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# Barriers to the Market Penetration of Façade-Integrated Solar Thermal Systems

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**Abstract**

For this paper, we analyzed the barriers to new façade-integrated solar thermal systems in a survey, literature review and workshops with experts. We focused on flat plate collectors and their application in residential buildings. Integrated systems are technically more challenging than simple roof installations, and we found a lack of knowledge among all participants in the market to be the second most important problem after economic issues. Especially for architects it is very difficult to use solar technologies as a part of their palette due to insufficient education. Especially for façade solutions a stronger awareness of solar technology is required for the selling process. The synergy advantages offered by integrating solar thermal systems into façades are largely unknown by the participants of the market.


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*Keywords:* Building-integrated solar thermal; fassade; barriers; market penetration

## 1. Introduction

Today's building stock causes 40% of the energy consumption in Germany. In his paper [1], Henning showed that energy efficiency cannot be the only answer, but that much more active solar technology is crucial for a 100% renewable national energy system. He also showed that the area available on the roofs of the existing building stock is not sufficient. Therefore also the façade has to be used for solar thermal applications. Activating the building

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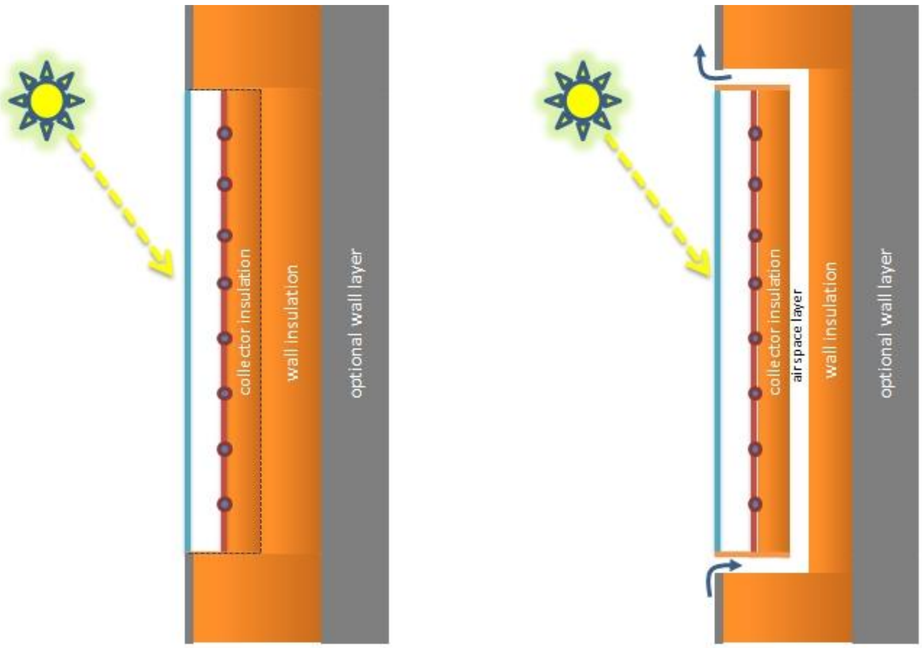
envelope for solar energy production will be mandatory for new buildings after the year 2020 due to the energy performance of buildings directive (EPBD) from the European Union.

The interplay of architecture and solar technologies was investigated in IEA-SHC Task 41. For solar thermal systems, there are several solutions and technologies that can be integrated into the envelope of the building. Vacuum tubes have been used as balcony balustrades. Unglazed or air collectors are installed mainly on industrial buildings. Other concepts (e.g. semi-transparent collectors) were implemented in demonstration buildings in research projects [3, 4]. Especially for residential buildings, glazed collectors are interesting. With the currently available products, essentially two glazed façade solutions are possible (Fig. 1). The simpler and more common one is to mount prefabricated collectors onto a wooden frame which is attached to the underlying wall structure. Especially in refurbishment, this can mean that customized collectors are needed to obtain an acceptable appearance of the building. The second solution is actual integration of the absorber into the wall system, in which the back wall of the collector is omitted. This means that there is no air gap between the collector and the wall. The solar façade becomes a single integrated component and the absorber and the wall share the same insulation (Fig. 1, left). The advantage of façade systems in general is that the solar gains are more constant throughout the year compared to roof-mounted systems due to a smaller incidence angle in winter. In the case of integrated absorbers, the wall itself is heated. This can also reduce the transmission heat losses of the building. However these systems are very rare.

We investigated the barriers to solar thermal façades in workshops with experts and in a survey (personal or telephone interviews) among 40 planners, construction companies, collector manufacturers and customers mostly from Germany (still one of the leading countries in the solar thermal market). The results of this survey and our literature review concerning technical, architectural, economic and social barriers are reported in this paper.




Collector fully integrated Collector with rear ventilation

Fig. 1: (left) Building-integrated, glazed solar thermal collectors with rear ventilation (right) and without (left), source: [2]

## 2. Technical Barriers

In this chapter we provide an overview of the most important issues concerning building physics, the installation and simulation of solar thermal façades. Our experience from former projects was complemented with a literature review and our survey. Since for residential buildings these are the most common solutions, we will focus on glazed, flat-plate systems.

### *2.1. Mounting & peak temperatures*

The problem in general is that the wall has to bear the additional structural load of the collector or the absorber and the glazing while thermal bridges should be avoided. This is also true for unglazed collectors, air collectors and systems using evacuated tubes.

In their study, Bergmann and Weiss [5] investigated 14 façade-integrated solar thermal installations with flat-plate technology. They found that in some cases, the absorber or the pipes were in thermal contact to wooden parts of the building. This can be the case if the absorber is attached with metal hooks, which are screwed into wood and hold the header pipe. The wood will be heated over a longer period of time and can decay or even slowly turn into charcoal, which means a loss of stability for the building. Due to the geometrical layout, high collector temperatures of up to 195°C [5] can be reached in spring and autumn during stagnation. For new integrated façade systems, this means that the absorber cannot be installed on any arbitrary underlying material. For the rear-ventilated solution, this issue is of minor importance. In our survey, only one installer reported problems with polystyrene that was in contact with the rear wall of a collector (probably with poor insulation). In general, one has to use heat-resistant materials that will not degas (plastics) and consider thermal expansion when choosing aluminum profiles and dimensioning the jointing. Bergmann and Weiss also investigated the maximum heat transferred through the wall from the collector for several wall constructions in residential buildings. The maximum required thickness of the insulation in order to fulfill building code dealing with overheating (2002, Austria) was only 10 cm of stone wool or mineral wool. For the winter case, they compared the heat transfer losses of similar walls with and without an absorber and glazing. They found that the losses can be cut by 60-90% during days with high irradiance.

### *2.2. Vapor Transfer*

The glazing acts as an external vapor barrier. Even for non-integrated standard collectors mounted on roofs, condensation on the glazing can be observed during the early morning. As long as a closed collector is installed on a standard wall construction, the situation regarding vapor transfer has not changed tremendously compared to a regular façade. In general, the rule applies that vapor exits the wall to the cooler environment of the building. Usually the outer layers are chosen to be more open to diffusion in order to avoid destructive condensation within the wall construction. In the case of absorbers and glazing integrated into the façade system, the direction of vapor transfer can change due to the fact that the outer layer of the wall is heated and reaches high temperatures. In this case vapor should be able to exit the wall to the interior of the building. This is why the inner layers should be more open to diffusion for integrated systems. This rule of thumb was elaborated by Bergmann and Weiss in [5]. Other wall constructions with weak vapor barriers were also calculated. For entirely new façade systems, simulations (e.g. with Wufi+) are necessary. The results for several fully integrated systems are shown in Fig. 2. Unfortunately, humidity introduced into the wall during the construction is often neglected in simulations. However, the measurements of Bergmann and Weiss on a wooden and a concrete test façade did not reveal any critical condensation in any layer behind the glazing or the absorber [5]. The fact that humidity from the construction process must exit the wall to the interior of the building confirms the rule of thumb that inner layers should be open to diffusion.

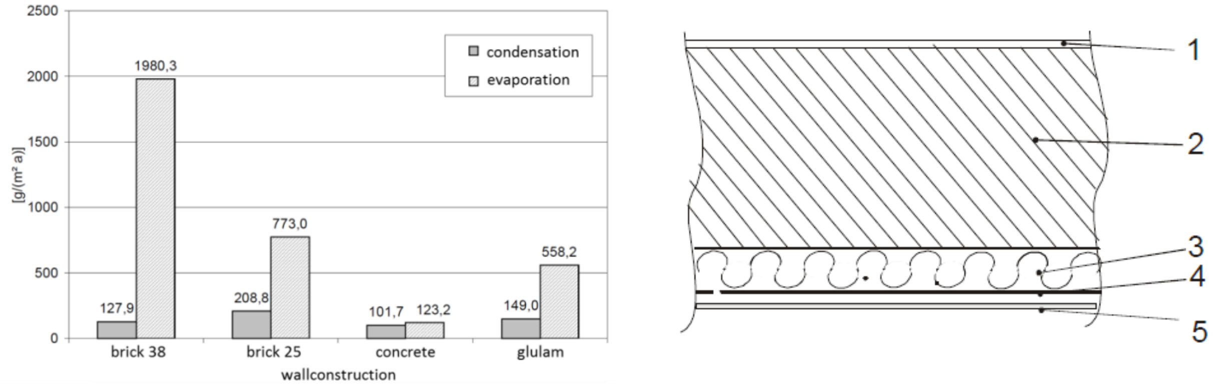



Fig. 2: (left) Annual condensation and evaporation potential for different wall constructions, source [5].
(right) Wall constructions: (1): interior plaster, (2): brick 38cm / brick 25cm / concrete, (3): insulation, (4): absorber, (5): glazing.
Similar configuration for "glulam" with more wooden layers, source: [5]

### *2.3. Hydraulics*

The rules concerning the hydraulics of glazed façade collectors with a fluid are generally the same as for roof installations. Both low-flow and high-flow systems are possible. A manual bleeder valve should be installed at the highest position of the hydraulic piping. The challenge is to achieve pressure equalization for probably customized collectors of different shapes and arrays of different size.

Small collector arrays are usually connected in parallel to ensure that the pressure drop is low. In order to get a higher annual solar fraction, especially in the façade, larger arrays and thus a mixture of parallel and serial connections are needed. The most convenient configuration is the Tichelmann interconnection, in which identical arrays with the same number of serially connected collectors are connected in parallel (fig. 3). Especially in retrofit, one has to face the problem that collector arrays might have different sizes, demanding a complex design for the hydraulics (fig. 3). This means that the pressure between the different arrays of different sizes has to be equalized due to different pressure drops resulting in different flow rates and different output temperatures. In order to choose or adjust the valves, one needs to know the pressure drop of each collector array. Usually this number is given by the manufacturer for single collectors under certain conditions (flow rate, fluid, mounting situation). Unfortunately this is not easily possible yet for customized collectors with individual shapes or completely new, integrated façade collectors/absorbers. Detailed calculations considering the geometrical configuration of each collector are not usually possible for the builder. The installer has to estimate the best values for the valves. This means that the total pressure drop is not known precisely and also the dimensions of the pump can only be estimated.

However, the companies that we addressed in our survey did not consider this to be a major problem. Guidelines for differently sized arrays exist [6] and the estimation for customized collectors is not considered to be a serious barrier.

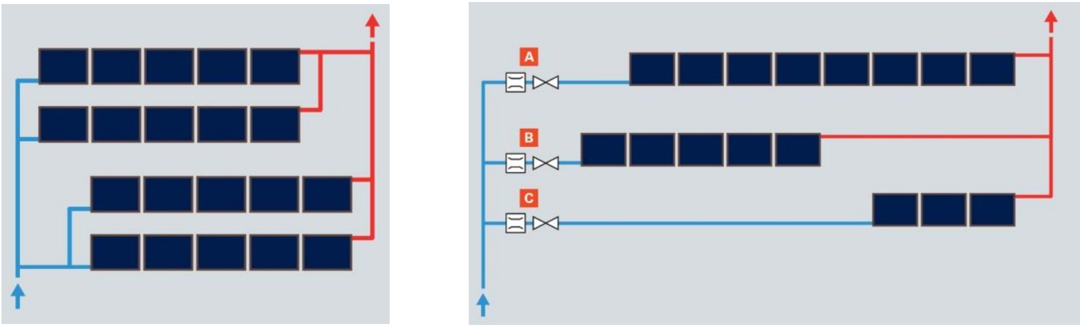



Fig. 3: (left) Tichelmann hydraulics for arrays of the same size, source: [6]
(right) Arrays of different sizes need valves for pressure equalization, source [6]

*2.4. Shading*

Buildings are often surrounded by other buildings of approximately the same height, which means hardly any shading on the roofs. For façades the situation is crucially different. Neighboring buildings or parts of the building itself can shade the collector and thus reduce the solar gains (fig. 4). Builders have to take this into consideration. For the owners or residents, it is important to remember that also plants can shade the collector.

Fig. 4: One building wing shading the solar collectors on another façade of the same building, source: [12]

*2.5. Standards*

The most relevant standards concerning solar thermal façades are EN 12975 for collectors, EN 12976 for solar thermal systems with non-separable collectors and EN 13830 (curtain walling) for the façade. These standards are independent of each other and a standard for integrated façade collectors, especially without rear ventilation, does not exist yet. National building regulations for glazing or for the façade have to be observed. In the measurements specified by EN 12975 there is only one ambient temperature considered instead of different temperatures at the front and rear of the collector as is the case for integrated flat-plate systems. Customized absorbers or entirely new façade systems can be installed simply on small buildings. For taller buildings (three or more floors), fire safety regulations and further building laws have to be considered. These differ strongly in different regions. Proving that unique, customized installations are safe is considered to be too expensive and construction companies are not willing to guarantee for legal issues in case of damage. By the companies in our survey, this problem was rated more important than the actual construction process. For writing a new appropriate standard, our suggestion is to adjust EN 12975 with different temperatures in front of and behind the collector and to include building directives for construction products (e.g. CPD 89/106/EWG) as well. Homogenous international building directives could strongly contribute to the success of facade integrated systems.

*2.6. Simulations*

Many simulation programs for solar thermal energy allow a collector slope of 90° to simulate façade collectors. However, with the standard collector models it is not possible to have different temperatures at the front and rear of the collector as is the case for façade-integrated absorbers without an air gap between the collector and the wall. For this new collector, simulation models had to be developed as described by Maurer [7] and Hauer and Streicher [8]. Unfortunately these new concepts have not been implemented in easy-to-use software for architects and construction companies yet. Shading is often neglected. This shall be a part of our future work.

When new systems are developed, one has to simulate the heat transfer from the collector through the wall, particularly for the case of stagnation, and the vapor transfer behavior. The total efficiency should be determined with detailed annual simulations.

## 3. Architectural Barriers

### *3.1. Planning solar buildings*

In the international survey of IEA-SHC Task 41 [9], it was found that a holistic building integration of solar technologies is a big problem for architects. In previous surveys, Bergmann and Weiss found that 85 % of the architects desire more freedom in the color of the glazing and the absorber. Especially thin corrugated absorbers give the façade of the building an inhomogeneous and uneven appearance. The appearance of the absorber behind the glazing is an important issue but not the major problem. For architects it is very difficult to include solar technologies in an early stage of planning, when the basic concept of the building is determined. For this, simple tools would be needed that give initial ideas of dimensioning, especially for integrated absorbers, and a rough impression of the appearance.

In [10], Munari Probst and Roecker give guidelines for architects and for collector developers. The characteristics of building integration are the size and the position of the collector field, the surface texture and color, the shape and size of the modules and the type of jointing. In the design process, all of these characteristics should give a holistic aesthetic impression of the whole façade while meeting the energy goals.

Engineers tend to focus on the efficiency of their collectors instead of focusing on easy integration into buildings. In general (also among customers), it is very common to consider the building and solar technologies as separate components. This is why most installations are simply mounted on the roof instead of being integrated within the building envelope. In order to ensure a good integration quality of new products, developers, architects and also customers should develop a common language. It is crucial for architects that solar technology and especially building integration becomes a commonly used element of their service range. Issues related to education will be discussed in chapter 5.

### *3.2. Product availability*

In general one can say that hardly any products declared as façade solutions are available on the market. Many collector manufacturers claimed to be able to produce any polygonal shape of collector for a price increase of 15 – 100 %. Colored glazing or absorbers (other than highly selective) are not offered by most manufacturers. In IEA-SHC Task 41, information on the most suitable products has been compiled [11]. Some companies prefer to use fin absorbers in triangular or polygonal collectors in order to be able to cut them to customized lengths. This keeps the effort for hydraulics lower. For a holistic integration, all this means a great effort for the planner or the construction company.

For roofs, integrated solar thermal solutions are offered by several companies. In our survey, some customers feared that after several years or at the end of the lifetime, the manufacturers might not be able to offer a suitable replacement for single components of the solar system.

Fig. 5: Examples of solar thermal façades, © Florian Lichtblau, Lichtblau Architekten

## 4. Economic Barriers

### *4.1. Costs & payback period*

In order to gain a first impression of the costs of integrated solar thermal façades, one of the authors calculated the prices for some chosen examples and compared them to regular wall constructions. The prices (including labor costs, excluding VAT) are 90 €/m² for a regular composite insulation system and 240 €/m² for a wooden façade with vacuum insulation panels. The prices with integrated absorbers behind customized glazing are 390 €/m² and 600 €/m² respectively. Photographs of these examples are given in fig. 5. This means that the investment costs for integrated solar thermal façades are currently 150 – 333% higher than for standard wall constructions. Since most integrated solar thermal façade systems must be considered to be prototypes, reliable data about the payback period of future mass products is not available. An estimation of this (including simulations) will be part of our future work.

In [5], factors are given for the needed collector area for the same annual solar coverage rate compared to roof installations. Factors between 1.5 and 2 were found. The factors are higher in the case of domestic hot water systems and lower for space heating, which indicates the benefits of matching the irradiance profile to the usage. The factors might be estimated too high due to the fact that in the simulations, the reduced heat transfer through the wall was not taken into account. These effects and a further comparison of installations of different sizes shall be part of our future work.

In order to give precise information about payback periods, further simulations and measurements will be necessary. Owners of dwellings claimed that solar installations should pay off in a maximum of 10 years because they fear damage within the expected lifetime of 20 years, while for big investors, payoff periods of 3 to 5 years are attractive. The question on the contribution of solar installations to an increased selling value of a building remained unanswered in our survey.

### *4.2. Incentives*

Since the situation in different countries is very diverse, we choose Germany as one of the leading nations in the solar thermal market as an example. The German Federal Office of Economics and Export Control (BAFA) pays approximately 90 €/m² to the customer for small installations of up to 40 m². For more details please check www.bafa.de. The problem is that the collectors need to have the Solar Keymark certificate. Manufacturers claimed that certification is too expensive for uniquely customized collectors. Customized integrated wall systems cannot get the certificate since it is designed for collectors of solar thermal systems according to EN 12975 and EN 12976 only. The German bank “Kreditanstalt für Wiederaufbau” (KfW) is based on bonds that are guaranteed by the federal government. They offer cheap credits to customers who ecologically refurbish their dwelling or install solar plants. Here only the energy-saving result has to meet certain standards. This means that simulations have to be performed (see chapter 2.6).

## 5. Social Barriers

In our survey we found that most of the construction companies claimed to be able to build solar thermal façades with rear-ventilated collectors. Customized, new, integrated wall systems seemed to be realizable as well. For this solution we expected a problem with the on-site interaction of different trades. This does not seem to be the case. The installation of the absorber in the solar thermal façade is considered to be the domain of the heating technician.

According to the companies, the strongest social barrier to solar façades is the lack of demand from customers. On the other hand, it should be noted that the companies do not advertise solar thermal façade solutions. The next step in the survey was to interview customers. They are aware of the basic rule that tilted collectors gain more radiation than vertically installed ones. The positive interactions and the better match between gain and usage, especially for installations with space heating, are not known by either customers or companies. Some companies explained that they calculate solar gains for roof installations if the energy-saving characteristics of the building are too poor. The business practice is to recommend a simple roof installation to the customer. Most customers are not aware of the fact that a coupled collector-façade can bring additional gains or reduce thermal losses through the wall. The appearance is only the third most important problem for customers, after economic issues and the lack of knowledge.

In [9], Munari Probst and Roecker found that the lack of knowledge is one of the biggest problems also for architects. In the past, solar technologies have not been included in planners’ education. Unfortunately, even professors do not have much experience with solar technology and their aesthetic integration into the building envelope. Additional lectures and an overcoming of conservative structures in the universities are necessary. Among practising architects as well as professors, the reservations against the optical appearance (especially vacuum tubes) are very strong.

For landlords, the user-owner dilemma is quite important. Appropriate and easy contracting or renting models are lacking for solar thermal technology in general.

## 6. Conclusion

In this paper we presented the results of our study on the barriers related to solar thermal façades. We found that economic issues are the number one problem as is the case for solar thermal technology in general. A huge lack of knowledge was identified as the second most important problem. More education for planners seems to be needed. In order to increase sales, companies must offer inexpensive solutions and especially for façade installations, advertisement must be strongly intensified. This should also include simple information for architects and building companies. The good news is that all the technology is available and that the companies are able to construct solar façades in principle. In order to obtain more inexpensive products that can be easily integrated into the building envelope, further research is crucial. Research programs for solar thermal façades are a good and necessary investment for a successful transformation towards clean energy.

## 7. Acknowledgements

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