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Locked post-fossil consumption of urban decentralized solar photovoltaic energy: A case study of an on-grid photovoltaic power supply community in Nanjing, China

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HIGHLIGHTS

- Fossil based energy lock-in and life style slows SPV development.
- The Nine Dream Island case was analyzed as the post-fossil power supply community.
- We illustrate how the on-grid SPV supply community emerged.
- We intend to create a new post-fossil production and consumption paradigm.
- The new post-fossil production & consumption paradigm unlocks a fossil energy lock-in.

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ABSTRACT

Due to enhanced economic production as well as incentivized demanding supply management (DSM) strategies, solar photovoltaics (SPV) have experienced a phenomenal global annual growth rate but with a very limited contribution from the personal consumption sector, especially that of on-grid decentralized SPV. One of the reasons for this lies in the difficulties involved in unlocking the traditional production paradigm and lifestyle, based on centuries of conventional fossil-energy consumption. In response, this paper examines the case of Nine Dream Island in Nanjing, China, a pioneer of post-fossil emerging power supply communities providing on-grid SPV, to reveal the obstacles that lie beyond technological and economic factors involved. Empirical data including in-depth interviews illustrate the politico economic strategies of these communities in creating a new post-fossil production and consumption paradigm. In particular, it is suggested that, despite the National Development and Reform Commission's economic driving force in the form of 0.42 ¥/kW h state subsidies in Nanjing, the complex pattern of governance structures and institutional arrangement characteristics overwhelmingly impedes public acceptance of a low-carbon model of production and consumption. Overall, the paper helps to shed light on the development and adoption of SPV as a post-fossil consumption and production technology in new market countries where administration forces provide a more important role in creating a new path-dependence for the adaptation of innovation technologies.

1. Introduction

The original doubts over the authenticity of global climate change have now been replaced by a consensus questioning how fast it is affecting the world [1]. In response to the 1980 s trend towards environmentalism, the Intergovernmental Panel on Climate Change (IPCC) focused on the mitigation of environmentally damaging emissions to slow global climate change and reduce the consequent risks to human beings [2]. Despite this, however, for a long period neither governments nor the general public were sufficiently concerned to develop coping strategies in production or consumption in pursuit of sustainable development practices to mitigate the release of carbon dioxide [3–5].

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More recently, due to cost reductions, technological improvements and government renewable energy incentives policies, solar photovoltaics (SPV) have experienced phenomenal growth worldwide [6–10]. For example, the total installed SPV capacity increased from 1.4 gigawatts (GW) in 2000 to approximately 139 GW at the end of 2013, at an average annual growth rate of 102.6% [11], of which an estimated 85% is due to grid-connected or centralized systems [12]. Being widely applied to pavements, residential areas and industry zones [13,14], the Chinese Government since 2000 has launched a series of national policies and regulations that actively promote solar PV industry R&D, production and application [6,15]. This has created an estimated potential to rise to over 360 GW production in urban areas by 2016 as the unprecedented increase in housing stock continues to take place [16,17]. Meanwhile, by the end of 2014, the total off-grid decentralized SPV capacity reached 16.65% of the total installed SPV capacity of 28.5 GW – amounting to 19.34% of new-build installed capacity of 10.6 GW (http://www.nea.gov.cn/2015-03/09/c_134049519.htm). However, this is mainly located in the more prosperous Middle and East China, with little regard for on-grid, decentralized SPV capacity [15].

Almost all of the capacity of decentralized SPV is from off-grid SPV systems in factory buildings and large public facilities, with a very limited contribution from the personal consumption sector, especially on-grid decentralized SPV at the community scale [18–20].[1] One of the obvious reasons for this lies in the difficulty in unlocking the conventional production paradigm and life style as a result of a century of fossil-based tradition in daily life and industry production. It was only the external threat of high petrol prices after the fourth Middle East War in 1973 that led many industrialized countries into the post-industrialized era [21]. Nevertheless, despite the Kyoto Protocol international treaty adopted in 1997, politicians and governments have still been struggling to obtain a consensus on carbon release due to the huge vested interests involved and the tremendous impediments of fossil-based industry complexes [22]. This is explained as *path-dependence* in the political arena [23] and with a lock-in effect that goes beyond techno-economic reasons [24,25].

Therefore, it is urgent and pivotal to change the path-dependence of the fossil-based production model and consumption style to a post-fossil alternative [26]. One way to accomplish this to break fossil dependency through Schumpeter's strategy [27,28]. SPV systems are one of the major sustainable post-fossil technologies; the gradually developing the technology and economical capacity of SPV power generation has been increasing in individual consumption since the 1980 s, and also promising to be used in the public sector too [12,29]. However, no statistics concerning on-grid SPV power generation were available for the consumption sector before 2014, even in the mass media, which suggests that the slow early adoption of on-grid SPV power generation may have been caused by the impedance of the political-economy rather than pure technology or economic factors. This prompts three scalar questions concerning the early adoption of on-grid SPV power generation:

(1) Have techno-economic factors impeded the appearance of SPV power suppliers?
(2) If not, why is the public hesitating to accept such a low-carbon model of consumption and production?
(3) What can be done to make low-carbon consumption and production by SPV power accepted and adopted more broadly?

[1] *on-grid SPV* in the following text refers to *on-grid decentralized or distributed SPV*.

In answering these questions, the remainder of this paper consists of five sections. The second section reviews the literature related to SPV power supply in the production and consumption sector and the associated technological and political economic circumstances. The third section examines the case of Nine Dream Island in Nanjing, China, a pioneer of post-fossil power supply in the form of on-grid SPV. Through the use of empirical data and in-depth interviews, it illustrates how the supply community emerged and the political-economy strategies involved. By revisiting the existing literature and empirical findings, the fourth section elaborates on the dynamics of on-grid SPV communities with the interweaving of institutional economy of path-dependence and the force of the political economy. The final section concludes on the importance of the political economy perspective in fostering newborn energy technologies in new market countries and undeveloped areas of China.

2. Literature review: beyond the techno-economy – understanding SPV power supply communities from a political economy perspective

Solar photovoltaic energy research involves two bi-fold economic perspectives [30,31], namely, the production versus consumption side of SPV, or supply versus demand side in the microeconomics milieu [32]. On the contrary, there is little literature concerning the consumption of solar photovoltaic energy, which may include the collective consumption of agencies or individual behaviors [33–35] and incentive policies for the demand side [36,37].

In reality, the cost reductions and central government policy incentives for renewable energy and technological improvements globally [6,15,38–40] suggest that both on-grid and off-grid SPV TIC should be developed step by step [41]. Similarly, other researchers contend that DSM strategies can be implemented based on different criteria, such as the price of SPV energy, maximization of self-consumption or limiting the maximum power between others [42–44]. In this context, significant improvements in the economic and DSM incentive policies from the government for renewable energy and improvements in technology have enabled the rapid growth of the SPV industry in the production sector, from a small base to a total global capacity of 139 GW at the end of 2013 (85% of the 160 billion kW h total SPV power output capacity) [11]. On the other hand, despite the disadvantage of centralized SPV energy due to losses and transfers in energy production, the potential market of the SPV industry for rural or urban on-grid personal consumption increased only very slowly [45]. In China, for example, the largest SPV production exporting country and the third but most quickly growing installed SPV market, the market volume only increased from CNY 180 billion in 2008 to CNY 510 billion in 2012. Worse still, the annual growth rate has been decreasing (Fig. 1).

Reports or records of on-grid SPV for personal consumption in China are rare and little was known before the mass media first reported the SPV power supply community of Nine Island Dream in Nanjing, China in 2015. Given that the techno-economics of on-grid SPV power generation have significantly improved, what has caused such a sluggish development of on-grid SPV power generation technology in the personal consumption sector? Is it simply due to a lack of renewable energy education, or other reasons related to social and political aspects instead of technology or economics [46,47]? In order to answer these theoretical and practical questions, it is necessary to offer a theoretical framework to uncover how an expected reliable phenomenon may emerge from a political-economy perspective. This is presented in the following subsections in the form of a political-economy framework that