

# IBHS PHOTOVOLTAIC HIGH WIND RESEARCH

By MURRAY J. MORRISON, PHD

As the use of solar energy installations continues to grow rapidly around the country, the Insurance Institute for Business & Home Safety (IBHS) is examining the effects of wind on roof-mounted photovoltaic (PV) solar panel arrays. This has been identified as an area of high priority, especially for commercial insurers and reinsurers. The focus of the research will be to determine whether panels are being attached properly to structures so they are able to withstand high winds. Detached solar panels and arrays can cause extensive damage to roofs, weakening a building's protection against severe weather; they can also become flying debris, which can be a hazard to anything in the vicinity. No general solar panel array attachment guidance is currently available for the construction industry relating to wind loads, such as that in the American Society of Civil Engineers' (ASCE's) ASCE 7, *Minimum Design Loads for Buildings and Other Structures*.

Work has begun to create these standards for the 2016 edition of ASCE 7 by the Structural Engineers Association of California, providing a timely opportunity for IBHS to conduct this research to help validate or improve the submissions to ASCE. Currently, the code change proposals under consideration by the ASCE Wind Loads Subcommittee (WLSC) are based on model-scale wind tunnel experiments at scales ranging from 1:20 to 1:100. Due to the scales in which these experiments are conducted, they have both

geometric (small-size) and flow simulation (correctly matching the turbulence characteristics of the real wind) constraints. Full-scale experiments at IBHS will allow the examination of the effects, if any, of these constraints—particularly the effects of small gap sizes on the wind loads on photovoltaic arrays. In addition, IBHS's research will provide preliminary information to inspectors and underwriters of these systems as it relates to best practices for array attachments.

## RESEARCH DESCRIPTION

Experiments conducted at IBHS in 2014 examined photovoltaic panel arrays on the roof of a building under realistic wind loading in the large test chamber. In total, 13 different array configurations were examined, resulting in more than 170 tests

and 60 hours of data being collected. The experiments examined the effects of wind angle, panel size, height of the panel above the roof, distance of the solar panels from the edge of the roof, distance between solar panel rows, and inclination angle of the solar panels.

Figure 1 shows the test building with one solar panel array configuration in the IBHS test chamber. Rather than use real photovoltaic panels, mock panels were constructed out of wood to match the geometry of real panels as closely as possible. The use of mock panels was necessary to allow the installation of instrumentation that would otherwise not have been possible with real panels. The two insets in Figure 1 show the three pressure sensors (black boxes) installed inside the mock panels, which are used to measure the wind forces on the



Figure 1 – Photograph of solar panels on the roof of a building in the IBHS test chamber.

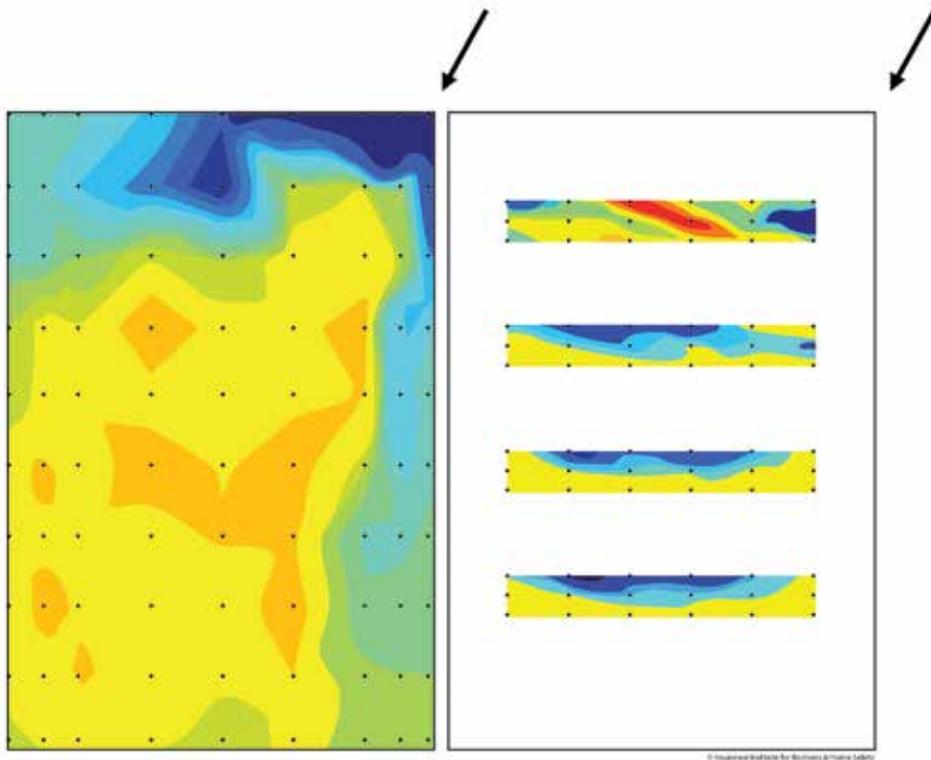


Figure 2 – Wind pressures on the roof of a building (left), and net loads on solar panels on the roof (right).

panel. Pressure sensors also were installed to measure the pressures on the roof surface under the panels and are used to examine how the wind loads on the roof of the building underneath are affected by the presence of the solar panels. As discussed above, these small gaps (i.e., between the panels and the roof surface) are often difficult and sometimes impossible to correctly simulate in model-scale wind tunnel experiments. In total, 304 pressure sensors were used in these experiments.

Figure 2 shows a comparison of wind pressures on the roof surface of a building to the net wind loads on solar panel arrays from a cornering wind direction of 30 degrees as shown. The solar panels shown are elevated 5.5 in. above the roof surface

and have a panel inclination relative to the roof of 10 degrees. For the roof surface, the highest wind loads (dark blue) are near the edges of the buildings. The highest wind loads on the solar panels occur further from the edge toward the center of the building, in contrast to the wind loads on the bare roof. This demonstrates that the distribution of wind loads on the roof of the building can be substantially different from the distribution of wind loads on solar arrays.

With the results from the current study and other studies found in the literature, the wind loads on solar arrays are relatively well-defined. However, the response of the panels to these wind loads is much less understood. Arrays of photovoltaic panels are attached together in rows and are often

ballasted with no solid physical connection to the roof. As a result, photovoltaic assemblies (i.e., rows) are a dynamic system and may be able to move in high winds. Following post-tropical Hurricane Sandy, small movement of the photovoltaic panels was observed that did not appear to damage or affect the functionality of the photovoltaic array system. However, even small displacements of solar panel arrays have the potential to damage other infrastructure on the roof or the roof cover itself.

Research to be conducted at the IBHS Research Center in 2015 will, for the first time ever, study the response of actual solar panel arrays to real wind loads, examining both the initial movement of the panels and how failures of the panels or arrays propagate. The distribution of ballast also will be examined to develop guidelines on both the quantity and appropriate distribution to prevent movement of the panels. 



Murray J. Morrison, PhD

Dr. Murray J. Morrison, research engineer and instrumentation director at the IBHS Research Center, earned his doctorate from the University of Western Ontario in the Department of Civil and Environmental Engineering, focusing on the failures of residential wood frame structures when subjected to full-scale realistic wind loading. Dr. Morrison has nearly 10 years of experience with full-scale structural and wind tunnel testing, and has conducted numerous full-scale experiments regarding boundary layer turbulence and wind-induced loads on structures.

## Solar Power Choice in Hawaii Threatened

Opponents of a proposed merger between the nation's largest solar and wind energy producer (NextEra Energy, parent of Florida Power & Light Co.) and Hawaii's principal electric utility (supplying 95% of the state) fear that NextEra Energy Inc. will halt the growth of distributed solar generation to favor utility-scale projects it would operate. Hawaiian Electric Industries Inc. (HEI) has agreed to be purchased by NextEra for \$4.3 billion.

Average retail electricity rates in Hawaii were the nation's highest—34.04 cents/kilowatt-hour—in 2012. Seeking relief, more than 11% of HEI's customers have installed rooftop solar panels. HEI's parent company stopped accepting applications for distributed solar interconnections in September 2013.

— ENR