Towards more effective behavioural energy policy: an integrative modelling approach to residential energy consumption in Europe

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Abstract

Energy behaviours represent an important underexploited resource in the context of promoting end-use energy efficiency, namely in the residential sector. However, addressing the multidimensional nature of energy behaviours is a complex task and more effective behaviour change interventions and policies grounded on comprehensive approaches are required. An integrative intervention to explore the influence of usage energy behaviours on energy consumption was developed through an innovative combination of modelling techniques. A real-world case study was utilised to generate contextualised understanding. This intervention supported problem structuring methods as pertinent tools to be utilised in complex human-centred energy research, such as energy behaviours, by enabling the development of tailored methodologies which minimise the human bias. It further confirmed real-world behaviour change interventions should involve the different energy stakeholders and be designed to be flexible and adaptive. Results confirmed variables associated with different dimensions significantly impact energy consumption. In this case study the promotion of residential energy efficiency includes both structural and energy behavioural actions, namely a better insulation of the dwellings and encouraging specific usage energy behaviours. These results support the need to consider an integrative perspective when addressing energy behaviours and designing effective behavioural change interventions and energy efficiency policies.

1. Introduction

Energy behaviours represent an important underexploited resource in the context of end-use energy efficiency in the residential sector. Energy savings through behavioural factors may reach 20%, but values vary among case studies [1, 2]. Programmes focusing on behaviour dimensions should be designed to materialise these potential savings and contribute to energy efficiency, complementarily to structural and technological interventions.

Several interventions have been implemented in the last decades by various stakeholders, which although sharing the same goal of promoting more efficient energy behaviours possess different interests concerning energy efficiency. For example, market agents aim at maximising profits, attracting and keeping customers, while political agents aim at reducing the dependence on non-endogenous energy sources and environmental impacts, improving the quality of energy services, end-users comfort and welfare [3]. Traditionally, interventions for promoting more efficient energy behaviours comprise antecedent, consequence and structural strategies [4, 5]. Considerable investments have been supporting these interventions, but recent assessments revealed that they have been ineffective in achieving enduring and more efficient energy behaviours and therefore substantial improvements are needed to increase their effectiveness [1, 6]. In particular, interventions should consider users' profiles and their personal and social context and target specific behaviours instead of focusing on the potential instruments of change *per se* (which has been the common practice). Furthermore, the theoretical background of interventions should be reinforced. In Europe, the most effective interventions have been feedback, energy audits, community-based initiatives and the combination of multiple strategies, all originating savings of 5 to 20% [1, 6]. However, these results may not be transferable since they are originated by projects with different characteristics (such as location, typology, scope, scale and energy policy context).

1.1 Energy behaviours: a challenging topic

Addressing energy behaviours is a complex task since they hold multiple dimensions. Energy behaviours are observed acts that lead to energy consumption and include investment, maintenance, and usage behaviours as well as the management and provision of energy resources [7, 8].

Investment behaviours are those involved in the purchase of new equipment, including its energy attributes and its relative importance in the choice process. They are also commonly designated as *efficiency behaviours* [9-12]. **Maintenance behaviours** refer to behaviours involved in the repair, maintenance and improvements of energy consuming equipment including the building [8]. **Usage behaviours** refer to the day-to-day usage of buildings and equipment therein installed, and may be characterised by its frequency, duration, and intensity. Usage behaviours decreasing the use of energy and contributing to achieve energy savings are also designated as *curtailment* or *conservation behaviours* [9-14]. The **management and provision of energy resources** comprises activities such as planning or time shifting energy usage, generating energy through local renewable resources, and storing or trading self-produced electricity, which is increasingly important in smart grid contexts [7].

Although the terms energy efficiency and energy conservation are often used in energy behaviours research (e.g. [4, 6, 15-21]), some authors argue the term energy efficiency should not be used when referring to energy behaviours since it denotes the adoption of specific technologies reducing the

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3 overall energy consumption without changing the relevant behaviours [22]. Instead, the term energy
4 conservation is often recommended. This study adopts the strict energy efficiency definition of
5 reducing the final energy consumed while achieving the maximum level of energy services possible.
6 Energy efficiency may not be achieved only by the change of technologies, but also by the way they
7 are used, which are related to energy behaviours [2]. Accordingly, in this study the term energy
8 efficiency will be used in an energy behaviour context, and 'more efficient energy behaviours' indicate
9 an increase of behavioural actions reducing the final energy consumption.
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13 Accordingly, increasing energy efficiency by adjusting energy behaviours to more efficient patterns
14 requires targeting which specific behaviours to adjust (e.g., investment, usage, maintenance, or
15 management of energy resources) and a comprehensive understanding of the factors leading to their
16 activation. In general, energy behaviours are shaped by personal and contextual factors and different
17 research disciplines address them through distinct, yet complementary, approaches [2, 23]. While the
18 social sciences concentrate on exploring the personal and contextual factors leading to the activation
19 of energy behaviours, engineering and more technological approaches focus on energy consumption
20 as a result of the technical characteristics of equipment and buildings. Economics considers
21 individuals to be totally rational, maximising utility and minimising cost in daily actions. However,
22 behavioural economics recognises that during this decision process individuals may have information
23 processing limitations and use heuristics and other information simplification processes. Psychology
24 focuses on the individual perspective, identifying personal determinants (e.g., intentions, attitudes,
25 norms, beliefs, values) or contextual influences to explain or predict energy behaviours. In turn,
26 sociology and other social studies see energy behaviours as the result of the social context and not a
27 consequence of individual decisions. In these disciplines, energy behaviours are considered to be a
28 result of the social organisation in which individuals live such as social rules, lifestyles, standards or
29 practices.
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33 Regardless the unquestionable value of each perspective and the recent focus given by the European
34 Environment Agency to the social practice approach [1], any single perspective becomes limited in
35 addressing the different dimensions of energy behaviours by neglecting other disciplinary visions [24].
36 The creative combination of different disciplines through integrative research is then required to
37 develop comprehensive approaches to the understanding of energy behaviours and promotion of end-
38 use energy efficiency in more effective interventions [25].
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41 42 43 44 45 46 47 48 **1.2 Modelling as a structuring approach of energy behaviours**

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50 Modelling is a central tool to modern science, management and policy making, guiding judgement and
51 supporting problem solving [23, 26, 27]. In energy efficiency studies, modelling is usually employed for
52 forecasting energy demand, predicting the adoption of new technologies or estimating the impacts of
53 energy efficiency programmes (e.g., [28]). Energy behaviours, in particular, have been modelled using
54 a variety of different techniques, depending on the objectives and the disciplines. For instance, the
55 social sciences use modelling to explain, interpret and predict behaviours (e.g., [29]) while engineering
56 utilise quantitative models to determine energy consumption (reviews may be found in [2, 30, 31]).
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60 Although there is a vast research on energy behaviours, integrative modelling approaches of energy
61 behaviours have had limited development. Integrative models are inclusive and flexible, considering all
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relevant aspects of energy behaviours while finding a balance among disciplines, and may be used by practitioners and policy makers to both theoretical and practical purposes [32]. In an effort of integration, in the last three decades multidisciplinary perspectives tackling energy behaviours in the residential sector have been developed [5, 8, 32-38]. These models provided multiple insights on energy behaviours but their level of detail, scale and approach differed substantially thus reflecting the different authors' backgrounds, disciplinary influences and study motivations. They further had a static perspective of energy behaviours, losing the intrinsic dynamic dimension of behaviours (except the model explored in [38]). In fact, energy behaviours do change over time and hence modelling approaches should pursue this dynamic dimension. Recent trends in energy behaviours modelling have explored the important qualitative and quantitative dimensions of energy behaviours by combining users' activities with patterns of energy consumption (e.g., diary approaches), or simply extracting behaviour patterns through data mining techniques [39-42].

Modelling is particularly relevant when addressing complex issues such as energy behaviours, since it enables structuring the knowledge and unveiling apparently hidden relationships thus promoting targeting the problem at hand more effectively. In this sense, modelling may be firstly used as a tool for enriching the comprehension of a relevant issue and secondly for simulation and optimisation purposes. Often utilised in such situations, problem structuring methods support the resolution of complex problems usually involving multiple stakeholders, different perspectives and interests, and uncertainties [43]. In real world problems, employing a single method is not usually the most effective approach and the combination of methods is often utilised to address the different dimensions of a problematic situation [44]. For example, soft systems methodology help to unveil the different visions of the stakeholders and build a consensus on an issue [45], while cognitive mapping may be used to represent those visions in a graphical way thus facilitating communication [46, 47] and system dynamics to understand the problem dynamics over time [48]. To the authors' knowledge, although these methods have not yet been used to address energy behaviours, they have been applied to tackle energy efficiency problems [3, 38, 49-52].

1.3 Objectives

There is a need for more effective real-world behaviour change interventions and energy policies grounded on comprehensive approaches of energy behaviours. The present work uses modelling as a structuring approach of multidisciplinary knowledge to establish the (qualitative and quantitative) influence of usage energy behaviours on energy consumption. It combines several modelling techniques to explore various perspectives of the impact of usage energy behaviours on energy consumption, as a basis for the development of a real-world behavioural change intervention. This work is exclusively focused on the usage dimension of energy behaviours and, inspired by [37], combines different disciplinary frameworks in the modelling process, namely the personal and contextual dimensions of psychology and sociology and the technical approaches of engineering. Furthermore, by exploring the use of different research methods and techniques (both quantitative and qualitative) of several disciplines, this work also aims to contribute to the development of integrative research methodologies and answer to the following research questions referred by [53, 54]:

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3 “- How can the benefits of ‘human-centred’ research methods be best coupled with quantitative forms
4 of data collection and analysis?

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6 - Human-centred, as well as ‘mixed’ research methods, tend to be more complex (difficult to fit in a
7 box), expensive, and subjective than others – how can they be improved?

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9 - How can researchers minimise bias – their own and that of their subjects – when doing research?

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11 - Are some disciplinary methods simply incompatible with an interdisciplinary approach?”
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13 It further aims at contributing to facilitate knowledge and information transfer between experts from
14 different areas to practitioners and policy makers [55], thus promoting more effective behaviour
15 change interventions and energy efficiency policies.
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17 This paper is organised in four major sections. The first provided the context, state of the art,
18 motivation and main objectives of this work. The second section presents the proposed methodology.
19 Section three presents and discusses this real-world intervention, namely concerning the perspective
20 of the different stakeholders, the system definition, the conceptual model, and contextualised data.
21 The main conclusions are presented in the last section.
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25 26 **2. Methodology**

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28 When addressing a complex issue, selecting the tools to use is ultimately a decision influenced by the
29 nature of the problem, limitations of time, resources and competences, reflecting the individual
30 researcher and team skills, experience, values and personality [44].
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33 This real-world behaviour change intervention has been developed by the authors from 2011 to 2014
34 and comprised three stages: (1) assessment of the socio-political, material and personal context; (2)
35 action and generation of contextualised understanding; and (3) transference to practice and policy
36 making (Figure 1). At each stage, methods and techniques from different methodologies were
37 combined to develop activities and involve the different agents. It is, however, worthwhile to mention
38 that methods were in some circumstances implemented just to the extent required by the
39 characteristics of the actual situation to be dealt with. Specific components of problem structuring
40 methods were carefully chosen to enrich and develop the comprehension of the problem and the
41 appreciation stage, while complying with the respective paradigm [56, 57]. Nevertheless, the overall
42 methodology developed conforms with the generic constitutive definition of problem structuring
43 methods [58], namely by embodying a systematic way to contribute to the improvement of the
44 problematic (and messy) situation under analysis, using a systemic approach, creatively combining
45 elements of problem structuring methods, acknowledging different worldviews, involving interactive
46 and iterative processes, recognising the stakeholders as insiders of the problem and the own limits of
47 the approach.
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Figure 1 – Methodology used to develop this behaviour change intervention

i. Identification of stakeholders, their roles and collection of visions

The first step consisted in identifying the stakeholders, their roles and collecting their visions on the complex situation. Different techniques were utilised, depending on the agents, with special emphasis on problem structuring methods specially designed to explore and elicit different points of view, such as the first stage of soft systems methodology [43]. Special attention was paid to clarify energy behaviours, their role in the energy consumption activation chain, all the factors influencing this relation as well as strategies to promote more efficient energy behaviours and the roles of energy stakeholders. The role, interests and points of view of the energy stakeholders (e.g., the scientific community, energy service companies, utilities, energy regulator, energy agencies, non-governmental organisations, society in general) were unveiled using interviews, meetings and workshops. In particular, the perspective of the scientific community has been further enriched through an extensive literature review in peer-reviewed journals and direct involvement of experts from different disciplines. Furthermore, the particular visions of residential users were indirectly collected using surveys. The energy stakeholders' role in energy behaviours was incorporated into a rich-picture making explicit their interests and enabling a clarification of roles, which contributes to minimise the potential research bias (sub-section 3.1). Information regarding the influence of energy behaviours on energy consumption was incorporated in the conceptual modelling stage (step iii).

ii. Focusing the problem and the system

After collecting the different perspectives, a “CATWOE” analysis was used to elicit and clarify the underlying system of this intervention, the specific agents involved, their interests and roles. Following the soft systems methodology, and complementarily to the rich picture, the use of the “CATWOE” analysis (i.e., *Customers, Actors, Transformation, Weltanschauung* or world view, *Owner*, and *Environmental constraints*) helps focusing and characterising a complex problem, while clarifying the different interests and views of the stakeholders involved [45]. Particularly in this intervention in which different agents were involved, the use of this technique enabled to focus the underlying system and made explicit the roles of the different agents involved, thus contributing to minimising potential bias associated (including the researchers’). This analysis is explored in sub-section 3.2.

iii. Integration of different perspectives

The last step of the assessment stage consisted in the integration of the multidisciplinary knowledge. Conceptual modelling was utilised to explore the influence of energy behaviours on energy consumption and to integrate the contribution of variables pertaining to different disciplinary domains. Both static (cognitive maps) and dynamic representations (causal diagrams) were used. Cognitive maps were structured around the chain of actions leading to energy consumption. Different levels of detail were developed: from a more aggregated version that provided an overall perception of the relationships (Figure 3) to a more disaggregated and detailed version where quantifiable variables were made explicit (Figure 4). Although cognitive mapping usually reflects actions required to change the situation in a positive way [46], in this study they were used to increase the comprehension on the topic and therefore the energy consumption activation chain was the main focus. Causal loop diagrams from system dynamics [48] were used to explore the dynamic dimension of this system (Figure 5). For simplification purposes, only a small part of the dynamic dimension is presented in this paper. The modelling process was implemented through an iterative improvement process until the conceptual model was accepted as consensual within the multidisciplinary research team. The proposed conceptual model is explored in sub-section 3.3.

iv. Design and implementation of the field actions

The first stage of generating contextualised understanding began with the design of *in-situ* activities. The agents involved in this intervention (two energy agencies, an energy service company, and residential consumers) were engaged through formal and informal strategies, namely meetings and written agreements to establish interests, tasks and data confidentiality issues. This intervention was designed to potentiate synergies with other on-going initiatives to use resources more efficiently while ensuring proper data gathering conditions (e.g., electricity monitoring equipment, access to households), which allowed overcoming some of the most common limitations of energy behaviour research. The objectives of the energy agencies, the energy service company and the authors of this work were thoroughly made compatible (e.g., concerning the intervention timeframe and milestones) to minimise the impacts of this intervention on the residential sample, which involved a total of 450 households living in Portugal.

The energy consumption of each household was monitored at the meter level using a smart meter (<http://www.cloogy.com/en/>) with a time step of 15 minutes. From the tools commonly used in the

social sciences [59], web-based surveys were chosen due to their resilience characteristics and since they minimise the households' disturbance (one example is available at <http://www.ces.uc.pt/inqueritos/sintra>). One survey was developed for characterising the conceptual model dimensions, namely: the socio-demographic context of the household (e.g., composition, age, professional occupation, education, dwelling ownership); their activities and social practices (e.g., time spent at home, schedule of cleaning activities); energy resources and services utilised (e.g., electricity supply conditions, ownership of technologies based on renewable energy sources, ownership of several home appliances including their efficiency class); the building characteristics (e.g., type, size, age, thermal comfort perception); the physical environment (e.g., location, climate characteristics); usage energy behaviours (frequency of performing behaviours such as turning appliances off to avoid waste consumption, eliminating stand-by consumption, use of passive strategies to control thermal comfort or lighting, efficient use of appliances, adjusting settings of appliances, using dual time tariffs, controlling and monitoring energy consumption) and a specific, yet important, investment behaviour (e.g., frequency of purchasing efficient appliances); and behavioural personal determinants (e.g., intentions, beliefs, values). Variables were selected taking into consideration their recognised importance in the literature and the challenges of collecting field data.

v. Collection of data and analysis of results

The final step in generating contextualised and specific understanding consisted in analysing the collected data. Although the initial dimension of the sample was 450 households, only 128 were selected for this phase since they complied with data quality criteria (e.g., minimum of nine months of electricity monitoring and simultaneously answering the full survey).

For each household, and based on electricity monitoring data, specific indices were determined allowing the characterisation of electricity consumption (e.g., daily average consumption, minimum and maximum power, ratios between average and maximum and minimum power, seasonal consumption). These electricity consumption indices were integrated with the answers of the survey in a database and analysed using statistical analysis (IBM® SPSS® Statistics v.22 software). Firstly, a frequency analysis was performed, followed by correlations among variables. Variables from the survey were reduced and synthesised through factor analysis and combined to provide the model dimensions. Finally, multiple regression analyses were performed to test the adequacy of the model and assess the contribution of usage energy behaviours to energy consumption. Sub-section 3.4 presents a summary of these analyses.

vi. Dissemination and recommendations to practitioners and policy makers

Dissemination ensures knowledge and experience exchange with practitioners and policy makers. Different methods were used according to the profile of each stakeholder, such as meetings, workshops, conferences and publications. Although represented as the last stage of the process, dissemination occurred continuously during the whole intervention.

3. Results and discussion

This section presents and discusses the main results of this intervention namely concerning the perspective of different stakeholders, the underlying system definition, the conceptual model, and contextualised understanding from a case study.

3.1 Energy behaviours influence on energy efficiency as perceived by energy stakeholders

As it is often the case in real-world situations, there are several agents interested and involved in the topic of energy behaviours influence on energy efficiency, such as governments, regulators, governmental and energy agencies, utilities, energy service companies (ESCOs), manufacturers, retailers, consumer associations, environmental non-governmental agencies, the scientific community, and the society as a whole.

Figure 2 depicts a rich-picture with the energy stakeholders' role in energy behaviours, which illustrates the context in which this intervention was developed. Following the European Union policies, the Portuguese government defines energy efficiency policies, regulations and efficiency goals. Both governmental agencies and the energy system regulator implement these policies. Energy utilities have recently been diversifying their offerings of energy services. ESCOs are also focused on selling energy services using technological solutions incorporating smart devices. Non-governmental associations represent consumers' interests and benefit from a trusted relation with them, while manufacturers and retailers develop their activities following regulations with no particular concern on energy efficiency. The scientific community promotes knowledge on energy efficiency and behaviours, whose results are disseminated within the community and policy makers and practitioners in general.

Figure 2 – A rich-picture displaying the energy stakeholders' role in energy behaviours

In Portugal, behaviour change interventions have traditionally been promoted by energy agencies through the support of the Intelligent Energy Europe programme (<http://ec.europa.eu/energy/intelligent/>), but recent energy efficiency policies created financing opportunities for behavioural change interventions. Hence, since 2007 the national energy regulator is promoting the most important funding initiative in energy efficiency (PPEC - Consumption Efficiency Promotion Plan) [60]. It aims at promoting more efficient behaviours when using electricity and the adoption of more efficient equipment. Energy stakeholders have been using this mechanism to promote behaviour change interventions despite, in some cases, their apparent conflicting interests (e.g., energy utilities, whose main aim is to maximise profits through selling energy) or overlapping of roles (e.g., the national governmental energy agency, responsible for the implementation of policies, also benefits from this financing mechanism). This created an environment of competition, but also of cooperation among energy stakeholders leading to the development of innovative behaviour change initiatives. In addition, these real-world interventions provide an excellent opportunity and context for cooperation and knowledge dissemination among the scientific community, practitioners and policy makers, in which this intervention is positioned.

All the stakeholders involved in the workshops and meetings held during this intervention recognised the influence of energy behaviours on energy end-use and their importance on energy efficiency. Their interest and visions on energy behaviours were not only influenced by their educational backgrounds and professional affiliations, as discussed by [24], but also by the Portuguese context. Energy efficiency was identified as a complex topic to end-users and energy literacy was emphasised as a key factor to the improvement of end-use energy efficiency. Re-materialising energy consumption, associating it with daily actions through the use of smart technologies, and simplifying the language used in communication and feedback tools (e.g. awareness campaigns, billing, in-house displays) were consensual strategies pointed out by energy agencies, energy service companies and utilities. However, some of the stakeholders (e.g., utilities, regulator, and governmental agencies) considered energy efficiency as a minor concern to households due to the small weight energy bills represent in the household monthly expenses, and consequently potential savings associated with energy behaviours are small when compared to infrastructural or equipment improvement costs. Further factors hampering more efficient energy behaviours included the disinformation originated by the multiplicity of stakeholders interacting with the households and communicating on energy efficiency (Figure 2). Better coordination between stakeholders and, in some situations, information delivered by reliable and trusted interveners was indicated as crucial to improve end-use energy efficiency. Moreover, the specific context of changes in the energy market, in which this study was conducted, was pointed out to be substantially influencing energy behaviours. Although the liberalised retail energy market was open to the residential sector in 2006, a decision of forcing residential consumers to entering the liberalised market was taken in July 2012. Since this date residential consumers have been encouraged to change their energy suppliers through numerous campaigns, not only improving end-users energy literacy but also creating a social awareness on the topic [61]. Other behaviour change strategies mentioned by the stakeholders comprised structural (e.g., regulation, prices), antecedent (e.g., proximity, gamification) and consequence strategies (e.g., peer comparison, financial rewards). One interesting perspective unveiled during this process was the opportunity of transforming traditional energy services into more sophisticated services to the households, in some way similarly to the evolution of communication services. Behavioural change interventions were also indicated by the stakeholders to be sometimes limited in their scope and impacts due to their small scale. Nevertheless, and regardless this limitation, the stakeholders were consensual to recognise behaviour change interventions as crucial steps towards more efficient energy behaviours.

In summary, energy stakeholders recognised the role and the challenges associated with energy behaviours and energy efficiency, being involved in the process of fostering higher levels of end-use energy efficiency. Considering their different roles, all energy stakeholders are relevant to the development of more effective behaviour change interventions. Yet, better coordination among them and design of integrative approaches contribute to maximise the full potential of behavioural interventions.

3.2 The intervention system: the players, their roles and the practical challenges

In the process of developing this integrative intervention on energy behaviours, a “CATWOE” analysis was used to elicit the underlying system, the specific agents involved, their interests and roles, in order to minimise the potential bias.

The underlying **system** if this intervention is defined as *a system to combine disciplinary perspectives on energy behaviours to foster more effective interventions and energy efficiency policies*. According to the “CATWOE” analysis, the relevant components of this system are:

- **Customers** – As the target of interventions, residential users are the main customers of this study. Indirectly, society as a whole also benefits from promoting end-use energy efficiency thus making it an indirect customer. Agents promoting these interventions, which have been ineffective in achieving enduring behaviour changes (e.g., utilities, energy service companies, manufacturers, energy agencies, consumer associations, environmental non-governmental organisations), are intermediaries in this process and for this reason they are also considered customers. In this intervention, two regional energy agencies and an energy service company are directly involved as clients being promoters of behaviour change interventions. These agents provided access to households and to energy monitoring data.
- **Actors** - The authors of this work. Their motivation in developing this intervention arose from consulting experience in energy efficiency, research on end-use energy efficiency (http://www.uc.pt/en/org/inescc/Projects/energy_box), and the R&D work leading to a PhD in Sustainable Energy Systems of the first author in a multidisciplinary environment (<http://www.uc.pt/en/efs/about/phd>). Also cooperating in this intervention, a research team composed of researchers in social sciences (e.g., psychology and sociology) and engineering (e.g., energy systems and decision aid) provided support to the planning, modelling, implementation and analysis of results.
- **Transformation process** - Disciplinary views of energy behaviours are limited in addressing the multidimensionality of the influence of energy behaviours on energy consumption. There is a need for a more holistic vision, built upon disciplinary approaches, which will provide an integrative perspective of the effects of energy behaviours on energy consumption. Accordingly, the transformation may be formulated as follows: *[input] single disciplinary behavioural intervention $\xrightarrow{T}$ [output] integrative behavioural intervention*.
- **Weltanschauung (world view)** – A comprehensive vision of the influence of energy behaviours on energy consumption, built upon disciplinary approaches, maximises the effectiveness of energy behaviour change interventions and promotes further end-use energy efficiency.
- **Owner** – From a perspective of energy efficiency initiatives, financing and promoters such as political agencies and regulators that may not adequately acknowledge comprehensive approaches, or the promoters of energy behaviour change programmes not using integrative approaches as a common practice, are both considered owners of this intervention. Furthermore, since this intervention is also developed in a research context, and from this specific point of view, the scientific community also plays a role as owner of this intervention

since it is able to restrict either the publication of this work or the development of the PhD project.

- **Environmental constraints** - Limited resources to support the development of this approach (e.g., financing, time, cooperation of the stakeholders).

Although real-world behaviour change interventions involving energy stakeholders are considered a valued asset when researching the impact of energy behaviours on energy efficiency, in this case it raised intrinsic challenges, such as: reconciling all players' specific and different interests, roles and visions; engaging households in behaviour change actions in particular in a context without a consolidated tradition in this field (such as the Portuguese reality); and dealing with the players' reduced engagement as the restrictive economic context evolved. Tackling these challenges involved designing this intervention to be flexible, constantly adapting, and using multidisciplinary and adaptive tools and skills (e.g., negotiation, communication, integration of information).

3.3 Conceptual model: from usage energy behaviours to energy consumption

As a result of daily activities and processes, households feel needs whose satisfaction leads to the activation of usage energy behaviours in order to provide for energy services (heating, cooling, lighting or electrical appliances powering) (Figure 3). Energy resources (e.g., electricity, gas, fuel) enable energy services. Several factors influence these relations, such as environmental (e.g., physical and socio-economic environment), structural (e.g., building and equipment characteristics), contextual (e.g., household socio-demographic characteristics, social practices) and personal factors (e.g., values, attitudes) (Figure 4).

Figure 3 – Energy consumption activation chain

People's daily activities are very diverse and comprise, in general, gainful work and study, domestic work, meals, personal care, travel, free time and sleep [62]. Most of these activities are performed at home and involve several processes that activate energy services (some of them energy intensive), such as food preparation, dish washing, cleaning, laundry, watching television, or even reading. These activities and processes are influenced by the socioeconomic environment (e.g., financial constraints) and the household socio-demographic characteristics (e.g., composition, stage of life, level of education, income, professional activity, dwelling ownership) and social practices (e.g., time spent at home, lifestyle) [63, 64].

The need for energy services is also influenced by the physical environment and the building characteristics. Climate directly affects the level of energy services required to achieve a comfortable indoor temperature and solar exposure influences both the thermal and the lighting comfort [65]. In fact, a considerable amount of energy is consumed for space heating in residential buildings, which

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3 reached in 2008 in the EU-15 a share of 67% of household energy use [66]. Two major building
4 characteristics influence the magnitude by which energy services are activated, thus leading to more
5 or less energy consumption: the dwelling size and its energy efficiency. The bigger the dwelling the
6 larger the area to be cooled or heated, more lighting power is required and more appliances need to
7 be powered, thus leading to a greater need of energy services. The energy efficiency of the building
8 directly influences the indoor comfort perception thus determining the level of energy services
9 required. The most important parameters affecting the energy efficiency of buildings are the thermo-
10 physical properties of the building envelope, which is directly related to the level of insulation and the
11 passive architectural features such as orientation, the building form and optical characteristics that
12 influence natural lighting [65].
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15 While the activation of energy services may be set in motion due to the need itself, processes shaping
16 the efficiency of energy behaviours or the magnitude of that activation may be influenced by personal
17 factors (e.g., habits, intentions, attitudes, norms, beliefs, concerns, self-regulation mechanisms,
18 perceived capabilities) [67-73]. These personal factors may also influence, and be influenced by, the
19 household socio-demographic characteristics and social practices. They may also indirectly induce
20 activities and processes occurring in the household. For example, an increased concern on energy
21 efficiency may lead to a change of habits and practices and to a replacement of existing processes by
22 others less energy intensive, or to the reduction of their frequency or magnitude.
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25 Existing energy consuming equipment influences the level of energy use in two opposite ways. The
26 number of energy consuming equipment increases the magnitude of the required energy services and
27 consequently the level of energy use, but the increase of their energy efficiency level reduces the
28 amount of energy required to perform energy services. Recent statistics have shown that regardless of
29 the improvements on energy efficiency standards of appliances, energy demand has substantially
30 increased in the residential sector due to the rapid growth of ownership and quantity of electricity
31 consuming devices [74], thus demonstrating the predominance of the effect of the increase of the
32 number of appliances over their energy efficiency. Moreover, the rebound effect associated with a
33 more efficient use of energy may lead to an increase in energy consumption [75].
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36 At a broader level, the socioeconomic environment also influences the household socio-demographic
37 characteristics and their capability of performing household activities and processes. It may also
38 influence the system of personal factors. For example, a favourable economic context increases the
39 household financial ability and therefore its capacity to diversify and intensify the household needs for
40 energy services thus increasing their energy demand (the reverse of this effect is nowadays being felt
41 in some European countries due to the economic crisis). In turn, the increase of energy prices creates
42 a higher expenditure with energy, which although reducing available resources also promotes further
43 energy awareness among households thus favouring more efficient energy behaviours.
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Figure 4 – Disaggregated factors influencing the energy consumption activation chain with the identification of the variables assessed during this intervention

A further component of this model comprises its dynamic dimension. Cognitive mapping represents systems at one point in time, neglecting the time lag associated with each effect [47, 76]. Hence, it becomes a limited modelling tool in situations whose dynamics over time is relevant, such as energy behaviours influence on energy efficiency. A *system dynamics* approach was used to explore this dimension. As an example, Figure 5 illustrates a “zoom” made into the influence of the socio-economic environment on energy behaviours. In general, the increase of energy awareness and literacy levels created by bill increases, behaviour change programmes or energy efficiency policies reinforce some of the personal determinants promoting end-use energy efficiency. Social pressure may also activate personal determinants (e.g., social norms) towards more efficient energy behaviours. One important dimension confirmed by this diagram is the *rebound effect*. The activation of more efficient energy behaviours contributes to reduce energy use, leading to a reduction of energy expenditure and to an increase of the household financial ability. However, this often originates an increase in the level/number of energy consuming activities and processes actually resulting in the increase of energy use, i.e., the opposite unintended effect – a rebound effect. Other “zooms” into the system relevant for this analysis may be explored.

Figure 5 – Causal diagram reflecting the influence of the socio-economic environment on energy behaviours

Previous cognitive maps represented the energy consumption activation chain in a static perspective allowing the identification and the structuring of variables being characterised during this intervention. The addition of causal diagrams exposed the type of influence between variables, clarifying the overall dynamics and promoting a better comprehension of the behaviours influence in energy efficiency. In fact, this technique revealed to be interesting by enabling the assessment of the evolution of this complex problem with time and translating it into programming (such as stocks and flows). This could support behaviours prediction, assisting the design of field interventions and energy efficiency policy making.

In short, modelling is a continuous process of improvement and as an on-going research this model is constantly being upgraded. Although it was developed for this particular intervention, it does not constitute the ultimate representation of this topic. Alternative formulations may be designed depending on each study or intervention objectives and requirements.

3.4 Evidence from a case study

Contextualised understanding from a case study is explored to provide indications on the relevance of using integrative approaches to address the qualitative and quantitative impact of usage energy behaviours on energy consumption. Results were selected from a wider analysis to illustrate this point of view and the adequacy of the model to reality. This section presents a summary characterisation of the sample and the main results of a multivariate statistical analysis.

The residential sample (N=128) is geographically located in Portuguese urban areas. Households live mostly in owned apartments (80%) of medium size (70% possess two or three bedrooms) (Table 1). In average, each family is constituted by 1.7 adults ($\sigma=0.8$) and 0.9 children ($\sigma=1.1$). Average electricity consumption is about 10.8 kWh/day ($\sigma=5.5$), similar to the national consumption (10.1 kWh [77]). The ownership of appliances is higher than national rates (laundry machine 84%, dishwasher 92%, tumble dryer 42%, air conditioning system 16%, and electric water heater 8%)¹. Respondents of the survey are mainly men (68%) with an average age of 38 years old ($\sigma=9$). Most respondents are highly

¹ National statistics indicate the following ownership rates: laundry machine 91%, dishwasher 41%, tumble dryer 19%, air conditioning system 7%, electric water heater 3% [77].

educated (98% has a higher education degree, which contrasts with the national average value of 19%), is currently employed (86%) and is married (70%).

Table 1 – Characteristics of the residential sample (N=128)

Dimensions	Variables	Level	
Building	Typology	Apartment	88 %
		Villa	12 %
	Size	Less than 2 bedrooms	7 %
		2 or 3 bedrooms	70 %
		More than 3 bedrooms	23 %
Energy use	Average electricity consumption		10.8 kWh/day
Electrical equipment	Ownership	Laundry machine	84 %
		Dishwasher	92 %
		Tumble dryer	42 %
		Air conditioning system	16 %
		Electric water heater	8 %
Household	Number	Adults	1.7, $\sigma=0.8$
		Children	0.9, $\sigma=1.1$
Respondents	Gender	Female	68 %
		Male	32 %
	Age	< 36	49 %
		36 - 45	36 %
		46 - 55	9 %
		> 55	6 %
	Education level	No university degree	2 %
		University degree	98 %
	Marital status	Single	23 %
		Married	70 %
		Divorced or widower	7 %
	Professional activity	Working	86 %
		Non-working (student, retired, unemployed)	14 %

The model dimensions were characterised using a list of 15 variables reduced from the original set. While factor analysis was used to reduce information on energy behaviours and behaviour determinants, the remaining variables were transformed and combined to characterise the intended dimensions (Figure 6). Factor analysis of self-reported energy behaviours enabled identifying three main factors in the studied sample: (1) *daily practices* (e.g., efficient use of appliances, avoiding waste and standby consumption, and passive strategies to control thermal comfort and lighting); (2) *specific know-how based* (settings adjustment of appliances and shifting practices to benefit from dual time-of-use tariffs and reduce costs); and (3) *information based* (investment in efficient appliances, auto-control and monitoring of energy use) (Table 2). Factor analysis of personal determinants comprising intentions (from Unified Theory of Acceptance and Use of Technology [78]) and beliefs enabled reducing this information to two factors associated with the *influence of social image* and *consequences to lifestyle*. In summary, variables characterising the model dimensions comprise: energy consumption (*daily average electricity consumption*), energy services (*weatherising need, energy intensive appliances, efficient equipment* and *use of renewable energy sources*), household characteristics (*stage of life*), activities and processes (*time spent at home, weekly washes*), energy

behaviours (daily practices, based on specific know-how and information), behaviour personal determinants (influence of social image and consequences to lifestyle, values and energy literacy), and the socio-economic environment (influence of the economic crisis).

Figure 6 – Integration of variables during the assessment of the model dimensions

Table 2 – Relation between the factors emerged from the factor analysis, the measured self-reported energy behaviours and the respective categories

Factor	Self-reported energy behaviours	Category
Daily practices	Turning appliances OFF to avoid waste consumption (e.g., turning off the lights in empty rooms; turning TV off when nobody is watching it; turning water heating system off when in holidays)	Usage
	Eliminating standby consumption (e.g., turning appliances off using central plugs to avoid standby consumptions; turning appliances off directly on the switch to avoid standby consumption)	
	Use of passive strategies to control thermal comfort or lighting (e.g., using sun light in the rooms; insulating windows and doors; in the summer, closing the curtains/blinds during the day, and opening the windows during the night; in the winter, leaving curtains/blinds open during the day and closing them during the night; keeping doors and windows closed when they are being warmed or cooled; turning heating/cooling equipment on only in occupied rooms)	
	Efficient use of appliances (e.g., turning the dishwasher on only when it is full; using the washing machine at low temperature programmes; using dishwasher with eco programmes; turning the washing machine on only when it is full; ironing in long periods, instead of short ones; not opening and closing the fridge door very often; leaving the fridge door open for the less time needed)	
Specific know-how based	Settings adjustment (e.g., adjust acclimatisation temperature according to the season: summer 23-24°C, winter 18-20°C; regulating the fridge temperature according to the season)	Usage
	Use of dual time-of-use tariffs (e.g., using a timer to schedule water heating; turning the washing machine/dryer on during the cheapest periods; using cumulative heaters to benefit from cheaper electricity consumption periods)	
Information based	Auto-control and monitoring (e.g., talking with the dwelling occupants about electricity consumption and savings; reading the electricity bill; providing the meter readings to the electricity supplier)	Usage
	Investment in efficient appliances (e.g., buying more energy efficient equipment)	Investment

The available literature acknowledges as the most important determinants of residential electricity consumption factors such as the climate, the dwelling and the household characteristics, and appliances ownership and use, in particular energy intensive ones [79-81]. In this case study, significant correlations were found between *daily average electricity consumption* and the following parameters of the model: *weekly washes*, *stage of life*, *weatherising need*, *specific know-how*, *energy intensive appliances*, and *consequences to lifestyle* (Table 3).

Table 3 – Significant correlations established between the model parameters and *daily average electricity consumption*

Model parameter	r
Weekly washes	0.61***
Specific know-how	-0.45***
Weatherising need	0.46***
Stage of life	0.54***
Energy intensive appliances	0.22**
Consequences to lifestyle	-0.20**

p<0.05, *p<0.001

Using the 15 synthesised variables of the model, a multiple regression analysis yielded a solution accounting for approximately 60% of the variance of the sample's daily average electricity consumption (Table 4, model 1). The best predictors of *daily average electricity consumption* include different dimensions of the conceptual model: energy services (*weatherising need*, B=3.14), followed

by energy behaviours (*specific know-how*, B=-1.85), household activities (*weekly washes*, B=0.56) and their characteristics (*stage of life*, B=0.24). The specific technical dimension associated with energy behaviours embedded in the variable *specific know-how* revealed to be significantly contributing to the reduction of electricity consumption. Further exploring the compound variable *weatherising need* in predicting daily average electricity consumption (Table 4, model 2), the *insulation level* of the dwelling (B=5.92) appears as statistically significant revealing a greater prediction ability than the *perception of the thermal comfort* or the *size of the dwelling* (also embedded in *weatherising need*). In this particular case, this variable measures the poorness of the insulation and not its quality (B>0). The variable *energy intensive appliances* (B=0.05) also emerges as statistically relevant. The behavioural dimension maintains its prediction significance (*specific know-how*, B=-2.10). Regardless these significant results, this complementary model accounts for a lower variance of the sample's electricity consumption (40%) than the main model (Table 4, model 1).

Table 4 - Regression models for predicting *daily average electricity consumption*

Dependent variable	Model		B	Std. Error	Beta	Adj. R ²	Observations
Daily average electricity consumption	1	(Constant)	4.03	0.94	-	0.6**	Stepwise method, collinearity statistics VIF<5 and tolerance close to 1
		Weekly washes	0.56	0.14	0.38***		
		Specific know-how	-1.85	0.48	-0.30***		
		Weatherising need	3.14	0.89	0.28***		
		Stage of life	0.24	0.10	0.22**		
	2	(Constant)	3.31	1.95	-	0.4**	
		Stage of life	0.40	0.10	0.36***		
		Specific know-how	-2.10	0.51	-3.51***		
		Insulation level*	5.92	2.77	0.18**		
		Energy intensive appliances	0.05	0.02	0.18**		

* Parameter originally embedded in "weatherising need", **p<0.05, ***p<0.001

When exploring the specific influence of the size of the household² through further regression analysis, predicting models account for lower variances of *per capita daily average electricity consumption* (only 30%) (Table 5). As previously, two complementary analysis are performed, the first one using the original variables (model 3) and the second one exploring the compound variable *weatherising need* (model 4). It is interesting to note that the calibration of the model against the size of the household highlights the influence of the same variables as predictors of *per capita daily average electricity consumption* as previously: energy behaviours (*specific know-how*, B=-1.18), household characteristics (*stage of life*, B=-0.25) and energy services (*weatherising need*, B=1.49). Further developing the influence of *weatherising need* components on predicting *per capita daily average electricity consumption*, this dimension loses statistical significance in the resulting model, while a behaviour personal determinant (*value self-enhancement*, B=-3.33) emerges as significant. Moreover, according to these results, *daily average electricity consumption* is reduced with increased *specific know-how*, *stage of life* and the *value of self-enhancement*.

² Both electricity consumption and weekly washes are normalised to *per capita* values.

Table 5 - Regression models for predicting *per capita daily average electricity consumption*

Dependent variable	Model		B	Std. Error	Beta	Adj. R ²	Observations
Per capita daily average electricity consumption	3	(Constant)	5.71	0.61	-	0.3**	Stepwise method, collinearity statistics VIF<5 and tolerance close to 1
		Specific know-how	-1.18	0.36	-0.35***		
		Stage of life	-0.25	0.06	-0.41***		
		Weatherising need	1.49	0.66	0.24**		
	4	(Constant)	5.57	0.87	-	0.3**	
		Weekly washes <i>per capita</i>	0.69	0.18	0.35***		
		Stage of life	-0.23	0.06	-0.35***		
		Specific know-how	-0.18	0.33	-0.33**		
		Value self-enhancement	-3.33	1.51	0.20**		

p<0.05, *p<0.001

For this particular case study, these results confirm the quantitative significant impact of different dimensions on electricity consumption, such as energy services, household activities and their characteristics, and more importantly, usage energy behaviours. The specific conceptual model for the case study is displayed in Figure 7 (following Table 4, model 1). According to these results, behavioural change actions integrated in this intervention were focused on both structural and behavioural strategies, namely by promoting a better insulation of the dwellings, providing specific and technical information and encouraging specific usage energy behaviours (e.g., settings adjustment, more efficient use of washing appliances).

Figure 7 – Specific conceptual model for the case study

Although the remaining variables of the model have not resulted as significant in this particular case study, they maintain their importance on influencing energy consumption and energy efficiency levels as derived from the conceptual model and may emerge as relevant in samples with different characteristics. Further analysis is underway but these results contribute to illustrate the need for considering an integrative perspective, while unveiling the important role of usage energy behaviours, when addressing energy efficiency in the residential sector.

4. Conclusions

The role of energy behaviours in energy efficiency is gaining increasing recognition and more effective behaviour change interventions should be designed in the framework of sound energy efficiency policies. Tackling energy behaviours is however a complex and challenging task since they hold multiple dimensions, which require to be addressed using complementary disciplinary perspectives. The combination of these different views through integrative research is needed to develop comprehensive approaches to the understanding of energy behaviours and promotion of adequate end-use energy efficiency actions and programmes.

An integrative intervention to explore the qualitative and quantitative influence of usage energy behaviours on energy consumption was developed through an innovative combination of modelling techniques. The use of problem structuring methods enabled the comprehension and characterisation of the problem from various perspectives, the identification of the best methods and techniques to be utilised and their integration into a unified and coherent methodology, while facilitating the communication and the involvement of different stakeholders. Problem structuring methods also made explicit the underlying system, the stakeholders' roles, visions and positioning (including the researchers') thus enabling reducing the associated bias. Although this intervention did not aim at reconciling the stakeholders' different visions towards a common one, future developments of this work will include this dimension. Yet, all the dimensions of the generic constitutive definition of problem structuring methods were properly established: improvement activity, systemic approach, adaptation/ creativity, methodological lessons, worldviews, messiness, interactive/iterative, subjectivity, limits. Also from a methodology perspective, the approach developed enabled to integrate both qualitative (e.g., behaviours characterisation) and quantitative information (e.g., energy monitoring data). Accordingly, problem structuring methods revealed to be pertinent tools to be utilised in complex human-centred energy research, such as energy behaviours, by enabling the development of tailored methodologies. However, in voluntary multi-agent contexts [82], in which an intrinsic lack of authority exists, problem structuring methods may offer limited results in promoting mutual accommodations, overcoming individual interests and coping with scarcity of resources at stake to lead to more effective actions.

Results from this intervention confirmed the statistical significant influence of the impact of usage energy behaviours on energy consumption. Furthermore, it also confirmed the impact in energy consumption of variables associated with different dimensions, thus supporting the need for considering an integrative perspective when addressing residential energy efficiency. In this case study, energy efficiency increases by promoting both structural and energy behavioural actions, namely a better insulation of the dwellings (which reduces energy consumption by a factor of 3.14) and encouraging specific usage energy behaviours (e.g., settings adjustment and efficient use of washing appliances, which reduce energy consumption by a factor of 1.85 and 0.56, respectively). However, these recommendations are case specific and may not be generalised since the sample under study is not representative of the overall population. This should be taken into account in future developments of this work.

More effective energy efficiency intervention policies addressing energy behaviours in the residential sector should involve the different energy stakeholders (e.g., regulators, governmental and energy agencies, utilities, energy service companies, consumer associations, scientific community), while ensuring their adequate coordination, since they play important and complementary roles. The development of behaviour change interventions in real-world contexts should also anticipate challenges such as uncertainty and constant changes (e.g., resources availability, stakeholders' involvement) and be designed to be flexible, adaptive and comprise important skills such as communication, negotiation, and integration of information.

In conclusion, integrative modelling approaches contribute to properly address energy behaviours and design more effective behavioural change interventions and energy efficiency policies.

Acknowledgement

The authors would like to express their gratitude to Dr. Paulo Peixoto for his contributions to the development of this study and to ISA – Intelligent Sensing Anywhere for the technical support in energy monitoring. This work has been developed under the Energy for Sustainability Initiative of the University of Coimbra and partially supported by the Energy and Mobility for Sustainable Regions Project (CENTRO-07-0224-FEDER-002004) and by Fundação para a Ciência e a Tecnologia (FCT) under grant SFRH/BD/51104/2010 and project grant UID/MULTI/00308/2013. The paper benefited from the constructive comments of the anonymous reviewers on an earlier version.

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48
49
50
51
52
53
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List of Tables

Table 1 – Characteristics of the residential sample (N=128)

Table 2 – Relation between the factors emerged from the factor analysis, the measured self-reported energy behaviours and the respective categories

Table 3 – Significant correlations established between the model parameters and daily average electricity consumption

Table 4 - Regression models for predicting daily average electricity consumption

Table 5 - Regression models for predicting per capita daily average electricity consumption

Table 1 – Characteristics of the residential sample (N=128)

Dimensions	Variables	Level	
Building	Typology	Apartment	88 %
		Villa	12 %
	Size	Less than 2 bedrooms	7 %
		2 or 3 bedrooms	70 %
		More than 3 bedrooms	23 %
Energy use	Average electricity consumption		10.8 kWh/day
Electrical equipment	Ownership	Laundry machine	84 %
		Dishwasher	92 %
		Tumble dryer	42 %
		Air conditioning system	16 %
		Electric water heater	8 %
Household	Number	Adults	1.7, $\sigma=0.8$
		Children	0.9, $\sigma=1.1$
Respondents	Gender	Female	68 %
		Male	32 %
	Age	< 36	49 %
		36 - 45	36 %
		46 - 55	9 %
		> 55	6 %
	Education level	No university degree	2 %
		University degree	98 %
	Marital status	Single	23 %
		Married	70 %
		Divorced or widower	7 %
	Professional activity	Working	86 %
		Non-working (student, retired, unemployed)	14 %

Table 2 – Relation between the factors emerged from the factor analysis, the measured self-reported energy behaviours and the respective categories

Factor	Self-reported energy behaviours	Category
Daily practices	Turning appliances OFF to avoid waste consumption (e.g., turning off the lights in empty rooms; turning TV off when nobody is watching it; turning water heating system off when in holidays)	Usage
	Eliminating standby consumption (e.g., turning appliances off using central plugs to avoid standby consumptions; turning appliances off directly on the switch to avoid standby consumption)	
	Use of passive strategies to control thermal comfort or lighting (e.g., using sun light in the rooms; insulating windows and doors; in the summer, closing the curtains/blinds during the day, and opening the windows during the night; in the winter, leaving curtains/blinds open during the day and closing them during the night; keeping doors and windows closed when they are being warmed or cooled; turning heating/cooling equipment on only in occupied rooms)	
	Efficient use of appliances (e.g., turning the dishwasher on only when it is full; using the washing machine at low temperature programmes; using dishwasher with eco programmes; turning the washing machine on only when it is full; ironing in long periods, instead of short ones; not opening and closing the fridge door very often; leaving the fridge door open for the less time needed)	
Specific know-how based	Settings adjustment (e.g., adjust acclimatisation temperature according to the season: summer 23-24°C, winter 18-20°C; regulating the fridge temperature according to the season)	Usage
	Use of dual time-of-use tariffs (e.g., using a timer to schedule water heating; turning the washing machine/dryer on during the cheapest periods; using cumulative heaters to benefit from cheaper electricity consumption periods)	
Information based	Auto-control and monitoring (e.g., talking with the dwelling occupants about electricity consumption and savings; reading the electricity bill; providing the meter readings to the electricity supplier)	Usage
	Investment in efficient appliances (e.g., buying more energy efficient equipment)	Investment

Table 3 – Significant correlations established between the model parameters and *daily average electricity consumption*

Model parameter	r
Weekly washes	0.61***
Specific know-how	-0.45***
Weatherising need	0.46***
Stage of life	0.54***
Energy intensive appliances	0.22**
Consequences to lifestyle	-0.20**

p<0.05. *p<0.001

Table 4 - Regression models for predicting *daily average electricity consumption*

Dependent variable	Model		B	Std. Error	Beta	Adj. R ²	Observations
Daily average electricity consumption	1	(Constant)	4.03	0.94	-	0.6**	Stepwise method, collinearity statistics VIF<5 and tolerance close to 1
		Weekly washes	0.56	0.14	0.38***		
		Specific know-how	-1.85	0.48	-0.30***		
		Weatherising need	3.14	0.89	0.28***		
		Stage of life	0.24	0.10	0.22**		
	2	(Constant)	3.31	1.95	-	0.4**	
		Stage of life	0.40	0.10	0.36***		
		Specific know-how	-2.10	0.51	-3.51***		
		Insulation level*	5.92	2.77	0.18**		
		Energy intensive appliances	0.05	0.02	0.18**		

* Parameter originally embedded in "weatherising need", **p<0.05, ***p<0.001

Table 5 - Regression models for predicting *per capita daily average electricity consumption*

Dependent variable	Model		B	Std. Error	Beta	Adj. R ²	Observations
Per capita daily average electricity consumption	3	(Constant)	5.71	0.61	-	0.3**	Stepwise method, collinearity statistics VIF<5 and tolerance close to 1
		Specific know-how	-1.18	0.36	-0.35***		
		Stage of life	-0.25	0.06	-0.41***		
		Weatherising need	1.49	0.66	0.24**		
	4	(Constant)	5.57	0.87	-	0.3**	
		Weekly washes <i>per capita</i>	0.69	0.18	0.35***		
		Stage of life	-0.23	0.06	-0.35***		
		Specific know-how	-0.18	0.33	-0.33**		
		Value self-enhancement	-3.33	1.51	0.20**		

p<0.05, *p<0.001

List of Figures

Figure 1 – Methodology used to develop this behaviour change intervention

Figure 2 – A rich-picture displaying the energy stakeholders' role in energy behaviours

Figure 3 – Energy consumption activation chain

Figure 4 – Disaggregated factors influencing the energy consumption activation chain with the identification of the variables assessed during this intervention

Figure 5 – Causal diagram reflecting the influence of the socio-economic environment on energy behaviours

Figure 6 – Integration of variables during the assessment of the model dimensions

Figure 7 – Specific conceptual model for the case study

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