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Understanding systemic analysis in the governance of sustainability transition in renewable energies: The case of fuel cell technology in Iran

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ABSTRACT

Considering the complex and evolutionary process of renewable energy development, it is imperative to have a framework for its governance. The governance of transition toward renewable energies can be divided conceptually into two phases, namely systemic analysis and policy making. This paper focuses on identifying different methodological steps in the systemic analysis phase. These steps provide requisite inputs for the second phase, policy making, by attaining a concrete understanding of the current status. In the first step, the boundaries of the transition process are defined by specifying the unit of analysis and identifying the system's components and relations. In the second step, and in order to have a big picture of the system's transformation, the dynamism of technological development is mapped through time. In the third step, an approach for analyzing and policy making of sustainability transition is chosen by comparing various approaches and selecting the most fitted one. All of these methodological steps are finally applied in the case of the Iran fuel cell technology development program to show the practicality of the proposed conceptual framework in a real case problem and to provide some insights for practitioners.

Contents

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1. Introduction

Although the most important source of energy in the world will be fossil fuels up to 2030, numerous countries strongly prefer to move toward a new source of energy named renewable energies (REs) [1]. In the same manner, Iran has also focused on developing different renewable energies from 20 years ago. Obtaining 44 and 54 percent of its energy from oil and gas, Iran is one of the biggest suppliers of fossil fuels in the world [2]. Nevertheless, forecasting the great demand for energy in the future as a developing country on one hand, and stressing the vitality of sustainable development on the other, motivates Iranian policy makers to attend to REs' development as a future source of energy. In this respect, fuel cell (FC) technology has been one of the selected options for electricity generation by Iran's government and energy sector in the past fifteen years. Iran has given priority to the fuel cell technology development because of the 9 to 10 percent annual growth in electricity demand up to 2025,[1] the ability of producing energy twice more efficiently than existing fossil plants, the emphasis of the government on distributed electricity generation due to inefficient transferring lines, and finally, the emergence of fuel cell motor engines [3].

Contrary to the countries' interest in developing REs, it is not easily achievable. The current system of energy has been evolved into a complex and inter-correlated set of actors, technologies, and institutions, which Unruh [4] "named carbon lock-in". In such conditions, the development of renewable energies needs a continuous stimulation to break the system's structural inertia and to build a new order. This process is referred to as "Transition" in the literature [5]. Transition is a process in which the social system is changed, existing structures are broken down, technological, political, and economical innovation occurs, and necessary driving forces are provided for change [6,7]. Researchers have also considered the subject of sustainability and presented the concept of "Sustainability transitions". According to their definition, sustainability transitions are long-term, multi-dimensional, and fundamental transformation processes that shift current socio-technical systems to more sustainable forms of production [8]. The gradual development process of REs technologies such as fuel cells can be considered a sustainability transition by this proposed definition.

Being a relatively long-term process, the sustainability transition toward REs should be considered as a complex-evolutionary system [9]. Some features including the existence of nonlinear relations, feedback loops, instability, varying boundaries, and numerous subsystems prove the complexity of such systems [10]. Besides, the other features including the dominance of dynamism, focus on innovation, system heterogeneity, actors' bounded rationality, and finally path dependency indicate the evolutionary aspect of this system [11]. Such systems are not developed spontaneously. They need a guiding power to show the right path of development. Hence, guidance and governance play significant roles in sustainability transition. A conceptual framework that is able to manage complex-evolutionary systems coherently can play this role [12].

The literature on sustainability transition and conceptual frameworks for its governance is highly broad. Recently, a paper has been published by Markard et al. [8] that investigates sustainability transition studies and classifies them into four core research streams comprising technological innovation systems (TIS), multi-level perspective (MLP), strategic niche management (SNM), and transition management (TM). Various researches have been carried out on the governance of renewable energy development from these points of view. They are classified into two major groups according to their overall goal: reviewing the theoretical concepts of sustainability transition and establishing methodological frameworks for analyzing the current status or policy making of real cases. In the first group, Coenen and Díaz López [13], by comparing existing approaches in innovation systems from different aspects including system boundary, actors and networks, institutions, knowledge, dynamism, and policy approach, have provided a clear picture of innovation policy models. Chang and Chen [14] have also explored the innovation systems literature, compared them from three perspectives including knowledge links, knowledge transfers, and system's boundary, and finally discussed some methodological challenges in that area. Furthermore, Markard and Truffer [15] have clarified commonalities, differences, strengths and weaknesses in two approaches, technological innovation systems and multi-level perspectives, by introducing basic concepts and system boundaries in each model. In addition to the first group, the other research group intends to develop a methodological or operational framework for guiding REs' development. In this group, Carlsson et al. [16] have applied a systemic approach in the area of innovation systems and stressed the necessary methodological aspects of the technological innovation system (system boundary, level of analysis, and performance). Based on the theoretical and empirical literature, Soltani and Kiamehr [17] have proposed a conceptual framework for formulating national science, technology, and innovation strategies using an interdisciplinary research method. Musiolik and Markard [18], Markard and Truffer [19], and Truffer et al. [20] have assessed technological innovation systems from three perspectives of networks, actors, and institutions, respectively. These three papers develop operational frameworks for analyzing the structure of innovation systems.

In the research that was just reviewed, different useful comparisons, methods, and models have been presented. They are fairly deep studies covering all facets of RE development. However, in order to successfully direct the sustainability transition in REs, a coherent and holistic framework is needed that encompasses all aspects of sustainability transition, from the analysis of the current status (as is) to policy making of the development process (to be). With respect to the mentioned framework, it is believed that it should consist of two major phases: systemic analysis and policy making. In the systemic analysis phase, the understanding of components, relations, dynamisms, and inducing and blocking mechanisms, which affect RE development, is provided. In the policy making phase, targeted measures are formulated for facilitating the transition process to RE based on the obtained knowledge of the first phase. The questions that will arise are what are necessary methodological steps in performing each aforementioned phase? This constitutes the main research question of our study.

For the beginning, the main idea of the study is concentrated on an explanation of the systemic analysis phase, and digging into

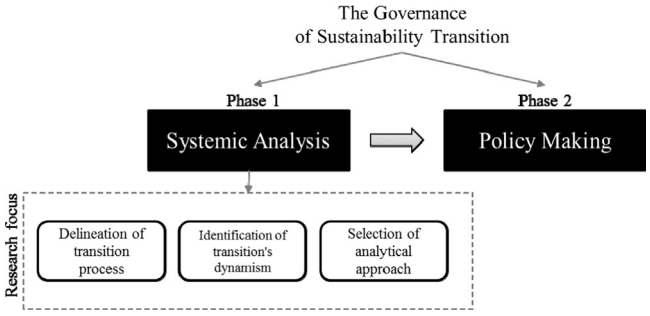

Fig. 1. The research focus of the paper in governance of sustainability transition.

[1] Iran 2025 Vision (www.IREC.ir).