

MSc in Architecture, Urbanism and Building Sciences  
**Building Technology, International Facade Master**

Development of three dimensional PV structures as shading devices for a  
Decentralized Facade Unit of the Future.

### **Reflection Paper**

Mentors: Arie Bergsma  
Craig Martin  
Wijnand van Manen

Dimitrios Sampatakos  
S.N.: 4251687

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## **Recommendations and further Potential** *(Reflection)*

Starting with a research that addressed several topics related to solar cells and their integration in buildings and facades more specifically by using the example of the NEXT Facade, this Graduation Project attempted to trace the potential of three dimensional shapes as active solar skins (used as shading devices) compared to conventional flat solutions.

Imagining a future of cheap, lightweight solar modules which are easy to curve, twist or fold an alternative approach compared to high tech tracking or concentrating solutions was developed, where shape and surface area increase can lead to better performance. Performance characteristics and properties of new generation solar cells especially in terms of diffuse light performance and partial shading are defining factors for a possible success of these structures in the future.

A four phase methodology was developed in which (at a first phase) the potential of PV surface area increase for a given facade space was researched. Best performing shapes in terms of maximum surface area were compared through a solar analysis to find the energy their surface receives on average and PV lab testing gave an indication of real performance for three dimensional structures. Finally the best performing designs were developed as structures and integrated in the decentralized NEXT Facade concept Module created by Alcoa.

Using the same methodology in a later work or project a multitude of different parameters and restrictions could be added and predefined in order to finally end up with an interesting variety of prismatic or curved three dimensional shapes. Only by changing the location and orientation of the developed structure already completely different 3d shapes emerge as most efficient. The absolute interdependence of the actual shape and the context has the potential of generating a large variety of different performance based forms that are both pleasing to the eye, efficient and unique.

The methodology itself could in the future include a more efficient shape generation process as a starting point, where a genetic algorithm process would “circle” through millions of shapes and shape versions in order to find the optimal performing ones according to the predefined needs and criteria. Surface area maximization, solar performance and PV performance, which in this case constitute three different steps could in the future be merged into one automatized process with specified boundary conditions. Additionally the effect of reflections between the prismatic or curved surfaces of a 3 dimensional PV shape could be of importance considering the final results, making specific shapes slightly more efficient than they look in the current calculations.

The PV testing Phase could in a future stage become a much more accurate filter of the total amount of well performing shapes. Overcoming cost restrictions accurate 3d models of exactly the designed curvatures and folding angles could be constructed out of polymer materials and thin film inorganic or organic PV cells. Time consuming real world testing in external conditions instead of only laboratory measurements is an additional step that could reveal more performance characteristics and possible advantages or disadvantages of three dimensional PV surfaces compared to what the present Thesis achieved.

As a final point, it could be argued that the charming process of connecting and correlating form, performance and context, into a unique for every combination result is in itself worth the effort and future development despite any emerging difficulties during implementation. Such a process has the potential of being translated into a future alternative approach not only as a different way of generating more electrical power from a given surface, but also as a different (more performance based) way of using form/shape in architecture.

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## Relation between research and design

The research phase of the present thesis is characterized by at least five initially distinguishable but finally interrelated aspects, namely:

- The solar irradiation as both an energy potential (benefit) and an overheating threat (deficit)
- Solar cell technology and the potential for new applications offered by the relevant recent technical (new sophisticated materials, methods of use and fabrication processes) and economic developments (decrease in PV prices, change in the subsidizing policies of the states).
- The development in the legislation as to the future need for zero energy buildings or even energy plus (producing) buildings in the future.
- Facade integration of PV cells, in particular having the NEXT facade of Alcoa as an excellent basis for further relevant improvement through PV use. The complete PV based systems using the energy generated in partly stand-alone ways.
- The development of shape optimization methods and relevant software.

The reader of the present thesis can identify in each step towards the final proposed designs the influence of these five aspects, since:

- Irradiation aspects have been carefully considered in each of the four Methodology “Phases”, (see relevant parts of the thesis, in particular the Ecotect Solar Analysis and PV Lab tests of 3rd and 4th Phase) and became the basis for all shapes and solution proposals.
- The recent PV technology has been researched, analysed (focusing on the possibilities given by thin film technology), evaluated (pros/cons) and taken into consideration in the final design aspects in both a theoretical (materials, peripheral devices etc.) and practical sense (lab tests).
- Maximization of the energy production in a modern comparatively high rise building on the part with the highest surface area (and therefore with a very high potential), namely its facade, has been the goal throughout the thesis as depicted in assumptions, calculations and the final design with up to extreme surface increasing shapes (like specific very dense origami patterns) in order to make optimal use of the available building surface, instead of only achieving a good output to cost balance.
- The specific characteristics of the NEXT FACADE have been the basis for the proposed designs so as to provide an already advanced product with additional value through devices which both solve existing problems (sun shading, avoiding overheating) and offer new energy advantages (in an eco-friendly way).
- Finally current methods with parametric software and genetic algorithm tools have been not only researched, but also used in practice in order to reach the final efficient three dimensional shapes proposed.

It follows from the above analysis that an almost “one to one” relation between the research and the design can characterize the present work.

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## **Relation between the methodological line of approach by the studio and the method chosen by the student**

In almost every part/project of the Building Technology Master Program research and a theoretical (more general) approach of a topic has been combined with a practical, applied part, real construction and experimenting with materials and structures. Testing, either using specific software tools or building and experimenting with real structures has been an indispensable part of the process leading to final solutions.

The same approach has been followed during the development of the current Graduation Thesis. A first research of the existing technology and emerging solutions with a high potential was followed by a methodology that would in an early phase make use of the possible advantages in a theoretical approach, then shapes/structures would be tested and evaluated through software tools to prove or compare their performance and finally tested in real or laboratory conditions.

The need to remain in consistence with a clear methodology with distinguishable steps and a clear research focus has on the other hand also made it impossible to present the total amount of work, designs, all different directions and topics that have been dealt with or produced during this Thesis. The initial goal to produce more efficient PV based solutions compared to conventional flat rigid panel has lead to different directions ranging from concentrated PV designs to complex 3d shapes which would be practically impossible to be all combined in one consistent “story” without deviating from the goal of a simple and easy to follow methodology.

## **Relation between the project and the social context**

The fact that buildings account for a very large part of the globally consumed Energy has in itself made research and designs related to possible solutions -in order to make our buildings more Energy efficient- an important contribution.

The use of renewable energy sources together with a significant reduction in Energy losses and passive Energy gain are the only way to achieve zero Energy Buildings, which has been set as a goal for the near future. In a longer term even Energy producing (Energy plus) buildings could be imagined as a reasonable demand (by the state) for new construction buildings. The impact of a significantly improved Energy balance for the large majority of existing buildings would of course be of extremely high significance.

On the other hand however Solar cells are nowadays no longer considered a novel and as fascinating topic for possible users as it was a few years ago and people are negatively biased against their integration in buildings due to the standard flat dark colored panels exclusively provided until recently.

Solutions in Solar Cell Technology that would at the same time make the final product more attractive and more efficient are considered a very important step towards wide use of renewable energy. Integration in buildings or other structures with more design freedom and a variety of shapes colors and transparency can convince people to start using active solar devices.

An additional -and probably the most important- concern of people who could probably invest on solar cells is the high price to output ratio but also the high price as a first investment. Thin film technology and emerging efficient organic thin film technology that can be produced using inexpensive production methods and materials will probably be an answer to this concern with their very low short back times.

Taking these facts into account the topic of the current Thesis project dealing with emerging low cost Solar cell technology and shapes deviating from the standard flat rigid and dark panels, could be considered an approach to not only increase the efficiency of a structure compared to a flat rigid panel but at the same time make the use of solar energy more attractive and adaptive to different conditions.

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## **Relation between the theme of the Studio and the Subject chosen by the Student within this Framework**

Building technology and more specifically Facade Design and Engineering are strongly related to the development of Energy efficient solutions for Integration in Building Facades. In parallel to projects and research dealing with the reduction of Energy losses to achieve a better Energy balance in buildings, also ACTIVE energy structures (energy producing) should be designed and optimized in order to become an integral part of the complete climate control system.

The integration of the proposed energy producing designs into a decentralised facade unit concept attempts to create a complete independent facade module that controls the inner climate, produces energy for its own operation and for additional devices and constitutes a highly adaptable system. The ability to use a single module including all needed operations from Energy Production to climate control and insulation has very important advantages in terms of refurbishment potential for existing buildings of many different types. In that sense the outcome of the current thesis is closely related to the main topic of the Building Technology/Facade Master track.