Improving the market up-take of energy producing solar shading: A communication model to discuss preferences for architectural integration across different professions

Femenías, Paula,
Department of Architecture and Civil Engineering, Chalmers University of Technology
(email: femenias@chalmers.se)
Thuvander, Liane,
Department of Architecture and Civil Engineering, Chalmers University of Technology
Gustafsson, Anna
Department of Architecture and Civil Engineering, Chalmers University of Technology
Park, Sofia
Department of Architecture and Civil Engineering, Chalmers University of Technology
Kovacs, Peter
RISE, Swedish Research Institutes

Abstract

Electricity producing solar shading provides possibilities for a combined solution for solar shading and building integrated locally produced energy from renewable sources. The multi-functionality of these products calls for collaboration between a range of actors from manufacturers, clients, architects, engineers, and contractors. Two major challenges for the increased up-take of the technology has been identified and is dealt with in a transdisciplinary research project, called ELSA, involving industry and academic institutions. First, the successful architectural integration of solar shading in terms of form, size, colour, detailing etc. in relation to the overall building design will be decisive in order to persuade architects. Second, the development of these multi-functional products to reach functional, technical, economic and aesthetical qualities is dependent upon communication between different professions.

As a means to initiate a dialogue between the different professional groups taking part in the ELSA project, a model, the AIQ-model (Architectural Integration Qualities), to assess preferences for architectural integration of energy producing solar shading was developed and tested in a workshop. The results indicate a large consensus across different professional groups when assessing successful architectural integrations. Consequently, discrepancies in aesthetic appraisal of energy producing solar shading should not be the main hindrance for a broader implementation of such solutions. The challenge rather lies in that architectural integration qualities will concur with other important aspects of the multi-functional solution, and not all professional groups will put architectural integration qualities above other functions. The workshop shows that the AIQ model serves its function to initiate and to focus discussions. The value of group discussions to reach consensus was also observed. The AIQ model provide definitions to clarify the judgment base behind aesthetic assessments that was appreciated but all groups but most easily applied by the architects. The model should be further developed to include also other aspects than aesthetics.

Keywords: Solar shading, photovoltaic, architecture, stakeholder, communication

1. Introduction

Although significant improvements have been made to increase the efficiency in terms of energy produced and to reduce the costs of active solar technologies, these are still little used in the building sector (Noord, 2010; Heinstein et al., 2013). International literature underlines that a crucial barrier for the wider implementation can be traced back to the visual expressions of the components and how well the photovoltaic (PV) electricity producing solar cell systems can be integrated in the overall building design (Krawietz, 2007; Kanters, 2011; Farkas and Horvat, 2012; Munari Probst et al., 2012; Heinstein et al., 2013). The architect, as one key actors in the early stages of the design process, will be reluctant to integrate the technology if the visual expression and the possibilities for a successful architectural integration is set aside.

The literature point to several barriers that keep architects away from using the full potential of solar technology in building design. Mastering the best balance between installed power, energy generation and aesthetic appearance of solar technology is not an easy task and the lack of information will be decisive (Zomer et al., 2013). Design supporting methods and tools are not yet well-defined and suitable for architects (Kanters, 2011). Obtaining initial competence in solar technology can also be expensive, especially for smaller architectural offices and smaller projects (Hermstad, 2006). Furthermore, prevailing negative perceptions of and prejudices against these systems among other actors will play an important role (Farkas, 2011). Architects are often in the situation where they must overcome not only their own associations to solar technology, they also need to convince their clients (Hermstad, 2006; Kanters et al., 2013). In addition, solar technology is often introduced late in the design process and as an engineering application, not as a design element (Hermstad, 2006). There is a lack of “architectural language” with respect to PV technology, a necessity to raise interest among architects (Kanters, 2011). Art could be credited as a powerful tool to express new ideas and values, and function as a “mediator” in the process of changing the perception of PV in general (Farkas, 2011).

The complexity and multi-functionality of solar technology in building design, especially if the solar technology will replace other building components, calls for collaboration between architects, solar technology producers, clients, engineers, contractors and end-users (Krawietz, 2007; Hagen and Jørgensen, 2012; Heinstein et al., 2013). The communication process between these actors is a major challenge (Hagen and Jørgensen, 2012). For example, architects and engineers tend to use different language when talking about PV. Architects communicate through “semantic descriptions and visual images” while engineers are used to interact with quantified terms (Hagen and Jørgensen, 2012). Munari Probst et al. (2005) argue that a consistency in the judgements of among architects point to a presence of general integration qualities, defined by architects, and which should be followed in order to successfully integrate PV in building design. In contrast, some authors argue that the development of PV in building design is in need of a common language or tool for communication across professions, that can be comprehensive for different actors (Farkas et al., 2013; Hagen and Jørgensen, 2012).

1.1 Aim and approach

This paper presents research carried out within a trans-disciplinary arena ELSA (*Elproducerande solavskärmning - Electricity producing solar shading*) aiming for improved understanding of mechanisms in market up-take of electricity producing solar shading in Sweden. The ELSA arena consists of representatives from: real estate, solar system manufacturers; architects; contractors;

Swedish organisations for solar technology and solar shading; and the academy (engineering, architecture, daylight, design and innovation). ELSA researches innovation processes with respect to these systems but also engages in prototyping and testing of new products[1].

Electricity producing solar shading combines the solution of shading and locally produced energy from a renewable source, and provides the opportunities to articulate a buildings design. Contemporary architectural ideals favour large windows (Roberts and Guariento, 2009), solar shading should thus be increasingly needed to fight excess heating, but can also be motivated by a strive for more energy efficient building envelopes. In addition, locally produced renewable energy production goes in line with European and national energy policy. Luque and Hegedus (2011) argue that there is a *"logical combination between shading a building in summer and producing electricity at the same time that makes this type of solution increasingly attractive among architects"*. Nevertheless, few examples of combined solar shading and PV is found in northern Europe and Sweden (Gustafsson and Xu, 2016).

The ELSA project takes one starting point on the one hand in the identified need for architecturally integrated solutions and on the other hand in the need for collaboration between different knowledge fields. The design of these multi-functional systems, especially if dynamic, has to deal with varied challenges with respect to wind loads, durability, access for cleaning and maintenance (Roberts and Guariento, 2009) but also daylight, glare and indoor comfort.

This paper presents results from a workshop within the ELSA arena where we explored the appraisal of architectural integration of energy producing solar shading among different actors. A simple model, the AIQ-model (Architectural Integration Quality-model), was developed as a means to support the inter-disciplinary communication about architectural integration and tested among the participants during a half day workshop. Two questions were posed: 1) Do different professional groups differ in their evaluation of architectural integration? and 2) Is the AIQ-model useful as a tool to enhance communication in an inter-disciplinary project environment?

2. The AIQ-model

(Munari Probst, 2009) was among the first to define criteria for successful architectural integration of solar technology, later further developed by Munari Probst et al. (2012). The architectural integration is defined by the position and dimension of the solar system in relation to the architectural composition, the material surface texture, colours, joints, visibility and zone sensitivity, i.e. if the system is situated in a sensitive heritage area or a more "permissive" area. These criteria have been the basis for developing an evaluation model for solar technology in the urban landscape, called LESO-QVS (quality-site-visibility) (Florio et al., 2015), which can assume three different levels of architectural integration: high, medium or low.

A number of other authors provide complementary guidance for evaluating architectural integration of solar technology. The Danish architects office 3XN (3XN, 2014) uses the parameters "Efficiency, Context and Identity", and concludes that the solar technology should either dominate or diminish the architectural values of the building. Hermstad (2006) highlights the importance of including shadow effects from solar technology systems on the façade. Krawietz (2007) lifts up the discussion of creating

[1] http://solartestbed.se/om-projekten/elsa-elgenerande-solavskarmning/

variations of pattern. de Groot (2008) emphasizes that solar technology should be applied "seamlessly" and underline the potential to explore new architectural concepts. Detailing and smooth integration is considered as paramount, not least in the case of retrofitting where the integration of solar technology needs to be *"addressed and solved in a craft logic"* (Bonomo et al., 2015). Important to note is that architectural integration can be in opposition to the ambition to articulate or brand an environmental profile or to showcase innovativeness (Noord, 2010; Heinstein et al., 2013; 3XN, 2014). The symbolic value of PVs and the combination of architecture and PVs makes up an opportunity to support or educate the observers' environmental awareness, or demonstrate the clients' or architect's care about the environment (Farkas, 2011).

Based on these general recommendations for architectural integration of solar technology in building design, and with the inspiration from 15 product specific criteria for defining architectural quality used by the British Design Review (CABE, 2006), a model for evaluating the architectural integration qualities (AIQ) was designed. The model was developed in an iterative process involving a test panel in which the authors, a number of practicing architects from the ELSA project and of some architect students took part.

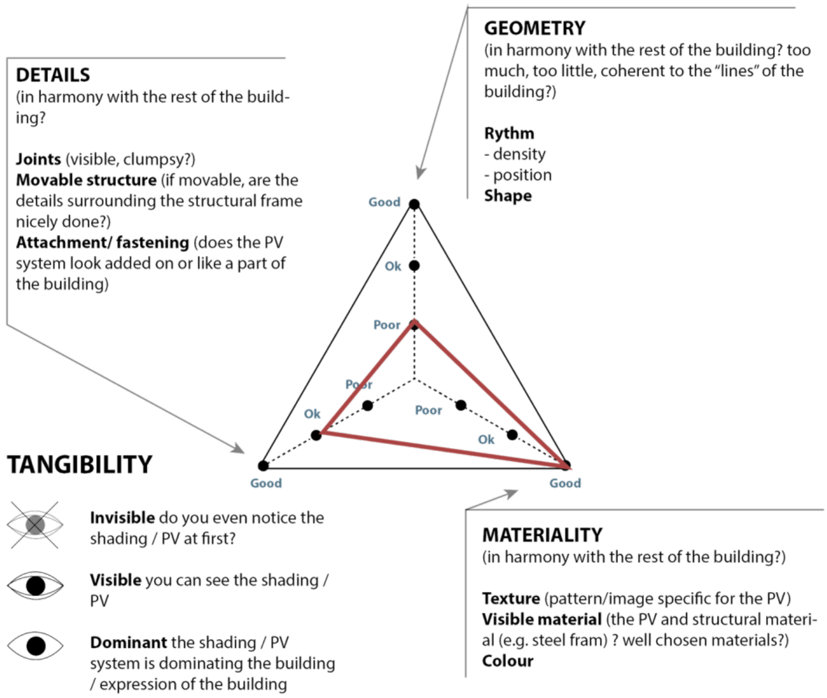

Figure 1: The AIQ-model, the triangle and the "Tangibility eye"

The AIQ-model is visualised as a triangle where each corner, representing geometry, materiality and detailing, is assessed with the prospect of answering whether the solar shading system is well integrated in the overall design. The model has three rating levels: poor, ok and good (Figure 1). Geometry assesses sight lines, shape, rhythm, density and position. Materiality assesses textures, patterns, colours and reflections. Detailing assesses attachment, structural elements, size and precision in design and production. Furthermore, the visibility of the system is assessed using an eye symbol evaluating if the solar shading system is dominant, visible, or invisible. High visibility can be judged as negative in a sensitive area but clients can be positive to high visibility if they wish for visibility for their investment in solar technology. The AIQ-model, in its present state, only considers external aspects of architectural integration not how the solar shading is perceived from the inside of the building.

3. The workshop

In March 2016, a workshop was carried out in order to explore architectural integration preferences among 18 participants representing all professional groups in the ELSA arena. Four of those were workshop leaders and did not participate in the test but acted as note-takers and leaders. All discussions were also recorded for enhanced documentation.

Figure 2: In the first step, each participant should make an individual judgment of the architectural integration quality of nine selected buildings with solar shading.

The workshop was carried out in three steps. In step one (15 minutes) each participant evaluated nine buildings with solar shading individually from a selection of photographs of the building presenting details as well as the whole building, and by using the AIQ-model (Figures 1 and 2).

In Figure 3, pictures of the nine building are presented. Buildings 1, 3 and 7 are retrofitting projects and the solar shading has been installed after the buildings were completed. For the rest of the projects, the solar shading has been designed as part of the original design. All but one of the buildings, example 4, are fitted with photovoltaic. Although not being energy producing, example 4 was included since the design of the solar shading was regarded as architecturally interesting by the research leaders and judged and possible to complement with photovoltaics.

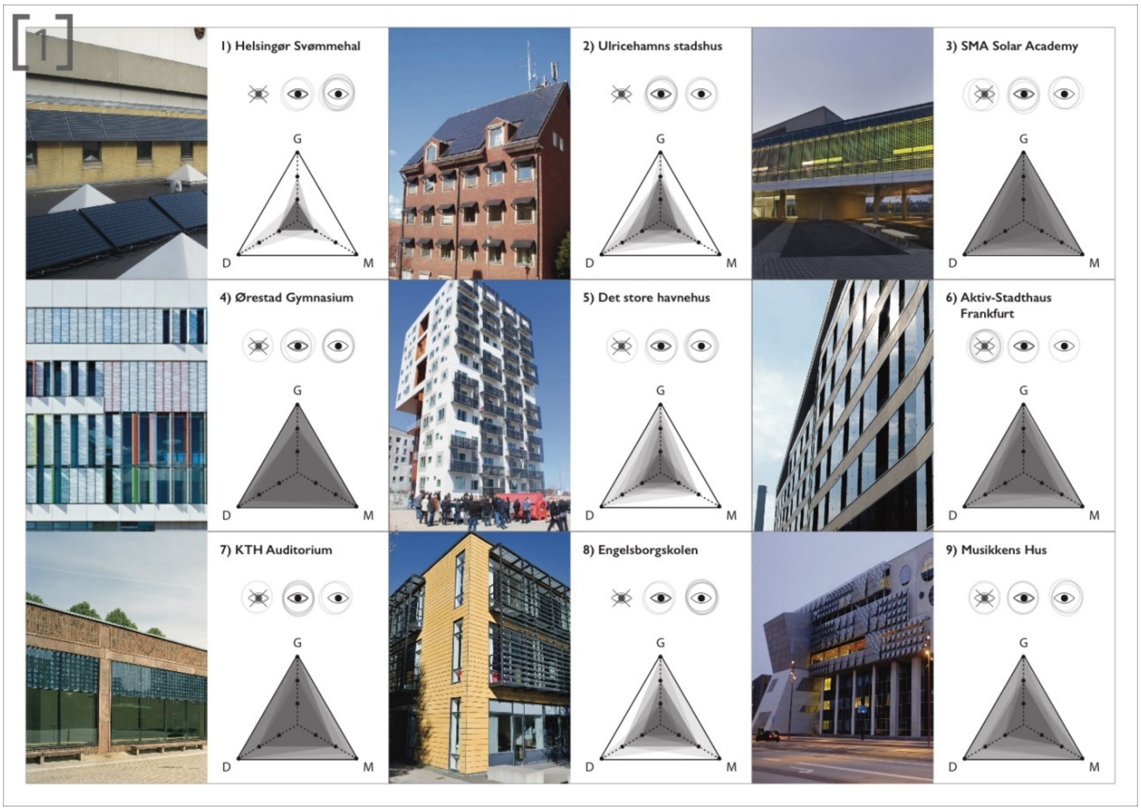

Figure 3: Aggregated results from the individual evaluations in step 1.

In step two (20 minutes), the 14 participants were divided into three professional groups for a group evaluation. Group one, the “installers”, was formed by five representatives from manufacturers. Group two, the “clients”, was formed by one property owner, one representative from a solar energy lobby organisation and three researchers in engineering having the function of clients for the prototyping in the ELSA project. Finally, in group three, the “architect-designers”, three architects, one architect/daylight expert and one product designer participated.

In step three (20 minutes), inter-disciplinary mixed groups with one or two from each profession were formed for a new group evaluation. The aggregated results of the evaluation of step two and three are presented in Figure 3. At the end, all groups joined for a final discussion about the outcome, experience and value of the exercise.

4. Results

In the following we give an extract from the discussion made in step two, the professional groups. The discussions in step 3 and the following general discussion is presented in the paragraph 6.

There was a large agreement in the group “installers” that the “cap” solution in **building one** was badly integrated in the overall design. *“Terrible”* was an expression used. However, one participant said that the building wasn’t that elegant to start with and the cap solution did not make such a big difference. One participant in the group found that the original building might even be enhanced by the solar shading. The group “owners” also found the solution *“terrible”* and *“clumsy”*. *“It changes the building for the worse, it is completely dominating the building”*. The “architect-designers” were not consistent in their view of the “cap” solution. Some said that the solar shading was *“very ugly”*. *“It is a bad building from the start, then this over-dimensioned shading bluntly screwed to the building. It is not good”*. However, one participant found that it somehow still fitted with the building and that the shading *“wasn’t that horrible”*. He argued that the cap fit with the geometry of the building and probably was a very economical solution.

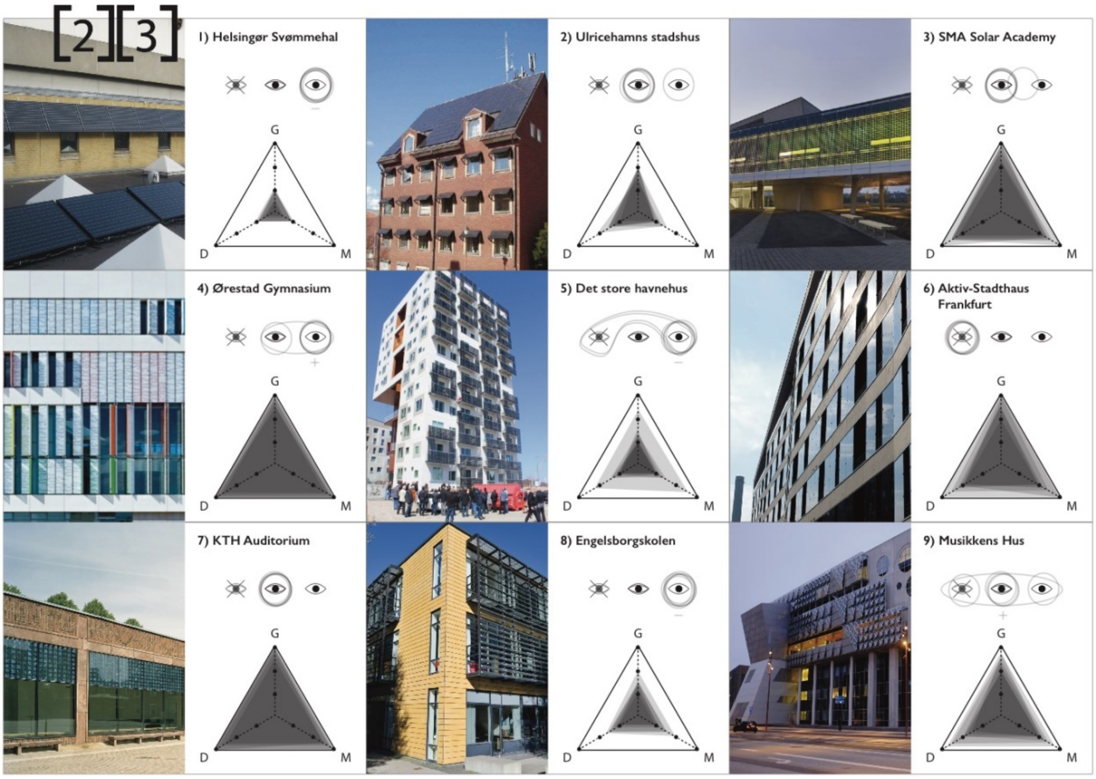

Figure 4: Aggregated results from the group evaluations in step 2 and 3

The reactions to **building two** were more positive among the “installers” and “architects”. These groups reasoned that the marquis solution fitted the building. The “installers” discussed that the photovoltaics on the roof draw too much attention, which pulled down the overall impression. One participant in the installer group declared that *“If I know that it produces much electricity, then I am more positive”*. One of the “installers” discussed the function of the shading. He declared that in order to be efficient as solar shading, a larger part of the window need to be shaded. The “owners” were divided about building two. The property owners in the group were very negative towards the geometry and the detailing: *“sad”* was one reaction. *“Terrible it destroys the whole building”,* said another. *“It fits even worse than number one”*. The two solar researchers in the “owner” group were more positive. The “architects” though that the solution *“worked”,* that the geometry was ok, the problem was the material, the detailing, and the PV roof.

The “installers” agreed that the solar shading in **building three** seemed to harmonise well with the building, but it was also designed as part of it making the task easier to fulfil than in retrofitting. The “installers” had doubt about the effect in terms of produced electricity. The “owners” generally liked this system, *“damn good”,* but one of the solar researchers through it made the building appear “heavy” and that thin film PV would have been more appropriate in this case. The “architects” discussed that the solar system was clearly visible and *“a design feature”.* Most of the architects liked it but it was not their favourite among the nine examples. The daylight designer reflected upon the possibility that the inside would lack of daylight: *“I would not like to work there. It would feel too cramped”.*

There was a large agreement among the “installers” that **building four** exemplified a very well integrated solar shading system. *“It is evident that somebody has been thinking here”.* The participants could easily see a thread in the design thinking. One comment was given about how this design probably could be very interesting at night. The “owners” were divided. One of the solar researchers was doubtful about the solution while the rest of the group gave top ratings. *“It makes you happy”. “It is dominating in a good way”.* The “architects” found the shading system very dominating *“It IS the building”*. They reasoned about the visibility. It is evident that the system is very visible but it might not be obvious for the public that the function is solar shading.

Building five was subject to lively discussions among the “installers” that had very opposing views. The installation is very visible, something some of them found attractive others not. *“Do we need to reach a consensus?”* Some disliked it. *“Why?”. “I don’t like this. It looks as it has been added on. It does not harmonise with the building”.* Others in the group liked the design and found it intriguing. *”I find it cool. A lot of design but not so practical! Half of the windows are still completely unshaded. But I don’t have a problem with that, I like it”.* The “owners” didn’t like the dominating feature. *“Worse the longer I look at it”. “Looks like somebody shoot it on the building with a machine gun”.* The ”architects” thought it was dominating but not in a good way. *”It looks glued on”.* The daylight designer once again noted that it would probably be very dark inside the building. The visibility of the system was judged as invasive but it is still not evident that this is a solar system.

The “installers” reaction to **building six** were positive. *“A bit better than good”.* The solar shading harmonises well with the overall design of the building. *“Seems like a cost-efficient solution”.* The “owners” also liked it but one of the property owners didn’t like the detailing, especially the attachment which he thought pulled down the overall rating. The “architects” were positive. *“They have tried to make something out of the attachment and they should be praised for that”. “Full marks – a very nice example”.*

The retrofitting solution in **building seven** was generally well appreciated by the “installers”. *“It enhances the façade at the same time it melts in with the brick wall”. “It is timeless”.* The design was judged as probably being more dominant from inside the building. The “owners” were generally positive and gave the building top notes. One in that group thought that: *“The building wasn’t nice but the solar cells fits in”*. The architects found it *“almost beautiful”.* The blue photovoltaics marries well with the brick wall. One architect found it lacking in detailing. Another one exclaimed: *“How can you get stuck on the detailing. This is almost a piece of art!”.*

Building eight was also subject to some diverging views among the “installers”, but the groups agreed upon a negative view. The system seemed rational but at the same time not so intriguing or visible. One called it *"German"*. However, the system was found to fit rather well with the overall design. *"The funny thing is that I actually think it harmonise with the building"*. Another comment was: *"you are probably never able to see the sky from the inside with this system"*. The "owners" found the system dominating and could not make out if the system was part of the building or attached afterwards. They didn't like the detailing although the geometry was found ok. One in the group made a comparison to a prison. The architects thought it looked like a cage. They didn't appreciate the detailing: *"It is too evident, heavy, clumsy, you can see some cables"*. They also found the design "closed": *"You would feel rather trapped behind that system, almost like a burglary protection"*.

Building nine was also subject to diverging views among the "installers". *"I like it, it is cool. It is more like a piece of art than solar shading"*. *"It for sure does add something"*. The fact that it was something of an art work actually made solar system less visible. Another participant found it to abstract *"This is not for humans"*. The "owners" also found that even though highly dominant and visible, the function of solar shading and PV was rather invisible. *"It is more of a general decoration"*. *"This really makes you think, but I find it funny"*. One owner was negative especially towards the detailing. Some of the "architects" liked the building, others found the facade to *"messy"* which *"pulled down the overall impression"*. The architects in general found the expression dominating and a bit confusing, and they doubted if the system actually serves as solar shading or if it is purely decorative.

5. Discussion

The workshop showed a much larger consensus across the professional groups regarding the perception of architectural integration of solar shading with PV than we had expected. None of the groups liked the simple "cap" solution in example one, while the design solution of examples four and seven was the most appreciated. The two examples five and nine with unconventional design solutions gave rise to the most vivid discussions.

The group of "installers" was the group with the most vivid discussions. They had especially opposing views on building number five and nine (Figure 4). The installers were often harsh in their negative judgements. They did not always refer to definitions in the AIQ model when making their evaluation but seemed to refer to personal judgments.

The "architects-designers" were in general more positive in their evaluations, although they did not always agree. They discussed with articulated arguments, referring to the definitions in the AIQ-model, which seemed to bring them closer to a group consensus. One of the participants in the group expressed her surprise about the positive views in the architect group. She had expected the architects to be harder in their judgments and harsh in their comments towards other architects. In response, another one in the group said that he had the feeling that this forgivingness might be reflect that the architects knew how difficult it is to deal with these questions in practice.

The "owners" held the most low-key discussions. The two property owners in that group were among the most negative in the whole workshop, also towards building two and seven for which the other two professional groups held more positive views.

Although a bit difficult to use for all groups, the AIQ-model was considered a support for the discussions. The architects had the advantage of being used to the terminology in the AIQ-model. For those not trained as architects, the concept of "materiality" was difficult to relate to. Instead, the non-architects seemed more prone to use personal expressions in their evaluation. One participant in the "owner" group said that he had preferred to rely more on his first impression and gut feeling than to try to look for specific aspects such as geometry, materiality and detailing. On the contrary, another participant in the same "owner" group thought that the model enriched the discussion as it forced them to express *what* and *why* they liked something or not.

Our results can be compared to an earlier larger European survey among architects, engineers and manufacturers about their perception of architectural integration of building integrated photovoltaics (Munari Probst et al., 2005). The study was a questionnaire filled out individually and without any AIQ-model to guide the respondents. Contrary to our study, the European study state differences in perception across the professional groups. They also found a large consistency within the group of architects. The authors conclude that the consistency among the architects confirm *"the existence of general integration principles, not necessarily appreciated by some engineers"* (Munari Probst et al. 2005, p.2). Munari Probst et al. (2005) thus argue that these general integration qualities, confirmed by the architects' perception, has to be followed in order to develop successful solar systems.

Our study shows consistency across professional groups. Furthermore, our participants in the "architect" group was not that aligned in their views. Thus, our results thus go against the idea of a prevailing architects' view of architectural integration, and the idea that other professions do not appreciate the same aesthetics. Our conclusion is that the differences between the professional groups rather lie in education, culture, language and the way the they evaluate and articulate their argumentation. The professions have different languages as stated by Hagen and Jørgensen (2012) but these differences could be bridged by introducing all actors to the same language. This could be done with a developed AIQ-model and supported by characterisation exercises, which is part of architects training, for also other professional groups in the building sector.

The groups discussion in itself appears as important to reach a better consensus in the groups. All participants found the workshop enrichening to the continued inter-disciplinary work in the ELSA project. We found a larger consistency after the group evaluations (Figure 4) compared to the wider spread of judgment in the individual evaluation (Figure 3). The lack of groups discussions in the European survey (Munari Probst et al., 2005) could explain the discrepancy they found in perception among professions. The workshop thus confirms earlier studies (Hagen and Jørgensen, 2012) that point to the value of collaboration between professions in the development of successful integration of PV in building design along with the value of a tool to support communication between the professions in inter-disciplinary environments.

Finally, there is room for further improvements of the AIQ-model. Some participants found the AIQ-model too simple. Instead of the three level point system, also used in LESO-QVS (Florio et al., 2015), a five level system including the level "excellent" would have worked better. Furthermore, colour could have been singled out as one assessment criteria instead of being part of materiality. The participants agreed that a more complicated model would have demanded more time for the workshop. One participant also drew the attention to the fact that some questions for the workshop were confusing. For example, the question: *"Is the solar shading dominating?"* The ambiguity of the question was demonstrated by the fact that some participants judged a system as dominating while others found it to be invisible. Although very dominating, a system can be perceived as well integrated and thus invisible, for example as in building four.

Maybe the largest deficiency with the AIQ-model is its mono-disciplinary nature. The group discussions revealed that other functional, technical and economic factors will be part of the overall evaluation of the energy producing solar shading and may compromise the importance of architectural integration and aesthetics. For example, one participant in the "architect" group found it difficult to give an opinion on only exterior aesthetics when she suspected that the function of the system was bad regarding daylight inside the building. The same kind of remark was given by one participant in the "installer" group, who declared that he would have been more positive and forgiving towards the un-aesthetic solutions in some cases if he knew that the system produced a lot of electricity. Discussion revealed that while the architects are interested in extending the number of innovative products, the participating PV manufacturers were more interested in the standardisation of design in order to scale up productivity and market shares.

6. Conclusions

The aim of this paper was to explore differences in perception of architectural integration qualities of energy producing solar shading in building design across different professional groups. A model to evaluate architectural integration qualities was developed as a tool to communicate about aesthetic values of such systems. The results of a workshop within the inter-disciplinary research project ELSA demonstrate a large consensus among the different professions when evaluating the successful architectural integration of energy producing solar shading. The conclusion we can draw is that diverging views on the aesthetics or architectural integration would not be the primary cause that impede a broader implementation of energy producing solar shading. Instead, the challenge lie in the fact that aesthetical integration qualities will concur with other aspects such as function, efficiency, energy production or economy. While architects might not want to comprise architectural integration qualities, other professions might value other aspects higher.

The workshop show the usefulness of groups discussion and tools that can enhance the communication between professions. This could potentially benefit the development and broader implementation of energy producing solar shading in building design. The AIQ-model helped the participants to articulate architectural integration and gave rise to interesting discussion appreciated by all workshop participants. Although architects had the best conditions to use the model, the other professions also found the model helpful to focus the discussions. A major limitation of the present AIQ-model is that while the design process for multi-functional energy producing solar shadings will be challenged by inter-disciplinary perspectives, the AIQ model is limited to valuing external integration and aesthetics. This experience should be the starting point for the continued development of inter-disciplinary communication tools.

Acknowledgements

This research was financed through the Swedish Energy Agency's programme E2B2, SBUF the Swedish Constructions Industry's organisation for research and development and by 11 industry partners. We are thankful for the valuable suggestions by two anonymous reviewers.

References

3XN (2014) Pv grid teknologirapport by 3XN_GXN. Copenhagen

Bonomo, P., Chatzipanagi, A. and Frontini, F. (2015) Overview and analysis of current BIPV products: new criteria for supporting the technological transfer in the building sector. *VITRUVIO-International Journal of Architectural Technology and Sustainability,* (1), 67-85.

CABE (2006) *Design review: How CABE evaluates quality in architecture and urban design.*

de Groot, H. (2008) SOLAR ENERGY–POWER FOR A NEW AGE.

Farkas, K., The art of photovoltaics. ed. *30th ISES Biennial Solar World Congress 2011, SWC 2011*, 2011, 2052-2063.

Farkas, K*., et al.*, (2013) *Designing photovoltaic systems for architectural integration.* Farkas, Klaudia pour International Energy Agency Solar Heating and Cooling Programme.

Farkas, K. and Horvat, M. (2012) Criteria for architectural integration of active solar systems IEA Task 41, Subtask A. *In:* Haberle, A. ed. *1st International Conference on Solar Heating and Cooling for Buildings and Industry.* Amsterdam: Elsevier Science Bv, 1195-1204.

Florio, P., Roecker, C. and Munari Probst, M. C. (2015) Urban acceptability of solar installations: LESO-QSV GRID, a software tool to support municipalities. *Proceedings of International Conference CISBAT 2015 Future Buildings and Districts Sustainability from Nano to Urban Scale*, , 981-986.

Gustafsson, A. and Xu, Y. (2016) *1B Collection of experiences, Stage 1: Collecting experiences of solar shading with integrated electricity production.* Göteborg: Chalmers University of Technology.

Hagen, R. and Jørgensen, O. B. (2012) *The Communication Process.*

Heinstein, P., Ballif, C. and Perret-Aebi, L.-E. (2013) Building integrated photovoltaics (BIPV): review, potentials, barriers and myths. *Green,* 3(2), 125-156.

Hermstad, K. (2006) Architectural Integration of PV in Norwegian Office Buildings. *Research made for Norwegian Research Council*.

Kanters, J. (2011) Adequacy of current design tools and methods for solar architecture–results of IEA-SHC Task 41's international survey. *Proceedings of PLEA conference* 2011, 65-70.

Kanters, J., Dubois, M.-C. and Wall, M. (2013) Architects' design process in solar-integrated architecture in Sweden. *Architectural Science Review,* 56(2), 141-151.

Krawietz, S. (2007) Building integration of thin-film photovoltaics - New architectural possibilities and future perspectives. ed. *ISES Solar World Congress 2007, ISES 2007*, 1595-1600.

Luque, A. and Hegedus, S. (2011) PV in Architecture. Chichester, UK: John Wiley & Sons, Ltd

Munari Probst, M., Roecker, C. and Schueler A. (2005) Architectural integration of solar thermal collectors: results of a European survey. *ISES 2005 Solar World Congress, Orlando, August*, 6-12.

Munari Probst, M. C. (2009) *Architectural integration and design of solar thermal systems.* (Dissertation). École polytechnique fédérale de Lausanne EPFL.

Munari Probst, M. C*., et al.* (2012) *Solar Energy Systems in Architecture-integration criteria and guidelines.* Munari Probst, Maria Cristina and Roecker, Christian for International Energy Agency Solar Heating and Cooling Programme.

Noord, M. (2010) *Byggnadsintegrerade solcellsanläggningar: Europeisk Best-Practice.*

Roberts, S. and Guariento, N. (2009) *Building integrated photovoltaics.* Basel/Boston: Birkhäuser.

Zomer, C. D*., et al.* (2013) Performance compromises of building-integrated and building-applied photovoltaics (BIPV and BAPV) in Brazilian airports. *Energy and Buildings,* 66, 607-615.