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Cost and CO_2 reductions of solar photovoltaic power generation in China: Perspectives for 2020

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ABSTRACT

To improve the understanding of the cost and benefit of photovoltaic (PV) power generation in China, we analyze the per kWh cost, fossil energy replacement and level of CO_2 mitigation, as well as the cost per unit of reduced CO_2 of PV power generation in 2020 at the province level. Three potential PV systems are examined: large-scale PV (LSPV), building-integrated PV (BIPV), and distributed PV systems used in remote rural areas (which have very low capacities). The results show that in 2020 PV power generation could save 17.4 Mtce fossil energy and 46.5 Tg CO_2, compared with 600 MWe coal-fired supercritical units. Also in 2020, the costs of solar electricity could be reduced by approximately 60% as compared to 2010, but would still be 11–74% higher than the current grid prices. The PV electricity costs vary significantly among provinces. In the economically developed eastern provinces, the PV electricity (mainly BIPV) is 0.67–0.86 RMB/kWh. This rate is close to grid parity owing to high grid prices, but the CO_2 mitigation cost is high (456–693 RMB/Mg CO_2). The PV electricity (mainly LSPV) in solar-resource-rich western provinces has lower cost (0.45–0.75 RMB/kWh) and lower CO_2 mitigation cost (172–419 RMB/Mg CO_2), but is farther from grid parity due to the low local grid price. From a cost-effective perspective, LSPV in the west provinces should be the first priority in PV deployment strategies, and should receive strong financial support from the government. This study provides a quantitative, province-specific analysis of PV power generation, which can be used to support various PV subsidy policies.

Contents

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1. Introduction

China ranks the first in the world in terms of both primary energy production and demand. In 2013, the total production and consumption of primary energy in China reached 3400 million tonnes of coal equivalent (Mtce) and 3750 Mtce [1], respectively, and the total primary energy demand was projected to be 4500 Mtce by 2020 [2]. Fossil energy dominates the primary energy consumption in China by accounting for 90.2% in 2013 [1]. The tremendous consumption of fossil energy has caused various energy and environmental issues in China, such as fossil energy security and greenhouse gas (GHG) emissions. Therefore, promoting the use of renewable energy has become a crucial national energy strategy in China.

Solar energy represents a promising renewable energy source. As an important application of solar energy, photovoltaic (PV) electricity generation has developed rapidly around the world. Worldwide, PV production has doubled every two years since 2002, making it the world's fastest growing energy technology. The global installed PV capacity increased by a factor of 37 within eleven years, from 1.8 GWp in 2000 to 67.4 GWp in 2011, representing a growth rate of 39% per year [3]. In 2012, the global PV capacity increased 30–32 GWp, to a cumulative installed PV capacity of more than 100 GWp [4].

While contributing approximately 40% to worldwide PV production, China accounted for a very small share of the global accumulative PV capacity. Nevertheless, China's PV use has experienced dramatic growth since 2009, resulting from government financial support (for example, the Golden Sun Program and large scale, on-grid, feed-in tariff projects) and the declining cost of PV [5,6]. In 2011, the accumulative PV capacity of China reached 3.0 GWp, over three times the level in 2010, as shown in Fig. 1. Accompanying PV growth, significant changes in PV use are taking place. In the early 2000s, China was mainly focused on off-grid rural electrification projects, but recently developed building-integrated PV (BIPV) systems and large-scale PV (LSPV) stations, which dominated the PV capacity in 2011 (Fig. 1) [7].

China continues to raise its national goals for solar power generation. In 2007, the National Development and Reform Commission (NDRC) issued its Mid- and Long-Term Plan for Renewable Energy Development, which aimed at achieving a solar power capacity of 0.3 GWp by 2010, and 1.8 GWp by 2020 [8] and had been accomplished now. Five years later, the 12th Five-Year Plan for Solar Power Development (12th Five-Year Plan hereafter), released by the China National Energy Administration, set a new goal of achieving a solar power capacity of 21 GWp by 2015 [9]. This goal was further raised to 35 GWp by the China State Council in July, 2013 [10] (Fig. 1).

Obviously, there is a sizable gap between the present installed volume and the government's mid- and long-term goals. It is widely recognized that high cost is the major restriction to wide application of PV in China [6,11–13]. Therefore, developing effective and feasible incentive policies to promote solar PV applications is the key for China to achieve its national PV goals. This task will involve a thorough analysis of PV market potentials, and the costs and benefits (such as GHG reduction) of PV applications.

Numerous studies have been conducted on solar energy development in China, including: economic analysis of LSPV power generation [14] and small PV systems [15]; regional PV applications [16–18]; comparisons between renewable energy sources in China in terms of resources, market, profitability, and policies [19]; life-cycle analysis of PV systems energy use and GHG emissions [20]; and social acceptance of solar energy technology [21]. However, the costs and benefits of PV applications are seldom analyzed at a regional level (for instance, province level) for the entire country. The results of such analyses would likely vary considerably because solar energy radiation intensity, the scale of PV applications, and associated costs would differ significantly

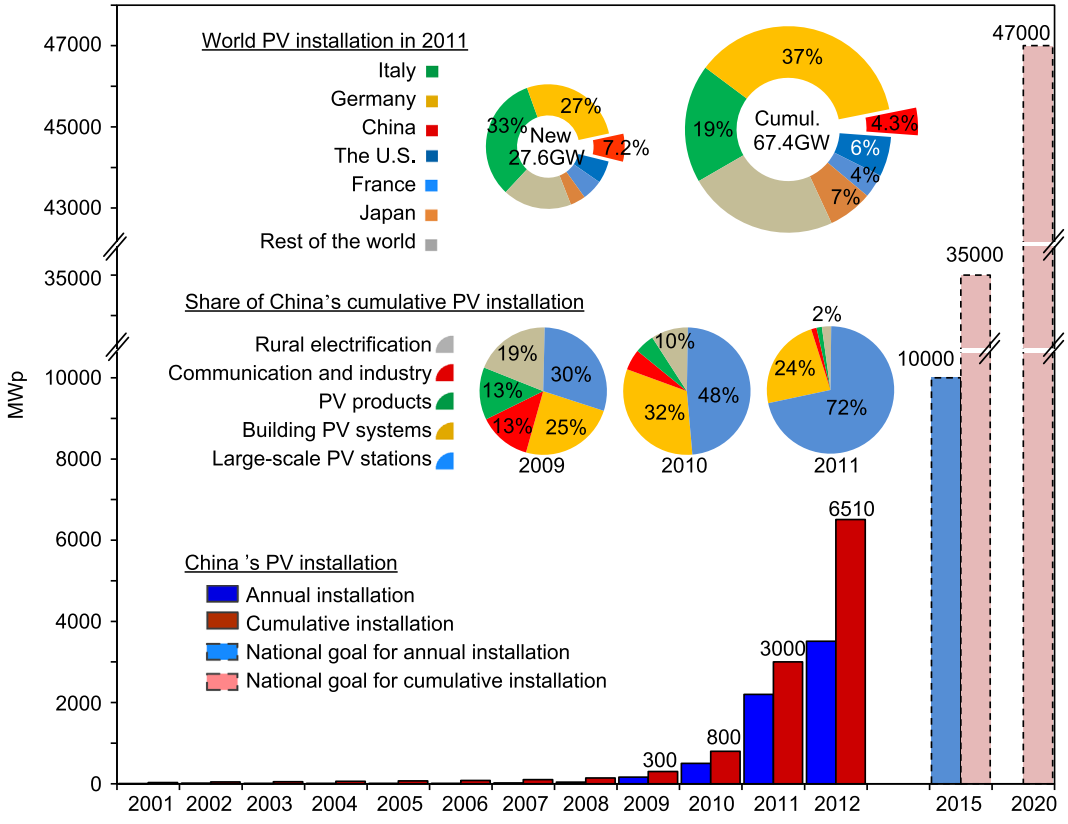

Fig. 1. Current PV capacity, uses, and future goals in China.