DESIGNING PV POWERED LED PRODUCTS – INTEGRATION OF PV TECHNOLOGY IN INNOVATIVE PRODUCTS

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ABSTRACT: This study covers the design of innovative product concepts based on a combination of PV and LED technology. The products were developed in a project that took place in 2008 and 2009 during a cooperation of the University of Twente with Philips Lighting. It is shown that surprisingly unpredictable - yet technically feasible – PV powered LED products can be designed by carefully selected industrial design methods and an open view towards potential applications. In this scope innovation is not just a matter of implementing advanced technology in existing products, but particularly a matter of sensing new opportunities which are created by the combination of new technologies such as LEDs and PV technology. The PV powered LED product concepts range from small products, like watches, remote controls and other electronic handhelds, to large-sized products such as tents. In this paper it is shown how the concepts have been developed and they will be visualized by high key renderings. Also attention will be paid to the prototyping a few product concepts to evaluate their functional requirements.
Keywords: Design, Products, Stand-alone PV systems, LED

1 INTRODUCTION

Adding to R&D on PV technology it would be useful to pay attention to the development of new applications of this autonomous energy technology with the purpose of finding useful product concepts that are supposed to be marketable in the (near-)future. Though many options already exist, the application of integrated PV systems in mass-produced consumer products is still unusual and rare [1]. According to a design study conducted in 2007 by University of Twente in the Netherlands it was found that technical issues aren't a bottleneck in the design process. Also the study couldn't explain why the potential of PV-powered products hasn't yet been fully explored and exploited [2]. Therefore, in 2008 a follow-up study was conducted by University of Twente in cooperation with Philips Lighting. This design project was focused on product innovation.

A recent emerge of outdoor PV lighting products like garden lamps and public lighting systems led to the following design question: what (other) kinds of products can be designed with PV and LED technology that fit well to present developments in industrial design engineering, such as mechatronics, interaction design and usability.

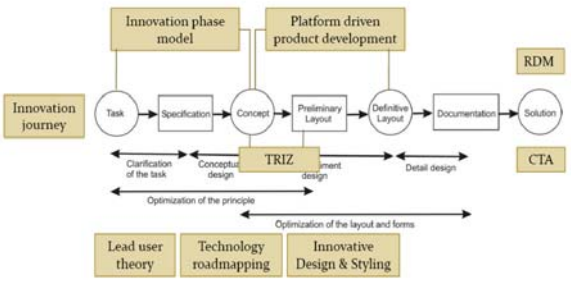

Figure 1: Linear design process in relation to innovation methods (brown squares) applied in this project.

Twenty-four teams of students of the master of Industrial Design Engineering were commissioned to design product concepts based either on a combination of LED and PV technology or solely on LED technology. The design project took place in a relatively short period of 10 weeks from September until November 2008. During this period students were informed about PV and LED technology by experts. Finally the project resulted in 12 PV powered LED products and 12 LED products.

The design approach was based on a standard design process - consisting of a clarification of the task, concept development and embodiment design – supported by several industrial design methods that favor innovation in the design process. Here we will shortly list them: Platform Driven Product Development (PDPD), Innovation Phase Model (IPM), Technology Roadmapping (TRM), TRIZ, Lead User Study (LU), Innovative Design and Styling (IDS), Risk Diagnosing Methodology (RDM), Innovation Journey (IJ), Constructive Technology Assessment (CTA). Descriptions of the methods are given by [2] and their relative position in a linear design process is given by Figure 1. Platform Driven Product Development was a compulsory method that had to be applied by all teams. In this paper we will present and discuss the resulting product concepts with a focus on PV powered LED products. Also we will endeavor to understand how a certain design approach favors product innovation.

2 RESULTING PRODUCT CONCEPTS

PV powered LED product concepts resulting from our design study are listed in Table I. Their applications are divers, varying from consumer products such as small electronic handhelds to building components and business-to-business products. Depending on the maturity of technologies used, products concepts can be either technically feasible or will be future products, for instance in the case of the application of OLED

technology (concept A and M), or LEDs integrated in fabric (concept D) or in porous concrete (concept L). PV technology though was not perceived as a technical barrier. Below we will shortly describe the product concepts.

Table I: Product concepts with PV and LED technology

	Product description	**Application area**	**Feasibility**
A	**Graphical user interface with OLEDs, Fig 2**	Consumer products	Future product
B	**Beach flag, Fig 3**	Business-to-business	Feasible
C	**Watch**	Consumer product	Feasible & future product
D	**Sunshade with integrated LEDs, Fig 4**	Business-to-business	Future product
E	**Ice rink markings, Fig 5**	Business-to-business	Feasible
F	**Light emitting brick, Fig 6**	Building component	Feasible
H	**Game, Fig 7**	Consumer product	Feasible
I	**Outdoor game**	Consumer product	Feasible
J	**Emergency tent**	Business-to-business	Feasible
K	**Remote control, Fig 8**	Consumer product	Feasible
L	**Urban furniture, Fig 9**	Building component	Future product
M	**Safety vest with OLEDs, Fig 10**	Consumer product	Future product

2.1 Concept A: Graphical user interface with OLEDs

This concept consists of a PV powered handheld, shown in Figure 2, that can connect to different appliances in a household in order to act as a universal control panel. The device's display uses OLED technology. The power requirement of this product ranges from 200 to 600 mW which is appropriate for PV technology. However, the application of two technologies which are not commercially available yet, namely transparent OLED technology and a universal communication protocol cause this product concept to be categorized as a future product. Also, due to an intensive use of the innovation support tools TRM and TRIZ, this product concept typically appears to have (too) many technical features.

Figure 2: Future graphical user interface of OLEDs powered by PV cells by Goossens, Kranen and Leppers.

2.2 Concept B: Beach flag

For the advertisement business a PV powered LED lighted flag has been designed, see Figure 3. From a lead user study a real issue in advertisement emerged for the situation of beaches after sunset. Until now restaurants and bars on the beach light customer attracting texts on flags by spot lights with long electricity cables. Therefore the use of an autonomously powered LED lighted advertisement flag would increase both the visibility, safety and usability. Also from a technical perspective this concept should function well; on many geographic locations 0.2 m2 of PV cells can generate sufficient energy to power 10 LEDs during 4 hours (energy required is 60 Wh).

Figure 3: Beach flag by Groen and Verduijn.

2.3 Concept C: Watch

This project mainly focused on the design and styling of PV powered watches with LED indicators. The PV powered watch is yet an established product though. Therefore by means of technology road mapping, the design was placed in the framework of near-future developments such as the integration of the watch, mobile phone and certain functions of the personal computer.

2.4 Concept D: Sunshade with integrated LEDs

During daytime this free standing sunshade provides shade and uses photovoltaics to charge a battery which is integrated in its frame, see Figure 4. After sunset the interior smart fabric containing LEDs provides mood light and communication functions for branding and advertisement. From the perspective of energy requirements this product concept will be feasible. For instance energy produced by the PV array will be 85 Wh/hour on a sunny day, which is sufficient for lighting purposes. However the development of a commercially feasible fabric with integrated LEDS that can be controlled like a display is the main reason for categorizing this concept as a future product.

Figure 4: Sunshade made from flexible PV foil with integrated LEDs by Bos and Hartman. Artist impression of use during night.

2.5 Concept E: Ice rink markings

By the evaluation of a product concept that aims at lighting sports fields during the evening by solar energy absorbed during daytime, see Figure 5a, another product concept was developed. This concept comprises PV powered LED lighted markings, see Figure 5b, that are fully covered by a thin top layer of ice of an ice rink. The product will significantly reduce time required for manually applying differently patterned and colored markings for different sports, such as ice hockey, curling and short track speed skating. As such the product will pay itself easily back in 10 years. By CTA, an innovation method that aims at a better understanding of the impact that technology has on society, it was found that PV technology (500 Wp) to power the markings might have an positive effect on clients leading to a broader application of the markings in other sports fields, i.e. floor of a gym or outdoor sports.

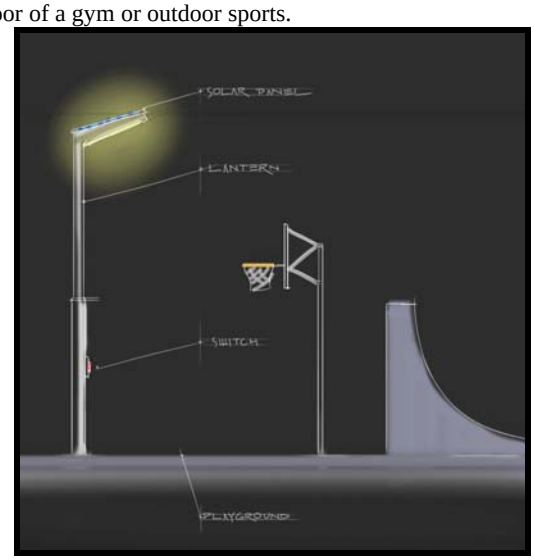

Figure 5a: Impression of solar powered sports field lighting.

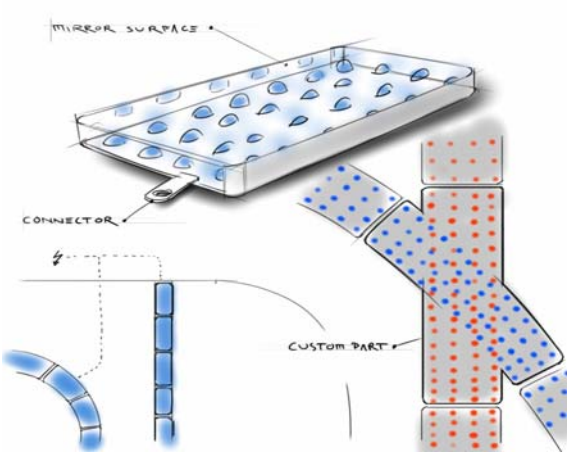

Figure 5b: Ice rink marking by Heemst and Henning.

2.6 F: Light emitting brick

The PV powered light emitting brick shown in Figure 6 can be described as a modular building component that interacts with users. Providing ambient lighting will be the main purpose of this product. Turning on the light of a wall built of these bricks can be controlled by either motion sensors that detect users, or a remote control (also suitable for dimming light). Interactivity will be enhanced in the near future when bricks should be able to react to arm gestures. PV power required will be about 10 Wp.

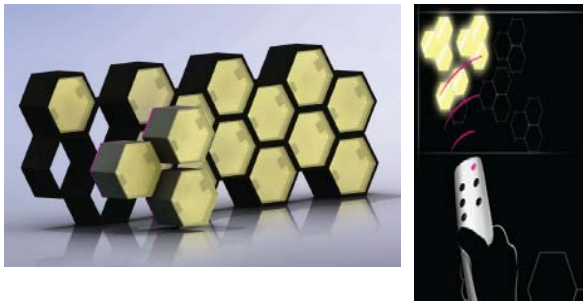

Figure 6: PV powered bricks which emit LED light by Jong and de Beurs, and the interaction with users.

2.7 Concept H: Game for toddlers

By the use of TRIZ a construction game for toddlers has been developed. The main principle is that the LED based building blocks will light up once electrically connected in the right order and serve as a night light that can be placed in the toddler's room where it can turn itself slowly off. The product is PV-powered to make it portable and give it an environmentally friendly character. Because of its autonomous energy supply it can also used outdoor or in developing countries. See Figure 7 for an impression of the product.

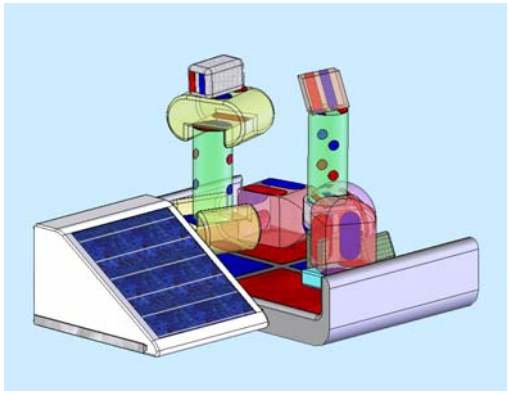

Figure 7: A solar powered game for toddlers consisting of light emitting building blocks by Kemper and Renkens

2.8 Concept J: Emergency tent

In this project the yet-known concept of a PV powered tent is placed in the context of sustainability, safety and usability by an IJ leading to a new situation of use, namely disaster areas. The Extent covers a package that eventually can be dropped down from airplanes. It contains a tent that can be easily popped up by an umbrella mechanism and flexible PV modules of 100 Wp that can be rolled out on the tent's roof. The package also contains a lead-acid battery pack, wiring, LED-modules and radio modules, to be connected to the PV modules.

2.9 Concept K: Remote control

Under worst lighting conditions of 1 W/m^2 a PV panel of 55 cm^2 would be sufficient to meet the low energy requirement of IR LED in remote controls for TVs. In

daytime a PV cell of just 8 cm^2 would be fine for an indoor situation. In this project the focus was on applying IDS in combination with TRIZ to find plausible configurations of integrated PV cells in the top cover of a remote control. Figure 8 shows the resulting geometric design variations.

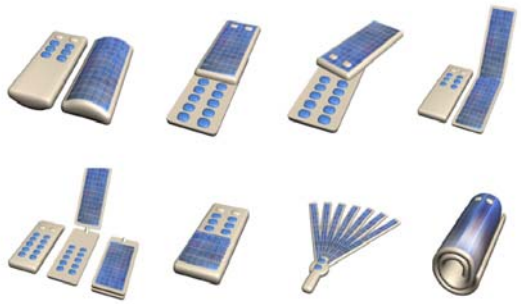

Figure 8: Geometric design variations of a PV powered remote control by Heeres and Kerkhoffs.

2.10 Concept L: Urban furniture

This concept called Living Cubes, see Figure 9, is a modular system with interactive tiles that react with the environment by emitting LED light at different intensities and colors. The tiles are supposed to be placed in public spaces, like a park, and to be autonomously powered by PV modules. Living Cubes has different functionalities during day time and night time. During day time it is merely decoration and personalizing public space. During night the product additionally has lighting and security functions. All light emitting tiles have one or more light sensors that detect when an object or person is standing on top of the tile. Once detected a CPU decides on an appropriate reaction, which could be personal coloring, fading colors or other reactions. A TRM supported the development of the product concept Living Cubes.

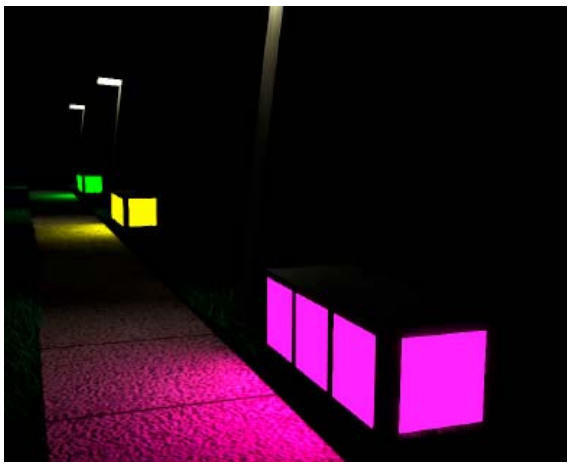

Figure 9: Solar powered LED light emitting urban furniture by Erkel and Reilink.

Figure 10: A solar powered safety vest with OLED display by Kok and Peters.

3 REMARKS REGARDING LED PRODUCTS

Besides PV powered LED products also 12 (solely) LED product concepts were developed during this design project. By discussions with the designers it was found that 6 out of 12 LED products could be powered by PV technology without harming the original concept and even improving the concept's usability. The LED product concepts found suitable for PV are: a runner's safety vest, water distillation with UV LEDs, a 3-dimensioal LED cube for outdoor advertisement, sign posting for train platforms, an autonomous interior lamp and, to end with, glasses for night vision.

4 PROTOTYPING OF CONCEPTS

A few of the product concepts developed were prototyped during the period of February until April 2009 to find out whether the expectations regarding the technical feasibility of these products were realistic. Below we will shortly discuss prototyping and testing of product F, the light emitting brick. Figure 11 shows three finished prototypes which were tested. Among other things, the power produced by the PV cells, the accuracy of the movement sensors and the light sensors, and the light emitted by the LEDs, see Figure 12, were measured. It was found that the product performed well. The solar cells could easily provide the energy required to light the 6 LEDs during 6 hours each day. However brighter, i..e. more powerful LEDs, would improve the total appearance and the lighting functions of this product. Some doubts existed about the energy matching between solar irradiance and energy required by the LEDs during Dutch winter months. On the other hand the casing seems spacious enough to allow a bigger battery for daily storage of energy.

Figure 11: Three finished prototypes of the solar powered light emitting brick, shown from the PV covered side.

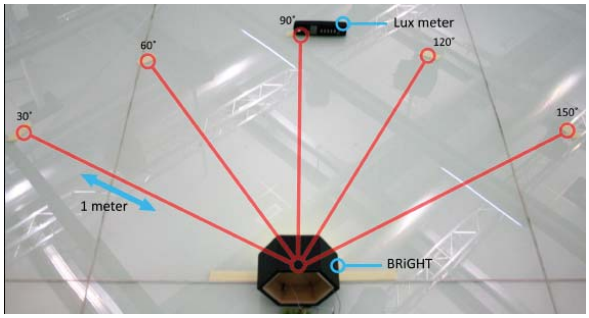

Figure 12: Experimental set-up for the testing of illuminance of the solar brick.

5 DISCUSSION

Technically seen PV and LED technology fit relatively well together because LEDs are operated at low voltage levels in the order of several volts, for which reason their energy requirement can be easily met by small battery-based PV systems.

The use of light emitting diodes (LEDs) in stand-alone battery-based PV systems might both reduce costs and environmental impact of lighting. Namely it is rare for a LED to fail completely. Instead the intensity of light emitted slowly decreases over time. The time towards 30% reduction of a LED's light output is considered a measure for its useful lifetime which is in the order of 30.000 to 100.000 hours. For this reason LEDs are fit for product integration, leading to low maintenance as is common for PV cells as well. Generally it's found that low junction temperature and a low forward current positively affect the LED's lifetime. Since a LEDs lifetime can be reduced considerably by continuous high currents, a LED has to be operated with a driver, an electronic device which applies either a constant current or pulses of higher currents.

6 CONCLUSIONS

6.1 Regarding product concepts

In our project 12 out of 24 concepts appeared to be interesting PV powered LED products far beyond the gadget stage. Most appealing concepts were not purely based on effective use of technology. Design aspects that enhance the product's appeal are usability, interactivity, safety and personalization. Particularly the portable features of autonomous energy supply by PV technology lead to a spatial freedom of use and interactions between a product and its user(s). Purely technology based concepts seemed to be future-oriented and not yet feasible. Moreover, operation at low DC voltage and low material contents appeared to be collective attributes of LEDs and PV technology that in principle favor the development of completely new products.

6.2 Regarding innovation

It was shown that surprisingly unpredictable - yet technically feasible – PV powered LED products can be designed by carefully selected industrial design methods and an open view towards potential applications. According to business models, innovation results in new markets for new products and services. In this scope innovation is not just a matter of implementing advanced technology in existing products, but particularly a matter of sensing new opportunities which are created by new technologies such as LEDs and PV technology.

7 REFERENCES

[1] Reinders, A.H.M.E. and Akkerman, R., Design, production and materials of PV-powered consumer products – The case of mass production, Proceedings of 20th European Photovoltaic Solar Energy Conference and Exhibition, Barcelona, 2005.

[2] Reinders, A.H.M.E., Product-integrated PV applications – How industrial design methods yield innovative PV-powered products, Oral presentation, Proceedings of 33rd IEEE Photovoltaic Specialists Conference, San Diego, USA, May 2008