

LED HYBRID PATHWAY LIGHTING for Sequoia National Park

PRELIMINARY TECHNOLOGY ASSESSMENT

DRAFT

Statewide Emerging Technologies Funding Program



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October, 2005

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Acknowledgements

Southern California Edison's Design & Engineering Services group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technology program.

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TABLE OF CONTENTS

Technology Description.....3

Background.....5

Statement of Work

 Occupancy Sensor Coverage Area and Range.....6

 Lighting Characteristics.....8

Conclusion.....10

Recommendation.....10

TECHNOLOGY DESCRIPTION

The LED hybrid fixture described within this report was developed by the California Energy Commission's Public Interest Energy Research (PIER) Program. PIER supports energy research, development and demonstration projects which aspire to bring energy efficient products to the marketplace.

This hybrid fixture combines light emitting diode (LED) technology with occupancy and photocell controls for incandescent lighting. Darkness turns on the LEDs to provide general, low-level light and to act as a marker for light fixture recognition at a distance. When motion is detected through the on-board occupancy/light sensor, the incandescent light turns on. After a few minutes of vacancy, the light turns off again leaving only the LEDs on.

The hybrid fixture can also accommodate a compact fluorescent bulb, when appropriate. The fixture was designed for pathway, porch, and security light applications.

The LED hybrid lighting technology promises to replace residential, commercial, and industrial pathway lighting, porch lights, and security lighting. The LED provides 20 lumens/watt of illumination and offers much longer life than that of its traditional incandescent counterparts.

There are a number of benefits associated with the installation of LED hybrid exterior lighting systems. A sample of the estimated annual operating kW and annual savings in kWh in comparison with existing lighting systems for this application is shown below.

Base Case:

60W Incandescent Lamp on 12 hours a night
= **720Wh** per night

New Technology Case:

60W Incandescent Lamp on 12 hours a night w/ 2 hour occupancy
= $5W * 12h + 60W * 2h = 180Wh$ per night

*12 hours of darkness per night assumed.

*2 hour occupancy per night assumed.

The yearly energy use and percent energy savings calculation based on the assumptions above are shown in Table 1.

Case	Nightly Energy Use (Wh)	Yearly Energy Use (kWh)	Percent kWh Savings
Base	720	262.8	0%
New Technology	180	65.7	75%

Table 1: Yearly Energy Use

According to the census profile for the state of California, we have about 5.5 million (5,527,618) single-family owner-occupied homes. Assuming the market penetration is 0.5%, the market size would be 27,500 residential homes in the state of California. The conservative market penetration number accounts for porches that do not have wall-mountable fixtures. Assuming the front and back porch lights are replaced with the technology, there would be 55,000 fixtures in use for homes. This number does not include non-residential markets. Table 2 shows the total energy saved for a year with the assumptions of 12 hours per night, 2 hours of occupancy per night, and 55,000 fixtures in use.

Going From	To	Before (kWh)	After (kWh)	Energy Reduction/ Fixture (kWh)	Number of Fixtures*	Total Energy Saved (kWh)
Base Case	New Technology	262.8	65.7	197.1	55,000	10,840,500

Table 2: Total Energy Saved per Year

*55,000 fixtures assumed.

Table 3 below shows the night time demand reduction. Going with the above assumptions, there would be a total of 3,025kW night time demand reduction, which is about a 90% reduction in night time demand.

Before	After (W)	Difference (W)	Number of Fixtures	Demand Reduction (kW)	% Reduction
60 W Incan.	5	55	55,000	3,025	91.67%

Table 3: Demand Reduction

*Main lights assumed off most of the time w/ only LEDs on

BACKGROUND

The National Park Service purchased a set of the hybrid LED pathway lights and was interested in installing them at the Wuksachi Lodge area in Sequoia National Park. The lodge is open year-round and is located on the western slope of the Central Sierra at 7,200 feet above sea level. During the winters the area experiences freezing cold temperatures and snow, as seen in Figure 1.



Figure 1: Wuksachi Lodge

An onsite meeting and survey with Gail Vize, Southern California Edison Account Executive, and Jack Vance, Sequoia National Park Director of Facilities, allowed us to see the existing fixtures and survey the site.

The existing fixtures are made of a 4-foot high 7-inch square metal tube with rectangular translucent acrylic lens on all four sides surrounding an incandescent light bulb. Figure 2 shows one of the fixtures in the lodge area.

The existing fixtures serve two purposes. They act as marker lights for the lodge area and provide general lighting for the immediate area around the fixture. The design provides 360° of long-range marker visibility and general illumination.

The fixtures were strategically located at the intersections and turns along the walkways. There were about twenty fixtures in the lodge area and spaced about an average of 50 yards apart from each other.

The on-site survey brought up several issues that needed to be addressed before moving forward with the project. They were:



Figure 2: Existing Pathway Light

- What is the area and range of the occupancy sensor coverage and is it sufficient?
- Can the LED hybrid outdoor fixtures provide adequate/equivalent lighting to that of the existing incandescent fixtures?

It was decided that the fixture be tested in the Southern California Lighting Technology Center to see if the occupancy sensor coverage range is sufficient and the lighting is adequate/equivalent to that of the existing fixtures.

STATEMENT OF WORK

Occupancy Sensor Coverage Area and Range

The LED hybrid fixture's range was tested by walking toward it at various angles at 15 degree increments. The sensor did not trigger the incandescent lamp until a distance of only a few feet from the fixture was reached. With a mounting height of 4 feet, the occupancy sensor triggers the main lighting at an average of about 3.3 feet. The longest range measured in the test was about 7 feet. Figure 3 provides a diagram of the detection points. In the diagram, the fixture is located at the origin facing upwards at 0°.

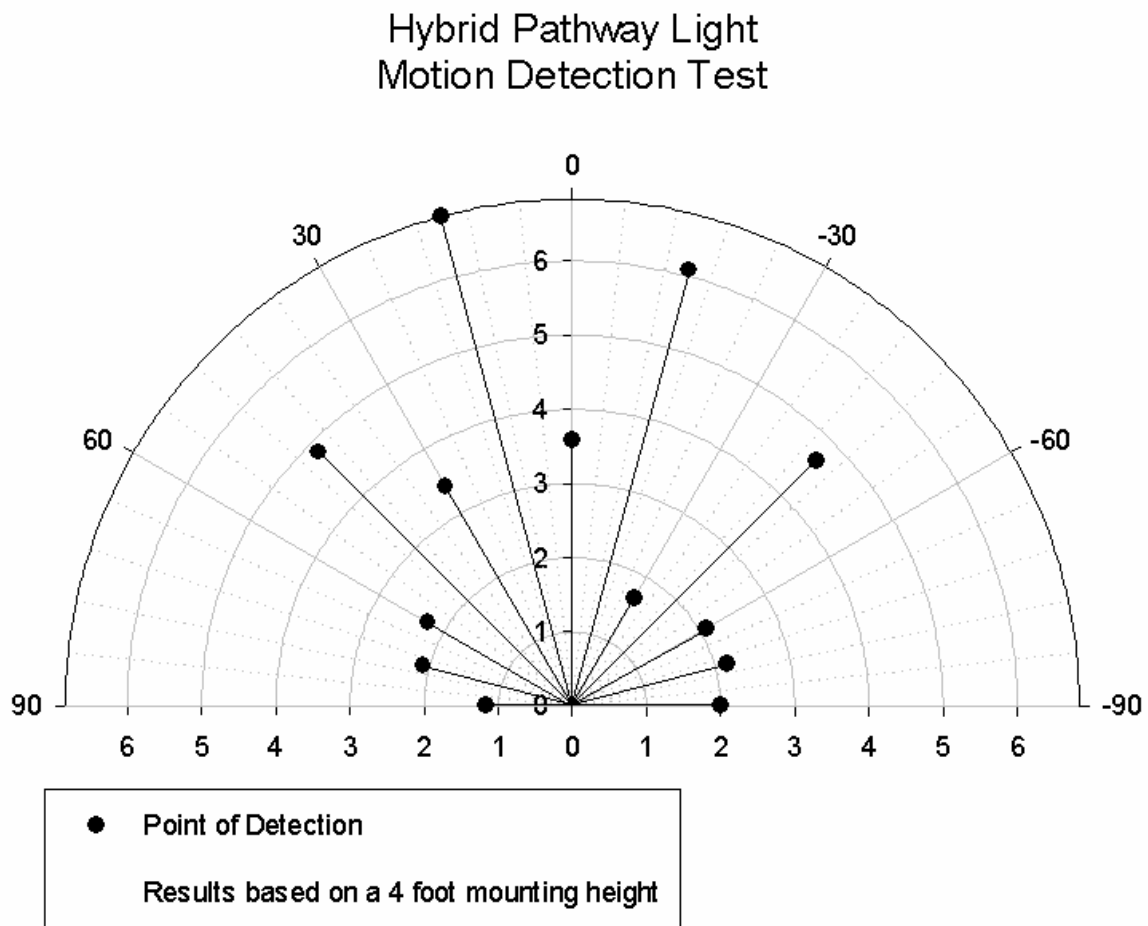


Figure 3: Detection Point Locations While Walking Towards the Fixture

After further research for the cause of the sparse occupancy pattern, it was discovered that the fixture's occupancy and light level sensor was not designed for outdoor ranges. According to the "Coverage Pattern" section of the manufacturer's sensor manual, the sensor was originally designed for indoor ceiling-mounted applications. The lens was designed to be mounted about 8 feet high and 6 feet away from the occupant. As the distance from the sensor increases, the sensitivity would decrease drastically. Figure 4 provides the manufacturer's occupancy sensor coverage pattern specification sheet for the specific sensor.

COVERAGE PATTERN

Density and range of the coverage pattern is determined by mounting height. The FS-155 has a multi-cell, multi-tier Fresnel lens with a view of 360°. This lens is designed to detect small motion when mounted within 6' of occupants. When mounted at a height of 8', the coverage area is approximately 10' diameter but sensitivity may be diminished.

Coverages shown in the diagrams below are maximum. They represent coverage for full-step walking motion, with no barriers or obstacles.

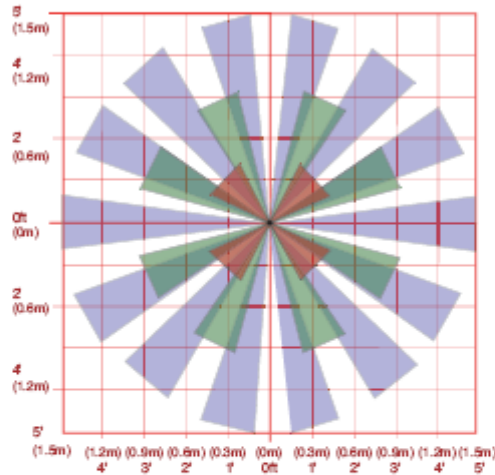


Fig 3: FS-155 coverage pattern, top view from 8' mounting height

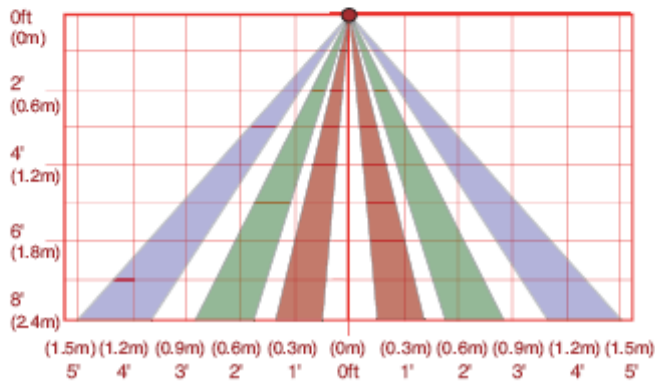


Fig 4: FS-155 coverage pattern, side view

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Figure 4: Manufacturer's Occupancy Sensor Specification Sheet

Lighting Characteristics

The existing pathway lights are about 4-feet high with translucent lenses on all four sides. This design provides 360° of general illumination and long-range marker visibility. Figures 5 and 6 show an example of the existing pathway lights, and the hybrid LED pathway light, respectively.



Figure 5: Existing Pathway Light



Figure 6: LED Hybrid Pathway Light

The LED hybrid pathway fixture was designed to be more directional than the existing fixtures. Figure 7 shows a ground illuminance map for the LED hybrid fixture with the incandescent light on which demonstrates this lack of multi-directionality.

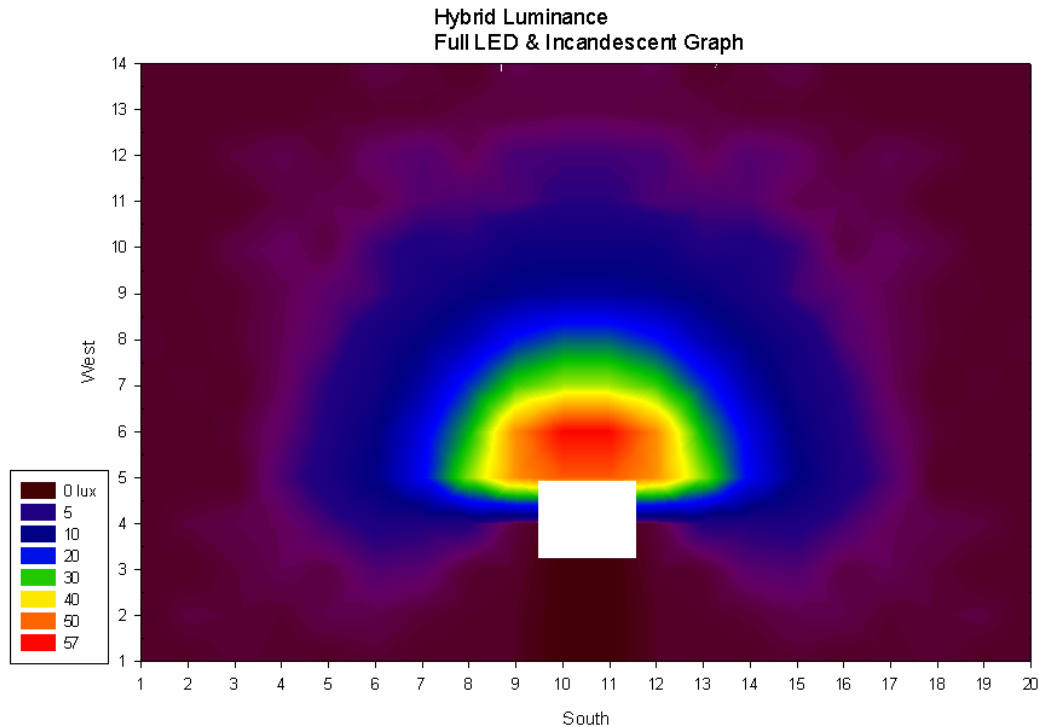


Figure 7: Ground Illuminance Map for Hybrid LED Pathway Light

As the ground illuminance map shows, the hybrid LED fixture illuminates the area in front of it far greater than area behind it. The white box represents the mounting pedestal used. The actual hybrid LED fixture is right above the red and brightest part of the graph. The fixture was mounted 4 feet off the ground to match the height of the fixtures currently in use at Sequoia National Park. For the test, the pedestal on which the fixture was mounted was fairly wide. If it was smaller, there would be more light towards the rear of the fixture, but it would not be equivalent to that of the existing pathway lights.

When the incandescent turns off, the LED would remain on for low level lighting. The ground illuminance level, at the brightest point, is about one-sixth the amount of light provided by the incandescent. Figure 8 shows the ground illuminance map for the LED hybrid fixture with only the LED light on. The scale was adjusted in order to see the lighting level differences and does not correlate with the scale in Figure 7.

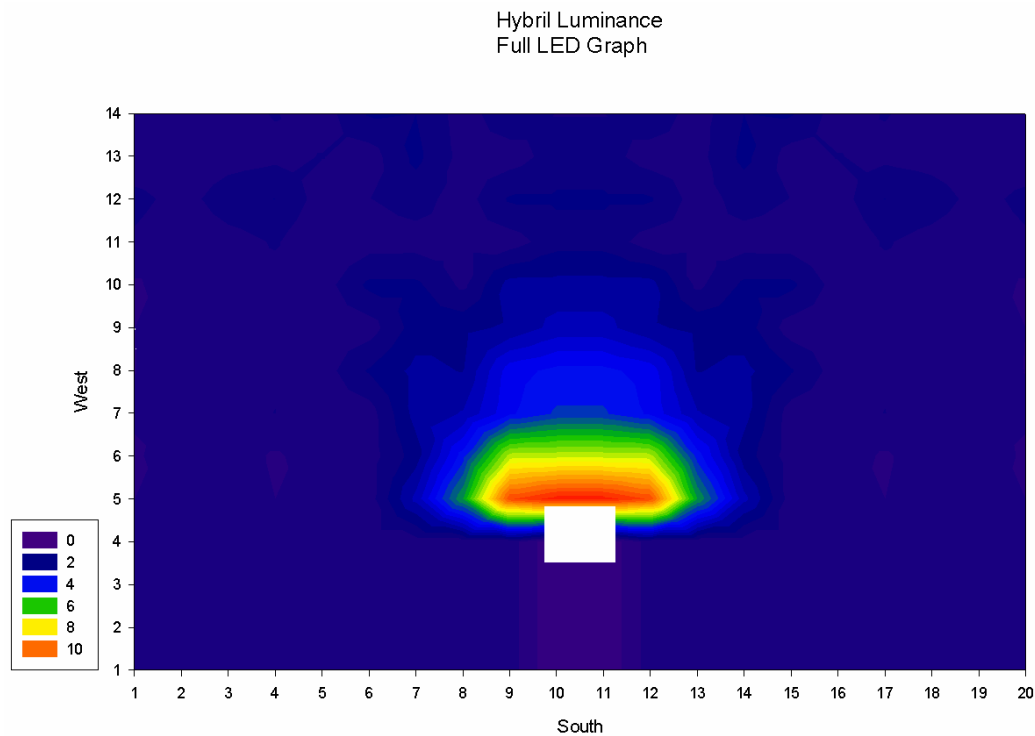


Figure 8: LED Ground Illuminance Map for Hybrid LED Pathway Light

The existing fixture provides 360° of light outwards and not downwards like the hybrid fixture. This provides very good long range marker visibility, but at close ranges, the existing fixtures produce a lot of disability glare. The LED hybrid fixture eliminates the disability glare by having full light cut-off and directing the light downwards with no direct view of the lens. Even under a full moon, the luminance of the background is nearly zero and the luminance of the fixture is about 5000 cd/m². The contrast ratio is in the thousands. This is well beyond the recommended contrast ratios for comfort. The IESNA’s general guideline states that the luminance ratios should not exceed 20:1.¹ The LED hybrid fixture’s full light cut-off also provides a clear view of the natural dark sky.

The LED markers of the hybrid fixture can only be seen within less than 180°. Figure 9 shows the areas where the LEDs are not visible.

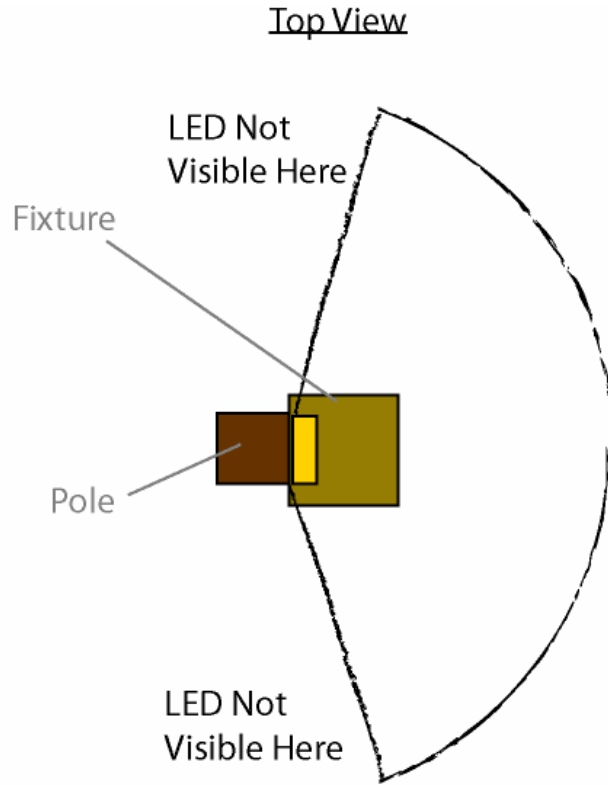


Figure 9: LED Visibility Angles

There are only certain angles at which the fixture can be seen. From a distance, it cannot be determined that the fixture is only visible within the 180°. A person can potentially walk off the path thinking that they can follow the light back. What is not known is that if they travel beyond the visible angles, the LED marker cannot be seen and the person may get lost in the dark. This can be a potential safety problem.

CONCLUSION

It is not recommended to replace the existing fixtures at the Wuksachi Lodge area in Sequoia National Park with the LED hybrid pathway light. The occupancy coverage pattern is not sufficient for outdoor ranges and it does not provide equivalent general and marker lighting to that of the existing fixture.

RECOMMENDATION

For applications similar to this, it is recommended that the current occupancy sensor be replaced with one that has a wider coverage pattern and longer range. In straight pathways, the sensor would not turn the lights on until one is approximately two feet away from the fixture.

One possible occupancy sensor replacement could be the sensor from the hotel night light. It was designed to be mounted about 4 feet high with a spread pattern that looks out and down. Figure 10 shows the manufacturer's occupancy sensor coverage pattern specification sheet for the hotel night light.

COVERAGE PATTERNS

The CN-100 has a coverage range of 180 degrees and a maximum coverage area of 300 sq. ft. To maintain its coverage capacity and optimally detect motion, the CN-100 must have a clear and unobstructed view.

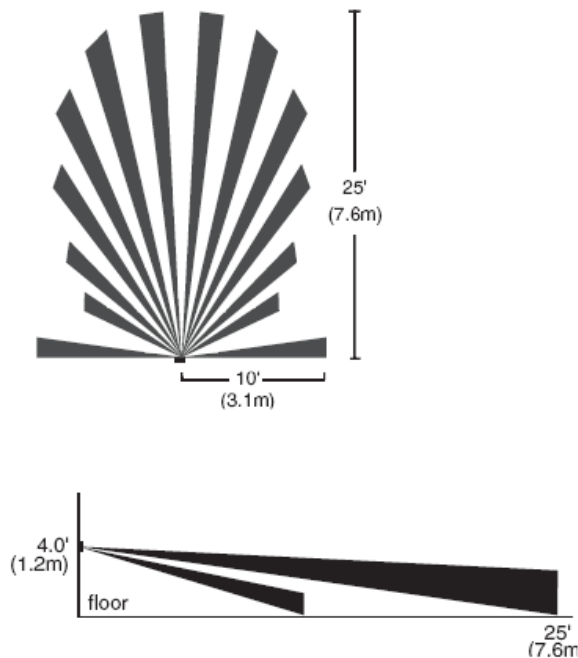


Figure 10: Manufacturer's Occupancy Sensor Specification Sheet

The occupancy range shown here is for ideal situations which may not be the case for the actual application. The same test was conducted as the LED hybrid pathway light occupancy sensor to see its actual coverage pattern. Figure 11 shows the measured coverage pattern of the hotel night light when walking directly toward it at various angles.

Hotel Occupancy Sensor Night Light Motion Detection Test

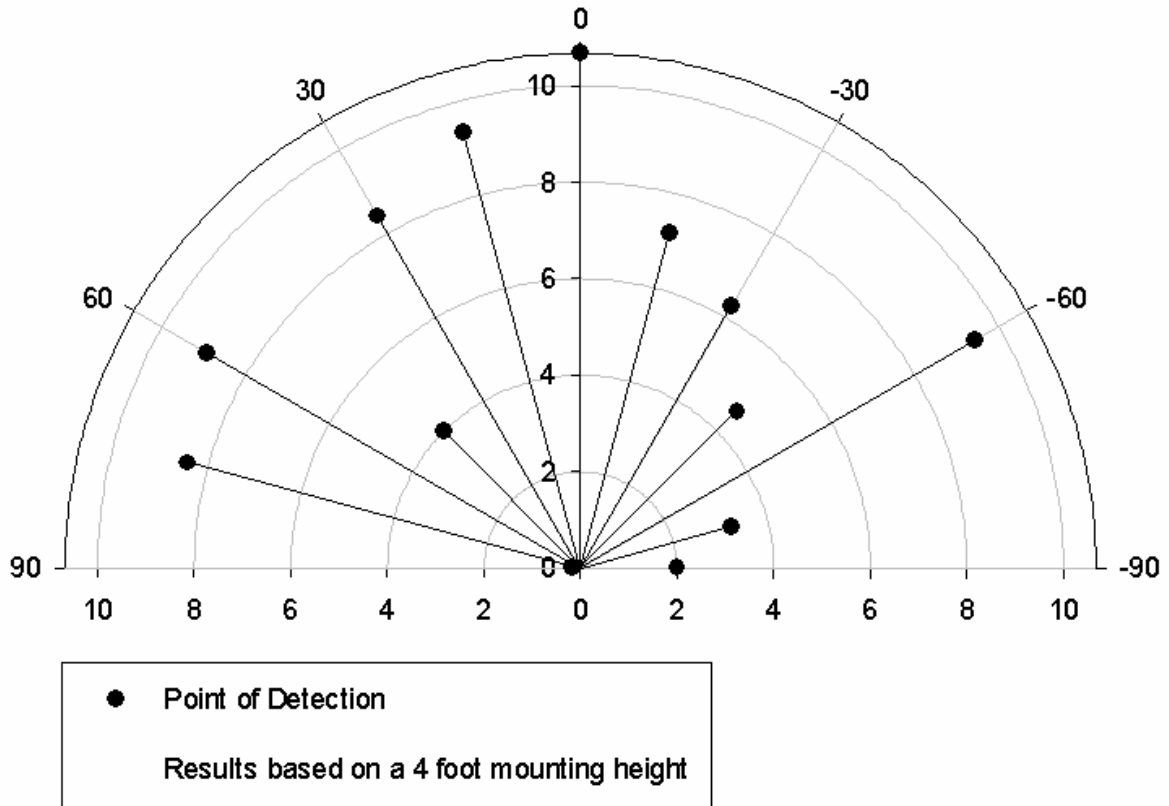


Figure 11: Detection Point Locations While Walking Towards the Night Light

From the measured data, the hotel night light sensor has a wider coverage pattern and longer reach. This is significant when it comes to applications in straight pathways. For example, given a six-foot wide straight path, the detection range would be improved due to the wider coverage pattern and longer range of the sensor. Figure 12 shows the detection points for both sensors with an orange line to represent the center of the path.

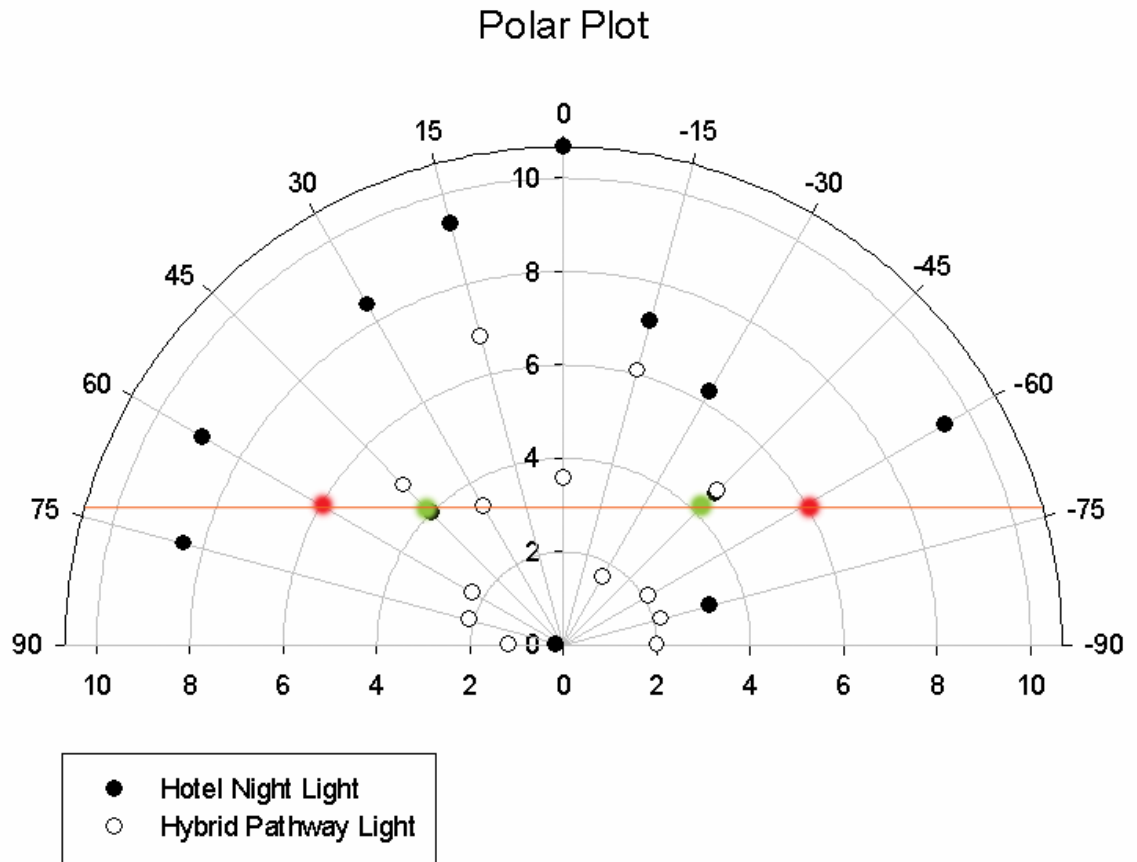


Figure 12: Detection Point Locations for Both Sensors

If a person walks down the center of the path along the orange line towards the sensor, the hotel night light sensor would detect the occupant at about six feet away. This is marked by a red dot in the diagram. The pathway light occupancy sensor, on the other hand, would detect the person at a distance of about four feet instead, represented by a green dot. This means that the hotel night light sensor senses the person two feet before the pathway light sensor does. In applications similar to this, the hotel night light occupancy sensor would provide better coverage than the occupancy sensor of the hybrid LED pathway light.

A good combination of coverage pattern and range is required for general pathway lighting. A sensor having very long range, but narrow coverage pattern, or one with a very large coverage pattern, but short range would not work well in most applications.

¹ Rea , Mark S. The IESNA Lighting Handbook: Reference & Application. New York: IESNA, 2000. (Page 21-3)