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Improving the Market Up-take of Energy Producing Solar Shading: Experiences from Three Cases of Retrofit

Paula FEMENIAS[a], Liane THUVANDER[b], Peter KOVÁCS[c]

[a] *Chalmers University of Technology, Sweden, femenias@chalmers.se*
[b] *Chalmers University of Technology, Sweden, liane.thuvander@chalmers.se*
[c] *Research Instiutes of Sweden, Sweden, peter.kovacs@rise.se*

ABSTRACT

The paper presents the test of a multi-value framework for the evaluation of energy producing solar shading on three cases of Swedish retrofitting projects. The evaluation framework was developed in collaboration between academics and industry partners in a transdisciplinary research project and considers: energy production, indoor environment and comfort, visibility and communication, aesthetics, design and process, and maintenance and repair. Results show that the model even though having few criteria gives a general and comprehensive feed-back about the outcomes, challenges and success of the projects. None of the projects scores high in all aspects, instead they exemplify different approaches to energy producing solar shading. All three have shading and low maintenance as important criteria for design. Furthermore, the availability of subsidies to add solar energy production to the shading has been decisive for choosing that solution. Case 1 has had energy production as an important driver and no architect was involved while in Case 3, being a listed building, aesthetics has been crucial. Case 2 shows a way forward with a good collaboration between the actors and a compromise between shading, energy production and aesthetics which respect the original design.

Keywords: building integrated solar energy, shading, retrofit

1. INTRODUCTION

With respect to global warming (Frank, 2005) and heat-islands in larger and denser cities (Santamouris et al., 2001), cooling is set to be a crucial element in building design in order to reach comfort levels. Modern architectural ideals with glass facades have also been identified as the origin of over-heating in buildings (Nässén & Holmberg, 2005). Solving the problem with energy consuming cooling systems goes against goals for increased energy efficiency and the growing importance of sustainability certifications. Solar shading proposes a solution for over-heating while a trade-off between reduced energy demand for cooling and increased need for artificial light has to be dealt with (Nielsen, Svendsen, & Jensen, 2011).

Energy producing solar shading proposes and attractive combined solution offering solar shading at the same time as renewable energy is locally produced. Although costs for solar cells has decreased such solutions are still uncommon sights. Challenges for the multi-functional system include a balance between energy reduction and indoor comfort regarding daylight and glare along with practical issues of maintenance, repair and wind-loads (Roberts & Guariento, 2009), especially for dynamic systems which are the most efficient in terms of balance between shading and daylight (Nielsen et al., 2011). Another crucial barrier for the wider implementation is traced back to the influence of architects and the possibility for a successful aesthetic architectural integration of solar energy in the overall building design (Munari Probst et al., 2013).

This paper presents on-going research on energy producing solar shading in Sweden. The ELSA (Elgenererande solavskärmning) project is carried out in a transdisciplinary setting involving three academic institutions representing architecture, daylight studies and technical expertise in collaborating with the industry representing architect firms, solar energy suppliers, solar shading suppliers, building contractors and lobby organisations for solar energy and shading. A process of gathering feed-back from ten cases of new building and retrofit applying energy producing solar shading was initiated in 2016. This paper focuses on three cases of retrofit which represent an important part of the building stock. The aim for the paper is twofold: 1) To test an analytic multi-value framework developed to evaluate the installation of energy producing solar shading from different value and stakeholder perspectives, and 2) To discuss general experiences from these case studies.

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1.1 Method and material

The choses cases of retrofit represent different types of solutions with respect to shading system and architectural integration. All cases are Swedish non-domestic buildings. In each case a number of key actors are interviewed: construction clients, architects, technical consultants, contractors, installers, operation managers, and end-users. Furthermore, representatives from the local public are interviewed as stakeholders to the visual effects of the systems on the urban environment.

The feed-back study gathers process information from the early design phase to the building in use. Technical information, energy performance and experiences from the system in operation and use are also collected. Opinions on the architectural integration of the system has been identified as one main questions to be addressed as well as the visibility and marketing values. Data collection, still ongoing, is based on structured interviews carried out face-to-face or by telephone. Table 1 shows the actors that has been interviewed so far. Results are to be used as basis for discussing different aspects of energy producing solar shading within the trans-disciplinary research arena.

Case		Actors that has been interviewed
City	*Type of building*	
1. Alvesta	Town Hall	Client (the energy manager); the solar system supplier; 3 users
2. Sollefteå	Hospital	Client (the energy manager); architect; solar system supplier
3. Stockholm	University, entrance hall	Client; architect; maintenance & operation; users/public

Table 1: Interview respondents and type of interview in the three case studies.

2. EVALUATION FRAMEWORK

An evaluation framework was designed based on workshops and discussions in the transdisciplinary research team. The aim is to reflect a manageable number of influential factors that an energy producing solar shading should be evaluated upon and still get a comprehensive idea of its function and value (Table 2). Economy and costs are considered but not explicitly included in the framework instead implicitly evaluated in terms of energy production, user satisfaction, and in branding and marketing. The framework was used to analyse data from the case studied. Three researchers were involved in the analysis and adjustments were made to align different perspectives.

	Grade 0	Grade 1	Grade 2	Grade 3
Energy production	Insignificant production of energy	Covers only a limited part of the building energy needs	Produces energy according to expectations but does not cover building needs	Produces energy according to expectations and covers building needs
Indoor environment	No improvement; significant heat over load and glare problems	Small improvements of over-heating and glare	Improved conditions for over-heating and glare	Large improvements, no over-heating or glare problems
Visibility & communication	No feed-back to users; no communication for the public	Information panel indicating the energy production inside or outside building	Visible information panel and regular feed-back and info online or in newsletter	Visible information panel, web information etc. and knowledge diffusion through partnerships
Aesthetics	Not appreciated among any respondent	A majority (>50%) does not find the plant attractive	A majority (>50%) find the plant attractive	All respondents find the plant to be attractive
Design & process	All parties found project difficult or almost impossible to carry out.	At least 50% found the project more problematic and costly than expected.	At least 50% found the project smooth and efficient.	All parties found the process smooth and efficient.
Maintenance & repair	In need of recurrent maintenance and repair.	Seldom in need of maintenance or repair.	No need for maintenance and only occasional repair.	No need of either maintenance or repair.

Table 2: Evaluation framework.

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3. CASE STUDIES

3.1 Case 1: Alvesta Town Hall

An office building from the 1960s had previously been renovated and fitted with a cooling system, but problems with over-heating persisted. In 2015, highly efficient solar cells mounted as on a 'baseball cap' shading were fitted on the eastern and southern facades to limit over-heating and energy use (Figure 1). The municipal agency who owns and manages the building had no previous experience of solar cells. Their energy manager was the initiator and promoter for the system. No architect was involved. National subsidies covering 35% of the total costs of 170.000 € was decisive for choosing solar cells. The system produces 65 MWh/year which covers the electricity need for the building on sunny days and delivers a surplus (~6MW7year) especially in the week-ends which is sold making savings of 25.000 € per year. Although the building now has higher tax rate for being an energy producer the total economic gain is positive.

The client wanted a system free from maintenance. The 'baseball caps' are 2 meters wide and the installation was difficult to attach to the façade. Today the system supplier only does 'caps' that are 1 meter wide. The client thanks the experienced entrepreneur for the success of the installation.

The system has received a lot of attention locally and the solar cells on the roof can be accessed for study visits. The client says that politicians and public servants as happy with the indoor climate and the aesthetics. The solar system supplier is also happy with the results but says that his architect friends does not like the looks. Both the client and the supplier agree that the system is best seen from a distance and that the shading defines the building as a landmark on an urban scale.

Three interviewed users all have different views on the comfort and aesthetics. The system seems to be less efficient on the top floors. Furthermore, the users seem little informed about the function and the value of the system. None of the users are favour of the aesthetics and details are found clumsy. However, they think that the building wasn't that attractive before as it had undergone several renovations. As one user state: "The building is now more blackish and the façade disappears. The building possesses no higher architectural value but it is still the Town Hall and a large visible building." A summary of the evaluation is found in Table 3.

Figure 1: Alvesta Town Hall before and after addition of solar shading.

Value area	Grade	Comment
Energy production	3	Produces energy according to expectations. Surplus energy is sold.
Indoor environment	2	Three users give varying testimony from good to bad.
Visibility & Communication	3	Information panel in the entrance hall. The building receives study visits. The owners engage in knowledge transfer to other municipalities.
Aesthetics	2	3 out of 5 respondents do not find the system attractive or does not have any opinion about the aesthetics.
Design & Process	1	The design process was costly due to extensive calculations for the façade attachments.
Maintenance & repair	3	No need for maintenance or repair so far.

Table 3: Evaluation of case 1, Alvesta Town Hall

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3.2 Case 2: Sollefteå Hospital

This hospital building from the 1960s had problems with over-heating and was retrofitted with energy producing solar shading in 2010. The decision to add energy production to the shading was supported by an enthusiastic client and guided by local policy to invest in renewables. The possibilities to get national subsidies was highly supportive for the investment in solar energy.

The architect was satisfied with the collaboration regarding the architectural integration although the other parties were not that interested in the aesthetics. The architect is satisfied with the results which he thinks is not that dominant on the façade. However, he claims that the system "does not add any aesthetic values to the building." A 'cap' like shading as in Case 1 was discussed and dismissed due to aesthetics. The client and the solar supplier are also satisfied with the aesthetics.

Important criteria for the design were shading, cost efficiency and low maintenance. With respect to his experience, the architect calls for more standardised products. In this project the shading lamellas had to be adapted to fit the size of the solar cells (12 cm). The client finds it remarkable that solar cells are not found in the dimensions of the shading as this kind of shading is very common. Due to the different dimension, the assemblage had to be done in two steps first the shading was fitted to the façade then the solar cells. This increased the costs and complication of the project. A summary of the evaluation is found in Table 4.

Figure 2: Sollefteå hospital with the energy producing solar shading.

Value area	Grade	Comment
Energy production	2	Production according to plans but does not cover more than a small part of the building's energy need.
Indoor environment	3	The shading give an improved indoor environment.
Visibility & Communication	3	Information panel at entrance. Information about collaboration on sustainability with the region. Seminars were given at the inauguration. A web-portal provides further information.
Aesthetics	3	All respondents are very satisfied with the aesthetics and the building integration.
Design & Process	2	The solar energy supplier is unhappy about the costly and time consuming installation.
Maintenance & repair	2	No maintenance but some smaller repair. Difficult to find replacement parts as these were specially produced.

Table 4: Evaluation of case 2, Sollefteå sjukhus

3.3 Case 3: Passage at the Royal Institute of Technology

The object is a passage between two building blocks originally built in 1948 and reconstructed as an entrance hall to a lecture hall in 2006 (Figure 3). The passage is designed by Swedish architect Nils Ahrbom and listed. During the reconstruction, the passage which only had high sitting windows were opened up with bay windows and an entrance. The client understood that over-heating would be a problem and searched for a solution. The university and the building manager did not want any exterior shading due to maintenance and risk for fall injuries would somebody climb the system. Instead, a system with glass integrated solar cells were installed in the upper part of the bay windows. The plant was financed to 70% with national subsidies which was crucial for the decision to use this solution. The situation of the passage which is lower than the surrounding buildings limits the insolation of the system and the payback time is consequently very long.

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The passage is still over-heated but this is not a problem as it is only a passage. The client considers the installation more of an aesthetic solution for shading than energy producing. All involved actors as well as users and by-passers appreciate the aesthetics. Some users never thought about it as a solar system but when informed they think it goes well together with the profile of the technical University. The system provides shadow on the inside and a pleasant light pattern. The architect had close contact with the City Museum and the son of the late architect during the whole design. A summary of the evaluation is found in Table 5.

Figure 3: Royal Institute of Technology, entrance to lecture halls from inside and outside.

Value area	Grade	Comment
Energy production	1	The plant produces very little energy. There were no high expectations for energy production when installed.
Indoor environment	2	The installation provides some shading and does protect against glare. The passage is warm on sunny days but as it is only a hall way there are no complaints.
Visibility & Communication	1	An information panel besides the entrance door indicate the production of electricity but without reference to the relevance of the production with respect to energy use.
Aesthetics	3	All respondents and the public found the installation very attractive and well integrated in the building.
Design & Process	3	The process worked very well according to all parties.
Maintenance & repair	3	There has been no use for maintenance or repair so far.

Table 5: Evaluation of the Royal Institute of Technology case

4. DISCUSSION

The multi-value framework shows a means to quickly get a comprehensive vision of experiences with energy producing solar shading. Only a few interviews have been made, still and overall picture of the project is achieved. The limited number of evaluation criteria in our model makes it easy to apply and visualise (Figure 4). Return of experience through case studies will always be a trade-off between depths of the study and the number of cases that are possible to include in the study. The weaknesses in our evaluation are the few interviews with end-users and possibly also with representatives from the local public. A full survey among all end-users would need much more resources and the active participation of the project owners. Regarding technical information and experience among professional actors, no more interviews would be needed, and the information should be correct.

On a general discussion on experiences form energy producing solar shading a few statements can be made. Reduction of over-heating has been the main driver for installing the systems. Low maintenance and repair has been important criteria for finding a solution. Only Case 1 put energy production as a top goal. The possibility to receive financial support for solar cells has been crucial in all cases. Aesthetics have to a varying degree been of importance even though discussed in each project.

None of the projects scores high on all aspects of the evaluation framework (Figure 4). Case 1 has been successful for energy production but scores badly in aesthetics. No architect was involved and the energy production has been achieved on behalf on both respect for the building, the urban landscape. The user respondents do not give a unified view of the indoor environment. This could reflect the common view but more interviews could be carried out to get a better picture.

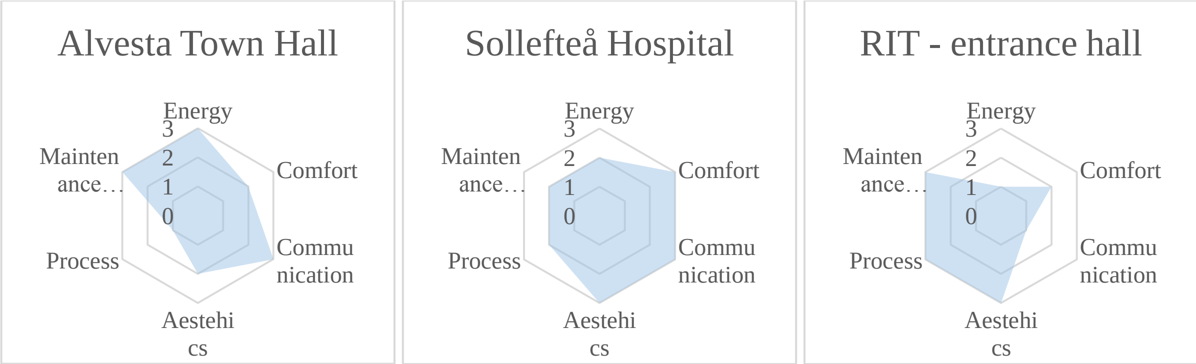

Figure 4: Visualisation of the evaluation of the three cases of retrofit.

Case 3, being a listed object the case has had aesthetics as a primary goal, the client even refers to the system as an "artistic installation". The image value could be discussed in this case as the low efficiency could give a negative impression of this kind of solar systems. Case 2 gives the most balanced outcome. Comfort is reported good and the system works in terms of architectural integration with the existing building. Compared to Case 1, in Case 2 there was an architect involved which has improved the aesthetics while still scoring high on energy production and comfort. With reference to earlier work that point out the architect as an important actor for a market-up take of building integrated solar systems (Kanters, 2011), Case 2, where there was a good collaboration between architect, solar supplier and client, shows a way forward. In Case 1, no architect was part of the project group, but in many projects this would not be permitted. The solar system is definitely a very dominating part of the building and its aesthetics can be discussed. In Case 3, the system is very well integrated and an appreciated part of the building. The energy production is limited but this could be due to the local situation.

None of the cases have had need for maintenance and only Case 2 has been in need of repair. However, especially Case 1 is newly installed and time will show how successful it will be regarding maintenance. Time will also show which of these solutions that will have follow-ups. Case 2 shows the importance of standardisation in order for solar systems to be successfully integrated with other building elements.

5. CONCLUSION

The paper shows that it is a challenge to find a balance between the different criteria which are of importance for achieving an energy producing solar shading system that is efficient in terms of shading and comfort; easy to apply to an existing building and operate and maintain; that produces enough energy to make the investment justifiable; and which can be integrated without compromising the original architecture. None of the studied system would have been installed had in not been for subsidies.

The many and varying aspects for energy producing solar shading calls for an interdisciplinary collaboration, where all aspects need to be discussed and considered. The tested multi-value framework is a means to quickly get a comprehensive vision of experiences which can be a basis for discussions in an inter- and trans-disciplinary team. The value of the results from the return of experience study will be subject for up-coming studies.

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