INTRODUCTION

This section focuses on considerations that arise in a scenario where solar energy begins to meet a significant fraction of the world's electricity demand. Chapter 6 considers the materials requirements for large-scale deployment of photovoltaic (PV) solar power. The next two chapters discuss the impact of large-scale PV deployment on electricity distribution networks (Chapter 7) and on the overall power system at the wholesale level (Chapter 8).

Chapter 6 explores the availability of three categories of resources — land, commodity materials, and critical elements — that are required for large-scale PV deployment. (There appear to be no serious resource constraints on large-scale deployment of concentrating solar power, the other major solar energy technology considered in this report.) Land does not present a significant obstruction to large-scale PV deployment. We evaluate potential constraints with respect to commodity materials and critical elements using a target deployment of 12.5 terawatts (TW) of PV capacity, the amount needed to supply roughly 50% of the world's projected electricity demand in the year 2050. With the possible exception of flat glass production, which would have to be ramped up, we find that commodity material requirements would not constrain large-scale PV deployment over the 35-year period from 2015 to 2050. In contrast, PV technologies — particularly commercial thin-film technologies that employ specific, often scarce, elements that cannot be replaced without fundamentally altering the technology — may face deployment ceilings due to materials constraints. Several of the critical elements used in some thin-film technologies are not mined as primary products, but instead are currently produced in small quantities as byproducts of the mining and refining of major metals.

Chapters 7 and 8 examine how the penetration of solar power affects the cost of electricity distribution networks and the operation, prices, and generation mix of the bulk power system. At the distribution level, our analysis examines only the impacts of solar PV; at the level of the bulk power system we consider the impacts of both PV (whether at the residential, commercial, or utility level) and concentrated solar power (CSP).

Specifically, Chapter 7 uses a powerful computer model to simulate the effects of a large volume of solar PV connected to the distribution network, for several locations and network configurations. We find that intermittent PV generation changes power flow patterns in the grid, causing local problems that may require network upgrades and modifications. Although the proximity of PV generators to end users may reduce some network investment costs as well as some resistive electricity losses, mismatches between load and solar generation — both in terms of location and time — may reduce or even cancel these potential benefits. This strongly suggests that revisions are needed in the methods used to calculate both the allowed remuneration of regulated distribution companies and the network charges imposed on users of the distribution infrastructure.

Significant penetration of PV and other forms of distributed generation not only means that
the uniformity of end-user demand patterns can no longer be assumed, it also means that the widely-used practice of applying volumetric, per-kilowatt-hour network charges with a single standard meter can result in serious issues of cross-subsidization between network users with and without generation assets.

Chapter 8 reports on simulations that examine the impact of significant levels of solar generation on the bulk power system. Specifically, the chapter considers impacts on operations, planning, and wholesale market prices.

At high levels of PV penetration, incremental additions of PV capacity have only limited impact on the total non-PV generating capacity needed to meet demand. Incremental PV additions have no impact at all in systems where annual peak load occurs at night. Impacts on market prices and plant revenues strongly depend on the existing generation mix. Adding substantial PV capacity displaces those existing plants with the highest variable costs and increases the cycling requirements imposed on thermal plants, leaving less room for electricity production using less flexible technologies. The more flexible the generating mix, the less relevant the cycling effect will be. Very large-scale deployment of solar PV will make it increasingly necessary to curtail solar production (and/or other zero-variable-cost production) for economic reasons, in particular to avoid costly cycling of thermal power plants. The coordination of solar production and storage (including the use of reservoir hydro) reduces cycling requirements for thermal plants on the system and enhances solar’s capacity value.

Even if PV generation becomes competitive at low levels of penetration, a substantial scale-up of PV deployment will reduce the per-kilowatt profitability of installed PV capacity until a system-dependent breakeven point is reached, beyond which further investments in solar PV are no longer profitable.