Summary - English

A big part of research in photovoltaics for buildings today has its focus on technical issues such as electricity conversion effect, durability and material efficiency during production. However, if photovoltaics only are to be considered as an energy source, they can be regarded as a rather long term investment from a user perspective due to a long economical payback time. The ecological effect can only be noticed sometime in the future. The focus in this project is to create an instant reward through perceptual qualities in the design of photovoltaics - qualities you can enjoy as soon as the photovoltaic panels are installed. Therefore, the starting point of this PhD thesis is to see photovoltaics as a facade material rather than just as an energy source.

The project has its background in a multi-disciplinary collaboration established by the architect Ellen Kathrine Hansen from Aarhus School of Architecture with physicists Hanne Lauritzen and Eik Bezzel Hansen from Danish Technological Institute – both conducting research on new types of translucent photovoltaics.

In this regard Danish Technological Institute has called for architectural design methods and techniques for the building integration of lightfiltering photovoltaics.

Therefore this project has a twofold purpose. On one hand, the purpose of the project is to study techniques that can contribute to the design of buildingintegrated lightfiltering photovoltaics. On the other hand, the project should explore how light can be filtered with façadeintegrated photovoltaics and identify their architectural potentials.

The theme of the project is lightfiltering photovoltaics in glass facades with patterns of small scale - both micro and mesoscale - and how these patterns affect the optical indoor environment. Therefore the focus is on lightfiltering photovoltaics seen from inside the building and not from the outside.

This project consists of a theoretical phase and a practical phase. The theoretical phase provides a base for the practical phase, which formulates research techniques, the conduction of the experiments and their evaluation. The project starts with the formulation of a research question in chapter 1 and methodology in chapter 2. The project continues then with theory about photovoltaics in chapter 3 and about daylighting related aspects in chapter 4. This theory is then translated into practice through the formulation of the research techniques in Chapter 5 which are implemented and recorded in Chapter 6. Then the applied investigation techniques are evaluated in regard to how they can contribute to the design of the lightfiltering photovoltaic facade panels. Likewise, the results from these lightfiltering studies are evaluated and juxtaposed to existing architectural examples with similar lightfiltering effects in Chapter 7, which identifies architectural potentials within the different ways to filter daylight with photovoltaics. The focus is mainly on architecture from around the last 15 years that displays an interest in a facade materiality with veiling qualities that explore the state between transparency and lightblocking.

The selected research method is the experimental method, where one can manipulate the chosen research variables in a laboratory setting and examine their outcomes in order to formulate cause and effect relationships that can be used in a design process.

The research technique draws on physical experiments using a scale model with a replaceable facade in a setting consisting of 2 daylight laboratories - one with diffuse sky light and one with direct sunlight. This research technique should provide information on how light is filtered through the lightfiltering photovoltaic pattern at these 2 very different but often occurring daylight conditions.

The model itself is a scale model of a generic, functionless space with lightfiltering photovoltaic pattern encapsulated in a glass façade. The interior space is where the influence of the optical environment is examined in the various experiments using exchangeable photovoltaic imitation in the facade. The applied research techniques include both quantitative measurements and subjective evaluation.

One thing that has proven to be a challenge in the use of a scale model, is experimentation

with photovoltaic patterns at a microscopic scale. The microscopic patterns such as micro-louvers or micro-perforation are physically difficult to scale down, because their size is already as small as it can be manufactured.

Moreover, if lightfiltering micro-patterns are scaled further down the microscopic scale, their interaction with light might be completely different when approaching a pattern size that directly affects the spread of the different wavelengths of light. This can potentially cause optical distortion such as interference. At this level it becomes a different pattern with a different visual effect rather than the same pattern on another scale.

Therefore, in order not to distort the research results the scale model applies a lightfiltering pattern in real size - 1:1. This means 2 different scales in the same model with a hypothesis that the experiments give a probable simulation of the optical indoor environment with correct light guidance, light direction and translucency.

The facade experiments are conducted in 5 experiment groups based on different principles of light filtering. The impact on the optical interior environment is assessed both objectively with measuring equipment and through a subjective evaluation. The assessment parameters include transparency, color rendering, modeling, illumination level and glare condition.

The observations illustrate both the risks such as secondary glare and the potentials for photovoltaic glazing design such as graphical raster patterns, transparent solar control, tinted transitions and colored transparency. However, most of the experiments show that an additional light regulating layer is needed on the interior side of a photovoltaic pattern in order to avoid secondary glare in direct sunlight.

Finally the applied research techniques are also evaluated on the basis of the usefulness and probability of their observations.

Cover Illustration:

Idea for a photovoltaic window consisting of small photovoltaic stripes with the size of a barcode stripe. The pattern is based on the artwork "Bar Code Jesus" by the artist Scott Blake. Each line can consist of for example a sliver-cell photovoltaic, where the pattern creates a visual interaction between the view and the various degrees of light transmission.

Photography source: www.barcodeart.com modified by Artur Slupinski