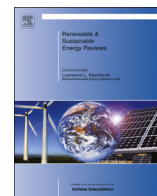




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What drives the development of renewable energy technologies? Toward a typology for the systemic drivers



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ABSTRACT

At present, governments are embarking on the ambitious undertaking of increasing their countries' market share of renewable energy. Political ambitions, however, are just one of the driving forces for energy companies' to engage in innovative climate projects. Energy companies' perceptions of business opportunities are dependent on a set of factors that influence their innovation ambitions. This research operationalizes previous work on the main drivers of the establishment of Renewable Energy Technologies (RETs), with the aim of presenting an overview of the typical systemic drivers within a technological innovation system (TIS) framework. This leads to the proposal of a comprehensive typology and categorization of drivers of RETs. The typology is validated empirically by analyzing data on the development of four types of RETs (wind, solar, biomass and wave energy) in eight European countries (EU-7 and Ireland). The study's results shed light on the multilateral drivers behind the development of RETs. Furthermore, a cross-case comparative study reveals the differences between drivers of RETs and the patterns of these drivers in different countries.

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1. Introduction

Energy markets have undergone profound changes over the past few decades. Depletable fossil fuels, growing concerns over climate change and catastrophic energy accidents such as the Fukushima disaster are among the challenges that have raised awareness and prompted immediate action [1]. The introduction of renewable energy technologies into the energy system offers a possible solution. Though, even with supportive policies, RETs have experienced difficulties in entering into the market. Despite the double-digit growth rate of these emerging technologies since 1990, their progress has so far been “slow”, “painful” and “highly uncertain” [2].

To boost the chances of success of such technological developments, politicians and governments have implemented a variety of initiatives. In 1997, the Kyoto protocol was among the first proactive political initiatives designed to trigger the development of RETs. This global agenda was just the beginning and has since been augmented by numerous political decisions on different levels. For instance, in Europe, policy makers have set the goal of achieving 20% total energy consumption from renewables by 2020 [3]. This target is supported by the roadmap to 2050, by which time the whole energy market should be decarbonized. To meet this ambitious target, however, political initiatives on their own are insufficient as drivers of RETs [1].

Factors that foster RETs (hereinafter, drivers) are defined as, “the processes that influence trends and our ability to meet agreed-upon targets.”¹ [4: p. 8086]. Based on this definition, the role of drivers in accelerating and enhancing the innovation processes of RETs is significant. This is even truer if the intention is to influence a function of society [5]. Keeping this notion in mind, many scholars endeavor to understand the underlying RETs development processes so as to identify their drivers and barriers [6–8]. Nevertheless, while scholars have proposed comprehensive frameworks to describe the barriers of RETs development [9–11], the literature lacks inclusive studies that examine drivers. Even still, a few studies that propose dispersed categories for the drivers are available [12–14], although findings and theories are inconsistent [15]. Given that the current aim to accelerate the development of RETs, this knowledge is essential to build a foundation primarily to exploit different drivers of future advances in renewable technologies, as well as to understand the effectiveness of each driver.

To address this research gap, the current study offers a comprehensive overview of the drivers of RETs, proposes a typology to classify these drivers, and then maps their significance with respect to different regions and technologies. The technological innovation

system (TIS) framework offers a suitable theoretical basis to present and conceptualize a typology of drivers of RETs development. Academics have consistently deployed TIS as an appropriate framework, both theoretically and empirically, for studying advances in RETs [16]. Justification of the deployment of this framework lies in the slow and risky technological processes that energy companies must undergo [2]. Furthermore, energy companies have strong links to TIS elements (i.e., institutions) [6]. Researchers in this framework have shown that innovation processes are influenced by the environment [9]. Thus, innovation occurs as a result of technology and knowledge rather than the actions of one single actor [17].

Overall, the study aims to shed light on this unexplored area by answering the following main research questions.

- 1) Which typologies of systemic technological innovation drivers are relevant for the development of renewable technologies?
- 2) How do these typologies relate to the level of maturity and the geographical features of each renewable technology?

This study addresses these specific objectives by first presenting an in-depth literature review and then using secondary empirical data from the available research on RETs to perform descriptive empirical analysis. The findings serve two main purposes. Firstly, they provide insight into the formative phase of TIS by identifying main RETs drivers. Secondly, they contribute in mapping important drivers of the four types of RETs under study and their patterns in different countries.

The remainder of the paper has the following structure. Section 2 presents a review of prior studies on TIS and the main contributions of this approach to examining RETs systemic development. Section 3 outlines the study methodology step-by-step. Section 4 contains details about forming and conceptualizing a typology for drivers of RETs. In Section 5, a discussion of the study's results and findings appears, before Section 6 brings together the main conclusions and limitations of this research.

2. The contribution of TIS to understanding the RETs development

In the mid-1980s the concept of an innovation system (IS)—with an emphasis on the technology and information flow among people, enterprises and institutions—was developed as a key to understanding innovation processes [17]. IS emerged as a policy concept with a number of systemic dimensions [6]. Among these systemic dimensions, the use of a technology innovation system (TIS) framework to study and understand the emergence of a new technology has been widespread. A TIS has been defined as, “a dynamic network of agents interacting in a specific economic/ industrial area under a particular institutional infrastructure and

¹ Drivers have received other names such as “motivators”, “driving forces”, “ambitions” and “delivery factor” among others.

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