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Open access decision support for sustainable buildings and neighborhoods: The nano energy system simulator NESSI

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ABSTRACT

The urgency of climate change mitigation, rising energy prices and geopolitical crises make a quick and efficient energy transition in the building sector imperative. Building owners, housing associations, and local governments need support in the complex task to build sustainable energy systems. Motivated by the calls for more solution-oriented, practice-focused research regarding climate change and guided by design science research principles, we address this need and design, develop, and evaluate the web-based decision support system *NESSI*. *NESSI* is an open-access energy system simulator with an intuitive user flow to facilitate multi-energy planning for buildings and neighborhoods. It calculates the technical, environmental, and economic effects of 14 energy-producing, consuming, and storing components of the electric and thermal infrastructure, considers time-dependent effects, and accounts for geographic as well as sectoral circumstances. Its applicability is demonstrated with the case of a single-family home in Hannover, Germany, and evaluated through twelve expert interviews.

1. Introduction

To mitigate the effects of climate change, global greenhouse gas (GHG) emissions must be substantially reduced. The building sector is considered one of the most emission-intensive, as building operations account for 27% of total energy sector emissions. In addition, the energy supply of buildings accounts for 30% of global energy consumption [1]. Based on these statistics, it is evident that the sustainable transformation of residential and commercial buildings is critical to achieve international climate (e.g., Paris Agreement) and development goals (e.g., United Nations Sustainable Development Goals). Recent political-economic developments such as Russia's invasion of Ukraine, persistent supply chain bottlenecks due to the Covid-19 pandemic, and rising inflation, significantly affected energy markets resulting in sharply rising energy prices [2]. As a result, emission-intensive countries (e.g., Germany and the United Kingdom) have defined goals and supporting measures for achieving energy transitions more quickly and efficiently. They set laws and policies toward fostering supply security, environmental as well as climate protection, and high efficiency in the energy sector [2]. The current developments and rising government support have additionally raised awareness of alternative energy supply among the general population and led to an upswing in the implementation of renewable energy systems in residential buildings, companies, and communities [2].

Thus, building owners, housing associations, and local governments are faced with the complex task of accommodating the often conflicting goals of cost-effectiveness, energy resilience, and environmental friendliness while transforming their building or neighborhood energy system. In particular, inexperienced stakeholders require intuitive and easily accessible decision support that is both accurate and reliable. Energy consultants are in higher demand than ever and equally need adequate tools to support their clients' decisions.

The Information Systems (IS) Research community has acknowledged this need and has been calling to use the transformative power of IS to provide solution-oriented, relevant studies that address climate change [3,4]. Moreover, Lehnhoff et al. [5] encourage solutions that reduce carbon emissions and explicitly state the value of decision support systems (DSS) that promote sustainable energy systems. Mathematical models, particularly multi-criteria DSS, have proven to reduce real-world complexities in decision problems [6]. Therefore, various energy models and software tools have been developed to reflect and combine the conflicting environmental, economic, and technological goals of sustainable energy transitions. However, based on

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