# Embedding energy user's behaviour into multi-criteria analysis: providing scenarios to policy-makers to design effective renovation strategies of the housing stock

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## Abstract

Nowadays, policy-makers are 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. Indeed, energy transition takes place on a local level and needs to involve individuals. The importance of tackling behaviour change to improve energy efficiency, especially in case of building retrofit, is increasingly recognised, as well as the urgency to combine the renovation of the housing stock with informative and feedback strategies, in order to reduce the gap between expected and actual energy consumption. The paper presents a methodology based on multi-criteria assessment of different strategies, 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's behaviour into the planning strategies and renovation measures to be assessed. Through the development of a multi-criteria analysis based on the Analytic Hierarchy Process (AHP), this study demonstrates that, to increase the sustainability of cities and communities, a holistic approach is required, and considerations on citizens' behaviour need to be embedded into energy renovation policies to address energy reduction targets.

**Keywords:** energy behaviour; renovation strategies; housing stock.

## 1. Introduction

Nowadays, urban environment is considered to be a key player in addressing climate change. The inclusion of energy considerations into the planning process 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.

The EU building sector is the largest single energy consumer in Europe. While the efficiency of new buildings has steadily improved over time, most of European existing building stock has yet to be affected by energy performance requirements. In fact, in most EU countries, half of the residential stock was built before 1970, prior to the first thermal regulations. Buildings in EU are responsible for approximately 40% of energy consumption and 36% of $CO_2$ emissions. 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 building stock is renovated each year, depending on the country. Therefore, the increase of the renovation extent 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. It also has a major impact on the affordability of housing and on energy poverty, a growing phenomenon since 2008, 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). 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 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 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 the beginning of 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 the theoretical consumption (Visscher et al., 2016).
In this context, the paper 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's behaviour into the assessment of planning strategies and renovation measures. In Section 2 , previous research is presented. Section 3 explains 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 discussed in Section 4, where the possible steps to unlock the energy saving potential of buildings are presented. In Section 5, conclusions and limitations are shown, and policy implications are drawn.

## 2. State of the art

On the one hand, the design of energy efficient buildings does not necessarily result in low energy consumption (Stevenson, Leaman, 2010; Guerra-Santin, Itard, 2010; Gupta, Chandiwala, 2010). Whenever the buildings are designed to be energy efficient, it is up to occupants decide how to use them (Gupta, 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 show 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 decision on measures to be implemented to unlock the energy saving potential of buildings. The results highlight 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 the most important objective of the cities – to increase the sustainability of the whole community. However, in both studies, the considered renovation strategies have not explicitly incorporated initiatives addressing user's behaviour among the recommended solutions to be implemented to effectively reduce energy consumption in the housing sector, both prior and 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 measures overestimated.

Policy instruments at different levels (i.e. EU, national, regional and local) are struggling to encourage decision-makers to include information to occupants as a prerequisite to implement effective energy renovation strategies of the housing stock. Measures 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 user, the latter (e.g. new appliances, infrastructures, services) are aimed at changing the context in which decisions are made, to increase the energy saving attractiveness. Policy instruments are responsible to translate these strategies into practices. Four main categories of policy instruments can be identified: information, economic, administrative and physical (Linden et al., 2006). Focusing on information, the importance of tailored information and feedback has been recognised (European Environment Agency, 2013). Feedback plays a significant role in raising energy awareness and changing occupant attitudes towards energy consumption. Among the different types of feedback, this research focus on direct feedback (e.g. smart meters), available on demand and indirect feedback (e.g. informative energy bills, energy awareness campaigns and collaborative learning). Faruqui et al. found that direct feedback provided by in-home displays 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% (Faruqui, 2010). The range of savings achieved through indirect feedback tends to be lower than the one reported in direct feedback studies (5%–15%). Nevertheless, they are important to make users aware of the impact of their daily practices, and are achievable at relatively low cost. Moreover, it has been studied that the combination of different informational feedback may lead to an increase of energy savings up to 20% (European Environment Agency, 2013).

## 3. Methodology

### *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 theory of measurement through pairwise comparisons and relies 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's 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.

### *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), 7 packages of measures – M(1) to M(7) – have been identified as potential alternatives to improve the energy performance of the housing stock (Table 1).

| 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 |

*Table 1: List of measures and level of dependency from behaviour*

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's behaviour.
The structure of the hierarchy framework described above is drawn in Figure 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.

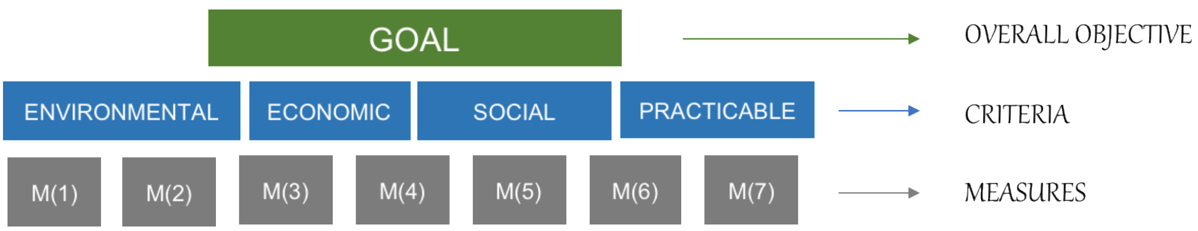


*Figure 1: Hierarchy framework*

## 4. 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.

### *4.1 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 2. 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's behaviour can lead to overestimate the environmental benefit of such measures.
Tables 3-5 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.

| **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 |

*Table 2: Pairwise comparison for environmental criterion. Consistency Ratio CR = 0.09*

| **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 |

*Table 3: Pairwise comparison for economic criterion. Consistency Ratio CR = 0.05*

| **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 |

*Table 4: Pairwise comparison for social criterion. Consistency Ratio CR = 0.03*

| 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 |

*Table 5: Pairwise comparison for social criterion. Consistency Ratio CR = 0.06*

Figure 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 that shows the most significant changes among the criteria considered.

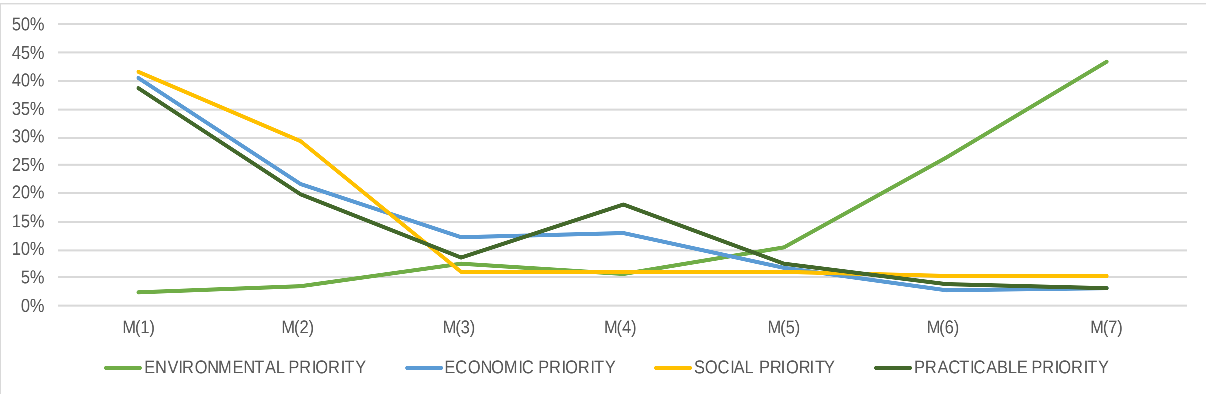


*Figure 2: Criteria priority*

## *4.2 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 5 possible scenarios that includes different combination of the selected criteria. The weights assigned for each scenario are presented in Table 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. 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 3.

| | 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% |

*Table 6: Weights assumption for sensitivity analysis*

| RECOMMENDED SOLUTIONS | NEUTRAL SCENARIO | | ENVIRONMENTAL SCENARIO | | ECONOMIC SCENARIO | | SOCIAL SCENARIO | | PRACTICABLE SCENARIO | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Priority | Ranking | Priority | Ranking | Priority | Ranking | Priority | Ranking | Priority | Ranking |
| 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 |

*Table 7: Results from sensitivity analysis and ranking of recommended solutions*

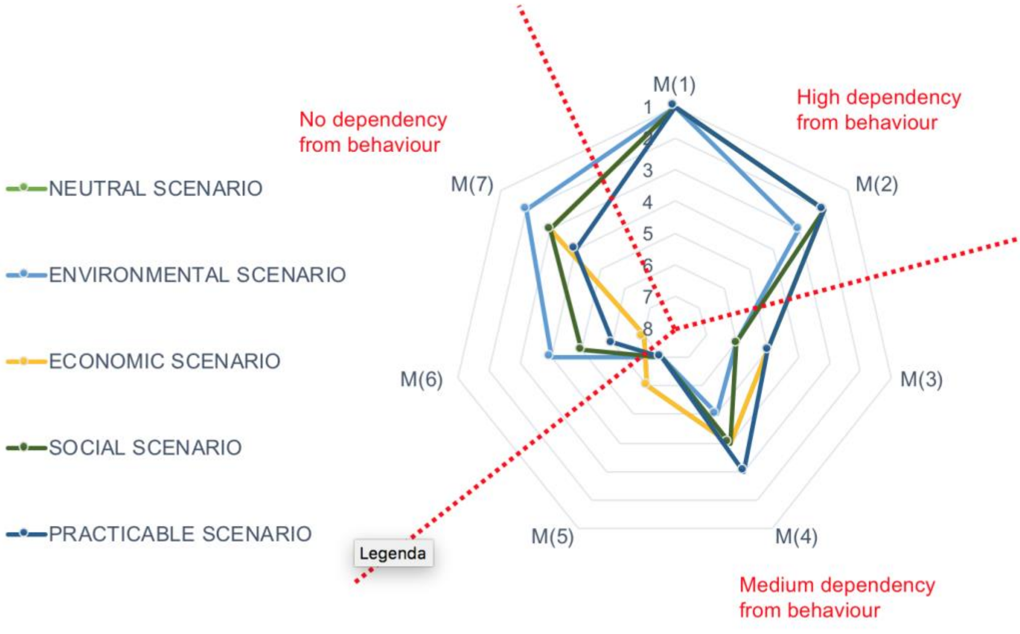


*Figure 3: Scenario analysis and evidence of energy behaviour relevance*

## 5. Conclusions, limitations and policy recommendations

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. The methodology allowed to combine quantitative and qualitative attributes and to translate qualitative

preferences into ratio scaled data. The AHP application goal has been defined as selecting the measures that more than others can lead to an effective implementation of the energy renovation strategies and can increase energy efficiency of existing housing stock. Four criteria and seven measures have been identified, respectively as intermediate level and lower level of the hierarchy framework. 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's 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 authors. Although they come from the evidence of long-lasting collaborations with public authorities (e.g. municipalities and regional 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 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, as more data on household energy consumption and indoor comfort levels become available, there are more possibilities of providing tailored feedback to occupants. However, 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 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. Better integrated complementary approaches to both the technical and social energy transitions are required.

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