Challenges to Developing Technological Innovation Systems Energy in Abu Dhabi

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Abstract

In this paper, we apply the technological innovation systems (TIS) approach to analyze the emergence of solar energy sector in the UAE. Using qualitative research, we examine two main research questions: (1) What are the dynamics in the emerging innovation system in Abu Dhabi? and (2) What are the driving factors that could sustain the transformation process, and what factors could potentially undermine the development of an innovation system locally? Our analysis contributes to the literature in several ways. While earlier studies have focused on how the innovation process evolved in retrospect, our analysis of an emerging innovation system allows us to examine the actual forces behind creating a new industry. We also add theoretical depth to the literature by integrating the conceptual work on TIS with empirical studies, through the lens of the solar energy sector. We identify several actors that act as major barriers during the formative stage of the innovation system, as well as factors that support further development.

Keywords: innovation systems, TIS, Abu Dhabi.

1. Introduction

The United Arab Emirates (UAE), especially the Abu Dhabi emirate, has recently embarked on a very ambitious path of developing a technology innovation hub in the area of alternative energy, focused on solar technologies in particular. This goal is part of Abu Dhabi's aspiration to diversify its economy and transition towards a knowledge-based economy. The economic transformation and diversification calls for a focus on creating an environment conducive to innovation and entrepreneurship.

In this paper, we apply the technological innovation systems (TIS) approach to analyze the emergence of solar energy sector in the UAE. Using qualitative research, we examine two main research questions: (1) What are the dynamics in the emerging innovation system in Abu Dhabi? and (2) What are the driving factors that could sustain the transformation process, and what factors could potentially undermine the development of an innovation system locally?

The hypothesis that frames this analysis is that the local environment in the UAE (as a wealthy developing economy), with respect to institutional, political, and cultural aspects, will impose different challenges from the ones faced by developed western economies. This in turn, will require either to have different institutions in place, or to alter the internal dynamics in the innovation system. For instance, while collaboration across and within different organizations (such as government, academia, private sector) has been critical for the development of solar industry in the U.S. and in Germany (Colatat et al., 2009), this model is not very common in the UAE and the larger Arabian Gulf region (IKED, 2009), where deference to centralized authority prevails.

Our analysis contributes to the literature in several ways. Previously, the innovation systems framework has been used to understand how industries have developed and how the innovation process evolved in retrospect. However, because of the very early stage in the restructuring process in the UAE, our analysis allows us to examine the actual forces behind the process of setting up an innovation-based economy and creating a new industry. We add theoretical depth to the literature (Edquist 2004) by integrating conceptual work on TIS with empirical studies. Moreover, studying the challenges and opportunities for developing the solar industry in the UAE will offer policy insights into how the innovation ecosystem could emerge locally, with a potential for drawing lessons of relevance to the larger Arabian Gulf region and other emerging economies.

The paper is organized as follows. We start with a brief literature review on the technological innovation systems framework and on how it can be applied to the solar energy industry. In Section 3 we lay out the regional context, describing the government's strategy for developing a solar industry and innovation hub in Abu Dhabi. Section 4 presents our research method and data collection process. In Section 5 we discuss our findings regarding the potential for developing a solar energy innovation system locally and the main factors that drive and constrain the transformation. Section 6 concludes with a summary of the main contributions of this paper, as well as directions for future research.

2. The Technological Innovation System approach

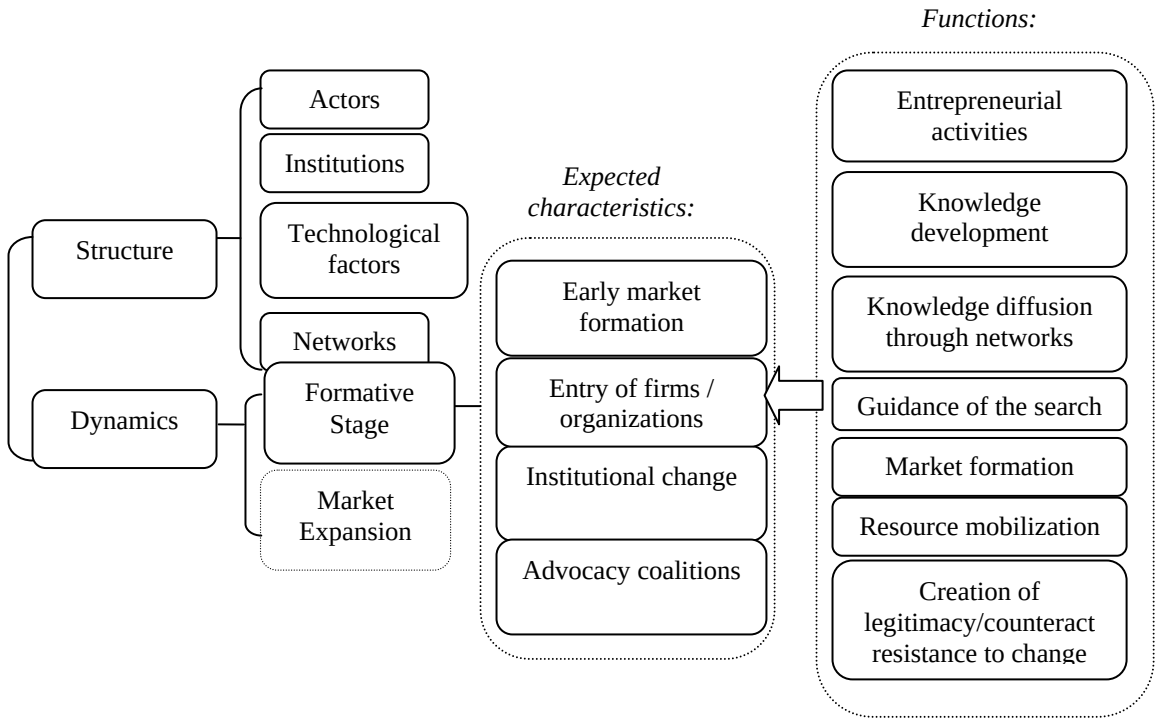
Traditional methods of innovation system analysis that mainly focus on defining the structure of an innovation system have proved to be insufficient for understanding the factors and processes that drive and sustain innovation (Hekket et al., 2007). In many studies, the system structures are regarded as static, "rendering them unfit to deal with technology dynamics" (Suurs and Hekkert, 2009). A better understanding of the process that takes place in innovation systems, so called functions or dynamics, is provided by Technological Innovation System (TIS) approach.

The TIS approach has been widely described in the literature (Hekkert et al., 2007; Suurs and Hekkert, 2009; Suurs et al., 2010; Jacobsson and Johnson, 2000; Jacobsson and Bergek, 2004; Jacobsson and Lauber, 2006; Suurs, 2009; Negro et al., 2007; Van Alphen et al., 2008). For this reason, below we discuss only briefly some of the concepts that are important for our analysis.

A TIS, by definition, is a network of actors, institutions, technologies, and the interrelations between them (Carlsson et al., 2002). In addition, rather than having a geography as a starting point (as in National Innovation Systems) or an industry (as in Sectoral Innovation Systems), the TIS focuses on a technology. By using this approach one seeks to understand "what are the conditions that foster the growth of an emerging innovation system in such a way that it becomes so large and entrenched in a society, that it is able to compete with and even become part of existing (innovation) systems" (Hekkert et al. 2007, p. 415-16). Moreover, when analyzing sustainability innovations, earlier studies have stressed the importance of a dynamic framework (Hekkert et al., 2007; Bergek, 2002; Jacobsson and Johnson, 2000; Negro et al., 2007; Negro et al., 2008). Figure 1 illustrates the structure, dynamics and functions of a TIS.

Because the solar industry in the UAE is in very early stages, the discussion of the TIS in this paper does not focus on a specific solar technology. We believe that, in general, the institutional challenges faced in the early stages of industry development are the same regardless of technology (e.g. photovoltaics, concentrated solar). For clarity, we define the solar TIS as those structural elements (and their mutual relations) that directly support (or reject) the development and, eventually, the diffusion of solar energy in the UAE (Suurs and Hekkert, 2009; Carlsson et al., 2002).

Figure 1: The structure, dynamics, and functions in a TIS



Source: Based on Suurs (2009), Hekkert et al. (2007), Jacobsson and Bergek (2004).

2.1 The TIS structure

The *actors* in a TIS refer to organizations involved in the emerging technology. The development of a TIS, as Suurs (2009) argues, depends on the interrelations between all these actors. For instance, while the government has played a key role in supporting the development of solar industry worldwide, the success of the TIS depended on how well its efforts have been coordinated with the needs of the entrepreneurs and of the business sector.

Institutions can be defined as "sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups and organizations" (Edquist and Johnson, 2000).

Technological factors consist of knowledge, skills and actions, viewed in relation to actors and institutions (Suurs, 2009). They can also include the techno-economic workings, such as costs, safety, reliability, and effects of up-scaling (Suurs, 2010). These features are crucial for understanding the feedback mechanisms between technological change and institutional change.

Networks can be perceived as modes for the transfer of tacit (Metcalfe, 1992) and explicit knowledge. Being strongly integrated in a network increases the resource base of an actor and facilitates the development of institutions and technological factors. Examples of networks are coalition of firms, industry associations, and research communities.

2.2 TIS dynamics and functions

The emergence of a TIS is a long and uncertain process (Jacobsson and Johnson, 2000; Suurs, 2010). The rate and direction of the process is driven by the evolution of its components and by improvements in the technology (Jacobsson and Johnson, 2000). In general, technological systems evolve in two main phases: formative period and market expansion (see Figure 1). For the purpose of our analysis, given the emerging nature of the solar industry in the UAE, the formative period is more important.

In the formative stage a TIS is characterized by high uncertainty, weak or absent institutions and technological structures, and lack of specific actors in the innovation system (Jacobsson and Bergek, 2004; Suurs, 2010). Nevertheless, as Figure 1 illustrates, this stage is highly critical for attracting new actors (as part of early market formation), designing institutions, and forming networks in the system, hence creating the necessary conditions to transition to the market expansion stage (Jacobbson and Bergek, 2004)[1].

The system functions are at the core of a TIS. The mutual reinforcement of these functions, through a process of cumulative causation, defines the ultimate outcome of the innovation process, and is considered necessary for TIS to occur (Suurs and Hekkert, 2009). System functions can reinforce themselves positively or negatively. For example, guidance of search can lead to resource mobilization, which in turn can improve knowledge production, diffusion through networks, and ultimately lead to market formation.

The formative phase can be hindered by several blocking mechanisms related to market failure, the networks between different actors, and the existing institutions. Furthermore, even if the formative stage is completed successfully, there are many difficulties in the transition to the expansion stage.

3. The UAE context

To understand how the TIS framework applies to the analysis of the transformation underway in the UAE, a brief overview of the regional context is needed.

UAE is a monarchy that is deeply entrenched in the tribal cultural patterns. As a result, the government is a strongly paternalistic and omnipotent decision maker, and decisions are made primarily at the highest levels of government authority. This characteristic differentiates the UAE's governance model from other developed and developing countries.

The country was created in 1971 as a federation of seven autonomous emirates. Abu Dhabi is the largest

[1] Incumbent technologies are often subsidized (Jacobsson and Bergek, 2004), and a new technology requires a long period of nurturing and diffusion before it achieves a price-performance ratio that makes it attractive to larger market segments. Therefore, creation of "protected spaces" (niche or early markets) may require government support (i.e. subsidy, investment in R&D, procurement) (Jacobsson and Johnson, 2000).

emirate geographically, and its waters contain the majority of the UAE's oil and gas deposits. While the oil and gas industry supported the fast growth of the UAE[2], also driven by Peak Oil concerns, economic diversification has been shown to be critical for future regional development (UNDP, 2003; Bradford, 2006).

In addition, more recently several reports have highlighted that the Arabian Gulf countries, UAE in particular, have the highest level of per capita CO_2 emissions and water use in the world (WWF, 2008; UNDP, 2009). Within this context, high solar insolation and large uninhabited desert areas, as well as high energy demand, make solar energy a potential niche for diversifying energy generation. Focusing on solar energy as a strategic development would strengthen the position of countries in the Arabian Gulf in the energy sector, and at the same time address sustainability and climate change issues. Nevertheless, currently, conventional energy is highly subsidized, making solar energy economically unattractive both for potential users as well as for investors.

4. Data collection and analysis

The data for this study was collected primarily from expert interviews (between February and August 2009). We conducted 20 semi-structured interviews with various experts in the solar energy field in the UAE, government officials and local utilities.

Given the very early stage of industry development in the UAE, our research has also contributed to identifying the baseline in terms of actors present. Our findings allowed us to create a national database of 72 companies with activities in the solar industry. Most companies are concentrated downstream (e.g., design, installation, maintenance, system integration) (see Table 2). Lack of specialization among these companies can be linked to the small size of the market. Only four among these 72 companies currently manufacture solar products (solar photovoltaic/PV cells, solar collector mirrors and solar thermal collectors). The main player, by size of investment and diversity of technologies, is the Masdar Initiative in Abu Dhabi. We also identified 16 consultancy companies offering various related services and four investment companies providing funds for renewable energy initiatives.

Table 2
Companies involved in the solar industry in the UAE by stage in the value chain

Stage in the value chain	Number
Downstream	
Installation and other activities*	41
Trading only	26
Upstream	
Assembly	1
Manufacturing	4
Total	*72*

*Note: This category includes companies involved in several of the following activities: consulting, design, installation, maintenance, turnkey, system integration.

Data analysis was conducted by first identifying a chronological list of events, matching them to the functions of the TIS, and then identifying interactions between the different events. Such an approach allowed us to gain a better understanding of the emerging dynamics in the innovation system.

[2] The contribution of the oil and gas sector to GDP in 2007 was almost 40% (NMC, 2009).

5. The emergence of the TIS for solar energy in Abu Dhabi

The development of the innovation system in Abu Dhabi is in its formative stage. Hence, we discuss recent developments from a historical perspective pertaining to the components of the TIS (main actors, institutions, technological factors and networks and the dynamics of the TIS (the dynamics between the different functions in the TIS). We also highlight the drivers and barriers within the structure of the TIS (see Table 3).

Based on the succession of events, we can conclude that, so far, the government of Abu Dhabi is the driving force behind developing a TIS around the solar technology. Yet limited interaction and coordination between the different actors (i.e. local solar companies, utilities, government, financiers) and lack of long-term and transparent strategy for developing the TIS impede development of the TIS. With regard to the dynamics, we infer that the following functions have been important for the development of the TIS: *Guidance of the Search*, *Resource Mobilization*, *Entrepreneurial Activities*, *Knowledge Development* and *Knowledge Diffusion*. The main dynamics have been driven by the *Guidance of the Search* arising from strong government commitment for diversifying energy sources, *Mobilization of Resources* for several landmark projects, and *Knowledge Production* and *Knowledge Diffusion* by establishing education and research institute for alternative energy technologies and sustainable development. The cumulative causation mechanism starts when specific actions require further involvement from different actors, leading to further *Mobilization of Resources*, and *Knowledge Production*.

Table 3
Drivers, barriers and impacts pertaining to actors, institutions and technologies in the emerging TIS in Abu Dhabi.

	Actors	**Institutions**	**Technologies**
Drivers	• Strong government commitment to alternative energy sources. • Establishment of Masdar Institute.	• Committed to 7% Renewable Portfolio Standard (RPS) target for 2020 for Abu Dhabi.	• High solar insolation. • Setting up testing fields for solar technologies.
Barriers	• Limited interaction between different actors constituting the TIS. • Lack of transparent policy-making. • Utilities' limited support for solar due to high cost of generation and short-term targets for increasing generation capabilities • Lack of research labs, research agencies, training, testing and certification centers.	• Low price for electricity. • Lack of regulatory framework (i.e. feed-in-tariff and/or RPS)	• Lack of experience with technology development and deployment. • Lack of R&D funding.
Impacts	• A network (Emirates Solar Industry Association) is established among solar companies in the UAE.	• Tentative discussions on an incentive scheme for RPS / renewable energy.	• First solar projects offer insights into local technological and institutional aspects of deployment.

First movers

The driving force behind this development is the government of Abu Dhabi, in response to concerns regarding Peak Oil, high CO2 emissions per capita, and calls for economic diversification. The main government initiative that aims to establish an entirely new economic sector, primarily based on solar technologies, is the Masdar Initiative, launched in 2006. With a $US 22 billion budget, the project is driven by Abu Dhabi Future Energy Company, a subsidiary of the Mubadala Investment Company. The landmark projects that are part of this initiative are the development of Masdar City, a carbon-neutral residential, work community and industrial and R&D cluster, and the set-up of a graduate research university, Masdar Institute, in collaboration with Massachusetts Institute of Technology[3].

Jacobsson and Johnson (2000) argue that an important element during the formative stage of a technology system is the creation of first movers, actors who lead the process of development. Masdar Initiative plays the role of a first mover in setting up the innovation system and in making the first steps towards creating linkages between the innovation system and the local economy. Since the period of expansion is path dependent on the formative period, the way in which Masdar Initiative evolves is likely to influence the subsequent development outcomes. Currently, Masdar drives the process of transformation, attracts foreign investors and companies, creates demand by investing in pilot projects, and aims to invest in R&D and in developing the solar industry value chain. In addition, by exploring applications of technologies such as PV, CSP, geothermal and carbon capture and storage technologies in the UAE, Masdar aims to support technological diversity, which is important for the formative stage (Jacobsson and Bergek, 2004; Jacobsson and Johnson, 2000).

Nevertheless, while Masdar is the driving force in the development of the TIS, our interviews suggest that there is limited interaction and coordination between the different actors (i.e. local solar companies, utilities, government, financiers). Hence, strategic decision regarding industry development tend to lack transparency. In an effort to bridge this lack of communication and coordination, under the initial guidance of Masdar Institute (as a neutral education and research organization), a group of local companies came together to form an industry association (ESIA-Emirates Solar Industry Association) to promote solar energy in the region and to foster closer collaboration. This effort also supports the *Creation of Legitimacy/Counteract Resistance to Change* function in the TIS. Moreover, positive interactions are expected with other functions, such as *Knowledge Diffusion* and *Market Formation*, as a result of this action.

Demonstration projects

The landmark technology project in Abu Dhabi is the 10MW solar photovoltaic (PV) plant meant to power the first phase of Masdar City development. Currently this is the largest solar photovoltaic plant in the Middle East. In addition, a 10kW beam-down pilot plant has been built in collaboration with Tokyo Institute of Technology in 2009, currently operated by Masdar Institute, and a 100 MW solar concentrated power plant (Shams 1) is under construction to supply the national electricity grid. Shams 1 will become the world's largest concentrator photovoltaic power station and the first of its kind in the Gulf region. Shams 2 is expected to be commissioned in January 2011, and Shams 3 is in design stage.

In addition, in 2008, Masdar has developed one of the largest field studies of solar panel technologies. Some 22 manufacturers had been involved in the study, for monitoring how different technologies endure the effects of heat, humidity and sand, over 18 months. These pilot projects make possible the early detection of technological drivers and barriers in the local environment, to be addressed in later stages. Hence, they are expected to have significant effects on the *Knowledge Development*, *Knowledge Diffusion*, and *Market Formation* functions, in the form of institutional learning and technological adaptation to local

[3] Masdar Initiative comprises two other units: Masdar Carbon and Masdar Power. Masdar Venture Capital manages the Masdar Clean Tech Funds, a series of diversified venture capital investment vehicles focused on building portfolios of direct investments in some of the world's most promising and pioneering technologies in cleantech and renewable energy. More details about the initiative can be found at www.masdar.ae .

environmental conditions. In particular, since all the major solar energy projects are currently concentrated in Masdar, the *Knowledge Diffusion* function of the TIS to the local/regional economy is significantly hampered.

Also, Masdar Institute is currently the only education and research institution with a curriculum focused on renewable energy technologies and sustainable development. The limited focus on renewable energy related education and research persists throughout the region, posing challenges regarding the necessary skills for technology development and deployment, as suggested by our interviews. As a positive step forward, in June 2009, Masdar signed a Memorandum of Understanding (MoU) with the Ministry of Education and Abu Dhabi Education Council to develop programs focused on sustainability, renewable energy, and environmental awareness in UAE schools (Masdar, 2009). This is likely to further activate the *Knowledge Development* function in the TIS. Nevertheless, significant barriers exist currently due to lack of R&D resources and experience in the region. Academic institutions rely on government funding for research, while research labs and research agencies (such as National Science Foundation in the U.S.) are entirely lacking.

Because of the void of research and development specialists in alternative energy in the UAE, there are expectations from the private sector for Masdar Institute to support the activities of local companies by offering testing and certification services for their technology, professional training courses for their employees, courses for specific qualifications, and research collaborations on problem solving. In more developed economies, however, these services (or activities) are performed by specialized groups in national research laboratories (such as the National Renewable Energy Laboratory in the U.S., Fraunhofer Institute in Germany) or in other organizations. The lack of such organizations in the formative phase places some barriers by slowing down the knowledge development and market expansion process.

Power utilities

Power utilities play a critical part in the emerging innovation system. The local utility is the Abu Dhabi Water and Electricity Authority (ADWEA), owned by the Abu Dhabi government.[4] The Regulation and Supervision Bureau (RSB) is responsible for the regulatory framework for tariff, grid ownership, and for a variety of overarching issues[5].

Although renewable energy is not advocated in the UAE as a substitute for fossil fuels (rather as a complementary energy source), and although utilities are familiar with energy generation, transportation and distribution, integration of renewable energy technology into the grid poses challenges to both utilities and solar energy generators. In addition, given the high power demands triggered by fast economic development, utilities are more concerned with short-term targets for increasing generation capabilities. Nevertheless, this reluctance or lack of strong support for solar energy from utilities, hinders several functions in the TIS, primarily *Market Formation*, *Entrepreneurial Activities*, and *Creation of Legitimacy/Counteract Resistance to Change*.

Securing utilities' commitment to supporting the transition and then ensuring that they are efficient and effective in planning, designing and implementing necessary changes will be vital for a successful integration of solar energy systems into the grid. It will also be critical for the government to ensure that utilities' short-term objectives (i.e. increasing generation capacity on an annual basis) triggered by the rapid development of Abu Dhabi, and the UAE in general, will not push the utilities to disregard renewable energy.

[4] ADWEA serves as an umbrella organization that sits over four other legal entities, responsible with generation of power and production of potable water, transmission and dispatch, distribution for power and water, and wastewater collection, treatment and disposal.

[5] For instance the connection of the 10MW solar power plant to Abu Dhabi's electrical grid was a joint effort by Masdar, Abu Dhabi Distribution Company (ADDC) and the RSB.

Institutional challenges

Another major challenge for solar energy deployment emerges from the low electricity tariffs (between $0.008-0.040 in Abu Dhabi, compared to $0.1 in the U.S.) as the government keeps the price for electricity artificially low through subsidies. This places electricity from solar energy at a high cost disadvantage compared to conventional energy sources. Without sufficient incentives, there is limited interest from users and investors in alternative energy sources. In the UAE, where the government subsidizes various services (e.g., housing, education, health, energy, water), individuals are less likely to pay a premium for clean energy. In November 2009 a proposal has been made for feed-in-tariff and rebates for small scale solar roof-top installations. This proposal was the result of joint consultation between ADWEA, Masdar's Power unit, and the Executive Council (the government main decision body). Nevertheless, to this date, the incentives program has not been implemented, still awaiting approval from power utilities. In January 2009 the government has made the only institutional commitment to achieve 7% of renewable energy target for 2020 for Abu Dhabi. Nevertheless, our interviews suggest that this target is to be achieved with projects developed by Masdar only, with no efforts to create the necessary environment for other players to participate in the market.

Hence, so far, the experience with developing solar project has been institutionally challenging, as no policies have yet been implemented to support a wider market expansion. For the Shams1 project, the government has signed an agreement to pay utilities a subsidy that would cover the difference between the cost of electricity generation from conventional sources and the cost of generation from solar energy (i.e. called green power payments). Nevertheless, the negotiation of such agreement has been tedious and lengthy. Since solar PV is more expensive, and the projects developed by Masdar are smaller in scale, the negotiation process with the utilities becomes much more complicated. In this context, given the lack of regulatory framework (such as designing a feed-in-tariff and/or renewable portfolio standards), it is unclear what agency should be in charge of policy development and how much should Masdar, as a first mover, be involved in this process.

These delays in the regulatory process pose significant barriers not only for *Market Formation*, but also for *Entrepreneurial Activities*, and the *Creation of Legitimacy/Counteract Resistance to Change* functions in the TIS. From our interviews we have learned that domestic and international companies are not willing to enter the solar market in the UAE, despite the high potential, without appropriate long-term incentive schemes in place. Ultimately, the lack of such incentives and the uncertainty of whether and when they will be implemented affects all functions in the TIS.

6. Conclusions

The aim of this paper was to examine the development the solar industry in Abu Dhabi, UAE, and provide insights into the emerging dynamics in a TIS under formation. In this section we provide a summary of the key findings and a discussion of their implications for policy-makers in designing intervention strategies.

In moving forward, one needs to assess and prioritize what are the most important shortcoming (or barriers) to be tackled in the near term and what are the issues that need to be addressed in the medium and long term. The experience of countries such as Germany, which succeeded in establishing both an industry cluster as well as building a functioning innovation system, suggests that multiple aspects need to be addressed simultaneously rather than on a piece-meal basis.

Also, studies on the emergence of sustainable innovations and the development of renewable energy industries, through the lens of TIS approach, suggest that the innovation system may break down if one or more functions are absent. In the case of the emerging Abu Dhabi solar industry innovation system, most functions are present, but several are significantly hampered, such as *Market Formation* (due to lack of incentive policy programs), *Knowledge Diffusion Through Networks* (due to the concentration of projects in Masdar and the limited collaboration with other actors in the system), and *Entrepreneurial Activities* (due to lack of start-up finance, and incentive policy programs). However, limiting these functions is likely to

impede the positive interactions within the system, preventing further *Knowledge Development*, *Resource Mobilization*, and *Creation of Legitimacy* within the TIS.

The strong role of government in the UAE can be an important catalyst for the solar industry. Nevertheless, if the capacity of other actors in the innovation system, such as universities and industry are not sufficiently leveraged, and utilities are not cooperative participants, the effect of government actions could be significantly curtailed. Hence, creating networks of communication and collaboration for knowledge transfer and exchange of ideas is critical for generating the appropriate dynamics.

While this paper focused primarily on understanding the different components of the technological innovation system (actors, institutions, networks) and the challenges and opportunities for developing a solar industry in the UAE, future research is needed to understand the local innovation process in a more fundamental way. Specifically, more research is needed to assess the knowledge production system in the UAE, the entrepreneurial culture in the region, and the type of policies that are likely to trigger the desired results in the transformation process to a knowledge-based economy.

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