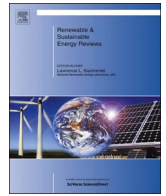




Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

The role of context in residential energy interventions: A meta review

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ARTICLE INFO

Keywords:

Energy intervention
Consumer behavior
Energy practice
Conservation
Efficiency
Smart grid

ABSTRACT

Residential energy interventions aim to structurally influence the way people behave in order to achieve a more sustainable behavior. However, the effectiveness of concrete residential energy interventions in specific circumstances varies widely: depending on the context interventions are more or less successful. This paper studies the effect of the context on the effectiveness of concrete residential energy interventions. We do this by means of a large meta analysis of literature. Our review consists of two main parts. First, we give an overview and categorization of all major types of residential energy interventions. Second, we use this categorization to study the effectiveness of different types of interventions in specific contexts: physical (environmental); socioeconomic; cultural; and political and governmental contexts. In addition, we propose to extend well known design methodologies for successful energy interventions by making the role the context plays in these explicit. Our ultimate goal is to provide both practitioners and researchers with a framework that helps with the design of successful energy interventions, hopefully leading to a more sustainable future.

1. Introduction

During the past 40 years, research has been conducted on influencing people towards a more sustainable behavior, with a large body of research that has a particular focus on energy consumption related behavior. Currently, the ideas and the developments of the emerging smart grid reinforce the need for such research. The smart grid is conceived as one of the responses to the worrying climate change situation. This means that interventions aimed at changing the values, attitudes and behaviors of people towards a more sustainable use of energy are especially relevant in the smart grid. There is an increasing agreement that the developments related to the smart grid and smart energy systems cannot and should not be performed without involving or considering consumers or prosumers [175,38,103,131,83,130,82,182,120,74]. The focus of this paper is on residential energy interventions, i.e., those involving consumers (prosumers). Other energy interventions, for example interventions targeted at the industrial sector or the service industry, are outside the scope of this paper.

A majority of the residential energy interventions applied so far present mixed results [78]. Additionally, long-term success and scalability of the residential energy interventions are rarely evaluated. The starting point of this paper is that we believe that the successfulness of interventions depends on the specific context involving a variety of factors. This is in line with a common opinion found in the literature that there is no a silver-

bullet type of a solution [92,93,169,75,139,179,188,97,77] and intervention strategies should be carefully designed and attend to the context [144,73,156]. Accordingly, an understanding about the influence of contextual factors to different energy interventions is required. We identify a couple of recent reviews (discussed below) that aim to support this understanding from certain angles. However, a research gap is present regarding a comprehensive picture of the role of context in energy interventions. This paper is written as a response to that research gap.

We analyze different studies considering reported outcomes and the context in which they are conducted. The aim is to provide a starting framework for selecting effective intervention strategies in different contexts. Contexts are categorized into four groups: physical (environmental), socioeconomic, cultural and, political and governmental. While we have considered including technology as another contextual dimension, we select not to do so, as technological factors are largely dependent on the other introduced contexts. Another reason is, as we will see later, that technology adoption (renewable, energy efficient, storage) is usually taken as an intervention target in the framework of the smart grid. In addition to presenting success of interventions in different contexts, we craft a set of more general recommendations that the state of the art research is in agreement about. We agree with Kollmuss and Agyeman [112] in that a single model covering all the different factors affecting residential energy interventions' success is

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not possible or useful. Instead we aim that our research brings more clarity to the existing findings and state of the art and that it can serve as a guide for selecting the most appropriate intervention model in a *particular intervention context*.

Recently, several review papers have been published with a similar aim to the one we describe [144,73,156]. However, the review we present is broader, since it covers all the identified energy intervention targets (see Section 2), while the mentioned reviews focus mainly on awareness, conservation or efficiency. Pothitou et al. [144] present a conceptual framework for behavioral change covering a wide set of factors from micro to macro level, however, they do not discuss the success of interventions under those different factors. Frederiks et al. [73] analyze how individual behavior determinants affect energy interventions. In our framework (see Section 2), such determinants correspond mainly to the internal factors and in part overlap with the socio-economic context. Similarly, Schultz [156] focuses only on a small set of selected interventions and mainly on psychological (internal factors). Hence, the range of factors we cover is broader since we focus on additional external factors, that are not included in those reviews, and we also cover a more comprehensive set of interventions.

The rest of the paper is structured as follows. First, we introduce relevant terminology and concepts (Section 2), following with the description of the methodology of our work in Section 3. Section 4 presents the results of our review, and Section 5 summarizes the role of context in energy interventions. Finally, Section 6 offers concrete recommendations for designing energy interventions based on previous results. Our conclusions and final remarks are given in Section 7.

2. Concepts and terminology

Environmentally significant behaviors are defined as a wide set of activities that directly or indirectly affect the availability of materials and energy and the dynamics of the biosphere [171]. This is an impact-oriented definition, focusing on the behaviors that 'significantly affect the environmental quality' [167]. Psychological research points out an additional perspective, the so called 'intention-oriented definition' [170], that emphasizes the motivations of an individual to act pro-environmentally. The difference between the two perspectives is apparent in cases where people intend to act pro-environmentally, but either fail to do so, or lack proper information, so their actions do not result in a positive impact for the environment [39,170]. Following this, we focus on the subset of environmentally significant behaviors that specifically relate to energy consumption and, depending on the studies reviewed, we consider both of those perspectives: in most of the cases, we consider impact-oriented behaviors, but also sometimes, when talking about internal factors and motivations, we consider the intention-oriented definition.

Precisely, we use the term *energy practices* to describe different human activities that directly or indirectly may lead to end-use energy consumption or prosumption, hence including both conventional and renewable energy (for an overview of residential end-use energy consumption, see [174]). Energy practices, in our definition, involve an activity, as one aspect, and may or may not involve the resulting energy consumption. Unlike Lopes et al. [117] who use the term energy behavior to represent a similar concept, we choose to talk about practices as they offer a wider meaning and there is a need 'to look beyond energy to understand energy' [173,27,83,143,29]. Practices are embedded deeply in everyday social life [20,29] and 'accentuate the continuity and habituation of activities affected and shaped by social and cultural factors' [154]. Strengers [172] discusses practices instead of people as the sources and carrier of attitudes, values and beliefs. It is also important to remind that there is a potential for some energy practices in our definition that now consume energy to become non-energy practices at a later point.

For describing different solutions, strategies and projects aimed at influencing human energy practices, we use the term *energy interven-*

tions. Diverse energy policies are found suggesting priorities for a sustainable modern energy system [58,181,137,41,40]. Among the suggested priorities are energy conservation and efficiency, exploitation of renewable and sustainable resources, and alternative and emerging technologies. Our review finds that the energy interventions proposed in the literature target all of these priorities and, in addition, some more concrete aspects of human behavior, as we present below.

2.1. Practice (behavior) change targets

Examining the literature on energy interventions reveals several categories of practice change targets. First, inline with our wide definition of energy practices, there is a large number of studies focusing on **raising awareness** and fostering discussions on energy topics. An early understanding of researchers was that in order for any behavior change to take place, people first must start thinking more about energy in the context of their everyday life [45,119,63]. However, interventions that solely or mainly focus on raising awareness by increasing knowledge are termed 'information deficit' models and received critique as an overly simplistic approach to behavior change, both from a theoretical and a practical perspective [166,139,112]. Our review reveals (see Section 3) that the largest number of energy interventions proposed is focused on **energy conservation**, also called curtailment or simply saving (usually requires a change in everyday or multiple-time energy practices). Another large subset of the studies targets **energy efficiency** (often one-time practices, such as to buy more efficient devices or apply better isolation). While not always directly contributing to the reduction of energy use, **demand side response (DSR)** is another important target in the context of the modern smart grid that can help to reduce greenhouse gas emissions. DSR includes all intentional electricity consumption pattern modifications by end-use customers that are intended to alter the timing, level of instantaneous demand, or total electricity consumption' [3]. Forms of DSR are also sometimes referred to as demand side management (DSM), shifting time of use, efficient demand response, flexibility of energy supply or short-term consumer flexibility. In addition to some suggested technical solutions, DSR is also often achieved through (in combination with) behavior change (e.g. performing energy practices in off-peak hours due to a dynamic pricing incentive). Finally, exploitation of **renewable, sustainable resources and/or storage technology** are structural energy interventions representing another of the suggested priorities in a sustainable modern energy system, that again require a shift in attitudes and behavior change from consumers. In particular, the transition to a distributed production energy system requires from consumers to become *prosumers*, a process that has shown to be slow, among other reasons, due to the required shift in people's attitudes towards energy and adoption of new technology. The promise of energy storage technology is large, especially to support the exploitation of renewable sources.

2.2. Energy intervention categories

Energy interventions have also been categorized based on their different approaches. The categorization based on *instrumentality* [53] distinguishes **information-based** (focusing on influencing behavior by providing some novel or differently presented information to consumers) and **structural interventions** (focused on changing the environment in which the behavioral decision takes place). Additionally, we also distinguish as a third category: **gamification and monetary rewards-based** interventions (as they fall in between the first two types). Another categorization of energy interventions is based on the *moment* (point of time) in which they target the behavioral decision [2,62]. The interventions taking place prior to the actual energy practice are **antecedent** and those applied after the activity has taken place are **contingency** (consequence-based) inter-

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