



Understanding the uneven diffusion of building-scale renewable energy systems: A review of household, local and country level factors in diverse European countries



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ARTICLE INFO

Keywords:

Households
Diffusion
Heat pumps
Solar systems
Advanced biomass heating

ABSTRACT

This review focuses on renewable energy technology deployment in residential buildings, which is part of current targets to develop net-zero-carbon buildings in Europe and to promote the deployment of renewable energy. We focus on the adoption of four technologies: heat pumps, solar photovoltaics, solar thermal systems for domestic hot water and space heating, and advanced biomass heating. While there are several studies on households' investment criteria, a research gap exists because building owners across Europe are quite diverse, and the European markets exhibit different stages of maturity. This article conducts a critical review of the literature on the diffusion of building-scale renewable energy solutions in order to answer the following questions: (1) to what extent can findings from studies on household adoption criteria be generalized from one country to another? and (2) what insights does the literature offer on factors that might explain the differences in adoption patterns between European countries?

1. Introduction

Buildings are increasingly key to decarbonizing the economy. Improvements to the energy efficiency of building envelopes and systems are the primary means envisaged for such decarbonization [1,2]. However, in existing buildings, renewable heating, cooling and power are likely to play an important complementary role to energy efficiency in bringing buildings closer to net-zero energy or carbon status [3,4] given the fact that the building stock is very long-lived [5], whereas building systems have shorter lifespans and are thus renewed more rapidly [6]. As a result, the adoption of new heating, cooling and power production technologies in buildings is of increasing interest for both policy makers and companies marketing renewable energy solutions for buildings.

This review focuses on renewable energy technology deployment in buildings, which is part of current targets to develop net-zero-energy or net-zero-carbon buildings in Europe, but also to promote the deployment of renewable energy [7]. It concerns the small-scale deployment of renewable energy in heating, cooling and power production in or near buildings to reduce imported energy, as well as to contribute to the share of renewable energy in the energy mix. From this perspective, the following technologies are most relevant [6,8–10]: heat pumps, solar photovoltaics, solar thermal systems for domestic hot water and

space heating, and biomass heating (especially advanced biomass central heating systems such as wood pellet boilers). In the following, these technologies are referred to as “building-scale renewable energy systems”.

Several studies investigate the economics of investing in building-scale renewable energy systems [11–13]. However, building owners' decisions are rarely driven by sophisticated financial analyses of alternatives [14,15]. The European building stock is owned by millions of diverse building owners, with different perspectives on investing in technical upgrades of their properties. A particularly problematic category consists of private homeowners (owners of single-family homes or apartments), who own most of the European building stock, but often lack technical expertise and capital to make investments, and whose investment criteria and investment environments are heterogeneous and difficult to predict.

Several recent studies have investigated factors influencing household adoption of building-scale renewable energy solutions [16,17], and there are already a few reviews focusing on motivations and barriers for adoption in particular countries [18]. However, we are not aware of any studies that systematically examine similarities and differences in adoption criteria across European countries or across technologies. This is a research gap, since the adoption levels of building-scale renewable energy technologies differ widely across

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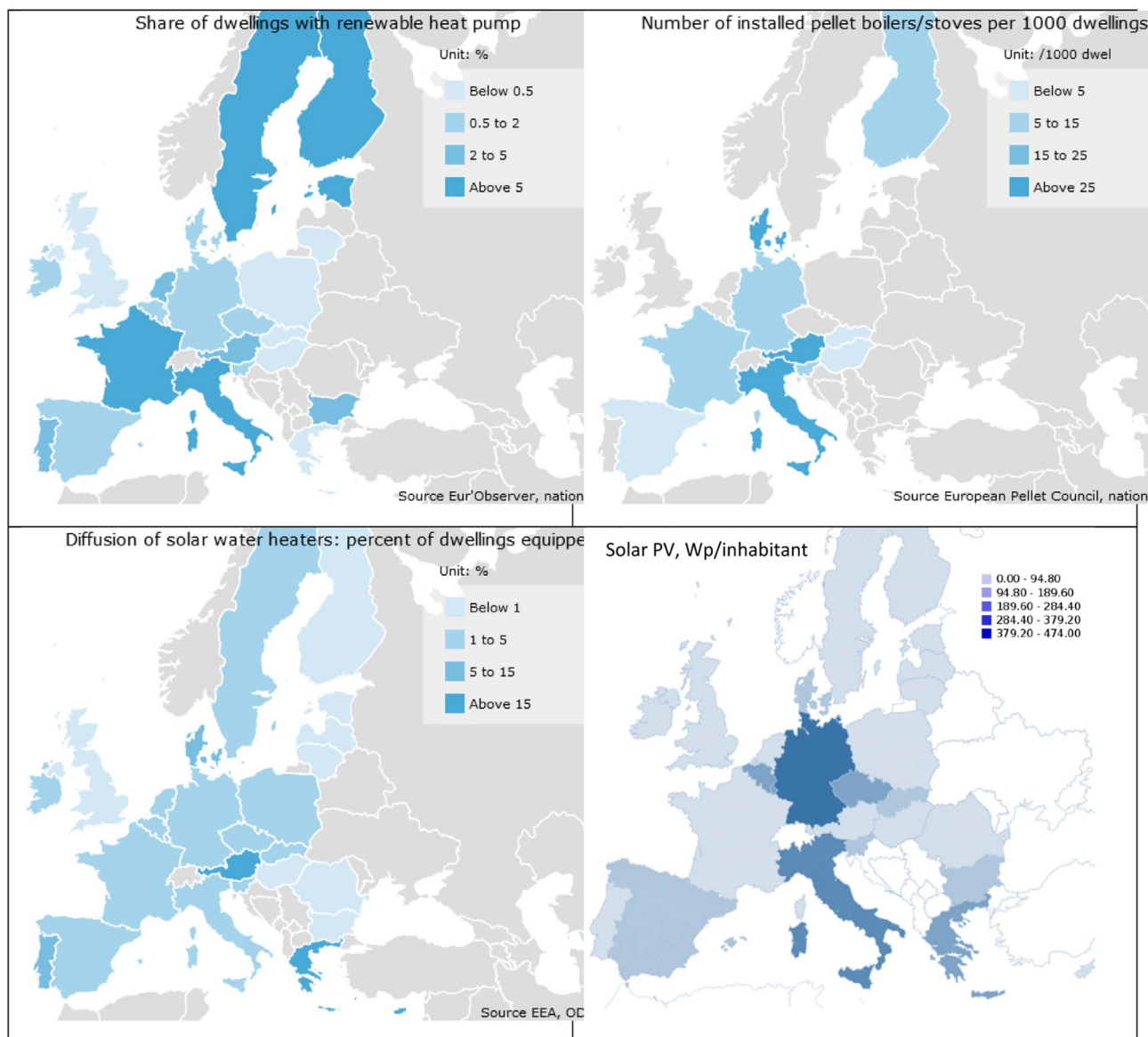


Fig. 1. Levels of market penetration of four building-scale renewable energy systems: (a) heat pumps, (b) pellet boilers, (c) solar collectors and (d) PV panels. Sources (a)–(c): Odyssee based on Eur'Observer, European Pellet Council and EEA, (d) Eur'Observer visualised via Datamaps.eu.

Europe (Fig. 1) in a way which is not readily explained by geography alone [11,19–21].

The uneven uptake of renewable energy solutions across countries suggests that the decision context of different types of building owners is important, and that findings from one country cannot be unproblematically transferred to another. The institutional and historical embedding of different technologies in specific local and country contexts is likely to be relevant for building owners' decision making, since driving forces and barriers can also be different at different stages of the diffusion of innovative solutions [8]. Unlike previous reviews, we separately examine literature pertaining to the importance of factors in the households' country context and local context, which has not been addressed in previous reviews on the adoption of building-scale renewable energy systems.

The aim of the current review is to investigate the literature concerning the diffusion of building-scale renewable energy solutions in order to answer the following questions arising from the uneven uptake of building-scale renewable energy solutions in Europe:

(1) To what extent can findings from studies on household adoption criteria be generalized from one country to another?

(2) To what extent does the existing literature offer useful insights on household factors and factors in the local and country context that might explain the differences between countries?

In the following, we describe the material and methods used. The first part of this review (Section 3) examines household-level studies of which factors influence investments in building-scale renewable energy systems. Based on this and additional material, the second part (Section 4) examines factors in the householders' local context that have been found to influence investments. The third part (Section 5) focuses on the country context, and alongside the obvious factors of geography, policy and markets, examines existing literature on the role of other contextual factors, such as professional and expert communities, the media and social movements. In our discussion and conclusions (Section 5), we then identify factors that are worth considering when researching and promoting building-scale renewable energy systems in European residential buildings. We develop propositions for quantitative research and ideas for qualitative research on how household, local and country contexts are interconnected.

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