Energy Research & Social Science 7 (2015) 84–98

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

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

Marta A.R. Lopes [a,b,*], Carlos Henggeler Antunes [a,c], Nelson Martins [d]

[a] INESC Coimbra, Rua Antero de Quental 199, 3000-033 Coimbra, Portugal
[b] Department of Environment, ESAC-Polytechnic Institute of Coimbra, 3045-601 Coimbra, Portugal
[c] Department of Electrical Engineering and Computers, University of Coimbra, 3030-290 Coimbra, Portugal
[d] Department of Mechanical Engineering, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

ARTICLE INFO

Article history:
Received 28 October 2014
Received in revised form 29 March 2015
Accepted 30 March 2015

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 5–20% [1,6]. However, these results may not be transferable since they are originated by projects with different

* Corresponding author at: IPC-ESAC, Bencanta, 3045-601 Coimbra, Portugal. Tel.: +351 239 802 940.
E-mail addresses: mlopes@esac.pt (M.A.R. Lopes), ch@deec.uc.pt (C.H. Antunes), nmartins@ua.pt (N. Martins).

http://dx.doi.org/10.1016/j.erss.2015.03.004
2214-6296/

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 overall energy consumption without changing the relevant behaviours [22]. Instead, the term energy conservation is often recommended. This study adopts the strict energy efficiency definition of reducing the final energy consumed while achieving the maximum level of energy services possible. Energy efficiency may not be achieved only by the change of technologies, but also by the way they are used, which are related to energy behaviours [2]. Accordingly, in this study the term energy efficiency will be used in an energy behaviour context, and "more efficient energy behaviours" indicate an increase of behavioural actions reducing the final energy consumption.

Accordingly, increasing energy efficiency by adjusting energy behaviours to more efficient patterns requires targeting which specific behaviours to adjust (e.g., investment, usage, maintenance, or management of energy resources) and a comprehensive understanding of the factors leading to their activation. In general, energy behaviours are shaped by personal and contextual factors and different research disciplines address them through distinct, yet complementary, approaches [2,23]. While the social sciences concentrate on exploring the personal and contextual factors leading to the activation of energy behaviours, engineering and more technological approaches focus on energy consumption as a result of the technical characteristics of equipment and buildings. Economics considers individuals to be totally rational, maximising utility and minimising cost in daily actions. However, behavioural economics recognises that during this decision process individuals may have information processing limitations and use heuristics and other information simplification processes. Psychology focuses on the individual perspective, identifying personal determinants (e.g., intentions, attitudes, norms, beliefs, values) or contextual influences to explain or predict energy behaviours. In turn, sociology and other social studies see energy behaviours as the result of the social context and not a consequence of individual decisions. In these disciplines, energy behaviours are considered to be a result of the social organisation in which individuals live such as social rules, lifestyles, standards or practices.

Regardless the unquestionable value of each perspective and the recent focus given by the European Environment Agency to the social practice approach [1], any single perspective becomes limited in addressing the different dimensions of energy behaviours by neglecting other disciplinary visions [24]. The creative combination of different disciplines through integrative research is then required to develop comprehensive approaches to the understanding of energy behaviours and promotion of end-use energy efficiency in more effective interventions [25].

1.2. Modelling as a structuring approach of energy behaviours

Modelling is a central tool to modern science, management and policy making, guiding judgement and supporting problem solving [23,26,27]. In energy efficiency studies, modelling is usually employed for forecasting energy demand, predicting the adoption of new technologies or estimating the impacts of energy efficiency programmes (e.g., [28]). Energy behaviours, in particular, have been modelled using a variety of different techniques, depending on the objectives and the disciplines. For instance, the social sciences use modelling to explain, interpret and predict behaviours (e.g., [29]) while engineering utilise quantitative models to determine energy consumption (reviews may be found in Refs. [2,30,31]).

Although there is a vast research on energy behaviours, integrative modelling approaches of energy behaviours have had limited development. Integrative models are inclusive and flexible, considering all 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 Ref. [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