the practical application and evaluation of a case study experience.

A multi-method approach to data collection is used, applying both qualitative research methods such as content analysis and surveys, and quantitative research methods such as statistical analysis, sensitivity analysis and simulation tools to assess the energy consumption-related human factor and to determine multiple scenarios to support decision-makers towards the implementation of effective renovation strategies.

Chapters 2, 3 and 5 make an extensive use of literature review as main method to investigate energy behaviour models in all the most relevant disciplines dealing with behavioural studies, the policy frameworks, the determinants of household energy behaviour, the strategies to promote behavioural change and the main characteristics of the Italian public housing stock in terms of roles and responsibilities. Chapter 4 presents two micro-level approaches to the topic, applying on the one side, quantitative research methods as statistical analysis on the census data, and on the other side, qualitative research method for the analysis of the questionnaires resulting from the survey. Chapter 6 applies building energy simulation to investigate the impact of behaviour and to build scenarios to inform decision-makers, while in Chapter 7 a multi-criteria decision-making tool is adopted to make evidence of the behaviour-related improvements in the framework of housing renovation strategies, and to then suggest new proposal for policy improvements.

The methods used to answer each research question are explained more in detail in a dedicated section called *Aim and methodology* embedded in each chapter.

1.5 Policy and societal relevance

Nowadays, the urban environment is considered to be a key player in tackling climate change. As such, understanding urban governance is a crucial aspect of understanding cities and their capacity to deal with urban energy issues. The inclusion of the energy considerations into the planning process in order to achieve a better sustainability of urban environment has grown the awareness that spatial and urban planning can be the strategic framework where both mitigation and adaptation measures are positioned in the broader perspective of sustainable development (Verones 2013).

Improving urban planning and design, providing affordable housing and lowering energy consumption are strategic objectives in the current debate on sustainable cities, as the inclusion of such topics in the Habitat III Urban Agenda approved in 2016 by United Nations clearly demonstrates.

The lack of public resources imposes a great challenge for policy-makers, who have to decide to invest only in the most promising and convenient interventions. Therefore, providing them tools able to support their decisions and to show the impact of occupant behaviour to reduce energy consumption in dwellings, and evidence of undertaking measures to inform households and to tackle behavioural change, are fundamental steps to support their decisions.

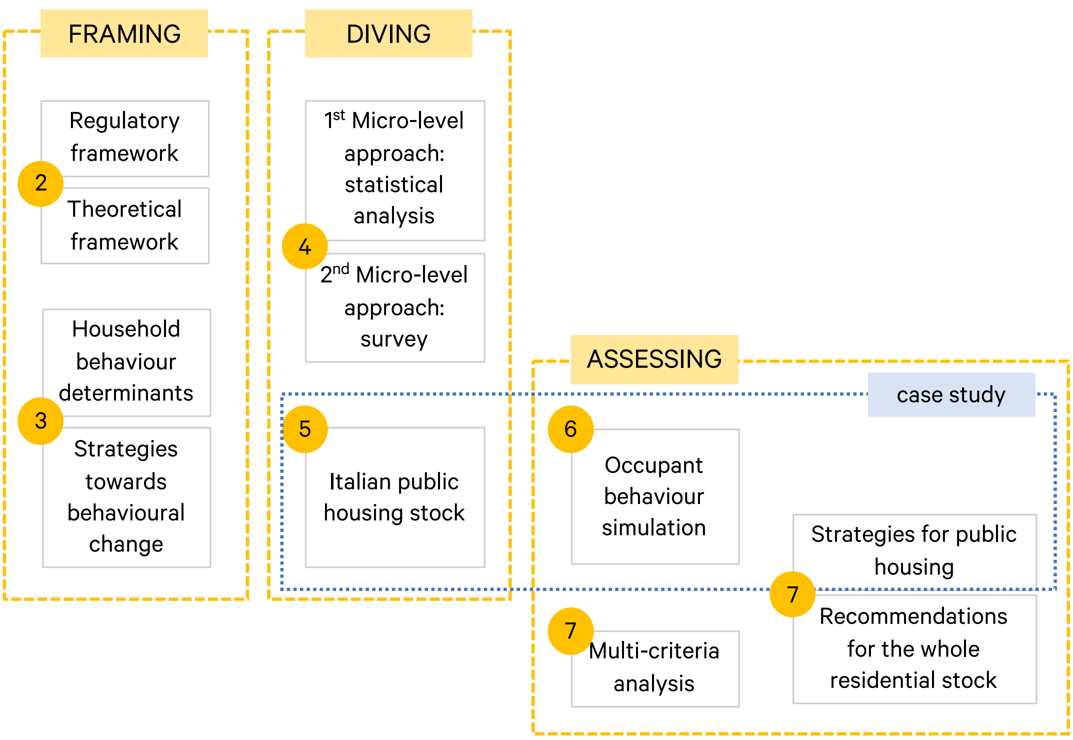
The research aims at contributing to the improvement of energy policy instruments and regulations, as well as providing advices to local authorities, public housing associations, energy companies and all the stakeholders having a part in the building renovation process. By building on this study findings on the impact of household energy behaviour, further research in urban planning and other architectural disciplines could increase the effectiveness of energy renovation measures.

1.6 Structure of the thesis

The dissertation is composed by three main parts as described below and in Figure 1.2.

The first part (framing) is structured in three main chapters, and it is devoted to define the main research questions, to frame the user behaviour in urban planning and energy policies, to investigate the theoretical framework and the main behavioural models applied by different disciplines that focus on the topic, to understand the determinants and existing strategies to address behaviour change.

Figure 1.2: Relation between chapters and main parts



Source: author's elaboration

Chapter 1 focuses on the problem definition, the aim of the research and the related questions, the description of the methodology and the relevance of the research topic.

Consumer behaviour is a key issue in understanding the impact that the society has on the environment. The aim of Chapter 2 is to investigate the policy framework and regulation elaborated at different territorial levels to verify to what extent consumer behaviour, building renovation and urgency to take actions on public buildings are embedded in the energy, urban and sustainable development policies. Sections 2.1 and 2.2 present respectively the introduction and the aim and methodology. Section 2.3 discusses the theoretical framework and models applied by different disciplines investigating the role of behaviour in lowering energy consumption. Section 2.4 provides a policy framework to understand to what extent consumer behaviour is embedded in the existing policy instruments, by considering four different territorial levels. Starting from an overview on international and EU level policy frameworks, the Italian level is further investigated, to check the relevance of the behaviour topic within the national, regional and local energy strategies. The relation between energy renovation and urban regeneration is then explained in section 2.5, while the direction for future research and key research findings are respectively discussed in Sections 2.6 and 2.7.

The central role of consumers for achieving energy saving is increasingly recognised, and it is even more important in the social housing sector, where the environmental value is combined with the social purpose of reducing inequalities and fuel poverty. The aim of Chapter 3 is to identify the determinants of occupant behaviour and energy consumption, and to understand the key success factors that should be embedded in the strategies to promote pro-environmental behaviour. Sections 3.1 and 3.2 present respectively the introduction, and the aim and methodology. Then the contribution examines the determinants of occupant behaviour (Section 3.3), the strategies to promote behaviour changes (Section 3.4), the co-benefits of implementing such actions in community-based programmes and suggestions to do so (Section 3.5). Four initiatives in Europe (i.e. Italy, the Netherlands, Sweden and UK) are further investigated to understand the effects of occupant behavioural change towards lower energy consumption in the social housing sector (Section 3.6). A comparative matrix for the analysis of the four cases is developed to highlight their common characteristics and divergences. Finally, the direction for future research and key research findings are respectively discussed in Sections 3.7 and 3.8.

The second part (diving) is structured in two main chapters, and it is aimed at going deep into two main issues: on the one side, the different approaches to data analysis to investigate the impact of behaviour, according to the data source, the data accuracy and the scope of the investigation; on the other side, the Italian public housing sector, to analyse the main characteristics of the sector, the interrelation among actors operating in the renovation of the public housing stock, and the contribution that understanding the human factor can give to alleviate energy poverty.

Chapter 4 undertakes two investigations in parallel applying two micro-level approaches to understand the impact of consumer behaviour on household energy consumption. The aim is to show the results of two different approaches to data analysis, depending on the availability of data and their accuracy, and their relevance when it comes to gain information to design policy instruments to build energy awareness among households.

Sections 4.1 and 4.2 present respectively the introduction and the aim and methodology. The first micro-level approach is applied in Section 4.3, where statistical data on energy consumption in buildings from the Italian statistical bureau are analysed to identify behavioural characteristics influencing energy consumption. Section 4.4 focuses on the second micro-level approach, where data from a survey conducted in Finland are analysed to get an insight on user behaviour and awareness, and the design of a questionnaire for the Italian case study is presented. The directions for future research and the key research findings are then respectively discussed in Sections 4.5 and 4.6.

The aim of Chapter 5 is to provide an overview of the current state of the public housing sector in Italy, highlighting main characteristics in terms of size, allocation system, tenure, housing quality and explaining the reasons behind the focus on it throughout the dissertation. Sections 5.1 and 5.2 present respectively the introduction and the aim and methodology. Section 5.3 describes, on the one side, the public housing characteristics in terms of sector size, different housing tenures, target groups and quality of the housing stock; on the other side, it presents the renovation policies targeted to the specific sector, and the equality or inequality of the regeneration process. The interrelation among actors and the emerging role of tenants are illustrated in Section 5.4, with the aim of making evidence of the interdependency among the actors and the need to address it, to make the regeneration process successful. The relation between occupant behaviour and energy poverty, and the role of the former to reduce the latter, is the focus of Section 5.5. Direction for future research and key research findings are respectively discussed in Sections 5.6 and 5.7.

The last part (assessing) is structured in two main chapters and it is aimed at assessing the impact of behaviour at different scales, to provide evidence to the policy-makers of the importance of tackling behaviour into account in the design and implementation of the renovation strategies for the existing housing stock.

The aim of Chapter 6 is to explore the role of occupant behaviour modelling in supporting decision-makers dealing with the design of renovation strategies for residential buildings. Sections 6.1 and 6.2 present respectively the introduction and the aim and methodology. An Italian multi-family public housing building located in Bologna is assumed as case study and developed in Section 6.3, where the description of an occupant behaviour model built to simulate the influence of three dimensions linked with occupant behaviour – management of the thermostat, management of the heating system, variation of building characteristics – on energy heating consumption is provided. Results are presented in Section 6.4 and they are discussed in Section 6.5, where two different scenarios are described to assess the impact of behaviour in case of non-retrofit or total retrofit of the building. Limitation of the research and the direction for future research are respectively discussed in Sections 6.6 and 6.7. In conclusion, key research findings are presented in Section 6.8.

The aim of Chapter 7 is twofold: on the one side, to provide evidence of user behaviour to policy-makers, by assessing the impact of renovation measures addressing consumer behaviour in different scenarios; on the other side, to suggest actions to address behaviour to be integrated in existing policy instruments. Sections 7.1 and 7.2 present respectively the introduction and the aim and methodology. Section 7.3 aims at providing support to policy-makers for their decisions concerning the reduction of energy consumption in buildings, by presenting the results of an Analytic Hierarchy Process (AHP) application. In Section 7.4, the focus is moved to the Italian public housing sector, where actors involved, barriers to the implementation of renovation and drivers to overcome the barriers are presented. Several actions are suggested to demonstrate how household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments are also highlighted. In Section 7.5 recommendations to deliver such measures addressing behaviour awareness and information to households of the private residential sector are drawn. In conclusion, directions for future research and key research findings are respectively discussed in Sections 7.6 and 7.7.

Chapter 8 provides the conclusions and recommendations drawn from the various investigations conducted in the dissertation. Section 8.1 briefly recaps the aim, methodology and structure of the thesis. Sections 8.2 to 8.4 present the conclusions of each of the three research questions analysed separately. Section 8.5 discusses the main limitations throughout the work, in particular on data availability and recommendations to overcome the gaps. Recommendations for further research are presented in Section 8.6.

References

Artola I, Rademaekers K, Williams R, Yearwood J (2016) Boosting Building Renovation: What potential and value for Europe? Study for the ITRE Committee

Bedir M (2017) Occupant behavior and energy consumption in dwellings: An analysis of behavioral models and actual energy consumption in the dutch housing stock. doi: 10.7480/abe.2017.16

BPIE (2011) Europe's buildings under the microscope – A country-by-country review of the energy performance of buildings

Bulkeley H, Betsill MM (2005) Rethinking sustainable cities: Multilevel governance and the "urban" politics of climate change. Environmental Politics 14:42–63. doi: 10.1080/0964401042000310178

Czischke D, Moloney C, Turcu C (2015) Raising the game in environmentally sustainable urban regeneration. In: Urbact (eds). Sustainable regeneration in urban areas. URBACT II capitalisation. Nancy

D'Oca S, Hong T, Langevin J (2018) The human dimensions of energy use in buildings: A review. Renewable and Sustainable Energy Reviews 81:731–742. doi: 10.1016/j.rser.2017.08.019

ENEA, Energy Efficiency Trends and Policies in ITALY, 2015

European Commission (2018) Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

Filippidou F, Nieboer N, Visscher H (2016) Energy efficiency measures implemented in the Dutch non-profit housing sector. Energy and Buildings 132:107–116. doi: 10.1016/j.enbuild.2016.05.095

Gargiulo C, Lombardi C (2016) "Urban Retrofit and Resilience. The challenge of Energy Efficiency and Vulnerability", Tema. Journal of Land Use, Mobility and Environment, Vol. 9, n. 2, pp. 137-162, DOI: 10.6092/1970-9870/3922

Gargiulo C, Russo L (2017) Cities and Energy Consumption: A Critical Review. TeMA Journal of Land Use, Mobility and Environment 10:259–278. doi: 10.6092/1970-9870/5182

Gargiulo C, Russo L (2018) Cities and Energy Consumption: Strategies for an Energy Saving Planning. In: Smart Planning: Sustainability and Mobility in the Age of Change, pp 49–70

Gram-Hanssen K (2010) Residential heat comfort practices: understanding users. Building Research & Information 38:175–186. doi: 10.1080/09613210903541527

Guerra-Santin O (2010) Actual Energy Consumption in Dwellings, the Effect of Energy Performance Regulations and Occupant Behavior. doi: 10.3233/978-1-60750-651-5-i

Huebner GM, Cooper J, Jones K (2013) Domestic energy consumption - What role do comfort, habit, and knowledge about the heating system play? Energy and Buildings 66:626–636. doi: 10.1016/j.enbuild.2013.07.043

IEA (2017) Energy technology perspective 2017. Catalysing energy technology transformation. Executive summary

ISTAT (2010) L'abitazione delle famiglie residenti in Italia

ISTAT (2014) I consumi energetici delle famiglie italiane. Anno 2013

La Greca P, Martinico F (2016) Energy and Spatial Planning: A Smart Integrated Approach. In: Papa R, Fistola R (eds) Smart Energy in the Smart City, Green Energy and Technology. Springer International Publishing Switzerland, pp 43-59. doi: 10.1007/978-3-319-31157-9_3

La Greca P, Tira M (2017) Pianificare per la sostenibilità energetica della città. Un'introduzione. In: La Greca P, Tira M (eds) Pianificare per la sostenibilità energetica della città. Politecnica. Maggioli Editore. Sanarcangelo di Romagna (RN). ISBN 8891615145

Lopes MAR, Antunes CH, Martins N (2012) Energy behaviours as promoters of energy efficiency: A 21st century review. Renewable and Sustainable Energy Reviews 16:4095–4104. doi: 10.1016/j.rser.2012.03.034

Majcen D, Itard LCM, Visscher H (2013) Theoretical vs. actual energy consumption of labelled dwellings in the Netherlands: Discrepancies and policy implications. Energy Policy 54:125–136. doi: 10.1016/j.enpol.2012.11.008

Majcen D (2016) Predicting energy consumption and savings in the housing stock: A performance gap analysis in the Netherlands. doi: 10.7480/abe.2016.4

Odyssee-Mure (2015) Energy Efficiency Country Profile: Italy

Papa R, Battarra R, Fistola R, Gargiulo C (1995) La città come sistema complesso in crisi strutturale. In: Bertuglia CS, Fuccella R, Sartorio GL (eds) La città come sistema complesso in crisi strutturale - strumenti e tecniche per il governo metropolitano. Giuffré, Roma. ISBN 88-14-05263-8

Papa R, Gargiulo C, Zucaro F, et al (2016) Energy and Climate Change Polices in Europe: Overview and Selected Examples from a Spatial Planning Perspective. In: Papa R, Fistola R (eds) Smart Energy in the Smart City, Green Ener. Springer International Publishing Switzerland, pp 237–274

Pittini A, Koessl G, Dijol J, et al (2017) The State of Housing in the EU 2017

Proli S, Santangelo A, Tondelli S (2016) Efficienza energetica ed edilizia sociale: il programma Rig.ener.a, sfide e prospettive a Bologna. In: XIX Conferenza Nazionale SIU Cambiamenti. Responsabilità e strumenti per l'urbanistica al servizio del paese. Planum Publisher, Catania 16-18 giugno

Sager-Klauss C V (2016) Energetic Communities: Planning support for sustainable energy transition in small- and medium-sized communities, PhD thesis, Faculty of Architecture and the Built Environment, Delft University of Technology

Santangelo A, Tondelli S (2017a) Occupant behaviour and building renovation of the social housing stock: Current and future challenges. Energy and Buildings 145:276–283. doi: 10.1016/j.enbuild.2017.04.019

Santangelo A, Tondelli S (2017b) Equità e qualità degli interventi di rigenerazione del patrimonio ERP: dallo studio del caso olandese, verso la definizione di un modus operandi. In: XX Conferenza Nazionale SIU URBANISTICA E/È AZIONE PUBBLICA. LA RESPONSABILITÀ DELLA PROPOSTA. Planum Publisher, Roma 12-14 giugno, pp 414–419

Steemers K, Yun GY (2009) Household energy consumption: a study of the role of occupants. Building Research & Information 37:625–637. doi: 10.1080/09613210903186661

Timothy WL (2003) Global Cities vs. "global cities": Rethinking Contemporary Urbanism as Public Ecology, Studies in Political Economy, 70:11-33. doi: 10.1080/07078552.2003.11827128

Tira M, Giannouli I, Sgobbo A, Brescia C, Cervigni C, Carollo L, Tourkolias C (2017) INTENSSS PA: A systematic approach for inspiring training energy-spatial socioeconomic sustainability to public authorities, UPLanD – Journal of Urban Planning, Landscape & environmental Design 2:65-84. doi: 10.6092/2531-9906/5258 van den Brom P, Meijer A, Visscher H (2018) Performance gaps in energy consumption: household groups and building characteristics. Building Research and Information 46:54–70. doi: 10.1080/09613218.2017.1312897

Verones S (2013) Energy and Urban Planning. Towards an Integration of Urban Policies, PhD Thesis, Department of Civil, Environmental and Mechanical Engineering, University of Trento

Visscher H, Meijer F, Majcen D, Itard L (2016) Improved governance for energy efficiency in housing. Building Research & Information 44:5-6:552–561. doi: 10.1080/09613218.2016.1180808

Yan D, O'Brien W, Hong T, et al (2015) Occupant behavior modeling for building performance simulation: Current state and future challenges. Energy and Buildings 107:264–278. doi: 10.1016/j.enbuild.2015.08.032

Zanon B, Verones S (2013) Climate change, urban energy and planning practices: Italian experiences of innovation in land management tools. Land Use Policy 32:343–355. doi: 10.1016/j.landusepol.2012.11.009

2. Framing consumer behaviour in urban and energy planning[1]

ENGLISH ABSTRACT
Consumer behaviour is a key issue in understanding the impact that the society has on the environment. The aim of this chapter is to investigate the policy framework and regulations elaborated at different territorial levels to verify to what extent consumer behaviour, building renovation and urgency to take actions on public buildings are embedded in the energy, urban and sustainable development policies. Sections 2.1 and 2.2 present respectively the introduction and the aim and methodology. Section 2.3 discusses the theoretical framework and models applied by different disciplines investigating the role of behaviour in lowering energy consumption. Section 2.4 provides a policy framework to understand to what extent consumer behaviour is embedded in the existing policy instruments, by considering four different territorial levels. Starting from an overview on international and EU level policy framework, the Italian level is further investigated, to check the relevance of the behaviour within the national, regional and local energy and urban strategies. The relation between energy renovation and urban regeneration is then explained in Section 2.5, while the direction for future research and key research findings are respectively discussed in Sections 2.6 and 2.7.

ABSTRACT IN ITALIANO
Il comportamento degli utenti è una questione chiave nella comprensione dell'impatto che la società ha sull'ambiente. Lo scopo di questo capitolo è investigare il quadro politico e regolamentare elaborato a diversi livelli territoriali per verificare in che misura il comportamento energetico degli utenti, la riqualificazione degli edifici e l'urgenza di intraprendere azioni sugli edifici pubblici siano incorporati nelle politiche energetiche e territoriali. Le sezioni 2.1 e 2.2 presentano rispettivamente l'introduzione, e lo scopo e la metodologia. La sezione 2.3 analizza i modelli applicati da diverse discipline per studiare il ruolo del comportamento degli occupanti nella riduzione del consumo di energia. La sezione 2.4 fornisce un quadro delle politiche in essere per comprendere fino a che punto il comportamento energetico degli utenti è incorporato negli strumenti politici esistenti, considerando quattro diversi livelli territoriali. Partendo da una panoramica a livello internazionale ed europeo, la ricerca si concentra poi sulle direttive e sugli strumenti italiani, per verificare la rilevanza del fattore umano nelle strategie nazionali, regionali e locali in materia di governo del territorio ed energia. La relazione tra riqualificazione energetica e rigenerazione urbana viene quindi spiegata nella sezione 2.5, mentre indicazioni per la ricerca futura e i principali risultati della stessa sono discussi rispettivamente nelle sezioni 2.6 e 2.7.

[1] An earlier version of sections 2.1, 2.3 and 2.6 have been accepted for publishing in the Encyclopedia of the UN Sustainable Development Goals, Goal 7 – Ensure access to affordable, reliable, sustainable and modern energy for all, edited by Springer (forthcoming).

2.1 Introduction

Economic theory of customer preference describes *consumer behaviour* as a "set of activities prospective customers undertake in searching, selecting, valuing, assessing, supplying and using of products and services in order to satisfy their needs and desires" (Čavoški and Markovíc 2015). Prior to this definition, it has also been identified as a process, which includes the issues that influence the consumer before, during and after a purchase or action (Foxall 1993; Solomon 2006).

When it comes to research in the field of energy consumption and energy efficiency, there is a lack of common understanding of what consumer behaviour is, since it is strongly related to the technical, economic, sociological and psychological models applied to understand how and why people perform energy-related actions, and to the disciplines which investigate these actions. Hence, consumer behaviour might be referred, among others, as occupant behaviour or (user) energy behaviour. When it comes to the residential sector, the household behaviour becomes relevant for referring to the energy consumption caused by more than one user, while pro-environmental behaviour is mostly used as a goal to reach in case of strategies to lead to behaviour changes are applied.

Occupant behaviour has been referred as a set of "observable actions or reactions of a person in response to external or internal stimuli, or respectively actions or reactions of a person to adapt to ambient environmental conditions such as temperature, indoor air quality or sunlight" (International Energy Agency EBCP 2013). However, this definition does not take into account individual attitudes and reasons which lead to a specific action, which instead have been intensively studied in social sciences.

Energy behaviour has been defined as "all human actions that affect the way that fuels (electricity, gas, petroleum, coal, etc.) are used to achieve desired services, including the acquisition or disposal of energy-related technologies and materials, the ways in which these are used, and the mental processes that relate to these actions" (International Energy Agency DSM Energy Efficiency 2014). Energy behaviour is the one leading to end-use energy consumption, incorporating two implicit dimensions: the behaviour itself, and the associated energy consumption (Lopes et al. 2012).

Pro-environmental behaviour has been referred to "intentional behaviour that harms the environment as little as possible, or reduces the environmental impact relative to comparable behaviours" (Wilson and Dowlatabadi 2007; Steg and Vlek 2009).
Rather than agreeing on unique terms and definitions, this chapter aims at providing an overview of the scope, policy implications and characteristics of the consumer behaviour in building energy use, focusing in particular on the household behaviour in the residential sector. People spend most of their lives indoor. Considering that "home" is the place where people have the greatest control on their circumstances in their own environment, it represents a crucial point in the effort for raising awareness about the role of consumer behaviour in lowering energy consumption (Hayles and Dean 2015).
To the purpose of this work, all the terms above are assumed to embed energy consumption as subject of investigation, therefore, consumer behaviour, user behaviour and occupant behaviour are used indifferently.

Consumer behaviour is a key issue in understanding the impact that the society has on the environment. The human preferences and actions have both direct and indirect impacts on the environment, as well as on personal and collective well-being. Energy use is embedded in everyday routines, mostly in a silent way. Since decisions to use energy are generally unconscious, it is difficult to deliberately decide to save energy. Nevertheless, there is a growing awareness of the need to understand the human factor as a prerequisite to achieve the goals set at international level by the Paris Agreement and affecting national energy policies, and many scholars call for inter-disciplinary knowledge and multi-disciplinary efforts to address user behaviour and thus unlock its energy efficiency potential.
Climate change is a fundamental societal challenge, that brings the reduction of global warming and global carbon dioxide (CO_2) emissions on the top of the governments' agendas. Main contributors to CO_2 emissions are business, transport and the residential sectors. The transport sector alone is responsible for more than 20% of the emissions worldwide (The World Bank 2014). It is clear that demographic (i.e. age, gender, household composition), economic (i.e. income, employment status), and structural (residence location, working location) factors affect personal transport choices. Changing behaviour in relation to transport modes has been studied for many years, although there are few results of the effectiveness of individual behaviour

change strategies in private mobility. A recent research on the effectiveness of nudges for sustainable consumption behaviour (Lehner et al. 2016) has analysed the impact of nudge mechanisms to influence personal transport behaviour. Framing information and providing feedback on transport use and mobility patterns resulted to be effective instruments to influence travel behaviour, together with changes in infrastructures and in physical environment, although it has identified the urgency for more large-scale experimentation and piloting in the field of mobility and travel behaviour, as there is less research available in this domain than in others (e.g. residential and food sector).

Being the residential sector the main contributor to energy consumption in buildings in EU (about 62%), most of the research on consumer behaviour has been essentially focused on it, investigating the human dimension of energy consumption with reference both to the occupants and to the energy-related behaviour of key stakeholders.

Occupant behaviour studies have mainly aimed at explaining the gap between theoretical and actual energy consumption in buildings (Steemers and Yun 2009; Yan et al. 2015; van den Brom et al. 2018), identifying behavioural patterns and household characteristics driving certain behaviours (Van Raaij and Verhallen 1983; Gram-Hanssen 2010; Ben and Steemers 2018), supporting decision-makers in promoting energy saving behaviour (Frederiks et al. 2015). Space heating represents the largest share of household consumption. In 2016 in EU, household consumption for space heating, water heating and electrical appliances accounted respectively for 65%, 15% and 14% of the total consumption. Therefore, occupant behaviour related to space heating has been investigated in various empirical studies, among others (Gram-Hanssen 2010; De Meester et al. 2013; Engvall et al. 2014; Ren et al. 2015; Santangelo et al. 2018). Behaviour related to electricity consumption has also gained attention in a number of studies (Grønhøj and Thøgersen 2011; Abreu et al. 2012; D'Oca et al. 2014a) while ventilation and window opening behaviour (Andersen et al. 2009; Fabi et al. 2012; D'Oca et al. 2014b), domestic hot water (DHW) (Feng et al. 2017; Mora et al. 2017) and water saving behaviour (Martínez-Espiñeira et al. 2014; Hayles and Dean 2015) have been so far less investigated. Few studies have attempted to study many occupant behaviours at the same time (Stazi et al. 2017).

Occupant behaviour in office buildings and tertiary sector have been studied as well (Masoso and Grobler 2010; Feng et al. 2015; Yan and Hong 2018), although they have received so far slightly less attention than the housing sector.

Finally, some researchers argue that key stakeholders (i.e. building designers, operators, managers, engineers, occupants, industry, vendors, and policymakers) need to be aware and educated on the relevance of the human factor to their particular perspective, in order to integrate the human dimension in their daily actions (Santangelo and Tondelli 2017; D'Oca et al. 2018).

2.2 Aim and methodology

Chapter 2 contributes to the research question 1 as presented below. Sub-question a) will be addressed in Section 2.4, while Sections 2.3 and 2.5 will provide evidence to sub-question b) as presented in the box below.

Research question 1:

To what extent are both energy behaviour and the role of household energy consumers embedded in current international and EU strategies, energy policies, urban planning policies and other policy instruments addressing energy renovation of the building stock, at different territorial levels?

Sub-questions:

a) Is there any relation between energy renovation, public buildings and user behaviour in the current policy instruments at EU level and at national, regional and local level for Italy?

b) How many approaches are there to understand household energy behaviour and which is the one that suits more for dealing with user behaviour in urban planning?

This chapter aims to gain a greater insight into the policy framework and regulation elaborated at four levels of governance (i.e. international and EU; national; regional; local) to verify to what extent consumer behaviour, building renovation and urgency to take actions on public buildings are embedded in the energy and sustainable development policies.

Starting from an overview of social science and technological theoretical approaches to consumer behaviour, this chapter provides an insight into international and EU level policy framework, where then the Italian level is further investigated, to check the relevance of the three above-mentioned topics within the national energy strategy. Since in Italy spatial and urban planning are topic tackled by regional legislation and local codes, these two administrative sub-levels are analysed as well, providing information on the energy strategies and plans for the Emilia-Romagna Region and for the municipality of Bologna, capital city of the Emilia-Romagna Region, where the case study further analysed in Chapter 6 is located. A comparison matrix for the analysis of the four policy levels is developed to facilitate clear trends and gaps between the policy instruments presented, and to facilitate the identification of possible future instruments needed to overcome current barriers (see Chapter 7). Analysing the consumer behaviour from an urban planning perspective is the content of Section 2.5.

2.3 Household energy behaviour: a theoretical framework

Whether consumer behaviour is based on long-lasting practices or new ones, it is overall influenced by both personal characteristics and the societal context. Macro-level factors such as technological developments, economic growth, demographic factors, institutional factors, cultural developments (so called TEDIC factors) influence consumer behaviour at the broader level, while micro-level factors such as motivation, opportunity and ability (MOA factors) shape user behaviour at the individual level (Abrahamse et al. 2005).

Investigating consumer behaviour towards energy efficiency and sustainable energy consumption requires a deep understanding of both the human factor and the technological asset, and the integration of both qualitative and quantitative methodologies. A brief review of the two main approaches – based on social science theories and on technological disciplines – is presented below. Both rely on modelling as key approach that helps explaining the reality and informing the users, while this dissertation is aimed at providing evidence of the importance of behaviour modelling for informing and guiding the policy-makers to assess scenarios and to take decisions.

2.3.1 Social science approach

From the economic point of view, one of the first behavioural theories is the rational choice model, also called utility-based decision model. It is grounded on the micro-economic theory of utility maximization given certain preferences. Consumers are assumed to behave rationally, but in order to weigh the costs and benefits of various options, they need information on the possible actions or goods they can choose from. However, after having been largely applied in the 1970s, this model has progressively been replaced by others, since it has been demonstrated that behaviour embeds a number of inconsistencies, and consumers do not make consistent rational decisions even if all the information is provided (Wilson and Dowlatabadi 2007; Lopes et al. 2012). Moreover, people make decision not only considering short-term monetary paybacks, but also mentally assessing other non-monetary positive or negative elements, although they account the two assessments separately, resulting in non-rational decisions.

Technology adoption and attitude-based decision models explain the relationship between innovations and behaviour. The Diffusion of Innovation (DoI) model assumes a linear progression of knowledge, awareness, intention and behaviour that results in the adaptation of technologies; the theory of cognitive dissonance is based on the assumption that consumers struggle to behave coherently and to keep consistency between their knowledge, attitudes, and actions; in the theory of planned behaviour (TPB), attitudes are formed from the personal belief about a behaviour as well as the evaluation of its outcomes. While these theories have been successfully applied to explain human choices in a wide variety of contexts, their application in energy efficiency and sustainable energy consumption has been limited (Kowsari and Zerriffi 2011).

Social and environmental psychology has started from the 1970s to explore behaviour in relation to residential energy efficiency. According to the ecological value theory, people with egoistic and self-interested values are less likely to perform pro-environmental behaviours than those who have pro-social values. However, having pro-environmental attitudes is not a sufficient condition for acting in an environmentally friendly way. The value-belief-norm (VBN) theory proposes a causality relation between personal values, ecological worldview, adverse consequences for valued objects, perceived ability to reduce threat and pro-environmental personal norms. The three causal variables that lead from values to personal norms that activate environmental behaviour are beliefs. As a consequence, information can play an important role in influencing beliefs, which in turn can change pro-environmental norms that finally lead to environmentally significant behaviours (Kowsari and Zerriffi 2011). However, decision models that exclude contextual factors often fail to adequately explain energy-related behaviour when it involves high-effort, high-cost and high-involvement decisions (Lopes et al. 2012). Hence, context has been included in the attitude-behaviour-external conditions (ABC) model, where attitudes are considered to lead to behaviour change only if contextual variables (e.g. physical, financial, legal, or social) provide either incentives or disincentives.

However, contrarily to the previous models, sociology approaches generally argue that energy use is not a consequence from choices of a single person, but it results from the social context. Sociologists and anthropologists believe that human behaviour is social and collective, and that energy models that intend to include behavioural dimensions should consider the social context of individual actions. Therefore, in the residential sector, they consider the household as the meaningful unit of analysis.

Coming to practice theory, it focuses on the collective structures of practices and on what guides the practices people perform in their everyday lives, where energy consumption is not a practice in itself, but it is a consequence of all the different energy-related activities that people do at home (Gram-Hanssen 2010; Hargreaves 2011; Moloney and Strengers 2014; Shove and Walker 2014). The notions of either behaviour or lifestyle are often used when discussing differences in energy consumption patterns. The methodological approaches to study household energy consumption include survey methods, statistical analysis of large databases, qualitative interviews, indoor measurements and detailed end-use metering. However, Gram-Hanssen (2014) argued that neither of these approaches is the most useful when analysing household energy consumption, as much of consumption relates to unconscious habits and technological structures which are not very well understood in behavioural or lifestyle

approaches. Practice theory is considered an approach that better includes both unconscious habits and technological structures.
Therefore, these considerations are particularly important when it comes to frame the intervention strategies to energy conservation and behavioural changes.

2.3.2 Technological and engineering-based approach

Energy modelling has been applied to quantify energy consumption either to inform the building design sector or to support policy-makers in assessing the effectiveness of different scenarios. Focusing on the bottom-up approach (Lopes et al. 2012), rather than on the top-down approach, which is unable to distinguish individual behaviour, these models make use of input data as household characteristics and building – or group of buildings – characteristics, to assess either the energy consumption embedded in certain behaviours or to cluster the users according to recurring behavioural patterns. Behaviour models do not represent deterministic events, but help investigating occupant behaviour which is complex, stochastic in nature, and diverse, with interdisciplinary characteristics. However, within certain boundaries, it can be represented quantitatively (Hong et al. 2017).

Happle et al. (2018) categorised the occupant behaviour modelling approaches according to two modelling techniques (i.e. deterministic vs. stochastic) and two levels of granularity (i.e. space-based vs. person-based). In deterministic schedules, a standard day profile is usually the same for all weekdays and both weekend days. Depending on the available data, this method assumes no change in occupancy schedules throughout the year. The stochastic models generate random non-repeating daily profiles of occupancy for a long-term (annual) building performance simulation, resulting in multiple building occupancy patterns to evaluate the uncertainties related to occupant behaviour (Yan et al. 2015). When it comes to the granularity, space-based approaches directly model the impact of aggregated occupant behaviour in a certain space, as an archetypical building, or a thermal zone or a functional zone inside a building, depending on the spatial resolution of the overall model. Examples of space-based approaches include models for occupant presence, space heating and cooling controls and ventilation rates for typical space occupancy types in building energy modelling standards. Person-based approaches model every single presence, activity and action. They are governed by the individual characteristics and behavioural patterns of each person-category (e.g. full time employed resident, part-time employed resident, unemployed resident).

The statistical approach, applied by many scholars (Guerra-Santin 2011; Chen et al. 2015; Mora et al. 2015; Yang et al. 2015; Guerra-Santin and Silvester 2016; Guerra-Santin et al. 2016; Ben and Steemers 2018) relies on statistical data collection, it requires large samples and it embeds the risk to not adequately deal with the socio-technical factors (e.g. how householders use domestic appliances or how they react to changes in the dwelling as a result of energy performance measures) (Lopes et al. 2012), although the added value is that it can lead to results generally valid at regional/national level.

The engineering approach makes use of building energy simulation programs (e.g. EnergyPlus, DeST, ESP-r) to assess the impact of certain behaviours in building energy performance. Indeed, it has been demonstrated that occupant behaviour is a major factor contributing to observed gap between the theoretical and actual energy consumption of buildings. Due to the stochastic nature of human behaviour, to achieve better predictions of building energy performance, models of human-building interaction have increasingly been integrated into building energy simulation algorithms. Such approaches typically rely on mathematical equations representing the relationship between specifically exercised energy-related behaviours (i.e. opening windows, drawing blinds and shades, operating artificial lights, using electrical equipment) and some physical variables of the indoor and outdoor environment, specific to a particular building setting (D'Oca et al. 2018). The appropriate model resolution depends on the problem that is being addressed, therefore, before developing a model to describe occupant behaviour, it is necessary to clarify the resolution for the spatial, temporal, and occupant dimensions (Yan et al. 2015). A single model is unlikely to be generic enough to cover all solutions at different scales.

Data patterns using statistical analysis procedures, data mining, and machine learning techniques have been widely analysed in recent research to automatically extract information on behaviour patterns from big data streams. In particular, analytical techniques for big data such as data mining (Yu et al. 2011; D'Oca and Hong 2015; Ren et al. 2015) have the capability to provide qualitative and quantitative information on diverse user profiles in a block of buildings, enabling the use of more realistic hourly schedules in building performance simulation programmes. Data mining techniques are not intended as a substitute to or contrast with direct stochastic modelling approaches (Hong et al. 2017), but as ways to gather information to overcome the shortcomings of more traditional techniques.

Moving the attention from the building to the urban scale, urban building energy models aspire to become key planning tools for the holistic optimization of buildings, urban design, and energy systems in neighbourhoods and districts. However, impacts of different occupant behaviour modelling approaches into the various purposes of urban building energy models are still largely unknown. Research shows that the inappropriate choice of occupant behaviour model could result in oversized district energy systems, leading to over-investment and low operational efficiency (Happle et al. 2018).

2.4 Consumer behaviour in different regulatory levels: a policy framework

Policy-makers are currently facing the challenge to design and implement effective housing renovation strategies both for the public and the private housing stock, able to support not only the technical and physical renovation, but also a change of paradigm in energy consumption. The more the energy efficiency of buildings is, the greater is the impact of household behaviour (Andersen et al. 2009; Guerra-Santin and Itard 2010; De Meester et al. 2013; Santangelo et al. 2018), therefore, there is a growing belief that the implementation of energy efficient measures should better cope with household needs and the ability and willingness of occupants to undertake changes in their daily behaviours.

Policies and regulations at different territorial levels are struggling to encourage decision-makers to include information to users as a prerequisite to implement effective energy efficiency strategies and to lower energy consumption. The sub-sections below provide an overview of current policy instruments (e.g. policies, regulations, directives, planning tools) clustered according to the level of governance, to find out to what extent and how the three main topics (i.e. renovation of buildings, consumer behaviour and awareness, and public buildings/ social housing) are addressed.

2.4.1 Global level

At international level, understanding the human factor in energy consumption is a topic which got an increasing attention in the last decade.

At organisational level, the Organisation for Economic Cooperation and Development (OECD) conducted a survey in 2011 to get an insight into the factors affecting people behaviour towards the environment and on what policy measures enable changes at the household level (OECD 2014). The International Energy Agency (IEA) identified occupant behaviour as one of the six driving factors of energy use in buildings (International Energy Agency 2016), and has developed the IEA EBC Annex 66: Definition and Simulation of Occupant Behavior in Buildings, aimed at analysing and evaluating the impact of occupant behaviour on building energy use and occupant comfort via building performance simulation (Yan and Hong 2018). The World Business Council for Sustainable Development recognised that occupant behaviour can have as much impact on energy consumption as the efficiency of equipment in reducing energy consumption (World Business Council for Sustainable Development 2007).

At policy level, there are several initiatives to further investigate. The Sustainable Development Goals (SDGs) are the set of 17 agreed goals which all 193 United Nations member states have committed to, that should guide policy and funding for the period 2016-2030. The SDGs build on results of the Millennium Development Goal of 2000 and they focus on key areas including poverty alleviation, democratic governance, climate change, disaster risk, and economic inequality. Among them, SDG7 and SDG11 focus respectively on Affordable and clean energy and Sustainable cities and communities. The former deals with ensuring access to affordable, reliable, sustainable and modern energy for all. Target 7.1 “by 2030, ensure universal access to affordable, reliable and modern energy services” is particularly relevant to the aim of this research, since it recognises the importance of household behaviour in energy consumption, and the need to investigate energy used differentially by household characteristics (i.e. gender), since it has different impacts on people well-being (UNSD 2016a). The latter is aimed at making cities and human settlements inclusive, safe, resilient and sustainable. Target 11.1 “by 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums” not only focuses on poor households and developing countries, but also to determine the structural quality/durability of dwellings in developed countries (UNSD 2016b).

The Paris Agreement (UN 2015), the first global agreement on climate change mitigation, has been adopted in 2016 under the United Nations Framework Convention on Climate Change, with the aim of keeping the increase in global average temperature to well below 2°C above pre-industrial levels, and strengthening societies' ability to deal with the impacts of climate change. The agreement recognises the role of non-party stakeholders in addressing climate change, including cities, other subnational authorities, civil society, the private sector and others. In particular, in Article 12 it explicitly asks parties to cooperate in taking measures to enhance climate change education, training, public awareness, public participation and public access to information.

The Habitat III New Urban Agenda (UN 2017) has recognized the role of sustainable consumption to ensure environmental sustainability (art. 14c) and the national, subnational and local governments as key actors to promote energy conservation and efficiency, and to develop sustainable, renewable and affordable energy and energy-efficient buildings (art. 75). Article 67 also stresses the importance of the promotion of well-connected networks to improve the resilience of cities to climate change, improving household quality, and promoting attractive and liveable cities.

Cities for Adequate Housing – Municipalist Declaration of Local Governments for the Right to Housing and the Right to the City – is the most recent initiative among the ones investigated (Cities for Adequate Housing 2018). It has been built on New Urban Agenda of Habitat III and SDGs of United Nations. It identifies five actions that local governments should undertake to ensure people actual access to adequate housing, understood by the United Nations as the one that has the correct affordability, legal security of tenure, habitability, availability of services, materials, facilities an infrastructure, accessibility, location and cultural adequacy. Among them, action 2 claims for more funds to improve the public housing stocks, to contribute to achieving cities where all people have equal access to affordable housing. To date, the agreement has been signed by fourteen cities worldwide and three metropolitan entities.

2.4.2 A focus on EU

At European Union level, the building sector is the largest single energy consumer. The European Commission has recognised the importance of buildings performance towards climate change mitigation and has set regulations to help promoting the use of smart technologies in buildings and to accelerate buildings renovation. Currently, about 35% of the buildings are over 50 years old and almost 75% of the building stock is energy inefficient, while only 0.4-1.2% of the buildings are renovated each year, depending on the Country. This renovation rate is clearly not enough considering that half of the residential stock was built before 1970, prior to the introduction of the first thermal regulations. Therefore, the increase of the renovation rate of existing buildings has the potential to lead to significant energy savings and the residential sector is the one which offers the greatest potential. Improving the energy efficiency of buildings can also generate other economic, social and environmental benefits. Better performing buildings provide higher levels of comfort, wellbeing and health for their occupants.

The Energy Performance of Buildings Directive (EPBD) 2010/31/EU, entered into force in 2010, together with the Energy Efficiency Directive (EED) 2012/27/EU of 2012, are the two main reference directives for EU Member States towards the implementation of energy saving measures. For what concerns the renovation of existing building stock, Articles 4 and 7 of the EPBD requires respectively to set minimum energy performance requirements for both new and existing buildings, and to stick buildings undergoing major renovation into these requirements, while, coming to technology, Article 8 requires Member States to encourage the introduction of smart meters whenever a building is constructed or undergoes major renovation. Art 4 of the EED is devoted to building renovation, while Article 5 sets a binding renovation target for public buildings and imposes related obligations. It also stresses that governments shall undertake an exemplary role in the energy retrofit of the building stock in their countries. 3% of the total floor area of heated and/or cooled buildings owned and occupied by central government should be renovated each year to meet at least the minimum energy performance requirements that it has set in application of Article 4 of the EBPD. Member States shall encourage public administrations to follow the exemplary role of the central government, adapting energy efficiency plans, implementing energy management systems in their buildings, and making use of Energy Performance Contracting and services of Energy Service Companies (ESCos) (Art. 18). When it comes to the attention to consumers as a key component of the energy efficiency process, Article 20 of the EPBD requires Member States to take the necessary measures to inform the owners/tenants of buildings of the different methods and practices for enhancing energy performance. The EED as well makes the role of consumers explicit through Articles 9

(Metering), 10 (Billing information) and 12 (Consumer information and empowering programme), suggesting that raising awareness of the cost saving potential of building renovation can be achieved through judicious use of the regular communication channels (i.e. meters and energy bills) to bill payers, as well as through other ways of engaging with building owners and energy consumers. Article 7 of EED requires EU countries to set up an Energy Efficiency Obligation Scheme. This scheme requires energy companies to achieve yearly energy savings of 1.5% of annual sales to final consumers. In order to reach this target, companies need to carry out measures which help final consumers improve energy efficiency. This may include more physical measures as improving the heating system, installing double glazed windows, and better insulating roofs, or alternative policy measures which reduce final energy consumption, as training and education initiatives.

The Directive 2018/844/EU, amending the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED), just entered into force in July 2018, aims at accelerating the cost-effective renovation of existing buildings and promoting smart-ready systems and digital solutions in the built environment, therefore, providing consumers with more accurate information about their consumption patterns. This Directive is part of the Clean Energy for All Europeans, a new package of measures introduced in 2016 with the goal of providing the stable legislative framework needed to facilitate the clean energy transition and enabling the EU to deliver on its Paris Agreement commitments. Among the package three main goals, providing a fair deal for consumers is the one which is aimed at making easier for households and businesses to become more involved in the energy system (i.e. by being entitled to generate electricity for either their own consumption, store it, share it, consume it or to sell it back to the market), to better control their energy consumption and respond to price signals. The shift from target group to actor, from consumers to prosumers requires to investigate behaviour at first, to being able to drive the change by addressing specific needs.

The Strategic Energy (SET) Plan, introduced in 2007 and integrated 10 years later in 2017, focus on preparation and endorsement of implementation plans which identify R&I activities and demonstration projects required to achieve the targets. It claims for a smarter energy system, empowering the consumers. However, in the pathway to define the measures to be implemented, it has lost the focus on the coordinated planning between the European level, Member States and the local level that some scholars identified in the earlier version of the SET Plan (Papa et al. 2016), and it is now more focused on sectoral innovations.

2.4.3 A focus on Italy – selected example of national, regional and local level

2.4.3.1 National level

Member states have adopted a wide range of policy instruments to embed EU strategies for energy efficiency into national contexts. In the case of Italy, the Legislative Decree 102/2014, which transposes the EED, identifies requirements designed to ensure optimal coordination of interventions and measures for energy efficiency. The requirements aim at the full implementation of the commitments made at EU level in terms of improving energy efficiency, reducing consumption of the national housing stock, and promoting compliance with the mandatory redevelopment of central public administration buildings. In this regard, Article 5 of the decree provides incentives for the energy renovation of publicly owned property. Furthermore, the Legislative Decree 102/2014 foresees that by the end of 2016, multi-dwelling buildings install individual meters for each housing unit. Nevertheless, even if providing data on energy consumption and expenditures is a key factor to raise awareness of the role of occupant behaviour on implementing energy efficiency measures, the metering of energy consumption for each dwelling alone might not lead to responsible behaviours. Legislative Decree 102/2014 also indicates the National Agency for Energy and Environment (ENEA) as responsible for the elaboration of the long-term strategy for the renovation of the building stock.

The Italian energy efficiency action plan (PAEE) developed in 2014 (ENEA 2014) describes the energy efficiency targets set by Italy for 2020 and the measures to achieve them. To reach the goals, ENEA was expected to implement an Integrated Plan for energy efficiency dissemination (PIDEE) to provide information and training activities on energy efficiency, together with a definition of objectives and target groups. Although it has never been implemented as such, in the second version of PAEE, updated in 2017, a specific three-year information and training programme (PIF) has been developed. The programme is divided into three different stages, each lasting one year: Stage 1 (Start-up) involves mass information/communication to provide a basic introduction to energy efficiency and energy savings, and selected actions are planned for selected target groups; Stage 2 (Specific targets) is the midpoint of the programme, which involves maximising information coverage and launching targeted actions for the target groups identified under Article 13 of Legislative Decree No 102/2014. Objective 5 – Households is aimed at raising awareness among households, particularly in multi-dwelling buildings, of the benefits of energy audits, the energy performance certificate (EPC) and environmentally conscious energy use. Stage 3 (Consolidation and testing) foresees the consolidation of initiatives, communication of results and analysis of the communication impact.

The Italian National Energy Strategy (SEN) 2017 lays down the actions to be achieved by 2030, in accordance with the long-term scenario drawn up in the EU Energy Roadmap 2050, which claims for a reduction of emissions by at least 80% from their 1990 levels. It aims to drive the national change towards a more competitive, more secure and more environmentally sustainable energy model. For the renovation of the residential sector, it foresees revising, strengthening and confirming the tax deduction scheme for energy-efficiency investments (so-called "Ecobonus"). Italian SEN recognises that low awareness of the impact of consumer behaviour is limiting the reduction of energy consumption. As a consequence, it aims at strengthening measures to support behaviour change and to build community awareness sharing the same energy reduction goal. For what concerns public buildings and social housing, it focuses on energy efficiency for mitigating energy poverty, and on financial instruments to lead to the deep regeneration of public housing.

2.4.3.2 Regional level: Emilia-Romagna Region

The Italian Emilia-Romagna Region, where the case study investigated in Chapter 6 is located, is considered for investigating the regional level of governance. The first Regional Energy Plan, approved according to the procedures established by Law no. 26/2004 on energy planning, was approved in November 2007 and designed to last ten years. The new Regional Energy Plan has been, therefore, released in 2017. Although the ten-years duration, to build regional scenarios coherent and comparable with the EU objectives, the horizon considered is the 2030. Two main scenarios have been identified and described: the "energy trend scenario" and the "energy goal scenario". The former takes into account the goals set by European, national and regional policies, the results achieved by the measures implemented and by the technological and market trends considered to be consolidated, without taking into account not yet foreseen interventions at any level of governance. The latter aims to achieve all the EU 2030 climate-energy objectives, including also the most challenging as the reduction of greenhouse gases (GHGs). This second scenario has been defined starting from the best national and European sectoral practices (Regione Emilia-Romagna 2017). In both scenarios, the residential sector is considered the key player to implement the strategies for increasing the energy performance of the building stock. The “energy trend scenario” foresees a reduction of 2% of electricity consumption yearly, a double rate of dwellings undergoing renovation and energy retrofit – from 35% to 63% and from 9% to 22% respectively – and installation of smart meters in dwelling with decentralised heating system. The “energy goal scenario” aims at reducing 3% of electricity consumption yearly, to reach 89% of renovation rate and 30% of energy retrofit. The renovation of buildings is expected to be boosted by the definition of urban regeneration regulatory system where the energy efficiency should be embedded. However, no more specific information is provided. When it comes to raise awareness among consumers on behaviour, and to public housing, the strategies are aligned with the ones at EU and national level, but no specific sub-strategies or actions to reach the overarching objectives are provided.

The Emilia-Romana Regional Energy Plan – Action Plan for 2017-2019 (PTA 2017-2019) is the responsible of driving the change for the first three-year period. Eight intervention axes are defined, whit the fourth one devoted to building renovation and urban regeneration. To raise awareness on the benefit of energy efficiency measures, specific actions targeted to multi-family building managers might be promoted (IV.2.4. Axis 4). The region is committed to renovate its own public building stock to at least 3% as required for national government buildings. In addition, the Action Plan foresees the support of the Region for energy efficiency initiatives for public housing.

Moving to understand how energy issue and the three main topics investigated in this section (i.e. renovation of buildings, consumer behaviour and awareness, and public buildings) are taken into consideration in the urban planning regional regulation, LR24/2017 Regional legislation on the territory protection has entered into force in 2018 to promote urban regeneration, to enhance the urban and built environment quality, healthy and energy efficient housing. Indeed, in Italy spatial planning is a regional legislative subject. To promote affordable housing, it foresees to promote new social housing buildings in case of energy renovation and urban regeneration projects through additional building floor area (art 8). Therefore, while renovation of buildings and enhancement of social housing as a common are stressed, no explicit reference is made to the role that people have in reducing energy consumption of buildings through their behaviour.

2.4.3.3 Local level: the City of Bologna

For several decades, the city of Bologna has undertaken a strategy for reducing CO_2 emissions and energy consumption by integrating energy policies within urban-scale strategies. This process began in 1982, with the Bologna Energy Study – BEST – on the city's energy consumption and continued with the project called UrbanCO2Reduction (1995), which paved the way to the definition of the first Municipal energy plan in 1999. Later on, in 2007, the Municipality of Bologna approved the municipal energy programme (Programma Energetico Comunale – PEC), aimed at defining the strategies to comply with the Kyoto protocol. Several Urban Energy Basins (Bacini Energetici Urbani – BEU) have been identified within the city to apply energy equalisation procedures between renovated and new buildings. Action factsheets are then designed to guide the interventions and to make distinctions between suggested and mandatory actions. The analytical phase includes a spatial dimension of energy demand and supply, which represent an innovative feature compared to similar tools (Verones 2013). The programme is target to public (municipal) buildings, municipal vehicle fleet and public street lighting, and it suggests to involve private actors on a voluntary basis for what concerns the building renovation, while it imposes energy performance requirements to be embedded in the building regulation and planning tools. The close integration between PEC, the structural planning tool and the methodology for the definition of the urban energy basins has been considered as a valuable example in the Italian national scene (Conticelli et al. 2017). However, as the majority of the policy instruments, all the considerations on energy savings are based on the reduction of the energy demand, rather than the reduction of energy consumption. Therefore, no considerations are made on consumer behaviour and awareness.

In 2008 Bologna joint the Covenant of Mayors, the main EU initiative promoting the involvement of local authorities in addressing climate change related issues. The key instrument is the elaboration of a Sustainable Energy Action Plan (SEAP) and the monitoring process to verify how the measures adopted contribute to achieve the targets. Bologna SEAP, approved in 2012, identifies a series of actions, clustered in fact sheets, according to six macro areas of intervention: residential sector, tertiary sector, industry, local energy production, urban mobility and public facilities. The public housing stock is considered to have a leading role in showcasing the energy saving potential of the residential sector. With about 12,000 dwellings, is the largest housing stock owned by a single entity (the Municipality of Bologna itself), therefore, each energy efficiency action has a high replication potential. Among the actions proposed addressing somehow consumer behaviour, the "Energy Point" (Il Punto Energia) is a public spot that provides information to citizens (both households and SMEs) on cost-effective measures for renovating buildings and for increasing energy efficiency of both housing and working places, while "What can you do?" (Cosa puoi fare tu?) is a web platform providing information to energy efficiency measures for building renovation. Other actions are particularly targeted to public buildings, either to renovate the public housing stock and other public buildings, or to support the urban regeneration of brownfields and former barracks increasing the energy efficiency of new buildings and energy infrastructures. Specific urban planning tools are foreseen to implement some of the actions with an urban planning scope (Proli et al. 2016). However, results are largely disregarded, due to the non-binding nature of the proposed actions, the construction sector stagnation as a consequence of the 2008 economic crisis, and the lack of public funding to be invested in the energy renovation of public buildings. However, two main limitations are embedded in the two plans: on the one hand, they devoted their attention mainly to new urban developments and green fields, rather than to existing built-up areas; on the other hand, the intention to integrate urban and energy planning resulted disattended.

To the aim of this analysis, the urban planning tools are considered as well, since they are the policy instruments responsible to translate the building strategies into actions at local level. The Municipal Structural Plan (Piano Strutturale Comunale – PSC), approved in 2008, is responsible to define the strategy and structural characteristics of the urban planning process. The Environmental and Territorial Sustainability Assessment (Valutazione di Sostenibilità

Ambientale e Territoriale – VALSAT), approved in 2008, is a mandatory step of the planning process aimed at assessing the effects of the PSC actions to guarantee the sustainability of transformations, both at the micro-scale and at the city scale of intervention. When it comes to the integration of energy-related issues into urban planning tools, VALSAT works as a bridge between the Municipal Energy Programme and the Municipal Structural Plan, aiming at implementing main objectives of sectoral plans.

According to the Emilia-Romagna Region law on urban planning (regional law n. 20/2000), the Municipal Structural Plan strategies and objectives are put in practice though the Urban Building Regulations (Regolamento Urbanistico Edilizio – RUE), establishing rules and procedures about how to intervene on buildings and the Municipal Operative Plan (Piano Operativo Comunale – POC), addressing the major urban developments to be implemented though detailed masterplan of the affected city areas[2].

Bologna RUE, approved in 2009, aims, by means of volumetric incentives, at improving the sustainability of building changes and the energy efficiency of the existing city. The RUE adopts a performance-based approach strongly founded on sustainability performances. It is grounded on a reward-based mechanism under the form of density bonus incentives to be granted in case of demolition and reconstruction as well as of global renovation of existing buildings, in case these interventions achieve higher performances against four main requisites, where one of them considers the energy efficiency of buildings.

The Municipality of Bologna has approved in 2015 a POC explicitly dedicated to a widespread qualification of some underused od degraded part of the cities, taking the benefits of public-private partnerships to provide energy efficiency retrofitting programmes in the wider framework of urban sustainability and regeneration. By a formal expression of interest, owners of underused or abandoned buildings and small-scale developers have been able to propose improvements, re-functioning, enlargements of existing buildings to be included within POC. In order to be accepted by the Municipality and included in the POC, the proposals had to achieve the main objectives described in POC public announcement: improvements in terms of energy efficiency, seismic performance, natural resources management, and improvements of urban

[2] The POC allows to make building interventions larger than 7,000 square meters, that cannot be addressed by the RUE

and social quality improving local public spaces and facilities and providing social housing. As a reward, proponents can count on additional building rights to be exploited within the belonging plot or in other plots to be agreed with the Municipality. The experience of Bologna POC shows an alternative way of planning small-scale interventions on the built environment, based on bottom-up proposals designed by small owners and local operators according with their aims and possibilities, but in line with the overall sustainability framework fixed by the municipal urban plan (Conticelli et al. 2017).

Starting from 2008, the Municipality of Bologna has raised its awareness about the problems of the existing city and this attention have been evident and more explicit since 2011, when the city has started redefining its municipal urban planning strategies by adopting a new approach more focused on the management and improvement of existing buildings and already built environment in terms of environmental and social benefits, rather than new urban developments (Conticelli et al. 2017). Therefore, the urban planning instruments presented above reflect this change. However, to the aim of this investigation, neither the RUE, nor the POC take into consideration the leading role the public authorities should have to implement the energy renovation strategies in their public building stock. No measures are foreseen to support the raise of awareness among citizens on the impact of their behaviour.

To this aim, the LR24/2017 Emilia-Romagna Regional legislation on the territory protection and use, just entered into force in 2018, seems to provide new opportunities. As explained above (section 2.4.3.2), besides no explicit reference is made to the role that people have in reducing energy consumption of buildings through their behaviour, the legislation is much more focused on home-owners and individuals as activators of urban regeneration process than the former spatial planning regulations. Indeed, due to the Italian housing stock tenure, totally unbalanced in favour of ownership (see Chapter 5), the involvement of individuals is a fundamental step to unlock the city regenerative potential. The General Urban Plan (Piano Urbanistico Generale – PUG), the new local planning tool, provides new opportunities for embedding considerations on behaviour within the overall evaluation of the interventions, for instance, by foreseeing the adoption of a new rating system to enhance the urban quality of urban regeneration projects, where the adoption of behaviour awareness strategies could be one of the elements to improve quality.

Table 2.1: Overview of global, EU and Italian policy instruments addressing renovation of buildings, consumer behaviour and awareness, and public buildings / social housing

Name and year	**Type**	**Renovation of buildings**	**Consumer behaviour and awareness**	**Public (residential) buildings**
Global level of governance				
Sustainable Development Goals: SDG7 and SDG11 (2016)	Policy	SDG11 Target 11.1 “by 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums” to determine the structural quality/durability of dwellings	SDG7 Target 7.1 “by 2030, ensure universal access to affordable, reliable and modern energy services” recognises the importance of household behaviour in energy consumption	n.a.
Paris Agreement (2015, into force in 2016)	Agreement	n.a.	Parties shall cooperate in taking measures, as appropriate, to enhance climate change education, training, public awareness, public participation and public access to information (art. 12)	n.a.
Habitat III New Urban Agenda (2016)	Policy	n.a.	Promotion of well-connected networks to improve the resilience of cities to climate change, improving household quality, and promoting attractive and liveable cities (art. 67)	National, subnational and local governments as key actors to promote energy conservation and efficiency, and to develop sustainable, renewable and affordable energy and energy-efficient buildings (art. 75)
Cities for adequate housing (2018)	Joint Declaration	Action 2 claims for more funds to improve the existing housing stocks	n.a.	Action 2 claims for more funds to improve the public housing stocks
EU level of governance				
Energy Performance of Buildings Directive 2010/31/EU (EPBD) (2010)	Directive	Major renovations of existing buildings, regardless of their size, provide an opportunity to take cost-effective measures to enhance energy performance (art. 4 and 7)	Member States shall take the necessary measures to inform the owners or tenants of buildings or building units of the different methods and practices that serve to enhance energy performance (art 20)	The public sector in each Member State should lead the way in the field of energy performance of buildings, and, therefore, the national plans should set more ambitious targets for the buildings occupied by public authorities

Energy Efficiency Directive 2012/27/EU (EED) (2012)	Directive	Member States shall establish a long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private (art. 4)	Member States shall take appropriate measures to promote and facilitate an efficient use of energy by small energy customers, including domestic customers (art. 12)	Exemplary role of public bodies' buildings. Buildings owned by public bodies account for a considerable share of the building stock and have high visibility in public life (art. 5)
Directive 2018/844/EU amending EPBD and EED (2018)	Directive	Art. 2a has been added to specify the long-term renovation strategy with a view to the long-term 2050 goal of reducing greenhouse gas emissions in the Union by 80-95 % compared to 1990, by specifying indicative milestones for 2030 and 2040	Smart-ready systems and digital solutions in the built environment offer new opportunities for energy savings, by providing consumers with more accurate information about their consumption patterns	Member States should provide clear guidelines and outline measurable, targeted actions as well as promote equal access to financing, for energy-poor consumers, for social housing and for households who are subjected to split-incentive dilemmas, also considering affordability
COM(2016) 860 final Clean Energy For All Europeans (2016)	Strategy	n.a.	Among the package three main goal, providing a fair deal for consumers is the one which is aimed at making easier for households and businesses to become more involved in the energy system	n.a.
Strategic Energy Technology (SET) Plan (2017)	Strategy	n.a.	It claims for a smarter energy system, empowering the consumer	n.a.
National level of governance (Italy)				
Legislative Decree 102/2014 (2014)	Regulation	Two instruments for building renovation: National buildings energy renovation strategy (STREPIN); Energy renovation plan for public administrations (PREPAC)	Prompting easy-to-read information on energy cost to consumers, allowing comparisons with average consumptions (art 9). Awareness raising to household, in particular those living in multi-family buildings, on the importance of energy diagnosis and sustainable consumption patterns (art 13)	Article 5 as a whole is devoted to energy efficiency of public buildings

Italy's National Energy Strategy (SEN) (2017)	Strategy	The establishment of a long-term renovation strategy for public and private buildings is foreseen. Revising, strengthening and confirming the tax deduction scheme for energy-efficiency investments (so-called "Ecobonus")	Low awareness of the impact of consumer behaviour is limiting the reduction of energy consumption. SEN aims at strengthening measures to support behaviour change and to build community awareness sharing the same energy reduction goal	Focus on energy efficiency for mitigating energy poverty, and on financial instrument to lead to the deep regeneration of public housing. Definition of the Energy renovation plan for public administrations (PREPAC) for the period 2021-2030
Italian Energy Efficiency Action Plan (PAEE 2014 and 2017)	Action Plan	The establishment of a long-term renovation strategy for public and private buildings is foreseen, in agreement with art 4 of 2012/27/UE Directive	In PAEE 2014, the integrated plan for the dissemination of energy efficiency (PIDEE) is foreseen, but never implemented as such; in PAEE 2017, specific three-year information and training programme (PIF) is developed. It is divided into three different stages	In PAEE 2014, funds are reserved to the renovation of public housing; in PAEE 2017, public housing associations are also eligible for tax relief on expenditure incurred for renovation works carried out on public housing they own/manage
Regional level of governance (Emilia-Romagna Region)				
Emilia-Romana Regional Energy Plan (PER) (2017)	Strategy	The residential sector has the highest potential when it comes to increase energy building performance. Therefore, the Region promotes the renovation of the existing stock	Promotion of campaigns to raise awareness among consumers and of projects for increasing the adoption of energy efficient behaviour	Public administrations have a leading role in showcasing benefit of retrofitting the public building stock, in agreement with 2012/27/UE Directive
Emilia-Romana Regional Energy Plan – Action Plan for 2017-2019 (PTA 2017-2019)	Action Plan	Axis 4 as a whole is devoted to building renovation and urban regeneration	To raise awareness on the benefit of energy efficiency measures, specific actions targeted to multi-family building managers may be promoted (IV.2.4. Axis 4)	The region is committed to renovate its own public building stock to at least 3% as required for national government buildings. Energy efficiency initiatives for public housing can be supported
LR24/2017 Regional legislation on the territory protection and use (2016)	Regulation	To promote urban regeneration, to enhance the urban and built environment quality, healthy and energy efficient housing	n.a.	To promote affordable housing, new social housing buildings can be made through additional building floor for renovation and urban regeneration projects (art 8)

Local level of governance (Municipality of Bologna)				
Municipal energy programme (PEC) (2007)	Strategy/ Action Plan	Several "energy urban basins" (BEU) have been identified within the city to apply energy equalisation procedures between renovated and new building complexes	n.a.	Actions within the "energy urban basins" reported in the atlas are targeted to public buildings
Bologna Sustainable Energy Action Plan (PAES) (2012)	Action Plan	Building renovation is a practice embedded throughout the Action Plan	"The Energy Point" is a public spot that provides information to citizens (both households and SMEs) on cost-effective measures to renovating buildings and to increase energy efficiency of both housing and working places	Actions targeted to public buildings, either to renovate the public housing stock and other public buildings, or to support the urban regeneration of brownfields and former barracks are foreseen
Municipal Structural Plan (PSC) (2008)	Planning tool	The energy issue is addressed through a set of building performance standards, promotion of building retrofit and renewable energy sources	n.a.	It is recognised the key role of maintenance and management of the public housing, particularly in those districts where it is concentrated
Environmental and Territorial Sustainability Assessment (VALSAT) (2008)	Environmental assessment tool	Assessment of impact of transformations included in PSC and design of different scenarios taking into account the energy equalisation principle introduced in the PEC	n.a.	n.a.
Urban Building Regulations (RUE) (2009)	Building regulation	Building renovation focuses on the retrofit of building envelopes and energy infrastructures. Reward-based mechanism under the form of density bonus incentives	n.a.	n.a.
Municipal Operative Plan (POC) (2015)	Planning tool	Public-private partnerships to provide energy efficiency retrofitting programmes	n.a.	The provision of social housing is among the criteria to comply with in order to implement the transformation

Source: author's elaboration

2.5 Energy renovation and consumer behaviour in buildings: is there a role for urban planning and urban regeneration?

Energy efficiency has been recognised as a multiscale issue, addressed by several policies and regulations. It concerns all the levels of governance and it involves multiple stakeholders. However, as clearly framed in the previous section, and already investigated by other scholars (Papa et al. 2016; Conticelli et al. 2017; La Greca 2017), there is a general tendency both in legislation and strategies to focus on the building scale, rather than the urban scale. At the same time, urban planning is still not much driven by energy planning, which in turn does not pay enough attention to the territorial level (La Greca 2017).

The challenges imposed by climate-change and energy issues are very complex and need to be addressed from the global to the local scale. As a result, at all level of governance, policy-makers are promoting integrated and adaptive strategies aimed at reducing or mitigating negative effects of climate change while reducing energy consumption and CO_2 emission.

Policy documents at the EU strategic level in the field of mitigation are primarily focus on the role that smart energy infrastructure, energy efficiency, renewable-energy projects, research and the deployment of new energy technologies may have in the reduction of energy consumption and CO_2 emission. While it is widely acknowledged in these documents that significant interventions are needed in the building sectors, there is no reference to the impact of spatial organization and physical planning on building consumption and associated GHG emissions in the EU (Papa et al. 2016).

Spatial planning is either a national or a regional legislation subject, depending on the Member States administrative characteristics and regulation, therefore, it is not surprising that is barely mentioned in International strategies and EU energy directives, with exception for the Habitat III New Urban Agenda. However, investigating the policy instruments at the Italian national level, the absence of measures and actions related to the design and use of territory is surprising and it is identified as a weakness element (Papa et al. 2016). Although the Italian national policy instruments have recognised the key role of building sector in changing the paradigms of energy demand and consumption, they identify either tax and financial measures or technological solutions as tools worth to be implemented, without any reference to the impact that spatial planning may determine.

On the one side, similarly to what already identified by Papa et al. (2016), by considering the energy policy instruments it emerges that in none of the levels of governance investigated above spatial planning is truly implemented. Even at the local level (i.e. in both PEC and PAES), where implementation should be at its most practical, measures are usually uncoordinated singular interventions grouped in factsheets, rather than according spatial planning objectives. On the other side, the urban planning tools (i.e. PSC, RUE, POC) at local level are still not enough driven by energy planning. The energy issue is always embedded in terms of performance and reduction of energy demand in buildings, while the role of building occupants in achieving such goals and the relationships between behaviour and building characteristics (see Chapter 3) are completely neglected. Energy efficiency is considered to be a technology-driven issue, rather than a matter of behaviour and consumption patterns.

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 aim of tackling energy poverty, boosting social cohesion and triggering local jobs. The active involvement of private actors and the citizens' empowerment is expected to boost the effectiveness of the urban regeneration actions, where the local authorities hold the role of public directors (Privitera 2017). Among the key ingredients of the regeneration process, there are: a strong long-term commitment from the public authorities; combination of social and physical measures; and involvement and empowerment of the people, who need to be much more aware of their role in lowering energy consumption in buildings.

As far as urban regeneration is concerned, the level of complexity is higher than for new development areas, consequently spatial planning should look for additional tools. Traditional analytical techniques, popular among spatial planners, have to be updated by using algorithms, models and data commonly used by computational social science. By using these technologies, new insights in the knowledge of urban structure and functions can be obtained. This updated level of knowledge is fundamental for fine-tuning the planning tools already described (Greca and Martinico 2016).

The urban scale is the most suitable level where all different renewal-oriented tools could be applied together, and the positive effects of incentives and rewards mechanisms could be multiplied. This would also allow the implementation of new and more collaborative approaches involving the public sector, occupants, households and developers acting in the building sector, driving the transition towards a credible and long-lasting model of low-carbon city (Conticelli et al. 2017). The energy efficiency process, to be effective in achieving energy reduction targets, should be conceived as a part of an integrated and broader urban strategy fostering urban regeneration of the existing city, where the local authorities have a key strategic role in coordinating and influencing the activities of a range of actors, in defining areas and communities to focus on, and in engaging people in changing behaviours in order to reduce energy consumption (Theobald and Shaw 2014). Therefore, investigating consumer behaviour in the framework of urban planning can provide an insight into the urban regenerative potential of cities, which relies – among others – on the one side, on energy awareness of people, their behaviour, capacity and willingness to adapt, on the other side, on the ability of public authorities to design renovation strategies to turn occupants into active actors, rather than passive target groups.

2.6 Directions for future research

Consumer behaviour is hugely complex, shaped by many factors, some of which are intrinsic to the individuals, others depend on the building characteristics and more generally on the local environment where people live. Research has shown that occupants can use three or more times as much energy for heating as their neighbours living in dwellings with similar characteristics (Haas et al. 1998; Steemers and Yun 2009; Gram-Hanssen 2010, Andersen 2012), and energy savings through behavioural factors can be as high as those from technological ones (Lopes et al. 2012), thus giving to the occupants the possibility either to reinforce the savings from energy efficiency measures, or to waste them. However, the difficulty to quantify behaviour has also contributed to limit the integration of the human factor in energy efficiency policies and building renovation strategies, with a consequent overconfidence in technology.

In order to change the consumer behaviour, the tools adopted can be divided in two main groups: disincentive and incentives through laws and regulations, and informative tools for increasing occupant knowledge and awareness. Both approaches require effective policy instruments to support all the stakeholders involved in the implementation of energy efficiency measures to deliver such change. Indeed, the role of policy instruments for energy efficiency should be further studied in order to effectively address the behavioural patterns of different user groups. Urban planning is one of the disciplines that has recently started to focus on the human factor as a driver for the effective implementation of urban renovation programs. Understanding and tackling user behaviour by embedding renovation measures and incentives to lead to behaviour change in urban planning tools could contribute to bridge the gap between the provision of energy efficiency measures in policy and regulations and their actual implementation (Santangelo and Tondelli 2017).

Furthermore, the majority of research on consumer behaviour focuses on single buildings and there are only a few studies that investigate the urban scale impacts (Delzendeh et al. 2017). As mentioned above, inappropriate choice of occupant behaviour model could result in oversized district energy systems, leading to over-investment and low operational efficiency (Happle et al. 2018). Future research should aim at assessing the impact of occupant behaviour on a larger scale, considering urban regeneration, rather than single building retrofit.

Consumer behaviour issue is going to face future challenges as soon as a new disruptive technology is taking over. As argued by Lopes et al. (2012), when it comes to the ongoing transformation of electric grids into smart grids, the latter will provide a completely different technological context, changing the customer–utility relations and raising significant challenges to user behaviour. Although it is expected that smart grids will increase energy awareness levels and encourage more efficient energy behaviours, in order to ensure their adequate implementation, energy behaviour research should be developed at the same time as the technological framework. In fact, the future electricity grid not only promises to be a radical technological, environmental and economic upgrade of the old system, it also will be a more pervasive technology, influencing the daily life of users. The extent to which users are willing to accept changes in their homes and daily routines will not only shape what smart grids will look like, it will also have a considerable impact on the chances of successful implementation (Verbong et al. 2013).

With an increasing share of renewable energy sources (RES) in the EU, the role of energy consumers as active producers in the energy system is bound to expand. A growing number of households, public organizations and small enterprises are likely to produce energy, supply demand-side flexibility or store energy in times of oversupply. Therefore, the concept of prosumers has emerged, although the extent of this potential in the EU is still under investigated (European Commission 2017).

As illustrated above, many different energy-related behaviours in the building sector have been investigated so far, with the heating pattern as the most studied. Future investigations about the interrelationship between different energy behaviours are needed, which will generate more realistic assumptions in building energy performance (Delzendeh et al. 2017). For being able to address the complexity of the human factor in energy consumption, the social effects, technical characteristics and building performance simulation models, the role of economic, taxes and incentives as well as the policy instruments should be further investigated in combination one with each other. Integrating quantitative and qualitative approach still remains an effort to make in order to better understand behaviour determinants and the drivers for changing it. A higher integration would be also beneficial among different research fields, with many scholars advocating for more collaboration among different disciplines. Although some studies have already applied multi-disciplinary approaches (Stephenson et al. 2010; Yan and Hong 2018), much more effort has to be taken in order to better understand determinants of behaviour, drivers to behavioural changes, and to what extent behaviour change can lead to urban regeneration.

2.7 Key research findings

- When it comes to research in the field of energy consumption and energy efficiency, there is a lack of common understanding of what consumer behaviour is, since it is strongly related to the technical, economic, sociological and psychological models applied to understand how and why people perform energy-related actions, and to the disciplines which investigate these actions.

- Investigating consumer behaviour towards energy efficiency and sustainable energy consumption requires a deep understanding of both the human factor and the technological asset, and the integration of both qualitative and quantitative methodologies.
- Being the residential sector the main contributor to energy consumption in buildings in EU (about 62%), most of the research on consumer behaviour has been essentially focused on it, investigating the human dimension of energy consumption with reference both to the occupants and to the energy-related behaviour of key stakeholders.
- Policy-makers are currently facing the challenge to design and implement effective housing renovation strategies both for the public and the private housing stock, able to support not only the technical and physical renovation, but also a change of paradigm in energy consumption. Policies and regulations at different territorial levels are struggling to encourage decision-makers to include information to users as a prerequisite to implement effective energy efficiency strategies and to lower energy consumption.
- Energy efficiency has been recognised as a multiscale issue, addressed by several policies and regulations. It concerns all the levels of governance and it involves multiple stakeholders. However, there is a general tendency both in legislation and strategies to focus on the building scale, rather than the urban scale.
- In none of the levels of governance investigated energy and spatial planning are truly integrated. At the local level, the urban planning tools are still not enough driven by energy planning. The energy issue is always embedded in terms of performance and reduction of energy demand in buildings, while the role of building occupants in achieving such goals and the relationships between behaviour and building characteristics are completely neglected. Energy efficiency is considered to be a technology-driven issue, rather than a matter of behaviour and consumption patterns.
- The energy efficiency process, to be effective in achieving energy reduction targets, should be conceived as a part of an integrated and broader urban strategy fostering urban regeneration of the existing city, where the local authorities have a key strategic role in coordinating and influencing the activities of a range of actors, in defining areas and communities to focus on, and in engaging people in changing behaviours in order to reduce energy consumption.

References

Abrahamse W, Steg L, Vlek C, Rothengatter T (2005) A review of intervention studies aimed at household energy conservation. Journal of Environmental Psychology 25:273–291. doi: 10.1016/j.jenvp.2005.08.002

Abreu JM, Câmara Pereira F, Ferrão P (2012) Using pattern recognition to identify habitual behavior in residential electricity consumption. Energy and Buildings 49:479–487. doi: 10.1016/j.enbuild.2012.02.044

Andersen R (2012) The influence of occupants' behavior on energy consumption investigated in 290 identical dwellings and in 35 apartments. In: Proceedings of Healthy Buildings 2012

Andersen RV, Toftum J, Andersen KK, Olesen BW (2009) Survey of occupant behaviour and control of indoor environment in Danish dwellings. Energy and Buildings 41:11–16. doi: 10.1016/j.enbuild.2008.07.004

Ben H, Steemers K (2018) Household archetypes and behavioural patterns in UK domestic energy use. Energy Efficiency 11:761–771. doi: 10.1007/s12053-017-9609-1

Čavoški S, Markovíc A (2015) Analysis of Customer Behaviour and Online Retailers Strategies Using the Agent-Based Simulation. Management - Journal for theory and practice of management 20:13–24. doi: 10.7595/management.fon.2015.0031

Chen S, Yang W, Yoshino H, et al (2015) Definition of occupant behavior in residential buildings and its application to behavior analysis in case studies. Energy and Buildings 104:1–13. doi: 10.1016/j.enbuild.2015.06.075

Cities for Adequate Housing (2018) Municipalist Declaration of Local Governments for the Right to Housing and the Right to the City. https://citiesforhousing.org/#section--0. Accessed 24 Sep 2018

Conticelli E, Proli S, Tondelli S (2017) Integrating energy efficiency and urban densification policies: Two Italian case studies. Energy and Buildings 155:308–323. doi: 10.1016/j.enbuild.2017.09.036

D'Oca S, Corgnati SP, Buso T (2014a) Smart meters and energy savings in Italy: Determining the effectiveness of persuasive communication in dwellings. Energy Research and Social Science 3:131–142. doi: 10.1016/j.erss.2014.07.015

D'Oca S, Fabi V, Corgnati SP, Andersen RK (2014b) Effect of thermostat and window opening occupant behavior models on energy use in homes. Building Simulation 7:683–694. doi: 10.1007/s12273-014-0191-6

D'Oca S, Hong T (2015) Occupancy schedules learning process through a data mining framework. Energy and Buildings 88:395–408. doi: 10.1016/j.enbuild.2014.11.065

D'Oca S, Hong T, Langevin J (2018) The human dimensions of energy use in buildings: A review. Renewable and Sustainable Energy Reviews 81:731–742. doi: 10.1016/j.rser.2017.08.019

Delzendeh E, Wu S, Lee A, Zhou Y (2017) The impact of occupants' behaviours on building energy analysis: A research review. Renewable and Sustainable Energy Reviews 80:1061–1071. doi: 10.1016/j.rser.2017.05.264

De Meester T, Marique AF, De Herde A, Reiter S (2013) Impacts of occupant behaviours on residential heating consumption for detached houses in a temperate climate in the northern part of Europe. Energy and Buildings 57:313–323. doi: 10.1016/j.enbuild.2012.11.005

ENEA (2014) Italian Energy Efficiency Action Plan (EEAP 2014), July.

Engvall K, Lampa E, Levin P, et al (2014) Interaction between building design, management, household and individual factors in relation to energy use for space heating in apartment buildings. Energy and Buildings 81:457–465. doi: 10.1016/j.enbuild.2014.06.051

European Commission (2017) Study on "Residential Prosumers in the European Energy Union" JUST/2015/CONS/FW/C006/0127. Framework Contract EAHC/2013/CP/04. https://ec.europa.eu/commission/sites/beta-political/files/study-residential-prosumers-energy-union_en.pdf

Fabi V, Andersen RV, Corgnati S, Olesen BW (2012) Occupants' window opening behaviour: A literature review of factors influencing occupant behaviour and models. Building and Environment 58:188–198. doi: 10.1016/J.BUILDENV.2012.07.009

Feng X, Yan D, Hong T (2015) Simulation of occupancy in buildings. Energy and Buildings 87:348–359. doi: 10.1016/j.enbuild.2014.11.067

Feng X, Yan D, Yu R, Gao Y (2017) Investigation and modelling of the centralized solar domestic hot water system in residential buildings. Building Simulation 10:87–96. doi: 10.1007/s12273-016-0315-2

Foxall GR (1993) Consumer Behaviour as an Evolutionary Process. European Journal of Marketing 27:46-57. doi: 10.1108/03090569310042936

Frederiks ER, Stenner K, Hobman E V. (2015) Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renewable and Sustainable Energy Reviews 41:1385–1394. doi: 10.1016/j.rser.2014.09.026

Gram-Hanssen K (2010) Residential heat comfort practices: understanding users. Building Research & Information 38:175–186. doi: 10.1080/09613210903541527

Gram-Hanssen K (2014) New needs for better understanding of household's energy consumption – behaviour, lifestyle or practices? Architectural Engineering and Design Management 10:91–107. doi: 10.1080/17452007.2013.837251

Greca P La, Martinico F (2016) Energy and Spatial Planning: A Smart Integrated Approach. In: Papa R, Fistola R (eds) Smart Energy in the Smart City. Springer International Publishing, pp 43–59

Grønhøj A, Thøgersen J (2011) Feedback on household electricity consumption: Learning and social influence processes. International Journal of Consumer Studies 35:138–145. doi: 10.1111/j.1470-6431.2010.00967.x

Guerra-Santin O (2011) Behavioural patterns and user profiles related to energy consumption for heating. Energy and Buildings 43:2662–2672. doi: 10.1016/j.enbuild.2011.06.024

Guerra-Santin O, Itard L (2010) Occupants' behaviour: determinants and effects on residential heating consumption. Building Research & Information 38:318–338. doi: 10.1080/09613211003661074

Guerra-Santin O, Romero Herrera N, Cuerda E, Keyson D (2016) Mixed methods approach to determine occupants' behaviour – Analysis of two case studies. Energy and Buildings 130:546–566. doi: 10.1016/j.enbuild.2016.08.084

Guerra-Santin O, Silvester S (2016) Development of Dutch occupancy and heating profiles for building simulation. Building Research & Information 1–18. doi: 10.1080/09613218.2016.1160563

Happle G, Fonseca JA, Schlueter A (2018) A review on occupant behavior in urban building energy models. Energy and Buildings 174:276–292. doi: 10.1016/j.enbuild.2018.06.030

Hargreaves T (2011) Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change. Journal of Consumer Culture 11:79–99. doi: 10.1177/1469540510390500

Haas R, Auer H, Biermayr P (1998) The impact of consumer behavior on residential energy demand for space heating. Energy and Buildings 27:195-205. doi: 10.1016/S0378-7788(97)00034-0

Hayles CS, Dean M (2015) Social housing tenants, Climate Change and sustainable living: A study of awareness, behaviours and willingness to adapt. Sustainable Cities and Society 17:35–45. doi: 10.1016/j.scs.2015.03.007

Hong T, Yan D, D'Oca S, Chen C fei (2017) Ten questions concerning occupant behavior in buildings: The big picture. Building and Environment 114:518–530. doi: 10.1016/j.buildenv.2016.12.006

International Energy Agency (2016) Energy in Buildings and communities programme. Total energy use in buildings: Analysis and evaluation methods (Annex 53). Project summary report. http://www.iea-ebc.org/Data/publications/EBC_PSR_Annex53.pdf. Accessed 3 Aug 2018

International Energy Agency DSM Energy Efficiency (2014) Task 24 Phase I – Closing the Loop: Behaviour Change in DSM – From Theory to Practice. http://www.ieadsm.org/task/task-24-phase-1/#section-2. Accessed 30 Jul 2018

International Energy Agency EBCP (2013) Final Report Annex 53. Total energy use in buildings Analysis and evaluation methods. http://www.iea-ebc.org/Data/publications/EBC_Annex_53_Main_Report.pdf. Accessed 2 Aug 2018

Kowsari R, Zerriffi H (2011) Three dimensional energy profile: A conceptual framework for assessing household energy use. Energy Policy 39:7505–7517. doi: 10.1016/j.enpol.2011.06.030

La Greca (2017) La pianificazione urbanistica e la sfida energetica. In: La Greca P, Tira M (eds) Pianificare per la sostenibilità energetica della città. Politecnica. Maggioli Editore. Santarcangelo di Romagna (RN). pp 21-40

Lehner M, Mont O, Heiskanen E (2016) Nudging – A promising tool for sustainable consumption behaviour? Journal of Cleaner Production 134:166–177. doi: 10.1016/j.jclepro.2015.11.086

Lopes MAR, Antunes CH, Martins N (2012) Energy behaviours as promoters of energy efficiency: A 21st century review. Renewable and Sustainable Energy Reviews 16:4095–4104. doi: 10.1016/j.rser.2012.03.034

Martínez-Espiñeira R, García-Valiñas MA, Nauges C (2014) Households' pro-environmental habits and investments in water and energy consumption: Determinants and relationships. Journal of Environmental Management 133:174–183. doi: 10.1016/j.jenvman.2013.12.002

Masoso OT, Grobler LJ (2010) The dark side of occupants' behaviour on building energy use. Energy and Buildings 42:173–177. doi: 10.1016/J.ENBUILD.2009.08.009

Moloney S, Strengers Y (2014) "Going Green"?: The Limitations of Behaviour Change Programmes as a Policy Response to Escalating Resource Consumption. Environmental Policy and Governance 24:94–107. doi: 10.1002/eet.1642

Mora D, Carpino C, De Simone M (2017) Energy consumption of residential buildings and occupancy profiles. A case study in Mediterranean climatic conditions. Energy Efficiency. doi: 10.1007/s12053-017-9553-0

Mora D, Carpino C, De Simone M (2015) Behavioral and physical factors influencing energy building performances in Mediterranean climate. Energy Procedia 78:603–608. doi: 10.1016/j.egypro.2015.11.033

OECD (2014) Greening Household Behaviour: Overview from the 2011 Survey – Revised edition, OECD Studies on Environmental Policy and Household Behaviour, OECD Publishing. doi: 10.1787/9789264214651-en

Papa R, Gargiulo C, Zucaro F, et al (2016) Energy and Climate Change Polices in Europe: Overview and Selected Examples from a Spatial Planning Perspective. In: Papa R, Fistola R (eds) Smart Energy in the Smart City, Green Ener. Springer International Publishing Switzerland, pp 237–274

Privitera R (2017) Efficienza energetica urbana. Nuove sfide per le città del sud Italia. In: La Greca P, Tira M (eds) Pianificare per la sostenibilità energetica della città. Politecnica. Maggioli Editore. Santarcangelo di Romagna (RN). pp 101-129

Proli S, Santangelo A, Tondelli S (2016) Efficienza energetica ed edilizia sociale: il programma Rig.ener.a, sfide e prospettive a Bologna. In: Proceedings of XIX Conferenza Nazionale SIU Cambiamenti. Responsabilità e strumenti per l'urbanistica al servizio del paese. Planum Publisher, Catania 16th-18th June 2016

Regione Emilia-Romagna (2017) Piano Energetico Regionale. http://energia.regione.emilia-romagna.it/documenti/doc-2017/allegato_2_PER2017conFrontespizio.pdf/at_download/file/allegato_2_%20PER%202017%20con%20Frontespizio.pdf. Accessed 29 Aug 2018

Ren X, Yan D, Hong T (2015) Data mining of space heating system performance in affordable housing. Building and Environment 89:1–13. doi: 10.1016/j.buildenv.2015.02.009

Santangelo A, Tondelli S (2017) Occupant behaviour and building renovation of the social housing stock: Current and future challenges. Energy and Buildings 145:276–283. doi: 10.1016/j.enbuild.2017.04.019

Santangelo A, Yan D, Feng X, Tondelli S (2018) Renovation strategies for the Italian public housing stock: Applying building energy simulation and occupant behaviour modelling to support decision-making process. Energy and Buildings 167:269–280. doi: 10.1016/j.enbuild.2018.02.028

Shove E, Walker G (2014) What Is Energy For? Social Practice and Energy Demand. Theory, Culture & Society 31:41–58. doi: 10.1177/0263276414536746

Solomon MR (2006) Consumer behaviour: A European perspective. Pearson education.

Stazi F, Naspi F, D'Orazio M (2017) A literature review on driving factors and contextual events influencing occupants' behaviours in buildings. Building and Environment 118:40–66. doi: 10.1016/j.buildenv.2017.03.021

Steemers K, Yun GY (2009) Household energy consumption: a study of the role of occupants. Building Research & Information 37:625–637. doi: 10.1080/09613210903186661

Steg L, Vlek C (2009) Encouraging pro-environmental behaviour: An integrative review and research agenda. Journal of Environmental Psychology 29:309–317. doi: 10.1016/j.jenvp.2008.10.004

Stephenson J, Barton B, Carrington G, et al (2010) Energy cultures: A framework for understanding energy behaviours. Energy Policy 38:6120–6129. doi: 10.1016/j.enpol.2010.05.069

The World Bank (2014) CO2 emissions from transport (% of total fuel combustion). https://data.worldbank.org/indicator/EN.CO2.TRAN.ZS. Accessed 1 Aug 2018

Theobald K, Shaw K (2014) Urban governance, planning and retrofit. In: Dixon T, Eames M, Hunt M, Lannon S (eds) Urban Retrofitting for Sustainability. London: Routledge, pp 87-98

UN (2015) Adoption of the Paris Agreement. FCCC/CP/2015/L.9/Rev.1. http://www.un.org/ga/search/view_doc.asp?symbol=FCCC/CP/2015/L.9/Rev.1

UN (2017) New Urban Agenda. http://habitat3.org/wp-content/uploads/NUA-English.pdf. Accessed 1 Aug 2018

UNSD (2016a) Metadata for Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all. https://unstats.un.org/sdgs/files/metadata-compilation/Metadata-Goal-7.pdf

UNSD (2016b) Metadata for Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable. https://unstats.un.org/sdgs/files/metadata-compilation/Metadata-Goal-11.pdf van den Brom P, Meijer A, Visscher H (2018) Performance gaps in energy consumption: household groups and building characteristics. Building Research and Information 46:54–70. doi: 10.1080/09613218.2017.1312897

Van Raaij WF, Verhallen TMM (1983) Patterns of residential energy behavior. Journal of Economic Psychology 4:85–106. doi: 10.1016/0167-4870(83)90047-8

Verbong GPJ, Beemsterboer S, Sengers F (2013) Smart grids or smart users? Involving users in developing a low carbon electricity economy. Energy Policy 52:117–125. doi: 10.1016/J.ENPOL.2012.05.003

Verones S (2013) Energy and Urban Planning Towards an Integration of Urban Policies. PhD thesis. University of Trento

Wilson C, Dowlatabadi H (2007) Models of Decision Making and Residential Energy Use. Annual Review of Environment & Resources 32:169–203. doi: 10.1146/annurev.energy.32.053006.141137

World Business Council for Sustainable Development (2007) Energy efficiency in buildings: business realities and opportunities: summary report. https://www.wbcsd.org/Programs/Cities-and-Mobility/Energy-Efficiency-in-Buildings/Resources/Business-realities-and-opportunities-Summary. Accessed 3 Aug 2018

Yan D, Hong T (2018) Definition and Simulation of Occupant Behavior in Buildings. Annex 66 Final Report. International Energy Agency

Yan D, O'Brien W, Hong T, et al (2015) Occupant behavior modeling for building performance simulation: Current state and future challenges. Energy and Buildings 107:264–278. doi: 10.1016/j.enbuild.2015.08.032

Yang S, Shipworth M, Huebner G (2015) His, hers or both's? The role of male and female's attitudes in explaining their home energy use behaviours. Energy and Buildings 96:140–148. doi: 10.1016/j.enbuild.2015.03.009

Yu Z, Fung BCM, Haghighat F, et al (2011) A systematic procedure to study the influence of occupant behavior on building energy consumption. Energy and Buildings 43:1409–1417. doi: 10.1016/j.enbuild.2011.02.002

3. Existing knowledge on household behaviour determinants and strategies to promote behavioural change[1]

ENGLISH ABSTRACT

The central role of consumers for achieving energy savings is increasingly recognised, and it is even more important in the social housing sector, where the environmental value is combined with the social purpose of accommodating low-income households, reducing inequalities and fuel poverty. The aim of this chapter is to identify the determinants of occupant behaviour and energy consumption, and to understand the key success factors that should be embedded in the strategies to promote pro-environmental behaviour. Sections 3.1 and 3.2 present respectively the introduction, and the aim and methodology. Then the contribution examines the determinants of occupant behaviour (Section 3.3), the strategies to promote behaviour changes (Section 3.4), the co-benefits of implementing such actions in community-based programmes and suggestions to do so (Section 3.5). Four initiatives in Europe are further investigated to understand the effects of occupant behavioural change towards lower energy consumption in the social housing sector (Section 3.6). A comparative matrix for the analysis of the four cases is developed to highlight their common characteristics and divergences. Finally, the direction for future research and key research findings are respectively discussed in Sections 3.7 and 3.8.

ABSTRACT IN ITALIANO

Il ruolo degli utenti per il raggiungimento dell'efficienza energetica è sempre più riconosciuto come centrale, e lo è ancora di più nel settore dell'edilizia sociale, dove al valore ambientale si affianca l'obiettivo sociale di dare una casa a famiglie con un basso reddito, ridurre le disuguaglianze e la povertà energetica. L'obiettivo del capitolo è quello di identificare gli elementi che determinano il comportamento degli utenti e i consumi energetici, al fine di studiare quali sono i fattori chiave da incorporare nelle strategie per promuovere un comportamento sostenibile. Le sezioni 3.1 e 3.2 presentano rispettivamente l'introduzione, e lo scopo e la metodologia. Il contributo esamina poi i fattori determinanti del comportamento degli occupanti (sezione 3.3), le strategie per promuovere comportamenti energeticamente più sostenibili (sezione 3.4) e i benefici ulteriori che derivano dell'attuazione di tali azioni ad una scala di comunità (sezione 3.5). Quattro iniziative in Europa sono state ulteriormente studiate per comprendere gli effetti del cambiamento comportamentale degli utenti nell'ambito dell'edilizia sociale (sezione 3.6). Una matrice comparativa per l'analisi delle quattro pratiche è stata quindi sviluppata per evidenziare le principali caratteristiche. Infine, indicazioni per la ricerca futura e i principali risultati sono discussi rispettivamente nelle sezioni 3.7 e 3.8.

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[1] An earlier version of this chapter has been published as: Santangelo A, Tondelli S (2017a) Occupant behaviour and building renovation of the social housing stock: Current and future challenges. Energy and Buildings 145:276–283. doi: 10.1016/j.enbuild.2017.04.019

3.1 Introduction

In the European Union, buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions. The residential sector, with the 75% of the total energy consumption in buildings (BPIE 2011), is an important target area for energy reduction. According to Eurostat data, in 2016 household energy consumption for space heating, water heating and electrical appliances accounted respectively for the 65%, the 15% and the 14% of the total consumption. While EU countries have agreed on a new 2030 framework for climate and energy (i.e. EU-wide targets and policy objectives for the period between 2020 and 2030), the EC statistical pocketbook providing figures on energy (European Commission 2017) has pointed out the increase of 25% in the domestic energy costs in the period 2009-2016. This might be due both to the low refurbishment rates of housing and the low replacement rates of inefficient equipment, which have not been sufficient to offset rising prices. But while high-income households have higher overall energy consumption, low-income groups spend a larger share of their income on energy costs (Schaffrin and Reibling 2015). Therefore, such an increase has further negative distributional consequences within the social housing sector[2].

Energy use in buildings has also been investigated from the social science perspective, rather than considered just a matter of technology (Abrahamse et al. 2005, 2007; Owens and Driffill 2008; Janda 2009; Karatas et al. 2016). Energy poverty is a growing phenomenon in the EU since 2008 with almost 52 million of people being unable to keep their homes adequately warm. It is often defined as a situation where households cannot access to and afford adequate level of heating or other required energy services to meet their basic needs (Bouzarovski et al. 2012; Pye and Dobbins 2015; Thomson et al. 2016), or they cannot afford other necessary goods due to the high utility costs (Schaffrin and Reibling 2015), while the current challenge for EU Member

[2] The term social housing refers to the definition provided by the CECODHAS (today Housing Europe) in 2006, when it started to be referred as housing for households whose needs are not met by the open market and where there are rules for allocating housing to benefiting households. To the scope of this work, it comprises housing stock managed by public or private housing associations, since the focus is on the mission (i.e. satisfy households' housing needs in terms of access and permanence in decent and affordable housing) rather than on the source of funding for implementing it. As a matter of fact, Sweden has by definition no social housing, since there are no benefits from special subsidies to the builder/owner, and reserved for low-income households. Nevertheless, almost half of the rental sector is owned by municipally owned housing companies, whose goal is to provide housing for all, regardless of gender, age, origin or incomes (Housing Europe 2015).

States is still to develop adequate definitions, supported by statistics, useful for policy making. While in the owner-occupied sector cost-savings are expected to be the main stimulus for building energy-efficient renovation, the interventions within the social housing stock combine the energy-saving goal with the social and economic co-benefits (e.g. poverty alleviation, health improvements), thus contributing to face stigmatisation, social segregation and fuel poverty, particularly prevalent in social housing sector.

As already framed in Chapter 1, although a number of policy regulations has been already introduced to reduce energy consumption in buildings, evidence from research shows that the design of energy efficient buildings does not necessarily result in low energy buildings (Guerra-Santin and Itard 2010; Stevenson and Leaman 2010). The gap between expected and actual energy consumption in buildings is highly dependent from the human factor, as energy efficiency is not only a matter of technology, but it is influenced by the use people make of it (Janda 2009; Paauw et al. 2009; Gram-Hanssen 2010; Gupta and Chandiwala 2010; Feng et al. 2016). Even in high-energy performance dwellings, they will still be the households who ultimately determine the energy consumption. Actually, the more the energy efficiency of the buildings is, the greater is the impact of households (Andersen et al. 2009; Guerra-Santin and Itard 2010). For instance, according to Huebner et al. (2013), the use of a programmable thermostat can significantly decrease the energy consumed both for heating and cooling, with savings up to 30% for heating systems and 23% for cooling systems through setting night- and day-time setback temperatures, but such savings are not necessarily realised unless the user knows the thermostat control mechanism. Furthermore, research has shown that occupants can use three or more times as much energy for heating as their neighbours living in dwellings with similar characteristics (Steemers and Yun 2009; Gram-Hanssen 2010). Gill et al. (2010) have found that energy-efficient behaviours accounted for 51%, 37%, and 11% of the variance in heat, electricity, and water consumption, respectively, between very similar dwellings. Schipper (1989) has shown that while approximately half of the energy used in the house depends on the building characteristics and its equipment, the occupant behaviour influences the rest.

The main factors that explain this performance gap and that have been investigated in recent years are:

a) the rebound effect (Haas et al. 1998; Barbu et al. 2013; Guerra-Santin 2013; Visscher et al. 2016), which occurs when households increase their consumption as a consequence of paying less attention to their energy-related behaviour, since they believe that the increase of energy efficiency in buildings should automatically be translated into a decrease of consumption, no matter the level of usage and their behaviour. According to the UK Energy Research Centre, it could offset 10–30% of energy savings (Elsharkawy and Rutherford 2015);
b) the prebound effect (Sunikka-Blank and Galvin 2012; Visscher et al. 2016), explaining the lower than expected energy use in old inefficient dwellings due to a lower comfort level accepted by the occupants;
c) the occupant interaction with the building component (Schipper 1989);
d) the uncertainty of building performance simulation results, associated with uncertain occupant behaviour model inputs (Yan et al. 2015; Hong et al. 2015).

These factors have to be considered as potential risks for the success of policy instruments for the reduction of household energy consumption. Moreover, when it comes to strategies and policies to drive the behaviour change towards lowering energy consumption, other risks may occur and reduce the effect of behaviour change strategies: the drawback effect is observed when people fall back on old habits after the newness of the experiment wears out, while the Hawthorne effect occurs where achievements may be considered as a temporary result of occupants aware of being observed (Barbu et al. 2013). Hence, user behaviour in relation to energy efficiency in buildings is an emerging research topic which requires the integration of different and complementary expertise.

3.2 Aim and methodology

The aim of the chapter is to investigate the determinants of occupant behaviour and energy consumption, in order to understand, on the one side the characteristics responsible of certain behaviour patterns, on the other side the key success factors that should be embedded in the strategies to promote pro-environmental behaviour.

The analysis and considerations that follow are the results of a desk research approach with a wide literature review, and the identification of a comparative matrix to support the investigation on how occupant behaviour is embedded in four building renovation programmes across Europe targeted to social housing sector.

Chapter 3 contributes to the research question 2 as presented in the box below. Sub-question c) will be tackled in Section 3.3 through the description of main findings in existing literature. Effort to contribute to sub-question d) will be delivered in Sections 3.4, 3.5. Sub-question e) will be investigated in Section 3.6 through a review of initiatives to address energy behaviour in the social housing sector.

Research question 2:

How to identify the determinants of occupant behaviour and energy consumption, to understand which are the best strategies to promote pro-environmental behaviour?

Sub-questions:

c) Which are the determinants of energy behaviour in residential sector for heating consumption?

d) Is there any added value in promoting behavioural change at community level rather than at household level?

e) How does social housing sector can have a role in showcasing the path for increasing the renovation rate of residential buildings while addressing awareness on behaviour?

Firstly, the determinants of energy behaviour in residential sector are investigated, on the one side through a literature review of household and building characteristics affecting behaviour, on the other side through a literature review of household behavioural patterns. Secondly, factors and strategies to promote efficient behaviours are presented, in particular focusing on the benefits and limits of the feedback approach. Moreover, the non-energy co-benefits of working through community-based initiatives instead of only retrofitting the buildings are illustrated as a possible way for moving from behaviour change to systemic change, and suggestions to properly design community behaviour change initiatives are provided. In the following section, building renovation initiatives in the social housing sector in Italy, the Netherlands, Sweden and United Kingdom are investigated to understand how the occupant behavioural change towards lower energy consumption has been supported. A matrix for the analysis of the four practices is developed to facilitate clear comparison of trends and gaps between the selected programmes and to identify possible future instruments needed to overcome current barriers. Finally, future challenges and policy implications are discussed, and key research findings are summarised in the last section.

3.3 Determinants of energy behaviour in residential sector

A number of studies both from social and technical fields have been performed in the last decades with the aim to investigate the determinants for explaining user behaviour and to identify consumption patterns. While the social science usually adopts both qualitative and quantitative methods to perform its studies, the scholars preferring a technological approach use extensively quantitative methods. They consist mainly of data collection through surveys and interviews (Andersen et al. 2009; Gram-Hanssen 2010; Huebner et al. 2013; Engvall et al. 2014; OECD 2014), reading from smart meters (Grønhøj and Thøgersen 2011; D'Oca et al. 2014a) and statistics (Schaffrin and Reibling 2015; Guerra-Santin and Silvester 2016), used individually or combined one to the others.
The research instruments mostly applied rely on theoretical framework and behavioural models (Van Raaij and Verhallen 1983b; Abrahamse et al. 2005; Stephenson et al. 2010) in the field of social science, and mostly on simulation tools (D'Oca et al. 2014b; Yan et al. 2015) and statistical analysis and data mining techniques (Steemers and Yun 2009; Ren et al. 2015) for the engineering science.

3.3.1 A literature review of determinants of household energy behaviour

Occupant behaviour is believed to be influenced by household characteristics, lifestyle, and cognitive variables (i.e. motivation, values and attitudes), but also buildings characteristics, which affect the interaction between the user and the building components and appliances.

3.3.1.1 Household characteristics

When it comes to household characteristics (i.e. demographic, educational and socio-economic), some links with user behaviour have been identified in the literature.

Based on self-reported behaviour of 145 households in the Netherlands for one year, Van Raaij and Verhallen (1983b) argued that life-style influences energy-related attitudes and behaviour. Family size and composition next to the presence or absence from home for work or leisure all have a direct effect on energy behaviour and energy use. Income, educational level, and employment showed also to be related to energy use. Two decades later, Poortinga et al. (2003) discovered differences in acceptability of energy-saving measures related to age, household type, income and education level.

However, the influence of some factors is strongly linked with the local/regional/national conditions (Guerra-Santin and Silvester 2016). Among them, income remains one of the most controversial factors. On the one hand, income has been shown to be a determinant of energy consumption in Mexico due to the inadequate thermal insulation of the buildings where low-income households mostly live (Romero et al. 2013). On the other hand, a study performed in the Netherlands showed no relationship between income and energy consumption (Guerra-Santin et al. 2009). Income is also one of the factors determining the prebound effect (i.e. the lower than expected energy use in old inefficient dwellings due to a lower comfort level accepted by the occupants). While high-income households have higher overall energy consumption, low-income groups spend a larger share of their income on utility costs (Schaffrin and Reibling 2015). Some studies have shown that ownership has a positive influence on energy savings (Andersen et al. 2009; Martinsson et al. 2011; Guerra-Santin and Silvester 2016), while gender has also turned to be a significant determinant, with women more environmentally conscious than men (Carlsson-Kanyama and Lindén 2007; OECD 2014) and the proportion of women in the house giving a reduction in energy use for heating, assuming all other factors being equal (Engvall et al. 2014).

Not surprisingly, the heating patterns vary depending on the age of households (Lindén et al. 2006) and employment status (Guerra-Santin and Silvester 2016), with older and retired people staying at home during daytime hours, therefore, with the heating system turned on for longer than other family groups. Brundrett (1977) showed that the number of open windows was higher in families where housewives stayed at home and that it increased with the size of the family.

The relation between occupant behaviour and health has been proved to be bilateral (Bedir 2017). Either the former affects the latter or the other way around. Indeed, household size and poor ventilation, volume of the dwelling and the heating system can have significant impact on NO_2 concentration, resulting in health problems like respiratory symptoms and reduced lung function (Cibella et al. 2015).

Education has been found to be insignificant in explaining energy consumption (Guerra-Santin 2010; Sapci and Considine 2014), while a higher education level might be related to fewer hours of the heating system at the highest chosen temperature setting and lower education and presence of elderly are all related to more hours on the use of radiators and thermostats (Guerra-Santin 2010). Schweiker and Shukuya (2009) indicated that the use of air-conditioning units differed depending on the origin of a person, experience from childhood and attitude towards air-conditioning.

Motivation is another important determinant of electricity consumption (Lindén et al. 2006; Vringer et al. 2007). The perception of the environment and other factors concerning the dwelling can also impact the window opening behaviour (Andersen et al. 2009). Motivation and perception could be influenced through information, feedback and other educational and economic measures. Feedback in particular has proven to have a strong influence on occupant behaviour (see Section 3.4). As environmental concerns increase, households take direct action to conserve energy (Sapci and Considine 2014)

3.3.1.2 Building characteristics

The impact of the building thermal characteristics on space heating demand, as well as the one of efficiency of existing heating, ventilation and air conditioning (HVAC) systems and electrical appliances on electrical consumption have been studied and quantified for years, and they are basic knowledge for technical innovations and building energy performance simulations. However, the interest in building characteristics in relation to occupant behaviour has started to grow in the last decade (D'Oca et al. 2018). Building characteristics can be explained by external factors as the site and climate characteristics where the dwelling is located (e.g. outdoor air temperature, wind velocity and direction, horizontal global irradiance, air pollution and noise) and internal factors (e.g. building envelope and type of windows, dwelling size, mechanical systems and appliances).

Guerra-Santin and Itard (2010) found that the main building characteristic determining behaviour is the type of temperature control, since households with a programmable thermostat were more likely to keep the radiators turned on for more hours than households with a manual thermostat or manual valves on radiators. Shipworth et al. (2010) found that households with thermostats set the mean temperature slightly lower than those without thermostat.

Hansen et al. (2018) found that practices of adjusting thermostats and the amount of clothing occupants wear indoors, as well as perceived indoor temperature, all correlate with building characteristics (e.g. energy efficiency of the building envelope and technical installations). These correlations are moderated by the socio-demographic characteristics of occupants. The results indicate that occupants dress warmer and keep lower temperatures in energy-inefficient dwellings.

One parameter having a high influence both on the energy consumption and on indoor environmental quality is the air change rate. Since the thermal load for ventilation is related to the air change rate, a close examination of this indicator is important to consider when investigating the effects of the occupant behaviour. Natural ventilation is closely related to the heating consumption, and it is one of the main concerns for designers struggling with building energy performance. In order to reduce energy consumption, ventilation rate should be reduced as much as possible. Nevertheless, indoor air quality relies on a certain level of ventilation rate. Behaviour is also related with the type of ventilation system (i.e. natural or mechanical). According to Fabi et al. (2012) consensus has not been reached about whether to use indoor temperature, outdoor temperature or both as the independent variable when simulating window use, because of the inherent interactions between indoor and outdoor temperature in naturally-ventilated buildings. For instance, rising indoor temperatures might drive the opening of windows, but how long the window stays open might depend more on outdoor temperature.

When it comes to the electrical equipment, the introduction of energy labels has produced a positive trend in the sales of more energy efficient appliances. Consumers have responded positively to this mandatory information scheme enabling comparison of energy-efficiency of various appliance models through the ranking into the proper energy class (A–G) (D'Oca et al. 2014a). The number of home appliances and lighting appliances is believed to be a crucial factor in electricity consumption (Bedir 2017). Lighting varies according to the characteristics of the dwelling and the activities performed inside it.

3.3.2 A literature review of household behavioural patterns

Several scholars have categorized consumers and their energy and environmental attitudes to different behaviour patterns. Starting from the 1980s, Van Raaij and Verhallen (1983a) focused on the definition of five energy-related behavioural patterns (i.e. conservers, spenders, cool, warm, average) and verified that the average difference between the two extreme usage levels accounted for 31%.

The large survey conducted in 2011 by the Organisation for Economic Cooperation and Development on people's behaviour towards the environment (OECD 2014) has identified three clusters of environmental attitudes labelled environmentally motivated, environmental sceptics, and technological optimists. The environmentally motivated comprise just under half of the pooled sample and gather together people who believe that environmental problems are real and express a willingness to make compromises in their lifestyle to solve them, with the least need for reciprocation from others. Environmental sceptics believe that environmental issues are overstated and do not wish to pay for government environmental policies, although they do report a general willingness to make compromises for the benefit of the environment. Technological optimists share the belief with the environmentally motivated cluster that environmental problems are real and appear willing to make lifestyles compromises to solve them, but they show a greater belief in the potential of technological progress to solve environmental problems.

Abreu et al. (2012) adopted a pattern recognition method to identify user profiles of electricity consumption. The study explained that approximately 80% of household electricity use results from the persistent daily routines and patterns of consumption or baselines, typical of specific weather and daily conditions. The applicable profiles for this population were unoccupied baseline, hot working days, temperate working days, cold working days, and cold weekend days. By investigating the effect of thermostat and window opening behaviours, D'Oca et al. (2014b) grouped residential occupants into active, medium and passive energy users. While the active users change the heating set point to get warmer or cooler, the passive ones do not and better tolerate some level of discomfort.

Paauw et al. (2009) contributed to the research by setting the framework for the definition of an Energy Pattern Generation. They worked with five groups of households in the Netherlands, studied on the basis of household composition. Four profiles were built by relating energy consumption to income, environmental concern and personal comfort: convenience/ease profile, based on comfort assessed as important, but no interest in saving energy, money or the environment; conscious profile, with comfort as important, and some environmental and cost awareness; costs profile, where energy costs and saving money are the most important issue; and climate/environment profile, where environment is the most important value.

More recently, Guerra-Santin (2011) has conducted a research to statistically determine behavioural patterns associated with the heating consumption and to identify household and building characteristics contributing to the development of energy-user profiles. While the results have shown clear relationships between occupant behaviour and household characteristics, it was difficult to establish relationships among energy consumption and behavioural patterns and household groups.

Linden et al. (2006) provided an insight into behavioural patterns in Sweden and gave a bottom-up perspective on the policy instruments for driving the behavioural change, revealing behavioural patterns that are already efficient and those that need improvements, and the role of policy instruments to support the shift to efficient behaviours.

Gram-Hanssen (2010) applied the practice-theory approach on a study focused on how users regulate their indoor climate, and proposed a framework for understanding why they act as they do.

Hendrickson and Wittman (2010) developed a post-occupancy assessment (POA) tool for identifying several different occupant household consumption patterns.

Karatas et al. (2016) proposed a conceptual framework for selecting occupancy-focused energy interventions in buildings. This framework adopts a motivation, opportunity and ability (MOA) approach from the consumer and social marketing fields and foresees: measuring occupants pre- and post- intervention exposure MOA level and energy-use profiles; clustering occupants based on identified characteristics; choose energy-efficiency intervention strategies accordingly.

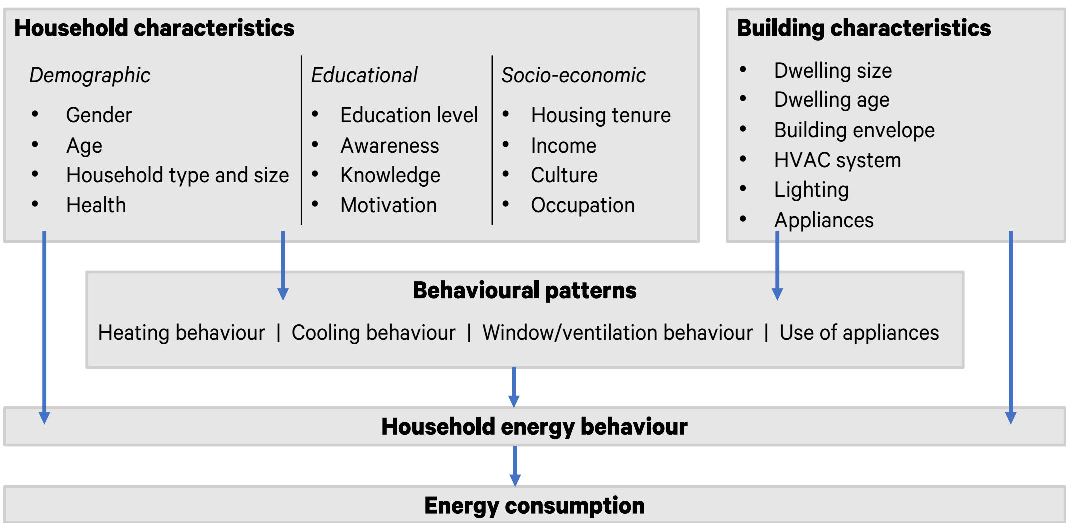
Energy Cultures (Stephenson et al. 2010; Barton et al. 2013), a research project aimed to help inform policy making related to residential energy use and energy efficiency in New Zealand, has clustered the energy consumers in four groups: energy economic; energy extravagant; energy efficient and energy easy. According to the project results, the lowest energy users tend to have substandard housing and inefficient energy technologies, yet have very economical energy practices. This combination of circumstances tends to be aligned with cold, and often damp, housing. This cluster of households (around 25% of the population) has lower incomes and restricted choices, creating a substantial barrier to improving their energy situation. Households with the highest energy use tend to be those that pay little attention to improving the energy efficiency of their house, own many energy-using appliances, and have little regard to energy-efficient practices. This cluster of households (around 20% of the population) is generally wealthier and thus has fewer barriers than others to making efficiency improvements. This group represents a policy opportunity to achieve significant gains in energy efficiency and conservation.

Household characteristics, building characteristics, and behavioural patterns are summarised in Figure 3.1.

Household behaviour can be influenced by: demographic factors as gender, age, household type and size, health; educational factors as level of education, awareness, knowledge, motivation; socio-economic factors as housing tenure, income, cultural background, occupation.

Building characteristics considered are external factor such as outdoor air temperature, wind velocity and direction, horizontal global irradiance, air pollution and noise, and internal factors such as building envelope and type of windows, dwelling size, mechanical systems and appliances.

Figure 3.1: Framework for household energy behaviour and consumption (interpreted from literature review)



Source: author's elaboration

Both household and building characteristics are determinants of household behaviour and can explain household behavioural patterns. Many scholars have attempted to identify behavioural patterns able to explain and predict behaviour. To the aim of this research, the patterns have been grouped according to the type of energy end-use: on the one side heating behaviour and window/ventilation behaviour affecting the heating consumption, on the other side use of appliances and cooling behaviour contributing to electricity consumption. The definition of further and more detailed user patterns is beyond the scope of this research. Behavioural patterns cannot be defined by literature review since they are closely related to the household and building characteristics of the sample studied.

3.4 Strategies and tools to promote behavioural change

A number of studies have investigated the factors influencing household energy use and conservation.

Technological developments, economic growth, demographic factors, institutional factors and cultural developments are the five general macro-level factors (known as TEDIC factors) that form the societal context that inevitably influences individual behaviour (Abrahamse et al. 2005). In turn, these TEDIC factors shape micro-level factors such as motivational factors (e.g. preferences, attitudes), abilities and opportunities which form the MOA model (Steg 2008; Karatas et al. 2016).

According to Steg (2008) "firstly, individuals need to be aware of the need for and possible ways to reduce household energy use. Secondly, they need to be motivated to save energy. Thirdly, they should be able to adopt the relevant behaviours".

Among others, Frederiks et al. (2015) applied behavioural economics and psychology to highlight the key cognitive biases and motivational factors that may explain why energy-related behaviour so often fails to align with either the personal values or material interests of consumers. However, insight from socio-economic and socio-technical research has recognised that changes in attitudes do not necessarily lead to changes in behaviour, and the choices of individuals are a key factor in the process of energy consumption (Owens and Driffill 2008; Moloney et al. 2010; Elsharkawy and Rutherford 2015).

Strategies to promote efficient behaviour can be divided in two groups, psychological strategies and structural strategies (Steg 2008). While the former (e.g. education, information) are aimed at influencing directly the users, the latter (e.g. new appliances, infrastructures, services) are aimed at changing the context in which decisions are made, to make energy conservation more attractive.

Policy instruments are responsible to translate these strategies into practices. According to Linden et al. (2006), four main categories of policy instruments can be identified, namely information, economic, administrative and physical instruments.

Focusing on information, it has been recognised the importance of tailored information (Van Raaij and Verhallen 1983a, b; Abrahamse et al. 2005; Paauw et al. 2009; Barbu et al. 2013) in delivering changes in energy-related behaviours and knowledge. However, information alone is unlikely to motivate changes. Information is also unlikely to result in sustained behavioural change beyond the life of a given campaign, since enthusiasm for new behaviour or actions tends to decrease in the absence of continual reinforcement (Moloney et al. 2010; Karlin et al. 2015). Although the limits of information strategies (Owens and Driffill 2008), informing the users is recognized an important first step in prompting people to change their behaviour, and an important element in the implementation of policy instruments to lead to reduction of energy consumption in buildings.

Therefore, physical renovation of buildings should be integrated by the information and training on sustainable occupant behaviour, especially in the case of housing stock where low-income people are accommodated, in order to ensure both environmental and social sustainability of the interventions.

3.4.1 Different types of feedback

Individual needs correct information for a responsible choice. Without an appropriate frame of reference, users cannot determine whether their energy consumption can be reduced or not (Gyberg and Palm 2009; Janda 2009; Barbu et al. 2013). Therefore, feedback plays a significant role in raising energy awareness and changing consumer attitudes towards energy consumption. There are a number of different feedback types: direct feedback (e.g. smart meters), available on demand; indirect feedback (e.g. informative energy bills); inadvertent feedback; energy audits (Darby 2006).

Direct feedback is the more immediate and easier accessible means to get on demand information. It is particularly useful for illustrating the impact on energy use of a specific behaviour pattern or device in real time. Feedbacks can be provided by a smart meter with In-Home Displays (IHDs) monitor or a clearly visible energy meter. By direct feedback measures energy consumption information is available in real time, all the times. Nevertheless, the effect of the direct feedback depends on how regularly users read the information, and also the literature (Fischer 2008; Barbu et al. 2013; Karlin et al. 2015) emphasizes the importance of frequent feedback in order to effectively influence user behaviour.

Indirect feedback is the one that has been processed in some way before being delivered to the users, as the case of informative energy bills. Consumers have no direct access to the real time consumption of a certain behaviour pattern and can only respond to previous consumption behaviours. This means that there is a time-delay between energy consumption and the moment the feedback reaches consumers. The means for providing indirect feedback can vary from more informative and also more frequent bills, information on web platform and email. As indirect feedback can include analysis of data collected over longer period, it is more suitable for showing longer-term effects. As for the direct feedback, the effect of indirect feedback depends on how frequent the feedback is available for consumers, and on how simple the information is.

Fischer (2008) summarised the knowledge about the qualities of “successful” feedback, acknowledging gaps in the research literature. Ideally, such feedback includes at least two of the following characteristics: multiple options for the user to choose from; an interactive element; frequency more often than monthly (continuously, daily load curves, or immediately after the action – switching on or off); detailed, appliance-specific breakdown of usage, and comparisons with previous periods. Faruqui et al. (2010) found that direct feedback provided by In-Home Displays (IHDs) can encourage occupants to make more efficient use of energy. Energy savings from occupant behaviour range between 3% and 13%, with an average of 7%. The range of savings achieved through indirect feedback (2%-10%) tends to be lower than the one reported in direct feedback studies (5%-15%); nevertheless, they may be important and are achievable at relatively low cost. Moreover, the combination of different informational feedback may lead to an increase of energy savings up to 20% (Barbu et al. 2013).

Jain et al. (2013) gave an insight on the impact of information representation on user behaviour. Their experiment in USA provided two study groups with real energy consumption data but according to different unit of measurement. Users who received feedback in terms of the environmental externality unit (i.e. trees needed to offset emissions) on average were able to save more energy than the group who received the feedback in the direct energy units of kWh. Frederiks et al. (2015) concluded that advising individuals that people similar to them (e.g. peers, neighbours) are using less energy or taking certain energy-saving actions, in addition to conveying social approval of such actions, will most likely motivate them to conform to these positive energy-saving attitudes and to reduce their consumption accordingly. The use of the energy bills in heating, domestic hot water and electricity saving measures may seem obvious. They are the occupant factsheets on how much energy they consume. The energy bill can also be used as a communication tool for saving tips, but for being an important saving measure, the information must be easy to understand for those it is aimed at. Henryson et al. (2000) have reported that the 67% of people interviewed think that bills should contain simple information on energy-savings, as the highest motivation to absorb them, occurs at their time of arrival.
However, providing a household with information tends to result in higher knowledge levels, but not necessarily in behavioural changes or energy savings (Abrahamse et al. 2005; Steg 2008; Moloney et al. 2010; Elsharkawy and Rutherford 2015). Statistics from seven public housing companies using individual metering and billing for heating in about 7,800 apartments in Sweden have indicated that most residents in these buildings have chosen an indoor temperature of around 21–22°C, slightly higher than the temperature of 20–21°C supplied in the buildings of property owners without individual metering and billing for heating (SABO 2016).

Inadvertent feedback occurs when community energy conservation and energy behaviour awareness campaigns are implemented. Increasing understanding and knowledge through inadvertent feedback can also apply in case of energy microgeneration, when housing buildings become sites for generation as well as consumption (Darby 2006). The Energy Cultures research project (Barton et al. 2013) found that family and friends are the key influences on household energy behaviour changes, more so than media, community action groups or other organisations such as councils or energy companies.

Energy audits are also an additional means to provide detailed information on energy demand and saving potential. They generally include the evaluation of the thermal characteristics of the building, its HVAC system and the appliances in use. Although the energy audit report does not address user behaviour directly, it can be successful in raising awareness on energy issues, a prerequisite for changing behaviour and consumption practices.

3.5 Community-based initiatives and behaviour change

There is a growing interest in applying insights from behavioural sciences to the design of policies and strategies for urban regeneration, but the potential to fully combine these insights within environmental and climate policy has not yet been fully explored. At the same time, in the wider discussions on design for policy and sustainable behaviour change, community behaviour change is an issue underexplored. Much of the research on and policy interventions for behaviour change are focused on individual rather than collective behaviour (Moloney et al. 2010; Karvonen 2013; Gram-Hanssen 2014). Defining sustainable communities can be a challenging issue, very much related to the context and the purpose of the investigation. Communities take many forms and exist over different levels (e.g. local, global), different spatial settings (e.g. urban and rural) and they are dynamic and constantly changing. In the broadest sense, sustainable communities actively and cooperatively work to reduce their environmental impacts both locally and globally, and to foster economic and social wellbeing. From a theoretical point of view, sustainable communities can be described either from the perspective of infrastructure and planning (e.g. neighbourhoods, land-use policy, housing) or from the social context by focusing on social relations, social practices, lifestyles and governance. From the citizen perspective, reflecting on complex issues as sustainability, climate change and regeneration from the communities' perspective can help to ground the actions and to make them more tangible.

Regenerating existing communities through the increase of energy efficiency in buildings and actions to support a sustainable lifestyle requires the participation of individuals prepared to embrace change and to support the transformation process that can last several years. In the field of energy research both on policies and buildings, informational feedback has a leading role in moving towards efficient behaviours. However, although the feedback approach is recognised to be useful, there are other factors that influence household consumption that may not be affected by this mechanism (Janda 2009). In order to make people taking responsibility for their role in the built environment, education has to be more comprehensive and to go beyond the house walls.

There is a growing body of science claiming for the shift from behaviour to practice (Gram-Hanssen 2010; Hargreaves 2011; Shove and Walker 2014). The transition towards changing and sustaining a new set of social practices rather than changing some behaviours in the short term will be necessary to see significant reductions in environmental impact over time (Moloney et al. 2010). Gram-Hanssen (2010) conducted a research on heating consumption in residential sector and defined five ideal types of families and how they relate to residential heat comfort by applying practice-theory approach. Although the five types do not necessarily represent the all possible groups, they do show important aspects and variations of comfort practices. The results suggested to learn from the four elements holding the practices together (i.e. technologies, knowledge, habits, and meanings), instead of looking for an exhaustive classification of behaviour patterns.

Community-based initiatives represent the step required for moving from behaviour change to systemic change. Being adopted by an increasing number of programmes, they have the potential to establish ownership and responsibility for actions to pro-environmental behaviour change, even in situations where individuals may otherwise feel that their contribution is insignificant. Compared to programmes addressing individual consumer behaviour, community-based programmes are more likely to address the more challenging social, institutional and technical barriers and constraints (Moloney et al. 2010). Moreover, community-based programmes are able to achieve multiple benefits in the same environment, resulting in high level of awareness on risks and barriers to the effective implementation of renovation programmes. The non-energy co-benefits are even more important in the social housing sector where energy efficiency of buildings and fuel poverty (Heffner and Campbell 2011) only represents one issue of a complex framework. However, low–income energy–efficiency programmes have traditionally been evaluated based on energy savings for participating households, by comparing household energy savings or bill reductions with the annual programme spending to determine whether an energy–efficiency programme is cost–effective.

On the contrary, programme evaluation frameworks should take into account the non–energy co-benefits that can result to different stakeholders or to society as a whole (Heffner and Campbell 2011). The most relevant are summaries in Table 3.1.

Table 3.1: Low-income energy efficiency co-benefit for beneficiaries

Beneficiaries	Co-benefits
Public authorities/energy providers	Subsidies avoided; arrearages savings
Property owners	High property value; rents paid on time
Households	Improved comfort, health, safety and education; preserve affordability

Source: Santangelo and Tondelli (2017a)

3.5.1 Suggestions for community behaviour change initiatives

While an exhaustive summary of all possible initiatives is beyond the scope of this chapter, there is a need to understand how to guide the effective design and delivery of community-focused strategies and public policy interventions to implement urban regeneration, particularly through actions that capitalise the resources to mobilise further changes. Indeed, throughout the following discussion, interventions on energy-related behaviour are suggested in order to stimulate and to activate further regeneration processes. In this respect, energy can be considered as a driver to urban regeneration, while addressing attitudes and behaviour change is a prerequisite for co-creating and co-implementing regeneration strategies (Santangelo and Tondelli 2017b). As result of literature review, investigation of behavioural determinants and patterns analysed in the previous sections, some key elements for successful behaviour change initiatives are summarised and proposed below.

→ Providing simplification strategies to facilitate more effective decision-making. Simplification strategies may help to reduce cognitive overload and facilitate more effective decision-making in regard to energy consumption – such as making a desired action easier, quicker and more convenient, minimising the physical and psychological demands needed to perform the action (e.g., making it the default) and reducing perceived uncertainty (e.g., encouraging people to try a new activity in a risk-free environment) (Steg and Vlek 2009). Unnecessary complexity and sensory overload should be avoided by framing messages in a clear, concise and comprehensible format. In terms of relaying information to consumers, keeping things short and simple is essential for effective communication. For example, avoid inundating people with too many energy-saving tips or too many choices, instead presenting smaller amounts of the most important information. Indeed, laboratory experiments and field studies have found that having more choices is not necessarily more desirable, appealing or intrinsically motivating, and people may even perform better in limited-choice contexts. Rather than delivering information-intensive campaigns and complicated users education programmes, behavioural strategies should instead focus on communicating simple messages that the average consumer can quickly and easily understand.

→ Incorporating examples of energy-saving actions in user-focused messages to make them easy to remember and especially salient. In situations where people simply forget to perform energy efficient behaviours, basic visual or auditory reminders can prompt consumers to act.

→ Framing energy-saving messages in terms of avoiding or minimising prospective costs and losses, as this may catch the attention and make the information more motivating (Frederiks et al. 2015). Rather than putting emphasis on saving energy, communication should focus on the costs (i.e., time, effort, money) associated with energy-wasting practices and highlight how pro-environmental behaviour will prevent future losses and costs. A previous research (Gonzales et al., 1988) had already suggested that, when communicating messages to improve energy efficiency in dwellings, framing recommendations in terms of loss (i.e., energy and money lost if people do not take actions) rather than gain (i.e., energy or money gained by taking actions) may be more effective.

→ Framing energy-saving practices as both common and socially desirable. For example, advising consumers that people similar to them (e.g. peers, neighbours) are using less energy or taking certain energy-saving actions, in addition to conveying social approval of such actions, will likely motivate them to conform to these positive energy-saving norms and to reduce their consumption accordingly. According to the results of a study conducted by Frederiks et al. (2015), households who received descriptive normative messages (e.g. information comparing a household energy usage to that of neighbours) used significantly less energy in the short-term compared to householders who only received energy saving tips.

→ Creating a shared group identity within the community where people can feel their individual contribution as important, and emphasising that many other consumers are also actively saving energy (i.e. capitalising on descriptive social norms), may help reduce free-riding and social loafing in group settings. Making any shared outcomes or collective achievements more salient, and publicly acknowledging the efforts of individuals, may also help motivating people to contribute to the greater goal.

→ Information strategies must avoid to “blame the victim” and simply suggest trying harder. A successful approach should allow inhabitants to feel empowered, rather than guilty (Stevenson and Leaman 2010).

→ Behaviour is more likely to be deliberately considered and changed when a discontinuity occurs in the household context (Huebner et al. 2013). Therefore, building renovation programmes are the key opportunity to involve households in order to make them reconsider their consumption practices. However, pro-environmental behaviour is likely to be taken into account if information and education measures come from credible, trustworthy sources. Thus, within the social housing sector, the impact of sustainable community programmes is closely linked to the relationship between social housing tenants and providers.

3.6 Review of initiatives to address energy behaviour in the social housing sector

This section discusses four practices that have been designed in four European countries, namely the Netherlands, Sweden, United Kingdom and Italy. Nevertheless, increasing energy efficiency through the renovation of social housing stock is not only a European issue, and at international level there are other initiatives (e.g. in USA, Australia and New Zeeland) (Barton et al. 2013; Moloney and Strengers 2014; Wolfe et al. 2014) that might be considered when it comes to the renovation of affordable housing through the integration of strategies to address occupant behaviour. Although the four initiatives described in this section are not exhaustive to represent the European situation, they have been selected among other initiatives since they share the overall aim (i.e. the increase energy efficiency of the social housing sector through renovation of existing buildings) and scope (i.e. renovation of social housing stock taking into account occupant behaviour), despite they show different structural characteristics (i.e. size of the housing stock and type of provider) and different approaches (i.e. in terms of means for the implementation and actors involved).

It has to be highlighted that social housing sectors vary widely across EU, as further investigated in Chapter 5. While giving a full understanding of the social and public housing characteristics of countries considered in the chapter is beyond the scope of this research, the most important information for properly analyse the four mentioned initiatives is summarised in Table 3.2. For a more comprehensive overview of social housing characteristics in European countries see (Scanlon et al. 2014; Pittini et al. 2015).

Table 3.2: Social housing consistency in Italy, the Netherlands, Sweden and UK

	the Netherlands	Sweden	UK	Italy
Type of provider	Private	Public	Public / Private	Public
Percentage of the total housing stock (%)	33	19	18	4
Total number of dwellings (thousands)	2,555	730	4,085	963

Source: adapted from Santangelo and Tondelli (2017a). Data refers to the timeframe 2012-2015.

The Netherlands is the EU country with the larger share of the social housing sector, where one third of houses being part of the sector accommodating primarily low-income households, while the UK has the larger housing stock among the considered cases. Sweden and Italy have different rate of social housing as percentage of the total housing stock, while the two sectors are comparable for number of social housing units.

The 2ndSkin refurbishment approach (Guerra-santin et al. 2015) has been developed by a consortium of academic and industrial partners in the Netherlands as a business opportunity for scalable refurbishment solutions. The main aim is to develop a strategy for an integrated and effective renovation solution that can be applied to rental apartment blocks in the Netherlands. This approach foresees also the development of a process for post-occupancy monitoring and evaluation in order to provide feedback to users to ensure the zero-energy target. The strategy also focuses on the involvement of households from an early stage of the process for increasing the acceptability of the renovation actions and the knowledge of occupants on the usage of the new or renovated systems.

In Sweden, the Skåne Initiative (Housing Europe 2014), promoted by the Swedish Association of Public Housing Companies (SABO) for the period 2007-2016, is aimed at reducing the energy use in public housing by 20%. It has involved 106 municipal housing companies affiliated to SABO and around 400,000 dwellings; nevertheless, according to the results at the end of 2014, the energy reduction accounted for only 12%. Different measures have been implemented to reach this goal, such as energy efficiency improvements in conjunction with renovation works (i.e. supplementary insulation, replacement windows and heat recovery of ventilation air). Technical measures have been implemented together with energy saving campaign material for the households, including tips about how to save energy (e.g. for saving water, saving energy in laundry rooms, switching off standby electricity).

In UK, the Community Energy Saving Programme (CESP) has been designed to target income-deprived homes in defined areas through a house-by-house, street-by-street approach. The scheme has promoted a “whole house” approach by installing a combination of measures that include internal wall insulation, loft insulation, replacing inefficient boilers, and fitting modern kitchens and bathrooms. The measures have been delivered through partnerships between local authorities, energy companies, housing associations, and community groups (Elsharkawy and Rutherford 2015). CESP was a three-year obligation (2009-2013) on major energy suppliers and generators to offer free or low-cost energy efficiency measures in certain low-income areas. It was structured to incentivise the energy companies to install particular measures (e.g. solid wall insulation) by using incentives and bonuses. Results have shown that, although improvements implemented in about 150,000 properties in low-income areas (Provan and Brady 2015), only the 85% of the target has been reached (Ofgem E-Serve 2013).

In Italy, Rig.ener.a[3] is a three-years programme (2017-2019, but formally approved in 2016) that has been promoted by the Municipality of Bologna as the main energy refurbishment

[3] All the information provided in this section and throughout the dissertation regarding the Rig.Ener.a initiative is the result of the direct involvement of the author in the definition of the steps for the programme implementation,

programme for the social housing sector. It foresees the involvement of Energy Service Companies (ESCos) for the energy renovation of the housing stock through the sign of an Energy Performance Contract (EPC). ESCos provide the technical and financial services needed for energy efficiency projects (i.e. implement a customised energy service package, consisting of, among others, planning, building, operation and maintenance). The contract between the ESCo and the public buildings owner (the municipality) contains guarantees for cost savings and takes over the financial and technical risks of implementation and operation for the entire project duration (14 years and a half). The EPC service is paid for by realised energy cost savings, while the household will economically benefit for the entire operation mainly at the end of the contracting period, since only the 5% of cost saving on household energy bills are expected during the EPC phase. The programme foresees also the involvement of the tenants through indirect feedback, mainly information materials, tips and informative energy bills.
The main characteristics, including strengths and weaknesses, of the four strategies described above are synthetised in Table 3.3.

The first consideration regards the roles of renovation promoters and executors. Although the 2ndSkin approach is still under development and no information could be found regarding its implementation, it has been investigated since it is interesting to notice the research and development nature of the promoter (i.e. a consortium of academic and industrial partners) and the scope (i.e. business opportunity). While the other renovation approaches are promoted either at government or at local administrative level, the Dutch strategy is probably the one which shows the highest potential for private stakeholders, who are not cut off by the focus of the interventions on social and public housing sector, generally recognised as service of general interest. The UK and Italian approaches both show the potential of delivering energy saving measures through public-private partnerships.
While the renovation strategies in the Netherland, Sweden and UK are targeted either to the reduction of the overall energy consumption or to the CO_2 emissions reduction, the Italian approach is aimed at reducing the space heating consumption. This might be seen as a difficulty

in particular concerning the information and feedback to households, through an agreement signed between the Municipality of Bologna and the University of Bologna.

of both public administrations and private sector to handle the increase of uncertainties when applying more comprehensive strategies.

Table 3.3: Renovation initiatives in the Netherlands, Sweden, UK and Italy

	2ndSkin (NL)	Skåne Initiative (SE)	CESP (UK)	Rig.ener.a (IT)
Promoter	Consortium of academic and industrial partners	Swedish Association of Public Housing Companies	National government	Municipality of Bologna
Executor	Housing associations	Housing associations	Energy suppliers and electricity generators in partnership with housing associations	Public housing associations in partnership with ESCos
Type of energy consumption addressed	all	all	all	Space heating
User behaviour addressed	Yes, through post-occupancy monitoring and feedback	Yes, through energy saving campaign material	Not directly by the programme, but by the housing providers implementing it	Yes, through tips, handbook and informative energy bills
Timeframe	2015 - ongoing	2007-2016	2009-2013	2016-ongoing
Strengths	Business opportunity; Strategy foreseen for post-occupancy monitoring and evaluation	High number of housing associations involved; Comprehensive approach to address the challenge	Public-private partnerships; Scope (national level)	Public-private partnerships; Leading role of public housing for implementation of renovation process
Weaknesses	Focus on apartment blocks; High dependency from the ability of the supply chain to change its paradigm	Lack of long-term monitoring scheme; Low degree of involvement of private partners	Lack of long-term monitoring scheme; Lack of a comprehensive approach to consider the impact of occupants	Only one type of energy consumption addressed; Low reduction of energy costs for the tenants during the EPC

Source: Santangelo and Tondelli (2017a)

All the four renovation initiatives show the importance of being aware of the occupant behaviour role for the success of the implementation. In the social housing sector, the role of housing providers should be to guide the adoption of an energy efficient life-style. In particular, when Energy Service Companies are involved in the renovation as in Italy, the household should be supported to deliver the energy consumption estimated in the design phase and to meet the payback periods. Different strategies are developed to ensure the involvement of the occupants, while the informative approach through feedback, tips and informative materials seems to be dominant. It has to be noticed that this might not be sufficient to limit the negative effects (e.g. rebound effect) which might arise after the completion of the energy efficiency measures. Unfortunately, at the stage of this analysis, none of the studied approaches have shown the implementation of a long-term monitoring of both renovation impact on energy consumption and behaviour change in relation to the renovation effects. In particular for the Sweden and UK approaches that have already been implemented, due to this lack of systematic monitoring, little is known about the long-term performance of equipment after renovation or the influence of household behaviour on the energy savings.

3.7 Directions for future research

The investigation reported in this chapter has reinforced two discourses: on the one side, around the role of human factor for the effective implementation of urban renovation programmes; on the other side, on the leading role that the social housing sector can have in demonstrating the feasibility and benefits of such programmes.

The analysed renovation initiatives have proven that private entities can play a significant part in the energy efficiency process and are not cut off when it comes to public housing stock. However, the occupant behaviour should be equally considered together with the technical aspects, since it can considerably affect the payback periods of the investments. The more the uncertainties related to the impact of the human factor are addressed, the more the payback time of the retrofitting interventions may be reduced, increasing the attractiveness of such investments. Previous studies have also shown that understanding user profiles is a key element for formulating targeted energy-saving policy for specific household life-styles. Energy-conscious households save more energy with systems that require active involvement, while less energy-conscious households save more energy with systems that do not require active involvement (Guerra-Santin 2011). Thus, more effort is required to make the technological improvement matched to the household characteristics. Future research should focus on the definition of user profiles to design different policy instruments able to address different consumption life-styles. However, in the social housing sector where public resources and private investments are particularly scarce, some simplification strategies and an "express methodology" may be necessary to define the user profiles.

The social effects, technical characteristics and building performance simulation models, the role of economic, taxes and incentives as well as the policy instruments should be further investigated in combination with each other to take into account all the issues related to the human factor in energy-savings. Moreover, the role of policy instruments for energy efficiency should be further studied in order to effectively address the behavioural patterns of different user groups. Any single discipline will provide a limited view of the topic at most. Interdisciplinary studies are required to get a more comprehensive understanding on ways to regenerate cities and face the climate change.

3.8 Key research findings

- Main determinants of energy behaviour are both household characteristics (i.e. demographic, educational and economic factors) and building characteristics (i.e. external factors related to outdoor conditions and internal factors related to the building envelop and mechanical systems installed).
- Understanding user profiles is a key element for formulating targeted energy-saving policy for specific household life-styles. Energy-conscious households save more energy with systems that require active involvement, while less energy-conscious households save more energy with systems that do not require active involvement.
- Physical renovation of buildings should be integrated with the information and training on sustainable occupant behaviour, especially in the case of social housing stock where low-income people are accommodated, in order to ensure both the environmental and social sustainability of the interventions.

- Individual needs correct information for a responsible choice. Without an appropriate frame of reference, users cannot determine whether their energy consumption can be reduced or not. In this framework, feedback plays a significant role in raising energy awareness and changing consumer attitudes towards energy consumption.
- Community-based programmes are able to achieve multiple benefits in the same environment, resulting in high level of awareness on risks and barriers to the effective implementation of renovation programmes.
- Private entities can play a significant part in the energy efficiency process and are not cut off when it comes to public housing stock. However, the occupant behaviour should be equally considered together with the technical aspects, since it can considerably affect the payback period of the investments. The more the uncertainties related to the impact of the human factor are addressed, the more the payback time of the retrofitting interventions may be reduced, increasing the attractiveness of such investments.
- The role of policy instruments for energy efficiency should be further studied in order to effectively address the behavioural patterns of different user groups. Any single discipline will provide a limited view of the topic at most. Interdisciplinary studies are required to get a more comprehensive understanding on ways to regenerate cities and to face climate change challenge.

References

Abrahamse W, Steg L, Vlek C, Rothengatter T (2005) A review of intervention studies aimed at household energy conservation. Journal of Environmental Psychology 25:273–291. doi: 10.1016/j.jenvp.2005.08.002

Abrahamse W, Steg L, Vlek C, Rothengatter T (2007) The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. Journal of Environmental Psychology 27:265–276. doi: 10.1016/j.jenvp.2007.08.002

Abreu JM, Câmara Pereira F, Ferrão P (2012) Using pattern recognition to identify habitual behavior in residential electricity consumption. Energy and Buildings 49:479–487. doi: 10.1016/j.enbuild.2012.02.044

Andersen RV, Toftum J, Andersen KK, Olesen BW (2009) Survey of occupant behaviour and control of indoor environment in Danish dwellings. Energy and Buildings 41:11–16. doi: 10.1016/j.enbuild.2008.07.004

Barbu A-D, Griffiths N, Morton G (2013) Achieving energy efficiency through behavioural change. what does it take? IEA Report

Barton B, Blackwell S, Carrington G, Ford R, Lawson R, Stephenson J, Thorsnes P, Williams J (2013) Energy Cultures: Implication for Policymakers. Centre for Sustainability, University of Otago

Bedir M (2017) Occupant behavior and energy consumption in dwellings: An analysis of behavioral models and actual energy consumption in the dutch housing stock. doi: 10.7480/abe.2017.16

Bouzarovski S, Petrova S, Sarlamanov R (2012) Energy poverty policies in the EU: A critical perspective. Energy Policy 49:76–82. doi: 10.1016/j.enpol.2012.01.033

BPIE (2011) Europe'S Buildings Under the Microscope

Brundrett WG (1977). Ventilation: A behavioural approach. International Journal of Energy Research 1:289-298. doi: 10.1002/er.4440010403.

Carlsson-Kanyama A, Lindén A-L (2007) Energy efficiency in residences—Challenges for women and men in the North. Energy Policy 35:2163–2172. doi: 10.1016/J.ENPOL.2006.06.018

Cibella F, Cuttitta G, Della Maggiore R, et al (2015) Effect of indoor nitrogen dioxide on lung function in urban environment. Environmental Research 138:8–16. doi: 10.1016/J.ENVRES.2015.01.023

D'Oca S, Corgnati SP, Buso T (2014a) Smart meters and energy savings in Italy: Determining the effectiveness of persuasive communication in dwellings. Energy Research and Social Science 3:131–142. doi: 10.1016/j.erss.2014.07.015

D'Oca S, Fabi V, Corgnati SP, Andersen RK (2014b) Effect of thermostat and window opening occupant behavior models on energy use in homes. Building Simulation 7:683–694. doi: 10.1007/s12273-014-0191-6

D'Oca S, Hong T, Langevin J (2018) The human dimensions of energy use in buildings: A review. Renewable and Sustainable Energy Reviews 81:731–742. doi: 10.1016/j.rser.2017.08.019

Darby S (2006) the Effectiveness of Feedback on Energy Consumption. A Review for Defra of the Literature on Metering , Billing and Direct Display.

Elsharkawy H, Rutherford P (2015) Retrofitting social housing in the UK: Home energy use and performance in a pre-Community Energy Saving Programme (CESP). Energy and Buildings 88:25–33. doi: 10.1016/j.enbuild.2014.11.045

Engvall K, Lampa E, Levin P, et al (2014) Interaction between building design, management, household and individual factors in relation to energy use for space heating in apartment buildings. Energy and Buildings 81:457–465. doi: 10.1016/j.enbuild.2014.06.051

European Commission (2017) EU energy in figures. Statistical pocketbook 2017

Fabi V, Andersen RV, Corgnati S, Olesen BW (2012) Occupants' window opening behaviour: A literature review of factors influencing occupant behaviour and models. Building and Environment 58:188–198. doi: 10.1016/J.BUILDENV.2012.07.009

Faruqui A, Sergici S, Sharif A (2010) The impact of informational feedback on energy consumption-A survey of the experimental evidence. Energy 35:1598–1608. doi: 10.1016/j.energy.2009.07.042

Feng X, Yan D, Wang C, Sun H (2016) A preliminary research on the derivation of typical occupant behavior based on large-scale questionnaire surveys. Energy and Buildings 117:332–340. doi: 10.1016/j.enbuild.2015.09.055

Fischer C (2008) Feedback on household electricity consumption: a tool for saving energy? Energy Efficiency 1:79–104. doi: 10.1007/s12053-008-9009-7

Frederiks ER, Stenner K, Hobman E V. (2015) Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renewable and Sustainable Energy Reviews 41:1385–1394. doi: 10.1016/j.rser.2014.09.026

Gill ZM, Tierney MJ, Pegg IM, Allan N (2010) Low-energy dwellings: the contribution of behaviours to actual performance. Building Research & Information 38:491–508. doi: 10.1080/09613218.2010.505371

Gonzales MH, Aronson E, Costanzo M (1988). Using social cognition and persuasion to promote energy conservation: a quasi-experiment. Journal of Applied Social Psychology 18:1049-1066. doi: 10.1111/j.1559-1816.1988.tb01192.x

Gram-Hanssen K (2010) Residential heat comfort practices: understanding users. Building Research & Information 38:175–186. doi: 10.1080/09613210903541527

Gram-Hanssen K (2014) New needs for better understanding of household's energy consumption – behaviour, lifestyle or practices? Architectural Engineering and Design Management 10:91–107. doi: 10.1080/17452007.2013.837251

Grønhøj A, Thøgersen J (2011) Feedback on household electricity consumption: Learning and social influence processes. International Journal of Consumer Studies 35:138–145. doi: 10.1111/j.1470-6431.2010.00967.x

Guerra-Santin O (2013) Occupant behaviour in energy efficient dwellings: Evidence of a rebound effect. Journal of Housing and the Built Environment 28:311–327. doi: 10.1007/s10901-012-9297-2

Guerra-Santin O (2010) Actual energy consumption in dwellings. The effect of energy performance regulations and occupant behaviour. Delft University of Technology

Guerra-Santin O (2011) Behavioural patterns and user profiles related to energy consumption for heating. Energy and Buildings 43:2662–2672. doi: 10.1016/j.enbuild.2011.06.024

Guerra-Santin O, Itard L (2010) Occupants' behaviour: determinants and effects on residential heating consumption. Building Research & Information 38:318–338. doi: 10.1080/09613211003661074

Guerra-Santin O, Itard L, Visscher H (2009) The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock. Energy and Buildings 41:1223–1232. doi: 10.1016/j.enbuild.2009.07.002

Guerra-Santin O, Silvester S (2016) Development of Dutch occupancy and heating profiles for building simulation. Building Research & Information 1–18. doi: 10.1080/09613218.2016.1160563

Guerra-Santin O, Silvester S, Konstantinou T (2015) 2nd Skin Approach To Zero Energy Rental Properties: Occupancy patterns to improve energy simulation. In: PLEA 2015

Gupta R, Chandiwala S (2010) Understanding occupants: feedback techniques for large-scale low-carbon domestic refurbishments. Building Research & Information 38:530–548. doi: 10.1080/09613218.2010.495216

Gyberg P, Palm J (2009) Influencing households' energy behaviour-how is this done and on what premises? Energy Policy 37:2807–2813. doi: 10.1016/j.enpol.2009.03.043

Haas R, Auer H, Biermayr P (1998) The impact of consumer behavior on residential energy demand for space heating. Energy and Buildings 27:195–205. doi: 10.1016/S0378-7788(97)00034-0

Hansen AR, Gram-Hanssen K, Knudsen HN (2018) How building design and technologies influence heat-related habits. Building Research and Information 46:83–98. doi: 10.1080/09613218.2017.1335477

Hargreaves T (2011) Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change. Journal of Consumer Culture 11:79–99. doi: 10.1177/1469540510390500

Heffner G, Campbell N (2011) Evaluating the co-benefits of low-income energy-efficiency programmes

Hendrickson DJ, Wittman HK (2010) Post-occupancy assessment: building design, governance and household consumption. Building Research & Information 38:481–490. doi: 10.1080/09613218.2010.494377

Henryson J, Håkansson T, Pyrko J (2000) Energy efficiency in buildings through information-Swedish perspective. Energy Policy 28:169–180

Hong T, D'Oca S, Turner WJN, Taylor-Lange SC (2015) An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs framework. Building and Environment 92:764–777. doi: 10.1016/J.BUILDENV.2015.02.019

Housing Europe (2014) Reducing energy consumption in Sweden, available at: http://www.housingeurope.eu/blog-380/reducing-energy-consumption-in-sweden

Huebner GM, Cooper J, Jones K (2013) Domestic energy consumption - What role do comfort, habit, and knowledge about the heating system play? Energy and Buildings 66:626–636. doi: 10.1016/j.enbuild.2013.07.043

Jain RK, Taylor JE, Culligan PJ (2013) Investigating the impact eco-feedback information representation has on building occupant energy consumption behavior and savings. Energy and Buildings 64:408–414. doi: 10.1016/j.enbuild.2013.05.011

Janda KB (2009) Buildings Don' t Use Energy: People Do. In: PLEA 2009 - 26th Conference on Passive and Low Energy Architecture, Quebec City Canada, 22-24 June 2009

Karatas A, Stoiko A, Menassa CC (2016) Framework for selecting occupancy-focused energy interventions in buildings. Building Research and Information 44:535–551. doi: 10.1080/09613218.2016.1182330

Karlin B, Zinger JF, Ford R (2015) The Effects of Feedback on Energy Conservation: A Meta-Analysis. Psychological Bulletin 141:1205–1227. doi: http://dx.doi.org/10.1037/a0039650

Karvonen A (2013) Towards systemic domestic retrofit: a social practices approach. Building Research & Information 41:563–574. doi: 10.1080/09613218.2013.805298

Lindén AL, Carlsson-Kanyama A, Eriksson B (2006) Efficient and inefficient aspects of residential energy behaviour: What are the policy instruments for change? Energy Policy 34:1918–1927. doi: 10.1016/j.enpol.2005.01.015

Martinsson J, Lundqvist LJ, Sundström A (2011) Energy saving in Swedish households. The (relative) importance of environmental attitudes. Energy Policy 39:5182–5191. doi: 10.1016/J.ENPOL.2011.05.046

Moloney S, Horne RE, Fien J (2010) Transitioning to low carbon communities-from behaviour change to systemic change: Lessons from Australia. Energy Policy 38:7614–7623. doi: 10.1016/j.enpol.2009.06.058

Moloney S, Strengers Y (2014) "Going Green"?: The Limitations of Behaviour Change Programmes as a Policy Response to Escalating Resource Consumption. Environmental Policy and Governance 24:94–107. doi: 10.1002/eet.1642

OECD (2014) Greening Household Behaviour: Overview from the 2011 Survey – Revised edition, OECD Studies on Environmental Policy and Household Behaviour, OECD Publishing. doi: http://dx.doi.org/10.1787/9789264214651-en

Ofgem E-Serve (2013) The final report of the Community Energy Saving Programme (CESP) 2009-2012

Owens S, Driffill L (2008) How to change attitudes and behaviours in the context of energy. Energy Policy 36:4412–4418. doi: 10.1016/j.enpol.2008.09.031

Paauw J, Roossien B, Aries M, Guerra-Santin O (2009) Energy Pattern Generator; Understanding the effect of user behaviour on energy systems. In: 1st European conference energy efficiency and behaviour. pp 1–11

Pittini A, Ghekière L, Dijol J, Kiss I (2015) The state of housing in the EU 2015

Poortinga W, Steg L, Vlek C, Wiersma G (2003) Household preferences for energy-saving measures: A conjoint analysis. Journal of Economic Psychology 24:49–64. doi: 10.1016/S0167-4870(02)00154-X

Provan B, Brady AM (2015) Energy Plus. Energy Efficiency in Social Housing, Centre for Analysis of Social Exclusion (CASE) CASEreport 89, 2015, March

Pye S, Dobbins A (2015) Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures. Policy Report-INSIGHT_E 91

Ren X, Yan D, Hong T (2015) Data mining of space heating system performance in affordable housing. Building and Environment 89:1–13. doi: 10.1016/j.buildenv.2015.02.009

Romero RA, Bojórquez G, Corral M, Gallegos R (2013) Energy and the occupant's thermal perception of low-income dwellings in hot-dry climate: Mexicali, México. Renewable Energy 49:267–270. doi: 10.1016/J.RENENE.2012.01.017

SABO (2016) Analysis. Temperatures chosen by tenants with individual metering and billing for heating. Report

Sapci O, Considine T (2014) The link between environmental attitudes and energy consumption behavior. Journal of Behavioral and Experimental Economics 52:29–34. doi: 10.1016/j.socec.2014.06.001

Santangelo A, Tondelli S (2017a) Occupant behaviour and building renovation of the social housing stock: Current and future challenges. Energy and Buildings 145:276–283. doi: 10.1016/j.enbuild.2017.04.019

Santangelo A, Tondelli S (2017b) Urban regeneration and sustainable communities: reflecting on energy-related roles, attitudes and responsibilities. Urbanistica Informazioni 272:431–435

Scanlon K, Whitehead C, Arrigoitia MF (2014) Social Housing in Europe. Wiley Blackwell

Schaffrin A, Reibling N (2015) Household energy and climate mitigation policies: Investigating energy practices in the housing sector. Energy Policy 77:1–10. doi: 10.1016/j.enpol.2014.12.002

Schipper L (1989) Linking Lifestyles and Energy Use: A Matter of Time?, Annual Review of Energy 14:273- 320

Schweiker M, Shukuya M (2009) Comparison of theoretical and statistical models of air-conditioning-unit usage behaviour in a residential setting under Japanese climatic conditions. Building and Environment 44:2137-2149. doi: 10.1016/j.buildenv.2009.03.004

Shipworth M, Firth SK, Gentry MI, et al (2010) Central heating thermostat settings and timing: building demographics. Building Research & Information 38:50–69. doi: 10.1080/09613210903263007

Shove E, Walker G (2014) What Is Energy For? Social Practice and Energy Demand. Theory, Culture & Society 31:41–58. doi: 10.1177/0263276414536746

Steemers K, Yun GY (2009) Household energy consumption: a study of the role of occupants. Building Research & Information 37:625–637. doi: 10.1080/09613210903186661

Steg L, Vlek C (2009) Encouraging pro-environmental behaviour: An integrative review and research agenda. Journal of Environmental Psychology 29:309–317. doi: 10.1016/j.jenvp.2008.10.004

Steg L (2008) Promoting household energy conservation. Energy Policy 36:4449–4453. doi: 10.1016/j.enpol.2008.09.027

Stephenson J, Barton B, Carrington G, et al (2010) Energy cultures: A framework for understanding energy behaviours. Energy Policy 38:6120–6129. doi: 10.1016/j.enpol.2010.05.069

Stevenson F, Leaman A (2010) Evaluating housing performance in relation to human behaviour: new challenges. Building Research & Information 38:437–441. doi: 10.1080/09613218.2010.497282

Sunikka-Blank M, Galvin R (2012) Introducing the prebound effect: the gap between performance and actual energy consumption. Building Research & Information 40:260–273. doi: 10.1080/09613218.2012.690952

Thomson H, Snell C, Liddell C (2016) Fuel poverty in the European Union: a concept in need of definition? People Place and Policy Online 10:5–24. doi: 10.3351/ppp.0010.0001.0002

Van Raaij WF, Verhallen TMM (1983a) Patterns of residential energy behavior. Journal of Economic Psychology 4:85–106. doi: 10.1016/0167-4870(83)90047-8

Van Raaij WF, Verhallen TMM (1983b) A behavioral model of residential energy use. Journal of Economic Psychology 3:39–63. doi: 10.1016/0167-4870(83)90057-0

Visscher H, Meijer F, Majcen D, Itard L (2016) Improved governance for energy efficiency in housing. Building Research & Information 44:5-6:552–561. doi: 10.1080/09613218.2016.1180808

Vringer K, Aalbers T, Blok K (2007) Household energy requirement and value patterns. Energy Policy 35:553–566. doi: 10.1016/j.enpol.2005.12.025

Wolfe AK, Malone EL, Heerwagen J, Dion J (2014) Behavioral change and building performance: Strategies for significant, persistent, and measurable institutional change

Yan D, O'Brien W, Hong T, et al (2015) Occupant behavior modeling for building performance simulation: Current state and future challenges. Energy and Buildings 107:264–278. doi: 10.1016/j.enbuild.2015.08.032

4. Investigating the impact of behaviour on household energy consumption by applying two micro-level approaches[1]

ENGLISH ABSTRACT

This chapter undertakes two investigations in parallel applying two micro-level approaches to understand the impact of consumer behaviour on household energy consumption. The aim is to show the results of two different approaches to data analysis, depending on the availability of data and their accuracy, and their relevance when it comes to gain information to design policy instruments to build energy awareness among households.

Sections 4.1 and 4.2 present respectively the introduction and the aim and methodology. The first micro-level approach is applied in Section 4.3, where statistical data on energy consumption in buildings from the Italian Statistical Bureau are analysed to identify behavioural characteristics influencing energy consumption. Section 4.4 focuses on a second type of micro-level approach, where data from a survey conducted in Finland are analysed to get an insight on user behaviour and awareness, and the design of a questionnaire for the Italian case study is presented. The directions for future research and the key research findings are then respectively discussed in Sections 4.5 and 4.6.

ABSTRACT IN ITALIANO

Il presente capitolo intraprende due indagini in parallelo, facendo ricorso all'applicazione di due approcci di micro-livello per indagare l'impatto del comportamento degli utenti sul consumo energetico delle famiglie. L'obiettivo è quello di mostrare come due diversi approcci per l'analisi dati, a seconda della disponibilità degli stessi e della loro risoluzione, producano risultati che contribuiscono ad aumentare la comprensione del fenomeno comportamentale nell'ambito del consumo energetico, e a fornire informazioni utili per disegnare le strategie di intervento verso un consumo energetico più consapevole.

Le sezioni 4.1 e 4.2 presentano rispettivamente l'introduzione, lo scopo e la metodologia. Il primo approccio è descritto nella sezione 4.3, dove vengono analizzati i dati statistici sul consumo di energia degli edifici dell'ISTAT, per identificare le caratteristiche comportamentali che influenzano il consumo di energia. La sezione 4.4 si concentra sul secondo approccio di micro-livello, in cui vengono analizzati i dati di un'indagine condotta in Finlandia per ottenere informazioni sul comportamento e la consapevolezza degli utenti, e viene presentato il progetto di un questionario per il caso studio italiano. La direzione per la ricerca futura e i principali risultati della stessa sono discussi rispettivamente nelle sezioni 4.5 e 4.6.

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[1] An earlier version of Section 4.4 has discussed during the XI INU Study Day *"Interruptions, Intersections, Sharings and Overlappings. New perspectives for the territory"*, 14th-15th December, Naples. The paper has been published as: Santangelo A, Vuorinen M, Tondelli S (2018) Household energy awareness as enabler of regeneration practices. Preliminary evidence from a Finnish case study, Urbanistica Informazioni 278s.i:260-264.

4.1 Introduction

4.1.1 Italian building stock and energy efficiency trends

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 increases particularly in metropolitan areas, where this share reaches 85.5% of the total housing stock. However, Italian multi-family buildings are rather small and low-rise, with high surface-area-to-volume ratio, resulting in very likely high thermal dispersions. When it comes to 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, with low efficiency rate, high maintenance costs for the owners and high energy costs for the households. Approximately 740,000 buildings are not used, due to the need of renovation interventions or poor safety conditions (ISTAT 2014).

For what concerns the energy performance, in 2015 the Italian building sector was responsible for 42% of the total final energy consumption. The same year, the residential sector accounted for 28% of the total final consumption. According to the last available country profiles of Odysee-Mure (2018), the Italian final energy consumption was 116 Mtoe, with a reduction of 7% compared to 2000. However, over the period 2000-2015, the residential sector recorded a 6% of increase in its share of final energy consumption, and it was the only sector with increasing energy consumption from the reference year 2000, despite the economic crisis. Space heating accounted for 68% of energy consumption followed by water heating (12%), electrical appliances (11%), and cooking (6%). Air-conditioning (3%), has more than doubled since 2000. The increased energy consumption in residential sector was mainly due to two factors: the increased number of dwellings that have been built and the greater comfort that they required, mainly due to more appliances per dwelling.

According to Nomisma (2016), in 2014 about 72% of households own their house, despite the real figure is closer to 80% due to the rate of households living in their house according to other types of tenure (e.g. bare propriety, family house) (9.6%), that can be assimilated more to the homeowners than to the renters. This large share of homeowners implies that dwelling renovation interventions are rather frequent, much more than the realisation of new buildings. Indeed, the 67% of the construction market consisted in 2012 of renovation of the existing stock, although these interventions have been mainly on technical systems or aesthetic enhancement and not aimed at improving the building energy performance (Caputo and Pasetti 2015). These energy efficiency interventions, which accounted for 3.7 billion euro of investments in 2017 for implementing about 420,000 interventions, are carried out mainly when there is a failure of the technical systems, a need to upgrade them, or when owners want to take advantage of government incentives. In fact, incentives for energy-saving measures have resulted in single interventions, rather than in a whole building approach, since the overall renovation measures for the period 2014-2017 accounted only for 8.9% of the total energy efficiency investments (ENEA 2018). Among the resources allocated in the period 2014-2017, over 6 billion euro involved the replacement of over 2.6 million windows (i.e. 46% of total investments), while over 2.1 billion euro have been allocated to around 70,000 interventions on roofs and slabs. In 2017, approximately 40% of investments (over 1.4 billion euros) concerned a detached or semidetached house, while about 35% of the resources (about 1.3 billion euros) involved blocks of flats with more than three floors. Thanks to the Italian Ecobonus scheme (ENEA 2018), in 2017 the estimated energy reduction accounted for 1,300 GWh/y. In the timeframe 2014-2017, energy retrofit of buildings and other energy efficiency interventions have led to an average saving on the annual energy bill between 250 euro in 2014 and 150 euro in 2017, also due to the different levels of gas prices, saving on average the 15% of the total annual energy expenditure of households.

Nevertheless, this renovation is usually limited to single housing units instead of involving the whole building. Indeed, propriety fragmentation can be considered one of the main barriers to comprehensive building retrofitting and urban regeneration.

Low awareness among homeowners and lack of skills of building managers are also some of the causes. Building managers, in particular, have very often neither competences nor the professional interest to support the owners in the improvement of the building stock. On the contrary, since in Italy for buildings with more than 8 owners is mandatory by law (i.e. L. 220/2012) to appoint a building manager, who is responsible for the management and maintenance of the heating systems and for the building energy certificate, it could be useful to extend his/her duties to the overall building efficiency and energy micro-generation, in cooperation with an energy manager. For smaller buildings, the management is directly done by one or multiple owners, with less people to come to an agreement about building retrofit, but with the same situation in terms of lack of awareness on energy efficiency measures, benefits and procedures.

4.1.2 Different approaches to data collection and analysis

The identification of major determinants of building energy consumption, and the thorough understanding of their impacts on energy consumption patterns, could assist in achieving the goal of improving building energy performance and reducing greenhouse gas emissions due to the building energy consumption.

According to Bedir (2017), the methodology for modelling the influence of occupant behaviour on the energy performance of buildings follows two main approaches: the deductive approach and the inductive one. The former uses the data on household characteristics, energy consumption and income level to find statistical correlation between energy use and occupant behaviour, whereas the latter calculates the building energy consumption based on actual occupancy and behaviour patterns determined by presence, circulation, and operation of lighting, system control devices and appliances. Survey collecting cross-sectional data is the most common method of collecting data in the deductive approach, and statistical models are claimed to be faster and easier tools than simulation models to predict energy consumption in large sample size. However, in the inductive approach, monitoring and/or observation of behaviour are preferred, while simulation tools can help in modelling detailed aspects of behaviour in a way that statistical models ignore (Bedir 2017; Hong et al. 2017).

To the aim of this dissertation, a distinction is made between two micro-level approaches, according to the size of data and the level of accuracy. The first micro-level approach to occupant behaviour relies on large sample size, collected either through national statistical survey with heterogenous data on energy consumption, building characteristics and household characteristics, or through data from the building monitoring system. This approach does not require ad-hoc survey or the *ex-ante* definition of variables, but can be performed using data coming from different sources, as long as the relevant information is available. Occupancy pattern can be identified by applying statistical analysis such as correlation, regression, analysis of variance (ANOVA), or through data mining and machine learning techniques. The objective of this approach is usually to understand the determinants of behaviour in order to define more accurate occupancy profiles per household type that can lead to more realistic predictions of energy demand.

In particular, analytical techniques for big data, such as data mining, have the capability to provide qualitative and quantitative information on diverse user profiles in a block of buildings, enabling the use of more realistic 24-h schedules in building performance simulation tools (Ren et al. 2015). Indeed, data mining techniques are not intended as a substitute to or contrast with direct stochastic modelling approaches. So far, it has been largely applied to research fields such as marketing, medicine, biology, engineering and social sciences, while the application to building energy consumption and operational data is still in the starting phase (D'Oca and Hong 2015).

The second micro-level approach is project-based, it does not necessarily require a large data sample, but questionnaires need to be designed taking into account the specific characteristics of the surveyed sample. Both quantitative and qualitative analysis can be performed, depending on the starting pool and the response rate. The results of surveys might help to establish a modelling framework, though they do not provide the resolution of data required for building detailed statistical models that sensors can provide (Yan et al. 2015). While the first micro-level approach can trace general trends, or discover some unexpected relations, the second one is mostly used to provide evidence on the strengthens or weakness of relations already assumed. Despite the revealing nature of surveys and interviews, there are some fundamental issues that need to be taken into account, as participants misrepresenting their behaviour or not recalling it, or responding the way they think they are expected to.

4.2 Aim and methodology

Chapter 4 contributes to the research question 2 sub-question c) as presented in the box below. The same sub-question has been addressed in Chapter 3 through extensive literature review, while in this chapter the determinants of household behaviour are investigated in Section 4.3

through a quantitative method such as statistical data analysis, and in Section 4.4 through the qualitative analysis of survey results on household behaviour and attitude towards energy efficiency.

The aim of this chapter is to show the applicability – both in terms of opportunities and limits – and the results of two different approaches to data analysis, depending on the availability of data and their accuracy, and their relevance when it comes to gain information to design policy instruments to raise energy awareness among households.

Research question 2:

How to identify the determinants of occupant behaviour and energy consumption, to understand which are the best strategies to promote pro-environmental behaviour?

Sub-questions:

c) Which are the determinants of energy behaviour in residential sector for heating consumption?

On the one side, the first micro-level approach presented is explained and applied in Section 4.3, where statistical data on energy consumption in buildings from the Italian Statistical Bureau (ISTAT) are analysed to identify behavioural characteristics influencing energy behaviour, and both the opportunities and limitations of such approach are presented. The data collection refers to the

Household Energy Consumption survey[2] that ISTAT performed in Italy in 2013. The most interesting variables regarding the household characteristics are identified and further studied through correlation analysis, t-test and one-way analysis of variance (ANOVA), in order to explain to what extent they are related to household energy behaviour.

On the other side, Section 4.4 focuses on the second micro-level approach, where data from one ad hoc survey conducted in Finland are analysed to get an insight on user behaviour and awareness of energy efficiency. A questionnaire was designed and sent by mail to the 168 households living in the dwellings where the pilot case has taken place. In addition to the Finnish

[2] Indagine Sui Consumi Energetici Delle Famiglie. The statistical analysis that follows only represent the author's elaboration and ISTAT is not liable for any use that may be made of the information contained therein. For more information on survey methodology, questions and variables list, see: https://www.istat.it/en/archivio/203349.

case study, the design of a questionnaire for an Italian case study is presented. The directions for future research and key research findings are then respectively discussed in Sections 4.5 and 4.6.

4.3 The first micro-level approach: analysing statistical data to identify household characteristics influencing behaviour

4.3.1 Literature review

Previous studies have highlighted that building characteristics explain only between 40% and 54% of variation in energy use (Sonderegger 1978; Guerra-Santin 2010). Scholars have agreed that, as the thermal properties of buildings improve, the impact of building characteristics decreases, making occupant behaviour more relevant. Furthermore, the relative impact of occupant characteristics and behaviour seems to differ in various studies confirming the importance of contextual analysis (Mora et al. 2015).

Statistical analysis has been found to be powerful tool to investigate the role of household behaviour in influencing energy consumption in residential buildings (Andersen et al. 2009; Guerra-Santin and Itard 2010; Mora et al. 2015; Schaffrin and Reibling 2015; Guerra-Santin and Silvester 2016). Among them, Andersen et al. (2009) conducted statistical analysis starting from survey results in Danish dwellings on occupant control of the indoor environment. Results have shown that window opening behaviour was strongly linked to the outdoor temperature, while, among household characteristics, the gender of the respondent and the perception of environmental variables (IAQ, noise and illumination) also affected the proportion of dwellings with open window. The average age of the inhabitants, the thermal sensation of respondents and gender also had an influence on the use of lighting. Mora et al. (2015) conducted a study to determine the influence of physical and behavioural selected factors in energy buildings performance in Mediterranean climate, starting from a survey-based data collection. The variables considered were classified into three categories: physical, occupants and energy. The results revealed that floor area and climate are the most significant physical parameters for electricity consumption; age, number of household members and income can be mentioned concerning the occupants. Other studies were conducted by starting from larger dataset, as the case of Guerra-Santin and Itard (2010) using Dutch dataset from statistical survey conducted at national level. In this study, results showed that the number of hours the heating system operates has a stronger effect on energy consumption than temperature setting. The main building characteristic determining behaviour turned out to be the type of temperature control. Households with a programmable thermostat were more likely to keep the radiators turned on for more hours than households with a manual thermostat or manual valves on radiators. In relation to household characteristics, the presence of elderly proved to be a determining factor in the use of the heating system and ventilation. As a result of wide variations in preferences and lifestyle, occupant behaviour has emerged as an important contributor to energy use in dwellings.

Due to the importance of contextual conditions, and the lack of this type of analysis on determinants of behaviour at Italian level, this dissertation aims at providing novel knowledge on the role of household characteristics on energy consumption in Italian residential buildings.

4.3.2 Data sample

As there are significant differences in energy consumption between households, it is increasingly important to get a clear insight into the relationship between type of occupancy, household characteristics and energy use. When it comes to the renovation of the existing housing stock, more certainty on the occupancy behaviour and determinants explaining it, before the renovation is conducted, can potentially help to reduce the financial risk associated with the interventions. For instance, the payback time and the prebound effect (Sunikka-Blank and Galvin 2012; Guerra-Santin and Silvester 2016) are strictly related to user behaviour, where the latter consists of households using less energy than foreseen due to energy poverty condition and low awareness of energy efficiency technology use.

To investigate heating patterns and occupancy attitude in relation to the Italian household composition in the Italian context, the results from the Household Energy Consumption survey performed by the Italian Statistic Bureau (ISTAT) in 2013 have been analysed. The survey was conducted from March to July 2013 by applying the CATI (Computer assisted telephone interviewing) technique. The survey has been the result of the agreement jointly signed in 2011 by ISTAT and the Italian National Agency for New Technologies, Energy and Sustainable

Economic Development (ENEA) to investigate the energy consumption in the residential sector. It has been conducted aiming at providing, for the first time in Italy, accurate statistical data on the energy behaviours of households living in Italy, filling the information gap at national and also international level. The resulting dataset includes information regarding household composition, housing needs, energy consumption, building characteristics and building operation. The sample population has been randomly selected from the official archive of households subscribing to the telephone network. The total responses consist of 20,000 records, coming from the 20 Italian Regions and 8,000 Italian municipalities with different sizes, from metropolitan areas to remote rural areas having less than 10,000 inhabitants, both in mountain and coastal areas.

To the aim of this research, only elements related to the heating consumption have been investigated. The descriptive statistics of household type, household characteristics and dwelling characteristics are presented in Table 4.1 and Table 4.2. The dataset embeds a series of limitations: first of all, information on household expenditures are expressed in a categorical non-fully-ordinal variables, which do not allow further analysis on the energy costs. In fact, besides being reported in categorical variables, the yearly costs for heating consumption are taken into account according to the type of fuel (i.e. gas, petroleum, LPG) instead of the type of end-use (i.e. space heating, water heating, cooking) with different categories among the variables (e.g. from 1 to 12 for the gas from network system, from 1 to 10 for petroleum, from 1 to 7 for LPG), and different sizes among the categories themselves, resulting in no possibility to sum them. Secondly, the dataset does not include information on energy expenditures for dwellings with a building centralised heating system operating, although the related question was included in the survey. Therefore, respondents with centralised heating system have been excluded from further analysis, as well as households who do not use the gas supply network for heating, and the sample size is reduced to 13,005 samples.

The average size of the households is 2.7 persons, while the average age of the household head is 57 years old. At least one senior occupant older than 65 is part of the 59% of the total households, while about 1/3 of the families have at least one member less than 20 years old. When it comes to the working condition, a crucial parameter directly influencing the household occupancy attitude, 3 out of 4 households have at least one retired and/or unemployed person and/or housewife.

Table 4.1: Descriptive statistics of variables on household characteristics and building characteristics

Household characteristics				
Continuous variable	Definition	Mean	SD	N
Household size	No. of household members	2.68	1.17	13,005
Age	Age of household head	57.24	12.84	13,005
Categorical Variable	Definition		%	N
Household composition	At least one senior (> 65 years old)		59	7636
	At least one member between 45-65 years old		57	7437
	At least one member between 20-45 years old		30	3938
	At least one young person (< 20 years old)		34	4449
Working condition	At least one retired and/or unemployed person and/or housewife		75	9,788
	Only working adult(s)		15	1,979
	Households with only working adult(s) and/or student(s)		10	1,238
Education level	Lower (no all members with high school qualification)		72	9313
	Middle (all household members with high school qualification)		29	3694
	Higher (at least one household member with university degree)		29	3738
Gender	Prevalence of male		23	3047
	Prevalence of female		29	3780
	Equality		48	6199
Dwelling characteristics				
Continuous variable	Definition	Mean	SD	N
Dwelling size	No. of rooms	3.60	1.27	13,005
Categorical Variable	Definition		%	N
Type of dwelling	Single/multi-family house with one or few housing units		53	6,961
	Dwelling in multi-family building up to 10 housing units		29	3,710
	Dwelling in multi-family building between 11-27 housing units		15	1,953
	Dwelling in multi-family building with more than 27 housing units		3	381
Year of construction	Before 1950		18	2,403
	Between 1950-1970		24	3,116
	Between 1970-1990		37	4,772
	After 1990		21	2,714
Dwelling size	Up to 59 m^2		4	537
	Between 60-89 m^2		27	3,462
	Between 90-119 m^2		39	5,081
	More than 120 m^2		30	3,925
Thermostat regulation	Yes		83	10,734
	No		17	2,271

Source: author's elaboration on ISTAT microdata

Table 4.2: Descriptive statistics of energy consumption and behaviour

Energy consumption				
Categorical Variable	Definition		%	N
Energy expenditure for heating from gas supply network	Up to 600 €/year		17	1,901
	Between 600 and 1,000 €/year		31	3,349
	More than 1,000 €/year		52	5,733
Behaviour and awareness				
Continuous variable	Definition	Mean	SD	N
Heating system	No. of operating hours between 5 am and 1 pm	2.34	2.13	12,386
	No. of operating hours between 1 pm and 9 pm	4.22	2.07	12,386
	No. of operating hours between 9 pm and 5 am	1.05	1.53	12,386
	No. of operating hours per day	7.62	4.30	12,386
Categorical Variable	Definition		%	N
Awareness of building energy label procedure	Yes		43	5,591
	No		57	7,414

Source: author's elaboration on ISTAT microdata

The education level has been also investigated, resulting in almost the same number of households with all high school graduated members and the ones with at least one university graduated person, while the great majority (72%) has at least one member without high school certificate. In terms of gender, households with a prevalence of male members are 23%, while the ones with a prevalence of females account for 29%, although almost half (48%) of the households have a gender balance situation.

When it comes to the dwelling characteristics, the largest share (i.e. more than 4,700 households, 37%) lives in buildings built between the seventies and the nineties, while the single/multi-family house with one or few housing units is the most prevalent housing type (53%). Dwelling in multi-family building up to 10 housing units represents the 29% of the total, confirming that Italian families live in low-rise buildings. More than 9,000 households live in housing units larger than 90 square meters, and, if considering the whole sample, the average number of rooms is slightly more than 3 and a half.

More than a half of households spend more than 1,000 €/year for heating from gas supply network, while the 30% spend between 600 and 1,000 €/year. However, as already explained,

the information about energy expenditure does not allow further investigation on the influence of household characteristics and building characteristic on energy costs.
Indeed, some more considerations can derive from the analysis of data concerning the number of operating hours of the heating system. Since the analysed data only include households who can decide by their own when to turn on and turn off the heating system, this variable is even more representative of the behaviour than energy expenditure. As shown in Table 4.2, the heating system is turned on, on average, for less than 2 hours and a half during the morning (i.e. from 5 am to 1 pm), more than 4 hours in the afternoon and evening (i.e. from 1 pm to 9 pm) and for about 1 hour only during the night (i.e. from 9 pm to 5 am), resulting in a total average of 7.62 hours during a day. However, the survey did not make any distinction between workdays and weekends, therefore, this results in a average estimation.

The awareness of building energy procedure is one of the very few questions aimed at investigating household knowledge and awareness towards energy savings. According to the results, 57% of respondents are not aware about the procedures. Questions regarding the dwelling energy class have been included in the survey, however the answers have not been processed and included in the dataset, making impossible to formulate more considerations on the energy efficiency of buildings can be performed.

Certainly, as the energy expenditures depend on the final price of the energy utilities, the number of operating hours of the heating system is related to the climatic conditions. Italian climate shows significant differences between the inlands and the coastal areas, both from north to south and from east to west. The national territory is divided in 6 climate zones (A–F) defined according to heating degree days (HDD) as established by the national regulation (DPR 412 1993). The HHD represents 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. For every zone, the norm fixes the period of the year and the maximum number of hours per day that heating may be switched on.
To reduce, on the one, side the degree of influence of the location on the heating system, and on the other side, the sample size to avoid the normalisation of the results, due to the low degree of variability in the attributes (Israel 1992), only data for Emilia-Romagna Region have been

further processed, since more than 85% of municipalities in this region are located in the E climatic zone. The dataset further reduced to 860 samples, is now much more closer to similar studies (Andersen et al. 2009; Mora et al. 2015; Guerra-Santin and Silvester 2016) in terms of size. The variables further considered are the one in Table 4.3, where data for Emilia-Romagna Region only are illustrated.

Building characteristics have not been included in the investigation since the focus of this part of the study is on the household determinants. Much is already evident about the link between energy efficiency of building and behaviour, while households characteristics causing certain behaviour patterns are generally salient and need to be further investigated.

Table 4.3: Descriptive statistics of variables selected. Data for Emilia-Romagna Region only.

Continuous variable	Definition	Mean	SD	N
Household size	No. of household members	2.45	1.14	860
Categorical Variable	**Definition**		**%**	**N**
Household composition	At least one senior (> 65 years old)		52	449
	At least one member between 45-65 years old		63	545
	At least one member between 20-45 years old		27	230
	At least one young person (< 20 years old)		23	199
Gender	Prevalence of male		26	220
	Prevalence of female		33	285
	Equality		41	355
Working condition	At least one retired and/or unemployed person and/or a housewife		71	612
	Only working adult(s)		20	171
	Households with only working adult(s) and/or student(s)		9	77
Education level	Lower (no all members with high school qualification)		73	631
	Middle (all household members with high school qualification)		27	230
	Higher (at least one household member with university degree)		27	229
Thermostat regulation	Yes		83	718
	No		17	142

Source: author's elaboration on ISTAT dataset

4.3.3 Results from the statistical analysis

The relationship between the use of the heating system and household characteristics has been analysed. The household characteristics taken into account are: age, gender, education level, household size and working condition. The possibility to regulate the thermostat has been added to the selected variables.

The statistical tests applied are related to the type of variables. Household characteristics are mostly in categories (see Table 4.3), while the use of heating system is expressed in hours, so in continuous form. For the only parametric variable in normal form (i.e. household size) Pearson product-moment correlation coefficient has been used to determine the effect on heating system operating hours. It is a measure of linear dependence between two variables with a value between -1 and +1. The t-statistic aims to analyse the differences between the means of two groups; if t-statistic is less than the significance level (or error), the null hypothesis is rejected. Independent-samples t-tests have been used to determine the differences on behaviour in dichotomous variables (i.e. thermostat regulation). One-way ANOVA tests have been used for categorical variables with more than two levels. The one-way ANOVA is used to determine whether there are any significant differences between the means of three or more independent groups. Statistical analysis results are presented in Table 4.4.

Table 4.4: Statistics from independent t-tests and one-way ANOVA tests for selected variables related to behaviour about operating hours of the heating system

Variable considered in relation to behaviour	**Statistics**	**Categories**	**Mean**	**SD**	**CV**
Thermostat regulation	t= -2,00 p<.05	Yes	9.08	4.63	0.51
		No	10.27	4.34	0.42
Household composition	F(3,1419)= 3.460 p<.05	At least one senior	10.21	4.72	0.46
		At least one member 45-65 years old	9.36	4.38	0.47
		At least one member 20-45 years old	9.63	4.40	0.46
		At least one young person	9.30	4.60	0.49
Gender	NS	Prevalence of male			
		Prevalence of female			
		Equality			
Working condition	F(2,857)= 10.22 p<.001	At least one retired and/or unemployed person and/or a housewife	10.07	4.64	0.46
		Only working adult(s)	8.32	3.89	0.47
		Households with only working adult(s) and/or student(s)	9.55	4.44	0.46
Education level	NS	Lower Middle Higher			

SD = standard deviation; CV = coefficient of variance; NS = not statistically significant
Source: author’s elaboration on ISTAT microdata

Household size turned out to be unconnected to the number of operating hours of the heating system. No correlation was found between the two variables (p=0.021).

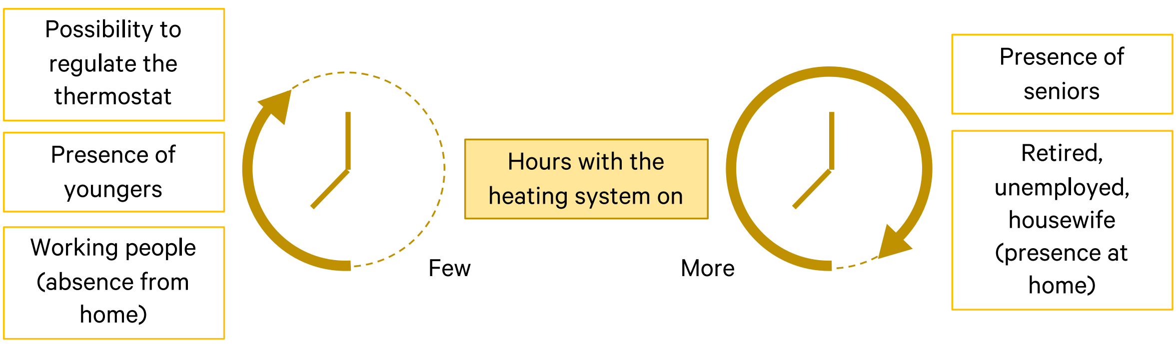
An independent-samples t-test uncovered a relationship between the presence of thermostat regulation and the number of hours that the heating system operates. The presence of thermostat regulation is related to less operating hours of the heating system. Household composition according to age also turned out to be a statistically significant variable, with households having at least one senior with more than 65 years old using the heating system for more hours than other family groups.

As expected, the working condition resulted to be also a statistically significant variable. Although no specific questions were asked regarding typical occupancy patterns, the results from the one-way ANOVA test shows that households with at least one retired and/or unemployed person and/or a housewife operate the heating system more than one hour and a half longer than households where all the members work and likely stay out from home most of the day, while families without retired and/or unemployed person and/or a housewife but with students turn the heating system on for approximately the same time than the first group.

One-way ANOVA tests determine that neither education is statistically significant (F(2,1086)=2.457, p=0.08) when it comes to the number of hours in which the heating system operates, nor gender (F(2,856)=1.09, p=0.34).

Figure 4.1 shows the relationship between occupant behaviour and household characteristics. Absence of thermostat, household composition and working condition affecting presence at home are all related to more hours on the use of the heating system.

Figure 4.1: Relationships between type of temperature control, household characteristics, and use of heating system



Source: author’s elaboration

4.3.4 Discussion and limitations

The results seem to be in accordance with the findings of other studies (see section 3.3 in Chapter 3), although the variables that have been possible to consider in this research are much less than the ones investigated in other studies conducted abroad, where more accurate statistical data are available. The results show that household composition in relation to age is a statistically significant variable, with seniors having more energy-intensive heating practices in terms of number of hours the heating system is turned on than households with younger occupants up to 20 years old. The differences in heating behavioural patterns seem to be caused by differences in lifestyle between households (e.g. hours at home due to the working condition), and household composition (e.g. presence of seniors or youngers). However, there are certainly other household conditions that could also affect the occupancy patterns for heating, that this investigation could not reveal.

Although the survey has been expressly delivered to collect information on household behaviour and building characteristics causing energy consumption and energy expenditures, it missed the opportunity to get a proper insight into the behaviour itself, the occupancy patterns, the household awareness and attitude towards energy efficiency. The energy costs express in macro-category not even fully-ordinal (i.e. in case of gas use from supply network, the range in euro of the category no. 12 embeds within itself the categories no. 9, 10 and 11) does not allow to investigate the relationship between household characteristics and energy expenditures. Moreover, the data on energy consumption in energy unit are completely missing, as the data on energy efficiency of the dwellings, although the latter issue is part of the questions, but not part of the micro data. Also data on energy expenditures for the centralised heating system have turned to be not available in the dataset, resulting in the impossibility to investigate household characteristics related to behaviour in the case occupants cannot choose by themselves when to turn on and off the heating system.

The use of statistics to determine the household characteristics related to energy use in buildings has proved to be useful to understand how age, household composition and occupancy influence the behaviour. As soon as more accurate data become available, in particular for energy consumption/expenditures and behaviour, through statistics it would be possible to determine the occupancy patterns to define the occupancy of a building when real information about the occupants is not available. This approach can represent a great opportunity for policy-makers and Energy Service Companies (ESCos) in case of building renovation, since the behaviour profiles can be integrated into the renovation process, resulting in a more accurate method to determine, on the one side, the expected building performance accounting for household variation, on the other side, the levers to be activated in order to support household in delivering the expected savings.

4.4 The second micro-level approach: understanding user behaviour and awareness through questionnaires

4.4.1 Literature review

Many studies have investigated people behaviour in residential buildings, and most of them recognised that not only physical conditions are not the only variables influencing the behaviour of building occupants. They have resulted in new understanding of household and building determinants and human behaviour patterns definition in relation to window opening, use of air-conditioning and temperature control, lighting and solar shading, depending on outdoor and indoor conditions (see Chapter 3). Among them, a consistent number has adopted survey methodologies to understand household awareness, behaviour and willingness to adapt to more sustainable consumption patterns. They main consist of questionnaires (Andersen et al. 2009; Gupta and Chandiwala 2010; Frontczak et al. 2012; Huebner et al. 2013; Feng et al. 2016), in-dept interviews (Gram-Hanssen 2010; Hayles and Dean 2015) and there have been also studies combining both (Peters et al. 2010; Brown et al. 2014), to get a deeper understanding. In case a disruptive change occurs, as the housing renovation to improve energy efficiency of building components, and installation of new technology systems as smart meters, some scholars have highlighted the importance of performing post-occupancy evaluation (Bordass and Leaman 2005; Hendrickson and Wittman 2010).

In some cases, the questionnaire based survey are preferred for reducing the direct-personal observation effects which causes the participants to feel observed and, therefore, alter their responses (Wilhite and Ling 1995; Vassileva and Campillo 2014; Boemi et al. 2017). In others, sending email instead of delivering the questionnaires by hand at home or by post has resulted to be effective in enlarging the target group reached (Jain et al. 2012; Feng et al. 2016). The survey tool has also been applied at community scale, rather than individual one, to determine their level of interest in the municipal Green Living Centre in London by distributing the questionnaires to visitors (Peters et al. 2010).

Due to the time people spend in indoor environment, and considering they have the greatest freedom to act and the greatest control at home, the residential sector is the one where user behaviour has been investigated the most, since raising awareness among households on their consumption behaviour patterns at home is believed to be a crucial point in lowering energy consumption (Hayles and Dean 2015). Therefore, studies performing survey-based investigations have mostly focused on the residential sector (Shipworth et al. 2010; Vassileva and Campillo 2014; Elsharkawy and Rutherford 2015; Hayles and Dean 2015; Feng et al. 2016), although the number of scholars working on assessing behaviour impact on office buildings through survey is also increasing.

4.4.2 The Finnish case study[3]

4.4.2.1 Background

The city of Helsinki has about 635,000 inhabitants, while the metropolitan area counts more than 1.4 million inhabitants, one-fourth of the total population of Finland. The population has been growing rapidly, by 8,000 annually on average in 2013–2016. Over 40% of Finnish population growth occurred in Helsinki.

When it comes to the building sector, building construction has been increasing in Helsinki, particularly towards housing. The aggregate floor space in building permits for new housing, in particular, grew significantly. Construction of business premises increased, too. As a whole, however, construction was more geared towards housing than it had been earlier. Between 2013 and 2016, around 15,500 dwellings were completed, either as new dwellings or extensions, and an additional 1,300 dwellings through change of intended use. There are considerably more

[3] The case study presented in this sub-section is the result of the research work conducted in 2017 during a one-month-placement at the City of Helsinki (Environmental Services Department) in the framework of the Climate KIC Pioneers into Practice programme. The questionnaires have been modified and delivered after the placement ended, and the data collected have been shared with the author to be investigated in the framework of this dissertation.

people living in apartment buildings and rental homes in the city of Helsinki than in the neighbouring municipalities. About one-third of residential buildings were built earlier than 1959 (Parviainen 2017), therefore, renovating the existing housing stock is a major concern in Helsinki, as for the rest of European cities. Housing sector causes approximately 60% of Helsinki GHG emissions. Among them, 85% comes from heating and domestic hot water, while the rest comes from electricity usage (City of Helsinki 2018). The heating consumption is a major cause of emissions. Approximately 90% of properties are part of the district heating network.

Helsinki is on the way to meet its target to reduce GHG emissions by 80% by 2035, having already achieved 25% reductions since 1990. However, to become carbon neutral in 2035, it recognises the urgency to tackle household energy behaviour as a prominent issue to effectively achieve the renovation and lower consumption of residential buildings. Therefore, the city of Helsinki is committed to raise awareness among citizens, and in particular through targeted information campaigns to households, who are believed to be the key factor for making the renovation practices effective and for activating and multiplying the urban regeneration benefits.

The aim of this work is to get an insight into household behaviour in relation to energy consumption through the application of a micro-level approach, consisting in delivering questionnaires to investigate user behaviour and awareness. The case study has been selected since it is part of the actions the City of Helsinki is developing in the framework of the H2020 mySMARTLife project[4]. The main objective of mySMARTLife project is the definition of an innovative urban transformation strategy for making cities more environmentally friendly by reducing CO_2 emissions and increasing the use of renewable energy sources, with the active participation of the citizens.

4.4.2.2 Merihaka district

Merihaka district (Figure 4.2) is located just outside the East boarder of the historical city centre. The total targeted area consists of 12 buildings, resulting in more than 1,300 dwellings. Buildings in Merihaka were constructed in the 1970s and 1980s. In general, the effectiveness of the

[4] Since 2016, 27 partners from 6 countries are collaborating to the project. Activities take place in the three demonstration cities Nantes, Hamburg and Helsinki. The three follower cities which are expected to learn from the demonstration city experiences are Bydgoszcz, Rijeka and Palencia.

building insulation materials of this residential building stock are already relatively good compared to average European buildings. More than two-layer windows have been a standard since 1970s in Finland, and a substantial amount of the residential buildings have already been renovated by improving either the building façade and/or the HVAC system.

The project action focuses on investigating how the municipality can support and promote energy efficiency solutions in buildings to increase energy performance and decrease energy consumption. Rather than implementing solutions to improve the building materials thermal proprieties (e.g. insultation of the envelop or replacement of windows), to increase replicability the interventions are mainly focused on the installation of new technological devices. Smart thermostats for managing the heating demand at the apartment level is one of the key retrofitting interventions.

Figure 4.2: Merihaka district

Source: author’s elaboration

A pilot project has been conducted between November 2017 and March 2018, when one building with 168 dwellings has been equipped with a smart heating control system that includes smart thermostats remotely connected to the cloud-based intelligence and district heating system to balance thermal loads. The smart thermostats allow households to set the schedule of each room with the preferred temperature and to select the vacancy mode when not at home. At the same time, they automatically collect information on the temperature set-point preferences, the temperature of the heat distribution water in radiator and the room temperature. The collected information will be then used to provide feedback to occupants. The strategy foresees also community events where households are invited to attend to receive additional feedback, to ask questions and to co-design the awareness campaign by adding information on their expectations and preferences. Therefore, the results presented in this paper represent only the first step of the investigation the City of Helsinki is carrying on to understand awareness on energy savings, user behaviour and the usability of the solutions.

4.4.2.3 Methodology

In order to investigate preferences, interests and understandings of household energy consumption, a questionnaire was designed and sent by mail to the 168 households living in the dwellings where the pilot case described above has taken place. Participants could also choose to participate through an online version of the survey. The questionnaire based approach was chosen in order to favour a higher relationship between what the respondents answered and reality, and also due to time limits for this first round of investigation. The questionnaire based survey was also preferred for reducing the direct and personal observation effects which cause the participants to feel observed and, therefore, alter their responses.

Household overall energy consumption patterns have been investigated in previous research (see Chapter 3) combining statistical data or large scale databases on energy consumptions with survey results. In this case only a qualitative research analysis has been performed meaning that results are based on the questionnaire responses only. Although this solution rises limits on the exploitation of the results, it can make a difference in the local context at an early stage of the design of a renovation strategy for the existing housing stock.

Three types of questions were included in the questionnaires: the one that requires the self-evaluation of comfort choosing the value among a scale 1-7, 1 for being very dissatisfied and 7 for being very satisfied; the other that foresees a choice among multiple answers, and the last type which is open questions for commenting or further detailing specific answers.

The topics targeted by the questions are divided into three groups. At first, questions addressing the level of satisfaction regarding comfort of the occupants. The second part consists of information on the new thermostats setting and how it has been easy to use and to configurate. The last part intended, on the one side, to gather the household preferences regarding temperature setting and type of feedback to receive, on the other side to understand the awareness that households have when it comes to energy savings.

4.4.2.4 Results from the survey

Since the response rate was only 17%, the replies from households cannot be considered as representative neither for the all population living in the district, nor for the households living in the pilot building, due to potential of biased selection. Nevertheless, they carry important information regarding current behaviour, awareness on energy consumption and attitude towards the use of thermostats in Finnish housing stock, data that are particularly scarce.

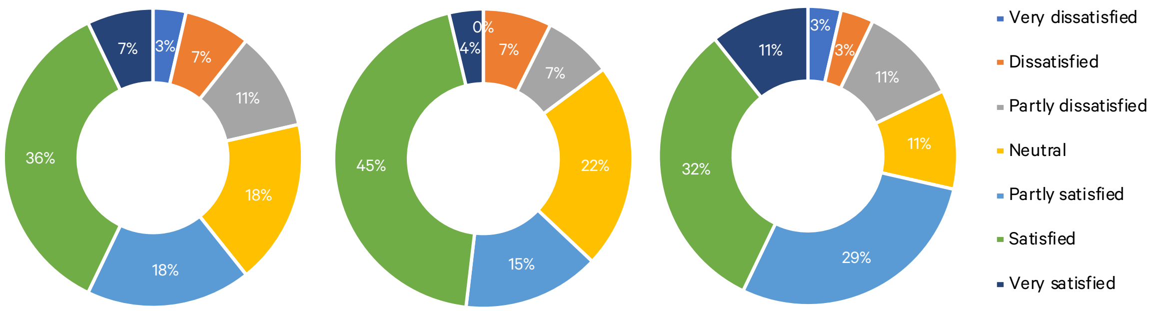
Respondents were generally satisfied with the overall indoor dwelling environment. Similarly to what was found by Frontczak et al. (2012), the highest satisfaction, considering the combination of the two highest scores, was observed for air quality (49% of responders), while the relatively lowest for the acoustic pollution. The thermal comfort satisfies the 36% of households, while 18% reported to be partly satisfied, and only 7% are very satisfied (Figure 4.3).

When it comes to the interface between privately and publicly owned spaces, households showed almost the same good level of satisfaction for the lighting of building common spaces, and for the overall community where they are living (Figure 4.4).

Households were asked to report their preferred set-point temperature in a range between 20°C and 23°C. Half of the respondents reported to choose 22°C, 2 degrees higher than 20°C, generally assumed as thermal indoor comfort temperature (ISO 2008), chosen in this case by only one-fifth of respondents (Figure 4.5).

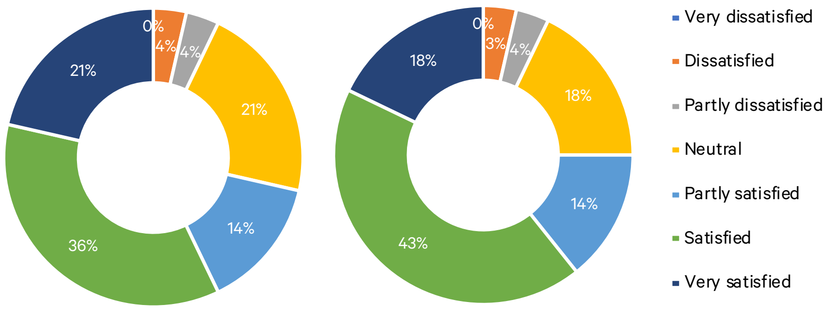
As already framed in Chapter 3, a number of studies both from social and technical fields have been performed in the last decades with the aim to investigate the determinants for explaining user behaviour and to identify consumption patterns. When it comes to understand the current occupant awareness level either on the impact of their behaviour on energy consumption or on the importance of energy savings, education and motivation are worth to be investigated. Results from this survey show that saving energy is considered by households a relatively important issue, with the great majority (more than 60%) stating that it is somehow important, while the 15% gave to energy savings even a higher importance. One of the reasons that could explain the rest of respondents considering this issue not important is the relatively low energy costs for end users, 15% less than the EU-28 average fuel price for domestic consumers (European Commission 2017).

Figure 4.3: Thermal, air and acoustic quality of indoor dwelling environment



Source: author's elaboration

Figure 4.4: Lighting quality of building common spaces and level of satisfaction of overall community environment

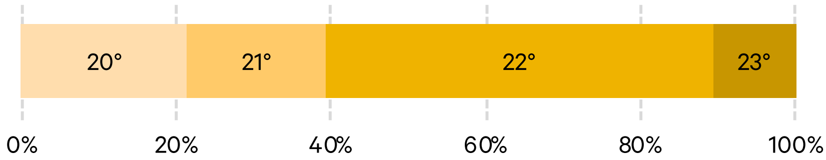


Source: author's elaboration

Education has been found to be insignificant in explaining energy consumption (Guerra-Santin 2010; Sapci and Considine 2014). For example, Schweiker and Shukuya (2009) indicated that the use of air-conditioning units differed depending on the origin of a person, experience from childhood and attitude towards air-conditioning. Motivation is another important determinant of electricity consumption (Lindén et al. 2006; Vringer et al. 2007). The perception of the environment and other factors concerning the dwelling can also impact the window opening behaviour (Andersen et al. 2009). Motivation and perception could be influenced through information, feedback and other educational and economic measures. Feedback in particular has proven to have a strong influence on occupant behaviour (Darby 2006; Fischer 2008; Faruqui et al. 2010). As environmental concerns increase, households take direct action to conserve energy (Sapci and Considine 2014). In order to maintain the positive behavioural changes for longer, some scholars suggest that factors such as human motivation and energy related interest should be included in the feedback developing process (Henryson et al. 2000). Several studies show that most of the households do not understand much about scientific units

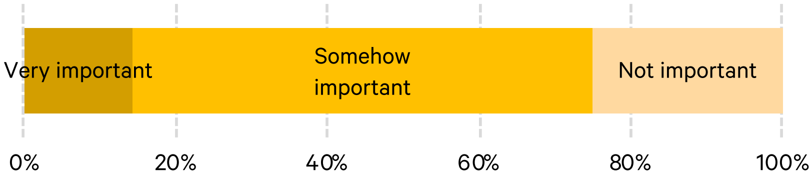
(Jain et al. 2013; Frederiks et al. 2015), therefore, feedback providing only consumption values in energy unit might not be very effective.

Figure 4.5: Preferred set-point temperature



Source: author's elaboration

Figure 4.6: Answers to question targeting interest in energy savings



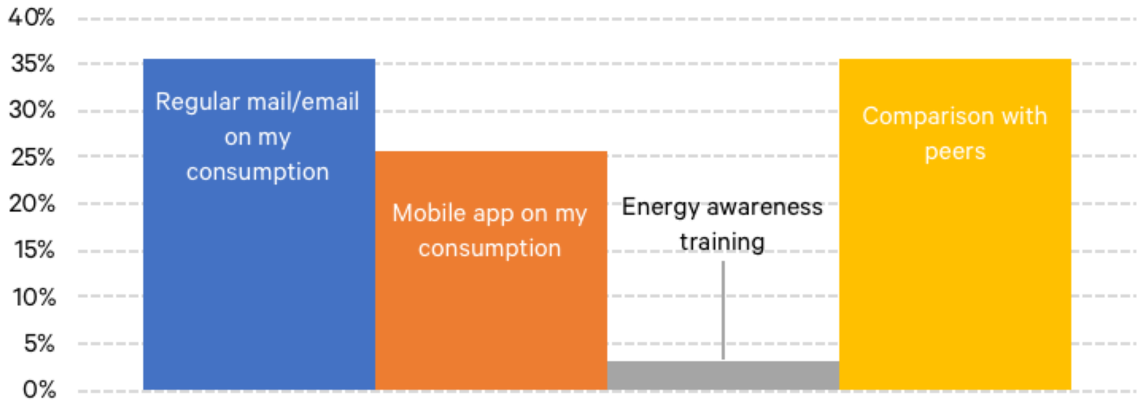
Source: author's elaboration

The results presented in Figure 4.7 shows that 35% of the households would prefer to receive feedbacks on their energy consumption either by regular mail or email, while the preferences for smart technologies such as mobile applications were lower. Interestingly, 35% of respondents would prefer to receive information on their consumption level compared with neighbours or other peers, no matter the means for delivering such information. Frederiks et al. (2015) have found that advising individuals that people similar to them (e.g. peers, neighbours) are using less energy or taking certain energy-saving actions, in addition to conveying social approval of such actions, will most likely motivate them to conform to these positive energy-saving attitudes and to reduce their consumption accordingly.

Household energy consumption should not only be presented quantitatively (as monthly/annual consumption or according to the size of the household) but other values should also be included, such as comparison with similar households, environmental impact caused by the consumption, and appliance specific breakdown. To achieve long lasting effects, the feedback needs to be dynamic, as consumers preferences and knowledge can change over time (Vassileva and Campillo 2014).

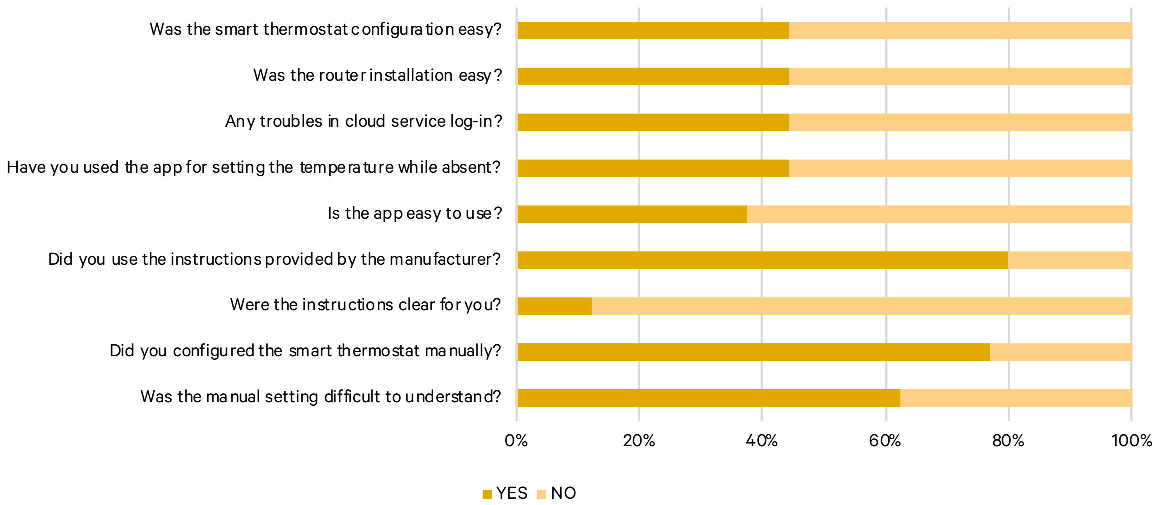
Some additional questions have been formulated to investigate household attitude towards the use of thermostats (Figure 4.8). The majority of respondents reported to had experienced troubles in installing, configuring and log-in with the new thermostats provided. Although 80% have declared that they used the instructions provided by the energy company, less than 20% of them found they were clear, and the manual setting of the thermostat resulted to be difficult to understand by more than 60% of the respondents. These findings suggest that more effort is needed to make occupants able to properly use the new technology installed. An overconfidence in technology might lead to an overestimation of benefits and energy savings.

Figure 4.7: Answers to questions targeting interest in energy savings



Source: author's elaboration

Figure 4.8: Answers to questions targeting interest in energy savings



Source: author's elaboration

4.4.3 The Italian case study

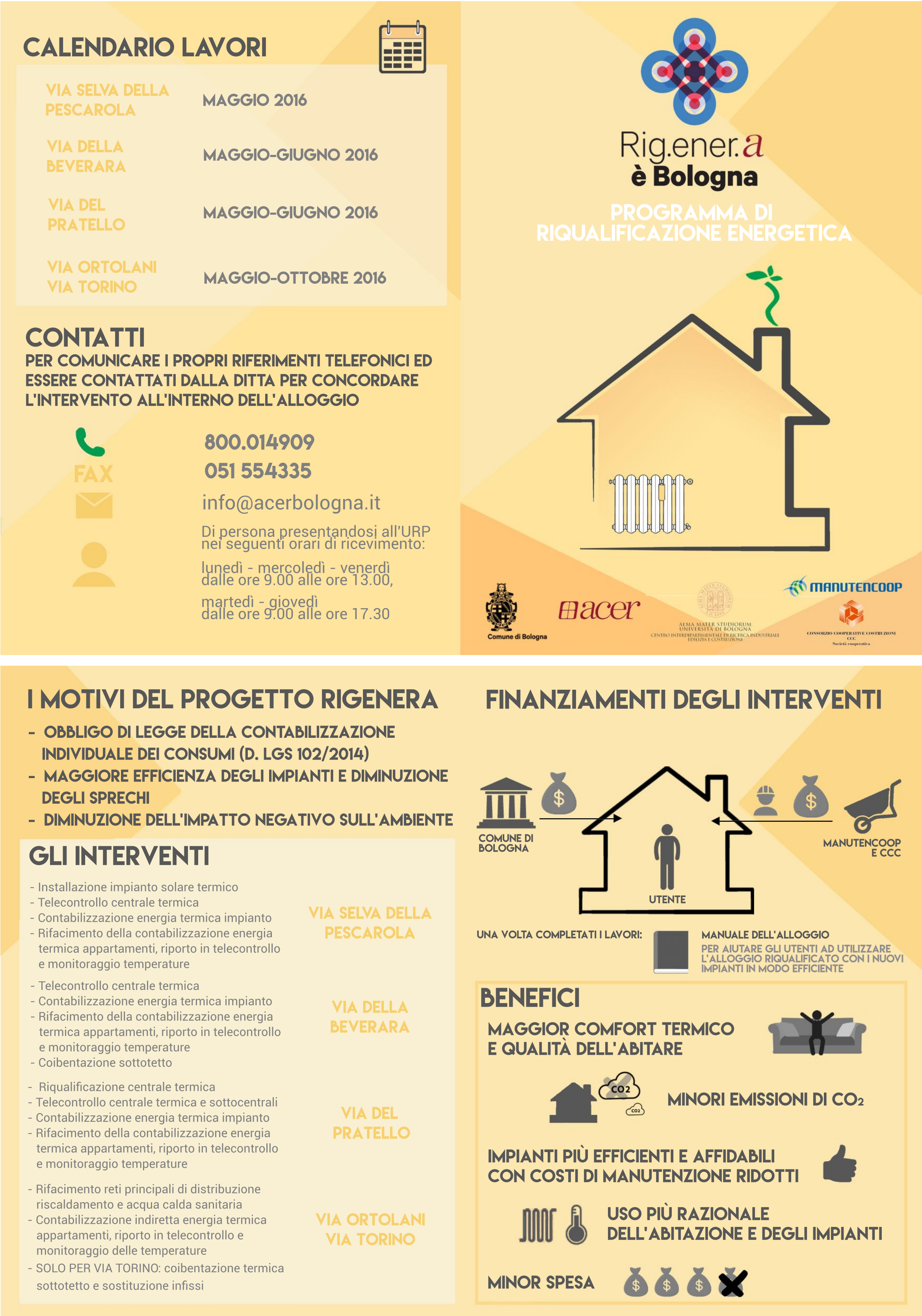
4.4.3.1 Background

As already described in Chapter 3, Rig.ener.a[5] is a three-years programme (2017-2019, formally approved in 2016) that has been promoted by the Municipality of Bologna as the main energy retrofit programme for its public housing stock. It foresees the involvement of an ESCo for the energy renovation of the housing stock through the signature of an Energy Performance Contract (EPC) to provide the technical and financial services needed for energy efficiency projects (for additional details, Proli et al. 2016). Besides the replacement of the heating system to increase efficiency and some physical renovation of the first eight buildings, accounting for more than 300 dwellings, the programme foresees also the involvement of the public housing tenants through indirect feedback, mainly information materials, tips and informative energy bills. The first informative event was organised in March 2016, when the tenants were invited to a general assembly to get to know the programme, the renovation activities and the agenda of interventions. A leaflet was designed (Figure 4.9) to provide them a catchy layout with basic information, to avoid the risk to provide too much information difficult to be processed.

The aim of the initial information strategy was twofold: on the one side, the housing provider (ACER) wanted to make households aware that, in order to deliver the energy retrofit of the buildings, they need to give access to the ESCo and to facilitate their work as much as possible; on the other side, ACER aimed at building trust around their work, to avoid delays and the raise of other issue that could prevent the ESCo to deliver the renovation. Informing the users about the new technologies, understanding their behaviour and willingness to adapt in order to build a strong and effective feedback campaign has been on the table too, but mostly on the background.

[5] All the information provided in this session and throughout the dissertation regarding the Rig.Ener.a initiative is the result of the direct involvement of the author in the definition of the steps for the programme implementation, in particular concerning the information and feedback to households, through an agreement signed between the Municipality of Bologna and the University of Bologna.

Figure 4.9: External and internal sides of Rig.ener.a leaflet



Source: Giulia Tonioni and author’s elaboration

4.4.3.2 Pilot cases

Eight buildings were included in the first renovation stage. The selection was the result of an internal process, where the public housing providers selected a panel of possible buildings more convenient to intervene in terms of management, where additional interventions were more urgent to be placed side by side to the regular maintenance. The selection of the ESCo and the renovation works were then performed following a public procurement process, where private energy service companies were invited to participate.
The buildings are located in three different districts around the city, and they are different in sizes, from few housing units to more than nineties. Three are located north-west to the city center, in Navile district, with 21 dwellings in total; one with 13 housing units within the city centre, in the pedestrian area of via del Pratello; and four of them (i.e. three towers 18-storey high with 63 housing units each, and a 10-storey building with 93 dwellings) located in the Savena district, east to the city centre. In particular, in the latter case, the four buildings hosting the great majority of the dwellings are located one next to the others in the same neighbourhood. Although this situation clearly would have represented an excellent opportunity to also regenerate the empty public space between the buildings, it has been missed, since the local authority has not succeeded in making the urban regeneration process appealing for the private investors (Proli et al. 2016).

4.4.3.3 Survey design

A survey was designed to be delivered prior to renovation works foreseen in spring-summer 2017, in order to collect information on household characteristics, occupant behaviour, occupancy patterns and thermal preferences, to tailor the contents of the feedback to be delivered after the renovation, on a monthly basis. An online version of the survey was prepared too, although it was supposed to be fulfilled by a very limited number of tenants, since the public housing provider does not have email addresses of all households living in their stock. The public housing provider was responsible to send the paper-based questionnaire to the tenants, or, in alternative, to deliver it to the mail box by hand. The ESCo was then responsible to collect the responses during their home visits to assess the specific condition of the dwelling. However, the collection phase has never occurred, due to organisational issues that postponed the renovation process.

Although the process has not been completed and the results from the survey are not available yet, the questionnaire is presented in this section (Figure 4.10 and 4.11) to explain the rationale behind its design, and the link between the questions and the expected data and information from the answers. The survey was designed as an express methodology to get information from the users in a brief and simple way, to favour the response rate. Indeed, it is essential that a pre-renovation occupant feedback approach is kept pragmatic, focusing on what is really important to know, keeping cost and time to a minimum, while still extracting most of the details needed (Gupta and Chandiwala 2010).

Clear and concise instructions were provided at the very beginning of the survey, together with a rough estimation of the time to deliver it. All the questions refer to the comfort perception and behaviour during the autumn and winter time, when the heating system is operating. The survey aims at investigating two different behaviours, very much related among each other: the heating behaviour and the ventilation behaviour. The questionnaire was aimed to address multiple issues by posing multiple-choice and scale-based questions:

- the occupancy patterns (i.e. presence/absence from home) in weekdays and during the weekend (Question 1);
- the comfort preferences and the reasons behind them, both for heating behaviour and ventilation behaviour (Questions 2-6);
- the awareness on energy consumption, attitude towards energy savings and willingness to adapt the behaviour (Questions 7-11, 13);
- the willingness to receive feedback and the means for receiving such information on their energy consumption and behaviour (Question 12);
- Basic information on the characteristics of the respondents, number of people living in the dwelling and the number of rooms (Question 14).

Figure 4.10: Front page of the Rig.ener.a questionnaire

Rig.ener.a
è Bologna

PROGRAMMA DI RIQUALIFICAZIONE ENERGETICA: LA PAROLA AGLI INQUILINI!

Il questionario è in forma anonima, prevede 14 domande e un tempo di compilazione di pochi minuti.
Se preferisci, puoi compilarlo online collegandoti all'indirizzo: https://goo.gl/forms/IdOGWTvHUBe9p8Y93
Conoscere la tua opinione e le tue abitudini è molto importante per rendere efficace l'intervento di riqualificazione energetica della tua casa!

Attenzione!
Tutte le domande si riferiscono al periodo invernale quando il riscaldamento è acceso

1) Considera una giornata tipo: quali ore trascorre fuori casa la tua famiglia?
Considera le 24 ore di una giornata e annerisci tutte le ore in cui nessuno è a casa

Dal lunedì al venerdì	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Nel weekend	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

2) Sei generalmente soddisfatto della temperatura interna quando il riscaldamento è acceso?
Una sola risposta

- ☐ Molto soddisfatto
- ☐ Abbastanza soddisfatto
- ☐ No, ho freddo
- ☐ No, ho caldo

3) Qual è la prima cosa che fai se senti molto caldo o molto freddo?
Una sola risposta

- ☐ Apro oppure chiudo la finestra
- ☐ Indosso una maglia in più oppure tolgo una maglia
- ☐ Bevo qualcosa di caldo oppure freddo
- ☐ Apro oppure chiudo le valvole dei radiatori

4) Considera una giornata tipo: in quali ore apri le finestre?
Considera le 24 ore di una giornata e annerisci tutte le ore in cui solitamente apri le finestre

Dal lunedì al venerdì	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Nel weekend	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

5) Quanto tempo tieni le finestre aperte ogni volta che le apri?
Una sola risposta

- ☐ Meno di 5 minuti
- ☐ 5-10 minuti
- ☐ 10-20 minuti
- ☐ Più di 20 minuti

6) Per quali ragioni apri le finestre?
Fino a due risposte

- ☐ Cambiare l'aria al mattino
- ☐ Eliminare gli odori e il vapore in cucina oppure in bagno
- ☐ Rinfrescare l'aria prima di dormire
- ☐ Non apro mai le finestre

Comune di Bologna — acer — ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA CENTRO INTERDIPARTIMENTALE DI RICERCA INDUSTRIALE EDILIZIA E COSTRUZIONI — MANUTENCOOP

Source: author's elaboration

Figure 4.11: Back page of the Rig.ener.a questionnaire

7) Quanto ti preoccupi di risparmiare energia?
Una sola risposta

☐ Molto ☐ Abbastanza ☐ Poco ☐ Per nulla

8) Qual è la ragione principale che ti spinge a fare attenzione ai consumi energetici della famiglia?
Una sola risposta

☐ Risparmiare soldi
☐ Ridurre l'inquinamento e difendere l'ambiente
☐ Dare il buon esempio
☐ Non faccio attenzione

9) Perché risparmiare energia è difficile?
Fino a due risposte

☐ Perché non so cosa devo fare
☐ Perché non posso regolare la temperatura
☐ Perché non riesco a cambiare le mie abitudini
☐ Perché non la sento come una priorità
☐ Perché non vedo un guadagno immediato
☐ Non è difficile

10) Cosa saresti disposto a fare per risparmiare energia?
Fino a due risposte

☐ Ridurre la temperatura quando non sono a casa
☐ Ridurre la temperatura quando dormo
☐ Vestirmi più pesante invece di aumentare la temperatura
☐ Niente
☐ Ridurre la temperatura di 1°C rispetto alle mie abitudini

11) Se si potesse regolare la temperatura in casa, quale sceglieresti quando sei a casa?
Una sola risposta

☐ 18°C ☐ 19°C ☐ 20°C ☐ 21°C ☐ 22°C

12) Se potessi scegliere, in quale modo vorresti ricevere informazioni sui tuoi consumi e consigli su come ridurli?
Una sola risposta

☐ Via email, ogni mese
☐ Via web oppure con un'applicazione sul telefono
☐ Via posta, ogni mese
☐ Non vorrei ricevere informazioni

13) Chi è più sensibile al tema del risparmio energetico nella tua famiglia?
Una sola risposta

☐ Tu ☐ Tuo marito o moglie ☐ I tuoi figli ☐ I tuoi genitori ☐ Nessuno

14) Puoi darci qualche informazione in più su di te e sul tuo alloggio?

Età: .... Sesso: M / F Nazionalità: ☐ Italiana ☐ Non italiana

Livello di istruzione: ☐ Licenza elementare / media ☐ Diploma ☐ Laurea

Numero di persone che vivono nell'alloggio: .... Numero di camere da letto nell'alloggio: ....

Grazie per aver partecipato!
Restituisci il questionario compilato all'incaricato che verrà a casa tua ad effettuare i lavori.
Ti terremo informato sui risultati raccolti e sui prossimi passi per imparare insieme a risparmiare energia

Source: author's elaboration

4.4.4 Discussion and limitations

This section aims at summarising and discussing the main results of the micro-level approach applied in the two case studies, the case of Helsinki and the one of Bologna. Reasons for the two cases can be explained by the limitations that characterised the research work, that could not be overcome: while the case of Bologna was the one to be developed, its sudden suspension has resulted in the need to test the designed questionnaire within a different real context. The Helsinki case study was then developed, but due to the different local conditions in terms of buildings and actors of the renovation process, and different aim of the project already running, only some of the findings expected with the original survey investigation could be gathered. The conducted survey has been useful to gain a first insight into household awareness, attitudes and willingness to be involved in actions targeted to the reduction of energy consumption.

Some limitations must be acknowledged. First of all, the questionnaire does not take into consideration the household characteristics of the respondents. Therefore, this issue excludes some possible findings that can explain certain behaviour patterns. Secondly, the low response rate makes impossible to further assess the responses through statistical analysis to reinforce the conclusions. However, this study only represents the first step of the set of activity the City of Helsinki is committed to perform for the district regeneration, and more findings will be added to this first insight in the next future.

Main results of the process, rather than of the survey itself, show that, on the one side, the availability of data and information concerning occupancy and behaviour is essential for modelling the profiles to be used in renovation design or assessment phase; on the other side, the availability of those data, together with the awareness and willingness to adapt have also a key importance for housing providers and ESCos, to better estimate the payback period, the rebound effect, and to avoid overestimation of technology effects. In fact, no matter how useful technological interventions are, it is unlikely that any of the targets set to reduce resource consumption in the domestic housing sector will be achieved without a greater focus on human behaviour (Hayles and Dean 2015). Investigating current behaviour and practices is not enough, it is also necessary to identify whether or not there is a willingness from the households to reduce consumption, and this is only possible through investigations prior renovation as the survey designed for the Italian case and then tested in the Finnish case.

It is also important to note that in the initial phase of the renovation process, there is usually little time to undertake comprehensive pre-renovation monitoring and occupant feedback surveys, and little attention is dedicated to this activity, as the occupants are seen much more as target groups, rather than active actors of the process. The housing provider and the energy service company are usually more interested in modelling renovation options, selecting them and planning the actual implementation of the interventions. Therefore, it is important to keep the pre-renovation monitoring survey as much pragmatic and simple as possible, to get hints to be then able to focus on the post-renovation phase, usually known as Post Occupancy Evaluation phase (Bordass and Leaman 2005; Hendrickson and Wittman 2010). Indeed, the survey delivered prior the renovation should be considered as part of a process including also the assessment phase after renovation. Understanding household behaviour, comfort preferences and willingness to change behaviour patterns is also considered to be able to activate the engagement of the occupants in the retrofit process, and generate awareness on energy use, positively influencing user behaviour (Gupta and Chandiwala 2010).

4.5 Directions for future research

The results of the investigations conducted in this chapter have reinforced two discourses: on the one side, the need of building robust framework for data collection and processing on energy behaviour and households preferences and practices; on the other side, the need to integrate occupant feedback methods before renovate the existing stock, to improve the uptake and effectiveness of household energy efficiency and low-carbon interventions, as an essential way to address the current gap in knowledge.

Future research should focus on how to make the tools for collecting information on occupant behaviour and energy consumption even more informative, towards standardised procedures easy to be applied. By using statistics to the census data available for Italy, it has emerged the need to improve the results by improving the questions and the issue addressed. Almost no questions were addressed to report behaviour, occupancy patterns and preferences. Ventilation behaviour was totally absent from the survey, although it is recognised to be an important factor affecting the heating consumption, for example. Data on energy expenditures were so aggregated to be not usable in statistical test. A much greater effort has to be put in place by public authorities and other public or private institutions participating to collect information, to allow research on the energy behaviour topic. To create occupancy profiles can be beneficial not only for public housing providers and ESCos operating to the renovation of the existing stock, but also to the energy utilities for improving the energy supply system. To this aim, the profile created through direct interview of the user seems to be the most reliable, but at the same time, it could be the most expensive and could not always be applicable, since in some cases the type of user is not known. A viable alternative might be the use of statistical data. But generally, currently available databases are not sufficiently detailed. Therefore, targeted surveys should be developed in order to create exploitable datasets for this specific purpose. Furthermore, analyses at a local level are needed since the habits and behaviours of users vary significantly depending on the geographical area (Mora et al. 2017).

For long-term sustainability, it is advisable to integrate the behaviour investigations, either at national scale or local one, within specific knowledge framework which provides the involvement of other professionals to continue supporting the tenants in delivering the expected energy savings.

4.6 Key research findings

- The use of statistics to determine the household characteristics related to energy use in buildings has proved to be useful to understand how thermostat, household composition and working condition affect the use of the heating system.
- As soon as more accurate data become available, in particular for energy consumption/expenditures and behaviour, through statistics it would be possible to determine the occupancy patterns, to define the home occupancy when real information about the occupants is not available.
- The first micro-level approach which makes use of statistics can represent a great opportunity for policy-makers and ESCos in case of building renovation, since the behaviour profiles can be integrated into the renovation process, resulting in a more accurate method to determine, on the one side, the expected building performance accounting for household

variation, on the other side, the levers to be activated in order to support household in delivering the expected savings.

- The survey conducted has been useful to gain a first insight into household awareness, attitudes and willingness to be involved in actions targeted to the reduction of energy consumption. However, identifying current behaviour is not enough, it is also necessary to identify whether or not there is a willingness to reduce consumption going forward.
- The housing providers and the energy service companies are usually more interested in modelling renovation options, selecting them and planning the actual implementation of the interventions, rather than engaging the occupants and making them aware of the impact of their behaviour. Therefore, it is important to keep the micro-level approach with pre-renovation monitoring survey as much pragmatic and simple as possible.
- Future research should focus on how to make the tools for collecting information on occupant behaviour and energy consumption even more informative, towards standardised procedures easy to be applied. By using statistics to the census data available for Italy, it has emerged the need to improve the results by re-thinking the questions and the issue addressed.
- To sum up, the energy efficiency process, to be effective in achieving energy reduction targets, should be conceived as a part of an integrated and broader urban strategy fostering urban regeneration of the existing city, where the local authorities have a key strategic role in coordinating and influencing the activities of a range of actors, in defining areas and communities to focus on, and in engaging people in changing behaviours in order to reduce energy consumption. Therefore, investigating consumer behaviour in the framework of urban planning by applying two micro-level approaches presented in this chapter can provide an insight into the urban regenerative potential of cities, which relies – among others – on the one side, on energy awareness of people, their behaviour, capacity and willingness to adapt, while, on the other side, on the ability of public authorities to design renovation strategies and to turn occupants into active actors, rather than passive target groups.

References

Andersen RV, Toftum J, Andersen KK, Olesen BW (2009) Survey of occupant behaviour and control of indoor environment in Danish dwellings. Energy and Buildings 41:11–16. doi: 10.1016/j.enbuild.2008.07.004

Bedir M (2017) Occupant behavior and energy consumption in dwellings: An analysis of behavioral models and actual energy consumption in the dutch housing stock. Delft University of Technology

Boemi S-N, Panaras G, Papadopoulos AM (2017) Residential Heating under Energy Poverty Conditions: A Field Study. Procedia Environmental Sciences 38:867–874. doi: 10.1016/j.proenv.2017.03.173

Bordass B, Leaman A (2005) Making feedback and post-occupancy evaluation routine 3: Case studies of the use of techniques in the feedback portfolio. Building Research & Information 33:361–375. doi: 10.1080/09613210500162032

Brown P, Swan W, Chahal S (2014) Retrofitting social housing: Reflections by tenants on adopting and living with retrofit technology. Energy Efficiency 7:641–653. doi: 10.1007/s12053-013-9245-3

Caputo P, Pasetti G (2015) Overcoming the inertia of building energy retrofit at municipal level: The Italian challenge. Sustainable Cities and Society 15:120–134. doi: 10.1016/j.scs.2015.01.001

City of Helsinki (2018) "Esitys Hiilineutraali Helsinki 2035 - toimenpideohjelmaksi" [Presentation of Carbon Neutral Helsinki 2035 - Operational Programme], available at: https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/HNH-2035-toimenpideohjelma.pdf.

Darby S (2006) The Effectiveness of Feedback on Energy Consumption. A Review for Defra of the Literature on Metering, Billing and, Environmental Change Institute University of Oxford

D'Oca S, Hong T (2015) Occupancy schedules learning process through a data mining framework. Energy and Buildings 88:395–408. doi: 10.1016/j.enbuild.2014.11.065

Elsharkawy H, Rutherford P (2015) Retrofitting social housing in the UK: Home energy use and performance in a pre-Community Energy Saving Programme (CESP). Energy and Buildings 88:25–33. doi: 10.1016/j.enbuild.2014.11.045

ENEA (2018) Italy's 65% Tax Deduction Scheme – Ecobonus for energy renovation of existing building stock. ANNUAL REPORT 2018

European Commission (2017) EU energy in figures. Statistical pocketbook 2017

Faruqui A, Sergici S, Sharif A (2010) The impact of informational feedback on energy consumption. A survey of the experimental evidence. Energy 35(4):1598–1608. doi: 10.1016/j.energy.2009.07.042

Feng X, Yan D, Wang C, Sun H (2016) A preliminary research on the derivation of typical occupant behavior based on large-scale questionnaire surveys. Energy and Buildings 117:332–340. doi: 10.1016/j.enbuild.2015.09.055

Fischer C (2008) Feedback on household electricity consumption: a tool for saving energy?. Energy Efficiency 1(1):79–104

Frederiks ER, Stenner K, Hobman EV (2015) Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renewable and Sustainable Energy Reviews 41:1385–1394

Frontczak M, Andersen RV, Wargocki P (2012) Questionnaire survey on factors influencing comfort with indoor environmental quality in Danish housing. Building and Environment 50:56–64. doi: 10.1016/j.buildenv.2011.10.012

Gram-Hanssen K (2010) Residential heat comfort practices: understanding users. Building Research & Information 38:175–186. doi: 10.1080/09613210903541527

Guerra-Santin O (2010) Actual energy consumption in dwellings. The effect of energy performance regulations and occupant behaviour. Delft University of Technology

Guerra-Santin O, Itard L (2010) Occupants' behaviour: determinants and effects on residential heating consumption. Building Research & Information 38:318–338. doi: 10.1080/09613211003661074

Guerra-Santin O, Silvester S (2016) Development of Dutch occupancy and heating profiles for building simulation. Building Research & Information 1–18. doi: 10.1080/09613218.2016.1160563

Gupta R, Chandiwala S (2010) Understanding occupants: feedback techniques for large-scale low-carbon domestic refurbishments. Building Research & Information 38:530–548. doi: 10.1080/09613218.2010.495216

Hayles CS, Dean M (2015) Social housing tenants, Climate Change and sustainable living: A study of awareness, behaviours and willingness to adapt. Sustainable Cities and Society 17:35–45. doi: 10.1016/j.scs.2015.03.007

Hendrickson DJ, Wittman HK (2010) Post-occupancy assessment: building design, governance and household consumption. Building Research & Information 38:481–490. doi: 10.1080/09613218.2010.494377

Hong T, Yan D, D'Oca S, Chen C fei (2017) Ten questions concerning occupant behavior in buildings: The big picture. Building and Environment 114:518–530. doi: 10.1016/j.buildenv.2016.12.006

Huebner GM, Cooper J, Jones K (2013) Domestic energy consumption - What role do comfort, habit, and knowledge about the heating system play? Energy and Buildings 66:626–636. doi: 10.1016/j.enbuild.2013.07.043

ISO, BS EN ISO 13790:2008 (2008) Energy Performance of Buildings – Calculation of Energy Use for Space Heating and Cooling, International Organization for Standardization, Geneva, Switzerland.

Israel GD (1992) Determining sample size. University of Florida. IFA Extension. PEOD6

ISTAT (2010) L'abitazione delle famiglie residenti in Italia. Anno 2008

ISTAT (2014) 15° censimento generale della popolazione e delle abitazioni. Edifici e abitazioni. Anno 2011

Jain RK, Taylor JE, Culligan PJ (2013) Investigating the impact eco-feedback information representation has on building occupant energy consumption behavior and savings. Energy and Buildings 64:408–414

Jain RK, Taylor JE, Peschiera G (2012) Assessing eco-feedback interface usage and design to drive energy efficiency in buildings. Energy and Buildings 48:8–17. doi: 10.1016/j.enbuild.2011.12.033

Lindén AL, Carlsson-Kanyama A, Eriksson B (2006) Efficient and inefficient aspects of residential energy behaviour: What are the policy instruments for change?. Energy Policy 34(14):1918–1927

Mora D, Carpino C, De Simone M (2015) Behavioral and physical factors influencing energy building performances in Mediterranean climate. Energy Procedia 78:603–608. doi: 10.1016/j.egypro.2015.11.033

Mora D, Carpino C, De Simone M (2017) Energy consumption of residential buildings and occupancy profiles. A case study in Mediterranean climatic conditions. Energy Efficiency. doi: 10.1007/s12053-017-9553-0

Nomisma (2016) Dimensioni e caratteristiche del disagio abitativo in Italia. Report

ODYSSEE-MURE (2018) Energy efficiency trends and policies. Italy Energy profile. June 2018

Papa R, Gargiulo C, Zucaro F, Cristiano M, Angiello G, Carpentieri G (2016) Energy and Climate Change Polices in Europe: Overview and Selected Examples from a Spatial Planning Perspective. In Papa R and Fistola R (eds) Smart Energy in the Smart City. Green Ener. Springer International Publishing Switzerland, pp. 237–274.

Parviainen E (2017) City of Vantaa. Asuminen ja rakentaminen, Helsingin seutu [Helsinki region dwelling and construction]. https://www.hel.fi/hel2/Helsinginseutu/HS_tunnusluvut/Asuminen_ja_rakentaminen. pdf

Peters M, Fudge S, Sinclair P (2010) Mobilising community action towards a low-carbon future: Opportunities and challenges for local government in the UK. Energy Policy 38:7596–7603. doi: 10.1016/j.enpol.2010.01.044

Proli S, Santangelo A, Tondelli S (2016) Efficienza energetica ed edilizia sociale: il programma Rig.ener.a, sfide e prospettive a Bologna. In: XIX Conferenza Nazionale SIU Cambiamenti. Responsabilità e strumenti per l'urbanistica al servizio del paese. Planum Publisher, Catania 16-18 giugno

Ren X, Yan D, Hong T (2015) Data mining of space heating system performance in affordable housing. Building and Environment 89:1–13. doi: 10.1016/j.buildenv.2015.02.009

Sapci O, Considine T (2014) The link between environmental attitudes and energy consumption behavior. Journal of Behavioral and Experimental Economics 52: 29–34.

Schaffrin A, Reibling N (2015) Household energy and climate mitigation policies: Investigating energy practices in the housing sector. Energy Policy 77:1–10. doi: 10.1016/j.enpol.2014.12.002

Schweiker M, Shukuya M (2009) Comparison of theoretical and statistical models of air-conditioning-unit usage behaviour in a residential setting under Japanese climatic conditions. Building and Environment 44:2137-2149. doi: 10.1016/j.buildenv.2009.03.004

Shipworth M, Firth SK, Gentry MI, et al (2010) Central heating thermostat settings and timing: building demographics. Building Research & Information 38:50–69. doi: 10.1080/09613210903263007

Sonderegger RC (1978) Movers and stayers: The resident's contribution to variation across houses in energy consumption for space heating. Energy and Buildings 1:313–324. doi: 10.1016/0378-7788(78)90011-7

Sunikka-Blank M, Galvin R (2012) Introducing the prebound effect: the gap between performance and actual energy consumption. Building Research & Information 40:260–273. doi: 10.1080/09613218.2012.690952

Theobald K, Shaw K (2014) Urban governance, planning and retrofit. In: Dixon T, Eames M, Hunt M, Lannon S (eds) Urban Retrofitting for Sustainability. London: Routledge. pp 87-98

Van Raaij WF, Verhallen TMM (1983) Patterns of residential energy behavior. Journal of Economic Psychology 4:85–106

Vassileva I, Campillo J (2014) Increasing energy efficiency in low-income households through targeting awareness and behavioral change. Renewable Energy 67:59–63. doi: 10.1016/j.renene.2013.11.046

Vringer K, Aalbers T, Blok K (2007) Household energy requirement and value patterns. Energy Policy 35(1): 553–566

Wilhite H, Ling R (1995) Measured energy savings from a more informative energy bill. Energy and Buildings 22:145–155. doi: 10.1016/0378-7788(94)00912-4

Yan D, O'Brien W, Hong T, et al (2015) Occupant behavior modeling for building performance simulation: Current state and future challenges. Energy and Buildings 107:264–278. doi: 10.1016/j.enbuild.2015.08.032

Yu Z, Fung BCM, Haghighat F (2013) Extracting knowledge from building-related data — A data mining framework. Building Simulation 6:207–222. doi: 10.1007/s12273-013-0117-8

5. Occupant behaviour and building renovation: the case of the Italian public housing sector

ENGLISH ABSTRACT

The aim of this chapter is to provide an overview of the current state of the public housing sector in Italy, highlighting main characteristics in terms of size, allocation system, tenure, housing quality and explaining the reasons behind the focus on it throughout the dissertation. Sections 5.1 and 5.2 present respectively the introduction, and the aim and methodology. Section 5.3 describes, on the one side, the public housing characteristics in terms of sector size, different housing tenures, target groups and quality of the housing stock; on the other side, it presents the renovation policies targeted to the specific sector, and considerations on the equality or inequality of the regeneration process. The interrelation among actors and the emerging role of tenants are illustrated in Section 5.4, with the aim of providing evidence of the interdependency among the actors and the need to address this relationship, to make the regeneration process successful. The relation between occupant behaviour and energy poverty, and the role of the former to reduce the latter, is the focus of Section 5.5. Directions for future research and key research findings are respectively discussed in Sections 5.6 and 5.7.

ABSTRACT IN ITALIANO

L'obiettivo del presente capitolo è quello di fornire una panoramica dello stato dell'arte del settore dell'edilizia pubblica in Italia, evidenziando le principali caratteristiche in termini di dimensioni, sistema di assegnazione, titolo di godimento, qualità degli alloggi, illustrando le ragioni alla base di questo focus all'interno del presente lavoro di ricerca. Le sezioni 5.1 e 5.2 presentano rispettivamente l'introduzione, e lo scopo e la metodologia. La sezione 5.3 descrive, da un lato, le caratteristiche dell'abitazione pubblica in termini di dimensioni del settore, tipologia di titolo di godimento, gruppi destinatari e qualità del patrimonio abitativo; dall'altra parte, le politiche di rigenerazione mirate al settore specifico e l'equità o iniquità del processo di rigenerazione. L'interrelazione tra gli attori e il ruolo emergente degli inquilini come parte attiva del processo sono illustrati nella sezione 5.4, con l'obiettivo di dimostrare l'interdipendenza tra gli attori e la necessità di considerarla per rendere il processo di rigenerazione efficace. La relazione tra il comportamento degli occupanti e la povertà energetica, e il ruolo del primo nel contenimento della seconda, sono al centro della sezione 5.5. La direzione per la ricerca futura e i principali risultati della ricerca sono discussi rispettivamente nella sezione 5.6 e 5.7.

5.1 Introduction

5.1.1 An overview on social housing in EU

The term social housing refers to the definition provided by the CECODHAS (today Housing Europe) in 2006, when it started to be referred as housing for households whose needs are not met by the open market and where there are rules for allocating housing to benefiting households.
At EU level, almost each Member State has various forms of housing designed to satisfy the needs of households who are unable to compete in the marketplace for housing of an acceptable standard, although each Country has its housing policy, allocation system and financial framework. Across Europe, social housing is a combination of public housing stock (i.e. owned and managed by central or local governments, depending on the Country) and a range of voluntary or non-profit associations and foundations, public or private non-profit companies, cooperative organizations and private investors.

The size of the social housing stock varies considerably between Countries. Although social housing is generally referred to the social rental sector, it also comprises other forms of housing tenure, as the provision of affordable dwellings for sale to households for ownership. Due to the difficulties in statistically identifying the stock of social home-ownership, of particular relevance in Countries such as Greece and Spain, the size of the sector is usually illustrated by data on social rental stock. These differences between Countries are not simply a consequence of current policies or the outcome of rational deliberations about how large the sector should be, but more often they are the result of decisions made over many decades. Small rental sectors can be partly attributed to policies that over time have favoured home-ownership, as the case of Italy, and larger rental sectors to policies that have placed less emphasis on owner occupation. The relative attractiveness of private rental housing and home-ownership as investments can also have important implications for the size of the social rental sector. However, figures show that, in the last decades, in several EU Countries the number of applicants for social housing has increased while at the same time the relative share of social housing in the overall stock has fallen.

According to the latest available data from Housing Europe (Pittini et al. 2017), the largest social rental housing sector in Europe is in the Netherlands where it constitutes 30% of the total housing stock, followed by Austria (24%) and Denmark (21%). The UK, Sweden, France, Czech Republic and Finland also have a relatively large social housing sector, accounting for 17% or more. On the opposite side, many Countries have a very small social rental housing sector, including Italy, Spain, Romania, Croatia, Estonia and Hungary, where 4% or less of the stock of each Country is classified as social rental housing. In most Central and Eastern European Countries, the share of social rental housing is extremely low too, with the exception of the Czech Republic and Poland, partly due to the fact that these Countries kept a bigger share of the stock as publicly owned even after the transition to a free market economy. In Greece, according to the definition of social housing and the data collected, there is no social rented housing. Indeed, it represents a peculiar case in which social housing is only provided in the form of low-cost housing for sale.

Affordability and the existence of rules for the allocation of dwellings not necessarily in agreement with the market mechanisms constitute the core common features of social housing in the European Union. Social housing is allocated outside of the market mechanisms, according to the housing need, rather than ability to pay. This means that administrative processes driven by policy decisions are necessary to allocate dwellings, and the access to the accommodation depends on how needs are defined and interpreted. The allocation criteria can be either universalistic or targeted: the former, typical for Sweden, the Netherlands and Denmark, considers housing as a public responsibility and guarantees that the whole population has access to quality and affordable housing, giving social housing a market-regulating role; the latter, typical of Countries with low share of social housing, is based on the assumption that housing policy goals are met predominantly by the market, and that only those households for whom the market is unable to deliver housing of decent quality at an affordable price should benefit from social housing. However, although housing is not a competence of the EU, Member States where social housing is allocated according to the universalistic approach have been running into problems with the EU for subsidising the undeserving, since only housing for the poor is considered to be a Service of General Interest (SGI) (Whitehead and Scanlon 2007).

In Italy, the term social housing is commonly associated with interventions in the field of housing policy of public interest that go beyond the traditional boundaries of public housing and foresee the participation of private and non-profit actors. Public housing can be considered as a subset of social housing, although the former represents the great majority of the latter, since the involvement of private investors and foundations in the provision of housing to lower costs than the market rent is a relatively recent phenomenon, still very much challenging to implement. Nevertheless, due to the confused and sometimes misleading role associated to the term social housing in the national context, the term public housing is used to describe the housing stock owned and managed by public bodies, identified with the Italian term *Edilizia Residenziale Pubblica (ERP)*.

5.2 Aim and methodology

Chapter 5 contributes to the research question 2 as presented in the box below. Sub-question e) will be addressed. The overall aim of this chapter is to provide an overview of the current state of the public housing sector in Italy, highlighting main characteristics in terms of size, allocation system, tenure, housing quality and explaining the reasons behind the focus on it throughout the dissertation.

Research question 2:

How to identify the determinants of occupant behaviour and energy consumption, to understand which are the best strategies to promote pro-environmental behaviour?

Sub-questions:

e) How does social housing sector can have a role in showcasing the path for increasing the renovation rate of residential buildings while addressing awareness on behaviour?

The applied methodology is based on the analytical review of the available literature. After presenting the reasons behind the focus of the dissertation on social housing, and the overview of the sector at EU level, the Italian public housing characteristics are presented. The size of the sector, and the reasons that explain its shrinking are illustrated, together with the characteristics of the tenure and the target group. The housing quality, energy efficiency and renovation policies are also investigated, to get an insight on the actual context, where the housing providers are operating and where the effective renovation strategies should take place. In addition, the equality issue of transformations is also considered. The description of different actors – the owners and the managers of the stock, private actors providing energy services and renovation expertise, and the emerging role of tenants in the regeneration of the existing public housing stock – is then analysed to provide evidence of the interrelationship among them. The role of occupant behaviour as an instrument to alleviate energy poverty in public housing stock is also investigated, since energy poverty is a growing phenomenon particularly prevalent in dwellings allocated to low-income households, and very few targeted policies are available. Finally, future challenges are discussed, and key research findings are summarised in the last section.

5.2.1 Reasons behind the focus on social housing

Propriety fragmentation, low awareness of home-owners on energy efficiency improvements and benefits, and low skills of building managers, who are responsible of building management, can be considered among the main barriers to the building retrofit, and, as a consequence, to the urban regeneration.
Starting from these considerations, the dissertation aims at reinforcing two issues: on the one side, the role of human factor for the effective implementation of urban renovation programmes; on the other side, the leading role that social housing sector – and particularly the Italian public housing one – can have in demonstrating the feasibility and benefits of such programmes.

First of all, according to the EU Directives extensively considered in Chapter 2, public authorities have the obligation to lead the renovation process of their building stock and to showcase an exemplary role. Secondly, energy-savings from the renovation of owner-occupied houses are expected to be the main stimulus for undertaking energy-efficient actions, while the focus on the social housing sector is more challenging due to the difficulties in addressing energy-savings within this vulnerable user group. Thirdly, the interventions within the social housing stock not only have an energy-saving value, but also enhance the role of energy efficiency in combination with the social and economic co-benefits (e.g. poverty alleviation, health improvements), thus contributing to avoid stigmatisation, social segregation and to reduce energy poverty. Furthermore, considering the exclusive role of social housing providers in building management and the similarities in the regulations for providers, working with them and their tenants through information and training practices could easily lead to a multiplier effect.

Behaviour is more likely to be deliberately considered and changed when a discontinuity occurs in the household context (Huebner et al. 2013). Therefore, building renovation programmes offer a key opportunity to involve households in order to make them reconsidering their consumption practices. However, pro-environmental behaviour is likely to be considered if information and education measures come from credible, trustworthy sources. Thus, the impact of the renovation programmes is closely linked to the relationship between social housing tenants and housing providers, as further investigated in Section 5.4.

The implementation of strategies for urban regeneration and urban resilience requires the identification of public spaces that can physically contain the transformations and trigger resilient behaviour. The left-over urban space that are part of the social housing districts become therefore the place where to realise the transformations towards energy efficient and resilient cities: they are located at the interface between the public built-up space – represented by social housing buildings – and the open public space; their ownership is public, thus allowing to overcome the property fragmentation and the inertia and disagreement of actors involved; they are unused or underused spaces resulted from urban planning standards, which represent opportunities for enhancing the urban environment and adapting to climate change. Among various experimentations, evidence from bottom-up good practices in the Balkans area and in particular in Tirana (Urbego 2015) has demonstrated the added value of the transformation of common spaces for feeling a sense of belonging and start to care of the public space, whether open or closed, and therefore to promote more conscious behaviour, with evident positive effects also on the management of energy consumption.

5.3 Italian public housing characteristics

5.3.1 Size, tenure and target group

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, the Italian social housing can be almost totally identified with public housing.

Today, Italian public housing is managed by municipalities, either directly or through special public housing providers. 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 2004, resulting in an increasing share both in the number of squatters and in the number of vacant dwellings due to insufficient maintenance condition. 55% of public housing tenants pay less than 100 euro per month, while the rate of households paying a rent higher than 300 euro is only about 7% (NOMISMA 2016). 45% of the total public housing stock is located in the 12 biggest urban areas, where the higher housing demand is concentrated.

The Italian model of housing policy is defined as “targeted residual” (Czischke and Pittini 2007), aimed at providing decent housing only to the households most in needs. Access to public housing is related to the income level, and the selection criteria for economic and social needs are tight. In practice, however, targeting is fair but not fully effective (Baldini and Poggio 2012). 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 improvements in their economic and social conditions. This propensity for stability, together with the reduction in the flow of new dwellings, explains the progressive ageing of occupants. Elderly people, in fact, are the main beneficiaries, with more than 44% of household heads having 65 years old or more, while the share reaches

28% for those having 75 years old or more (NOMISMA 2016). Although the tight eligibility criteria, about 650,000 households across the whole Country are subscribed to the waiting list to access to the public housing sector (Federcasa 2015). Interestingly, public housing tenants and households in the waiting list have opposite household characteristics in terms of citizenship: while about 12% of families living in social housing stock are foreign, they are 57% of the total households meeting the allocation criteria and waiting for a public dwelling.

Although housing needs have constantly increased, both in terms of affordability and quality of the housing stock, public housing sector has been continuing to shrink since the 1990s. However, the limited dimensions of public housing supply are not only due to progressively reduction of public investments. Privatization plans were presented as a way to finance the new stock and the refurbishment of the existing one. In reality, dwellings have been sold far below their market value and each new dwelling needs 4 times more resources than the earnings from the sails (Federcasa 2015). What characterises the sector is the constant tendency of Italian governments to privatise public dwellings, and to promote the ownership over renting. To some extent, many households have been forced to become home-owners as a way of getting a secure and affordable dwelling (Baldini and Poggio 2012).
Over the last decades, important changes have also taken place in the institutional framework of public housing. Competences in this area were transferred from the state to the regional governments in the early 2000s, but the funding of public housing has emerged as a major unresolved issue. The large-scale public housing schemes developed after World War II were funded by dedicated compulsory social contributions. This scheme (e.g. GESCAL) was abolished in 1998. As a result, there is no longer an automatic, stable financing mechanism dedicated to public housing at any level of government national, regional, or local. Transfers from the State to public housing agencies have been cut to almost zero, and funds from the regions have been severely reduced.

The public housing sector is therefore affected by several structural issues. The first is certainly the aforementioned lack of constant resources to be used to manage, maintain and refurbish the existing stock, not to mention the realisation of new housing stock. Cuts in public investments cumulate with other financial issues. It should be stressed that the traditional rent-setting model raises financial sustainability issues. It operates by setting a rent to cover costs, to later discount it according to the tenants' income. This model is not sustainable without a constant and consistent flux of resources to cover the expenditures and loss (Poggio and Boreiko 2017).

5.3.2 Energy efficiency of the housing stock and urban regeneration

As already explained in Chapter 2, to the aim of this investigation, building energy renovation of public housing stock is believed to be a key opportunity to roll-out a comprehensive urban regeneration strategy with the aim of tackling energy poverty, boosting social cohesion and triggering local jobs. The active involvement of private actors is expected to activate the physical improvement of the built environment, but also to empower citizens to boost the effectiveness of the urban regeneration actions, where the local authorities hold the role of public directors, rather than actuators.

Going back to the 1980s, public housing regeneration strategies in Western Countries were characterised by severe limitations. Scholars across Europe have noted that regeneration programmes of the 1980s emphasised physical renovation over the development process of empowering local people to achieve real and lasting benefits for themselves or their communities. Communities were considered the place for fragmented and discontinuous activities, rather than active partners of the process (Hoatson and Grace 2002). By the mid-1990s experience led to new thinking that successful regeneration could not rely on one strategy, but needs a holistic approach applying a range of strategies (Hoatson and Grace 2002).

A certain number of planning instruments have been put in place also in Italy at national and regional level since the 1990s, to renovate the housing stock and to promote urban regeneration: PRU (Programs of Urban Renewal) targeted to public housing complexes, PRIU (Urban Regeneration Programs) to regenerate build-up areas as well as brownfields, PRUSST (Urban Regeneration Programs and Sustainable Development Planning), Contratti di Quartiere I and II. However, the results have been criticised by many scholars, due to the preference for the technical and architectural approach over the planning of interventions through participatory process (Tosi and Cremaschi 2001; Bronzini 2014). More recently, a series of housing policies has been promoted, namely Housing Plan 2008 and 2014, including also considerations on the existing public housing stock. However, they have always been targeted more to the private owners, rather than to the public housing providers. Even the taxation of public housing organizations has been less favourable than the one applied to home-owners and private landlords: about 30% of the rents – which are the main revenue of the public housing providers – is due in taxes (Poggio and Boreiko 2017).

Nowadays, housing and urban regeneration are important policy fields for Italian regional and local authorities. Regeneration has moved beyond 'bricks and mortar' approaches and now often involves social and economic initiatives. The government, however, is increasingly retreating from direct involvement in housing and urban issues and in many cases no longer has the power or the resources to determine the outcomes of decision-making processes. As a consequence, more and different actors and resources are needed to deliver housing and urban regeneration policies (van Bortel 2011; Copiello 2015).

When it comes to public housing neighbourhoods, they are generally located in peripheral areas of the city, where they experience lack of maintenance and embed high risk of social exclusion. Public-private partnership approaches may overcome obstacles such as lack of funding and lack of entrepreneurial ability of public housing providers, where improving energy efficiency of buildings is recognized as a driver of feasibility in order to involve private partners (Copiello 2015). The Italian Residential housing sector has shown a remarkable energy performance improvement, particularly since the early nineties when the first national law on energy efficiency in buildings had been enacted (i.e. law 10/91). When it comes to the energy efficiency renovation rate, it has been positive but negligible, namely 0.5% as annual average. Nevertheless, the potential for improving building energy performance is still substantial, particularly in the field of social housing (Copiello 2015). Today, the Italian housing stock is generally characterised by increasing ageing and poor energy efficiency. About 65% of the total dwellings belong to one of the three lowest energy class (i.e. E, F, G classes) (Lodi Rizzini 2013). About 500,000 public dwellings belong to the three lowest energy class, where households spend more than 10% of their income on the energy costs (Federcasa 2015).

5.3.2.1 A focus on the City of Bologna

As part of the Sustainable Energy Action Plan (Piano D'azione per l'Energia Sostenibile - PAES) and of the collaboration between the public and private sectors, the Municipality of Bologna has been working for some years on the energy efficiency programme of the public housing called Rig.ener.a (see Chapters 3 and 4), which has set the goal of energy renovation of public housing and of the activation of private resources for the implementation of the strategies for the resilience of the city. Divided into three sections, the overall strategy seeks to realise energy efficiency interventions in 23 buildings owned by the Municipality of Bologna, accounting for 954 accommodations in total, out of about 12,000 dwellings mostly located out from the city centre, in peripheral areas (Figure 5.1).

Figure 5.1: Location of public housing buildings in Bologna (in red colour)

Source: Stefania Proli (copyright)

Of the approximately 20,000 housing units owned by all the municipalities part of the Bologna metropolitan area, in 2013 only about 10% had an energy certificate. Among them, 90% resulted to have an average energy performance index of 219 kWh/m^2 per year, resulting in the last energy class (i.e. G energy class). These data, even if partial, can be assumed as representative of the high energy demand not only of the public housing stock, but of the residential sector as a whole, considering that in the Bologna metropolitan area more than 60% of residential buildings was built between the 1945 and 1990, over 300,000 housing units in total (Proli et al. 2016).

5.3.3 Housing quality and (in)equality of the regeneration process

Equality and quality are two of the elements that qualify urban regeneration interventions. This sub-section aims to investigate, on the one side, the issue of equality on a micro scale, taking into account the social rent; on the other side, housing quality on a macro scale, considering the relationship between the retrofit interventions on the buildings and the public space next to them.

In Italy the regulation on the public housing rent is a regional subject. In Emilia-Romagna, for example, the discipline that specifies the requirements for access and stay to public accommodation has recently been changed (Regione Emilia-Romagna 2015). An "objective rent" is calculated for every dwelling taking into account the physical dwelling and building characteristics, the location, on the basis of the discipline for the determination of the "canone concordato" (agreed rent), which applies to the private rental market. The public housing rent should therefore represent a percentage of the "canone concordato" that varies according to the certified household income (i.e. ISEE calculation). Different groups of users are identified on the basis of income level, and each group results to have a different rent calculation as follows:

- *protection group* for the less advantaged tenants, for which the maximum incidence of the rent is defined based on the income, regardless the value of the dwelling;
- *access group* for households outside the protection group, with a value per square meter of the accommodation fixed by the Municipality within the minimum and maximum limits set by the Region;
- *permanence group*, with value per square meter duplicated or tripled with respect to the access group;
- *exit group*, referred to the households with an economic condition such that they cannot stay longer in public housing. They have a limited time to stay, and the rent is calculated according

to free market fares and should be higher than the one for the permanence group, within the limits set by the Region.

The calculation methodology illustrated above is aimed to guarantee the observance of adequate levels of horizontal equality (i.e. in terms of economic condition, rent, equal accommodation characteristics) and of vertical equality (i.e. increased rent as the income increases), requirements that are often dissatisfied according to the rent calculation criteria applied so far according to the previous regulation (Tondani, 2006), only based on the income levels. Among the innovative features, the new discipline recognises the possibility of taking into account the energy efficiency of housing units. However, this does not represent an obligation, leaving unresolved the random results of the allocation system typical of the public housing system. In fact, housing is allocated on the basis of availability and size in relation to the household composition. Consequently, while the free residential market is able to manage the differences in energy consumption of the building stock, the allocation of public housing is effected by the risk of inequality when it comes to incorporate energy considerations into rent calculation (Proli et al. 2016). Moreover, income level and housing needs being equal, households living in energy efficient dwellings will result to have lower energy expenditures than peers living in old inefficient dwellings, with a consequent disparity in energy poverty conditions and both horizontal and vertical inequality (Santangelo and Tondelli 2017a).

Liveability is also an important issue in neighbourhoods regeneration. The quality and safety of public space and housing have been important pillars of urban policies and neighbourhood regeneration. Indeed, place-based issues, which are specific to some areas or perhaps even to a certain type of neighbourhood, may require a targeted approach. However, the current Italian approach can be defined as asset-based, rather than place-based. Interventions are focused on the building physical components of buildings and on the technological system, rather than targeted on the neighbourhood characteristics and needs. The overconfidence in technology, and the will to reduce the maintenance costs, have led public institutions to promote any energy intervention on technological components and building elements, without taking into account the role of people leaving there in actually reducing the energy consumption.

5.4 The interrelation among actors and the emerging role of tenants

As already reported, the European context is characterised by a wide variation in national housing systems and urban regeneration practices, variation caused by differences in institutional and policy contexts, the diversity of actors involved and resources available to implement both housing policies and regeneration strategies.

Across Europe social housing is a combination of public housing stock and a range of voluntary or non-profit associations and foundations, public or private non-profit companies, cooperative organizations and private investors. Besides providing solutions to low income people in housing needs, the purpose of social housing varies from country to country and from time to time, but broadly the suppliers can be required to contribute to neighbourhood renewal and environmental improvements. There is an increasing emphasis on mixed tenure and mixed income communities in order to avoid the social housing ghettos which often typified social housing provision in the past. Indeed, nowadays social housing may also have wider objectives including promoting mixed tenure communities, ensuring social mix in urban areas and contributing to social, economic and environmental objectives. Efforts are also being made to introduce a greater mix in the existing stock and to use public assets more effectively. The potential for public/private partnership is being explored in several Countries.

For the sustainability of the social housing sector, there is a growing recognition of the need for additional provision, better maintenance and improvement, regeneration and a wider range of services. However, the identification of additional streams of funding remains a challenge. The majority of investment schemes involve either using existing assets more effectively, selling property on the market, or mechanisms by which land values can be used to cross-subsidise development. This process is carried out by the decentralisation of housing policy in most EU Member States, which has changed the relationship between the State and social housing providers (Czischke and Pittini 2007). Indeed, from hierarchical control and standardised production of social housing, the sector has moved towards more contractual relationships between the public authorities and the increasingly independent providers.

The institutional framework concerning housing and urban regeneration is nowadays more fragmented, involving more actors than in the past, both for-profit and non-profit. The role of the government is becoming less prominent, while the influence of market actors and civil society organisations is increasing. By building on existing findings from previous research investigating the role of the third sector and governance networks particularly in the housing sector (Brandsen et al. 2005; van Bortel 2011), an overview of actors involved in the regeneration process of public housing sector has been developed. Five main categories of actors can be identified (Santangelo and Tondelli 2017b): the public authority, responsible for housing policies and strategies to tackle housing needs; social housing providers; the market-based organisations (e.g. ESCos, banks), mainly driven by economic purpose; the community, characterised by a heterogeneous group of actors (e.g. organisations, foundations, associations, cooperatives), mainly operating to promote social and environmental sustainability; the residents, intended here as individuals representing personal interests. As identified by van Bortel (2011), these groups are delineated by three conceptual borderlines: the border between formal and informal organisations, the one between profit and non-profit actors, and the last distinction between the public sector and the private one. One conceptual borderline has been added to the framework (Figure 5.1), namely the border between actors providing Services of General Interest (SGI) (European Commission 2011) and the ones providing services out from the SGI classification.

Table 5.1: Actors involved in regeneration of social housing provision according to categories and conceptual borderlines

Categories	Formal/informal organisations	Profit/non-profit actors	Public/private sectors	Services of general interest
Public authority	Formal	Non-profit	Public	Yes
Social housing provider	Formal	Non-profit	Public	Yes
Market-based organisation	Formal	Profit	Private	No
Community (collectivity)	Informal	Non-profit	Private	No
Residents (individuals)	Informal	Non-profit	Private	No

Source: Santangelo, Tondelli (2017b)

In the Italian framework, the regulation on the public housing stock is provided at regional level. Public housing management is up to the owner, either municipality or public housing associations (i.e. former IACP – *Istituti Case Autonome Popolari*), with the exception of the

Emilia-Romagna and Tuscany Regions, which have separated the two roles and have transferred the ownership to the former, while the latter are in charge of the stock management.
The housing providers are therefore responsible for the municipalities' housing stock according to the rules defined by each Italian Region on housing allocation, rent calculation, mobility within the housing stock, and in some Regions also on households in arrears and property alienation. Roles and responsibilities are further specified in Table 5.1.

Table 5.2: Actors involved in regulation, provision and management of Italian public housing

	Central government	Regional authority	Municipality	Public housing provider (former IACP)
Housing allocation	Guarantees the coherence of criteria among Regions	Provides the regulation	Responsible of public procurement procedures and allocation list	Manages the allocation list and fixes the rent for each household
Rent calculation	n.a.	Provides the regulation	n.a.	Applies the rent levels
Regular management	n.a.	Provides the regulation	n.a.	Draws up the management regulation and the rental contract
Check of the allocation criteria	n.a.	Provides the regulation	Checks prior to the allocation	Checks the persistence once every two years
Check of the persistence of allocation criteria	n.a.	Fixes the criteria	Revokes the allocation	Takes care of the effective leave
Sell of dwellings	Defines prices and characteristics of beneficiaries	Gives approval to the sales plan	n.a.	Elaborates the sales plan

Source: adapted from Federcasa (2015)

Energy Service Companies (ESCo) are for-profit or non-profit organisations specialised in providing a range of energy services to their clients. They promote energy efficiency and water consumption reduction on the premises of their customers. The building occupants then benefit from the energy savings and pay a fee to the ESCo (e.g. usually a higher energy bill than actual consumption, but still lower than the one prior renovation) for the whole payback period. Depending on their agreement with the client, ESCos take project performance risks and

the implementation risk. This is done through the Energy Performance Contract (EPC), which can either be in the form of a shared savings contract or a guaranteed savings contract.
In Italy in 2017, certified ESCos have increased by about 30% compared to 2016, with a consequent increase in employment. The growth in 2017 has been greater than the total recorded in the period 2012-2016, both for number of enterprises (75 more) and for the number of employees (2.476 more, about 34% of increase) (Info Build Energia 2018).

Communities and residents have been so far less involved in renovation of the housing stock and regeneration process than the other actors described above. Especially tenants living in social housing stock have been considered as a target group, rather than active stakeholders to be engaged for the success of the transformation process. Community is here intended as comprehensive of various forms of associations, formally or informally set-up. They exist over different levels (local, global), different spatial settings (urban and rural) and they are dynamic and constantly changing. In the broadest sense, sustainable communities actively and cooperatively work to reduce their environmental impacts both locally and globally, and to foster economic and social wellbeing. From a theoretical point of view, sustainable communities can be described either from the perspective of infrastructure and planning (e.g. neighbourhoods, land-use policy, housing) or from the social context by focusing on social relations, social practices, lifestyles and governance. From the citizen perspective, reflecting on complex issues as sustainability, climate change and regeneration from the communities' perspective can help to ground the actions and to make them more tangible. Regenerating existing communities through the increase of energy efficiency in buildings and actions to support a sustainable lifestyle requires the participation of individuals prepared to embrace change and to support the transformation process that can last several years.

Implementing an integrated approach is the overall aim of regeneration programmes. In the case of public housing, in addition to the physical renovation, these comprises a number of linked policy areas such as citizens' empowerment, employment creation, crime prevention, energy efficiency and environmental improvement. The principles of cooperation and coordination of different actors are seen as crucial to effectively implement these programmes (Czischke and Pittini 2007; Santangelo and Tondelli 2017b; Governa and Saccomani 2009): most of them include mechanisms of public participation, and social housing providers work in partnership with other public, private and social agencies involved in initiatives of urban regeneration.

The redevelopment of the public residential assets aimed at improving energy efficiency in Italy over the last decade have essentially been driven by two factors: reducing the costs associated with the ordinary maintenance of the stock and contributing to the energy reduction goals set at European and national level, to avoid to incur in penalties. The implementation of the interventions has seen in many cases the involvement of the ESCos, which operate by setting a payback time during which the tenants benefit from a limited energy and economic savings, reduced by the amount allocated to the ESCo for the recovery of the investment. In this scenario, there is an overcoming of public-private dualism, in which the public administration provides the funds assuming all the risks, while the private actors just perform their work as contractors. However, transformations and co-benefits which are not easily quantifiable in economic terms are difficult to be implemented, as for the regeneration of the public space and the initiatives to raise awareness among occupants on energy efficiency and energy behaviour (Santangelo and Tondelli 2017a).

5.5 Occupant behaviour and energy poverty

Historically, an EU-wide definition of energy poverty or vulnerable consumers has been deliberately avoided by the institutions because of the difficulties in designing a concept which fits with all existing national contexts (Bouzarovski 2018). Different Countries require different policy mixes and measures to address energy poverty. However, the lack of a common definition has also been identified in literature as the fundamental cause of the insufficient measures taken to date and the primary barrier to more coherent EU actions (Thomson et al. 2016).

The driving actor in pushing an EU energy poverty policy forward has been the European Commission. Indeed, following numerous failed attempts to create a common energy policy framework prior to 2007, the Commission has ensured that energy poverty forms an important strand of the now wide-ranging EU action in energy (Bouzarovski 2018).

The energy poverty, also known as fuel poverty, can be understood as a phenomenon encompassing the various sorts of affordability-related challenges of the provision of adequate energy services to the domestic space (Thomson et al. 2017). These typically represent situations in which households with access to modern energy infrastructures cannot comfortably satisfy their energy service needs, due to their inability to afford sufficient energy services and/or due to the costs they have to bear for those energy services (Ürge-Vorsatz and Tirado Herrero 2012).

According to Housing Europe (Pittini et al. 2017), almost 1 out of 10 (9.4%) households in the European Union are unable to keep their homes adequately warm. While the proportion of households in energy poverty across Europe has remained relatively stable at around 10%, there are significant variations both across Countries and in terms of the changes over time. For instance, in the UK the average social rented home is of significantly higher energy efficiency than any other tenure. Despite this, with 22% of social rented households saying that they are unable to keep their home adequately warm the proportion is higher than among home-owners or private renters reflecting the concentration of low incomes in social housing.

Somehow surprisingly, the highest levels energy poverty can actually be found in Countries of South and South East Europe. In Bulgaria, Greece, Cyprus and Portugal more than 20% of all households declare that they are unable to keep their home adequately warm (Pittini et al. 2017). While some of these high rates are certainly the outcome of the low quality and low energy efficiency of residential buildings, the recent growth in energy poor households in Countries such as Greece, Italy and Spain can at least partially be explained with the worsening social and economic conditions in the aftermath of the financial crisis and austerity measures. Lower levels of energy poverty are observed in Scandinavian and other Northern and Central European Countries, including Germany, the Netherlands or Austria. In these Countries, less than 5% of all households report that they are unable to keep their home adequately warm m (Pittini et al. 2017). In many Eastern Europe Countries, inadequate housing quality is still a big issue, with potentially a huge negative impact on health. The phenomenon does not only concern social housing sector, but also home-owners living in dwellings badly in need of renovation, as in Bulgaria, Estonia, Romania, where, however, residents cannot afford it without public support.

Therefore, it is evident that energy performance of the housing stock can have a significant impact on the cost of utilities and contribute to energy poverty. Nevertheless, building characteristics alone do not explain the energy consumption, and energy behaviour and practices should be taken into account too. Energy efficient technologies, together with awareness on energy behaviour and information on how to reduce the energy consumption have the potential to alleviate energy poverty. However, 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, lack of appropriate financing schemes, low awareness of decision-makers about the alternatives, split incentives between tenants and owners), deep efficiency is often not applied on a private investor or market basis in spite of its larger societal benefits. However, this dissertation is aimed at showing the positive role behaviour can have on reducing energy consumption and alleviating energy poverty even in the case of non-physical-intervention on the building, as illustrated in the next chapter (Chapter 6).

To summarise, technology and climate change are two strategic directions likely to affect the direction of the EU energy poverty policy in the coming years. 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 on the role of user behaviour (Darby 2012). Low-carbon urban and regional development policies also hold significant energy poverty reduction opportunities, especially if justice contingencies are taken into account (Bouzarovski 2018). There are also important intersections between climate change policy and energy poverty policy (Ürge-Vorsatz and Tirado Herrero 2012), not only in terms of mitigation efforts but also in relation to the impacts of global warming on the need for additional energy appliances at home, such as space cooling systems.

5.6 Directions for future research

As already framed by Di Biagi (2006) more than a decade ago, the housing quality relies on the definition of new planning paths based on the interaction between inhabitants and local institutions, where the active participation of the inhabitants in the definition, implementation and management of common areas and equipment for collective use appears a key factor.

Indeed, it is necessary to define a *modus operandi* able to guarantee the equality and quality of the regeneration interventions on public housing stock, based on the involvement of the tenants.

It should consist of a pact between the municipality owning the stock, the public housing providers as managers and the tenants to build trust and to agree on interventions, as a combination of bottom-up micro-generation practices and the top-down approach, with physical intervention on the built environment. Within the scope of the agreement, the quantities (i.e. areas to intervene, expected energy savings), the benefits and the actions to achieve them have to be defined.

The success of urban regeneration and energy efficiency practices relies on the ability of the market to incorporate some of the benefits - both in the short- and medium-term, as the energy savings of buildings, and in the long-term when it comes to urban regeneration and resilience to climate change (Zanon and Verones 2013), where the role of users becomes decisive for achieving environmental, social and economic benefits.

The behaviour of users inside the accommodation conditions the energy consumption. It is therefore necessary to use information tools to help tenants understanding and reducing their impact on the environment. This also concerns the open space, which must be established as a place for the implementation of interventions to improve the resilience of the city, for the collection of rainwater, for the re-naturalization of waterproof surfaces. In addition, compensatory quotas have to be defined to take into account the increase in quality of rehabilitated housing, to respect the principle of fairness and to encourage users to use energy responsibly. Experiments and practices recently implemented have shown that, if there is a lack of these elements, the interventions remain still too much tied to the building scale, leaving some fundamental issues for the urban regeneration unsolved. Acting on the built fabric, including the public space, represents one of the challenges that the modern city, not only the public one, is called to face in order to implement urban sustainability (Santangelo and Tondelli 2017a).

In the public housing sector, the role of housing providers should be to guide the adoption of an energy efficient life-style (Santangelo and Tondelli 2017c). In particular, when Energy Service Companies are involved in the renovation as in the case of Bologna (see Chapter 3), the households should be supported to deliver the energy consumption estimated in the design phase and to meet the payback periods. Different strategies are developed to ensure the involvement of the occupants, while the informative approach through feedback, tips and informative materials seems to be dominant. It has to be noticed that this might not be sufficient to limit the negative effects (e.g. rebound effect) which might arise after the completion of the energy efficiency measures. The physical renovation of buildings should be integrated by the information and training on sustainable occupant behaviour, especially in the case of housing stock where low-income people are accommodated, in order to ensure both environmental and social sustainability of the interventions.

5.7 Key research findings

- Propriety fragmentation, low awareness of home-owners on energy efficiency improvements and benefits, and low skills of building managers, who are responsible of residential building management, can be considered among the main barriers to the building retrofit, and, as a consequence, to the urban regeneration. This chapter has contributed to reinforce two discourses: on the one side, around the role of human factor for the effective implementation of urban renovation programmes; on the other side, on the leading role that Italian public housing one can have in demonstrating the feasibility and benefits of such programmes.
- The institutional framework concerning housing and urban regeneration is nowadays more fragmented, involving more actors than in the past, both for-profit and non-profit. The role of the government is becoming less prominent, while the influence of market actors and civil society organisations is increasing. Five main categories of actors have been identified, where the community and the residents are intended as active actors, rather than passive target groups.
- The redevelopment of the public residential assets aimed at improving energy efficiency in Italy over the last decade have essentially been driven by two factors: reducing the costs associated with the ordinary maintenance of the stock; and contributing to the energy reduction goals set at European and national level. The implementation of the interventions has seen in many cases the involvement of the ESCos, which operate by setting a payback time during which the tenants benefit from a limited energy and economic savings, reduced by the amount allocated to the ESCo for the recovery of the investment. In this scenario, there is an overcoming of public-private dualism, in which the public administration provides the funds assuming all the risks, while the private actors just perform their work as

contractors. However, transformations and co-benefits which are not easy to assess in economic terms are difficult to be implemented, as for the regeneration of the public spaces and the initiatives to raise awareness among occupants on energy efficiency and energy behaviour.

- Equality and quality are two of the elements that qualify urban regeneration interventions. The issue of equality needs to be considered on a micro scale, taking into account the social rent; in addition, housing quality also affects the macro scale, considered as the relationship between the retrofit interventions on the buildings and the public space next to them. These two issues are particularly relevant in the social housing sector where the energy poverty phenomenon is prevalent, and where the focus on behaviour can represent one of the key factors for the success of the renovation practices.
- Summarising, the complexity of housing and urban regeneration indicates that no single actor has the capacity, neither the power nor the resources, to effectively implement regeneration strategies alone. The public authorities, housing providers, private companies and communities cannot mobilise the power or resources needed to face these challenges unilaterally. Hence, the rise of governance networks is driven by the aim to create win–win outcomes based on collaboration, reciprocity, and trust, rather than competition, control, and power play. Direct public authority intervention has moved to the background and the public sector is increasingly looking for private partners to implement actions, while it conserves its role of supervisor.

References

Baldini M, Poggio T (2012) Housing Policy Towards the Rental Sector in Italy: A Distributive Assessment. Housing Studies 27:563–581. doi: 10.1080/02673037.2012.697549

Baldini M, Poggio T (2014) The Italian housing system and the global financial crisis. Journal of Housing and the Built Environment 29:317–334. doi: 10.1007/s10901-013-9389-7

Bouzarovski S (2018) Energy Poverty Policies at the EU Level. In: Energy Poverty. Palgrave Macmillan. Cham. 41–73

Brandsen T, van de Donk W, Putters K (2005) Griffins or Chameleons? Hybridity as a Permanent and Inevitable Characteristic of the Third Sector. International Journal of Public Administration 28:749-765. doi:10.1081/PAD-200067320

Bronzini M (2014) Nuove forme dell'abitare. L'housing sociale in Italia Carocci editore. Roma

Copiello S (2015) Achieving affordable housing through energy efficiency strategy. Energy Policy 85:288–298. doi: 10.1016/j.enpol.2015.06.017

Czischke D, Pittini A (2007) Housing Europe 2007: review of social, co-operative and public housing in the 27 EU member states. CECODHAS European Social Housing Observatory. Brussels

Darby SJ (2012) Metering: EU policy and implications for fuel poor households. Energy Policy 49:98–106. doi: 10.1016/j.enpol.2011.11.065

Di Biagi P (2006) La periferia pubblica: da problema a risorsa per la città contemporanea. In Belli A (eds) Oltre la città: Pensare la periferia. Cronopio. Napoli

European Commission (2011) A Quality Framework for Services of General Interest in Europe. COM (2011) 900 final, Bruxelles

Eurostat (2018) Government expenditure on social protection. Data refer to 2016. https://ec.europa.eu/eurostat/statistics-explained/index.php/Government_expenditure_on_social_protection

Federcasa (2015) L'Edilizia residenziale pubblica: Elemento centrale della risposta al disagio abitativo e all'abitazione sociale. Rome: Federcasa

Governa F, Saccomani S (2009) Housing and Urban Regeneration Experiences and Critical Remarks Dealing with Turin. European Journal of Housing Policy 9:391–410. doi: 10.1080/14616710903357193

Hoatson L, Grace M (2002) Public Housing Redevelopment: Opportunity for Community Regeneration? Urban Policy and Research 20:429–441. doi: 10.1080/0811114022000032628

Huebner GM, Cooper J, Jones K (2013) Domestic energy consumption - What role do comfort, habit, and knowledge about the heating system play? Energy and Buildings 66:626–636. doi: 10.1016/j.enbuild.2013.07.043

Info Build Energia (2018) Energy Efficiency Report 2018. Executive summary. https://www.infobuildenergia.it/Allegati/13719.pdf

Lodi Rizzini C (2013) Il social housing e i nuovi bisogni abitativi, in Franca Maino, M. F. (ed.), Primo Rapporto sul secondo welfare in Italia. Centro di Ricerca e Documentazione Luigi Einaudi, Torino, Torino 2013: 237- 270

Nomisma (2016) Dimensioni e caratteristiche del disagio abitativo in Italia. Report

Pittini A, Koessl G, Dijol J, et al (2017) The State of Housing in the EU 2017

Poggio T, Boreiko D (2017) Social housing in Italy: old problems, older vices, and some new virtues? Critical Housing Analysis 4:112–123. doi: http://dx.doi.org/10.13060/23362839.2017.4.1.330 Social

Proli S, Santangelo A, Tondelli S (2016) Efficienza energetica ed edilizia sociale: il programma Rig.ener.a, sfide e prospettive a Bologna. In: XIX Conferenza Nazionale SIU Cambiamenti. Responsabilità e strumenti per l'urbanistica al servizio del paese. Planum Publisher, Catania 16-18 giugno

Regione Emilia-Romagna (2015) DELIBERAZIONE DELL'ASSEMBLEA LEGISLATIVA DELLA REGIONE EMILIA ROMAGNA 9 GIUGNO 2015, N. 15. Specificazione dei requisiti per l'accesso e la permanenza negli alloggi di ERP, di cui all'art. 15 della L.R. 8 agosto 2001, n. 24, e metodologia per il calcolo dei canoni di ERP. (Proposta della Giunta regionale in data 15 aprile 2015, n. 388). https://bur.regione.emilia-romagna.it/area-bollettini/bollettini-in-lavorazione/n-130-del-16-06-2015-parte-seconda.2015-06-16.4083035640/at_download/pdf_firmato

Santangelo A, Tondelli S (2017a) Equità e qualità degli interventi di rigenerazione del patrimonio ERP: dallo studio del caso olandese, verso la definizione di un modus operandi. In: XX Conferenza Nazionale SIU URBANISTICA E/È AZIONE PUBBLICA. LA RESPONSABILITÀ DELLA PROPOSTA. Planum Publisher, Roma 12-14 giugno 414–419

Santangelo A, Tondelli S (2017b) Urban regeneration and sustainable communities: reflecting on energy-related roles, attitudes and responsibilities. Urbanistica Informazioni 272:431–435

Santangelo A, Tondelli S (2017c) Occupant behaviour and building renovation of the social housing stock: Current and future challenges. Energy and Buildings 145:276–283. doi: 10.1016/j.enbuild.2017.04.019

Thomson H, Snell C, Liddell C (2016) Fuel poverty in the European Union: a concept in need of definition? People Place and Policy Online 10:5–24. doi: 10.3351/ppp.0010.0001.0002

Thomson H, Bouzarovski S, Snell C (2017) Rethinking the measurement of energy poverty in Europe: A critical analysis of indicators and data. Indoor and Built Environment 26:879–901. doi: 10.1177/1420326X17699260

Tondani D (2006) Equità e criteri di selettività dei beneficiari di edilizia residenziale pubblica in Emilia-Romagna. MPRA paper n. 27. http://mpra.ub.uni-muenchen.de/27

Tosi A, Cremaschi M (2001) Housing Policies in Italy. Vienna: Interdisciplinary Centre for Comparative Research in the Social Sciences (ICCR). http://www.iut.nu/members/Europe/West/Italy_Housing%20policies.doc

Urbego, Urban pockets: reclaiming the public in left-over open spaces. https://issuu.com/urbego/docs/urban_pockets-reclaiming_the_public

Ürge-Vorsatz D, Tirado Herrero S (2012) Building synergies between climate change mitigation and energy poverty alleviation. Energy Policy 49:83–90. doi: 10.1016/j.enpol.2011.11.093

van Bortel G (2011) Institutions and Governance Networks in Housing and Urban Regeneration, Smith, S., eds, International Encyclopedia of Housing and Home, Elsevier, Amsterdam

Zanon B, Verones S (2013) Climate change, urban energy and planning practices: Italian experiences of innovation in land management tools. Land Use Policy 32:343-355. doi: 10.1016/j.landusepol.2012.11.009

Whitehead C, Scanlon K (2007) Social housing in Europe, LSE London School of Economics and Political Science, London

6. Applying building energy simulation and occupant behaviour modelling to support decision-making process for the renovation of the Italian public housing stock[1]

ENGLISH ABSTRACT

The aim of this chapter is to explore the role of occupant behaviour modelling in supporting decision-makers dealing with the design of the renovation strategies for residential buildings. Sections 6.1 and 6.2 present respectively the introduction and the aim and methodology. An Italian multi-family public housing building located in Bologna, assumed as case study, is described in Section 6.3, where the description of an occupant behaviour model built is provided to simulate the influence of the management of the thermostat, the management of the heating system, and the variation of building characteristics on energy heating consumption. Results are presented in Section 6.4 and they are discussed in Section 6.5, where two different scenarios are considered to assess the impact of behaviour in case of non-retrofit or retrofit of the building. Limitations of the research and the direction for future research are respectively discussed in Sections 6.6 and 6.7. In conclusion, key research findings are presented in Section 6.8.

ABSTRACT IN ITALIANO

L'obiettivo di questo capitolo è quello di esplorare l'applicazione di software per la simulazione energetica del comportamento degli utenti per supportare i decisori che si occupano della definizione di strategie di riqualificazione degli edifici residenziali. Le sezioni 6.1 e 6.2 presentano rispettivamente l'introduzione, e lo scopo e la metodologia. Un edificio plurifamiliare di edilizia residenziale pubblica a Bologna è assunto come caso studio nella sezione 6.3, dov'è descritto il relativo modello utilizzato per simulare l'influenza della gestione del termostato, della gestione dell'impianto di riscaldamento, e della variazione delle caratteristiche dell'edificio sul consumo di energia legata al riscaldamento. I risultati sono illustrati nella sezione 6.4 e sono discussi nella sezione 6.5, dove sono presentati due diversi scenari per valutare l'impatto del comportamento sia in caso di non intervento sull'edificio, sia in caso di riqualificazione dello stesso. I limiti della ricerca e le direzioni per la ricerca futura sono rispettivamente discussi nelle sezioni 6.6 e 6.7. In conclusione, i principali risultati sono sintetizzati nella sezione 6.8.

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6.1 Introduction

Although in the last decades an increasing number of energy policies and building regulations has been introduced to reduce energy consumption in the built environment, requirements set both at national and international level are far to be met. As a matter of fact, the low renovation rates of existing buildings and the low replacement rates of inefficient equipment have not been sufficient to meet the energy reduction targets. On the one side, although national renovation programmes have been promoted by many governments – in particular for the residential sector, which offers the greatest potential to reduce energy usage from buildings – and the interest among citizens in sustainable development has grown, households have not been sufficiently motivated or supported in undertaking changes, and they are still not enough aware of the impact of their lifestyles and decisions on energy consumption. Moreover, the property fragmentation represents a limit to the implementation of renovation strategies, while public administrations have failed in leading the renovation process through the intervention on public buildings. On the other side, evidence from research has showed that the design of energy efficient buildings does not necessarily result in low energy consumption (Guerra-Santin and Itard 2010; Gupta and Chandiwala 2010; Stevenson and Leaman 2010). Whenever the buildings are designed to be energy efficient, it is always people who use them (Janda 2009; Paauw et al. 2009; Gram-Hanssen 2010; Gupta and Chandiwala 2010; Suárez and Fernández-Agüera 2015; Feng et al. 2016), therefore the gap between expected and actual energy consumption is largely related to the human factor. Thus, improving models that simulate the behaviour of human beings within the context of building energy simulation is believed to reduce the uncertainties related to the simulation of building performance. In building simulation tools, occupants are conventionally represented in terms of static schedules. This simplification does not properly allow to take into account the complex influence of occupant behaviour on building energy consumption and the indoor environment. Actually, there is a dynamic interaction between a building and its occupants. Occupant behaviour not only varies according to people individuality, but it also tends to evolve in time (Yan et al. 2015). Energy related occupant behaviour includes, among others, the usage of HVAC systems and the adjustment of thermostat set-points, window and blind operations, dimming/switching lights, occupancy and movement between spaces (Hong et al. 2016). Several stochastic models have been developed to describe how building occupants interact with the above-mentioned elements (Haldi and Robinson 2011; Peng et al. 2012; De Meester et al. 2013; Fabi et al. 2013; D'Oca et al. 2014; Hong et al. 2016; Zhou et al. 2016). Despite their results cannot be generally applied to any buildings, since environmental, social and technical variables might change, they provide an insight on the role of suitable models for assessing the human factor in energy consumption.

Many researches have already been devoted to combining occupant behaviour to residential building simulation. An et al. (2017) have introduced a novel stochastic modelling method of occupant behaviour into cooling load simulation, the results of which agree well with the measured data. Yu et al. (2011a; 2011b) have used basic data mining techniques (i.e. cluster analysis, classification analysis, and association rules mining) to demonstrate that improving occupant behaviour can facilitate the evaluation of building energy-saving potential. Johnson et al. (2014) have considered time use survey data as the input data to obtain Markov chain model to simulate individuals to show how an occupant interacts with the major residential energy consuming loads throughout the day. Yamaguchi et al. (2011) have also proposed a stochastic occupant behaviour model based on time use data to produce a high-temporal resolution electricity demand profile. Brandemuehl and Field (2011) have focused on the identification of the types of occupant-driven residential behaviour variations that most significantly impact the ability to predict energy consumption and peak electrical demand of a house, finding that cooling set-points and lighting power have the highest influence.
Nevertheless, although occupant behaviour simulation is increasingly recognised as a key factor in the evaluation of technologies used in building design and retrofit (Yan et al. 2015), its role to support the decision-making process is not fully exploited. Understanding the actual energy use as well as the behaviour and preferences of occupants is an essential element for the set-up and implementation of successful governance strategies and instruments. Furthermore, the engagement with occupants and the implementation of information strategies have an important role to demonstrate the potential of new social practices and to monitor the energy savings (Suárez and Fernández-Agüera 2015; Visscher et al. 2016; Feng et al. 2017).

In Italy, both residential sector renovation and the occupants' awareness raising have become increasingly important issues in the last few years. Firstly, a growing number of Italian cities has decided to revise their spatial planning tools in order to promote land preservation policies (Tondelli and Conticelli 2017) and to manage more effectively the densification and the regeneration of the built environment (Conticelli et al. 2017); the 7.8% of the national territory has already been consumed – 4.6% the average for Europe – with peaks of 25-30% in metropolitan cities (ISPRA 2015), therefore the current challenge is to regenerate the built environment. Secondly, according to the recent national legislative decree D.Lgs. July 4th 2014 no. 102 implementing the Directive 2012/27/EU on energy efficiency, starting from 2017 the installation of meters to account energy at household level is mandatory in existing buildings with central heating system. This increase in households' freedom-to-choose is believed to be a strong incentive for occupants to save energy (Semprini et al. 2015), although it also makes urgent to adopt informative strategies towards the occupants to make the energy savings effective. Furthermore, as already discussed in chapter 2, European Union has stressed that the Member States shall undertake an exemplary role in the energy retrofit of the public building stock in their countries, encouraging public administrations to adopt energy efficiency plans, to implement energy management systems in their buildings, and to make use of Energy Performance Contracting (EPC) and services of Energy Service Companies (ESCos).

In this framework, the renovation of the Italian public housing stock has not only an environmental purpose, but it acquires also an economic and social value. Under the economic point of view, the increasing operation and maintenance costs of the aged building stock, together with the lack of public resources to properly renovate it, prevent to meet the national targets. Therefore, there is a need to establish public-private-partnership (e.g. with ESCos). At the same time, the renovation of public residential buildings represents the opportunity to work towards a sustainable community, taking energy as a driver to improve the sense of ownership of inhabitants and the liveability of neighbourhoods. In addition, the renovation of the public housing stock can contribute to the reduction of energy poverty, a growing phenomenon with 12.8% of the population reporting inadequately heated homes across EU, which rises to 20.0% by considering the ten Central and Eastern European member states (EU10), and 16.6% for the eight EU countries that border the Mediterranean Sea (Bouzarovski 2014). Energy poverty, also known as fuel poverty, is often defined as a situation where households cannot access to and afford adequate level of heating or other required energy services to meet their basic needs, or they cannot afford other necessary goods due to the high utility costs. Despite the lack of a common EU definition or complex comparable data, it is clearly recognised as an extensive and increasing problem that is impacting on people's living standards and rights (Jones 2016), and it is particularly prevalent in European public and social housing sector (Heffner and Campbell 2011).

6.2 Aim and methodology

Chapter 6 contributes to the research question 3, and in particular to sub-question f) as presented in the box below.

The overall aim of this chapter is to investigate the role of occupant behaviour simulation tools as instruments to support decision-makers in designing the renovation strategies for existing public housing stock.

Research question 3:

How to make evidence of the impact of household energy behaviour and provide scenarios to support policy-makers in taking decision on the renovation of buildings?

Sub-question:

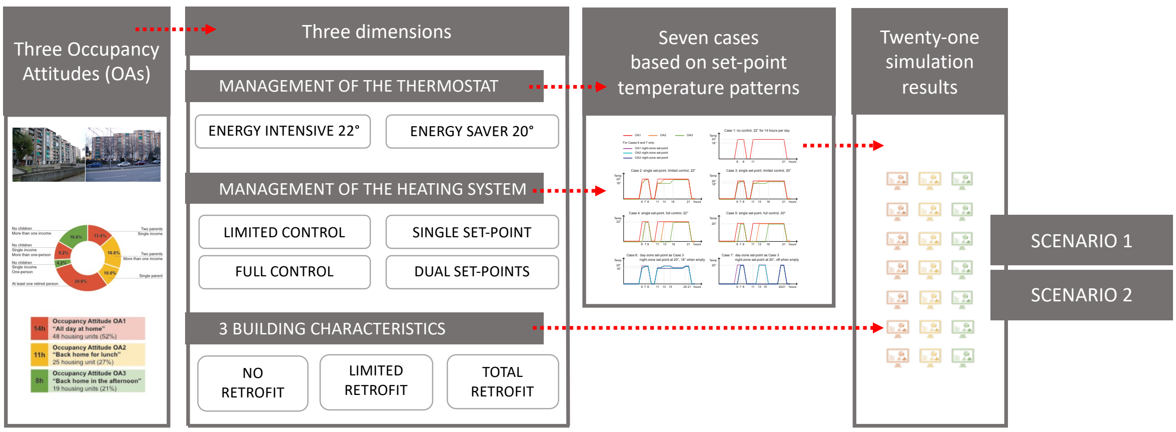
f) What is the sensitivity of the heating energy consumption of a public housing building to occupant behaviour?

An Italian multi-family public housing building is assumed as case study to estimate the influence of three dimensions linked with occupant behaviour – management of the thermostat, management of the heating system, variation of building characteristics –on energy heating consumption. A building performance simulation tool is applied to investigate the impact of behaviour and to build scenarios to inform decision-makers. The integration of occupant behaviour models with existing building performance simulation programs enables scholars and practitioners to simulate energy-related occupant behaviour in buildings (Hong et al. 2015a, b). Quantifying the savings from occupant behaviour is a key issue, since it contributes to understand to what extent an energy-saving scenario is likely to occur.

The case study is modelled using the dynamic building simulation program DeST (Yan et al. 2008; Zhang et al. 2008). Its graphical input interface is based on AutoCAD, while the results are given in Excel table formats. Since its development in 1989, DeST has been mainly applied for design consultation on new buildings, despite it has also been used in renovation projects of existing buildings to evaluate the effects of measures, and in some national and local energy efficiency regulations as a prediction and evaluation tool (Zhang et al. 2008). It allows to set hourly schedules for occupancy, HVAC system, lighting and equipment.

Figure 6.1 provides an overview of the research framework adopted. The selected Italian case study, the occupancy attitudes, the occupant behaviour in relation to three dimensions (i.e. temperature set-point, heating system and building characteristics) and main assumptions to validate the model are described in section 6.3. The findings are presented in section 6.4, where they are reported both considering the building level and the dwelling level, according to the studied parameters. In section 6.5, the results are discussed, and two scenarios are presented to underline the steps needed to reach the energy saving potential presented in the previous section. In section 6.6, the main limitations to this research approach and the research developed are presented, in section 6.7 directions for future research are drawn, while in the last section, conclusions and key research findings are illustrated.

Figure 6.1: Overview of the research framework



Source: Santangelo et al. (2018)

6.3. The case study: a public housing complex in Bologna

In Italy, 54.9% of the housing stock consists of apartments, while detached and semi-detached houses represent 38.1%. The number of houses in multi-family buildings increases particularly in metropolitan areas, where the share reaches 85.5% of the total housing stock. According to the type of tenure, apartments reach 78.1% of the housing stock for renting, 80.6% for housing rent lower than the market price – as the case of the public housing sector (ISTAT 2008). More than 75% of households live in buildings built before 1990, with low efficiency rate, high maintenance costs for the owners and high energy cost for the households.

In Italy, social rental housing accounts for 3.7% of the total housing stock, private rental for 14.8% while home ownership officially represents 71.9% (Pittini et al. 2017), although it accounts more realistically for the 80%, since the unclassified stock is more likely to be assimilated to home ownership than the rest. The great majority of social housing stock refers to public housing for rent, managed by public housing associations, which are responsible for the allocation and maintenance, while the dwellings are mainly owned by the municipalities. Housing cooperatives and most recently foundations have also been involved in social rental housing provision.

The study focuses on heating consumption of an Italian public multi-family residential building located in the city of Bologna, the capital city of Emilia-Romagna region. Despite the low rate of public housing stock, this case study has been chosen as representative not only of the Italian public residential stock, but also of the whole Italian housing sector. Due to the high percentage of houses in multi-family buildings, the analysis of the impact of occupant behaviour for the reference building can lead to a wide replicability of the method to more than a half of the Italian housing stock.

As shown in Figure 6.2, the reference building is a ten-storey building (ground floor on *pilotis*) built in 1976, with five staircases and 92 housing units. Each storey 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 one – 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 allow the occupants to regulate the temperature according to their presence and needs.

Figure 6.2: The reference building

Source: Santangelo et al. (2018)

6.3.1 Occupant behaviour module in DeST

6.3.1.1 The climate data

Italian climate shows significant differences between the inlands and the coastal areas, both from north to south and from east to west. The national territory is divided in 6 climate zones (A-F) according to the degree-day, the unit representing 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. For every zone, the norm fixes the period of the year and the maximum number of hours per day that heating may be switched on. The city of Bologna belongs to the E climate zone, where the heating system may operate from the 15th of October to the 15th of April, for a maximum of 14 hours per day. That is the case of the reference building, where each year the centralised heating system operates for 14 hours per day during the reference period, from 6 to 9 am, and from 11 am to 10 pm. Since the measured consumption refers to the 2011, the Bologna meteorological data of the whole 2011 are used for the analysis of the heating consumption. The decision to use the data of 2011 instead of the typical year of Bologna of the G. De Giorgio collection is mainly due to the significant difference between the 2011 and the typical year in terms of average temperature (12.97°C for the typical year; 14.82°C in 2011).

6.3.1.2 The internal gains

Internal gains may have a significant influence on household heating consumption, particularly as the energy efficiency of houses increases. The internal gain schedules are set for each room (i.e. living room, kitchen, bedroom, small bedroom and bathroom) in accordance with the occupancy attitude assigned to the apartment. Since the Italian average household size is 2.4 persons (ISTAT 2015), the number of people considered for each housing unit in the model is the statistical number rounded up to 3 people. The average household size has been confirmed by the housing association managing the case study. The heat emission of each room type is set according to the Italian norm on energy performance of buildings (UNI/TS 11300-1:2014), which foresees an average hourly value of 9.0 W/m^2 for the living room and the kitchen, 3.0 W/m^2 for other rooms.

6.3.1.3 The thermal characteristics

Table 6.1 shows the thermal characteristic values of main building elements of the case study. The current situation is representative of the residential buildings built between '60s and '80s in Italy, particularly in the public housing sector where the greater amount of the stock is the result of the combination between precast and construction materials with poor thermal properties. Window surface is larger than the average for similar buildings and it is made by aluminium frame with single glass, resulting in a high heat-dissipating element. Thermal values for the reference building elements are calculated in coherence with Italian norms and standards (UNI/TS 11300-1:2014; UNI 10351). An average ventilation rate of 0.5 air volume change per hour is set.

Table 6.1: Thermal properties of main reference building components

Type of element	Type of material	U value [W/m2K]
External wall	concrete slab + bricks	1.50
Internal wall	bricks	2.50
Roof	reinforced concrete slab + roof tiles	1.50
Floor	reinforced concrete slab lightened by bricks	1.60
Window	single glass, steel frame	4.90

Source: Santangelo et al. (2018)

6.3.1.4 The model validation

The yearly performance of the heating system for the reference public housing building in Bologna is simulated using the model. Climate data, occupancy schedules, average number of occupants, average ventilation rate, internal gains, thermal characteristics of the building and heating system settings for the reference year are considered as described above. The simulated and actual performances during the whole year are compared to validate the model. Simulation results show that simulated energy demand tends to be less than 2% higher than the actual energy used for heating, while the discrepancy is relatively small compared to the total amount. The simulated result is 562,043 kWh/y, while the measurement showed 552,869 kWh/y, which could be regarded quite accurate. Therefore, the model can be considered as validated and can be used to further analyse the impact of occupant behaviour and building characteristics on the household heating consumption.

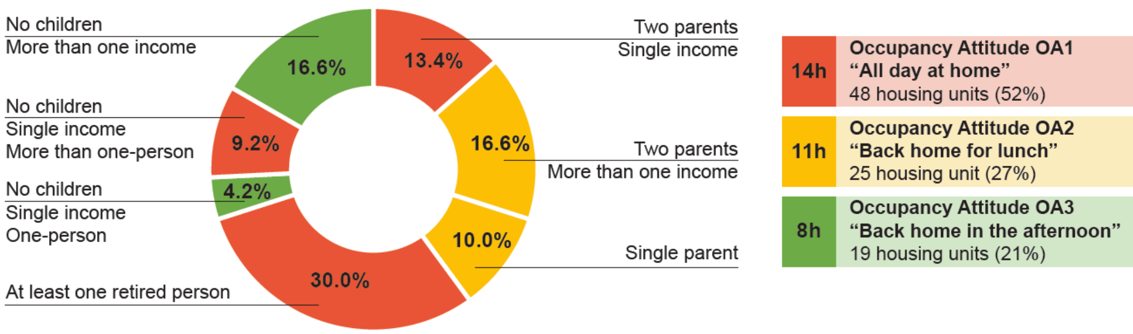
6.3.2 Occupancy

Since information for the reference building on household characteristics as age, presence of children, working status and life-styles were not available, Italian statistical data from ISTAT (ISTAT 2010; ISTAT 2015) have been used to combine significant housing characteristics into three Occupancy Attitudes (OAs). Each OA is representative of the number of hours that household spend at home with the heating system on and the thermostat at the highest preferred temperature, as further explained in section 3.4. Statistical data show that 60% of Italian households have no children living with them. Among them, half have at least one retired person among the family-members, while 31% are single-person households. 55% of Italian households earn more than one income. Among families with children, 75% are two-parent households.

Some preliminary assumptions are considered in order to group the household data and to generate the three Occupancy Attitudes. Firstly, households with retired people spend the most of their day at home, therefore they need to set the thermostat at the preferred temperature for the maximum number of hours that the system can allow (i.e. 14 hours per day). Secondly, households with children are used to go back home right after school and to spend at home the whole afternoon, therefore they set the heating system at the preferred temperature for 11 hours per day. The rest of the families, as households without children working full-time, are supposed to spend most of their day out from home, using the heating system 8 hours per day only.

The occupancy for the case study is presented in Figure 6.3. 48 housing units (52%) are occupied by households who set the heating system at the preferred temperature for 14 hours per day (from 6 to 9 am and from 11 am to 10 pm), since they spend at home most of the day. They represent Occupancy Attitude OA1 “All day at home”. 25 housing units (27%) are heated for 11 hours per day (from 7 to 9 am and from 1 to 10 pm); they are occupied by households with children who come back home right after school. They represent Occupancy Attitude OA2 “Back home for lunch”. 19 housing units (21%) are allocated to households spending out from home most of their day, therefore they need to use the heating system at the maximum preferred temperature for only 8 hours per day. They represent Occupancy Attitude OA3 “Back home in the afternoon”. Due to the lack of specific information from the housing association on the actual household distribution within the building, the distribution of the three Occupancy Attitudes is randomly chosen among the 92 housing units.

Figure 6.3: Occupancy Attitude distribution and household characteristics for the reference building



Source: Santangelo et al. (2018)

Any behavioural change is likely to have a relative impact. Assessing this impact is a fundamental step to make the energy-saving-strategies effective and to support policy-makers, particularly in the case of public housing where the public funds are usually scarce, and they need to be allocated properly to maximise the results.

6.3.3 Occupant behaviour in relation to three dimensions: temperature set-point, heating system and building characteristics

This section aims at analysing the impact of three behavioural dimensions on household energy consumption. The three dimensions and their variations are presented below. They are analysed in turn to identify the behavioural impact of each dimension.

6.3.3.1 Temperature set-point characteristics

The first dimension addresses the management of the temperature set-point. At present, during the heating season (from the 15th of October to the 15th of April), the central heating system of the whole reference building is turned on for 14 hours per day (from 6 to 9 am and from 11 am to 10 pm). The persistence of this current situation is considered in the analysis of the variations of this first dimension. Thus, 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 hours that the system is on. Two types of attitudes to energy use are considered. The first one is "energy intensive behaviour", when the temperature is set at 22°C in all the rooms for the maximum number of hours defined by the Occupancy Attitudes. For OA1, the temperature set-point is 22°C from 6 to 9 am and from 11 am to 10 pm (14 hours); for OA2, 22°C from 7 to 9 am and from 1 pm to 10 pm (11 hours); for OA3, 22°C from 7 to 9 am and from 4 pm to 10 pm (8 hours). The second attitude is "energy saver behaviour", when the temperature is set at 20°C, generally assumed as thermal comfort temperature (ISO, BS EN ISO 13790:2008), in all the rooms for the maximum number of hours defined by the Occupancy Attitudes as detailed above.

6.3.3.2 Management of the heating system

The second dimension is based on the management of the heating system. The study investigates the impact of the number of set-points per apartments and the degree of control that the occupants may have. Both the cases of single set-point and dual set-point per housing unit are considered. In case two set-points are foreseen, the day zone set-point is considered to work as the single set-point, while the night zone temperature varies according to the Occupancy Attitudes. For OA1, the bedrooms are heated at 20°C from 6 to 9 am, from 1 to 4 pm and from 8 to 10 pm. For OA2, at 20°C from 7 to 9 am, from 1 to 4 pm and from 8 to 10 pm. For OA3, at 20°C from 7 to 9 am and from 8 to 10 pm. The rest of the day, the heating system is on/off in the night zone according to the two degrees of control considered. "Limited control" is the regulation that allows occupants to choose the preferred temperature between 18°C – 22°C according to the first dimension when the system is on, but they cannot turn off the heating system. For OA2, the temperature is set at lowest set-point (18°C) from 11 am to 1 pm; for OA3, the temperature is set at the lowest set-point (18°C) from 11 am to 4 pm. In case of dual set-point, the heating system is at the lowest set-point (18°C) in night zone when empty. "Full control" applies when the heating system can be switched on/off from occupants. When the heating system is on, the temperature can be set according to the first dimension and the Occupancy Attitudes. For OA2, the heating system is off from 11 am to 1 pm; for OA3, the heating system is off from 11 am to 4 pm. In case of dual set-point, the heating system is off in night zone when empty.

The composition of the first two dimensions (i.e. management of the thermostat and management of the heating system) generates seven cases (Figure 6.4) which have been simulated separately.

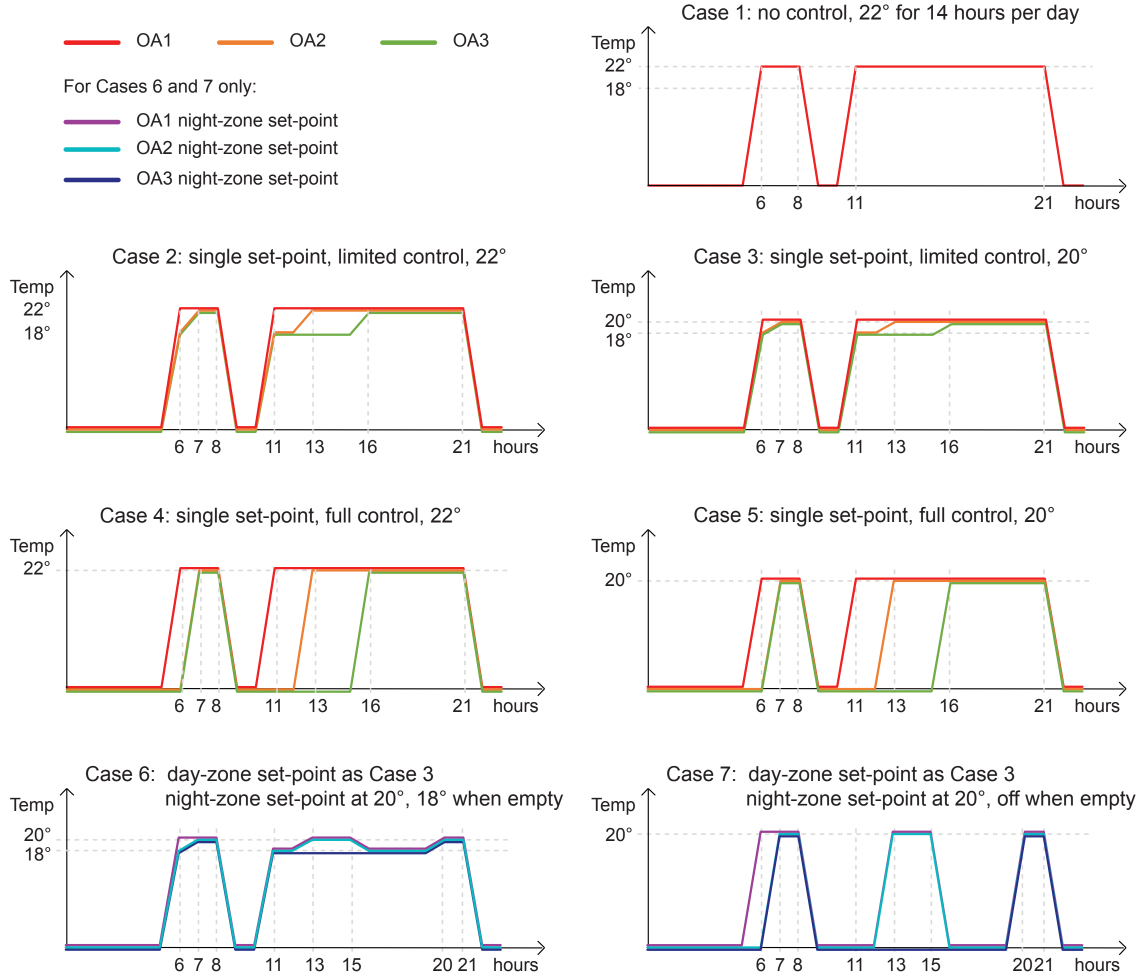
Case 1 occurs when there is no control from occupants, either they do not know how to operate the system, or they do not care about the impact of their behaviour. They choose the maximum set-point for the whole daily operation period of the heating system (i.e. 14 hours per day). Cases 2 and 3 are characterised by the variation of the set-point temperature, while the control over the heating system is limited and there is a single set-point per apartment. Cases 4 and 5 occur when the set-point temperature changes, while there is a "full control" from occupants over the heating system and there is a single set-point per apartment. Cases 6 and 7 foresee a dual set-point and the highest temperature of 20°C for the day-zone set-point as in Case 3, while the level of control for the night-zone set-point varies from 18°C when the bedrooms are empty (Case 6) to the switch off of the heating system (Case 7).

6.3.3.3 Building characteristics

The last dimension is the building retrofit stage (Table 6.2). Three cases have been analysed. "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 (D.G.R. 967 20 luglio 2015).

Although ventilation is recognised to be an important element for building energy balance, highly dependent from the occupant behaviour and therefore included in several models and analysis (Stevenson and Rijal 2010; Fabi et al. 2013; D’Oca et al. 2014; Jeong et al. 2016), this study does not focus on it. The ventilation rate is therefore considered 0.5 m^3/h for all the rooms when no retrofit occurs, 0.3 m^3/h in case of limited or total retrofit, when more efficient windows are installed. The seven cases are analysed considering the third dimension – the three different levels of retrofit – resulting in twenty-one simulation results.

Figure 6.4: Temperature patterns and definition of the 7 cases



Source: Santangelo et al. (2018)

Table 6.2: Thermal properties for the two building retrofit stages studied

	U value [W/m^{2}K]		
Type of element	No retrofit (current state)	Limited retrofit	Total retrofit
External wall	1.50	1.50	0.30
Internal wall	2.50	2.50	2.50
Roof	1.50	0.26	0.26
Floor	1.60	1.60	1.60
Window	4.90	1.90	1.90

Source: Santangelo et al. (2018)

6.3.4 Assumptions for a preliminary economic evaluation

A preliminary economic evaluation is performed through the total net present value (NPV). A usage phase of 15 years after retrofit is assumed. No assumption is made on the building after 15 years, therefore no considerations on the end of building life are included in the calculations. The investment costs are evaluated taking into account the price list for public buildings of the Emilia-Romagna region (Regione Emilia-Romagna 2015). They include costs for workmanship, while it is assumed to be 30% of the net cost in case no further information was available. A net discount rate of 5% is assumed, with an energy price of 0.01 euro/kWh and a yearly net increase of the price of 1.2% considering the mean of yearly prices for the period 2009-2016. The yearly net increase of the investment and maintenance costs is assumed to be 0%. Similarly to G. Verbeeck et al. (2005), although the uncertainty for these values is high, the main purpose of the study is to compare and optimize energy saving measures, so the relative values are more relevant than the absolute figures.

6.4 Results

6.4.1 At building level

The results report the simulation of heating consumption at the building scale, with Occupancy Attitudes fixed according to the methodology illustrated above. This analysis aims at evaluating the impact of the three dimensions explained in subsection 6.3.3, therefore the results are presented separately for each of the dimension. Table 6.3 presents the heating loads for the whole multi-family public housing building according to the 21 cases studied.

Cases 4 and 5 presented in the table are not further analysed since they do not present significant differences from case 2 and 3. Indeed, only up to 1% of decrease is showed between the simulation heating loads for the cases of limited control and the simulation results for the cases of full control. This might be due to the weather conditions not tight enough to produce a significant variation between the circumstances when the heating system is always on for 14 hours per day and only the maximum temperature can be set (Cases 2 and 3) and the cases when the heating system is off when occupants are not at home (Cases 4 and 5).

Table 6.3: Monitored and simulated heating loads for the whole reference building (kWh/y) and per m² of heated area (kWh/m²y) for the 21 cases

	Building characteristics					
	No retrofit		Limited retrofit		Total retrofit	
	kWh/y	kWh/m²y	kWh/y	kWh/m²y	kWh/y	kWh/m²y
SIMULATED HEATING LOAD FOR VALIDATION	562,043	87.1				
SIMULATED HEATING LOAD						
Case 1: maximum set-point for the maximum hours						
Energy intensive (22°C) for 14h per day	576,953	89.4	286,340	44.4	55,975	8.7
Case 2 and 3: single set-point, limited control						
Energy intensive (22°C)	553,343	85.8	266,444	41.3	42,534	6.6
Energy saver (20°C)	520,218	80.6	250,655	38.9	39,292	6.1
Case 4 and 5: single set-point, full control						
Energy intensive (22°C)	550,689	85.4	265,511	41.2	42,609	6.6
Energy saver (20°C)	515,579	79.9	248,998	38.6	39,127	6.1
Case 6: dual set-point, limited control						
Both set-points at 20°C, 18°C in bedrooms when empty	510,059	79.1	244,635	37.9	38,421	6.0
Case 7: dual set-point, full control						
Both set-points at 20°C, OFF in bedrooms when empty	493,810	76.5	237,881	36.9	37,626	5.8

Source: Santangelo et al. (2018)

Table 6.4 shows the influence of the thermostat management behaviour on building heating loads. In Case 1, with the highest temperature set (22°C) for the maximum number of hours per day and no retrofit of the building, simulated heating load is slightly higher than the monitored consumption. The adoption of an energy intensive behaviour with set-point at 22°C (Case 2) represents an improvement between 4% and 24% of heating load reduction depending on the levels of retrofit, since the set-point is simulated to be at the maximum temperature for a limited number of hours than the case of no control, depending on the Occupancy Attitudes. In case a behaviour change occurs and occupants adopt an energy saver behaviour setting the thermostat at 20°C (Case 3), heating load can be reduced 5-6% further, reaching up to the 10% in case of no building retrofit, 12% in case of limited retrofit of the building and 30% when this change in occupant behaviour is combined with a deep improvement in building thermal characteristics. In general, the more the building characteristics improve in terms of thermal properties, the greater is the impact of occupant behaviour in terms of percentage on the total consumption, while the no retrofit scenario shows the highest potential for occupants to decrease the building heating load up to 57,735 kWh/y of reduction by adopting an energy saver behaviour, reducing the temperature set-point to 20°C.

Table 6.4: heating load simulations related to behaviour changes in the management of the thermostat in case of a single set-point and limited control (kWh/y).

	Management of the thermostat		
	No control	Limited control, energy intensive (22°C)	Limited control, energy saver (20°C)
Building characteristics	(Case 1)	(Case 2)	(Case 3)
No retrofit	576,953	553,343	520,218
Limited retrofit	286,340	266,444	250,655
Total retrofit	55,975	42,534	39,292

Source: Santangelo et al. (2018)

Heating load simulations related to the management of the heating system are shown in Table 6.5. In case a dual set-point is installed and used properly, when occupants choose the highest temperature of 20°C for the day-zone set-point and 18°C in bedrooms when they are empty (Case 6), heating loads can be reduced up to 12-31% depending on the levels of retrofit. In case

of dual set-point and full control, when occupants may choose to switch off the heating system when out from home, heating load can be reduced 2-3% further, reaching up to the 14% in case of no building retrofit, 17% in case of limited retrofit of the building and 33% when this change in occupant behaviour is combined with a deep improvement in building thermal characteristics.
The more the building is energy efficient, the more the occupant behaviour has an impact and therefore possible rebound behavioural change following retrofit may reduce energy savings from physical improvements. In the modelling analysis presented, the rebound effect occurs for limited and total renovation of the building when occupants increase the heating temperature, the starting and duration of the heating system, generally when they increase their comfort level and/or they do not care to control it according to their occupancy. The two extreme cases are Case 1 and Case 7.
For instance, if occupants just decide to change the thermostat from 20°C in 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 7 to Case 1), then the consumption increases and the rebound effect reaches up to 17% for limited retrofit of the building and 33% for total retrofit in comparison with the expected consumption after the renovation.

Table 6.5: Heating load simulations related to the management of the heating system and the degree of control of occupants (kWh/y).

	Management of the heating system			
		Limited control (only set-point)		Full control
Building characteristics	No control (Case 1)	Limited control, single set-point (Case 3)	Limited control, dual set-point (Case 6)	Full control, dual set-point (Case 7)
No retrofit	576,953	520,218	510,059	493,810
Limited retrofit	286,340	250,655	244,635	237,881
Total retrofit	55,975	39,292	38,421	37,626

Source: Santangelo et al. (2018)

Table 6.6 shows the impact of behaviour change on heating loads in terms of heat demand and saved energy consumption for the three levels of renovation. The results reveal the importance of the retrofit to reduce energy demand. As expected, the renovation and/or replacement of existing building characteristics permit a huge reduction in heating loads and it shows a greater impact than the benefit gained from changing in occupant behaviour. Nevertheless, strategies to raise awareness on energy consumption are a powerful tool to save energy particularly in the case of no retrofit of the building, when 83,143 kWh/y can be saved for the whole reference building by adopting certain behaviour changes.

The total investments for the three levels of renovation, the ones to support behaviour changes and the economic savings due to behaviour changes are presented in Table 6.7. The upper part of the table presents the total costs for both physical interventions and energy awareness campaign to support the shift to a saver behaviour. The study foresees an investment cost of 60,000 euro for roof insulation, 561,000 euro for new windows and 512,000 for the external wall insulations. Therefore, the total investment cost for the building renovation is estimated in 621,000 euro for limited retrofit and 1,133,000 euro for total retrofit. The total investment costs for a 15-years energy awareness campaign to address behaviour changes are estimated in 54,000 euro: 20,000 euro to be spent during the first year for setting the basis of the work, 5,000 euro once every five years and 2,000 euro every other year. The bottom part of Table 6.7 only foresees costs related to address behaviour change and takes for granted the physical interventions, considering the building as already renovated.

Table 6.6: The impact of behaviour change on energy loads

	No retrofit		Limited retrofit		Total retrofit	
	No control (Case 1)	Optimal behaviour (Case 7)	No control (Case 1)	Optimal behaviour (Case 7)	No control (Case 1)	Optimal behaviour (Case 7)
Heat demand (kWh/y)	576,953	493,810	286,340	237,881	55,975	37,626
Heat demand per m^2 (kWh/ m^2y)	89.4	76.6	44.4	36.9	8.7	5.8
Saved energy compared to the highest energy consumption for the reference building (kWh/y)	-	83,143	290,614	339,072	520,979	539,327
Saved energy compared to Case 1 (kWh/y)	-	83,143	-	48,458	-	18,348
Saved CO_2 emissions (ton/y)	-	17	58	68	104	108

Source: Santangelo et al. (2018)

Results show that, when physical intervention occurs, the NPV is negative both for limited and total retrofit, meaning that the payback period is longer than 15 years, and the investments in the framework of public housing need to be economically supported by the public authorities in order to be attractive for private companies. When investments are only aimed at behaviour change, the saved costs for energy consumption and for CO_2 emissions are able to produce a positive net present value (NPV) for the case of no retrofit and the case of limited retrofit, when the renovation costs are not considered, and the awareness campaign is supposed to start when the renovation is completed. However, the amount of energy consumption saved after a total retrofit of the building is not high enough in absolute terms to fully cover the costs of the energy awareness campaign, resulting in a negative NPV.

Table 6.7: Costs and savings from behaviour change

	No retrofit Optimal behaviour (Case 7)	Limited retrofit Optimal behaviour (Case 7)	Total retrofit Optimal behaviour (Case 7)
Costs and savings due to both physical interventions and awareness campaign			
Total investment costs for energy awareness campaign for 15 years (€)	54,000	54,000	54,000
Total investment costs for building retrofit (€)	0	621,000	1,133,000
Total investments	54,000	675,000	1,187,000
Saved costs for energy (€)	125,930	490,982	794,292
Saved costs for CO_2 emissions (€)	6,479	22,705	38,915
Total saved costs	132,409	513,687	833,207
Net present value (€)	46,286	- 291,113	- 565,935
Costs and savings only due to the awareness campaign			
Total investment costs for energy awareness campaign for 15 years (€)	54,000	54,000	54,000
Saved costs for energy (€)	125,930	73,396	27,791
Saved costs for CO_2 emissions (€)	6,479	3,567	1,482
Total saved costs	132,409	76,963	29,273
Net present value (€)	46,286	9,373	- 22,398

Source: Santangelo et al. (2018)

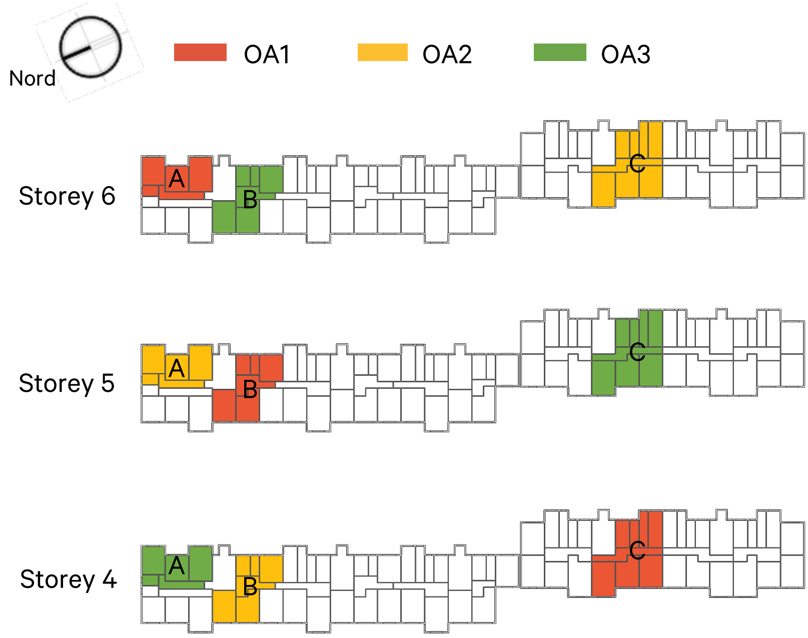
6.4.2 At dwelling level

The conducted simulations provide also significant results at dwelling scale. Indeed, they are analysed aiming at evaluating how the heating loads vary according to the Occupancy Attitude considered and the type of dwelling. The three levels of renovation are also considered to check whether the variation among Occupancy Attitudes and types of dwelling remains stable or not as the energy efficiency of the dwelling changes.

Three different dwellings have been considered, as shown in Figure 6.5. They are located in mid storeys (i.e. fourth, fifth and sixth storeys) to limit the influences of the heating loads due to the poor thermal properties of floor and roof.

Housing unit A is the smallest among the considered ones, the total net size is 65 m^2 with one bedroom, kitchen, living room, bathroom and 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 Attitude is foreseen to vary among the different storeys, therefore OA1 is assigned to housing unit A at storey 6, OA2 at storey 5, while OA3 at storey 4.

Figure 6.5: Housing units and Occupancy Attitudes distribution



Source: author's elaboration

Housing unit B is located on the opposite side of the staircase, it is 79 m^2 large and it has two bedrooms, kitchen, living room, bathroom and corridor. The kitchen and one of the bedrooms face east, while the living room and the other bedroom face west. OA1 is allocated to housing unit B at storey 5, OA2 at storey 4, and OA2 at storey 6. The last dwelling considered, housing unit C, has a surface of 99 m^2, one more bathroom and one more 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, on the other side a specular housing unit.

Table 6.8 shows the heating load simulation results according to the different housing units and different Occupancy Attitudes, also taking into consideration the building retrofit level.

Similarly to what resulted from the investigation at building scale, the analysis at dwelling scale confirms that the more the dwelling is energy efficient, the greater is the impact of occupant behaviour in terms of percentage on the total consumption, up to 52% of reduction for housing unit B with Occupancy Attitude OA3 (i.e. "back home in the afternoon" with the heating system at the maximum preferred temperature for 8h / day) in case of total retrofit. However, the no retrofit scenario is the one which 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 OA3 by adopting an energy saver behaviour, with full control and dual set-point (Case 7).

Table 6.8: Heating load simulations related to types of dwelling and Occupancy Attitudes (OAs) for the three levels of renovation

	No control (Case 1)		Full control, dual set-point (Case 7)					
			OA1 (14h)		OA2 (11h)		OA3 (8h)	
	kWh/y	kWh/m²y	kWh/y	kWh/m²y	kWh/y	kWh/m²y	kWh/y	kWh/m²y
NO RETROFIT	→		- 11-14%		- 12-15%		- 17-21%	
HOUSING UNIT A	4,244	65.3	3,779	58.1	3,748	57.7	3,426	52.7
HOUSING UNIT B	3,667	46.4	3,167	40.1	3,120	39.5	2,891	36.6
HOUSING UNIT C	4,709	47.6	4,184	42.3	4,157	42.0	3,896	39.4
LIMITED RETROFIT	→		- 15-23%		- 16-24%		- 23-29%	
HOUSING UNIT A	2,241	34.5	1,912	29.4	1,886	29.0	1,715	26.4
HOUSING UNIT B	1,036	13.1	794	10.1	786	9.9	739	9.4
HOUSING UNIT C	1,558	15.7	1,252	12.6	1,213	12.3	1,135	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

Source: author's elaboration

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 as housing units B and C, with the same building component thermal proprieties, but located in a more favourable position within the building. In case of 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 Attitudes 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 to an energy demand decrease as the number of hours the heating system is operating decreases. Taking into account the highest freedom of occupants (Case 7) compared to the case of no control from the occupants (Case 1), results show that, in case of no retrofit occurs, the energy reduction is in the range of 11-14% for OA1, 12-15% for OA2 and 17-21% for OA3, 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 OA1, 16-24% for OA2 and 23-29% for OA3 when the limited retrofit occurs; and 31-51% for OA1, 35-51% for OA2 and 39-52% for OA3 when the dwellings are totally retrofitted. However, for all the three retrofit levels and all the dwellings considered, lower time spent at home with the heating system on generates higher energy savings. Despite these 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. In particular, when an ESCo is involved and a payback time for the renovation investment is estimated, it is important that households receive targeted feedback to understand their saving potential and to avoid to "blame 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.

Heating load simulations related to the management of the heating system are shown in Table 6.9, 6.10 and 6.11, respectively for the case of no retrofit, limited retrofit, and total retrofit. In case a dual set-point is installed and used properly, when occupants choose the highest temperature of 20°C for the day-zone set-point and 18°C in bedrooms whenever empty (Case 6), there is a general tendency in reduction of the heating loads from OA1 to OA2. In particular, heating loads can be reduced up to 10–16% in case of no retrofit, depending on the housing unit considered, but it can reach the range 31-50% for total retrofit of the dwellings.

Table 6.9: Heating load simulations in case of no retrofit, related to the management of the heating system and the different housing units (in kWh/y and in % of reduction from case of no control)

NO RETROFIT	No control (Case 1)	Limited control, single set-point (Case 3)		Limited control, dual set-point (Case 6)		Full control, dual set-point (Case 7)	
		kWh/y	%	kWh/y	%	kWh/y	%
HOUSING UNIT A	4,244						
OA1 (14h)	→	3,900	- 8	3,825	- 10	3,779	- 11
OA2 (11h)	→	3,868	- 9	3,803	- 10	3,748	- 12
OA3 (8h)	→	3,786	- 11	3,720	- 12	3,426	- 19
HOUSING UNIT B	3,667						
OA1 (14h)	→	3,227	- 12	3,155	- 14	3,167	- 14
OA2 (11h)	→	3,193	- 13	3,143	- 14	3,120	- 15
OA3 (8h)	→	3,184	- 14	3,097	- 16	2,891	- 21
HOUSING UNIT C	4,709						
OA1 (14h)	→	4,297	- 9	4,224	- 10	4,184	- 11
OA2 (11h)	→	4,262	- 9	4,209	- 11	4,157	- 12
OA3 (8h)	→	4,178	- 11	4,121	- 12	3,896	- 17

Source: author's elaboration

Table 6.10: Heating load simulations in case of limited retrofit, related to the management of the heating system and the different housing units (in kWh/y and in % of reduction from case of no control)

LIMITED RETROFIT	No control (Case 1)	Limited control, single set-point (Case 3)		Limited control, dual set-point (Case 6)		Full control, dual set-point (Case 7)	
		kWh/y	%	kWh/y	%	kWh/y	%
HOUSING UNIT A	2,241						
OA1 (14h)	→	1,989	- 11	1,937	- 14	1,912	- 15
OA2 (11h)	→	1,978	- 12	1,929	- 14	1,886	- 16
OA3 (8h)	→	1,923	- 14	1,877	- 16	1,715	- 23
HOUSING UNIT B	1,036						
OA1 (14h)	→	837	- 19	807	- 22	794	- 23
OA2 (11h)	→	827	- 20	796	- 23	786	- 24
OA3 (8h)	→	783	- 24	767	- 26	739	- 29
HOUSING UNIT C	1,558						
OA1 (14h)	→	1,264	- 19	1,238	- 21	1,252	- 20
OA2 (11h)	→	1,239	- 20	1,225	- 21	1,213	- 22
OA3 (8h)	→	1,222	- 22	1,184	- 24	1,135	- 27

Source: author's elaboration

Table 6.11: Heating load simulations in case of total retrofit, related to the management of the heating system and the different housing units (in kWh/y and in % of reduction from case of no control)

TOTAL RETROFIT	No control (Case 1)	Limited control, single set-point (Case 3)		Limited control, dual set-point (Case 6)		Full control, dual set-point (Case 7)	
		kWh/y	%	kWh/y	%	kWh/y	%
HOUSING UNIT A	356						
OA1 (14h)	→	251	- 29	247	- 31	247	- 31
OA2 (11h)	→	239	- 33	240	- 33	232	- 35
OA3 (8h)	→	236	- 34	229	- 35	217	- 39
HOUSING UNIT B	305						
OA1 (14h)	→	168	- 45	159	- 48	148	- 51
OA2 (11h)	→	164	- 46	156	- 49	148	- 51
OA3 (8h)	→	165	- 46	153	- 50	146	- 52
HOUSING UNIT C	311						
OA1 (14h)	→	211	- 32	201	- 35	208	- 33
OA2 (11h)	→	205	- 34	203	- 35	200	- 36
OA3 (8h)	→	206	- 34	193	- 38	178	- 43

Source: author's elaboration

In case of dual set-point and full control (Case 7), when occupants may choose to switch off the heating system whenever out from home, heating load can be reduced 1–7% further, reaching up to the 21% of energy reduction in case of no building retrofit, 29% in case of limited retrofit of the building and 52% when this behaviour change is combined with a deep improvement in building thermal characteristics.

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. In fact, if occupants just decide to change the thermostat from 20°C in 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 7 to Case 1), then the consumption increases and the rebound effect reaches up to 23%, 29% and 27%, respectively for limited retrofit 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.

6.5 Discussion

This chapter gives an insight on the impact of occupant behaviour on the energy efficiency potential by considering a reference building and by analysing 21 simulation cases. The main objective of this analysis is to explore the role of occupant behaviour modelling in supporting decision-makers when it comes to renovation strategies for residential buildings.

Occupant behaviour modelling is an important tool to quantify the impact of occupant behaviour on energy saving potential. It provides estimation of the gap between expected and actual energy savings linked to the human factor. It explains the impact of rebound effect in case of building retrofit, as well as the impact of “green behaviour” (Ben and Steemers 2014) when positive behavioural changes occurs. The findings at building level suggest a range up to 14-33% for the impact of human factor on energy savings, depending on the simulated cases and the levels of retrofit considered, while an insight into the simulation results at dwelling level shows that impact of occupant behaviour can reach up to 52% of energy savings. This impact increases as the retrofit level increases in terms of percentage on the total heating consumption, while the amount of saved energy due to behaviour change decreases as the retrofit level increases.

This research contributes to demonstrate the importance of integrating strategies to tackle behavioural factors to retrofit strategies to improve the energy performance of residential buildings. This section describes two divergent explorative scenarios aiming at demonstrating that complementary approaches to reduce energy consumption are required, since physical improvements and behavioural change show different impact on energy savings that need to be addressed at the same time. The zero scenario foresees the installation of meters to assess the energy consumption for each housing unit. It is considered the ground for further discussion, in accordance to the Italian regulation implementing the Directive 2012/27/EU on energy efficiency, therefore the economic assessment of this operation has not been calculated. According to the zero scenario, energy bills are going to be calculated by considering the actual energy consumption (in kWh) instead of a flat rate based on the heated volume of the apartments. This disruptive change in the calculation of heating related costs has also consequences on occupant behaviour and households’ perception of it.

6.5.1 Scenario 1: no retrofit, only investments to support behaviour change

The first scenario represents the hypothesis in which the municipality of Bologna and the public housing provider, respectively owner and manager of the reference building as part of the public housing stock, decide to include the case study within a regeneration programme that aims at reducing heating consumption in existing residential public buildings. Due to the lack of funding, they decide to implement a significant and long-lasting energy awareness campaign, rather than intervening on the physical elements of the building. From the content side, it includes communication materials and organisation of events to inform on the regeneration programme; explanatory material to properly use new technologies installed and to set the temperature; education material to raise awareness on behaviour impact and how to optimise energy consumption; direct and indirect feedbacks and tips by email and regular mail. In terms of costs, it foresees a total investment of 54,000 euro for 15 years: 20,000 euro for the first year to properly design and launch the campaign; 5,000 euro once every five years to recall aim and impact of the regeneration programme; and 2,000 euro every year to support the daily activities, tackling also the household turnover in social housing dwellings where allocation is subject to the persistence of certain criteria.

The theoretical investigation on occupant behaviour simulation shows that behavioural change has a significant impact on the total amount of energy consumption. After the meters are installed, households can set their preferred temperature in a range between 18°C-22°C. They choose to set 22°C, since their energy bills are going to be calculated in a different way than before, they do not perceive the consequences of their behaviour; they simply choose to increase their comfort by choosing 1°C more than the set-point previously fixed by the public housing manager. As consequence, the building heating consumption increases, and the public housing owner, together with the provider, decides to invest on raising awareness on the need to change behaviour. By setting a lower temperature of 20°C in coherence with the Occupancy Attitudes, the building heating consumption decreases and up to 10% of the total consumption can be saved. Savings can reach the 14% when this energy saving behaviour is combined with the suitable use of the dual set-point and the heating system is off when the dwellings are empty, in coherence with the Occupancy Attitudes. The findings suggest a range between 23,610 and 83,143 kWh/y for the energy savings on total building heating consumption, up to around 4-13 kWh/m^2/y, depending on what extent occupants change their behaviour. The preliminary economic evaluation, taking into consideration the total investment costs for energy awareness campaign for 15 years and the saved costs both for energy and CO_2 emissions, shows a positive NPV, meaning that investing on occupant behaviour to reduce energy consumption is fully sustainable also from the economic point of view. Due to occupant behaviour change, the saved costs for energy consumption of the whole building reach more than 130,000 euro for the 15-years period considered. Moreover, the investments to support behaviour change represent the first step to achieve energy reduction and it can be easily combined with the renovation of the building when more funds are available, to maximise the benefits.

6.5.2 Scenario 2: investments on building retrofit, no campaign to support behaviour change, rebound effect

The second scenario foresees a consistent investment on building retrofit. In this hypothesis, both the owner and the manager of public housing stock decide to retrofit the whole building by insulating the external walls and roof and by replacing the windows; the thermal proprieties of the building elements are chosen in coherence with the criteria set by the Emilia-Romagna regional directive for the renovation of existing buildings (D.G.R. 967 20 luglio 2015). To implement the retrofit, an ESCo is involved and an Energy Performance Contract (EPC) is signed. Due to the considerable drop of expected energy consumption compared to the current situation, no campaign is foreseen to tackle occupant behaviour impact.

In terms of costs, it foresees a total investment of about 1.1 million euro, 50% for the replacement of windows, 45% for insulating the external walls, 5% for the roof insulation. This high retrofit level solution is expected to save more than 800,000 euro of costs for energy and CO_2 emissions in 15 years, but the savings are not enough to cover the total investment, therefore the municipality should decide either to cover a part of it, or to extend the EPC duration. However, the higher is the uncertainty related to occupant behaviour, the higher might be the payback time for renovation investments, decreasing the attractiveness for private companies to deliver such renovation.

Despite results show the global renovation is the best way to decrease significantly the heating consumption of the building, the impact of the rebound effect has proven to be relevant. The results of the present study on occupant behaviour simulation show that rebound effect increases the energy spending of 17% for limited retrofit of the building and 33% for total retrofit, due to different occupant behaviour than the one simulated. The findings suggest that, if this second scenario occurs, the heating consumption for the whole building decreases considerably. Nevertheless, the rebound effect may affect energy savings by increasing up to 1/3 the total energy consumption, resulting in difficulties to meet the investment payback period and low attractiveness of the renovation practices from private partners.

6.6 Limitations

Some research limitations must be acknowledged. First of all, although ventilation-related behaviour is recognised to be an important element for energy consumption, this research has focused on the management of the thermostat and the management of the heating system, while the ventilation rate has been estimated.

Moreover, it should be mentioned that other studies have shown higher occupant behaviour impact on heating consumption. This research takes into consideration behaviour with a limited degree of control (i.e. the temperature can be adjusted between the predefined range 18°C-22°C and cannot always be switched off).

Finally, occupant behaviour patterns have not been calculated due to the limited data set. Occupancy Attitudes and the related behaviour are based on statistical data and the observation of Italian habits and life-styles. Further analysis is needed to investigate how attitude and ability to behaviour changes are related to household characteristics.

There is a need to coordinate and better integrate complementary approaches to both the technical and social transitions. Addressing the human factor is a prerequisite to support the transition to low carbon communities.

6.7 Directions for future research

The investigation conducted in this chapter has some policy implications and can lead to suggestions for future research. Firstly, public authorities designing and implementing policy instruments (e.g. Sustainable Energy Action Plan and Sustainable Energy and Climate Action Plan) should provide funding for addressing behaviour change programmes as part of their broader support to energy efficiency as and energy innovation. Criteria for funding such behavioural research should be similar to those used for allocating resources to “hard science” research (Allcott and Mullainathan 2010). The results presented in this paper have clearly demonstrated that the human factor effects related to the energy consumption can be quantified by applying simulation technologies, as for the case of the physical retrofit of the buildings. Nevertheless, in order to be commonly accepted and implemented, behavioural interventions should build on theoretical findings and empirical evidences to design strategies with a clearly measurable impact and a wide scalability and replicability.

Secondly, for policy instruments to be effective, these funds should be considered complementary to the ones for building retrofit. Behaviour is more likely to be deliberately considered and changed when a discontinuity occurs in the household context (Huebner et al. 2013). Therefore, building renovation programmes are the key opportunity to involve households in order to make them reconsider their consumption practices. However, pro-environmental behaviour is likely to be considered if information and education measures come from credible, trustworthy sources. Thus, the impact of the renovation programmes is closely linked to the relationship between social housing tenants and housing providers. Moreover, the effect of information on choices highly depends on how the information is provided, therefore renovation programmes should carefully focus on tackling the behavioural factors, rather than on blaming the inefficient behaviours. More investigations are needed to understand how to understand current behaviours and to properly address behaviour change. Different methods should be combined with an interdisciplinary approach.

Thirdly, through market incentives, policy-makers can encourage – or fail to encourage – the private sector to apply behavioural innovations that “nudge” (Thaler and Sunstein 2008) consumers to make better choices. Utilities, for example, can either give consumers clear information about energy efficient goods, energy-efficiency promotions and nudge consumers in ways that cause them to decrease consumption; or can dismiss some information and suggest behaviour that increase energy consumption, depending on their company strategies (Allcott and Mullainathan 2010). An active role of the public sector is therefore essential to promote a new consumption paradigm. Additional scenarios should be investigated to provide evidence of the importance of behaviour to policy-makers.

Finally, embedding behaviour strategies into renovation programmes of the public housing stock might be a fundamental step forward to tackle energy poverty and energy vulnerability, particularly prevalent in the public and social housing sector. Engaging occupants into activities to raise awareness on the impact of their daily practices might led to achieve other co-benefits, rather than the optimisation of energy consumption, with a positive impact on social inclusion. Energy poverty policies should embed household behaviour in their considerations as a driver to alleviate the energy poverty conditions, in particular in absence or scarcity of structural policies.

6.8 Key research findings

- This research has contributed to quantify the impact of occupant behaviour on residential heating consumption for a multi-family public housing building in Italy, and it has demonstrated the importance to tackle behavioural change to improve energy efficiency, especially in case of building retrofit.
- The findings suggest that, while the occupant behaviour influences the heating loads up to 1/3 in case of high level of building retrofit, the less the building is renovated, the higher is the behavioural impact in absolute terms of energy reduction.
- When limited resources are available, to invest on tackling behaviour change, rather than retrofitting the building, is the most economic sustainable and efficient way to implement energy efficiency strategies. As soon as other funds are available, it is important to combine informative and feedback strategies with the renovation of the building, both to reduce the gap between expected and actual heating consumption, and to reduce the rebound effect.
- Despite a comprehensive building retrofit is the best way to decrease significantly heating consumption for the reference building, the impact of the rebound effect (17-33%) that occurs in case of building renovation should not be underestimated. The investigation at dwelling level shows that the rebound effect can be even higher than the one identified with heating load simulations at building level, reaching up to 52% of shift of the energy consumption for some of the housing units studied.

- The study demonstrates that modelling occupant behaviour through the application of building simulation tools is relevant to support policy-makers to assess the impact of renovation strategies. A better understanding of renovation strategies and occupant behaviour change will help to improve energy savings in practice.
- As measures on both occupant behaviour and physical improvement have influences on energy savings to various extents, effective renovation strategies should be developed by combining both building technologies and behavioural change.

References

Allcott H, Mullainathan S (2010) Behavior and energy policy. Science 327:1204–1205. doi: 10.1126/science.1180775

An J, Yan D, Hong T, Sun K (2017) A novel stochastic modeling method to simulate cooling loads in residential districts, Applied Energy 206:134-149. doi: 10.1016/j.apenergy.2017.08.038

Ben H, Steemers K (2014) Energy retrofit and occupant behaviour in protected housing: A case study of the Brunswick Centre in London. Energy and Buildings 80:120–130. doi: 10.1016/j.enbuild.2014.05.019

Bouzarovski S (2014) Energy poverty in the European Union: Landscapes of vulnerability. Wiley Energy and Environment 3:276–289. doi: 10.1002/wene.89

Brandemuehl MJ, Field KM (2011) Effects of variations of occupant behavior on residential building net zero energy performance. Proceedings of 12th Conference of International Building Performance Simulation Association, Sydney 14-16

Conticelli E, Proli S, Tondelli S (2017) Integrating energy efficiency and urban densification policies: Two Italian case studies. Energy and Buildings 155:308–323. doi: 10.1016/j.enbuild.2017.09.036

D'Oca S, Fabi V, Corgnati SP, Andersen RK (2014) Effect of thermostat and window opening occupant behavior models on energy use in homes. Building Simulation 7:683–694. doi: 10.1007/s12273-014-0191-6

De Meester T, Marique AF, De Herde A, Reiter S (2013) Impacts of occupant behaviours on residential heating consumption for detached houses in a temperate climate in the northern part of Europe. Energy and Buildings 57:313–323. doi: 10.1016/j.enbuild.2012.11.005

D.G.R. 967 20 luglio 2015 (2015) Approvazione dell'Atto di coordinamento tecnico regionale per la definizione dei requisiti minimi di prestazione energetica degli edifici (Artt. 25 e 25-bis L.R. 26/2004 e s.m.), Regione Emilia-Romagna

Fabi V, Andersen RV, Corgnati SP, Olesen BW (2013) A methodology for modelling energy-related human behaviour: Application to window opening behaviour in residential buildings. Building Simulation 6:415–427. doi: 10.1007/s12273-013-0119-6

Feng X, Yan D, Wang C, Sun H (2016) A preliminary research on the derivation of typical occupant behavior based on large-scale questionnaire surveys. Energy and Buildings 117:332–340. doi: 10.1016/j.enbuild.2015.09.055

Feng X, Yan D, Yu R, Gao Y (2017) Investigation and modelling of the centralized solar domestic hot water system in residential buildings. Building Simulation 10:87–96. doi: 10.1007/s12273-016-0315-2

Gram-Hanssen K (2010) Residential heat comfort practices: understanding users. Building Research & Information 38:175–186. doi: 10.1080/09613210903541527

Guerra-Santin O, Itard L (2010) Occupants' behaviour: determinants and effects on residential heating consumption. Building Research & Information 38:318–338. doi: 10.1080/09613211003661074

Gupta R, Chandiwala S (2010) Understanding occupants: feedback techniques for large-scale low-carbon domestic refurbishments. Building Research & Information 38:530–548. doi: 10.1080/09613218.2010.495216

Haldi F, Robinson D (2011) The impact of occupants' behaviour on building energy demand. Journal of Building Performance Simulation 4:323–338. doi: 10.1080/19401493.2011.558213

Heffner G, Campbell N (2011) Evaluating the co-benefits of low-income energy-efficiency programmes, OECD/IEA

Hong T, D'Oca S, Taylor-Lange SC, et al (2015a) An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema. Building and Environment 94:196–205. doi: 10.1016/j.buildenv.2015.08.006

Hong T, D'Oca S, Turner WJN, Taylor-Lange SC (2015b) An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs framework. Building and Environment 92:764–777. doi: 10.1016/J.BUILDENV.2015.02.019

Hong T, Taylor-Lange SC, D'Oca S, et al (2016) Advances in research and applications of energy-related occupant behavior in buildings. Energy and Buildings 116:694–702. doi: 10.1016/j.enbuild.2015.11.052

Huebner GM, Cooper J, Jones K (2013) Domestic energy consumption - What role do comfort, habit, and knowledge about the heating system play? Energy and Buildings 66:626–636. doi: 10.1016/j.enbuild.2013.07.043

ISO, BS EN ISO 13790:2008 (2008) Energy Performance of Buildings – Calculation of Energy Use for Space Heating and Cooling, International Organization for Standardization, Geneva, Switzerland

ISPRA (2015) Il consumo di suolo in Italia. Rapporto 218

ISTAT (2010) L'abitazione delle famiglie residenti in Italia. Anno 2008

ISTAT (2015) Annuario Statistico Italiano 2015

Janda KB (2009) Buildings Don' t Use Energy: People Do. In: PLEA 2009 - 26th Conference on Passive and Low Energy Architecture, Quebec City Canada, 22-24 June 2009

Jeong B, Jeong JW, Park JS (2016) Occupant behavior regarding the manual control of windows in residential buildings. Energy and Buildings 127:206–216. doi: 10.1016/j.enbuild.2016.05.097

Johnson BJ, Starke MR, Abdelaziz OA, Jackson RK, Tolbert LM (2014) A method for modeling household occupant behavior to simulate residential energy consumption. Proceedings of Innovative Smart Grid Technologies Conference (ISGT), IEEE PES 1-5. doi: 10.1109/ISGT.2014.6816483

Jones S (2016) Social causes and consequences of energy poverty, in K. Csiba (Ed.) Energy Poverty Handbook. The Greens / European Free Alliance in the European Parliament, Brussels 21-37

Paauw J, Roossien B, Aries M, Guerra-Santin O (2009) Energy Pattern Generator; Understanding the effect of user behaviour on energy systems. In: 1st European conference energy efficiency and behaviour. pp 1–11

Peng C, Yan D, Wu R, et al (2012) Quantitative description and simulation of human behavior in residential buildings. Building Simulation 5:85–94. doi: 10.1007/s12273-011-0049-0

Pittini A, Koessl G, Dijol J, et al (2017) The State of Housing in the EU 2017

Regione Emilia-Romagna (2015) Elenco regionale dei prezzi delle opere pubbliche della regione Emilia-Romagna

Semprini G, Barbieri D, Gober A, Zandi F (2015) Effect of occupant behavior and control systems on the reduction of energy needs of residential buildings. Energy Procedia 78:633–638. doi: 10.1016/j.egypro.2015.11.044

Stevenson F, Leaman A (2010) Evaluating housing performance in relation to human behaviour: new challenges. Building Research & Information 38:437–441. doi: 10.1080/09613218.2010.497282

Stevenson F, Rijal HB (2010) Developing occupancy feedback from a prototype to improve housing production. Building Research and Information 38:549–563. doi: 10.1080/09613218.2010.496182

Suárez R, Fernández-Agüera J (2015) Passive energy strategies in the retrofitting of the residential sector: A practical case study in dry hot climate. Building Simulation 8:593–602. doi: 10.1007/s12273-015-0234-7

Thaler RH, Sunstein CR (2008) Nudge. Improving Decisions About Health, Wealth, and Happiness. Yale University Press, New Haven & London

Tondelli S, Conticelli E (2017) Esperienze significative di rigenerazione urbana: verso la definizione di una nuova urbanistica a consumo di suolo nullo, in AA. VV., Proceedings of XIX Conferenza Nazionale SIU. "Cambiamenti. Responsabilità e strumenti per l'urbanistica al servizio del paese", Roma Milano, Planum Publisher, 1312–1317

UNI/TS 11300-1:2014 (2014) Prestazioni energetiche degli edifice. Parte 1: Determinazione del fabbisogno di energia termica dell'edificio per la climatizzazione estiva ed invernale (Energy performance of buildings. Part 1: Evaluation of energy need for space heating and cooling)

UNI 10351:2015 (2015) Materiali e prodotti per edilizia - Proprietà termoigrometriche - Procedura per la scelta dei valori di progetto, Ente Italiano di Normazione

Verbeeck G, Hens H (2005) Energy savings in retrofitted dwellings: economically viable?, Energy and Buildings 37:747–754. doi: 10.1016/j.enbuild.2004.10.003

Visscher H, Meijer F, Majcen D, Itard L (2016) Improved governance for energy efficiency in housing. Building Research & Information 44:5-6:552–561. doi: 10.1080/09613218.2016.1180808

Yamaguchi Y, Fujimoto T, Shimoda Y (2011) Occupant behavior model for households to estimate high-temporal resolution residential electricity demand profile. Proceedings of BS2011 1548-1555

Yan D, O'Brien W, Hong T, et al (2015) Occupant behavior modeling for building performance simulation: Current state and future challenges. Energy and Buildings 107:264–278. doi: 10.1016/j.enbuild.2015.08.032

Yan D, Xia J, Tang W, et al (2008) DeST — An integrated building simulation toolkit Part I: Fundamentals. Building Simulation 1:95–110. doi: 10.1007/s12273-008-8118-8

Yu Z, Fung BC, Haghighat F, Yoshino H, Morofsky E (2011a) A systematic procedure to study the influence of occupant behavior on building energy consumption. Energy and Buildings, 43:1409-1417. doi: 10.1016/j.enbuild.2011.02.002

Yu Z, Haghighat F, Fung BC, Morofsky E, Yoshino H (2011b) A methodology for identifying and improving occupant behavior in residential buildings, Energy, 36:6596-6608. doi: 10.1016/j.energy.2011.09.002

Zhang X, Xia J, Jiang Z, et al (2008) DeST—An integrated building simulation toolkit Part II: Applications. Building Simulation 1:193–209. doi: 10.1007/s12273-008-8124-x

Zhou X, Yan D, Feng X, et al (2016) Influence of household air-conditioning use modes on the energy performance of residential district cooling systems. Building Simulation 9:429–441. doi: 10.1007/s12273-016-0280-9

7. Embedding strategies tackling consumer behaviour into existing policy instruments[1]

ENGLISH ABSTRACT

The aim of this chapter is twofold: on the one side, it aims at providing evidence of user behaviour to policy-makers, by assessing the impact of renovation measures addressing consumer behaviour in different scenarios; on the other side, it suggests actions to address behaviour to be integrated in existing policy instruments. Sections 7.1 and 7.2 present respectively the introduction and the aim and methodology. Section 7.3 presents the results of an Analytic Hierarchy Process (AHP) application to support policy-makers in their decisions concerning the reduction of energy consumption in buildings. In Section 7.4, the focus is moved to the Italian public housing sector, where actors involved, barriers to the implementation of renovation and drivers to overcome the barriers are presented. Several actions are suggested to demonstrate how household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments are also highlighted. In Section 7.5 recommendations to deliver such measures to households of the private residential sector are drawn. In conclusion, directions for future research and key research findings are respectively discussed in Sections 7.6 and 7.7.

ABSTRACT IN ITALIANO

L'obiettivo di questo capitolo è duplice: da un lato, mira a rendere esplicito l'impatto del comportamento degli utenti per i decisori, prendendo in considerazione differenti misure volte alla riqualificazione degli edifici, diversi criteri e diversi scenari; dall'altro intende suggerire azioni per tener conto del comportamento, da integrare nelle politiche e negli strumenti esistenti. Le sezioni 7.1 e 7.2 presentano rispettivamente l'introduzione, lo scopo e la metodologia. La sezione 7.3 intende dimostrare come sia possibile fornire supporto ai decisori in merito alle strategie di riduzione del consumo energetico degli edifici, presentando i risultati di un'applicazione di un'analisi multi-criteri (AHP). Nella Sezione 7.4, l'attenzione è rivolta al settore dell'edilizia residenziale pubblica (ERP) in termini di attori coinvolti, ostacoli all'applicazione del rinnovamento del patrimonio edilizio pubblico e strategie per superare le barriere. Sono quindi proposte azioni per dimostrare come il comportamento energetico delle famiglie possa essere incorporato negli strumenti e pratiche attualmente in atto. Sono inoltre evidenziati i vantaggi di favorire l'aumento di consapevolezza del comportamento degli utenti negli strumenti per il governo del territorio. Nella sezione 7.5 sono presentate alcune raccomandazioni per estendere i risultati della ricerca a tutto il settore residenziale. In conclusione, le direzioni future della ricerca e i risultati chiave sono discussi rispettivamente nella sezione 7.6 e 7.7.

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[1] Earlier versions of sections 7.1 and 7.3 are part of the paper that have been discussed during the 54th ISOCARP Congress 2018 and published as: Santangelo A, Tondelli S (2018) Embedding energy user's behaviour into multi-criteria analysis: providing scenarios to policy-makers to design effective renovation strategies of the housing stock, in: Proceedings of 54th ISOCARP Congress Bodø, Norway, October 1-5, 2018, The Hague, 1414-1424.

7.1 Introduction

As presented in Chapters 2 and 3, the European Commission has recognised the importance of buildings performance in the effort to mitigate climate change and has set regulations to help promoting the use of smart technology in buildings, to streamline existing rules and to accelerate buildings renovation. While the Energy Performance of Buildings Directive (EPBD) has set minimum energy performance requirements for all buildings that undergo major renovation (European Commission 2010), Article 5 of the Energy Efficiency Directive (EED) has set a binding renovation target for public buildings and it has imposed related obligations, stressing that public authorities, especially governments, shall undertake an exemplary role in the energy retrofit of public buildings (European Commission 2012). The revision of the EPBD, just entered into force on July 2018, aims at accelerating the cost-effective renovation of existing buildings and promoting smart-ready systems and digital solutions in the built environment, therefore, providing consumers with more accurate information about their consumption patterns (European Commission 2018). However, researches have started questioning the effectiveness of retrofitting policies, since they are mainly based on theoretical assumptions (Galvin 2014) and do not accommodate user energy practices (Gram-Hanssen et al. 2018). In order to achieve real energy reduction, policy instruments need to include considerations on the actual use of buildings, rather than the theoretical consumption (Visscher et al. 2016).

On the one hand, the design of energy efficient buildings does not necessarily result in low energy consumption (Stevenson and Leaman 2010; Guerra-Santin and Itard 2010; Gupta and Chandiwala 2010). Whenever the buildings are designed to be energy efficient, it is up to occupants decide how to use them (Gupta and Chandiwala 2010; Janda 2011; Feng et al. 2016; Santangelo et al. 2018), introducing a consistent uncertainty on the level of energy savings, very often resulting in a gap between expected and actual energy consumption.

Despite the central role of users to lower energy consumption has been increasingly recognised, more recently in regulatory frameworks and earlier in research field, evidence from research has showed that so far households have not been sufficiently motivated or supported in undertaking changes, and they are still not enough aware of the impact of their lifestyles and decisions on energy consumption.

On the other hand, public administrations have still to find ways to face the lack of public resources and increase the renovation rate of their building stock. They have so far failed in leading the renovation process on public buildings, while the property fragmentation represents a limit to the implementation of renovation strategies in the private housing sector.

Some past studies have shown multi-criteria analysis as a powerful tool to identify priorities for energy efficiency measures. A study conducted in Dortmund analysing energy efficiency measures in public buildings (März et al. 2011) has shown as Multi-Criteria Analysis (MCA) can simplify complex situations when it comes to allow decision-makers to include a full range of social, environmental, technical and economic criteria to their decisions on measures to be implemented to unlock the energy saving potential of buildings. The results highlighted which energy efficiency measures should be implemented to achieve the greatest benefit for the city, resulting in a ranking list of measures and recommended solutions. A similar research has been performed in Italy by considering the Sustainable Energy Action Plan of the city of Melzo (Dall'O' et al. 2013). Results have demonstrated how considering only the economic approach to make decisions on the renovation of buildings leads to results that do not take into consideration one of the most important goals of cities – to increase the sustainability of the whole community. However, in both studies, the considered renovation strategies have not explicitly incorporated initiatives addressing user behaviour among the recommended solutions to be implemented neither prior, nor after renovation. Without considering energy behaviour has a key factor for the success of strategies addressing buildings renovation, the expected energy savings have been demonstrated to be misleading, and the impact of such energy reduction measures overestimated.

7.2 Aim and methodology

Chapter 7 contributes to the research question 3, and in particular to sub-question g) as presented in the box below.

The aim of this chapter is twofold: on the one side, it aims at providing evidence of user behaviour impact to policy-makers, by presenting the relevance of measures tackling consumer behaviour in different scenarios; on the other side, it suggests measures to address behaviour to be integrated in existing policy instruments. The relationship among actors operating in the public housing sector, together with barriers, drivers and benefits of integrating the proposed measures, will be described in order to provide an easy-to-use guide for policy-makers and public housing providers. New evidence on the urgency to tackle occupant behaviour while implementing renovation measures will be presented addressing the private stakeholders too.

Research question 3:

How to make evidence of the impact of household energy behaviour and provide scenarios to help policy-makers in taking decision on the renovation of buildings?

Sub-question:

g) Which tools can be provided to policy-makers to assess user behaviour impact and to promote effective renovation strategies?

The first section presents a methodology based on multi-criteria assessment of different strategies by applying the Analytic Hierarchy Process (AHP), aiming at providing support to policy-makers for their decisions concerning the reduction of energy consumption in buildings. The methodology has been designed to explicitly incorporate the impact of user behaviour into the assessment of planning strategies and renovation measures. Previous research is presented, together with the adopted methodology, the main steps of the AHP, and the selected measures, criteria and scenarios. The alternatives that are more dependent from behaviour are identified, and the way to tackle this uncertainty in the pairwise comparisons is presented. The findings are then discussed in terms of possible steps to unlock the energy saving potential of buildings.

Afterwards, the focus on the Italian public housing sector in terms of actors involved, barriers to the implementation of renovation and the identification of drivers to overcome the barriers is presented as results of literature review and analysis. Several measures are suggested to demonstrate how household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments are also highlighted. In conclusion, recommendations to deliver such measures addressing behaviour awareness and information to households of the private residential sector – including homeowners and other tenants from the private sector – are also presented, aiming at showing the replication potential of a new governance model targeting environmental awareness, rather than just technical implementation of energy efficiency measures, and the planning instruments to work on in order to deliver such change.

7.3 Making the relevance of consumer behaviour explicit: a multi-criteria analysis

7.3.1 The Analytic Hierarchy Process (AHP)

The main issue policy-makers are struggling with is to understand which measures offer the greatest benefit within the framework of interacting environmental, economic and social factors. In fact, when it comes to increase the sustainability of cities, an economically oriented cost-benefit analysis alone is not adequate to take into consideration the multiplicity of determinants towards an energy efficient building stock.

To support decision-makers to design effective energy efficiency renovation policies, a methodology based on the application of the Analytic Hierarchy Process (AHP) is presented. AHP is a decision support technique based on pairwise comparisons and on the judgements of experts to derive priority scales. The comparisons are made using a scale of absolute judgements that represents, how much more, one element dominates another with respect to a given attribute. Through these scales, is possible to measure intangibles in relative terms. The judgements may be inconsistent, therefore, consistency should be checked and kept within certain values (Saaty 1990; Saaty 2008). To generate priorities to support decisions, four main steps have to be followed: i) to define the problem, and to set the goal; ii) to structure the decision hierarchy from the top (the overall objective), through the intermediate level (criteria), to the lowest level represented by the alternatives (measures); iii) to build pairwise comparison matrices and undertake a consistency test; iv) to estimate the relative weighs of the components of each level. AHP scale considered is as follows: 1 for equal importance; 3 for moderate importance; 5 for strong importance; 7 for very strong importance; 9 for extreme importance; pair values are used for priorities in-between the odd ones.

The methodology described in the following paragraphs aims to demonstrate that the measures tackling user behaviour are the most urgent to be implemented and, therefore, they should be on the top of the priority list when it comes to design effective renovation strategies of the housing stock. Thus, energy behaviour of occupants needs to be embedded in renovation policies, in order to reduce the gap between expected and actual energy consumption, to raise awareness on the individual impact on the energy consumption and to build sustainable communities. A sensitivity analysis is performed to design different scenarios based on the allocation of priorities among different criteria. The scenarios are intended as multiple ways to achieve the above-mentioned goal.

7.3.2 Definition of measures, criteria, scenarios and their hierarchy

The overall objective considered as the goal of the AHP application, is to lower energy consumption in housing sector by selecting the measures that more than others can lead to an effective implementation of the energy renovation strategies.

Among the numerous criteria and indicators that are normally used in environmental assessment of buildings, four criteria have been taken into consideration for the aim of this study. The *environmental criterion* is the one aiming at maximising the energy and CO_2 reduction, no matter the economic, social and practicable feasibility of implementing the renovation alternatives. The *economic criterion* aims at maximising the revenues and/ or minimising the loss, thus takes into consideration the cost-effectiveness of measures. The *social criterion* is the one recognising the importance of social and cultural values, and support inclusion of these values in the selection of energy renovation measures. The last criterion considered is the *practicability* of such energy efficiency measures, evaluating how easy and free from operational barriers is the applicability of the foreseen measures.

As results of literature and case studies review, taking as a reference the renovation practices of Italian residential building stock (Semprini et al. 2015; Santangelo et al. 2018), seven packages of measures – M(1) to M(7) – have been identified as potential alternatives to improve the energy performance of the housing stock (Table 7.1).

These measures have been clustered according to their levels of dependency from the occupant behaviour. M(1) and M(2) are the two alternatives strongly dependent on occupant behaviour, since they are designed to address directly the behaviour change and the households awareness of their impact on energy consumption. M(3), M(4) and M(5) are dependent to a certain degree on occupant behaviour. In fact, whether the heating system, the home appliances and the windows are efficient or not, it will still be the occupant who decides how to use them, introducing a level of uncertainty of such measures to increase the energy efficiency of housing buildings. On the contrary, M(6) and M(7) have been clustered as non-dependent on behaviour, since they represent the alternatives that more than others are able to reach the target of energy efficiency they are designed for, with limited influence of occupant behaviour.

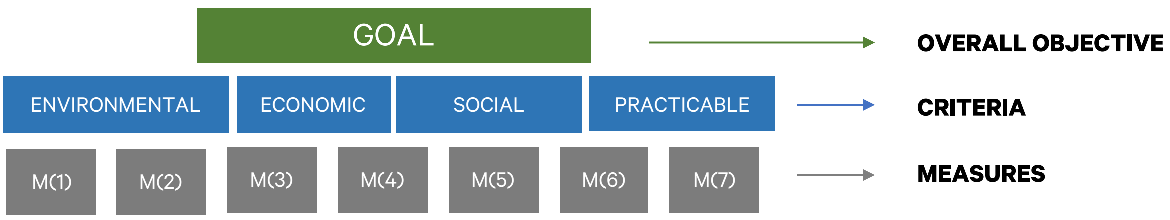
The structure of the hierarchy framework described above is drawn in Figure 7.1. The first level represents the goal of the analysis. The second level is composed by multiple criteria. The last level is made by the alternative choices or measures.

Table 7.1: List of measures and level of dependency from behaviour

MEASURES	**DEPENDENCY FROM BEHAVIOUR**
M(1) - Indirect feedback	High
M(2) - Direct feedback/ smart meters	High
M(3) - Replacement of the heating system	Medium
M(4) - Replacement of home appliances/ lights	Medium
M(5) - Replacement of windows	Medium
M(6) - Insulation of building envelope	Low/ None
M(7) - Renewable energy systems	Low/ None

Source: Santangelo and Tondelli (2018)

Figure 7.1: Hierarchy framework



Source: Santangelo and Tondelli (2018)

7.3.3 Results and discussion

The results report the application of AHP according to the hierarchy of goal, criteria and measures described above. The second sub-section describes the scenarios selected and how the criteria are combined among them to define the five scenarios.

7.3.3.1 AHP pairwise comparisons

The consistency test is one of the essential features of the AHP method which aims to eliminate the possible inconsistency revealed in the criteria weights through the computation of consistency level of each matrix. The consistency ratio (CR) is used to determine and justify the inconsistency in the pairwise comparison (Saaty 1990). The acceptable CR values is assumed 0.10 for matrix larger than 4x4. All the CR values of the matrixes considered are below this limit, therefore, the weight results can be assumed as valid and consistent.

The results from the environmental criterion decision matrix are presented, prioritised and ranked in Table 7.2. The priorities have been assigned by the author and fine-tuned by involving a restrict panel of scholars. Results already available in literature have been used to assess the measures M(1)-M(7) in pairwise comparisons. In order to highlight the medium-dependency level of M(3), M(4) and M(5) from behaviour, the preference of such measures pairwise compared to M(1) and M(2) have been lowered (i.e. two points decreased in the scale of preference). This assumption has been made to incorporate the somehow dependency on behaviour of such measures. Selecting M(3), M(4) and M(5) without taking into consideration that they are influenced from user behaviour can lead to overestimate the environmental benefit of such measures.

Tables 7.3-7.5 present the results from pairwise comparisons taking into consideration respectively the economic, social and practicable criteria. Each table shows the priority of selected measures according to the results of the decision matrix, and the ranking of the alternatives when each criterion is considered alone, in absolute terms.

Table 7.2: Pairwise comparison for environmental criterion. Consistency Ratio CR = 0.09

ENVIRONMENTAL CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	0.33	0.33	0.33	0.33	0.14	0.11	2.6%	7
M(2)	3.00	1	0.33	0.33	0.33	0.14	0.11	3.6%	6
M(3)	3.00	3.00	1	3.00	0.33	0.20	0.14	7.6%	4
M(4)	3.00	3.00	0.33	1	0.33	0.20	0.20	5.8%	5
M(5)	3.00	3.00	3.00	3.00	1	0.20	0.14	10.5%	3
M(6)	7.00	7.00	5.00	5.00	5.00	1	0.33	26.5%	2
M(7)	9.00	9.00	7.00	5.00	7.00	3.00	1	43.4%	1

Source: Santangelo and Tondelli (2018)

Table 7.3: Pairwise comparison for economic criterion. Consistency Ratio CR = 0.05

ECONOMIC CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	3.00	5.00	3.00	7.00	9.00	7.00	40.5%	1
M(2)	0.33	1	1.00	3.00	5.00	7.00	7.00	21.7%	2
M(3)	0.20	1.00	1	1.00	1.00	5.00	5.00	12.3%	4
M(4)	0.33	0.33	1.00	1	3.00	5.00	5.00	12.9%	3
M(5)	0.14	0.20	1.00	0.33	1	3.00	3.00	6.9%	5
M(6)	0.11	0.14	0.20	0.20	0.33	1	1.00	2.8%	7
M(7)	0.14	0.14	0.20	0.20	0.33	1.00	1	3.0%	6

Source: Santangelo and Tondelli (2018)

Table 7.4: Pairwise comparison for social criterion. Consistency Ratio CR = 0.03

SOCIAL CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	3.00	5.00	5.00	5.00	7.00	5.00	41.5%	1
M(2)	0.33	1	3.00	3.00	3.00	5.00	3.00	29.4%	2
M(3)	0.20	0.33	1	1.00	1.00	1.00	1.00	6.0%	3
M(4)	0.20	0.33	1.00	1	3.00	3.00	1.00	6.0%	3
M(5)	0.20	0.33	1.00	0.33	1	1.00	1.00	6.0%	3
M(6)	0.14	0.20	1.00	0.33	1.00	1	0.33	5.5%	6
M(7)	0.20	0.33	1.00	1.00	1.00	3.00	1	5.5%	6

Source: Santangelo and Tondelli (2018)

Table 7.5: Pairwise comparison for social criterion. Consistency Ratio CR = 0.06

PRACTICABLE CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	3.00	5.00	3.00	5.00	9.00	7.00	38.9%	1
M(2)	0.33	1	3.00	1.00	5.00	5.00	5.00	20.0%	2
M(3)	0.20	0.33	1	0.33	1.00	5.00	3.00	8.8%	4
M(4)	0.33	1.00	3.00	1	3.00	5.00	5.00	18.0%	3
M(5)	0.20	0.20	1.00	0.33	1	3.00	3.00	7.4%	5
M(6)	0.11	0.20	0.20	0.20	0.33	1	3.00	3.9%	6
M(7)	0.14	0.20	0.33	0.20	0.33	0.33	1	3.1%	7

Source: Santangelo and Tondelli (2018)

Figure 7.2 shows the priority trend of each criterion. "M(1) – Indirect feedback" and "M(2) - Direct feedback/ smart meters" are the top alternatives considering three out of four criteria, while implementing "M(7) - Renewable energy systems" has the highest priority when the environmental criterion is considered. Beside these three solutions, "M(4) - Replacement of home appliances/ lights" is the measure showing most significant changes among the criteria.

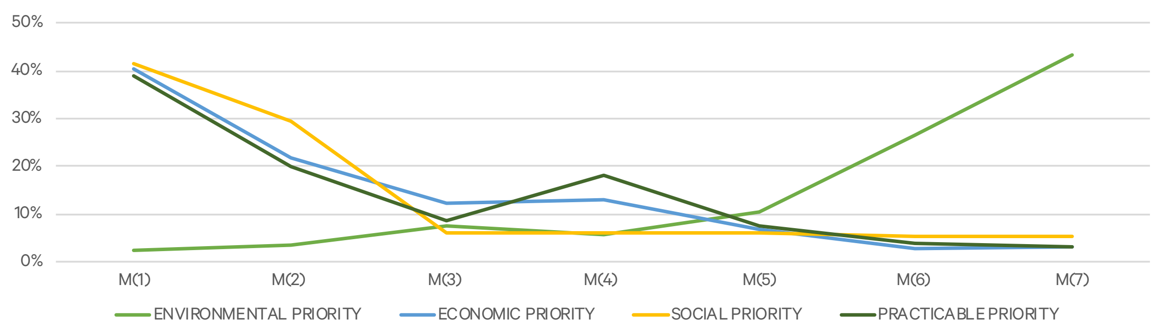
7.3.3.2 Sensitivity analysis

In order to include all the main alternative decisions that policy-makers might face to reach the overall objective of lowering energy consumption in housing sector, a sensitivity analysis has been performed to define five possible scenarios that includes different combination of the selected criteria.

The weights assigned for each scenario are presented in Table 7.6. The neutral scenario foresees a decision made by equally evaluate the four criteria. The rest of the scenarios are designed to make one criterion prevail, with a double weight with respect to the other three criteria.

The results of the sensitivity analysis are presented in Table 7.7. The rows represent the seven measures, while the five main columns show both the priority and the ranking of each scenario. Recommendations on which measures should be selected first are drawn by taking into consideration the results of each ranking list. The traffic light colours from green to red show the priority of recommended solutions. The evidence of how behaviour is embedded into the measures with the highest scores is presented in Figure 7.3.

Figure 7.2: Criteria priority



Source: Santangelo and Tondelli (2018)

Table 7.6: Weights assumption for sensitivity analysis

	ENVIRONMENTAL CRITERION	ECONOMIC CRITERION	SOCIAL CRITERION	PRACTICABLE CRITERION
NEUTRAL SCENARIO	25%	25%	25%	25%
ENVIRONMENTAL SCENARIO	40%	20%	20%	20%
ECONOMIC SCENARIO	20%	40%	20%	20%
SOCIAL SCENARIO	20%	20%	40%	20%
PRACTICABLE SCENARIO	20%	20%	20%	40%

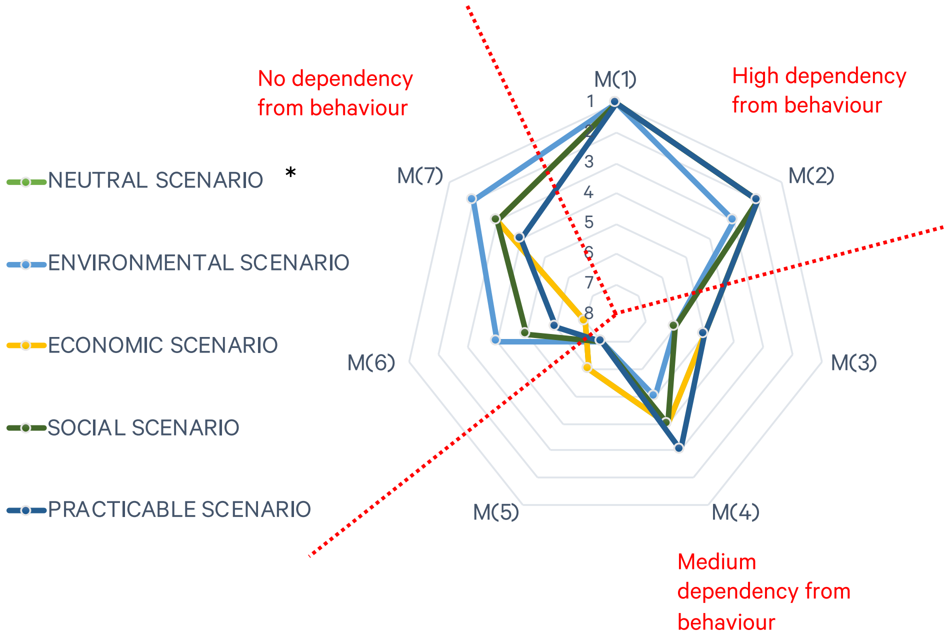
Source: Santangelo and Tondelli (2018)

Table 7.7: Results from sensitivity analysis and ranking of recommended solutions (P: priority, R: ranking)

RECOMMENDED SOLUTIONS	NEUTRAL SCENARIO		ENVIRONMENTAL SCENARIO		ECONOMIC SCENARIO		SOCIAL SCENARIO		PRACTICABLE SCENARIO	
	P	R	P	R	P	R	P	R	P	R
M(1)	30.9%	1	25.2%	1	32.8%	1	33.0%	1	32.5%	1
M(2)	18.7%	2	15.7%	3	19.3%	2	20.8%	2	18.9%	2
M(3)	8.7%	5	8.5%	6	9.4%	5	8.1%	6	8.7%	5
M(4)	10.7%	4	9.7%	5	11.1%	4	9.7%	4	12.1%	3
M(5)	7.7%	6	8.3%	7	7.5%	6	7.4%	7	7.6%	7
M(6)	9.7%	7	13.0%	4	8.3%	7	8.8%	5	8.5%	6
M(7)	13.8%	3	19.7%	2	11.6%	3	12.1%	3	11.6%	4

Source: Santangelo and Tondelli (2018)

Figure 7.3: Scenario analysis and evidence of energy behaviour relevance



* Neutral scenario is coincident to economic scenario
Source: Santangelo and Tondelli (2018)

7.3.4 Evidence from the AHP application, limitations and policy suggestions

This research has contributed to highlight the central role of household behaviour and daily practices to lower energy consumption when it comes to renovation of existing housing buildings. A methodology based on multi-criteria assessment of different strategies by applying the Analytic Hierarchy Process (AHP) has been presented. Results show that “M(1) - Indirect feedback” and “M(2) - Direct feedback/ smart meters”, the two measures that more than the other considered rely on user behaviour, have resulted to be the top alternatives by three out of four criteria. Afterwards, a sensitivity analysis has been performed to define five possible scenarios that includes different combination of the selected criteria. The aim has been to include all the main alternative decisions that policy-makers might face to reach the reduction of energy consumption by renovating the housing stock. The analysis has confirmed the urgency and convenience to implement the first two measures prior to the other alternatives.

The research embeds also some limitations. First of all, the decisions on the scores of pairwise comparisons have been made directly by the author and fine-tuned by involving a restrict panel of scholars. Although they result from the evidence of collaborations with public authorities, to enhance the robustness of the results, it might be suggested to design a participatory process to directly involve experts in decisions, or to deliver a survey to gather stakeholders' feedback on the priorities. Secondly, to the extent of the study, informational feedback – both direct and indirect – has been considered to lead to behaviour change due to rational behaviour. However, this approach has been criticised for relying on assumptions of consumers as guided by economically rationally decisions, while in practice it is not the case. Although the limits of this kind of strategy, informing the users still represent an important element in the implementation of structural strategies intended to increase the energy efficiency of buildings.

Two main policy recommendations can be drawn. On the one hand, even if the increasing availability of data on household energy consumption and indoor comfort levels gives more possibilities of providing tailored feedback to occupants, there is a limited evidence of post-occupancy evaluation studies in existing literature. Thus, the measures proposed in this research, with a high dependency on behaviour, are intended as complementary to the others, and the first to implement to raise awareness and drive behaviour towards more energy sustainable practices, but they certainly cannot reach the goal if implemented alone. Information, awareness campaigns, feedback and other informative policy instruments should be integrated by other measures addressing the physical renovation. On the other hand, public authorities are seeking for services, rather than products to increase the renovation rate of the housing stock. Technologies should be only one aspects of a complex system where spatial organization, consumer behaviour and technologies interact with each other, determining the actual and future pattern of energy consumption (Papa et al. 2016). Better integrated complementary approaches to both the technical and social energy transitions are required.

7.4 No "one-size-fits-all" solution: proposals for addressing consumer behaviour through different policy instruments by different actors

As result of the previous section (section 7.3), measures tackling user behaviour to reduce energy consumption in buildings have been identified as the most urgent and convenient for all the scenarios analysed, especially when it comes to the renovation of the existing building stock. However, no "one-size-fits-all" solution is possible due to particularities across household and building characteristics (Barbu et al. 2013; Karvonen 2013; Tweed 2013; Economidou 2014; Bedir 2017). Therefore, the next step foresees the analysis of the Italian public housing sector in terms of actors involved, barriers to the implementation of renovation and the identification of drivers to overcome the barriers. Several measures are suggested to demonstrate to what extent household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments are also highlighted, and a decalogue made by ten proposed solutions tailored to the public housing sector is framed.

7.4.1 Analysis of actors, barriers and drivers

As described in Chapter 5, the Italian public housing sector has some specific characteristics which make possible to identify the actors involved when it comes to the energy management and renovation of public housing stock. The extreme fragmentation of housing demand, the increasing energy poverty of tenants living in public buildings, the overall decline of public spending on the housing sector, and the ongoing redefinition of the role of public authorities are only some of the elements describing the Italian housing issue. New conceptual and methodological advancements are needed in order to properly address housing needs, both from the point of view of scholars and of decision-makers (Governa and Saccomani 2009), where the provision of information, awareness raising and new skills can be the driver not only for 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.

7.4.1.1 Actors

As investigated in Chapter 5, public rental housing stock in Italy can either be owned by municipalities or public housing providers, depending on the regional laws. In both cases, the latter are responsible for the management, allocation process and maintenance, while the former, whenever owner, is responsible to transfer to the latter the necessary resources to deliver a proper service. The dissertation takes as a reference the roles and responsibilities that apply in the Emilia-Romagna Region, since it is where the case study building investigated in Chapter 6 is located.

Beside what happens in the public housing sector, it must be acknowledge that cooperation between public and private sector in Italy has achieved a remarkable widespread over the last two decades (Copiello 2015). Energy Service Companies (ESCos), and more generally private-market-parties and investors have been increasingly involved in the renovation of the public housing stock. However, when it comes to the reduction of energy consumption, the tenants cannot be left apart since household behaviour has been found to significantly contribute to the energy usage in dwellings (Janda 2009; Guerra-Santin and Itard 2010; Gupta and Chandiwala 2010; Ben and Steemers 2014; Santangelo et al. 2018).

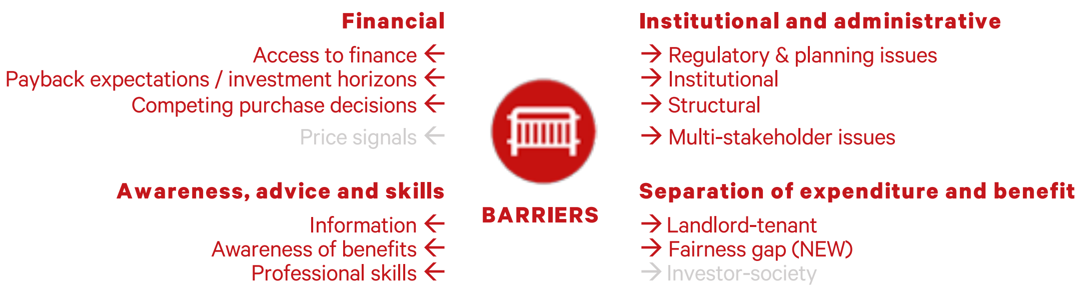
Despite the clarity of the actors involved, the relationship among them is rather than simple and does not follow a straight path, and a number of barriers have been identified to the energy renovation of the building stock (BPIE 2011; Achtnicht and Madlener 2014; Economidou 2014; Pasetti 2016; Caputo and Pasetti 2017; MISE 2017). Starting from the ones analysed and categorised by the Building Performance Institute Europe in 2011 and updated in 2013 (BPIE 2011, 2013), this work describes to what extent those barriers apply to the renovation of the Italian public housing sector, and how the consumer behaviour can be turned as a driver to effectively deliver energy savings.

7.4.1.2 Barriers

Improving the energy performance of buildings is a consequence of a multi-stakeholder decision process (BPIE 2011). This is also true for the public housing sector, although the limited number of stakeholders and the large building stock make it a particular favourable case study to understand the barriers and challenges that policy-makers have to face to improve the public

housing stock. Evidence from research and practical experiences have highlighted that consumers and investors, either private or public actors, are not keen on investing in energy saving (BPIE 2011). A study performed by the International Energy Agency (OECD/IEA 2014) highlighted that, under existing policies to all sectors, two-thirds of the economically viable energy efficiency potential through 2035 will remain unrealised, due to information failures, split incentives, subsidised pricing of energy, inadequate pricing of externalities and a shortage of financing. But mainly, due to the fact that energy efficiency represents a negative quantity (i.e. energy not expended), it is often perceived as an intangible concept. Its societal value is not clearly apparent to investors, consumers and policy-makers. Hoever, people's decisions are affected by a number of factors, and the human dimension has started to be further investigated not only in the design sector, but also in the policy field (Santangelo and Tondelli 2017a; D'Oca et al. 2018) as a turning point to deliver energy efficiency.
When it comes to the renovation of the Italian public housing sector, the barriers that emerge can be classified as in Figure 7.4.

Figure 7.4: Classification of barriers to the renovation of the Italian public housing stock.



Source: author's elaboration, adapted from BPIE 2011, 2013.

Financial barriers are probably the ones which firstly come up, since the implementation of renovation programmes requires considerable resources, particularly limited for public administrations, always seeking to do not exceed the annual disposable budget. Financial barriers can be classified as: lack of funds or access to finance, particularly prevalent for public authorities but also private bodies, looking for securing finance on acceptable term in order to be more competitive on the market. However, in many cases the barrier is more linked to lack of awareness or lack of interest, rather than lack of funds (BPIE 2011). For example the implementation of soft measures as information programmes and behaviour change campaigns has been demonstrated to be cost-effective over the long-term, to have low initial costs and to produce a positive Net Present Value (Santangelo and Tondelli 2017a). Nevertheless, they have been seldomly applied.

The payback expectation / investment horizon is a major concern of ESCos, which base their business on their capability to recover their initial investment through the energy saving, and for public authorities too, struggling to make the renovation of their public stock appealing and profitable. However, the longer the payback time is, the less is the interest of private organisations to invest. In this scenario, the household behaviour takes also an important part, since the payback period is also linked to the change of consumption patterns from tenants, who need first of all to be informed and secondly to be motivated, in order to deliver energy savings (Santangelo and Tondelli 2017a).

Competing purchase decision is also an issue that public administrations usually have to face, since investments on energy efficiency are not visible and, therefore ,less attractive (BPIE 2011). This is particularly relevant for soft measures addressing consumer behaviour, and it also applies to public housing low-income tenants who struggle to afford the energy costs, and find easier to pay a recurring cost than to make an investment (e.g. buy more efficient lights and other appliances) that is perceived as high (Pasetti 2016).

The price signal, the last one among financial barriers included in BPIE (2011), has not found to be relevant for the Italian public housing sector, since it regards the lack of motivation for the majority of consumers to take actions due to the small share of the housing energy costs. On the one side, in Italy this issue is not a barrier since the energy prices for domestic consumers are among the highest in Europe, far above the EU-28 average price (European Union 2017). On the other side, tenants in public housing are not supposed to implement renovation measures, which are responsibility of the public authorities owning the housing stock.

There is a wide range of *institutional and administrative barriers* that applies to the renovation of the public housing stock, affecting both the implementation rate and the ambition of the renovation process. According to the Building Performance Institute Europe (BPIE 2011, p.57), *“evidence from Italy indicates that fragmentation, delay and gaps in the regulatory action of public planning have not allowed the public sector to be the driver for improved energy efficiency in buildings that it should be”*. Indeed, results from Chapter 2 highlighted the inability

of public authorities in recognising urban planning as the discipline able to deliver significant changes in the adoption of energy efficiency measures. Institutional barriers apply both to the public sector and to the private one. In case of public sector, there might be institutional barriers in using new services (i.e. as renovating by involving ESCos in the process) or building new partnership (e.g. with the tenants, by involving them to agree on certain energy saving targets). In case of private sector, there is a bias among institutional investors more familiar with large-scale financing, rather than generally smaller projects perceived as more risky (BPIE 2011), as the renovation of the public housing stock might look like, also due to the general lack of trust on public housing providers from tenants and private stakeholders.
Structural barriers are the ones faced by public housing providers, due to the age and poor energy efficiency of the building stock. In Italy demolition is considered to be the last option, also due to the difficulties related to the reallocation of households, therefore, the quality improvement of the buildings is subjected to the relative lower energy efficiency, which is inversely proportional to the age of the building stock.
Multi-stakeholder issues are a significant barrier for the renovation of the public housing stock, due to the mix of tenures of the multi-dwelling buildings. In fact, as described in Chapter 5, from the 1990s, several dwelling sales campaigns have been promoted by public authorities, resulting in a mix of multiple family-owners and public owners, making even more difficult to take decision on maintenance and renovation works than in case of multi-private ownership.

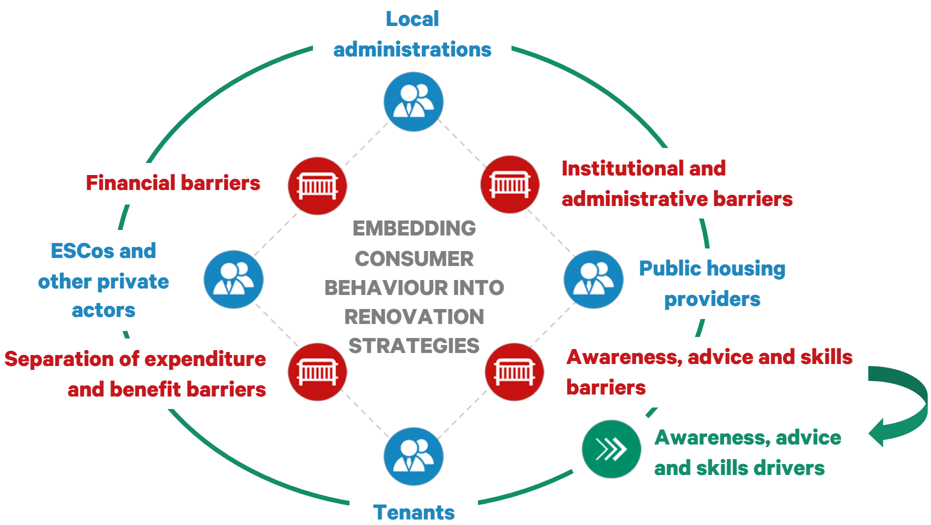
Awareness, advice and skills barriers are the ones more cross-sectoral to all the actors involved. Ambitious renovation requires all the stakeholders to get involved to take their part, and particularly tenants who have a key but underestimated and unexplored role, unless right advices and proper information are available. The human factor and the provision of new skills and knowledge are also relevant for ESCos, usually discouraged from taking deep renovations of the buildings, and for public authorities and housing providers, to overcome the inertia of the status quo and the difficulties in assessing the impact of measures and managing the complexity related to multi-stakeholder involvement. The awareness of cost-effective energy saving opportunities has been increased but remains still low, while the focus is on individual solutions and the holistic approach – at the basis of the urban planning approach – still remains unexplored.

Separation of expenditure and benefit is the last barrier to be presented. It is related to the fact that the owner and the user of the dwelling are two different entities. For the owner, any investment has to bring a benefit which is not necessarily linked with energy savings, unless it is a situation where the landlord pays the energy bills and the energy consumption is included in the rent as a lump sum. Since the tenant does not own the dwelling, any investment in lowering energy bills has to be seen as financially advantageous for both actors, often resulting in no action taken (BPIE 2011). In case of renovation of the Italian public housing stock, the landlord-tenant barrier may apply caused by the impossibility of providers to raise the rent after the renovation, due to both legislative restrictions and low-income situation of tenants. However, due to the housing allocation system characteristics, an additional barrier should be added to this category, namely the *fairness gap barrier*. The allocation of dwellings is based on a waiting-list system: low-income households who meet specific criteria (i.e. a minimum period of residency in the city or region and income not exceeding a certain level) can apply for a rented public dwelling. The rent is calculated according to the income level and does not take into account the dwelling characteristics, despite some Italian regions recently revised the regional legislation to accommodate the possibility – rather than the duty – to do so (Santangelo and Tondelli 2017b). The vacant housing units are then allocated according to the family size. Each family, once gets on the top of the waiting-list, can normally choose among two or more options. However, the energy efficiency of the dwelling is not taken into account neither as an allocation priority, nor in the calculation of the rent. Therefore, unfair situations arise among low-income tenants with the same difficulties in meeting housing and energy costs, whit tenants paying the same rent but having different expenditures for energy services and experiencing different comfort and healthy housing conditions. Once the housing stock is renovated, especially when ESCos are involved and an Energy Performance Contact (EPC) is signed among housing providers, ESCos and tenants, the fairness among households is again compromised due to the higher energy costs than the real consumption that tenants of renovated buildings have to pay, to allow the ESCos to recover the initial investment. While homeowners in the private housing market may decide to renovate their houses and to sign an EPC, to then benefit of energy and money saving after the payback period, public housing tenants are required to pay the renovation costs without having the housing right to live in the same dwelling after the EPC ends (Proli et al. 2016). The fairness gap is, therefore, an additional barrier that needs to be overcome to avoid exacerbating the relationship between housing providers and tenants, and to facilitate an increasing public housing renovation rate.

7.4.1.3 Drivers

While there are several studies available describing and categorising the barriers to the renovation of the building stock for improving the energy performance (BPIE 2011; Achtnicht and Madlener 2014; Economidou 2014; Pasetti 2016; Caputo and Pasetti 2017; MISE 2017), the drivers to overcome those barriers have been less investigated (Pasetti 2016), and the gap can be explained by the high dependency of drivers to the specificity of different contexts in different countries. The aim of the dissertation is to provide an insight on the role of the human factor to boost the renovation of the Italian public housing stock from a planning perspective, by suggesting improvement of policy instruments and planning tools. Therefore, since barriers can also be reversed and seen as drivers, the awareness, advice and skills element presented above is now taken as the main driver to the implementation of effective building renovation strategies and plans (Figure 7.5).

Figure 7.5: Interplay between actors, barriers and drivers



Source: author's elaboration

Individuals need correct information for a sustainable choice. Without an appropriate frame of reference, users cannot determine whether their energy consumption can be reduced or not (Gyberg and Palm 2009; Janda 2009; Jain et al. 2012, 2013; Barbu et al. 2013; Frederiks et al.

2015), and whether their behaviour can be improved to reduce consumption and increase sustainability. Therefore, information and feedback play a significant role in raising energy awareness and changing consumer attitudes towards energy consumption. Understanding the benefits is not only useful for the households, but also for the public housing providers, who often lack of competences to address consumer behaviour both within the daily management operations and when it comes to the building renovation. The improvement of professional skills is also beneficial for private actors as ESCos and construction companies, more oriented to technological measures, rather than holistic renovation approaches including information and awareness measures. The role of occupants in delivering effective energy saving is also neglected from the local authorities, that need to increase their understanding of the consumer behaviour impact and the possibilities to address it by including appropriate measures in their policy instruments.

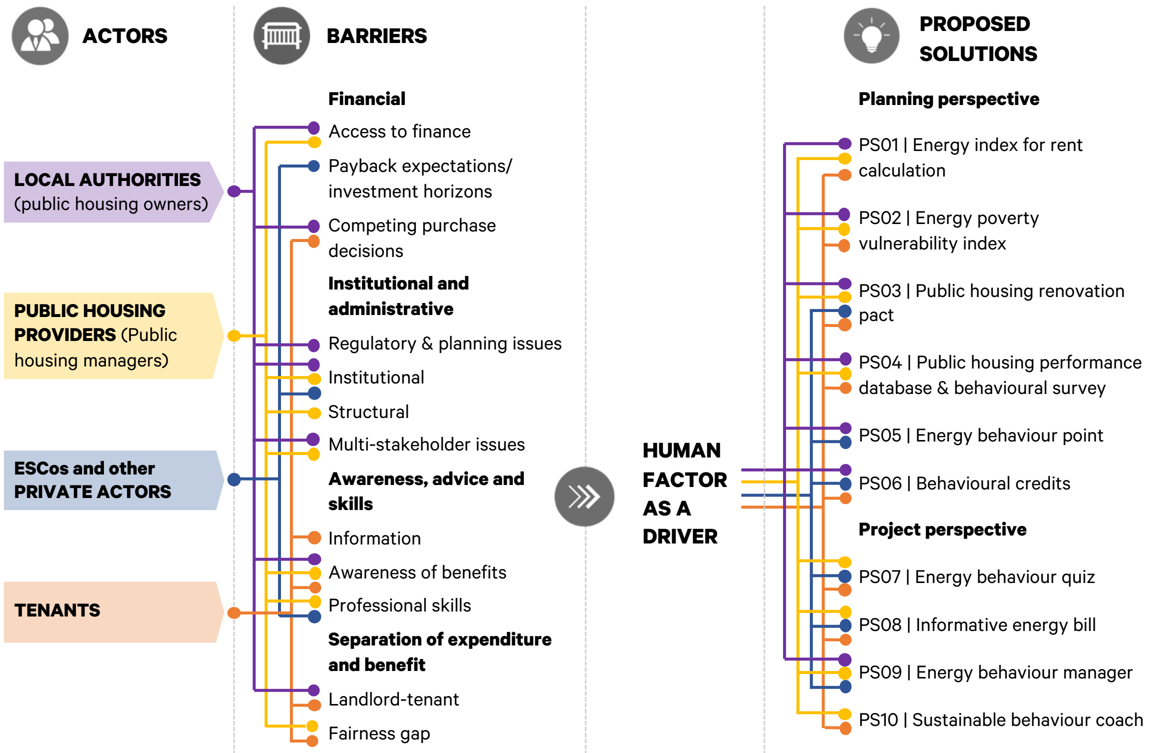
Actions to address the barriers described above should be taken to unlock the energy saving potential of the Italian public housing stock. These measures include, but are not limited to, new policies and regulatory initiatives from a planning perspective, and new measured tailored to specific needs. Hence, they are further discussed in section 7.4.2.

7.4.2 Description of proposed solutions

To effectively enforce energy issue within the public housing stock, the description of the interplay between actors, barriers and drivers should be completed by adding information, on the one side, on how to deliver behaviour awareness campaigns, tailored feedback and information to households; on the other side, on how to enable local authorities, public housing providers and private actors to take actions to trigger such behaviour change. Thus, ten Proposed Solutions (PS01-10) have been identified and grouped in two main categories (Figure 7.6).

The first group of proposed solutions (PS01-06) includes proposals which are aimed at improving the planning process. They are mostly top-down proposals suggesting a process change to deliver a long-term impact on public housing management and renovation, rather than the implementation of a single project-tailored measure.

Figure 7.6: Overview of actors, barriers, drivers and proposed solutions



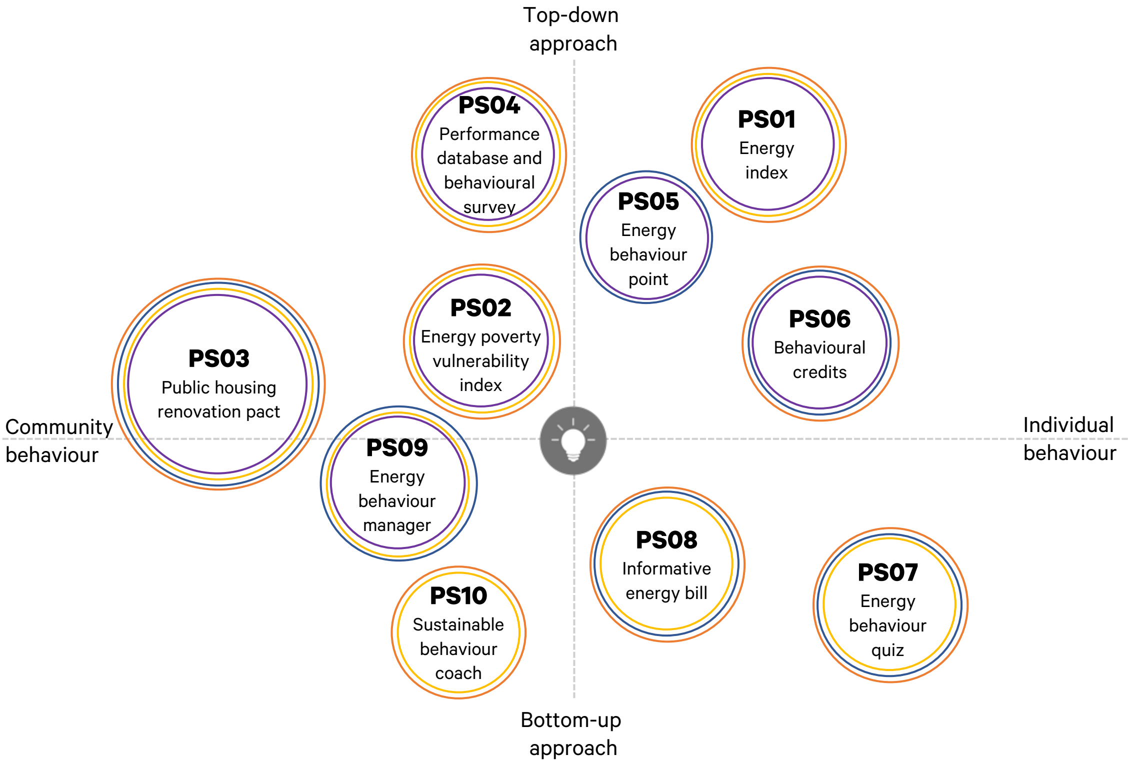
Source: author's elaboration

PS01, PS02 and PS06 are designed to embed user behaviour into economic and welfare instruments. PS03 is aimed at improving the policy level of building renovation through the proposal of a new policy instrument, while PS04 and PS05 are tailored respectively to increase knowledge among stakeholders and to raise awareness among households.

The project perspective is then included in the actions described afterwards (PS07-PS10), tailored to demonstrate the short-term impact of specific tools. PS07 is designed to get information from occupants, while PS08 and PS10 are aimed at providing information and feedback to the occupants. Finally, PS09 is suggested to increase knowledge and skills at organisation level. Figure 7.7 shows the positioning of the proposed solutions in relation to the type of approach (i.e. top-down or bottom-up) and the behaviour addressed (i.e. community or individual). The coloured circles give indications about the type of actors involved, while their sizes inform on the number of actors involved.

The ten factsheets that follow further describe the proposed solutions.

Figure 7.7: Positioning of proposed solutions in relation to type of approach and behaviour



Source: author's elaboration

PS01 | Energy index for rent calculation

Actors to be involved

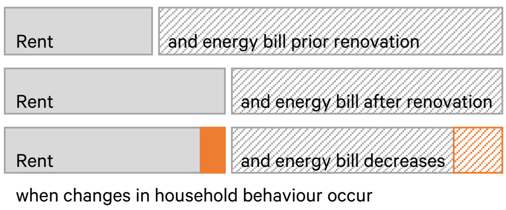
- → Local authorities
- → Public housing providers
- → Tenants

Main features

The energy index is aimed at embedding energy issue into social rent calculation for public housing stock. Currently, the rent calculation is based on income categories, rather than dwelling characteristics, and the housing renovation does not lead to a rent increase.

On the one side, the existing system does not motivate households to adopt energy-saving behaviour, since they are neither aware of the energy performance of their accommodation, nor required to pay attention to energy consumption after retrofit interventions. On the other side, it leads to inequalities among tenants, since households within the same low-income category might be allocated to dwellings with totally different building characteristics, resulting in different energy costs.

The proposed energy index is based on a score system. Different energy-related building characteristics lead to different scores. Public housing providers may fix certain prices per point, tailored to the income categories. As the energy index increases, the rent increases according to the price per point of each income category. Afterwards, some reductions both for the rent and for the energy bill are foreseen if users adopt sustainable behaviour. There is no standard behaviour, therefore, households should agree their sustainable behaviour targets in cooperation with the sustainable behaviour coach (PS10).



Rent decrease is an economic incentive that could be quantified as a percentage of the energy-savings.

Pros

It contributes to ensure energy justice (Jenkins et al. 2016) for low-income households in energy poverty conditions living in dwellings with higher energy expenditures than those renovated.

Rent increase after renovation helps housing providers to properly manage the housing stock.

It contributes to reduce housing allocation inequalities among tenants.

It is an energy behaviour awareness tool, since it is expected to stimulate and motivate behaviour changes in order to save money.

Cons

There are legislative barriers, since in Italy only few regional legislations (Santangelo and Tondelli 2017b) and public housing regulations foresee the possibility either to increase rent after renovation, or to calculate the rent according to energy performance.

It only works if the benefits (e.g. increased earnings for housing providers; lower expenditures for households) are split among the two actors. However, the incentives both for housing providers and for tenants are difficult to realise if the renovation is carried out by an ESCo due to energy costs saving for investment repayment.

It could lead to stigmatisation and social exclusion, with the poorest unable to afford the rent increase.

The calculation of the rent increase should be based on real consumption data, rather than energy simulation performance, to avoid overestimation in energy savings.

PS02 | Energy poverty vulnerability index

Actors to be involved

→ Local authorities
→ Housing providers
→ Tenants

Main features

The energy poverty vulnerability index is aimed at increasing knowledge among local authorities and housing providers on the vulnerability level of households to energy poverty. Energy poverty, also known as fuel poverty, is defined as a situation where households cannot access to and afford adequate level of heating or other required energy services to meet their basic needs, or they cannot afford other necessary goods due to the high utility costs (see Chapter 5 and Glossary section).

The energy poverty vulnerability index is a composite index based on:

i) dwelling characteristics and energy index (PS01);

ii) household characteristics (e.g. family size, composition, age);

iii) household behaviour assessed through questionnaires and (smart) meter readings of the actual energy consumption.

The index can be reduced both by moving to another dwelling with higher energy performance, and by optimizing behaviour. Since the former is seldomly an option, due to the scarce rotation rate of public housing stock, and the social instability that such change may cause, raising awareness on behaviour represents the best option for the short-medium term. Behaviour changes should be supported at community level through a set of measures and behaviour awareness campaign, avoiding to blame the victim, but providing a knowledge framework for a pro-environmental choice.

As the index increases, additional welfare measures should be put in place by the local administration to mitigate the energy poverty condition.

Pros	Cons
Knowledge increased among local authorities, responsible to address energy poverty issue. Improvement in the definition and measurement of energy poverty phenomenon, by including the household behaviour as one of the possible drivers to decrease energy poverty vulnerability.	Mapping households living in public housing stock is a time-consuming activity which requires the collaboration between local authorities and public housing providers, to combine different data sources. New skills should be developed among public authorities to tackle the energy poverty phenomenon and to design welfare measures to address it. There is the risk to blame the victim and to put on vulnerable tenants the responsibility of wasting energy, while high energy consumption is always due to a combination of building characteristics and behaviour, not behaviour alone.

PS03 | Public housing renovation pact

Actors to be involved

- → Local authorities
- → Housing providers
- → ESCos and other private actors
- → Tenants and tenant's union

Main features

The public housing renovation pact is an agreement jointly signed by the municipality, the housing provider, the tenants and the private entity managing the renovation phase, if the participation of an ESCo applies.

This solution is aimed at building trust among the stakeholders involved and at defining common goals and actions to deliver improvements in building energy performance and energy savings. Interventions should be based on a combination of practices, from micro-urban regeneration actions involving the tenants with a bottom-up approach, to top-down and physical interventions on the built environment. The definition of quantities (i.e. intervention areas, expected energy savings), responsibilities and expected benefits should be also included.

The pact should be the opportunity to establish long-term engagement with tenants and to raise awareness among households on the impact of their behaviour on energy consumption. The signature of the pact could be celebrated to also launch the behaviour change campaign as an opportunity to adopt pro-environmental behaviour and to reduce energy costs.

Another opportunity to do not miss should be the regeneration of the public indoor and outdoor spaces. Although asking to the market to incorporate the urban regeneration benefits is still a challenge, the interventions to improve the outdoor space (i.e. to recover rainwater, to increase soil permeability, to recover abandoned spaces for vegetable gardens, coworking spaces and other community activities) may contribute to give visibility to the renovation process inside the buildings to citizens living outside.

Pros	Cons
Increased social sustainability through the involvement of the target group in the intervention strategy definition. Co-ownership of targets and results.	Difficulties in reaching consensus among all the actors, due to the different personal motivations and interests, but also due to the lack of trust between housing providers and tenants.

PS04 | Public housing performance database and behavioural survey

Actors to be involved

- → Local and regional authorities
- → Federcasa (umbrella organisation of Italian public housing providers)
- → ENEA (Italian National Agency for New Technologies, Energy & Sustainable Economic Development)
- → ISTAT (Italian Statistic Bureau)
- → Energy utilities

Main features

The monitoring database is aimed at investigating the state of the art of rental public housing stock at national level, and at building a knowledge baseline for the development of strategies and tools to renovate the housing stock and addressing the impact of behaviour on energy savings.

On the one side, it should collect data updated on yearly bases on building characteristics (e.g. insulation, type of glazing, ventilation, heating and domestic hot water systems) and energy-related information such as the estimated energy performance based on energy labels, the actual energy consumption (i.e. per housing unit), the energy consumption breakdown for consumption end-use categories (e.g. heating, electricity, water), the energy poverty vulnerability index (see PS02).

On the other side, technical and energy data should be coupled with data on household characteristics, behaviour and energy awareness. Data on occupant characteristics include income level and type, household composition, number of occupants, occupants above and below 65 years old, number of children and age of children. Information should be collected by housing providers, since they are responsible of the allocation procedure.

An ambitious survey should be promoted to investigate behaviour in the pre-renovation phase (Gupta and Chandiwala 2010), while a follow-up survey should follow the first one once the behaviour awareness campaign has been implemented and renovation measures introduced, to monitor the behaviour changes (i.e. post occupancy renovation survey).

Pros	Cons
Knowledge baseline for the development of strategies and tools to renovate the housing stock and addressing the consumption behaviour impact on energy savings. The availability of building assets and energy-related information shows to private investors (e.g. ESCos) the high replication potential of interventions on the public housing stock. Joint efforts required from public and private bodies to build the database is a valuable interdisciplinary experimentation. The survey on behaviour makes possible to explain and to limit the likely gap between expected and actual energy performance.	High resolution data are not always available. Despite the Italian national legislative decree D.Lgs. 102/2014, implementing the Directive 2012/27/EU on energy efficiency requires the installation of meters to account energy at household level in existing buildings with central heating system, it has been seldomly implemented by public housing providers, due to lack of funds and separation of expenditures and benefits barrier (see section 7.4.1.2).

PS05 | Energy behaviour point

Actors to be involved

→ Local authorities
→ Urban centres, public libraries and other public offices/facilities
→ Private organisations as energy utilities, multi-utilities and ESCos interested in investments with a social revenue

Main features

The energy behaviour point is a permanent info point aimed to give information and to raise awareness not only among the public housing tenants, but also to the whole citizens, on the impact of household behaviour on energy consumption.

It should be located in a public place with high visibility and people flow (e.g. urban centres, public libraries), to turn the spotlight to the public housing stock as a public service, able to undertake innovations that can be beneficial for all the citizens.

Household recruitment to behaviour change projects largely relies upon communications materials. Studies have noted that engagement is constrained since energy consumption feedback often lacks salience for many householders. This is partly because energy is invisible and is consumed only indirectly, but also because the units of measurement of energy are confusing to many householders. Therefore, the energy behaviour point should provide evidence of the impact of household behaviour on energy consumption through interactive activities, games and quantitative results (i.e. not only in terms of direct energy units but also money saving and environmental externality units, as tree needed to offset emissions (Jain et al. 2013)).

Activities of the energy behaviour point should be coupled with the ones already in place. For example, Bologna SEAP foresees the energy point (i.e. "il punto energia"), an information desk for citizens who would like to get information on building renovation measures and enterprises on white certificate schemes. The energy behaviour point could, therefore, be extended to all citizens.

Pros	Cons
High visibility of the energy user behaviour topic, reducing lack of salience of energy feedback and energy invisibility. Twofold aim: tailored info to engage public housing tenants; general information to raise awareness among the rest of citizens.	Strong political commitment needed to make the proposal sustainable and effective.

PS06 | Behavioural credits

Actors to be involved

→ Local authorities
→ Public/private companies
→ Tenants

Main features

The aim of the behavioural credits campaign is twofold: on the one side, to provide users with rewards to support their behaviour changes, as credits to be spent for certain services, according to the agreements with partner institutions; on the other side, to build-up a complementary welfare system that provides direct benefits to those households committed to reduce energy consumption at home. In addition, this solution could also be beneficial for raising awareness among other tenants not part of the programme, to claim the same possibility, activating further bottom-up activities.

Behavioural credits can be gained through changes in energy-related behaviour. Direct or indirect feedback would provide the framework for making such change, informing the occupants on the impact of their current behaviour and the benefits of optimising it. For instance, the preferred set-point temperature can be reduced from 21°C to 22°, or the heating system can be turned off by reducing the thermostat when a room or the whole housing unit is empty. The behaviour changes can be reported through surveys and the answers can be matched with the data from smart meters, to provide then feedback to the occupants and to update the credit scheme.

A behavioural credit scheme should be built, either according to the amount of energy saved, or by assigning a weight to different behaviour changes according to the easiness to implement them.

Agreements should be signed between the local authorities and the public/private companies, to select the benefits and to fix the purchasing ability of the credits.

Successful similar experiences have been implemented in the field of sustainable mobility (e.g. “Bella Mossa”, “WeCity”, “Bike Challenge”). Examples of services are: selected food products, vouchers for the grocery store, public transport tickets, tickets for sport events, cinema or theatre.

Pros	Cons
The access to services at reduced price makes behavioural change desirable and its effect more tangible. Credit accumulation may allow to build gamification projects where different communities living in different districts might play with each other to gain more benefits to share with the community than the one that is possible to reach as individuals. It is a measure having a positive impact on the welfare system, since the credits can be spent to acquire other basic services at discounted fares (e.g. bus monthly/yearly ticket).	Investments for In Home Displays (IHDs) or other monitoring system should be foreseen in order to be able to quantify behaviour change effects on energy savings. IHDs can provide frequent and direct feedback which can foster the commitment to the initiative.

PS07 | Energy behaviour quiz

Actors to be involved

→ Housing providers
→ ESCos and other private actors
→ Tenants

Main features

The main purpose of the energy behaviour quiz is learning-by-doing. Differently from energy questionnaires that are mainly aimed to gather information to be then processed for providing feedback to the occupants, the energy behaviour quiz is intended as a tool to raise awareness while, at the same time, providing knowledge on the current situation. In addition, another issue which makes the energy behaviour quiz different from a traditional survey, is the fact that the quiz can be performed by each occupant of the housing unit, while answers to surveys are usually done only once per household. Inviting each occupant to take time for the quiz will raise awareness of all the household members taking part to it, not only the household representative as the case of the survey. The multiple replies can also activate gamification process among the family members, to make each other aware that each person has a role in optimising energy consumption.

The energy behaviour quiz should be organised to associate a score to the multiple answers, so to provide to the users the results in real time in terms of consumer profiles. Some examples are provided below:

- energy saving super star → "Perfect score! When it comes to put energy efficiency into practice, you know your stuff"
- energy saving trainee → "You are on the road to understand how energy affects our everyday lives"
- energy saving rookie → "There is so much more to learn, but taking this test is a good start"

Examples of questions can include:

"Which uses less energy – taking a hot bath or a hot shower?"
"Each degree higher on the thermostat can save how much on your heating costs?"

Pros	Cons
Learning-by-doing process. The quiz does not require so much time. It can be performed as a game to understand who is more aware on energy consumption within the family. It can provide some baseline information useful, on the one side, to the housing providers to then build an informative campaign on the current knowledge and awareness; on the other side, to the ESCos and other private actors involved to understand actual knowledge of users about the technology installed in case building renovation occurs.	It could not be taken seriously if not adequately promoted and supported by housing associations, leading to misleading knowledge. It can create expectations among households. Therefore, housing providers should plan the energy behaviour quiz as a first step of an energy informative campaign, not as a one-time initiative.

PS08 | Informative energy bill

Actors to be involved

- → Housing providers
- → ESCos, energy utilities, accounting companies, other private actors
- → Tenants

Main features

Provision of a more frequent and informative energy bill has proven to lead to energy conservation (Wilhite and Ling 1995; Barbu et al. 2013; Jain et al. 2013). Households can see a reduction in their energy bills by changing their energy behaviour and reducing consumption.

To make energy bills more informative, can include:
- charts which visualise trends on household energy use;
- comparisons of energy use (e.g. to the previous month or the same month in the previous year);
- comparisons to selected user groups (e.g. households in the same building/street). The comparisons with similar households enable customers to easily understand whether their consumption is low or high. Benchmarking makes possible to rank energy performance in a way similar to that of the efficiency of home appliances.

With billing information sometimes “more” is “less”. Occupants need advice easy to understand and feasible to put in practice. Consumers are not always motivated only by saving money, ecological reasons and social norms can be sometimes more important.

The well-being aspect of informative energy bill includes the sense of satisfaction from personal improvement, and improvement against other people behaviour, individually or as a group, depending on the benchmark provided. Tips would provide respondents with ideas about how they could conserve both energy and money. Smart meters alone would not deliver significant changes in consumer behaviour on their own, but they do constitute an essential part of wider behaviour change programmes, as they provide information necessary for more informed decision-making on energy use.

The key is to provide householders with more informative bills on how much energy they use and how much it is costing them, either in monetary or environmental terms. Indirect feedback like this could reduce energy consumption by 5-10% (Barbu et al. 2013).

Pros	Cons
It enables tenants to receive indirect feedback on their energy consumption, tips to save energy, advices on behaviour change and the impact of such changes on the energy consumption. It is a key measure in case smart meters are not installed. However, if they are operating, informative energy bill can represent a complementary feedback to the direct one resulting from the smart meter readings done by the occupants.	Making the energy bill more informative requires an initial effort to change the current bill layout, to make new calculations starting from the data available. Personalised tips to occupants require skills in the energy field that housing providers not always have. Therefore, cooperation with other public or private actors is necessary, as well as the appointment of an energy behaviour manager. High resolution data are not always available.

PS09 | Energy behaviour manager

Actors to be involved

- → Local authorities
- → Housing providers
- → ESCos and other private actors

Main features

The energy behaviour manager is a new professional figure that public and private organisations could engage and add to their staff in order to be able to deal with the impact on energy consumption caused by household behaviour.

The expert is expected to provide innovative ways to include considerations on behaviour into the strategies and measures to be implemented, and to provide an expertise currently missing. In fact, energy managers, mandatory by law for local public administrations with more than 10,000 inhabitants, do not necessarily have expertise on occupant behaviour and tools to assess it. However, this compulsory activity is scarcely implemented (Caputo and Pasetti 2015).

In the municipality context, the energy behaviour manager can ensure that both the energy and planning tools are designed to take into consideration the impact of user behaviour. For instance, he/she should be responsible to design behaviour awareness campaigns, to set-up the behavioural credits scheme (PS06), to coordinate the activities of the energy behaviour point (PS05) and to design the policy instruments to tackle energy poverty through behaviour change initiatives.

Housing providers can also benefit from the integration of the energy behaviour manager expertise into their staff, since he/she will be fundamental to coordinate data collection (PS04), to coordinate the sustainable behaviour coach (PS10) in designing, delivering and analysing survey results on energy behaviour, to design the informative energy bill (PS08), and to provide support into the daily operations involving the tenants.

When it comes to private actors, it would be more than beneficial to add the energy behaviour manager to the staff of an ESCo, for example, since behaviour has been demonstrated to be a key component of the energy consumption, and to effectively save energy is important to be able to include dynamic simulations into the scenarios assessing the energy efficiency of selected measures.

Although it is out of the scope of this dissertation, the energy behaviour manager can also have the important role of raising awareness among occupants in the office buildings he/she works, since user behaviour is an issue to be investigated and tackled not only at household level, but also in the work environment.

Pros	Cons
New skills to public and private actors to properly manage the impact of occupant behaviour at organisational level Complementary to the energy manager expertise, making the measures to save energy more effective	Lack of skills to properly address this role

PS10 | Sustainable behaviour coach

Actors to be involved

- → Public housing providers
- → Tenants

Main features

The sustainable behaviour coach is a new professional figure that should be integrated in the public housing provider staff to support behavioural change with a very pragmatic approach. He/she should be coordinated by the energy behaviour manager (PS09) in order to facilitate the communication with tenants to help households not only to achieve the overall behavioural campaign targets, but mostly to set their own targets to change behaviour and normalising it.

Coaching programmes can be phone or social media-based services aimed at intensifying participation in energy conservation, for normalising behaviour, and forming a basis of social marketing strategies.

Among the sustainable behaviour coach responsibilities, there are:

- identifying the barriers to engage households into sustainable behaviours through focus groups, online discussion boards and surveys;
- designing a strategic approach that integrates behaviour change tools, appropriate messaging and graphics;
- launching media advertising, promotions, announcement letter, to make explicit the willing of the public housing providers to commit to the programme. Lack of trust is a tangible barrier in Italian public housing stock (Santangelo and Tondelli 2017c);
- delivering educational materials, which should be brief and easy to understand;
- designing and delivering feedback/progress letters followed by coaching phone calls whenever necessary.

Pros	Cons
He/she will be the main referee for the tenants in the behaviour change campaign, supporting the public housing associations to provide an effective service.	Lack of trust: pro-environmental behaviour is likely to be considered if information and education measures come from credible, trustworthy sources.

7.4.3 Description of benefits

According to the International Energy Agency, energy efficiency can be referred as the hidden fuel, since it is measured as a negative value (i.e. the energy not consumed or energy cost saved), and its benefits are to some extent intangible, threatened by uncertainties related to consumer behaviour (OECD/IEA 2014). Energy efficiency investments are mainly driven by the need of lowering energy demand and delivering energy cost savings. However, evidence from research is increasingly demonstrating that reducing energy costs and demand are only two among the multiple benefits that such investments can introduce. Some co-benefits may even deliver two or three times more value than the energy demand reduction (OECD/IEA 2014).
Although energy efficiency experts and policy-makers are aware to a certain degree that improving energy efficiency generates broader impact than cost savings and reduced environmental impact, they are certainly not fully aware of the household behaviour impact on energy building consumption, whether the housing stock is energy efficient or not. Hence, this section focuses on the description of multiple benefits that can be delivered through the introduction of the proposed solutions in section 7.4.2, to tackle consumer behaviour awareness and behaviour change campaigns. Some of them are more tangible and easier to assess than others, in particular the social benefits, which are more likely to be only qualitative quantified. They are classified in Figure 7.8.

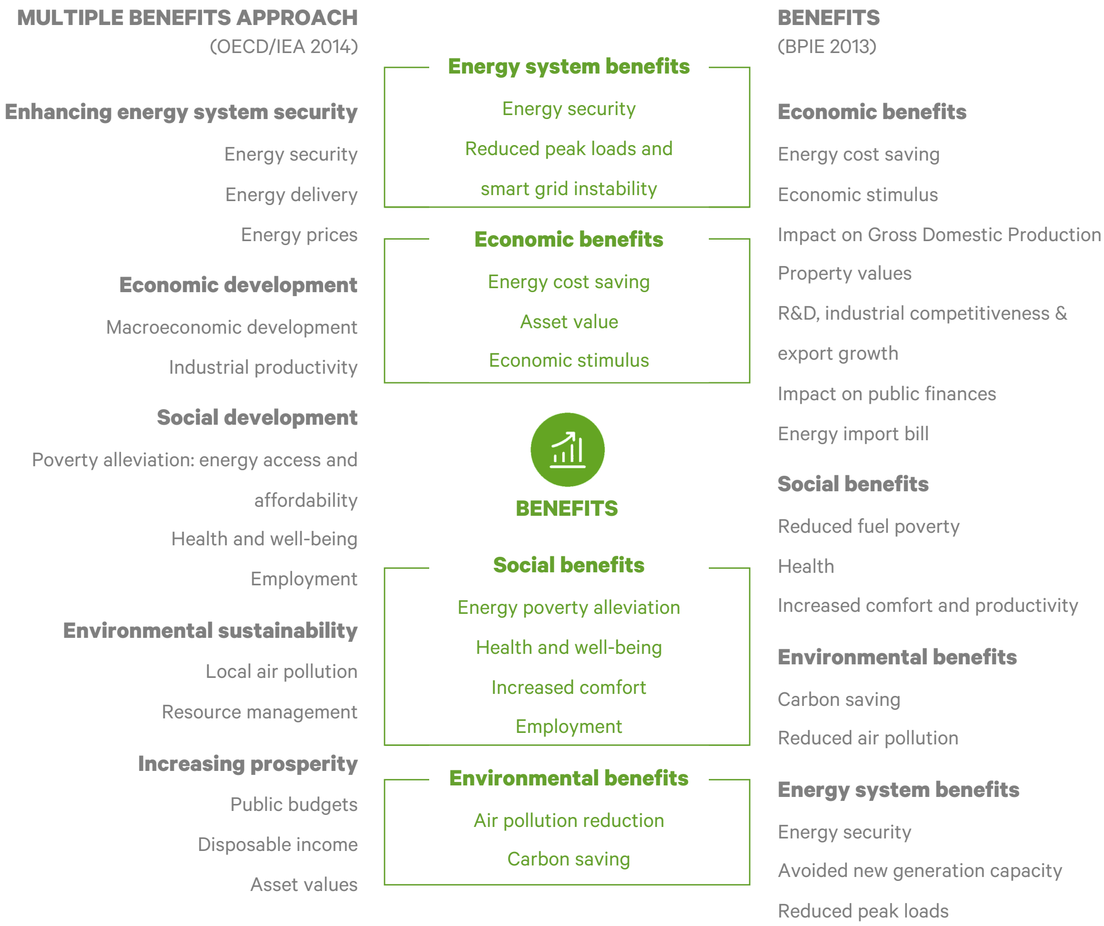
The *energy system benefits* are the ones related to the energy system characteristics in terms of energy production, distribution and consumption. Raising awareness among consumers, providing information and improving professional skills can facilitate the effectiveness of energy efficiency improvements in delivering the expected benefits. In fact, without tackling consumer behaviour, reduced energy demand cannot be ensured due to the rebound effect (Haas et al. 1998; Jenkins et al. 2011; Guerra-Santin 2013; Ben and Steemers 2014; Guerassimoff and Thomas 2015; Santangelo and Tondelli 2017a), therefore resulting in exposing energy security and reduced peak loads at risk. Tackling energy behaviour while improving energy efficiency in housing sector can improve energy security in terms of fuel availability, accessibility, affordability ad acceptability (OECD/IEA 2014).
To help consumers to lower their energy consumption, with clear billing information and smart energy meters, is one of the five long-term measures promoted by the European Commission

Energy Security Strategy released in 2014 (European Commission 2014). Other benefits as avoided new generation capacity and energy delivery, respectively identified by BPIE (2013) and OECD/IEA (2014) have been here included in the energy security benefit.

Reduced peak loads is another positive consequence of improving energy awareness among households and delivering feedback towards behaviour change. Measures reducing energy demand save a disproportionate amount at times of high demand (i.e. through reduced winter heating and summer cooling) (BPIE 2013).

Smart grid stability is affected by consumer behaviour and the information available to act (Juelsgaard et al. 2013). To actively involve users and stakeholders in smart grid projects has been demonstrated to have positive effects towards the implementation of a low-carbon economy (Verbong et al. 2013).

Figure 7.8: Classification of consumer behaviour strategy multiple benefits



Source: author's elaboration

Economic benefits, in particular energy cost savings due to reduced energy demand and lower energy consumption, are the most evident results of energy efficiency measures addressing consumer behaviour. Behaviour change can lead to the effective implementation of deep renovation scenarios, estimated by BPIE analysis (BPIE 2011) in 1,300 billion euro (present value) of energy cost savings. New professional skills can also deliver energy efficient measures to increase the building asset value and to reduce the maintenance costs, which represents one of the highest concerns for public housing providers.

More efficient building energy performance has also consequences for the market value for private buildings, and for the social and economic value for public building stock. Addressing consumer behaviour in building renovation process will also be an economic stimulus, resulting in an increase of the total investment for energy efficiency through new jobs and new skills development. Macroeconomic development, industrial productivity, public budgets (OECD/IEA 2014), and impact on GDP, impact on public finances, R&D, industrial competitiveness and export growth, and energy import bill (BPIE 2013) also fall into the economic benefits category.

When it comes to the public housing stock, energy poverty alleviation is one of the most important *social benefits* of increasing energy efficiency towards reducing energy consumption, as resulted from the investigation in Chapter 5. Improving the energy efficiency of homes has been recognised as vital to achieve energy affordability for low income households (BPIE 2013). The provision of information and feedback can lead to behaviour changes, which are fundamental to achieve building deep renovation and to reduce energy bills. In fact, in both developed and developing countries, the low-income households are more likely to live in inefficient housing stock and less able to afford the up-front cost of energy efficiency goods and services, thus, facing higher energy costs than others (OECD/IEA 2014).

Health and well-being benefits resulting from the improvement of indoor environment, as a consequence of implementing energy efficiency measures, are consistently strongest among vulnerable groups (OECD/IEA 2014). Health benefits from energy retrofits could be worth more than the value of energy savings. A case study in New Zeeland has demonstrated that programmes for energy efficiency retrofitting of low-income housing can deliver the greatest benefits, with health improvements representing as much as 75% of the total return on the investment for these interventions (Grimes et al. 2011).

Increased comfort is also a social benefit. However, it can also turn to higher energy consumption than expected if no awareness programme are coupled with energy retrofit one. Investments in energy efficiency and behaviour change campaigns can also lead to an increase in employment rates both directly and indirectly (i.e. through an expenditure shift effect) (OECD/IEA 2014), generating a variety of social benefits in addition to the economic ones. The increase of disposable income (OECD/IEA 2014) is also grouped among the social benefits.

Lastly, consumer behaviour is one of the responsible factors of delivering *environmental benefits* such as reduction of air pollution and carbon emission reduction, resulting in environmental improvements only possible if supported by pro-environmental behaviours.

7.5 Beyond public housing: recommendations for the residential sector as a whole

As already specified at the very beginning of the dissertation (Chapter 1), despite the limited size of the Italian public housing stock, it has been investigated in this research due to the following favourable conditions:

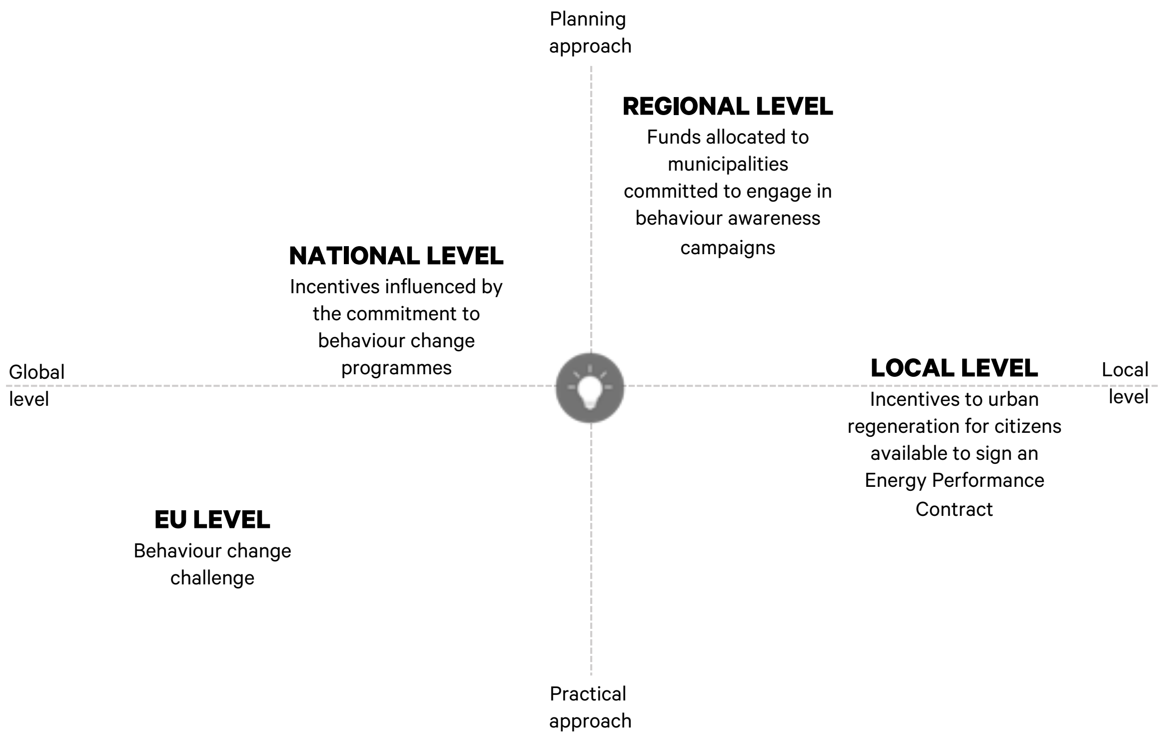
- the housing is publicly owned by either the municipalities, or the housing providers, while the latter have an exclusive role in public housing stock management. Therefore, decisions about renovation requires to come to an agreement between a very limited number of actors;
- public housing stock is owned by local authorities, while the regulation on this sector is a regional subject, and, across Italy, regional regulations and managing and allocation procedures among housing providers are similar, resulting in a high replication potential;
- multi-dwelling building is a building typology representative not only for the Italian public residential stock, but also for the Italian housing sector in general, therefore, the simulation results provided in Chapter 6 can be considered exploitable also for the private sector;
- while in the owner-occupied sector cost-savings are expected to be the main stimulus for building energy-efficient renovation, the interventions within the public housing stock not only have an energy-saving value, but also contribute to achieve social and economic co-benefits, to avoid stigmatisation, social segregation and to mitigate energy poverty.

Nevertheless, consumer behaviour is certainly not only an issue for the social housing sector. Household income has proven to be an important factor in determining energy use (see Chapter 3), but scholars investigating the determinants of consumer behaviour have found controversial results on the income as a behaviour determinant (Guerra-Santin et al. 2009; Romero et al. 2013; Wei et al. 2014; Schaffrin and Reibling 2015). Therefore, user behaviour is worth to be investigated in the social housing sector as well as in the private one, regardless the housing tenure and the public or private nature of the housing landlords. Several studies on occupant behaviour and energy consumption have been conducted in the social housing stock, due to either the size of the sector within the national context (Gupta and Chandiwala 2010; Crilly et al. 2012; Huebner et al. 2013; Brown et al. 2014; Hayles and Dean 2015; Guerra-Santin et al. 2016), or specific renovation programme opportunities (Elsharkawy and Rutherford 2015; Jones et al. 2017; DellaValle et al. 2018). However, none of them concluded that the focus on social housing has represented a limitation to the soundness of the results. On the contrary, the focus on social housing has been found to be beneficial to test a methodology to identify a range of context-specific variables that can be then used as levers to align behaviour to retrofit interventions (DellaValle et al. 2018).

In this section, considerations on how to embed energy behaviour in current policy instruments are, therefore, extended to the residential sector as a whole. Practical recommendations are provided according to four main groups (Figure 7.9), which are the four territorial governance levels analysed in Chapter 2, by considering the context (i.e. global vs local) and the type of approach (i.e. planning vs practical).
As framed in Chapter 2, the European Commission has no right to regulate spatial planning, since it is a subject directly managed at Member State level. However, consumer behaviour is a topic which has started to gain increasing attention at the European level, and energy policies and directives have recognised the role of human factor in achieving energy savings in the building sector. Therefore, the main recommendation is to contribute by adopting a practical approach, directly promoting activities aimed at engaging citizens in saving energy through behaviour, raising awareness among the role of behaviour to effectively implement energy efficiency, and creating a strong network of actors operating in this field. The "Behaviour Change Challenge" could be a proposal for new measures to implement. Similar initiatives have already

been promoted at EU level in the field of mobility, as, for instance, the European Cycling Challenge[2], which has been a successful competition since 2012 among European cities, won by the city which runs by bike the longest distance thanks to the registered users activating the GPS during their rides. The "Behaviour Change Challenge" could similarly operate on yearly basis by engaging households in providing information on their current energy consumption and behaviour, to be compared either with data on energy consumption of the previous year, or through benchmarking with users living in dwellings with similar characteristics. Energy savings due to behaviour should be normalised taking into consideration the different climate conditions of EU regions. Within the same cities, teams could be created aimed at engaging the users at community level in addition to the individual level. Indeed, the commitment at community level is expected to last longer than the life time of the EU public campaign, resulting in delivering long-lasting benefits.

Figure 7.9: Positioning of recommendations in relation to type of approach and level of influence



Source: author's elaboration

[2] http://www.cyclingchallenge.eu/

At Italian national level, the main recommendation is to rethink the current tax deduction scheme by including considerations on user behaviour. At present, taxpayers paying personal or business income taxes are entitled to claim back certain percentages of total building renovation costs, according to the type of interventions and degree of energy efficiency implemented. On the contrary, in the new recommended scenario, incentives are influenced by the willing of citizens to opt in an occupant behaviour change programme. They are not distributed anymore according to the saving potential of renovation measures installed, but according to the effective energy consumption, through data and behaviour analysis, where pre- and post-renovation occupancy evaluations should be performed to build the framework for assessing the energy savings. Different percentages of incentives can be associated to different abilities to reduce the gap between expected and actual energy consumption.

In addition, private actors such as energy utilities, which own an enormous amount of data, today mostly used for marketing uses only, should be increasingly forced to promote social aims, such as tackling energy poverty through initiatives addressing behaviour. In the framework of the Italian Energy Efficiency Obligation Schemes, implementing Article 7 of Directive 2012/27/EU on Energy Efficiency (MISE 2013), energy companies having more than 50,000 end users have the obligation to generate each year a certain amount of savings or, alternatively, to purchase an equivalent amount of White Certificates[3]. However, the only measures included towards energy savings through behaviour awareness and change are specific incentives for energy audit and energy certification, as these are currently considered to be important awareness-raising tools able to drive household choices and daily behaviour. On the contrary, other EU countries (i.e. UK, France, Ireland, Austria and Greece) have chosen to adopt a more far-seeing approach in their Energy Efficiency Obligation Schemes, including specific provisions with a social aim that can be either incentives or mandatory actions addressed to households meeting eligibility criteria (e.g. social housing tenants living in E to G energy class, households meeting certain income level) (Atee 2017). Utilities have potentially at their disposal the necessary data and means to identify energy poverty among their clients and effectively address it by fulfilling in

[3] White certificates, also known as energy efficiency securities, are tradable securities certifying the achievement of energy savings in the final uses of energy through energy efficiency measures and projects. The white certificates mechanism is based on the creation of an obligated market for these certificates. The obligation scheme was introduced by the legislative decrees that liberalised the electricity and the natural gas markets (Ministerial Decrees of 20 July 2004), placing Italy at the forefront in Europe and worldwide and yielding positive results over time especially in terms of cost/effectiveness (MISE 2013).

this way the energy efficiency obligation. The way in which energy company relationships with their customers are changing is relevant to the future of this kind of policy (Fawcett et al. 2018). Therefore, the main recommendation for Italy is to does not miss the opportunity to persuade the obligated parties to contribute more and more to the social aim of energy efficiency by addressing occupant behaviour.

At regional level, funding schemes are usually subject to the compliance of local initiatives with regional goals. In the field of urban regeneration and energy efficiency, funds – or additional funds – might be distributed to municipalities which commit themselves to implement activities towards behaviour change, and to sign agreements with public and private actors aimed at engaging citizens in behaviour awareness initiatives. When it comes to private actors – either ESCos, private building managers representing several homeowners, or private landlords – who seek to improve the energy performance of the existing building stock, implementing some of the proposed measures for public housing (see section 7.4.2) as, for instance, PS07 Energy behaviour quiz and PS08 Informative energy bill, could lead to an extra score to receive financial or non-financial incentives. In fact, both public and private initiatives which contribute to increase behaviour awareness of citizens and to collect information and data to improve energy household consumption and behaviour should be encouraged with tangible rewards. The Italian Regions could, therefore, contribute to this aim by allocating part of the European Regional Development Funds to initiatives addressing behaviour, and, even more important, working to strongly embed this issue into the regional policy instrument for the next programming period. When it comes to urban planning regional regulation, as framed in Chapter 2 for the Emilia-Romagna Region, to promote urban regeneration and to enhance the urban and built environment quality are already among the most ambitious goals of the regional legislation. To pursue these objectives by prioritising planning strategies able to embed the human factor, in addition to technology, could lead to a disruptive social innovation change, which is what urban regeneration process might need to move from being an opportunity to be the solution.
In this framework, the LR 24/2017 Emilia-Romagna Regional legislation on the territory protection and use, just entered into force at the beginning of 2018, can provide new opportunities. Indeed, it innovates the traditional methods for both planning and implementing territorial transformations, and it foresees a flexible and negotiated urban regeneration model

based on densification, demolition and reconstruction, aimed at improving the performance of buildings and at the simultaneous redesign of open spaces, with the goal of raising the resilience of the city. Such transformations require new models and integrated tools for planning, implementation, management and monitoring of regenerative interventions, able to integrate the interventions in a dynamic and evolving urban context. Law n.24/17 explicitly requires the municipalities to build the regeneration strategies for their territories basing on an accurate analysis of the state of the art, focusing in particular on seismic safety and energy performances of the buildings. Information and dataset on actual energy consumption and household behaviour would therefore improve the analysis of the state of the art (i.e. *quadro conoscitivo*) for what concerns energy efficiency, enriching the understanding about the current situation and helping in prioritising the regenerative measures.

Coming to the local level, the main recommendation is to embed household behaviour into urban planning tools, to contribute to make energy efficiency goal more horizontal and central, rather than a side effect. Scholars have argued that, for being successful, the challenge of planning tools and regulations is not only to address GHG emission control and energy savings in buildings, but also to promote energy efficiency as a cross-cutting and integrated issue addressing all the relevant aspects of sustainable urban development (Conticelli et al. 2017). When it comes to the Bologna case study (Table 7.8), the General Urban Plan *(Piano Urbanistico Generale – PUG)*, the new local planning tool foreseen by the LR 24/2017, together with the Operational Agreements between the local authorities and private parties in order to define each development, will have to focus on building seismic and energy performances as the key issues to be addressed by urban regeneration. The General Urban Plan (PUG) is the main plan establishing the municipal competences on territorial use and transformation, specifically focusing on urban regeneration and land-use reduction. Information on user behaviour and data on actual energy consumption could be aimed at improving the analysis of the state of the art for what concerns energy efficiency, enriching the understanding about the state of the art and helping in prioritising the regenerative measures. Among the elements which are imbedded in the PUG, the Strategy for Urban and Ecological-Environmental Quality is aimed at setting performance indicators and sustainability requirements to which interventions should be compliant with. It also identifies and spatially localised the actions that are needed to the strategy objectives. It could therefore benefit of a deepen knowledge on users' behaviour so to be able to set targets and to define incentives basing on the actual consumes thus making the urban strategies more effective.

Table 7.8: Suggestions to embed behaviour into urban planning tools. The Bologna case study.

Planning tools	**Main objectives**	**Suggestions to embed behaviour**
General Urban Plan *(Piano Urbanistico Generale - PUG)*	It establishes the municipal competences on territorial use and transformation, with a focus on urban regeneration of existing assets	Information on user behaviour and data on actual energy consumption would improve the framework for the state of the art *(quadro conoscitivo)* for what concerns energy efficiency, enriching the understanding about the state of the art and helping in prioritising the regenerative measures.
Strategy for urban and ecological-environmental quality *(Strategia per la qualità urbana ed ecologico-ambientale)*	The strategy is part of the PUG. It is aimed at set performance indicators and sustainability requirements to which interventions should be compliant with. It also identifies and spatially localised the actions that are needed to implement the strategy objectives	Engaging households in delivering energy savings could be among the actions that allow to reach the performance levels set by the strategy. The non-implementation of actions addressing behaviour should be also considered in the monitoring framework, to avoid overestimating the results of energy efficiency measures
Operational agreements (Accordi Operativi)	They specify the transformations and new developments foreseen in the PUG. They are the results of agreements on the implementation of urban transformations between public and private partnerships	Incentives in terms of reduction of construction burden, or other sort of bonuses could be foreseen for private developers who include deprived and low efficient built areas to their scope of actions. Public lump sums could be also delivered to private developers to launch the behaviour awareness campaign as an integral part of urban regeneration projects. Fiscal/economic incentives to private citizens could be conditioned to their availability to opt in a behavioural awareness campaign at municipal level

Source: author's elaboration

Indeed, as the results of this dissertation have shown, incentives in exchange for higher environmental performances, already foreseen in the legislation, should be calculated on actual consumption, rather than predicted one, to be more effective and to better reflect the actual target that the local administration wants to pursue. The increased knowledge coming from actual energy consumption data and behaviour patterns should be used to drive the urban regeneration strategies, promoting transformations in some portion of the existing city more problematic than others, targeted to reach an energy balance at neighbourhood or district level over the long term.

Engaging households in delivering energy savings is an action that could allow to reach the performance levels set by the strategy. Moreover, the non-implementation of actions addressing behaviour should be also considered in the monitoring framework, to avoid overestimating the results of energy efficiency measures.
In the framework of the LR 24/20017, the Operational Agreements are specific tools that complement the PUG. They are aimed at further specify the transformations and new developments foreseen in the PUG, as results of agreements on the implementation of urban transformations between public and private partnerships. Recommendations to embed into the operational agreements considerations on behaviour can take different forms. Incentives in terms of reduction of construction burden, or other sort of bonuses could be foreseen for private developers who develop behaviour awareness campaign within deprived and low efficient built areas. In addition, public lump sums could be also delivered to private developers to launch the behaviour awareness campaign as an integral part of urban regeneration projects. Moreover, fiscal/economic incentives to private citizens could be conditioned to their availability to opt in a behavioural awareness campaign at municipal level. Indeed, when it comes to the role of homeowners, the research results may suggest that fiscal incentives to implement energy efficiency measures should be given only to citizens available to sign an Energy Performance Contract (EPC) for a certain timeframe with the Municipality. By signing the EPC, the individuals commit themselves to participate to a behaviour awareness campaign, to let energy utilities or ESCos monitoring their energy consumption, to reach certain energy saving targets, and to pay an extra cost in case the energy performance is disattended.

7.6 Directions for future research

A major driver behind energy efficiency investments is the capacity to lower energy demand and to deliver energy cost savings. However, as remarked by the International Energy Agency (OECD/IEA 2014), only a widespread adoption of the multiple benefits approach could stimulate higher uptake of programmes and measures, ultimately shifting energy efficiency from an asset measured as a negative value (e.g. the energy not consumed, or the energy costs avoided) to a major opportunity. While energy efficiency experts and, to some extent policy-makers, are aware that energy efficiency generates broader impacts, these impacts have not been systematically assessed. To better inform the policy decision-making process, further research should focus on the development of more robust methods for measuring multiple benefits, so that the important social and economic co-benefits might be better integrated into energy policy instruments.

Presenting the evidence of user behaviour impact on energy consumption, the mechanisms by which occupant behaviour can be measured, and how behaviour can be integrated into policy instruments, is expected to support policy-makers in their efforts to deliver energy efficiency in urban areas as a whole. However, in order to be effective, the proposed solutions and recommendations presented in this chapter need to be further developed and assessed, considering both qualitative and quantitative approaches. To make explicit the applicability of one (or more than one) proposed solutions, the interrelations among actors and the soundness of the benefits, a case-study based methodology should be developed, while occupant behaviour and energy consumption should be investigated prior and after renovation.

The availability of energy data and information on behaviour and attitude towards energy efficiency has been found to be a strategic component for investigating occupant behaviour and behaviour change. It has emerged throughout the whole dissertation, and it has been one of the main limitations. Therefore, one of the most urgent proposed actions regards the setting of a residential building performance database to be combined with results from behavioural survey to be coordinated at national level. As framed in the proposed solution PS04, for example, this activity might start from the public housing sector, where the methodology for data collection and database management could be tested and fine-tuned, to be then extended to the whole residential sector. Indeed, building a knowledge baseline for the development of strategies and tools to renovate the housing stock, and for addressing the consumption behaviour impact on energy savings, constitutes the driver to show to private investors the high replication potential of implementing the regeneration of the existing cities. As long as data would be fragmented and co-benefits difficult to assess, the occasional interventions will not turn to a systematic approach. Being urban planning a discipline able to hold different interests and multiple territorial needs, it is expected to be a key contributor to manage the complexity of such change.

7.7 Key research findings

- Researches have started questioning the effectiveness of retrofitting policies, since they are mainly based on theoretical assumptions and do not accommodate user energy practices. In order to achieve real energy reduction, policy instruments need to include considerations on the actual use of buildings, rather than the theoretical consumption.
- Despite the central role of users to lower energy consumption has been increasingly recognised, more recently in regulatory frameworks and earlier in research field, evidence from research has showed that so far households have not been sufficiently motivated or supported in undertaking changes, and they are still not enough aware of the impact of their lifestyles and decisions on energy consumption.
- A methodology based on multi-criteria assessment of different strategies by applying the Analytic Hierarchy Process (AHP) has been designed, to support policy-makers on their decisions concerning the reduction of energy consumption in buildings. The methodology explicitly incorporates the impact of user behaviour into the assessment of planning strategies and renovation measures. Four criteria and seven measures have been identified. Results show the two measures that more than the other considered rely on user behaviour, have resulted to be the top alternatives by three out of four criteria. A sensitivity analysis to define five possible scenarios that includes different combination of the selected criteria has confirmed the urgency and convenience to implement those two measures prior to the other alternatives.

- Two main policy recommendations can be drawn. On the one hand, the measures proposed to address behaviour are intended as complementary to the others, and first to implement to raise awareness and drive behaviour towards more energy sustainable practices, but they certainly cannot reach the goal if implemented alone. Information, awareness campaigns, feedback and other informative policy instruments should be integrated by other measures addressing the physical renovation. On the other hand, public authorities are seeking for services, rather than products to increase the renovation rate of the housing stock. Technologies should be only one aspects of a complex system where spatial organization, consumer behaviour and technologies interact with each other, determining the actual and future pattern of energy consumption. Better integrated complementary approaches to both the technical and social energy transitions are required.
- The focus on the Italian public housing sector in terms of actors involved, barriers to the implementation of renovation of the public housing stock and the identification of drivers to overcome the barriers is presented. No one-size-fits-all solution is possible due to peculiarities across household and building characteristics. Therefore, several measures are suggested to demonstrate how household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments are also highlighted.
- The extreme fragmentation of housing demand, the increasing energy poverty of tenants living in public buildings, the overall decline of public spending on the housing sector, and the ongoing redefinition of the role of public authorities are only some of the elements describing the Italian housing issue. New conceptual and methodological advancements are needed in order to tackle the housing issue, both from the point of view of scholars and of decision-makers, where the provision of information, awareness raising and new skills can be the driver not only for the renovation of the public housing stock, but also for a new housing policy based on providing housing as a services, rather than just an asset.
- In conclusion, recommendations to deliver such measures addressing behaviour awareness and information to households of the private residential sector, including homeowners, are also presented, aiming at showing the replication potential of a new governance targeting environmental awareness, rather than just technical implementation of energy efficiency measures, and the planning instruments to work on in order to deliver such change.

References

Achtnicht M, Madlener R (2014) Factors influencing German house owners' preferences on energy retrofits. Energy Policy 68:254–263. doi: 10.1016/j.enpol.2014.01.006

Atee (2017) Snapshot of Energy Efficiency Obligations schemes in Europe: 2017 update. http://atee.fr/sites/default/files/part_6-_2017_snapshot_of_eeos_in_europe.pdf

Barbu A-D, Griffiths N, Morton G (2013) Achieving energy efficiency through behavioural change. what does it take?, EEA Technical Report No 5/2013

Bedir M (2017) Occupant behavior and energy consumption in dwellings: An analysis of behavioral models and actual energy consumption in the dutch housing stock. Delft University of Technology

Ben H, Steemers K (2014) Energy retrofit and occupant behaviour in protected housing: A case study of the Brunswick Centre in London. Energy and Buildings 80:120–130. doi: 10.1016/j.enbuild.2014.05.019

BPIE (2011) Europe's Buildings Under the Microscope

BPIE (2013) A Guide to Developing Strategies For Building Energy Renovation

Brown P, Swan W, Chahal S (2014) Retrofitting social housing: Reflections by tenants on adopting and living with retrofit technology. Energy Efficiency 7:641–653. doi: 10.1007/s12053-013-9245-3

Caputo P, Pasetti G (2017) Boosting the energy renovation rate of the private building stock in Italy: Policies and innovative GIS-based tools. Sustainable Cities and Society 34:394–404. doi: 10.1016/j.scs.2017.07.002

Caputo P, Pasetti G (2015) Overcoming the inertia of building energy retrofit at municipal level: The Italian challenge. Sustainable Cities and Society 15:120–134. doi: 10.1016/j.scs.2015.01.001

Conticelli E, Proli S, Tondelli S (2017) Integrating energy efficiency and urban densification policies: Two Italian case studies. Energy and Buildings 155:308–323. doi: 10.1016/j.enbuild.2017.09.036

Copiello S (2015) Achieving affordable housing through energy efficiency strategy. Energy Policy 85:288–298. doi: 10.1016/j.enpol.2015.06.017

Crilly M, Lemon M, Wright A, et al (2012) Retrofitting Homes for Energy Efficiency: An Integrated Approach to Innovation in the Low-Carbon Overhaul of UK Social Housing. Energy & Environment 23:1027–1056. doi: 10.1260/0958-305X.23.6-7.1027

D'Oca S, Hong T, Langevin J (2018) The human dimensions of energy use in buildings: A review. Renewable and Sustainable Energy Reviews 81:731–742. doi: 10.1016/j.rser.2017.08.019

DellaValle N, Bisello A, Balest J (2018) In search of behavioural and social levers for effective social housing retrofit programs. Energy and Buildings 177:91–96. doi: 10.1016/j.enbuild.2018.05.002

Economidou M (2014) Overcoming the Split Incentive Barrier in the Building Sector. Workshop Summary

Elsharkawy H, Rutherford P (2015) Retrofitting social housing in the UK: Home energy use and performance in a pre-Community Energy Saving Programme (CESP). Energy and Buildings 88:25–33. doi: 10.1016/j.enbuild.2014.11.045

European Commission (2014) Energy Security Strategy https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/energy-security-strategy

European Union (2017) EU energy in figures. Statistical Pocketbook 2017

Fawcett T, Rosenow J, Bertoldi P (2018) Energy efficiency obligation schemes: their future in the EU. Energy Efficiency. doi: 10.1007/s12053-018-9657-1

Frederiks ER, Stenner K, Hobman E V. (2015) Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renewable and Sustainable Energy Reviews 41:1385–1394. doi: 10.1016/j.rser.2014.09.026

Grimes A, Denne T, Howden-Chapman P, Arnold R, Telfar-Barnard L, Preval N, Young C (2011) Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Program, report for the Ministry of Economic Development, Motu Economic and Public Policy Research, Wellington

Governa F, Saccomani S (2009) Housing and Urban Regeneration Experiences and Critical Remarks Dealing with Turin. European Journal of Housing Policy 9:391–410. doi: 10.1080/14616710903357193

Guerassimoff G, Thomas J (2015) Enhancing energy efficiency and technical and marketing tools to change people's habits in the long-term. Energy and Buildings 104:14–24. doi: 10.1016/j.enbuild.2015.06.080

Guerra-Santin O (2013) Occupant behaviour in energy efficient dwellings: Evidence of a rebound effect. Journal of Housing and the Built Environment 28:311–327. doi: 10.1007/s10901-012-9297-2

Guerra-Santin O, Boess S, Konstantinou T, Silvester S (2016) Renovation of social housing in the Netherlands. User research approach. In: PLEA 2016

Guerra-Santin O, Itard L (2010) Occupants' behaviour: determinants and effects on residential heating consumption. Building Research & Information 38:318–338. doi: 10.1080/09613211003661074

Guerra-Santin O, Itard L, Visscher H (2009) The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock. Energy and Buildings 41:1223–1232. doi: 10.1016/j.enbuild.2009.07.002

Gupta R, Chandiwala S (2010) Understanding occupants: feedback techniques for large-scale low-carbon domestic refurbishments. Building Research & Information 38:530–548. doi: 10.1080/09613218.2010.495216

Gyberg P, Palm J (2009) Influencing households' energy behaviour-how is this done and on what premises? Energy Policy 37:2807–2813. doi: 10.1016/j.enpol.2009.03.043

Haas R, Auer H, Biermayr P (1998) The impact of consumer behavior on residential energy demand for space heating. Energy and Buildings 27:195–205. doi: 10.1016/S0378-7788(97)00034-0

Hayles CS, Dean M (2015) Social housing tenants, Climate Change and sustainable living: A study of awareness, behaviours and willingness to adapt. Sustainable Cities and Society 17:35–45. doi: 10.1016/j.scs.2015.03.007

Huebner GM, Cooper J, Jones K (2013) Domestic energy consumption - What role do comfort, habit, and knowledge about the heating system play? Energy and Buildings 66:626–636. doi: 10.1016/j.enbuild.2013.07.043

Jain RK, Taylor JE, Culligan PJ (2013) Investigating the impact eco-feedback information representation has on building occupant energy consumption behavior and savings. Energy and Buildings 64:408–414. doi: 10.1016/j.enbuild.2013.05.011

Jain RK, Taylor JE, Peschiera G (2012) Assessing eco-feedback interface usage and design to drive energy efficiency in buildings. Energy and Buildings 48:8–17. doi: 10.1016/j.enbuild.2011.12.033

Janda KB (2009) Buildings Don' t Use Energy: People Do. In: PLEA 2009 - 26th Conference on Passive and Low Energy Architecture, Quebec City Canada, 22-24 June 2009

Jenkins D, Middlemiss L, Pharoah R (2011) A study of fuel poverty and lowcarbon synergies in social housing

Jenkins K, McCauley D, Heffron R, et al (2016) Energy justice: A conceptual review. Energy Research & Social Science 11:174–182. doi: 10.1016/J.ERSS.2015.10.004

Jones R V., Fuertes A, Goodhew S, De Wilde P (2017) The Actual Performance of Aspiring Low Energy Social Houses in the United Kingdom. Energy Procedia 105:2181–2186. doi: 10.1016/j.egypro.2017.03.615

Juelsgaard M, Andersen P, Wisniewski R (2013) Stability concerns for indirect consumer control in smart grids. Proceedings of European Control Conference (ECC)

Karvonen A (2013) Towards systemic domestic retrofit: A social practices approach. Building Research and Information 41:563–574. doi: 10.1080/09613218.2013.805298

MISE (2013) Applicazione dell'articolo 7 della direttiva 2012/27/UE sui regimi obbligatori di efficienza energetica. Notifica del metodo

MISE (2017) Strategia Energetica Nazionale (SEN)

OECD/IEA (2014) Capturing the Multiple Benefits of Energy Efficiency

Papa R, Gargiulo C, Zucaro F, et al (2016) Energy and Climate Change Polices in Europe: Overview and Selected Examples from a Spatial Planning Perspective. In: Papa R, Fistola R (eds) Smart Energy in the Smart City, Green Ener. Springer International Publishing Switzerland, pp 237–274

Pasetti G (2016) Stimulate Energy Renovation of the Building Stock: Policies and Tools At Municipal Scale. Politecnico di Milano

Proli S, Santangelo A, Tondelli S (2016) Efficienza energetica ed edilizia sociale: il programma Rig.ener.a, sfide e prospettive a Bologna. In: XIX Conferenza Nazionale SIU Cambiamenti. Responsabilità e strumenti per l'urbanistica al servizio del paese. Planum Publisher, Catania 16-18 giugno

Romero RA, Bojórquez G, Corral M, Gallegos R (2013) Energy and the occupant's thermal perception of low-income dwellings in hot-dry climate: Mexicali, México. Renewable Energy 49:267–270. doi: 10.1016/J.RENENE.2012.01.017

Santangelo A, Tondelli S (2017a) Occupant behaviour and building renovation of the social housing stock: Current and future challenges. Energy and Buildings 145:276–283. doi: 10.1016/j.enbuild.2017.04.019

Santangelo A, Tondelli S (2017b) Equità e qualità degli interventi di rigenerazione del patrimonio ERP: dallo studio del caso olandese, verso la definizione di un modus operandi. In: XX Conferenza Nazionale SIU URBANISTICA E/È AZIONE PUBBLICA. LA RESPONSABILITÀ DELLA PROPOSTA. Planum Publisher, Roma 12-14 giugno, pp 414–419

Santangelo A, Tondelli S (2017c) Urban regeneration and sustainable communities: reflecting on energy-related roles, attitudes and responsibilities. Urbanistica Informazioni 272:431–435

Santangelo A, Tondelli S (2018) Embedding energy user's behaviour into multi-criteria analysis: providing scenarios to policy-makers to design effective renovation strategies of the housing stock, in: Proceedings of 54th ISOCARP Congress Bodø, Norway, October 1-5, 2018, Cool planning: changing climate & our urban future, The Hague, 1414-1424

Santangelo A, Yan D, Feng X, Tondelli S (2018) Renovation strategies for the Italian public housing stock: Applying building energy simulation and occupant behaviour modelling to support decision-making process. Energy and Buildings 167:269–280. doi: 10.1016/j.enbuild.2018.02.028

Schaffrin A, Reibling N (2015) Household energy and climate mitigation policies: Investigating energy practices in the housing sector. Energy Policy 77:1–10. doi: 10.1016/j.enpol.2014.12.002

Tweed C (2013) Socio-technical issues in dwelling retrofit. Building Research and Information 41:551–562. doi: 10.1080/09613218.2013.815047

Verbong GPJ, Beemsterboer S, Sengers F (2013) Smart grids or smart users? Involving users in developing a low carbon electricity economy. Energy Policy 52:117–125. doi: 10.1016/J.ENPOL.2012.05.003

Wei S, Jones R, De Wilde P (2014) Driving factors for occupant-controlled space heating in residential buildings. Energy and Buildings 70:36–44. doi: 10.1016/j.enbuild.2013.11.001

Wilhite H, Ling R (1995) Measured energy savings from a more informative energy bill. Energy and Buildings 22:145–155. doi: 10.1016/0378-7788(94)00912-4

8. Conclusions

ENGLISH ABSTRACT

The overall aim of the research has been to contribute to the discussion about urban regeneration enhancement through the energy renovation of residential buildings. The specific aim has been to show, on the one side, the relevance of the occupant behaviour, at present seldomly included in the consideration of the measures to renovate the buildings; on the other side, the relationship among stakeholders involved in the renovation process, in order to suggest governance improvements to increase renovation process effectiveness. The main focus has been on the Italian context, where implementing energy efficiency through building renovation and urban regeneration is a major challenge. In particular, the public housing sector has been taken as case study.

The following sections present the conclusions and recommendations drawn from the various investigations conducted in the dissertation. Section 8.1 briefly recaps the aim, methodology and structure of the thesis. Sections 8.2 to 8.4 present the conclusions of each research question analysed separately. Section 8.5 discusses the main limitations throughout the work, in particular on data availability and recommendations to overcome the identified gaps. Recommendations for future research are presented in Section 8.6.

ABSTRACT IN ITALIANO

L'obiettivo generale della ricerca è stato quello di contribuire alla discussione sull'attuazione di processi di rigenerazione urbana attraverso la riqualificazione energetica degli edifici residenziali. L'obiettivo specifico è stato quello di mostrare, da un lato, la rilevanza del comportamento degli occupanti, attualmente difficilmente incluso nelle considerazioni sulle misure da adottare per riqualificare gli edifici; dall'altro, la relazione tra le parti interessate coinvolte nel processo di riqualificazione, al fine di suggerire l'adozione di nuove misure di governance per aumentare l'efficacia del processo. L'indagine si è concentrata sul contesto italiano, in cui l'efficienza energetica attraverso la riqualificazione degli edifici esistenti e la rigenerazione urbana sono tra le sfide più importanti. In particolare, il settore dell'edilizia residenziale pubblica è assunto come caso studio.

I paragrafi che seguono illustrano le conclusioni e le raccomandazioni a chiusura delle diverse indagini condotte. Il paragrafo 8.1 ripercorre brevemente le principali questioni, la metodologia applicata e la struttura della tesi. I paragrafi 8.2-8.4 presentano i risultati relativi a ciascun quesito di ricerca, che sono quindi presentati separatamente. Il paragrafo 8.5 discute i principali limiti del lavoro, in particolare relativi alla disponibilità dei dati e le raccomandazioni per superare le lacune individuate. Le raccomandazioni per le ricerche future sono infine presentate nell'ultimo paragrafo 8.6.

8.1 Introduction

In order to achieve better sustainability of the urban environment, the inclusion of energy considerations into spatial and urban planning allows to build the strategic framework where both mitigation and adaptation measures can be positioned in the broader perspective of sustainable development. To achieve energy reduction targets, energy efficiency measures should be conceived as a part of an integrated and broader urban strategy fostering a comprehensive urban regeneration of the existing city, where the local authorities have a key strategic role in coordinating and influencing the activities of a range of actors, in defining target areas and communities to focus on, and in engaging people in adopting sustainable behaviours in order to make the measures effective.

The overall aim of the research has been to understand the linkage and reciprocal contribution of urban regeneration and energy renovation of residential buildings. The research specific contribution has been targeted to show the relevance, the urgency and the feasibility of improving energy policy instruments to take into account consumer behaviour, and to provide new solutions to local authorities, public housing associations, energy companies and all the stakeholders having a part in the building renovation process. The dissertation goal has been to show, on the one side, the relevance of the occupant behaviour, at present seldomly included in the consideration of the measures to renovate the buildings; on the other side, the relationship among stakeholders involved in the renovation process, in order to suggest improvements to increase the process effectiveness.

The research focus has been on the Italian context, where energy efficiency through building renovation and urban regeneration is a major challenge, and where building renovation can be considered as one of the strategies to achieve city regeneration. This work has been aimed at demonstrating to what extent understanding the impact of the human factor on energy efficiency can enhance the effectiveness of housing renovation policies. This requires long term involvement of all stakeholders, including the final users, in developing policy, measures, technologies, and monitoring schemes.

Public housing, social housing and housing policies have always been studied by urban planning as ways to achieve sustainability in cities. Demonstrating, prior in public housing stock than in the rest of the housing stock, the interrelation among stakeholders to implement energy renovation, and the relevance of household energy behaviour to effectively reduce energy consumption in buildings, could lead to a multiplier effect.
Behaviour is more likely to be deliberately considered and changed when a discontinuity occurs in the household context. Therefore, building renovation programmes are the key opportunity to involve households in order to make them reconsider their consumption practices.

The problems framed above make explicit the urgency to tackle household energy behaviour as a prominent issue to effectively achieve building renovation and energy savings. Many disciplines have already contributed to suggest how to better incorporate the human factor in their core research topics. In fact, the gap between expected and actual energy consumption, together with the impact of occupant behaviour on building energy use, have been increasingly studied by scholars, who contributed to demonstrate that energy savings through behavioural factors can be as high as those from technological ones, thus giving to the occupants the possibility either to reinforce the savings from energy efficiency measures, or to waste them. This research has provided an additional contribution from the urban planning perspective.
A multi-method approach to data collection has been used, applying both qualitative research methods such as content analysis and surveys, and quantitative research methods such as statistical analysis, sensitivity analysis and simulation tool to assess the energy consumption-related human factor and to determine multiple scenarios to support decision-makers towards the implementation of effective renovation strategies. A distinction has been made between two micro-level approaches, according to the size of data and their level of accuracy.

The first part (framing) has been structured in three main chapters, and devoted to defining the main research questions, to frame the user behaviour in urban planning and energy policies, to investigate the theoretical framework and the main behavioural models applied by different disciplines that focus on the topic, and to understand the determinants and existing strategies to address behaviour change. The second part (diving) has included two main chapters, aimed at going deeper into two main issues: on the one side, the different approaches to data analysis to investigate the impact of behaviour, according to the data source, the data accuracy and the scope of the investigation; on the other side, the Italian public housing sector, to analyse its main characteristics, the interrelation among actors operating in the renovation of the public housing stock, and the contribution that understanding the human factor can give to alleviate energy poverty. The last part (assessing) has been structured in two main chapters, aimed at assessing the impact of behaviour at different scales, to provide evidence to the policy-makers of the importance of tackling behaviour into account in the design and implementation of the renovation strategies for the existing housing stock.

The following sections present the conclusions and recommendations drawn from this research. Sections 8.2 to 8.4 present the conclusions of each research question analysed separately. Section 8.5 discusses the main limitations throughout the work, in particular on data availability and provides suggestions to overcome the gaps. Recommendations for future research are presented in Section 8.6.

8.2 Findings addressing research question 1

The first research question, presented in the box below, has been intended to build the state of the art on energy behaviour, to understand how and to what extent it is currently embedded in existing strategies and policies at different levels of governance.

To what extent are both energy behaviour and the role of household energy consumers embedded in current international and EU strategies, energy policies, urban planning policies and other policy instruments addressing energy renovation of the building stock, at different territorial levels?

Sub-questions:

a) Is there any relation between energy renovation, public buildings and user behaviour in the current policy instruments at EU level and at national, regional and local level for Italy?

b) How many approaches are there to understand household energy behaviour and which is the one that suits more for dealing with user behaviour in urban planning?

8.2.1 Sub-question a) Relation between energy renovation, public buildings and user behaviour in the current policy instruments

Energy efficiency has been recognised as a multiscale issue, addressed by several policies and regulations. It concerns every governance level and it involves multiple stakeholders. However, the investigation conducted in Chapter 2 has confirmed that there is a general tendency both in legislation and strategies to focus on the building scale, rather than the urban scale. At the same time, urban planning is still not much driven by energy planning, which in turn does not pay enough attention to the territorial level.

The analysis in Chapter 2 has provided an insight into the policy framework and regulation elaborated at four levels of territorial governance (i.e. international and EU; national; regional; local) to verify to what extent consumer behaviour, building renovation and urgency to take actions on public buildings are embedded in the energy and sustainable development policies.

Consumer behaviour and awareness on behaviour impact are key issues currently somehow embedded in EU Directives, since they are mentioned when it comes to smart meters and new way to deal with the energy market (i.e. from consumer to prosumer). However, the implementation of measures to support behaviour change and to build community awareness are left to the Member States, with neither indication on possible ways to achieve the goal, nor recognition that urban planning tools could contribute to deliver such behavioural change.
When it comes to the renovation of the existing stock, the analysis has shown that policy-makers are currently facing the challenge to design and implement effective housing renovation strategies both for the public and the private housing stock, able to support not only the technical and physical renovation, but also a change of paradigm in energy consumption. Policies and regulations at different territorial levels are struggling to encourage decision-makers to include information to users as a prerequisite to implement effective energy efficiency strategies and to lower energy consumption.
For what concern spatial planning, it emerged that in none of the investigated levels energy is truly integrated. At the local level, the urban planning tools are still not enough driven by energy planning. The energy issue is generally embedded in terms of performance and reduction of energy demand in buildings, while the role of building occupants in achieving such goals and

the relationships between behaviour and building characteristics are completely neglected. Energy efficiency is considered to be a technology-driven issue, rather than a matter of behaviour and consumption patterns. Spatial planning is either a national or a regional legislation subject, depending on the Member States administrative characteristics and regulation, therefore, should not surprise that it is barely mentioned in international strategies and EU energy Directives. However, the absence of measures and actions related to the design and use of territory within the Italian policy instruments has been identified as a weakness element.

The urban scale has turned to be the most suitable level where all different renewal-oriented tools could be applied together, and the positive effects of incentives and rewards mechanisms could be multiplied. This would also allow the implementation of new and more collaborative approaches involving the public sector, occupants, households and developers acting in the building sector, driving the transition towards a credible and long-lasting model of low-carbon city. Investigating consumer behaviour in the framework of urban planning can provide an insight into the urban regenerative potential of cities, which relies, among others: on the one side, on energy awareness of people, their behaviour, capacity and willingness to adapt; on the other side, on the ability of public authorities to design renovation strategies to turn occupants into active actors, rather than passive target groups.

8.2.2 Sub-question b) Approaches to understand household energy behaviour in urban planning

Investigating consumer behaviour towards energy efficiency and sustainable energy consumption requires a deep understanding of both the human factor and the technological asset, and the integration of both qualitative and quantitative methodologies.

Two main approaches have been identified in Chapter 2, namely the social science approach and technological and engineering-based one. They have been broadly investigated to understand how different disciplines have contributed to the topic, and where insights from urban planning discipline could increase knowledge on the topic. Both approaches rely on modelling as the key element that helps explaining the reality as well as informing the users.

The first approach has been initiated with the first behavioural theories, the rational choice model, also called utility-based decision model. It is grounded on the micro-economic theory of utility maximization given certain preferences. However, after having been largely applied in the 1970s, this model has progressively been replaced by others, since it has been demonstrated that behaviour embeds a number of inconsistencies, and consumers do not make consistent rational decisions even if all the information is provided. Social and environmental psychology has started from the 1970s to explore behaviour in relation to residential energy efficiency. According to the ecological value theory, people with egoistic and self-interested values are less likely to perform pro-environmental behaviours than those who have pro-social values. However, having pro-environmental attitudes is not a sufficient condition for acting in an environmentally friendly way. Sociology approaches generally argue that energy use is not a consequence from choices of a single person, but it results from the social context. Practice theory focuses on the collective structures of practices and on what guides the practices people perform in their everyday lives, where energy consumption is not a practice in itself, but it is a consequence of all the different energy-related activities that people do at home.
The second approach is mainly based on energy modelling, applied in various forms to quantify energy consumption mainly to inform the building design sector. It comprises the statistical approach which relies on statistical data collection, and the engineering approach which makes use of building energy simulation programmes, where the latter typically relies on mathematical equations representing the relationship between specifically exercised energy-related behaviours.

Results from the investigation conducted have shown that many different energy-related behaviours in the building sector have been investigated so far, with the heating pattern as the most studied. The research has contributed, on the one side, to build the state of the art on consumer behaviour, and on the other side, to provide evidence of the importance of behaviour modelling. When it comes to research in the field of energy consumption and energy efficiency, it has emerged that there is a lack of common understanding of what consumer behaviour is, since it is strongly related to the technical, economic, sociological and psychological models applied to understand how and why people perform energy-related actions, and to the disciplines which investigate these actions. In previous studies, no single model came out to be developed to inform the policy-makers of effectiveness of taking behaviour into account while implementing renovation strategies. Therefore, the research conducted has contributed to clarify the contribution that urban planning can give, and the more appropriate approach to be adopted, which should consist of informing and guiding the policy-makers to assess scenarios and to take decisions.

8.3 Findings addressing research question 2

The second research question, presented in the box below, aimed to investigate the energy behaviour determinants and behavioural change strategies to be implemented in order to address the impact of behaviour on energy consumption.

How to identify the determinants of occupant behaviour and energy consumption, to understand which are the best strategies to promote pro-environmental behaviour?

Sub-questions:

c) Which are the determinants of energy behaviour in residential sector for heating consumption?

d) Is there any added value in promoting behavioural change at community level, rather than at household level?

e) How does public housing sector can have a role in showcasing the path for increasing the renovation rate of residential buildings while addressing awareness on behaviour?

8.3.1 Sub-question c) Determinants of energy behaviour in residential sector for heating consumption

The determinants of energy behaviour in residential sector have been investigated within the thesis by following two methodologies: on the one hand, through literature review on household and building characteristics affecting behaviour, and household behavioural patterns in Chapter 3; on the other hand, through statistical analysis on Italian dataset resulting from a census on energy consumption in buildings, and qualitative analysis of survey responses and considerations on questionnaire-based investigation method.

Among the main key factors determining energy behaviour, there are both household characteristics (i.e. demographic, educational and economic factors) and building characteristics (i.e. external factors related to outdoor conditions and internal factors related to the building envelop and mechanical systems installed). In particular, investigation conducted in Chapter 3 has found that household behaviour can be influenced by: demographic factors as gender, age, household type and size, health; educational factors as level of education, awareness, knowledge, motivation; socio-economic factors as housing tenure, income, cultural background, occupation. Among building characteristics, there are: external factors such as outdoor air temperature, wind speed and direction, horizontal global irradiance, air pollution and noise; and internal factors such as building envelope and type of windows, dwelling size, mechanical systems and appliances.

The results of the investigations conducted in Chapter 4 have reinforced two discourses: on the one side, around the need of building a robust framework for data collection and processing on energy behaviour and household preferences and practices; on the other side, around the need to integrate occupant feedback methods before renovating the existing stock, to improve the uptake and effectiveness of household energy efficiency and low-carbon interventions, as an essential way to address the current gap in knowledge.
Results from the statistical analysis have contributed to demonstrate that the use of statistics to determine the household characteristics related to energy use in buildings is a powerful tool to investigate the relationship between energy behaviour and household characteristics. In the specific case of Italian statistical, three variables – thermostat, household composition and working condition – have resulted to be statistically significant in affecting the use of the heating system. However, many gaps in the dataset have emerged, and a much greater effort has to be put in place by public authorities and other public or private institutions participating to collect data, to enable scholars to contribute to the energy behaviour topic.

The survey conducted in Chapter 4 has been useful to gain a first insight into household awareness, attitudes and willingness to be involved in actions targeted to the reduction of energy consumption. However, it has emerged that identifying current behaviour is not enough, it is also necessary to understand whether or not there is a willingness to reduce consumption.

It has clearly emerged as an energy efficiency process should be conceived as part of an integrated and broader urban strategy fostering urban regeneration.

8.3.2 Sub-question d) Promoting behavioural change at community level

Strategies to promote efficient behaviours have been presented in Chapter 3, in particular focusing on the benefits and limits of the feedback approach. Results from the investigation contributed to stress the fact that individual needs correct information for a responsible choice. Without an appropriate frame of reference, users cannot determine whether their energy consumption can be reduced or not. Therefore, feedback plays a significant role in raising energy awareness and changing consumer attitudes towards energy consumption. Among the different feedback types, direct feedback and indirect feedback are the two deeply investigated. Regenerating existing communities through the increase of energy efficiency in buildings and actions to support a sustainable lifestyle requires the participation of individuals prepared to embrace the behaviour changes and to support the transformation process that can last several years. In the field of energy research both on policies and buildings, informational feedback has a leading role in moving towards efficient behaviours. However, although the feedback approach is recognised to be useful, there are other factors that influence household consumption that may not be affected by this mechanism. In order to make people taking responsibility for their role in the built environment, education has to be more comprehensive and to go beyond the house walls.

Although most of the studies available in literature focus on individual behaviour, there is a growing body of science claiming for the shift from behaviour to practice. The transition towards changing and sustaining a new set of social practices, rather than changing some behaviours in the short term, will be necessary to achieve significant reductions in environmental impact over time.

Community-based initiatives represent the step required for moving from behaviour change to systemic change. Being adopted by an increasing number of building renovation programmes, they have the potential to establish ownership and responsibility for actions to pro-environmental behaviour change, even in situations where individuals may otherwise feel that their contribution is insignificant. Compared to programmes addressing individual consumer behaviour, community-based programmes are more likely to address the more challenging social, institutional and technical barriers and constraints. Moreover, community-based programmes are able to achieve multiple benefits in the same environment, resulting in high level of awareness on risks and barriers to the effective implementation of renovation programmes. According to the existing literature, the non-energy co-benefits have resulted to be even more important in the social housing sector where energy efficiency of buildings and energy poverty only represents two among the many open issues of a complex framework.

Therefore, results have shown that physical renovation of buildings should be integrated by the information and training on sustainable occupant behaviour, especially in the case of housing stock where low-income people are accommodated, in order to ensure both environmental and social sustainability of the interventions. Energy can be considered as a driver to urban regeneration, while addressing attitudes and behaviour change is a prerequisite for co-creating and co-implementing regeneration strategies. As result of literature review, some key elements for successful behaviour change initiatives have been identified and presented.

8.3.3 Sub-question e) The role of public housing sector in showcasing the benefits of addressing behaviour

Despite the limited size of the Italian public housing stock, due to the favourable situation of public housing providers having an exclusive role in public housing stock management, and the similarities in the regional regulations and procedures among providers, the public housing sector has been selected as a case study for this research.

On the one side, Chapter 3 has contributed to the topic by investigating four building renovation initiatives within the social housing sector in Italy, the Netherlands, Sweden and United Kingdom, to understand how the occupant behavioural change towards lower energy consumption has been supported. A matrix for the analysis of the four practices has been developed to facilitate clear comparison of trends and gaps between the selected programmes, and to identify possible future instruments needed to overcome the current barriers.
The analysed renovation initiatives have proven that private entities can play a significant part in the energy efficiency process and they are not cut off when it comes to public housing stock.

However, the occupant behaviour should be also considered together with the technical aspects, since it can considerably affect the payback periods of the investments. The more the uncertainties related to the impact of the human factor are addressed, the more the payback time of the retrofitting interventions may be reduced, increasing the attractiveness of such investments. Previous studies have also shown that understanding user profiles is a key element for formulating targeted energy-saving policy for specific household life-styles.

On the other side, the analysis conducted in Chapter 5 has identified the main characteristics of the Italian public housing sector, the interrelation among actors operating in the renovation of the public housing stock, and the contribution that the understanding of the human factor can give to alleviate energy poverty. The institutional framework concerning housing and urban regeneration is nowadays more fragmented, involving more actors than in the past, both for-profit and non-profit. The role of the government is becoming less prominent, while the influence of market actors and civil society organisations is increasing. Five main categories of actors have been identified, where the community and the residents are intended as one of the active actors, rather than passive target groups.
The redevelopment of the public residential assets aimed at improving energy efficiency in Italy over the last decade have essentially been driven by two factors: reducing the costs associated with the ordinary maintenance of the stock and contributing to the energy reduction goals set at European and national level. The implementation of the interventions has seen in many cases the involvement of the Energy Service Companies (ESCos), which operate by setting a payback time, during which the tenants benefit from a limited energy and economic savings, reduced by the amount allocated to the ESCo to recover the investment. In this scenario, there is an overcoming of the public-private dualism, in which the public administration provides the funds assuming all the risks, while the private actors perform their work as contractors. However, transformations and co-benefits, which are not easily quantifiable in economic terms are difficult to be implemented, as for the regeneration of the public open space, and the initiatives to raise awareness among occupants on energy efficiency and energy behaviour.

8.4 Findings addressing research question 3

The third research question, as presented in the box below, has been intended to provide evidence of the impact of household behaviour to support policy-makers in taking decision and setting priorities on the renovation of buildings.

How to make evidence of the impact of household energy behaviour and provide scenarios to support policy-makers in taking decision on the renovation of buildings?

Sub-questions:

f) What is the sensitivity of the heating energy consumption of a public housing building to occupant behaviour?

g) Which tools can be provided to policy-makers to assess user behaviour impact and to promote effective renovation strategies?

8.4.1 Sub-question f) Sensitivity of the heating energy consumption of a public housing building to occupant behaviour

An Italian multi-family public housing building has been assumed as case study in Chapter 6 to estimate the influence of three dimensions linked to occupant behaviour – management of the thermostat, management of the heating system, variation of building characteristics – on energy heating consumption. A building performance simulation tool has been applied to investigate the impact of behaviour and to build scenarios to inform decision-makers.

Results have shown that occupant behaviour modelling has emerged as an important tool to quantify the impact of occupant behaviour on energy saving potential. It provides estimation of the gap between expected and actual energy savings due to the human factor. It explains the impact of rebound effect in case of building retrofit, as well as the impact of “green behaviour” when positive behavioural changes occur. The findings suggest that, while the occupant behaviour influences the heating loads up to 1/3 in case of high level of building retrofit, the less the building is renovated, the more is the behavioural impact in absolute terms of energy reduction. Despite the total building retrofit has been found to be the best way to significantly decrease heating consumption for the reference building, the impact of the rebound effect (17-33%) that occurs in case of building renovation should not be underestimated. The investigation at dwelling level shows that the rebound effect can be even higher than the one identified with heating load simulations at building level, reaching up to 52% of energy consumption for some of the housing units.

This investigation has contributed to demonstrate the importance of integrating measures to tackle behavioural factors into the retrofit strategies to improve the energy performance of residential buildings. Two divergent explorative scenarios have been presented aiming at demonstrating that complementary approaches to reduce energy consumption are required, since physical improvements and behavioural changes have shown different impact on energy savings that need to be addressed at the same time. When limited resources are available, investing on tackling behaviour change, rather than on building retrofit, has resulted to be the most economic sustainable and efficient way to implement energy efficiency strategies. As soon as other funds become available, it is important to combine informative and feedback strategies with the renovation of the building, to reduce both the gap between expected and actual heating consumption, and the rebound effect.

8.4.2 Sub-question g) Tools for policy-makers to assess user behaviour impact and to promote effective renovation strategies

Scholars have started questioning the effectiveness of current retrofitting policies, since they are mainly based on theoretical assumptions and do not accommodate user energy practices. In order to achieve real energy reduction, policy instruments need to include considerations on the actual use of buildings, rather than the theoretical consumption. Despite the central role of users to lower energy consumption has been increasingly recognised, more recently in regulatory frameworks and earlier in research field, evidence from research has showed that so far households have not been sufficiently motivated or supported in undertaking changes, and they are still not enough aware of the impact of their lifestyles and decisions on energy consumption. The investigations in Chapter 7 have shown, on the one side, evidences of the urgency to take informative measures to address occupant behaviour; on the other side, concrete feasible proposals to deliver such change.

A methodology based on multi-criteria assessment of different strategies by applying the Analytic Hierarchy Process (AHP) has been designed, to support policy-makers on their decisions concerning the reduction of energy consumption in buildings. The methodology explicitly incorporates the impact of user behaviour into the assessment of planning strategies and renovation measures. Four criteria and seven measures have been identified. Results have shown that the two measures that more than others are considered to rely on user behaviour, have resulted to be the top alternatives by three out of four criteria (i.e. environmental, social, practicable). A sensitivity analysis to define five possible scenarios through different combinations of the selected criteria has confirmed the urgency and convenience to implement the measures addressing behaviour prior to the other alternatives.

Two main policy recommendations can be drawn. On the one hand, the measures proposed to address behaviour are intended as complementary to the others, and first to be implemented in order to raise awareness and to drive behaviour towards more energy sustainable practices, but they certainly cannot reach the goal if implemented alone. Information, awareness campaigns, feedback and other informative policy instruments should be integrated by other measures addressing the physical renovation. On the other hand, public authorities are seeking for services, rather than products, to increase the renovation rate of the housing stock. Technologies should cover only one aspects of a complex system where spatial organization, consumer behaviour and new energy efficient technologies interact with each other, determining the actual and future pattern of energy consumption. Better integrated complementary approaches to both the technical and social energy transitions are required.

The focus on the Italian public housing sector in terms of actors involved, barriers to the implementation of the building stock renovation, and the identification of drivers to overcome them has been investigated. No one-size-fits-all solution is possible due to peculiarities across household and building characteristics. Therefore, several measures are suggested to demonstrate how household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments have also been highlighted.

Recommendations to deliver such measures addressing behaviour awareness and information to households of the private residential sector, including homeowners and other tenants from the private sector, have also been presented. They have been aimed at showing the replicability potential of a new governance targeting environmental awareness, rather than just technical implementation of energy efficiency measures, and the planning instruments to work on in order to deliver such change. A focus on the local planning tools of the City of Bologna has been considered, to further specify how and where behaviour should be embedded to achieve a better understanding on the role of energy efficiency for urban regeneration.

8.5 Limitations on data collection and recommendations

The availability of energy data and information on behaviour and attitude towards energy efficiency has been found to be a strategic component for investigating occupant behaviour and behaviour change. It has emerged throughout the whole dissertation, and it has to be reported as one of the main limitations.

Microdata on energy consumption resulting from the reading of smart meters in the residential sector are owned by private companies, either energy utilities or ESCos. Besides the privacy issue – surely relevant, but that is possible to overcome through the application of data processing procedures – there are other reasons behind the difficulties in getting data for research purpose. While explaining those reasons is beyond the scope of this research, it should be noted that the informative nature of the data to deliver feedback to users is not commonly recognised. The energy utilities and service companies that own the data are mainly interested in increasing their profits, rather than supporting users to deliver changes towards energy savings and contributing to alleviate energy poverty. This role should be performed by the public authorities, which should not miss the opportunity to persuade the private parties to take their steps to contribute to deliver energy efficiency social benefits by addressing occupant behaviour.

The statistical dataset embedded a series of limitations that have been specified in Chapter 4. Limitations are related both to the issues excluded from the investigation, and to the unavailability of results for some variables, although the related questions were included in the survey. It has clearly emerged the need to improve the results by improving the questions and the issue addressed. Almost no questions were asked regarding reported behaviour, occupancy patterns and preferences. For instance, ventilation behaviour was totally absent from the survey,

although it is recognised to be an important factor affecting the heating consumption in winter time. Data on energy expenditures were so aggregated to be not usable in statistical tests. A much greater effort has to be put in place by public authorities and other public or private institutions participating to collect information, to allow the research on the energy behaviour topic. Future research should focus on how to make the tools for collecting information on occupant behaviour and energy consumption even more informative, towards standardised procedures easy to be applied.
As investigated in Chapters 3 and 4, as soon as more accurate data become available, in particular for energy consumption, energy expenditures and behaviour, through statistics it would be possible to determine the occupancy patterns to pre-define the occupancy of a building when real information about the occupants is not available. This approach can represent a great opportunity for policy-makers and ESCos in case of building renovation, since the behaviour profiles can be integrated into the models for assessing the renovation process, resulting in a more accurate method to determine: on the one side, the expected building performance accounting for household variation; on the other side, the levers to be triggered in order to support household in delivering the expected savings.

Some limitations must be acknowledged also for what concerns data collection through the surveys. Results from the case study in Finland have shown that, when it comes to the survey design, defining the questions to get the most from the responses is the most challenging issue. To ensure a high response rate is also important, since low response rates make impossible to properly assess the responses through quantitative analysis to reinforce the conclusions. Coming to the case of Italy, the work performed has contributed to highlight that, in the initial phase of the renovation process, there is usually little time to undertake comprehensive pre-renovation monitoring and occupant feedback surveys, and little attention is dedicated to this activity, as the occupants are seen much more as target groups, rather than active actors of the process. The housing provider and the energy service company are usually more interested in modelling renovation options, selecting them and planning the actual implementation of the interventions. Therefore, it is important to keep the survey as much pragmatic and simple as possible, in order to run the process smoothly. Great efforts should be made to ensure that all the actors of the process are aware about the role of the survey, that should be considered as one of the key parts of the renovation process.

Therefore, as presented in Chapter 7, one of the most urgent actions regards the setting of a residential building performance database that should be combined with results from behavioural survey to be coordinated at national level. As framed in the proposed solution PS04, this activity might start from the public housing sector, where the methodology for data collection and database management could be tested and fine-tuned, to be then extended to the whole residential sector. Indeed, building a knowledge baseline for the development of strategies and tools to renovate the housing stock, and for addressing the consumption behaviour impact on energy savings, constitutes the driver to show to private investors the high replicability potential of implementing the regeneration of the existing cities. As long as data are fragmented and co-benefits difficult to assess, the occasional interventions will not turn to a systematic approach. Being urban planning a discipline able to hold different interests and multiple territorial needs, it is expected to be a key contributor to manage the complexity of such change.

8.6 Recommendations for future work

This research has contributed to show that occupant behaviour is worth to be investigated. At the same time, urban planning has proved to be able to contribute to address the occupant behaviour issue from the policy instrument perspective, and to find the triggers to embed the role of consumers into the planning tools and plans aimed at improving energy efficiency of the housing stock and contributing to urban regeneration.

Throughout the dissertation, different methods have been applied, depending on the data availability and the aim of the investigations. Even those methods and tools which are not usually applied in urban planning studies, have turned out to be powerful sources to provide evidence of the impact urban planning can have in addressing occupant behaviour.

Chapter 6, in particular, has illustrated the use of a building performance simulation tool to investigate the impact of behaviour and to build scenarios to inform decision-makers. Besides this tool is usually applied by scholars dealing with the design of new buildings and the need to simulate behaviour patterns prior to the occupancy phase, in the case of this research, this approach has resulted in an increased understanding of the role of occupant behaviour to improve the effectiveness of renovation strategies, particularly relevant for policy-makers which are always struggling with the lack of resources and have to choose to invest on the most promising measures.

By building on the research findings, further research in urban planning and other disciplines could contribute to increase the effectiveness of renovation measures, in terms of energy savings, economic feasibility and social acceptability. Future investigations about the interrelationship between different energy behaviours are also needed, which will generate more realistic assumptions on building energy performance. The application of the proposed solutions in Chapter 7 has not been tested within this research. Indeed, the assessment of measures addressing occupant behaviour needs to be performed in real cases.

For being able to address the complexity of the human factor in energy consumption, the social effects, technical characteristics, the building performance simulation models, the role of economic, taxes and incentives as well as the policy instruments should be further investigated in combination one with each other.

Integrating quantitative and qualitative approaches still remains an effort to be made in order to better understand behaviour determinants and the drivers for changing it. A higher integration would be also beneficial among different research fields, with many scholars advocating for more collaboration among different disciplines. Although some studies have already applied multi-disciplinary approaches, much more effort has to be taken in order to better understand determinants of behaviour, drivers to behavioural changes, and to what extent such changes can lead to urban regeneration.

Concluding, this research has provided novel knowledge on the relevance the impact of the human factor has on energy efficiency, and how this knowledge can be applied to enhance the effectiveness of housing renovation policies. The role of behavioural patterns of different user groups for implementing energy efficiency should be further studied in order to effectively include this new perspective into policy instruments and urban planning tools. Urban regeneration requires a deep understanding of the built environment and a strong engagement of citizens, who have to be considered more and more as the catalyst factor of the regeneration process. Any single discipline investigating energy and occupant behaviour issues will provide a limited view of the topics at most. Interdisciplinary studies are required to get a more comprehensive understanding on effective ways to regenerate cities and to face the climate change.

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