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Executive Summary

By the third quarter of 2012, the United States had deployed more than 2.1 gigawatts (GWac[1]) of utility-scale solar generation capacity, with 4.6 GWac under construction as of August 2012 (SEIA 2012). Continued growth is anticipated owing to state renewable portfolio standards and decreasing system costs (DOE 2012a). One concern regarding large-scale deployment of solar energy is its potentially significant land use. Efforts have been made to understand solar land use estimates from the literature (Horner and Clark 2013); however, we were unable to find a comprehensive evaluation of solar land use requirements from the research literature. This report provides data and analysis of the land use associated with U.S. utility-scale[2] ground-mounted photovoltaic (PV) and concentrating solar power (CSP) facilities.

After discussing solar land-use metrics and our data-collection and analysis methods, we present total and direct land-use results for various solar technologies and system configurations, on both a capacity and an electricity-generation basis. The total area corresponds to all land enclosed by the site boundary. The direct area comprises land directly occupied by solar arrays, access roads, substations, service buildings, and other infrastructure. We quantify and summarize the area impacted, recognizing that the quality and duration of the impact must be evaluated on a case-by-case basis. As of the third quarter of 2012, the solar projects we analyze represent 72% of installed and under-construction utility-scale PV and CSP capacity in the United States. Table ES-1 summarizes our land-use results.

[1] All capacity-based land-use intensity figures in this study are expressed in terms of MWac or GWac. This is to maintain consistency within the paper because CSP power plants are rated in terms of MWac. The conversion factor between dc-rating and ac-rating is discussed in Section 3.

[2] We define utility-scale as greater than 1 MWdc for PV plants and greater than 1 MWac for CSP plants.

Table ES-1. Summary of Land-Use Requirements for PV and CSP Projects in the United States

Technology	Direct Area		Total Area	
	Capacity-weighted average land use (acres/MWac)	Generation-weighted average land use (acres/GWh/yr)	Capacity-weighted average land use (acres/MWac)	Generation-weighted average land use (acres/GWh/yr)
Small PV (>1 MW, <20 MW)	5.9	3.1	8.3	4.1
Fixed	5.5	3.2	7.6	4.4
1-axis	6.3	2.9	8.7	3.8
2-axis flat panel	9.4	4.1	13	5.5
2-axis CPV	6.9	2.3	9.1	3.1
Large PV (>20 MW)	7.2	3.1	7.9	3.4
Fixed	5.8	2.8	7.5	3.7
1-axis	9.0	3.5	8.3	3.3
2-axis CPV	6.1	2.0	8.1	2.8
CSP	7.7	2.7	10	3.5
Parabolic trough	6.2	2.5	9.5	3.9
Tower	8.9	2.8	10	3.2
Dish Stirling	2.8	1.5	10	5.3
Linear Fresnel	2.0	1.7	4.7	4.0

We found total land-use requirements for solar power plants to have a wide range across technologies. Generation-weighted averages for total area requirements range from about 3 acres/GWh/yr for CSP towers and CPV installations to 5.5 acres/GWh/yr for small 2-axis flat panel PV power plants. Across all solar technologies, the total area generation-weighted average is 3.5 acres/GWh/yr with 40% of power plants within 3 and 4 acres/GWh/yr. For direct-area requirements the generation-weighted average is 2.9 acres/GWh/yr, with 49% of power plants within 2.5 and 3.5 acres/GWh/yr. On a capacity basis, the total-area capacity-weighted average is 8.9 acres/MWac, with 22% of power plants within 8 and 10 acres/MWac. For direct land-use requirements, the capacity-weighted average is 7.3 acre/MWac, with 40% of power plants within 6 and 8 acres/MWac. Other published estimates of solar direct land use generally fall within these ranges.

Both capacity- and generation-based solar land-use requirements have wide and often skewed distributions that are not well captured when reporting average or median values. Some solar categories have relatively small samples sizes, and the highest-quality data are not available for all solar projects; both of these factors must be considered when interpreting the robustness of reported results. Owing to the rapid evolution of solar technologies, as well as land-use practices and regulations, the results reported here reflect past performance and not necessarily future trends. Future analyses could include evaluating the quality and duration of solar land-use impacts and using larger sample sizes and additional data elements to enable a thorough investigation of additional land-use factors.