PERCEPTION OF FORMAL AND SYMBOLIC AESTHETICS OF PHOTOVOLTAICS

Klaudia Farkas[1]

[1] Department of Architectural Design, History and Technology, Faculty of Architecture and Fine Art, NTNU Trondheim, (Norway)

1. Abstract

Photovoltaic modules have long been perceived as technical devices that are added elements on the building. However, lately a variety of products have been developed to match architects' needs. There have been also experimentations by architects to find out the architectural language of solar cells. Still there is a lack of knowledge and information about the possibilities among architects, that long has kept them away to use this potential.

The following paper is the summary of the results of three research methods that were investigating the perception of architect students and architects in Norway about solar cells used in architecture. Ten international projects with building integrated photovoltaics have been chosen for evaluation. The projects are public buildings, presenting a high variety of formal possibilities for façade integration of solar cells, while they do not necessarily represent high quality architecture. Three different methods as triangulation have been used to evaluate the projects.

The results show how the formal and symbolic characteristics of PV are perceived among Norwegian architects. Furthermore it gives a summary of architects' needs for a wider use of photovoltaics in architecture.

2. The research methods

2.1. The research methods

The research is part of a thesis that is investigating the perception of formal and symbolic aesthetics of building integrated photovoltaics. The aim is to provide a guideline for discussions about the quality of building integrated photovoltaics while providing knowledge for architects about the design possibilities. Moreover the research investigates the need of practitioners for further product development.

Three methods have been used:

- 1-2-3 method with walk method
- Semi-structured group discussions
- Paper-based evaluative questionnaire

The first two are qualitative methods, while the third is quantitative, however the approach in all three tactics are qualitative.

2.1.1. 1-2-3 method

The 1-2-3 method of environmental aesthetics consists of immediate perception, cognitive evaluation and final assessment (Cold 1998). It was conducted in the framework of the Energy and Environment course at the Faculty of Architecture in NTNU, Trondheim, Norway with the active participation of 23 architect students. Three Scandinavian case studies with façade integrated photovoltaics (Opera House in Oslo, BP Solar Skin in Trondheim and the Valby Gable in Copenhagen) were selected for evaluation. Visits have been organized to each site, where the "walk method" was conducted. Five-six stops (depending on the case) were defined at different distance and angle from the analyzed façade to create a cognitive framework. During the "walk" at each stop participants had 10 minutes to draw sketches (as immediate perception) and to write down their reflections, descriptions, judgments (cognitive evaluation) about the facade. The stops were chosen to have an overall visual perception of the building starting from a further distance to the interior. The results of the perception and observation provided basic guideline for an architectural critique (final assessment), that the students were asked to write after the walk. The assessment focuses on the architectural integration of photovoltaics, discussing the building and the contextual environment as well.

2.1.2 Semi-structured group discussions

Semi-structured group discussions were conducted during workshops in the framework of the national activities of IEA Task41, to spread the knowledge about solar energy in architecture among practitioners. The aim of group discussions was to discuss the formal and symbolic characteristics of photovoltaics through ten pre-chosen cases of facade integrated photovoltaics. Five workshops have been organized in architect offices. The workshops consisted of three parts. The first was a lecture (appr. 20-30 minutes) about the formal characteristics of photovoltaics and their architectural expressions to provide knowledge and vocabulary for further discussions. The second part was an immediate evaluation of the ten cases. The projects were visually presented with images on A3 size posters The respondents were asked to give immediate judgment by giving scores to the projects. As a third part of the workshop a semi-structured group discussion was conducted. The architects were asked to give general feedback of actual PV products, to explain their judgments of each case and to give proposals for further product development. The framework for this discussion was provided by the ten projects and the given votes. The discussion became also an interactive communication, since it created platform to provide more knowledge about photovoltaics and the individual cases to the architects.

2.1.3 Evaluative questionnaire

The third method was a paper-based questionnaire conducted in combination with the first and second methods. The architect students were asked to fill out the questionnaire after the 1-2-3 method and the architects after the workshop. The paper-based questionnaire was asking for detailed evaluation of the above mentioned ten cases based on a set of pre-defined formal and symbolic characteristics. The respondents were asked to evaluate the architectural quality of the overall design and the detailed characteristics for each case.

2.2 Focus groups

The focus groups of this research were architect students studying at the Norwegian University of Science and Technology (NTNU), Trondheim in Norway and Norwegian architects.

The students were attending the course Energy and Environment (AAR4915) at the Faculty of Architecture in NTNU in the fall semester of 2009. Solar cells are upcoming technology that probably will be part of every day practice in the near future, therefore it is very important that education, knowledge distribution and research goes hand in hand in this field. During the course the students learnt about solar energy use in architecture in theory that they applied in a parallel design course. A three week workshop was held about photovoltaics, where the theory part consisted of lectures on basics and the formal and symbolic characteristics of photovoltaics, the 1-2-3 method including the walk and the evaluative questionnaire. 23 students attended the workshop and participated in the walk of the BP Solar Skin in Trondheim. Out of the 23 students 10 (43%) travelled to Oslo and Copenhagen to attend the walk of the other two cases (Opera House, Oslo and Valby Gable, Copenhagen).

The other focus groups of this research were Norwegian architects. Free workshops were conducted in the framework of the national activities of IEA Task41, to spread the knowledge about solar energy in architecture among practitioners. The aim was to distribute the knowledge of current architectural possibilities of photovoltaics in Norway and to get feedback from practitioners about their perception of existing products and projects. Furthermore the architects were asked about their needs of product development for a better architectural integration. A list of architect offices were collected from Trondheim and Oslo that have a minimum number of 10 employees and have already done projects with active solar technologies or have the interest in doing so. Finally the offer of a free workshop was sent to ten offices via e-mail, from which five gave a positive reply (50%). The workshops were held in September and October in 2010 with the participation of altogether 49 architects.

21 out of 23 students and 30 out of 49 architects filled out the questionnaire, altogether 51 people that gave a result of a response rate of 71%.

2.3. Cognitive framework

A study of existing materials, technologies and products has been done to investigate the formal characteristics of photovoltaics. Moreover a large international sample of building examples with integrated photovotaics was examined to study the formal and symbolic characteristics. Based on this collection a list of characteristics for cognitive evaluation was set up to create a framework for discussion about aesthetical issues of architectural integration of photovoltaics. Lectures with this topic were held both for the architects students in the framework of the course Energy and Environment (AAR4915) and for the architects in the national workshops to provide basic knowledge and vocabulary for discussions and evaluation. The characteristics are presented in Table 3.

Tab. 3: Cognitive framework for discussion about aesthetical integration of photovoltaics

OVERALL DESIGN	.
A.1 Overall assessment	The overall quality of the architectural integration of photovoltaics.
FIELD AND SIZE POSITION	
B.1 Field size and position regarding composition of the façade	This issue discusses whether the formal and conceptual positioning and the size of the PV modules match the formal design and composition of the overall project.
PV CELLS	
B.2 Color of cells	Photovoltaic cells have a variety of possibilities in color on the market by adding an antireflection layer on the original cell.
B.3 Texture of cells	The cells texture depends on the different technology. Monocrystalline cells have a more solid, while poly-, multicrystalline cells have a marble-like texture.
B.4 Composition of cells	The composition (pixelling) of the wafer-based solar cells (that has a size of 10/10 or 12/12 cm) or smaller thin film modules can create different patterns on the facade.
PV MODULES	
B.5 Color and type of framing	The most common frames of modules are made of aluminium. Modules can be integrated into curtain-wall systems as well. There is also possibility for frameless modules to match architect's needs.
B.6 The color and texture of added elements	Certain added elements can enhance the façade design. These can be in front, in the level, or behind the surface of the PV modules. Some examples are glass painting, different lightning systems (LED)…etc.
B.7 The detailing of components	The mounting and jointing, the electric wiring and connections to other components of the façade provide a variety of structural detailing issues.
B.8 The overall surface texture of the PV components (modules)	The characteristics of the cells, the framing and the added elements create an overall design of the module.
B.9 The shape and size of the PV components (modules)	The characteristics of the cells, the framing and the added elements together with the conceptual grid of the façade define the shape and size of the module.
ADDED VALUE	
B.10 Structural added value	The PV modules can serve several structural functions like glazing, façade cladding, outer layer of double-skin façade, shading…etc.
B.11 Artistic added value	The composition of the cells can create or be part of an artistic, ornamental approach on the façade.
B.12 Symbolic added value	The visual characteristics of PV cells exposed to the public can play an educational or representational role about environmental awareness

2.4. The selection of cases

The aim of the group discussion and the evaluative questionnaire was to discuss the formal and symbolic characteristics of photovoltaics through pre-defined ten real cases. The cases have been chosen based on the criteria presented in Table 4.

Tab. 4: Criteria for the selection of the ten cases

CHARACTERISTIC	CRITERIA
Technology	crystalline cells
Product type	custom-made
Type of building	public building
Integration into the building skin	façade

In the last thirty years the PV market was ruled by crystalline cells. Even in 2010, silicon wafer-based technologies accounted for about 80% of sales. Thin film cells are upcoming technology, still the European Photovoltaic Industry Association (EPIA) expects that 61% of market will be ruled by crystalline cells even in 2020. Custom-,made products are specifically designed to match architectural integration needs, studying them can provide knowledge and influence further development of mass production. Public buildings that are exposed to the public have the potential to enhance people’s environmental awareness and to be good examples for further developments. Façade integration of PV as a visual media can be a playground for aesthetic expressions and symbolic meanings. These reasons were the basis to set up the criteria for the selection of the ten cases (Table 4). The cases are not necessarily best examples from architectural quality point of view, but they were chosen to provide architectural solutions that present the possible highest variety of the above defined formal and symbolic characteristics (Table 5).

Tab. 5: Variations of characteristics for the selection of the ten cases

CHARACTERISTIC	VARIATIONS
Technology	mono- / multicrystalline cells
Structure	cladding / glazing
Façade composition	modules cover part of façade / overall façade
Color of cells	standard / colorful
Composition of cells	equal / grouping in line / following image
Framing	standard framing / custom-made / no-framing
Added elements	glass painting / lighting
Added values	multifunctional / artistic / symbolic

The ten selected cases are presented in the following paragraph (Fig 1).

Three particular cases have been selected for the 1-2-3 method (Fig. 2). The cases have been chosen from Scandinavia (Norway and Denmark) to have possibility to gather the most amount of data and to easily reach the sites by the group of students, since the research is conducted from Norway. The basic criterion for the selection was that they should be public buildings which have a strong representational role in their context. Another criterion was to present high variety of architectural integration strategies and moreover to provide a high variety in symbolic, structural and artistic added values.

Tab. 6: The three cases selected for 1-2-3 method

	BP SOLAR SKIN	OSLO OPERA	VALBY GABLE
BUILDING			
FUNCTION	research and education	cultural institution	cultural institution
PV			
SOLAR CELL	multi-crystalline	mono-crystalline	multi-crystalline
SOLAR MODULE	customized translucent	customized translucent	customized opaque
ADDED VALUES			
SYMBOLIC	educational	representational	symbol of urban PV project in Valby
STRUCTURAL	double-skin façade	shading	-
ARTISTIC	-	express horizontality	artistic composition

2.5. Introduction to the selected cases

Case 1: Paul-Horn Arena, Tübingen, Germany

The Paul-Horn Arena in Tübingen is an innovative example of using custom-made colored PV modules on the overall façade. The modules use green polycrystalline cells developed specifically for this project (Weller 2010), which gives an interesting architectural expression responding to the green context of the building. The components use an existing mounting system, generally used for façade cladding panels. This structure required a framing in the glass-glass modules. The architect chose a strong expression of the white wide framing, which defines a strong grid for the whole façade.

Case 2: Wind Tower, UBC College, Vancouver, Canada

The glass painter Sarah Hall was asked to make a design for the Wind Tower of the UBC Regent College in Vancouver. The glass tower itself is part of the environmental design by contributing to the natural ventilation of the building complex. The idea was to make an image on the façade that is an artistic element and at the same time illustrates the environmental consciousness of the College. The final image is a superposition of a glass painting, writings from Bible, colourful crosses, and the pixels of PV cells that follow the painting image (Wehlander 2008).

Case 3: BP Solar Skin, NTNU, Trondheim, Norway

The BP Solar Skin is an experimental project to combine a double skin façade with building integrated photovoltaics (Aschehoug 2000). An existing office building at the campus of NTNU, in Trondheim, was chosen for the prototype. The additional skin has a standard aluminium framing that follows the original grid of the facade. Semi-transparent PV modules are integrated at the level of the parapet areas. The cells are placed in a quadratic grid with a distance of 30mm between them.

Case 4: Lillis Complex, Oregon, California, USA

The University of Oregon’s Lundquist College of Business needed to replace an aging building that connected three existing smaller buildings. The new four storey atrium, called Lillis Complex became the most energy efficient building on the campus combining natural ventilation, daylighting and different integrations of photovoltaics. The aim was to make it a showcase of sustainable solutions as an educational environment. On the skylights and the south-facing facade wall semi-transparent PV modules were used. The five-storey BIPV curtain wall was designed with a varying density of solar cells.

Case 5: Tourist Office, Ales, France

The Tourist Office in Ales was originally a church from the eleventh century. The municipality of Ales decided to use the remains of the old building to host the new Tourist Office in Ales. There was a need to increase the space for offices, therefore three bay windows were designed under the south facing arches of the existing stone church. The façade of the bays are double layer skins, where the outer layers have integrated semi-transparent PV modules with crystalline cells. The brown color of the cells was developed to match the color of the existing stone wall.

Case 6: Zara Fashion Store, Cologne, Germany

The Zara Fashion Store is situated in an urban context in a shopping street of Cologne. The idea of the developer was to use an exclusive material on the facade like polished marble. However the intention to represent environmental consciousness finally resulted in using blue polycrystalline solar cells. The glass-glass PV panels are integrated into the curtain wall system of the façade. The context and the façade concept required the use of 16 different shapes and sizes of custom-made opaque PV modules.

Case 7: GreenPix Media Wall, Beijing, China

The Green Pix Wall in Beijing is a Media façade that combines the artistic composition of the cells with changeable lighting images. The “Media Wall” is the largest colour LED display in the world. Moreover, it is the first glass curtain wall with integrated PV in China (Simon and Guarentino 2009). The wall is a self-sufficient system, which uses the energy collected during the day for the LED lighting in the night. The general frameless glass modules contain 4x4 or 5x5 polycrystalline photovoltaic cells with a distance between that creates a semi-transparent module.

Fig. 1: The selected 10 cases for evaluation

Case 8: Valby Gable, Copenhagen, Denmark

The Prøvehallen building was an old factory building for porcelain production built in 1930s. Lately it was turned into an energy efficient cultural house as part of the overall low energy renovation plan in Valby district. The southern gable was chosen for an artistic expression of façade integrated solar modules and a smaller PV-T array was integrated into the roof. Anita Jørgensen, Danish artist was asked to design the facade composition with PV modules. She used photovoltaic modules, neon tubes and black galvanized aluminium plates to create a work of art that generates electricity.

Case 9: Opera House, Oslo, Norway

The main architectural concept of the Opera House in Oslo is based on the formal design of the building (Hofseth 2008). However during the design process photovoltaic cells were chosen to integrate into the large Southern glass façade. The black monocrystalline cells are grouped in horizontal lines with a vertical distance of 10 cm between the lines. This composition expresses horizontality while functions as a fix solar shading for the entrance hall as well. An interesting feature of this project is the use of dummy elements on the northern façade to achieve the same architectural expression.

Case10: Pearl Avenue Library, San Jose, California, USA

The Pearl Avenue Library Branch in San Jose chose to give home for a public art installation that combines PV cells and glass art in an architectural application. The installation called "Solar Illumination I: Evolution of Language" was designed by the artist Lynn Goodpasture who has experience of working with art in architecture. Her aim was to make a piece of art that functions as an environmental statement. The electricity generated from the cells light a suspended glass LED-illuminated lamp in the library.

3. Analysis and results of the research methods

3.1. The 1-2-3 method including walk method

The results of the walk method were collected first for each stop of each case. Then the perceptions were structured based on the formal and symbolic characteristics. Those formal characteristics were collected that were highlighted for each case with different levels of importance. The importance level was the result of how often these characteristics were mentioned at the stops. The important category was very often mentioned in all cases, characteristics of the second category were discussed dependent on the distance of the stop from the analyzed façade and characteristics of the third category were relevant for translucent facades.

Tab. 7: The three cases selected for 1-2-3 method

CHARACTERISTICS	APPRECIATION
IMPORTANT	
Image of the building	Silent, elegant image
Composition of the façade	Defined surface on facade
Composition of the cells/modules	Grouping of cells
Reflection	Reflection creates contact with surroundings
Color of cells/modules	Black color was appreciated in relation with white and red color
Size of cells/modules	
Texture of cells/modules	Homogeneous texture of module
DEPENDENT ON DISTANCE	
Visible materials	Not too many different visible materials, that gives messy image
Structure	Clear and light structure
Detailing	Elegant and precise detailing
DEPENDENT OF TRANCLUCENCY	
Shading	Shading pattern should have its surface for visual experience
Interior	Do not disturb visual contact but acts as ornamentation, creates privacy and intimacy comparing to huge transparent glazed areas

These characteristics were either appreciated or criticized depending on the case and respondent. Table 7 shows the reasons of appreciation. The results showed a general style of Norwegian architecture that represents clarity and simplicity with silent elegancy. Solar modules with a conscious design can easily match these requirements that present the potential use of photovoltaics in Norwegian architectural practice.

The perception of the symbolic characteristics showed a wide palette of possible symbolic meanings of PV integration. The representational role was highlighted at each case. The BP Solar Skin was perceived to represent the function itself and the technical profile of the university. In case of the Oslo Opera the elegancy of the project was seen to represent Norwegian cultural institution, while the Valby Gable was considered to be a representation of an urban solar plan. The artistic added values were appreciated also at each case. In the first and second case the PV cells were perceived as ornamentation on the glazing, while the Valby Gable was considered to be an art concept. The educational role was mentioned only in case of the BP Solar Skin, due to its location in an educational institution. Among these all the ornamentation and the educational role highly appreciated.

Fig. 2: The BP Solar Skin, Trondheim, Norway; Opera House, Oslo, Norway; Valby Gable, Copenhagen, Denmark

Two kinds of integrations have been discussed by the students. These are the structural and conceptual integrations. In case of the BP Solar Skin the PV cells were perceived well-integrated into the double-skin, but not into the building design. The PV integration into the Oslo Opera was appreciated as well-integrated into the curtain wall system, while the artistic composition of the Valby Gable was perceived as an add-on structure. Regarding the conceptual integration the PV cells were perceived to be integrated into the double-skin in the case of the BP Solar Skin, into the building design in case of the Oslo Opera and into the art installation in case of the Valby Gable. Among these perceptions the Oslo Opera was appreciated that was considered to be well-integrated structurally and conceptually into the overall design.

3.2. Group discussion

3.2.1 Immediate evaluation

The architects were asked to give immediate evaluation of the ten described cases based on A3 posters with photos without deep knowledge about the projects. They could give three votes, zero if they do not like the project, 1 if they find it acceptable and 2 if they like it particularly. The votes were counted and converted into scores on a scale from 0 to 100. The immediate evaluation showed that five of the ten projects were found to be acceptable as good architectural integrations while the other five not (Table 8).

Tab. 8: Immediate evaluation of the ten cases

POS.	CASE	SCORE
1.	Media Wall, Beijing, China	**77**
2.-3.	Opera House, Oslo, Norway	**60**
2.-3.	Paul-Horn Arena, Tübingen, Germany	**60**
4.	Zara Fashion Store, Cologne, Germany	**55**
5.	Wind Tower, Vancouver, Canada	**52**
6.	Valby Gable, Copenhagen, Denmark	**33**
7.	BP Solar Skin, Trondheim, Norway	**31**
8.	Lillis Complex, Oregon, USA	**24**
9.	Pearl A. Library, San Jose, California, USA	**20**
10.	Tourist Office, Ales, France	**7**

3.2.2 Group discussions

The first part of the group discussions were focusing on the ten previously scored cases. The architects were asked to explain why they gave the scores. The discussions gave results of what are those features that are favorable in the formal and symbolic characteristics of architecturally integrated photovoltaics.

In the case of the mostly appreciated Media Wall basically all formal characteristics were found to be well-designed. The modules had no framing, the cell composition provided an interesting image and translucency and colorful image was achieved by changing lighting. Through all these the project presented a **variety of possibilities** that can be designed with integrated PV, moreover the PV modules were integrated into a well-designed curtain wall structure. The **expression of material characteristics** were highly appreciated in the case of the Paul-Horn Arena and the Zara Fashion Store. These were the color, shape and texture of the cells. An interesting feature that both cases used opaque modules, where the above mentioned cell characteristics are dominant. Even if the material characteristics were expressed, still the PV cells were found to be recognizable only from close distance. The architects called it **natural integration**, that the PV cells are so naturally part of the structural and aesthetical design of the building that they are even not recognizable. This was further explained as discreteness, cleanliness, not too expressive and subtle design with structural integration, that was very highly appreciated among Norwegian architects.

The architects were mainly interested in the **overall architectural and artistic design**. However innovative is the integration of photovoltaics into the building, if they do not like the overall architecture or art, the building got low score and strong critique. This can be seen by comparing the Oslo Opera and the Lillis Complex, where the main idea of using horizontal rows of solar cells as shading is the same, however Norwegian architects found the building of the Oslo Opera more pleasing, therefore they gave much higher score. The same comparison can be done with the artistic projects. The Wind Tower in Vancouver and the Library in San Jose both combine glass painting with solar cells as an environmental statement, but the architects liked more the aesthetics of the Wind Tower, therefore gave it a higher score and favorable judgment. **The formal integration and the field size and positioning of the solar cells** are also main criteria to judge the architectural integration of the solar cells. The Tourist Office in Ales is a very innovative project regarding the color development of the cells to match the overall design, however due to the formal design, the project got a very low score and bad critique.

Tab. 9: Suggestions for further product development

SUGGESTIONS FOR FURTHER PRODUCT DEVELOPMENT IN BIPV	
Industry	• building industry should develop to match with existing materials and products
Materiality	• combine solar panels with glass architecture • glass should be replaced with other material • look more like existing materials
Color	• more options in color
Texture	• more options in texture • images like painting
Composition-translucency	• possibility to controll transparency • flexibility in transparency
Shape and size of PV components	• flexibility in shape • bendability • could be a painting on the wall
Dummies	• options for dummies
Function	• use as multifunctional element • PV used in active solar shading • PV combined with ST • PV combined with curtain
Maintenance	• readymade products that are easy to maintain and change
Economy	• lower costs
Efficiency	• shading should not be a big problem

The artistic projects got very controversial critiques. Mostly Norwegian architects did not like the too much decoration and too much colorfulness like in the case of the Wind Tower or the Pearl Avenue Library. The artistic image of the Valby Gable was also criticized. However the architects agreed that the artistic approach is very innovative, though they would do it in a different way to match the taste of Norwegian people.

In the second part of the group discussions architects gave suggestions of how products should be developed to fulfill this need. The summary of the architects' suggestions is collected in Table 9.

Current market provides already products that meet some of these needs of architects. Among thin film products there are flexible laminates with plastic covering, where bendability and the elimination of glass is already achieved. Certain building product producers already have realized the potentials of photovoltaics and either they integrated solar cells into their existing product systems or developed products specifically for building integration. On one side there is a lack of knowledge of these products, on the other hand there is still need for development to match all the above mentioned requirements. However due to the limitations of wafer based and thin film technology, certain needs might be fulfilled only through new technological breakthroughs (like PV to become as a painting).

3.3. Evaluative questionnaire

The paper-based questionnaire was asking for detailed evaluation based on the pre-defined formal and symbolic characteristics (Table 3) of the ten pre-chosen cases (Fig.1) The respodents were asked to evaluate the cases by the quality of the architectural integration of photovoltaics through rating the overall design and the detailed characteristics. They had to choose from the following scale - - (bad), - (not so good), 0 (neutral), + (good), + + (very good). The questionnaire for the students contained only the evaluation of the ten cases, while in case of the architects a final question was added about the level of importance of the detailed characteristics with the scale of - - (not important), - (not so important), 0 (neutral), + (important), + + (very important).

The aim of the questionnaire was to have a structured analysis of the respondents' preferences based on a cognitive framework of the formal and symbolic characteristics, that makes the comparison of the cases and characteristics easier.

Three final scores were calculated for each case to compare the appreciation of the projects. The first is the **overall perception** that was the first characteristic to evaluate in the questionnaire. The second is the **detailed perception** that is the average of the scores for the following 12 detailed characteristics. The third is a weighted average of the 12 detailed scores and the importance factors of each characteristic defined as **rated perception**. Further analysis was focusing on deviation of scores among the respondents for each case related to the average, the deviation of scores for the detailed characteristics related to the average per case, the scores of added values for each case and the **importance factors of each detailed characteristic**. This paper will present the results of the three final scores and the importance factors of characteristics.

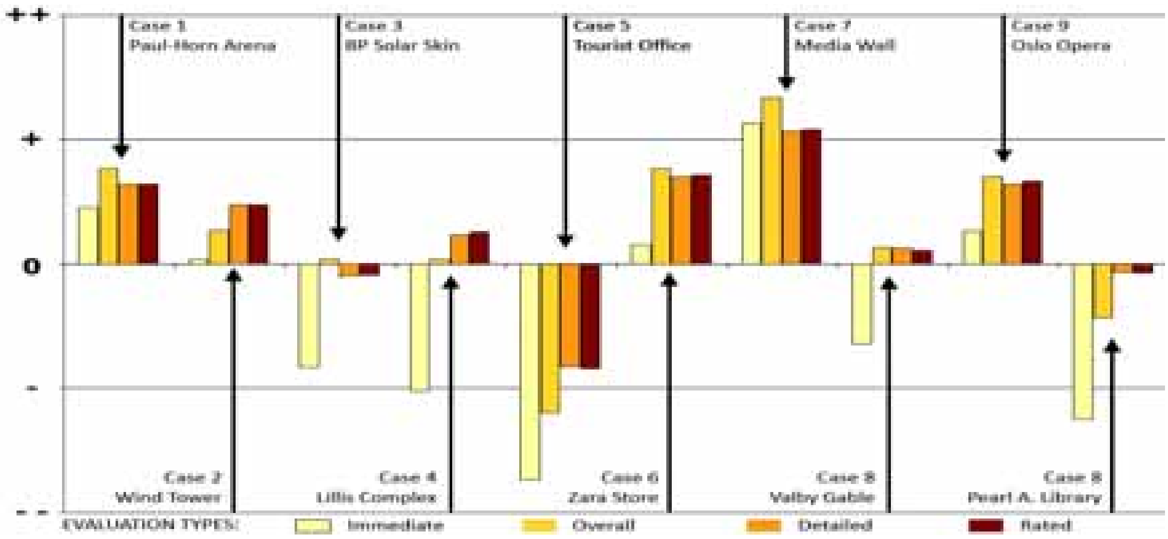

Fig. 3: Immediate, overall, detailed and rated perception of the ten cases

The results of the final scores are presented in Figure 3 with the addition of the immediate evaluation scores from the group discussions. A general tendency is that the immediate judgments were more critical especially in those five cases that got lower score, but also in the case of Zara Fashion store, that has been very highly appreciated later in the detailed evaluation. In other four cases the immediate scores were lower but not with so much deviation. The detailed and rated results did not show much difference, however the difference of the overall results compared to the detailed one showed certain coherence. Those cases that got negative score (Pearl Avenue Library, Tourist Office), the overall judgment was even more negative, while those positive got more positive (with the exception of the Wind Tower and the Lillis Complex).

This shows that immediate judgments without proper knowledge are more critical and purely based on the aesthetical judgment of the overall design. When the respondents filled out the questionnaires they have already had more knowledge and opinion about the projects. The overall results - more influenced by the taste of the overall design - were more extreme in negative and positive direction, compared to the average of the detailed evaluation that covers several aspects of the building integration of photovoltaics.

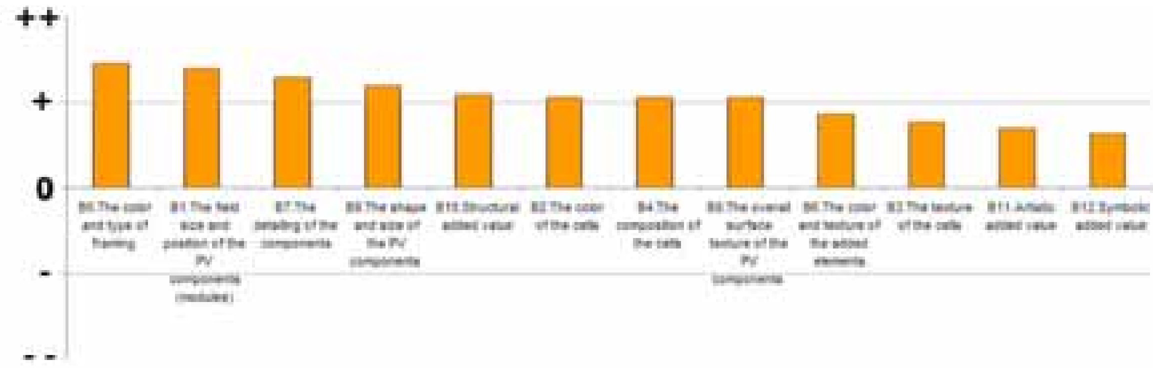

Fig. 4: Importance of the detailed characteristics

The final question for the architects was about the level of importance of the different detailed characteristics in the architectural evaluation (Fig. 4). The respondents found the color and type of framing the most important issue, the detailing of the components the third and the structural added value the fifth. These issues are strongly connected to each other. The structure defines very much the jointing possibilities and the type of framing influences very much detailing issues. In two cases the total score got lower due to the low scores on the framing (Paul-Horn Arena and the Wind Tower).

The second highest importance was chosen for the field size and position of the PV components. This issue is very much connected to the overall design concept that has to be in harmony with the formal and surface composition of the building. These issues are shaped from the conceptual phase, therefore it is important to consider the use of photovoltaics from the very early design stage. If the filed size and position was not appreciated the project got low score in general, however innovative product was integrated into the building or however strong were the added values.

The shape and size of the PV components was found to be the fourths important issue. The shape and size of the PV modules should match the grid of the composition of surfaces, the scale of the building, the shape and size of other components. The color and composition of cells and the overall surface texture of the PV components got middle importance. In most cases the original blue and black color of the cells was accepted. The green colored cells of the Paul-Horn Arena were considered to be very good in that context, however the light brown cells of the Tourist Office that had the aim to match the color of the existing stone wall were not appreciated at all. Regarding the composition the grouping in horizontal lines was appreciated in the Oslo Opera. Different lighting and glass painting have been used in certain projects, however the color and texture of these added elements were not found to be so important in the evaluation. The texture of the cells got even lower importance level.

The artistic and symbolic added values were found to be the least important issues that shows formal characteristics are considered to be more important than symbolic ones.

4. Summary and conclusions

Based on the results of the three methods the following conclusions have been summarized that can be a guideline for architects what to consider during the design process. In each case the most important factor for evaluation was the overall design. The results showed that Norwegian architects prefer mostly silent, clear and elegant design or really bold, but honest ones (like the Media Wall in Beijing). The second most important factor is related to the building concept. The PV modules should be formally and compositionally integrated into the overall design concept. This requires that the filed size and positioning of the PV cells should be already concerned in the early conceptual design phase and photovoltaics should be considered like other building materials. PV modules require well-designed detailing and framing for a mounting system in order to achieve a successful structural integration. In case of neglecting these issues, the originally well-designed concept can be ruined totally when the project is finally realized. Regarding the PV design, as mentioned above, PV modules should be concerned ad other building materials. Knowledge about their material, formal and energetic characteristics is indispensable for a successful PV design. The respondents appreciated those projects, where these characteristics were presented, where the advantages of the material were expressed, still the PV cells remained unrecognizable. These were no more technical devices, but building components naturally integrated into the building skin. Regarding added values, one of the architects mentioned that this is still a transitional period in the life of photovoltaics, where is still need to spread knowledge and enhance environmental awareness of people, therefore art as medium and symbolic like representational and educational values have importance.

Tab. 10: Suggestions for designing BIPV

	APPRECIATED	CHARACTERISTIC
1. Building overall design	- Silent, elegant, clear - Bold but honest	overall design
2. Building concept	- Formally integrated - Compositionally integrated	field size and positioning composition of facade
3. Structure	- Structurally well-integrated	framing detailing
4. PV design	- Presents a variety of possibilities - Expresses material characteristics - Discrete, subtle design (PV not immediately recognizable)	color, size and texture of PV cells/modules
5. Added values	- PV as ornament - Educates the observers	artistic added value symbolic added value

The vision is that photovoltaics become natural part of architectural practice and our everyday life. There is a need for a shift in perception to achieve this goal to look at PV modules as building components that have high potential in building integration and for architectural expressions.

5. References

Aschehoug Ø. et al, 2000. BP Amoco Solar Skin – A Double Façade With PV, Eurosun 2000, Copenhagen

Cold B., 1998. Metode for opplevelse og bevisstgjøring av arkitektur og steder. Educational material. Faculty of Architecture, NTNU, Trondheim, Norway

Hofseth M., 2008. The new opera house in Oslo- a boost for urban development?, Urban Research & Practice, Volume 1, Issue 1, 101-103

Simon R. and Guarentino N., 2009. Building Integrated Photovoltaics/a handbook, Birkhäuser, Basel-Boston-Berlin, pp. 82-85

Wehlander K. K., 2008. The language of light, In Creating Change – the arts as catalyst for spiritual transformation, Copper House, Canada, 60-62

Weller B. et al, 2010. Photovoltaics, Technology, Architecture, Installation, Birkhäuser, Edition Detail, Munich