ECS 300/310 SOLAR PANEL

ECS 300/310 SOLAR PANEL – DESIGN CONSIDERATIONS

25 July 2026

Observe precautions! Electrostatic sensitive devices!

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REVISION HISTORY

The following major modifications and improvements have been made to this document:

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1.0	CB		2011.02	Original version
1.1	CB		2020.01	Update figures and clarify specifications
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Components of the modules are considered and should be disposed of as hazardous waste. Local government regulations are to be observed.
Packing: Please use the recycling operators known to you.

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1 Introduction

One of the most widely used energy-harvesting elements today is the solar cell. Solar radiation is by far the largest naturally available energy resource, and the discovery of the photovoltaic effect opened up entirely new possibilities for converting light directly into electricity. Indoors, however, only around 0.1 to 0.2 % of outdoor sunlight levels is typically available (Figure 1), so choosing the right solar panel means matching it carefully to the specific light source and to the energy requirements of the application.

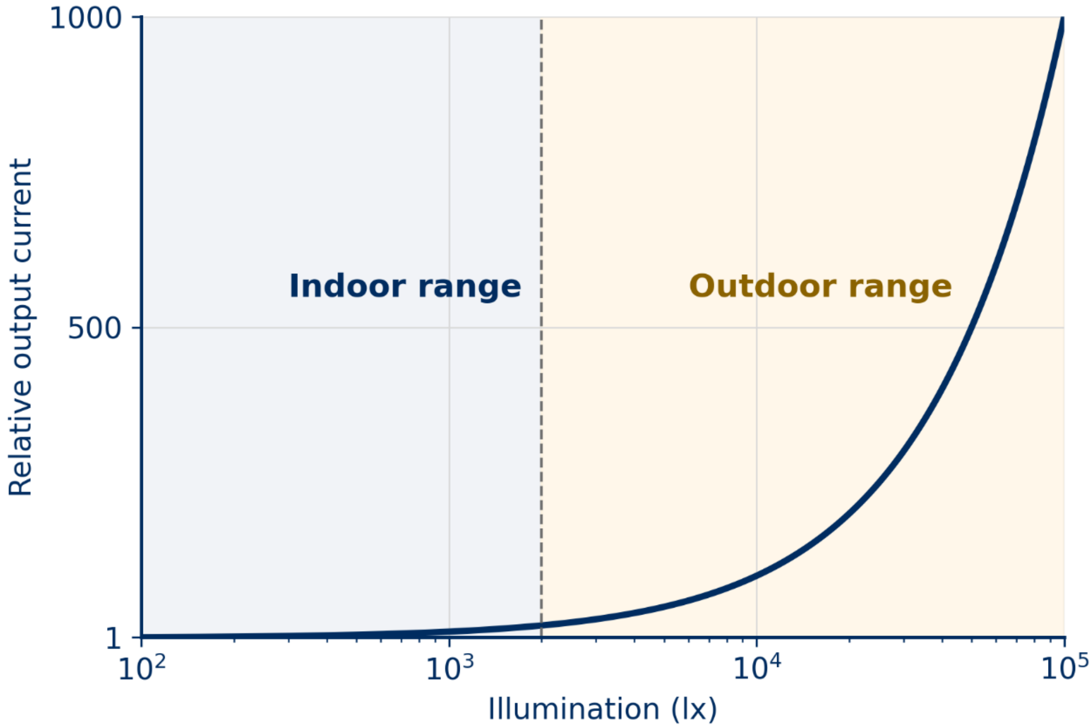

Figure 1 Relative output current vs. illumination

EnOcean's indoor solar panel family, ECS 300/310 (**E**nOcean **C**onverter **S**olar), is available in two sizes optimized for typical EnOcean applications: the compact ECS 300 and the medium-sized ECS 310. This application note gives a short introduction to using these panels as energy harvesters indoors. For more detail on typical indoor light levels and how to measure them, see EnOcean AN 201.

2 Solar Cell Technology for Indoor Use

2.1 Cell Types and Spectral Sensitivity

Solar cell efficiency depends heavily on the manufacturing technology, specifically on the cell's spectral sensitivity (Figure 2) relative to the spectrum of the available light source (Figure 3). Two main solar cell technologies are relevant for energy harvesting:

Crystalline silicon cells (“outdoor” cells) reach their best efficiency under sunlight, with peak spectral sensitivity around 800 nm.
Amorphous silicon cells have a larger bandgap and are optimized for artificial and indoor light; they typically deliver a higher open-circuit voltage, up to 0.8 V per cell, with peak spectral sensitivity around 550 nm — close to that of the human eye.
While conventional crystalline cells are roughly twice as efficient under optimum outdoor daylight, amorphous cells outperform them by far at low indoor light levels and win over the full 24-hour energy cycle, since they can also make efficient use of dim artificial light and early morning or evening daylight.

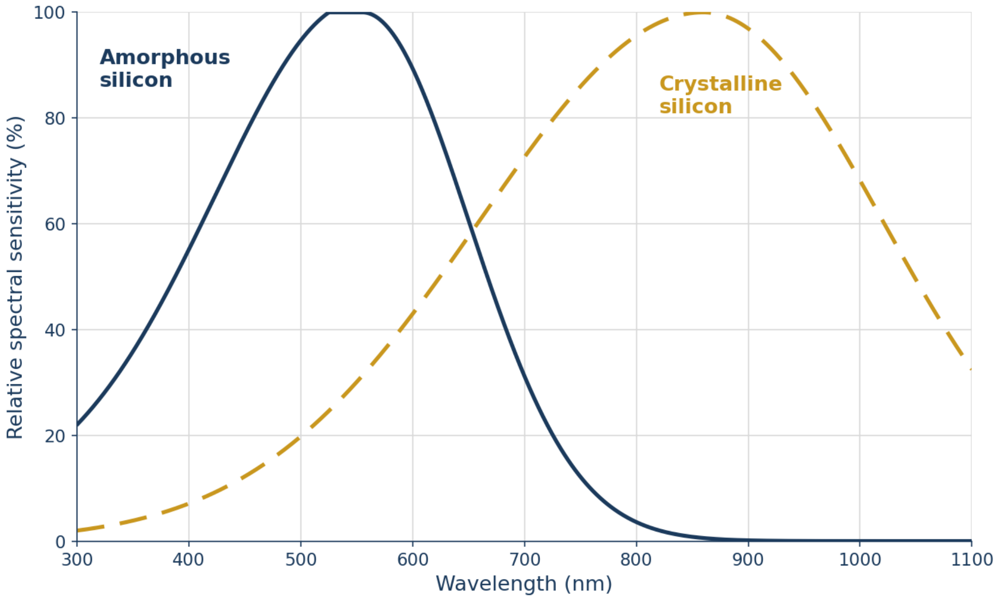

Figure 2 Spectral sensitivity of solar cell types

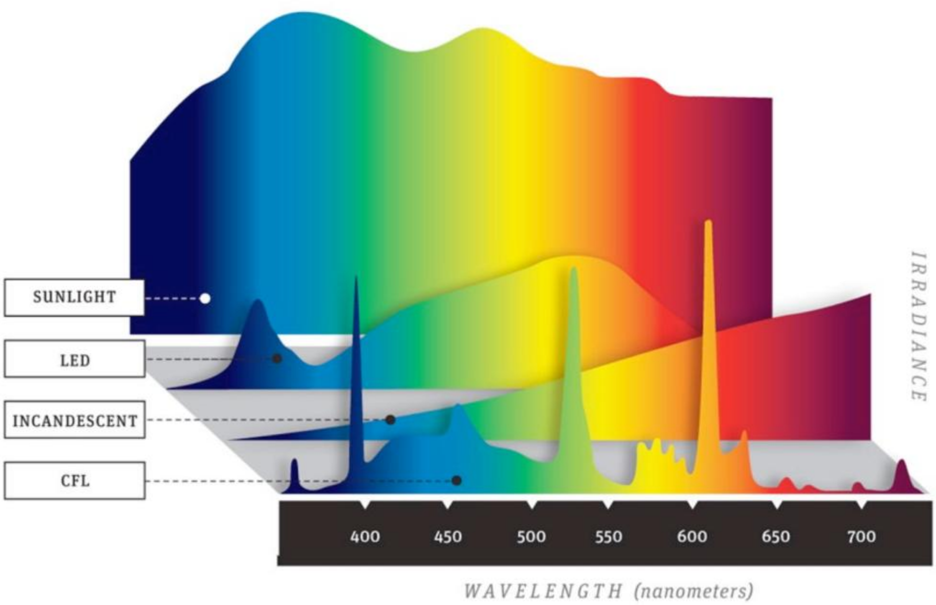

Figure 3 Relative sensitivity of common light sources

2.2 Output Voltage and Current Characteristics

Solar cells behave as light-dependent current sources. Their open-circuit output voltage depends only weakly on illumination across several decades of brightness (Figure 4), whereas their short-circuit current is directly proportional to light intensity and to the cell's active area (Figure 5). Brightness — how intensely a light source is perceived by the human eye — is measured in lux (lx).

The delivered power is not perfectly linear: it is slightly reduced by the cell's own voltage dependence and by internal or peripheral leakage currents. These effects become more pronounced for smaller individual cell areas and at lower light intensities.

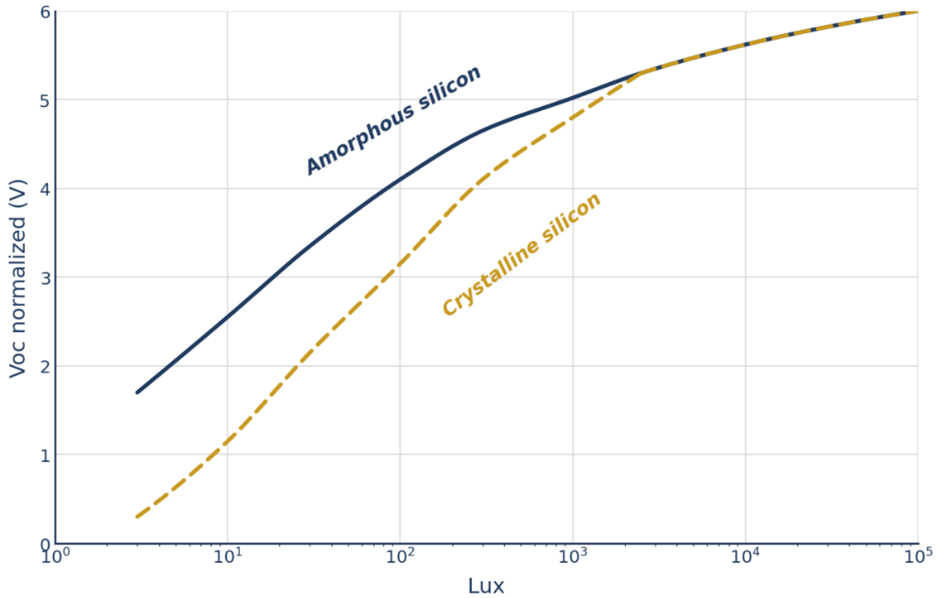

Figure 4 Normalized open-circuit voltage (Voc) vs. illumination

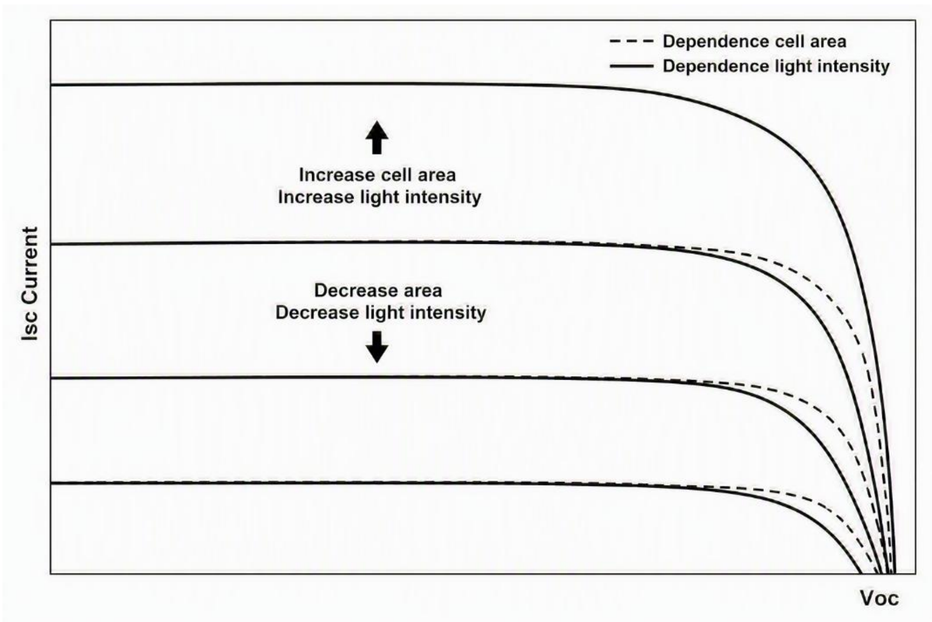

Figure 5 Effect of cell area and light intensity on the current/voltage curve

3 Solar Panel Selection Guidelines

3.1 Estimating Available Current and Power

As a conservative rule of thumb, small-area (a few cm²) amorphous indoor solar panels can be expected to deliver an operating current of around 10 µA/cm² at 200 lx (cool white, fluorescent light). This figure scales roughly linearly with illumination and area — for example, about 4.5 µA/cm² can be expected at 100 lx. Figure 6 illustrates this trade-off between cell area and illumination for a constant delivered current.

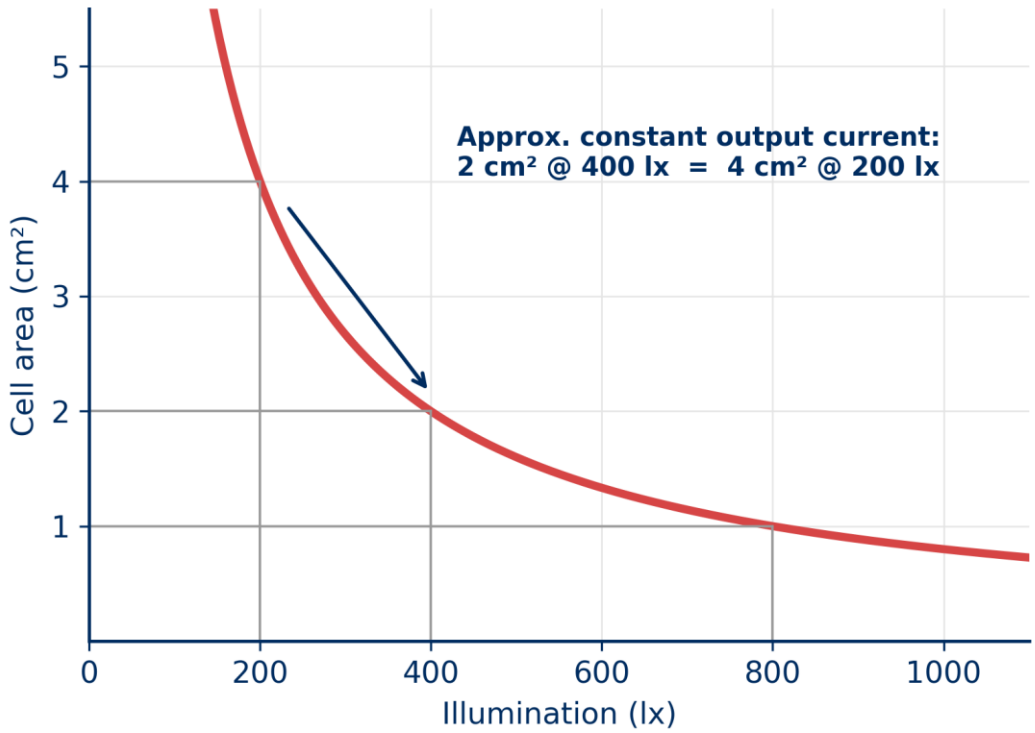

Figure 6 Required cell area vs. illumination for constant output current

Amorphous cells also typically deliver a nominal power density of around 4 µW/cm² at 200 lx, or below 2 µW/cm² at 100 lx (roughly 4.5 µA × 0.35 V).

3.2 Matching Panel Voltage to the Application

For best performance, the solar panel's output voltage should be close to the operating voltage required by the application. Output voltage is primarily determined by the number of cells connected in series (Figure 7). Always verify that under worst-case conditions, whether poor lighting or full, the direct sunlight delivered voltage stays within the powered electronics' rated limits, adding voltage-limiting circuitry where appropriate.
Note that the maximum current deliverable from a series string is limited by its weakest single cell (a bottleneck effect): a single shadowed cell can cause a disproportionate even total loss of output, and partial shading reduces the current accordingly.

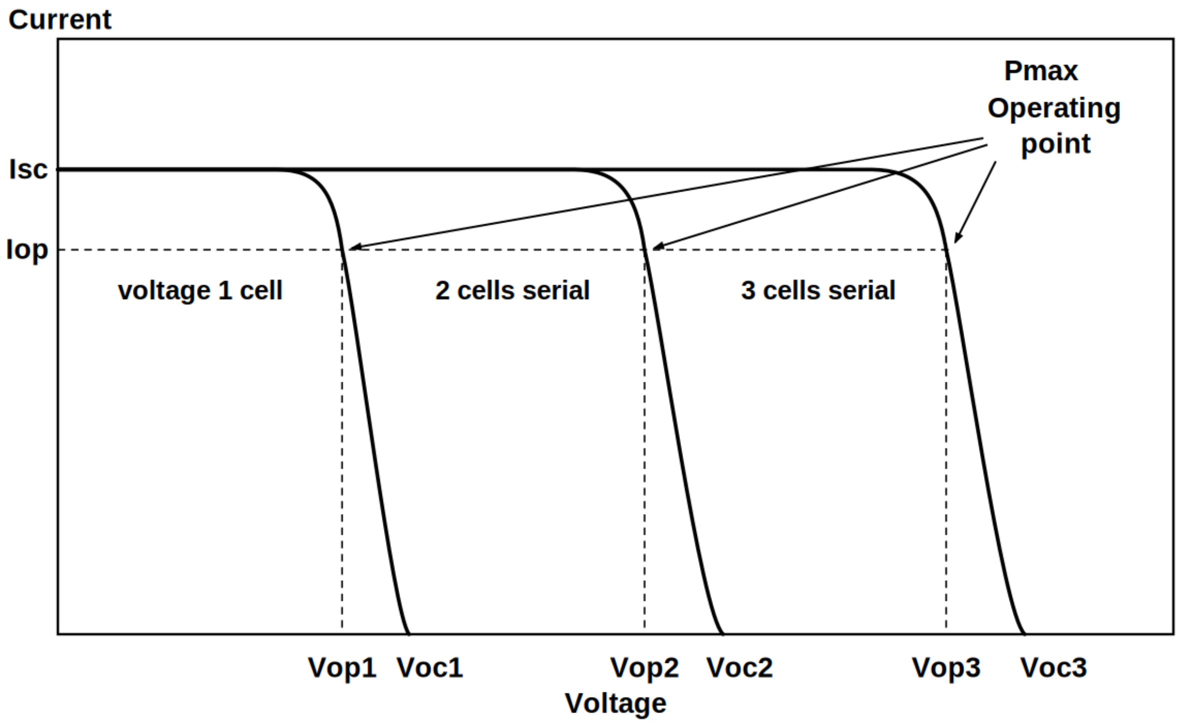

Figure 7 Current/voltage curves for one, two, and three series-connected cells

3.3 General Recommendations

These figures are rough estimates only; actual performance depends on many variables. Always characterize the specific target environment, define worst-case requirements, and add at least 20% margin when dimensioning the solar panel. Verify assumptions by measuring actual panel output under worst-case lighting. As a general guideline, treat 25 lx as the practical lower brightness limit for ambient-light-powered devices below this level, solar cell efficiency drops sharply.
Make sure the full active cell area remains exposed to light — in particular, check that the peripheral cells are not shadowed by the device housing or cover design.

4 Calculation Example: STM 300 Room Sensor

Consider an EnOcean STM 300–based room sensor that must transmit environment data every 100 seconds under a constant ambient brightness of 100 lx. What solar panel dimensions are required?
Current requirement: The STM 300's current consumption can be found in the STM 300 user manual (chapter 3.11; see also AN 209): approximately 160 µC (160 µAs) per transmission, including an external sensor circuit and storage-capacitor leakage. With one wake-up and transmission every 100 seconds, the storage capacitor needs a recharge current of at least 1.6 µA over that interval (1.6 µA × 100 s = 160 µAs). A single 1 cm² solar cell delivers roughly 4.5 µA at 100 lx (see Section 3.1), so half a cm² of cell area is enough to supply the required 2 µA at 0.35 V.
Voltage requirement: The STM 300 requires a supply voltage between 2.6 V (at start-up) and 5 V. At 100 lx, this means eight single cells (approximately 0.35 V each) must be connected in series.

Result: Combining the voltage and current requirements at 100 lx gives the minimum panel area: 8 cells × 0.5 cm² = 4 cm². An amorphous silicon panel with eight series-connected cells and a total area of 4 cm² meets this requirement. EnOcean's smallest panel, the ECS 300 (3.5 × 1.28 cm = 4 cm², eight serial amorphous cells; see Table 1 and the datasheet for details), which exactly meets this need.
For applications with higher energy demand, such as bidirectional room controllers using Smart Ack (see AN 501), the larger ECS 310 (eight series cells, 5 × 2 cm = 10 cm²) is recommended. For examples requiring even larger panels, see AN 306 and AN 311 (motion sensors).

Table 1 ECS 300 vs. ECS 310 key parameters

Parameter	**ECS 300**	**ECS 310**
Dimensions	3.5 × 1.28 cm	5 × 2 cm
Active area	4 cm²	10 cm²
Cells (series)	8	8
Typical use case	Compact sensors (e.g. STM 300)	Higher power / bidirectional applications (e.g. Smart Ack)

5 Important Notes on Sunlight Exposure

The ECS 300/310 indoor solar panels can generate an open-circuit (unloaded) voltage above 6 V under direct sunlight. To keep the STM 300(C) input supply voltage below its 5 V limit during accidental prolonged sunlight exposure, connect its VDD and VDDLIM terminals together (see the STM 300(C)/STM 400 user manuals, or the corresponding Dolphin (V4) Core Description).
Note also that prolonged direct-sunlight exposure of "indoor" amorphous silicon cells (hundreds of hours at illumination levels above 10,000 lx) can reduce their efficiency by up to 25 %, due to the Staebler–Wronski effect (a light-induced degradation mechanism). However at such high light levels, the panel still delivers far more power than needed, so this effect has little practical impact.

6 New Developments

Beyond crystalline and amorphous silicon, emerging technologies such as dye-sensitized cells (DSSCs), organic photovoltaics, and perovskite cells show strong potential for indoor use. These thin, flexible, lightweight devices can be shaped to fit almost any surface, and under low, diffuse indoor lighting can significantly outperform standard amorphous silicon cells.
The broader trend is toward thinner, more manufacturable form factors — often via low-cost, roll-to-roll production — combined with efficiency gains tuned specifically for indoor spectra rather than direct sunlight. As these technologies mature, they are expected to complement, and in some cases outperform, amorphous silicon for ambient-light energy harvesting, widening the range of viable power sources for battery-free wireless sensors.

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