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Solar PV and solar water heaters in China: Different pathways to low carbon energy

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ABSTRACT

This review paper examines pathways towards solar energy in China by examining two different solar energy technologies, namely solar photovoltaic (PV) and solar water heaters (SWH). The paper investigates these two case studies to understand how different pathways for low carbon innovation are promoted and challenged by China's changing financing and policy-making, and how they relate to changing practices among producers and consumers. The paper finds two distinct approaches to solar energy. Chinese solar PV is predominantly produced for the export market, relies on intellectual property-intensive technology and has received much financial and political support from the central and provincial governments. On the other side, solar water heaters are an indigenous Chinese technology that is found everywhere across China, especially in rural areas. They have developed from grass-roots levels to mass products with very little central government support. Although being largely absent from high-level discussions and policies, solar water heaters could contribute a lot to China's low carbon transitions that are driven at the local level.

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1. Introduction

This paper aims to review how innovation in solar photovoltaics (PV) and solar water heaters (SWH) is promoted and challenged by China's changing financial and policy-making setting, and how they relate to changing practices among producers and consumers of solar energy. This review paper aims to explore the status, prospects and politics of solar energy in China.

80% of the world's primary energy supply comes from fossil fuels, primarily oil and coal [1]. Solar energy is important as an alternative energy source as fossil fuel resources are limited and their use is associated with a number of negative environmental effects – such as global climate change and air pollution. The Intergovernmental Panel on Climate Change (IPCC) estimates that about 70% of all greenhouse gas (GHG) emissions world-wide, particularly carbon dioxide (CO_2) emissions, come from energy-related activities. This is mainly from fossil fuel combustion for electricity generation, heat generation and transport [2]. Avoiding dangerous climate change and staying below a 2 °C warming requires cutting global emissions rapidly [3]. Energy efficiency and energy from non-fossil fuels, such as renewable energy, are thus important for achieving a global low carbon transition.

China invests more in renewable energy than any other country in the world, including in solar energy. China is central to a low carbon transition: today China is the world's largest energy user and largest total CO_2 emitter [1]. China's energy use and CO_2 emissions have increased rapidly since the beginning of its economic reforms about three decades ago. In the past, China had low per capita energy use and GHG emissions and the country's historic (or cumulative) GHG emissions are also lower than many high-income countries. However, China has been catching up in recent years with regards to per capita emissions and cumulative emissions. The country's per capita CO_2 emissions are increasingly comparable with those of the European Union [1,4], and it is estimated that China may lead globally on cumulative emissions within 10–20 years [5].

At the same time as China's energy use and GHG emissions have reached unprecedented heights, the country has also become a world leader in renewable energy, most importantly in hydropower, wind energy and solar energy (both solar PV and SWH). China leads the renewable energy field globally in terms of investments, installed capacity and manufacturing [1]. China invested nearly US$ 90 billion in renewable energy in 2014 [6] and is expected to spend even more in the coming years [6,7]. Dincer (2011) stressed the role of China for the global solar energy market [62]. Duan et al. (2016) argue that solar PV could contribute significantly to China's greenhouse gas emission reduction efforts, achieving a peaking of emissions by 2030 and keeping mitigation costs to less than 3% of GDP [63].

This review paper examines pathways towards solar energy in China by examining two different solar energy technologies, namely solar PV and SWH. The paper finds two distinct and different approaches to solar energy. Chinese solar PV is predominantly produced for the export market, relies on intellectual property-intensive technology and has received much financial and political support from the central and provincial governments. On the other side, solar water heaters are an 'indigenous' Chinese technology that are found ubiquitously across China, especially in rural areas. They have developed from grass-roots levels to mass products with very little government support. Although being largely absent from high-level discussions and policies, solar water heaters could contribute a lot to China's low carbon transitions that are driven at the local level. These two different pathways to solar energy are being discussed and contrasted in this paper.

Section 2 presents the materials and methods, Section 3 elaborates the theory, Section 4 presents the findings, Section 5 discusses the findings and their implications and Section 6 concludes the paper.

2. Materials and methods

This paper is based on a review study of solar energy in China, with specific focus on the different pathways for solar PV and solar water heaters. It follows a case study methodology based on Yin [8]. Following Miles and Huberman [9], our case selection criteria consider the significance of the case, its representativeness, its theoretical relevance, and data accessibility. Solar PV and SWH are significant, because they are the most market-ready and commercialised solar technologies in China. They are representative as they are used everywhere in China. In the case of SWH, 85 million systems are installed in China and they are found in every province [10]. This case is theoretically relevant as we examine the status, prospects, politics and financing of these technologies, hence socio-political issues that tend to be under-represented in China's low carbon innovation studies. The study draws on a large number of data and materials, including data from the Chinese Statistical Yearbooks, the IEA, the World Bank, academic literature published in journals, books and working papers, and a wide range of policy documents.

Globally, China is the largest investor and manufacturer of solar PV systems and SWH. It also has the world's largest installed capacity of SWH [10,11]. Scholars have noted the differentiation between 'home grown' or indigenous innovation and technology transfer in low carbon innovation pathways [12,13]. Historically, technology transfer has played a large role in renewable energy pathways in China, particularly for wind energy but also for solar energy [13–15].

For these reasons, the solar sector presents an interesting study of indigenous innovation of low carbon technology and the dynamics of the diffusion of innovation. There are a range of other issues where PV and SWH have different pathways with different technological, economic and social characteristics and dynamics. For instance, most solar PV tends to be still rather expensive, hi-tech and unlike solar water heaters needs integration with the electricity grid which is a major bottle-neck, mainly of institutional and political nature. PV also needs to overcome higher barriers associated with intellectual property (IP) on key upstream technologies. SWH is cheaper, involves less high-tech and is a standalone technology. See Fig. 1 for a summary of these issues.

3. Theory

Recent years have seen the emergence of a large body of literature on low carbon innovation and its links to international development, including solar energy technology [11,27]. China is often considered as being in an exceptional position to lead the global low carbon transition. Its government is committed to low carbon development strategies, including building up the innovative capacity of key firms; it has made huge investments in low carbon industries and abundant capital is available; and it has a wide range of approaches in place for accessing the latest low carbon technologies. The government is also committed to tackling climate change, becoming a global leader in low carbon innovation,

Solar PV	Solar water heaters
Higher tech due to systems integration with grid	Lower tech due to stand-alone system
Partly dependent on tech / knowledge transfer	Indigenous innovation
High IP barriers	Lower IP barriers
Higher cost	Lower cost
More centralised due to integration with grid	Decentralised
Export-oriented	Domestically-oriented

Fig. 1. Key differences in solar PV and solar water heaters.