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Review

Renewable electricity finance in the United States: A state-of-the-art review

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ABSTRACT

This paper discusses a range of existing and emerging options for financing renewable electricity. We use the United States as a reference case study. To contextualize the discussion, we begin with scenarios for the deployment of various renewable energy technologies globally, followed by coverage of the United States renewable energy supply, supporting policies, and an introduction to renewable electricity finance for the non-specialist reader. We subsequently cover several prominent historical delivery mechanisms for the provision of renewable electricity finance, as well as key emerging opportunities. Further research in this area is encouraged.

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1. Introduction

Electricity from renewable energy sources such as wind, solar and biomass energy has gone far beyond its humble roots as a costly alternative to fossil fuel generation to become the fastest growing source of electricity in many regions. This rapid growth is especially pronounced in the United States (U.S.). The 2017 Annual Energy Outlook from the U.S.-based Energy Information Administration (EIA) envisions renewable energy growing rapidly as a result of dramatic decreases in the levelized cost of renewable electricity generation - particularly for photovoltaic (PV) electricity [100]. This is part of a general phenomenon where some forms of solar, wind, and other renewable electricity are now competitive with fossil fuel electricity in terms of unit electricity costs (in what Sanzillo et al. [79] refer to as a deflationary cost curve) and favourable policy environments continue to spur this trend along.

At the same time, there is increasing pressure to move away from fossil fuels in response to the threat of catastrophic warming of the climate due to anthropogenic emissions of greenhouse gases, as exemplified by the evolving framework supporting the recent international Paris Agreement under the ***United Nations Framework Convention on Climate Change*** (UNFCCC) [93]. Due to the combination of increasing economic competitiveness and policy push, continued rapid growth in the rate of deployment of renewable electricity generation is anticipated over the coming decades. Although the investment cost per unit of renewable electricity generation capacity is expected to continue to decrease,[1] the growth in deployment rates needed to meet climate policy goals is so large that the annual financing requirements will continue to grow substantially.[2]

Renewable electricity power plants have a host of financing options. This paper reviews the various ways in which large-scale renewable electricity generation can be or could be financed privately by using the United States (a destination for $58.8 billion in direct and indirect investment in 2016, according to the Sustainable Energy in America Factbook [12]) as a case study. The U.S. was chosen due to it a) being a deep and active market for financing, b) being a home to some of the world's largest financial centres (such as New York City and San Francisco), c) having a long history of renewable electricity deployment and technological innovation, and d) being the source of several new and innovative financing tools.

This paper is intended as a primer for non-specialists that will contextualize emerging private financing opportunities within an awareness of historical financing mechanisms, delivery methods, and policies. While acknowledging that there is no “one size fits all” and that any mass renewable electricity deployment effort would be greatly abetted by greater government-provided direct investment, significant scope exists for private investment. Accordingly, this paper constitutes a discussion on the private financing alternatives available in competitive markets, rather than a definitive “ranking” or hierarchy. Each renewable electricity developer's situation is inherently different, and determining the optimal financial structure for a renewable electricity project depends on a large number of factors that range from the size of the transaction to the risk-appetite of the investor. This article reflects that diversity.

We do, however, see this work as a mobilizing effort. If we are to ensure the integration of an ever-greater percentage of renewable electricity into the supply mix and reach $1 trillion of annual investment in clean energy,[3] it is crucial that the outstanding past and present work in renewable energy finance (coming out of both the private sector and a variety of academic centres, national research laboratories, international entities, and government institutions) is tapped, implemented, and, where appropriate, modified to suit on the ground demands. This work, which is part of a broader research synthesis effort designed to outline the renewable electricity finance environment of different regions (see, for example, [27,47,73]), attempts to facilitate this knowledge transfer.

2. Trends, financing, and policies

2.1. Status of renewable electricity deployment (global)

Fig. 1 shows the trend from 2000 to 2015 in the global installed capacity of onshore and offshore wind, solar PV, and CSTP (concentrating solar thermal power) – 4 dominant renewable electricity technologies. The global capacity of wind and solar reached 552 gigawatts (GW) by the end of 2015, along with 1055 GW of hydropower, 93 GW of biopower, and 13 GW of geothermal power, for a total 2015 renewable electricity capacity of 1713 GW. By comparison, fossil fuel and nuclear capacity was 4277 GW by the end of 2015 [95].

Jacobson and Delucchi [42] argue that all new energy could come from renewables by 2030 and all energy could be renewable-derived by 2050. The International Energy Agency [37] argues that up to 45% penetration of variable renewable energy sources is possible, with minimal additional cost compared to a thermal-heavy electricity supply.

In our scenarios regarding theoretical deployment of renewables necessary to mitigate anthropogenic climate change, we have

[1] Again, solar photovoltaic modules are perhaps the best example of this potential for further declines. Their prices have dropped in cost by a factor of about 2330 since 1956, according to Farmer & Lafond [25], with additional declines forecast. Richard Swanson, the founder of the US solar company SunPower, argued that a standard learning curve would lead to a 20% drop in panel cost for every doubling in total volume produced [19].

[2] The Organisation for Economic Co-operation and Development (OECD) believes that over $50 trillion USD will be required in the near future for global energy supply infrastructure and energy efficiency. See, for example, the report *Mapping channels to mobilise institutional investment in sustainable energy*, which lays out a 20 year timeline for this cumulative capital expenditure if the world is to have even a small chance of staying below a 2 °C warming limit [70].

[3] The “Clean Trillion” was put forward by the non-profit CERES [14].