The carbon neutral workspace

Katrine Flarup Jensen, Faktor 3 Aps. MSc in Engineering

The power consuming workspace

Abstract

This article presents the work process and results gained in the ongoing project 'The Carbon neutral workspace', which was started up in 2008. The objective of the project is focused on elucidating and uncovering the great potential for usage of Photovoltaics (PV) in indoor applications to power the standby electricity consumption.

The work performed in the project evolves on an electrical adjustable table used in office spaces, where the result is 3 functioning showcases of the table with photovoltaic cells implemented to power the standby consumption. In this case the standby energy consumption is estimated to be 15 times greater than in operation. The work carried out involves investigation of light in office spaces where light measurements have been conducted, dimensioning of photovoltaic cells under indoor, lowlight conditions, redesign of the electrical configuration in order to reduce the standby consumption as well as consideration of materials and integration of the PV.

Background

As the world develops, the requirement for more electrical equipment in everyday life is increasing rapidly. The power consumption of electrical appliances both in operation and in standby mode therefore greatly contributes to our total energy consumption. When regarding the energy lifetime of an electrical product, the amount of energy used for standby cannot be neglected and will in many cases exceed the power used in operation. The potential of PV used indoor to supply the standby power is a fairy unexploited field, but can have a revolutionary effect on the total energy consumption worldwide.

The project

The project was initiated by the manufacturer of electrical adjustable tables and electrical actuators, respectively Montana Group and Linak, who found interest in integrating solar cells in the desk top. An intercultural project group was formed, with competences ranging from the theoretical research institution DTU Fotonik, representatives of the end-use product (Montana Group and Linak) and producer of PV modules, Gaia Solar, as well as the designers and engineers from Faktor 3, who all joined in the project, funded by the Danish Energy Association.

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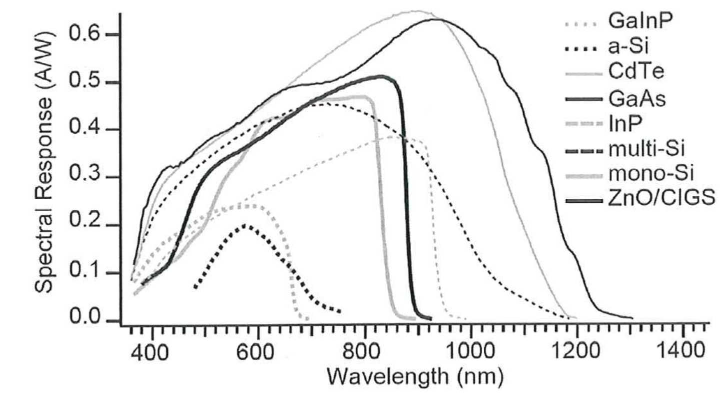

Figure 1:
Electrical response of different types of Photovoltaic technologies
Reference: H. Field: "Solar Cell Spectral Response Measurement Errors Related to Spectral Band Width and Chopped Light Waveform", 26th IEEE Photovoltaic Specialists Conference, September 29-October 3, 1997, Anaheim, California

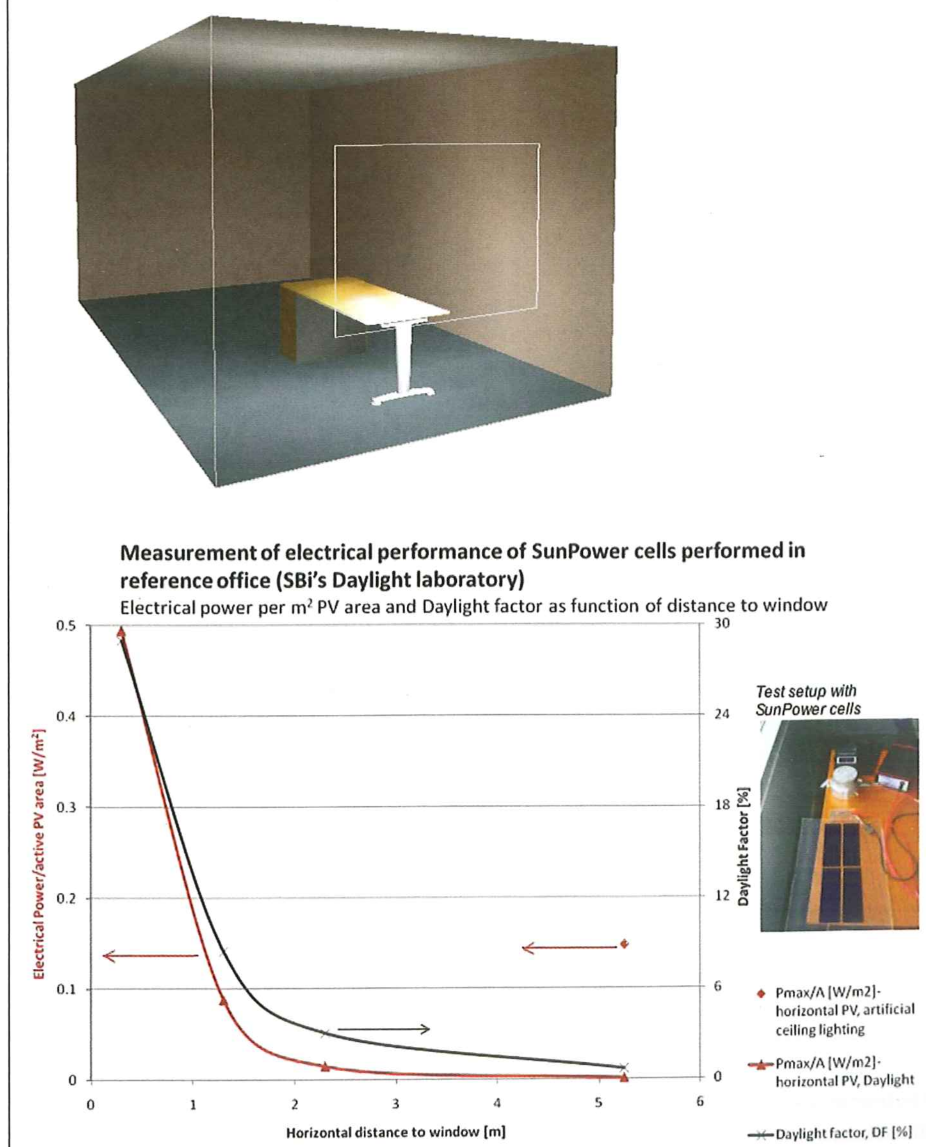

Figure 2:
Correlation between measurements indoor of electrical performance of SunPower cell as function of distance to window and Daylight Factor)

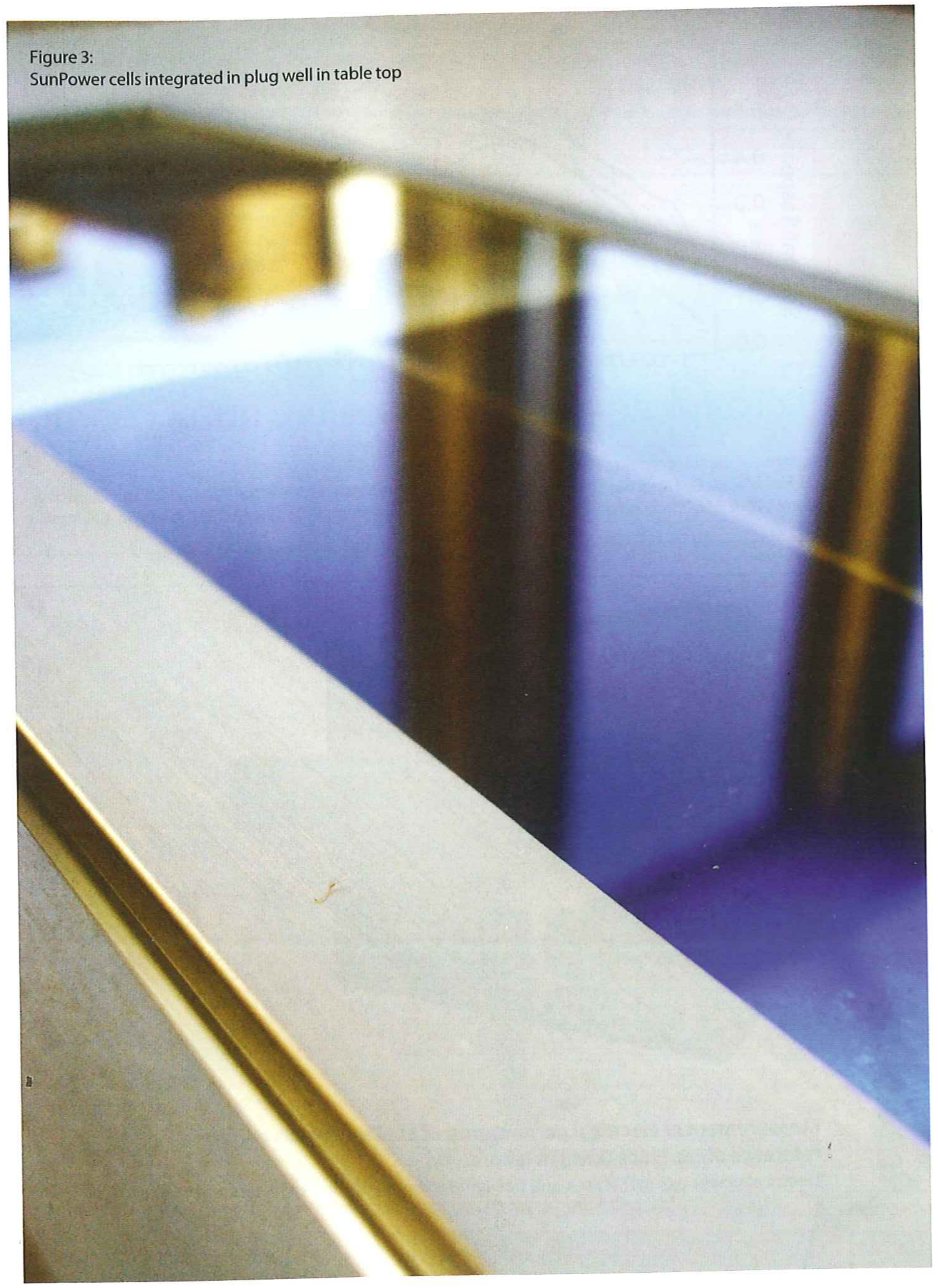

Figure 3:
SunPower cells integrated in plug well in table top

The project was divided into different phases, where a research survey with regards to different PV technologies as well as actual light measurements in a representative office environment was followed by work concerning reduction of standby consumption and redesign of the electrical configuration. Further a design process concerning integration of PV cells into the table was conducted. The phases will be described in the following.

Technical survey of PVs and light measurements in an office space

It is well known that the electrical characteristic of a photovoltaic cell depends on technology (eg. Crystalline silicon, amorphous silicon, organic PV etc.), with the variables: cell temperature, spectral light distribution and irradiation intensity, that all influence the overall performance. It is therefore crucial to have knowledge about the electrical behavior of different types of PV under relevant conditions in order to choose and dimension the PV for the specific application and energy consumption (Figure 1, previous page).

A technical survey of different PV technologies has been carried out with the aim to identify strengths and weaknesses with regards to electrical performance under lowlight, indoor conditions in a typical office. Experimental measurements have been carried out at a representative office to correlate PV performance to the light level as function of room depth and orientation. The solar cells chosen to be implemented in the electrical tables have therefore been dimensioned based on measurements of electrical performance under realistic conditions.

The Danish Building Code contains regulations to ensure good indoor climate in office spaces, and prescribes that the Daylight Factor (DF) in work space level of 0.85 m above floor level, must be minimum 2%. The dimensioning of solar cells for the electrical adjustable table is therefore based on a DF at minimum 2%; otherwise it is assumed that the daylight is supplemented by an artificial light source. A simulation of DF for the test room, performed in ReluxPro, is illustrated in (Figure 2, on previous page) where a graph illustrating the result of measurement for one PV is shown as function to placement in room, DF and lighting source.

From Figure 2, it is seen that Daylight Factor in correspondence with the electrical performance P_{max}/m^2 greatly reduces as function to window distance. The illuminance (in the visible area) with artificial lighting was equivalent to daylight in 1.2 meters distance from the window which was data used to dimension the PV cells for the table. Hereby the PV cells were dimensioned for electrical performance with an overlay of artificial lighting starting 1.2 meters in the room.

Electrical configuration

Traditional control devices operating electrical adjustable tables have a standby consumption of 1-2W, corresponding to an energy consumption of minimum 24 Wh per day. This was reduced markedly to less than 1mW by integrating a powerless coupling; meaning that the table will be operational at all times, but only has a power consumption from the grid under operation. The electrical control has to be modified to the output of the PV as well as the requirement for the actuator, so this is tailored to support the chosen solar cell.

Even though the standby consumption has been greatly reduced, a survey of operational patterns for the electrical table indicated that the standby consumption is up to 15 times greater than used for operation.

Design process

Based on the investigations performed concerning the electrical behavior of PV cells under indoor conditions as well as aesthetic conditions for integration, 3 types of PV were selected. The required PV area was considered with regards to the user behavior and experience for the end-user, in order to create a well-designed product without high requirements and formation of genes for the user. In order to integrate the solar cells, work with different expressions of lamination and montage has been considered. The final design integrations of the three different PV cells are:

- A mono-crystalline silicon panel integrated in a plug well at the table top, figure 3.

- The Sunpower cells are characteristic by their dark, uniform appearance and with the highest conversion efficiency, the required PV area is well suited to integrate directly into the table surface. The cells are laminated in tempered glass with thin conductor lines in order to enhance the simplicity and beauty of the very clean materials.

- Two PV windows of small silicon spheres integrated in a dividing wall, figure 4.

- The Kyosemi Sphelar panels are fascinating to hold up against the light and look through the fine network of silicon spheres. As a supplement to the electrical table, two panels have been integrated into a dividing wall which creates privacy, yet a visual link between the work space and the rest of the office.

- A blotting pad with flexible organic solar cells, figure 5.

- The organic solar cells fabricated at DTU Risoe are characteristic in their thin flexible plastic laminate, resembling a piece of paper. The blotting pad has been designed to be an additional element to the table top, which can easily be rolled out and integrate well with documents and other paper cases. Consideration to partial shadowing as well as the relatively low conversion efficiency has been taken when dimensioning required solar cell area.

The design concepts all supports the existing aesthetic of the table and adds an important futuristic prospect: a huge leap towards a Carbon neutral workspace without compromising with the design.

Figure 4:
Kyosemi panels integrated in dividing wall

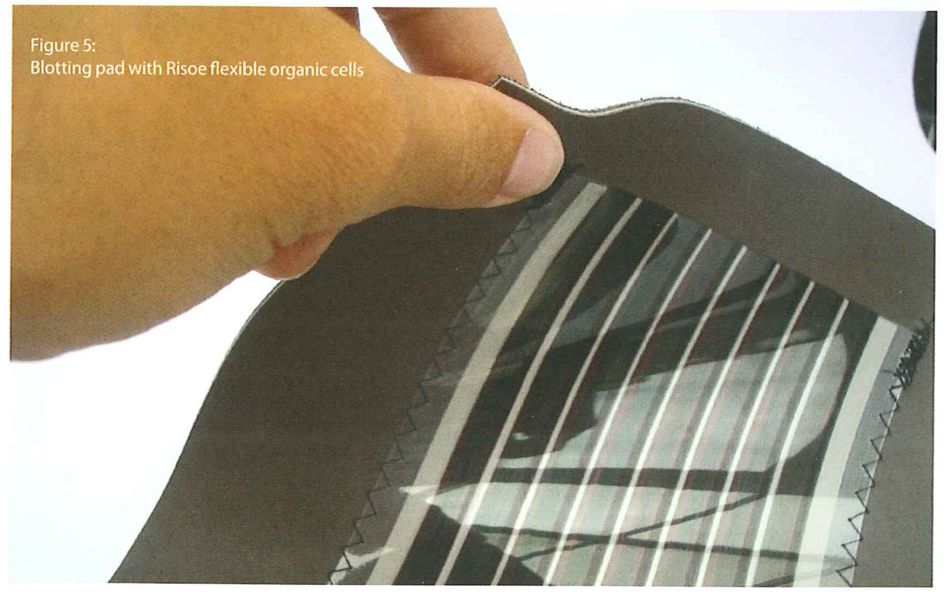

Figure 5:
Blotting pad with Risoe flexible organic cells

The three functioning prototypes of a electrical adjustable table with standby consumption covered by solar cells are to be showcased in December at the COP 15 in Copenhagen, Denmark.

Future outlook

The work carried out in the project is not bound to the specific product, but is seen as a platform to showcase the enormous potential for usage of PV indoor.

Other appliances characterized by relative low energy consumption but in need to be turned on continuously, have great potential to reduce their total energy consumption by powering of PV cells.

The further work in the project involves development of an artificial solar simulator based on LEDs, which will provide a test facility to characterize solar cells under low light conditions (0-200 W/m^2). An added future to the LED Sun will be the possibility to change spectral distribution of the light, which enables testing of the solar cell under resembling conditions to that, the solar cell will be subjected to.

This test facility will create possibility to systematically measure different solar cell technologies and collect data for electrical response, so a design tool with regards to surrounding light conditions, PV technology and energy consumption of the specific appliance can be developed.

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