

Introduction

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Sunlight fell upon the wall; the wall received a borrowed splendour. Why set your heart on a piece of earth, O simple one? Seek out the source which shines forever.

(Rumi, Masnavi II, 708–709)

Challenging as it might be to provide a comprehensible and meaningful description of the sun's vast potential as a source of energy, it is surely worthy of an attempt to do so. Total solar energy absorbed by the earth is estimated to be 3.8 million exajoules (EJ) per year, which is equivalent to more energy being absorbed in one hour than the global population consumes in a year. Put another way, researchers at Stanford University calculated that the amount of solar energy reaching the earth's surface in a year is about twice as much energy as human civilisation can reasonably be expected to extract from all the world's known and estimated resources of fossil fuels and mined uranium combined. Of course, not all of that solar energy is available for harvest. The United Nations Development Programme in its 2000 World Energy Assessment estimated the annual potential for harnessing solar energy by various means being between 1,575 EJ and 49,837 EJ (taking into account insolation levels, cloud cover and usable land resources). Even this lower figure is substantially higher than global energy consumption in 2012 of 560 EJ.

While energy from the sun has been utilised in various ways by humankind for thousands of years, the first commercial adaptations such as water heating, steam generation and water treatment emerged in the 19th century. Solar energy as a means of electricity production is a more recent phenomenon. The first photovoltaic (PV) cell was constructed by Charles Fritts in the 1880s, with further technical advances leading to American engineer Russell Ohl patenting the first modern solar PV cell in 1946 and the manufacture of the first crystalline silicon solar PV cell in 1954. From humble beginnings, the oil crises of the mid-1970s led to the development of the first commercial-scale solar PV power generation plants. Concentrated solar power (CSP) systems, which employ lenses or mirrors to focus sunlight into a beam which is used as a heat source in thermal power generation, employ technology which harks back to the early days of solar energy exploitation. However, realisation of CSP generation on a commercial scale did not occur until the mid-1980s.

In recent years, solar power generation has enjoyed a period of unprecedented growth. Since 2000, global solar power installed capacity has increased from 1 GW to over 300 GW and the curve is not linear; the last five years have seen a marked

acceleration as technologies have become more efficient, manufacturing costs have fallen and more governments adopt low-carbon power generation policies in which solar power plays a key part. Moreover, in contrast to some forms of renewable power generation where deployment is constrained by topographical, environmental and other physical factors which are often beyond the influence of technological progress, developments in solar power technology have led to an expansion in its use across a diverse range of geographies.

Much of this growth has been driven by China, which alone saw an increase of solar power installed capacity of 33 GW in 2016 (and where the China PV Industry Association has predicted substantial additional growth in both the short and long term). Together with China, the United States and Japan make up the top three solar power producers globally and these too have seen significant growth over the last decade. It is true that in some 'mature' solar markets, perhaps most notably in Western Europe where there has been a marked reduction in subsidies and other incentives for renewable power generation, the pace of growth has slowed somewhat since the high watermark of 2015. However, any such slowing is likely to be more than offset over the next few years by the expansion of solar power in developing markets such as Africa, where several countries enjoy some of the highest insolation rates in the world and demand for technology suitable for use in distributed generation systems is increasing.

The purpose of this book is not to dispense a history lesson on solar power so, having used the introduction to indulge in a little 'scene-setting', we must now turn to our main task – to provide a practical guide to various aspects of the solar power market. However, the subject area is vast, and we have had to focus on particular facets which we think will be of most relevance to those interested in the development of solar power on a commercial scale. For that reason there is no coverage of the residential solar market or other small-scale applications. We also readily admit to employing editorial favouritism towards discussion of PV projects at the expense of those involving CSP technology. There is no doubt that the latter will continue to play an important, and perhaps growing, part in the project landscape of the future, but the absolute dominance of PV technology in terms of global installed capacity demands a privileged position in a book of this size.

Aside from this introduction (Part I), the remainder of the book is divided into five parts. While these will bear reading chronologically, we have set out below a brief description of each remaining part in order to assist the reader in taking a more bespoke approach to navigating the book's content, should they wish to do so.

Part II seeks to analyse the fundamental drivers of the solar power market. In most respects these are shared with the other renewable power generation technologies, particularly in terms of the regulatory framework in which they operate at both an international and domestic level. They all have their genesis in the policy maker's desire to incentivise low-carbon power generation, even if many markets are now transitioning towards a low, or no, subsidy regime. This section also looks in detail at the technology deployed in solar power projects and the way in which both the regulatory and technological aspects drive the economics of solar power project development.

Having explored the market's fundamentals, Part III goes on to dissect solar power at the project level. This begins with an overview of a typical project structure, a description of the key participants and the contractual framework which binds them together, and an analysis of how common internal and external risks are allocated or otherwise mitigated. The remaining chapters of this section look in greater detail at particular elements of a project which are critical to its implementation and success, including establishing real estate rights, negotiating construction and related contracts, securing project income and understanding the fundamentals of debt financing in the project context.

Project development is only one important element of a more complex marketplace. Part IV focuses on corporate activity involving the buying and selling of development projects, operating assets and the companies which own them. In common with other forms of renewable energy assets, a high proportion of solar power projects are developed by land owners or small development companies, often with a view to selling them on to larger market participants at either a pre or post-construction stage. Likewise, some of these buyers might in turn sell on portfolios of projects to larger asset aggregators, such as infrastructure funds or similar financial investors. All of these activities play a role in generating an active mergers and acquisitions market in solar power.

While solar power generation is, in general, more straightforward than its thermal power equivalent in terms of technology, construction, operation and economics, the global market in which it functions is, nonetheless, complex. As well as advances in technology and manufacturing processes, and variations in how such technology is deployed, the regulatory and fiscal policies adopted in each country, and indeed even within individual countries, can vary widely. It is for this reason that Part V, a significant proportion of the book, is dedicated to a series of regional perspectives. We have sought to balance this section by providing the commentary one would expect on the largest national solar power markets, while also leaving space for countries of particular interest by dint of other metrics, such as the speed of their emergence as promoters of solar power or the relative growth of solar power in a market otherwise dominated by other forms of power generation. Once again, the scope of this section has been limited by the size of the book and we readily apologise if we have omitted a regional perspective deserving of a seat at the table.

The book concludes with Part VI, which considers solar power's place in an ever-changing global power market. In particular, we look at how solar power integrates with power storage, smart grids and other emerging technologies. And we also look to what the future might hold for a technology which, in many respects, can still be regarded as being in its infancy.

To draw this introduction to a close we invite the reader to consider solar power as not just another sub-sector of renewable energy but, in fact, as transcendent. The sun had been shining on earth for 4.5 billion years before our ancestors gazed heavenwards in fear, celebration and worship of the great golden orb. Our modern civilisation, blessed with a degree of scientific understanding, has become more familiar, perhaps even at ease, with our star. But if familiarity has not bred contempt, we are sometimes guilty of neglecting or underestimating the sun's immense

potential as a source of energy, our attention drawn instead to finite and irreplaceable terrestrial resources. Only in the last century have we truly started to appreciate, and even more recently to realise, how the sun can energise our civilisation in the millennia to come.

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