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BAPV and BIPV Installation Trends in Sweden

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Abstract

In recent years, Sweden has seen a notable increase of solar photovoltaic (PV) installations, but with less than 50 MW installed at the end of 2013, the market is still very small. To reach a point where PV is considered in all building projects it has to be cost effective, aesthetically appealing, and reliable. Issues that are all connected to how a system is mounted. This paper aims to describe the current situation regarding the mounting of PV systems on Swedish buildings and for this, two separate studies have been conducted. The first study comprises well over 400 existing PV systems with a minimum peak power of 10 kW, and the second includes interviews and a questionnaire survey with system suppliers and owners. The results show that the most common mounting position is steep-slope roofs, mostly pantile or metal, followed by low-slope roofs. A majority of the installations on steep-slope roofs are applied on top of the roof, parallel to the slope. The most common mounting types for low-slope roofs are tilted and parallel systems secured to the roof. The share of ballast-only systems is however increasing. The most common building-integrated photovoltaic (BIPV) applications are modules used in shading devices and modules integrated in steep-slope roofs. Despite the rapid market growth, there seems to be few problems with medium sized installations, and most of the property owners are satisfied with the companies that have delivered and installed the systems.

Key words: photovoltaic systems, mounting systems, roofing materials, BIPV, BAPV, Sweden.

1. Introduction

Several studies (e.g. by BCC research, 2011) anticipate that the global market for building-applied and building-integrated photovoltaic (BAPV and BIPV) systems will increase. In recent years, there has been a rapid growth in installed PV capacity in Sweden, primarily due to reduced module prices and a direct capital subsidy. The majority of the systems are roof-top installations, while ground-mounted installations are few. The Swedish solar PV market is however, with less than 50 MW installed at the end of 2013 (Lindahl, 2014), still very small. To reach a point where PV is considered in all building projects it has to be cost effective, aesthetically appealing and reliable. These issues are all connected to how a system is mounted.

- With reduced module prices, the installation costs make up a larger part of the total cost in a PV project. Fast and easy installations as well as cost-effective mounting systems are crucial for the life cycle cost. BIPV systems have the potential of cutting conventional material and construction costs. This requires compatibility with conventional building products.
- Aesthetical aspects become more and more important as the market grows. The appearance of an installation now also has to be accepted by the general public, especially if located in cities. There are many ways in which PV can be used for adding positive architectural values to a building.
- A PV installation, whether integrated in or applied on a building, must not degrade the function of the building. Problems related to fire safety, weather tightness of the building, loads (including snow and wind loads), and future maintenance have to be identified and solved. Moreover, several issues related to electricity generation have to be considered, for example shading, soiling and snow coverage.

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2. Aims

This paper aims is to describe the current situation regarding the mounting of PV systems on Swedish buildings, with the purpose to contribute to a positive development of the Swedish PV market. The main objectives are the following:

- To show the proportions of PV installations on different building types (offices, schools etc.)
- To show the proportions of PV installations on low-slope roofs, steep-slope roofs, and façades.
- To present the most common roofing materials for low- and steep-slope roofs respectively.
- To give a general description of how the PV panels are mounted on low-slope roofs, steep-slope roofs, and façades.
- To examine the incidence of BIPV systems and how the share of these systems has changed over the years.
- To present experiences and opinions, from both system owners and suppliers, regarding questions related to the mounting of PV systems on buildings.

3. Definitions

Definitions of central concepts used in this paper are described below.

PV system: A PV system comprises all the components and subsystems needed to convert solar energy into electric energy suitable for local utilization or distribution to the electric utility network. It includes: the array of PV panels, inverters, charge controller and energy storage (if any), switches, wiring etc. This paper focuses, however, exclusively on the PV array; and everything about installation and mounting systems only regard this part of the system. Moreover, in some of the larger systems in this study, there are PV panels installed on more than one building. Panels on multiple buildings are considered to belong to the same system if put into service at the same time, by the same property owner.

BIPV system: There is no consensus definition of BIPV systems. Instead it varies greatly with context and perspective (architectural, technical or financial). Some definitions are wider, including partially integrated systems and systems integrated with architectural designs (e.g. Zomer, 2013), while other are more narrow with specific requirements on the level of integration (e.g. MEDDE, 2013).

Many definitions limit BIPV to modules replacing a part of the climate shell (i.e. roof and façades) (Sinapis, 2013), therefore excluding systems with modules integrated in external shading devices. As described by Peng et al. (2011), "the integration of PVs in shading devices is an intermediate solution falling between the BIPV and BAPV". Definitions where these systems are considered to be building integrated are however also used, for example in the upcoming European Standard prEN 50583 'Photovoltaics in Buildings' (Pellegrino et al., 2013).

In this paper, a BIPV system is defined based on technical functions. The modules in a BIPV system must replace, or be inseparable from, a conventional building material or component, and thereby fill a function additional to generating electricity. Systems where PV modules are integrated in shading devices and balcony balustrades are also considered to be building integrated (Fig. 1). A closely mounted add-on system is however not considered a BIPV system, no matter how well it has been integrated into the design.

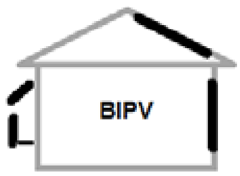

Fig. 1: Building-integrated applications

BAPV system: Naturally, this acronym also has different definitions, and even the meaning of the letter "A" varies among them. In this paper, "BA" is short for "Building Applied", and a system is considered to belong to this category if the PV modules are mounted on a building but do not fulfil the BIPV criteria above (Fig. 2).

Fig. 2: Building-applied applications

4. Methods

In order to fulfil the objectives, studies were conducted on existing PV systems in Sweden, as well as on the experiences of Swedish stakeholders. Descriptions of these two studies are given in the sections below.

4.1 Study on existing Swedish BAPV and BIPV systems

Information about existing BAPV and BIPV systems in Sweden was collected and analysed. The study was limited to systems with a minimum peak power of 10 kW and a startup before 2014. Only systems where both the total installed capacity and the installation position could be identified were included.

The data includes location, peak power, module make and type, inverter make, installation position, type of mounting system, roofing material, system supplier, and property owner. Information was obtained from national and international databases of PV systems, as well as from system suppliers and property owners. The systems were grouped into the three categories: "Steep-slope roofs", "Low-slope roofs" and "Façades". For each group, the proportions of different roofing materials, and also different types of mounting systems, were specified. This part of the method is illustrated in Fig. 3. Explanations of the mounting types are given in Tab. 1. For tilted modules on low-slope roofs, a classification based on the mechanism used to hold the system to the roof was chosen (Maffei et al., 2014). Because of the relatively few number of façade installations in Sweden, a more generalized classification was chosen for this category.

The method described above was chosen since it enables the examination of a large number of systems, in a reasonable amount of time, and at a low cost. The main disadvantage is that, dispite an extensive collection of data, details about how the systems are mounted are relatively few. To obtain mounting details for each system, interviews with suppliers or numerous on-site visits would have been necessary. Both of these methods were however considered far too time consuming to be feasible.

It has not been possible to include all Swedish medium sized systems on buildings and an exact figure of the number of missing systems cannot be given. The study does, however, cover a large part of the total installed PV capacity in the country and is therefore considered comprehensive enough to meet the aim.

A lot of the information was gathered from photographs of PV systems and roofs, which leaves room for interpretation errors. The roofing materials and mounting types could sometimes be difficult to establish from photographs taken from a distance or from a disadvantageous angle. In about 5% of the systems on low-slope roofs the roofing material is unknown. The equivalent number for steep-slope roofs is as high as 20%, which is somewhat compensated with a larger number of systems in total. In about 5% of the installations on both low- and steep-slope roofs, the mounting type is unknown.

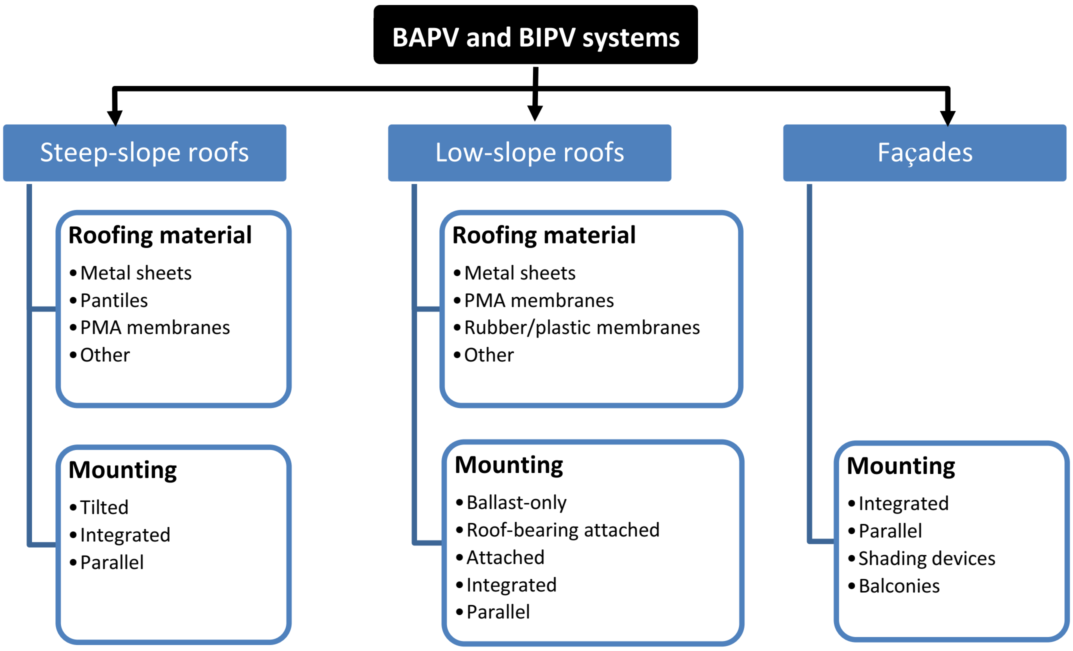

Fig. 3: Process of data handling within the study on existing Swedish BAPV and BIPV systems

Tab. 1: Definitions of mounting types on steep-slope roofs, low-slope roofs and façades

Mounting types on steep-slope roofs ≥1:4 (14 degrees)	Tilted	PV modules mounted on metal racks on top of the roof. The PV modules have a higher inclination than the roof.
	Integrated	The PV modules replace or are inseparable from the roofing material. See definition of BIPV in chapter 3. Systems with modules integrated in skylights are also included.
	Parallel	PV modules parallel to the roof surface, but not integrated.
Mounting types on low-slope roofs <1:4 (14 degrees)	Ballast-only	The support structure stays in place only by friction and weight. The weight could either be accommodated by self-weight or by extra ballast. The support structure is not fixed to the roof in any way. The PV modules have a higher inclination than the roof.
	Attached roof-bearing	Some support points are fixed to the roof and some are not. Friction and/or ballast in combination with attachments are used. The PV modules have a higher inclination than the roof.
	Attached	Fully framed systems that are fixed to the roof in all support-points. The PV modules have a higher inclination than the roof.
	Integrated	PV modules replace or are inseparable from the roofing material. See definition of BIPV in chapter 3. Systems with modules integrated in skylights are also included.
	Parallel	PV modules parallel to the roof surface, but not integrated.
Mounting types on façades	Integrated	PV modules replace or are inseparable from the façade material. See definition of BIPV in chapter 3. Systems integrated in windows are also included.
	Parallel	PV modules parallel to the façade, but not integrated.
	Shading devices	PV modules integrated in shading devices.
	Balconies	PV modules integrated in balcony balustrades.

4.2 Study on experiences of Swedish stake-holders

A project within the national PV research program “SolEl-programmet” (Energimyndigheten, 2013), with the title “Evaluation of building integrated and building-applied photovoltaic (PV) installations”, has been carried out by CIT Energy Management AB in collaboration with the authors of this paper. With the purpose to collect, and benefit from, the experiences from Swedish PV installations on buildings, system suppliers as well as system owners were asked to participate in interviews and a questionnaire survey. In this paper, relevant results related to mounting systems are presented. All the results from the study described above will be published in an Elforsk-report in the end of 2014.

The interviews and questionnaire survey primarily focus on the mounting of PV panels and include questions concerning everything from preliminary investigations to maintenance and repair. Interviews were performed with some of the suppliers and property owners having the most experience from medium sized (>10 kWp) PV systems on buildings. The questionnaire was sent to most of the Swedish system suppliers (about 70 companies) and about 60 property owners. The group of system suppliers includes distributors, installers and entrepreneurs. The property owners selected either own a minimum of two systems with a peak power above 10 kW or at least one system with a peak power above 75 kW.

5. Results

Results from the two studies described in chapter 4 are given in the sections below.

5.1 Results from the study on existing Swedish BAPV and BIPV systems

The study comprises 444 PV systems with a peak power of at least 10 kW installed on buildings. The total capacity is 16,6 MW, which is equal to 38% of the total PV capacity installed in Sweden by the end of 2013 (Lindahl, 2014). A distribution of system sizes is shown in Fig. 4. The interval “10-20 kWp” has the most number by systems by far, while there are very few in each of the intervals above 70 kWp.

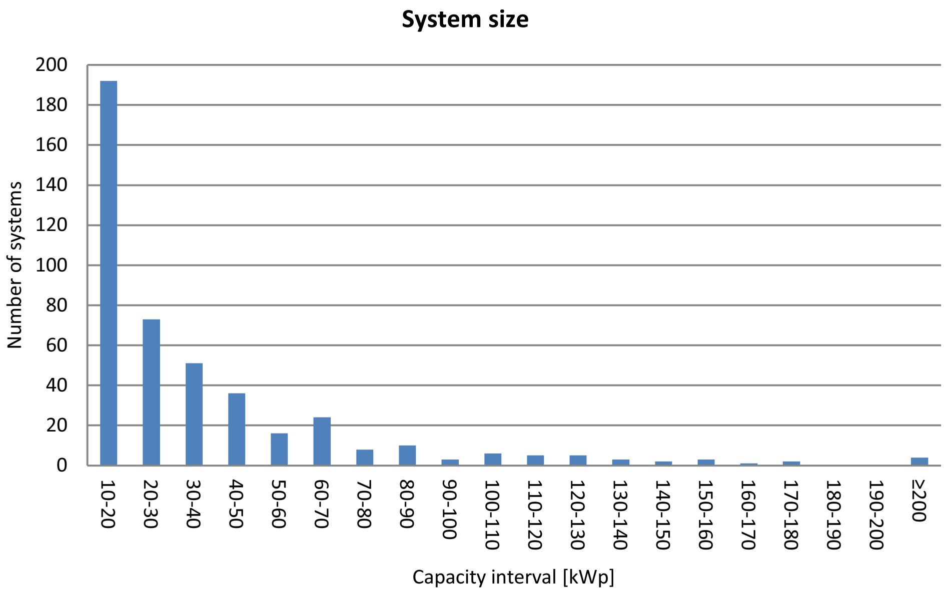

Fig. 4: Diagram showing the sizes of systems included in the study in terms of installed capacity in kWp

Building type

The systems in the study are situated in urban and rural settings all over Sweden. Just over 60% of the systems are installed on buildings owned by private persons, companies and co-operatives, while the rest are installed on public buildings. Distributions of the systems based on the type of buildings that they are installed on are shown in Fig. 5. Agricultural buildings have the largest share of the number of installations (25%) followed by schools (14%) and single-family houses (14%). When the distribution is based on installed capacity instead, agricultural and school buildings are still on top but the previous third is now replaced by multi-family buildings. Only 5% of the capacity is installed on single-family houses.

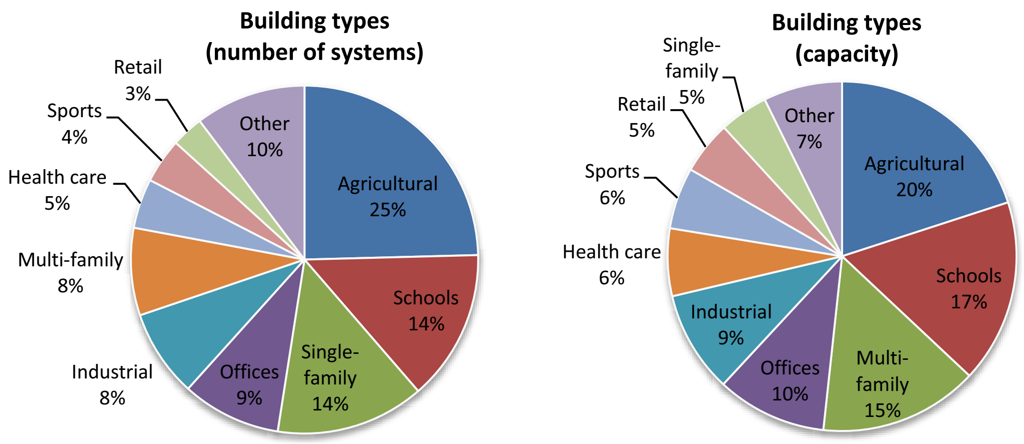

Fig. 5: Ratios of different building types based on installed number of PV systems (left) and installed PV capacity (right)

Installation position

The results show that a majority of the Swedish BAPV and BIPV systems of at least 10 kWp are mounted on steep-slope rooftops (64%). The share of these systems has grown rapidly the last two years, mostly due to an increased number of medium sized PV systems on farm buildings and single-family houses. This evolvement is visualized in a diagram, showing yearly installations from 2010 to 2013, below (Fig. 6). The second most common installation position is low-slope rooftops with about one fourth of the systems. Façade installations (including PV modules in shading devices and balcony balustrades) are relatively few (11%).

In a distribution based on installed capacity, instead of number of systems, the share of low-slope roofs becomes slightly larger (32%), mostly at the expense of steep-slope systems (Fig. 7).

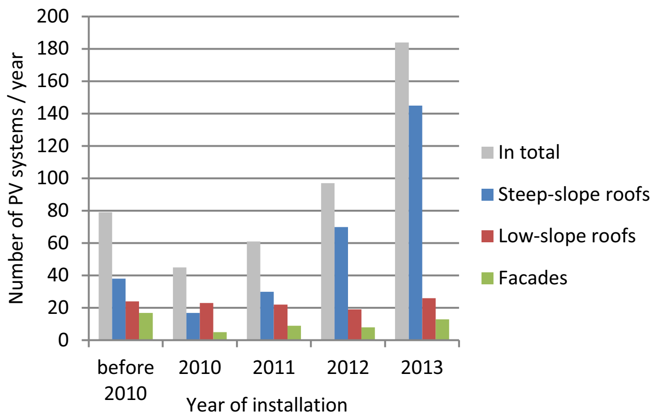

Fig. 6: Yearly installed number of PV systems with different installation positions

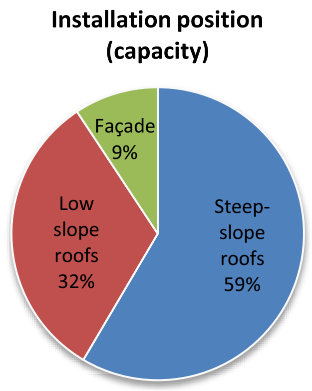

Fig. 7: Ratios of different installation positions based on cumulated PV capacity in the end of 2013

Steep-slope roofs

The most common roofing materials on the steep-slope roofs included in the study are metal sheets (standing seam, trapezoidal and corrugated) and pantiles (concrete and clay). The group of materials with the third largest share is polymer modified asphalt membranes (PMA membranes). In Fig. 8 it can be seen that as much as 98% of the installations are mounted on these roofing materials. The last 2% include rubber membranes, fibre cement sheets, metal tiles and shingle. Fig. 8 shows the ratios of different roofing materials based on installed capacity. A chart based on number of installations would however show similar percentages, although with a slightly higher share of PMA membranes in favour of pantile roofs.

About 90% of the PV panels on steep-slope roofs are mounted on top of the roof surface, parallel to the slope. The remaining 10% are either integrated in the roof (BIPV) or mounted on tilted metal racks (Fig. 9).

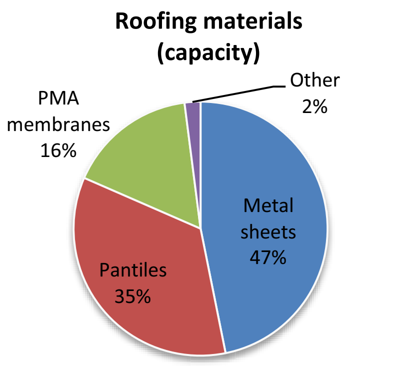

Fig. 8: Ratios of different roofing materials on steep-slope roofs based on cumulated PV capacity in the end of 2013.

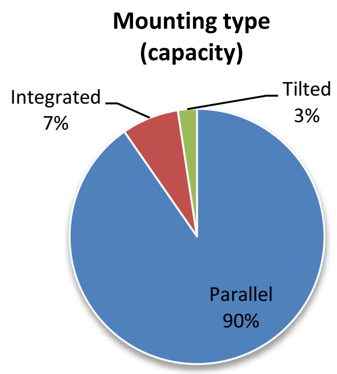

Fig. 9: Ratios of different mounting types on steep-slope roofs based on cumulated PV capacity in the end of 2013.

Low-slope roofs

The most common roofing material on the low-slope roofs included in the study is PMA membranes, followed by rubber membranes and metal sheets. Other materials are green sedum roofs and gravel. Fig. 10 shows a distribution of roofing materials based on installed PV capacity. When the distribution is instead based on installed number of systems, the shares of PMA membranes and metal sheets are slightly larger, at the expense of rubber membranes. Thus, the PV arrays on rubber membranes are relatively large. When comparing installed PV capacity, parallel systems are most common (Fig. 11) but when comparing installed number of systems modules mounted on tilted racks fixed to the roof ("attached") are most common (Fig. 12). Ballast-only systems make up about one third of the systems, both considering capacity and number of systems. Integrated systems and attached roof-bearing systems are few. Fig. 13 and 14 show examples of two PV arrays with different mounting types, one horizontal (parallel) and one attached roof-bearing, recently installed on a low-slope roof in Sweden.

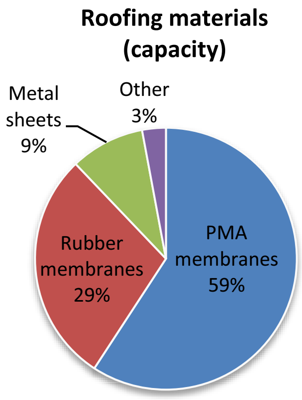

Fig. 10: Ratios of different roofing materials on low-slope roofs based on cumulated PV capacity in the end of 2013.

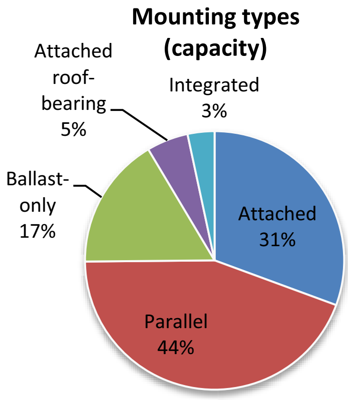

Fig. 11: Ratios of different mounting types on low-slope roofs based on cumulated PV capacity in the end of 2013.

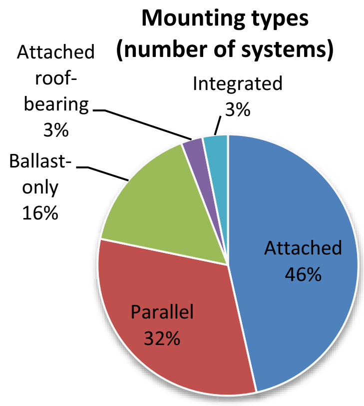

Fig. 12: Ratios of different mounting types on low-slope roofs based on number of PV systems in the end of 2013.

Fig. 13: Example of a parallel PV array on a low-slope roof in Sweden

Fig. 14: Example of an attached roof-bearing PV array on a low-slope roof in Sweden

The figures shown above are, however, not likely representative for how Swedish PV systems on low-slope roofs are mounted today. Relatively many "ballast-only" systems have been installed during the last two years and the share of these systems is steadily increasing. On the contrary, yearly installations of systems with modules mounted on tilted metal racks have decreased. It is not possible to see a clear trend for systems with modules parallel to low-sloped roofs.

<u>Façades</u>

In about 40% of the PV systems on façades, the modules are integrated in shading devices. Many of these systems are however relatively small, so when comparing installed capacity they only make up one third of the systems. Parallel systems have the largest share of the installed capacity with a little less than 40%, while systems on balconies are few and relatively small (Fig. 15). Systems integrated in the façade are relatively large and make up one fourth of the total capacity.

<u>BIPV systems</u>

Building-integrated systems make up about 10% of all systems included in the study. The most common application is PV modules installed as external shading devices, followed by modules integrated in steep-slope roofs. Solutions for steep-slope roofs generally consist of integrated full-size modules. Modules in balconies are rare among Swedish PV systems larger than 10 kWp. The annually installed number of BIPV systems has been stable during the last three years, and the total share of BIPV systems has consequently become smaller and smaller.

Fig. 15: Example of PV modules in balcony and roof balustrades on a residential building in Sweden

5.2 Results from the study on experiences of Swedish stake-holders

The questionnaire was answered by about 40 suppliers and 40 property owners. Many of the later own one or two systems larger than 10 kWp, while there were only a few in each of the categories “3-5 systems”, 6-9 systems”, and “10 systems or more”. Regarding the suppliers, a majority had installed 1-20 systems larger than 10 kWp at the time. A few only had experience of installing smaller systems (<10 kWp) and a few had installed more than 20 medium sized systems.

<u>Mounting on different roof types and roofing materials</u>

The results from the interviews and questionnaire survey show that most of the suppliers are prepared to install PV on almost any type of roof and roofing material. About one in four prefer not to install panels on asbestos cement, though. Additionally, there are a few advices against installations on wooden shingle and thatch.

For standing seam metal roofs, clamps are generally used to fix the mounting brackets to the seams without penetrating the metal. Fixing devices on trapezoidal and corrugated metal roofs are either screwed to the ridges of the metal sheet or fixed to the underlying supporting structure with screws through the metal. On pantile roofs, rails are mounted on hooks that are fastened either to roof battens, an underlying structure, or the supporting structure of the roof. Mounting systems on membrane roofs are either glued or welded to the surface material, or fastened to an underlying structure or the supporting structure of the roof. Only-ballasted systems on low-slope roofs are also common. Moreover, various combinations of these methods exist. A couple of suppliers give advice against using fixing devices that are screwed only to the metal sheet, with the argument that this will not stand the test of time. Another supplier advice against tilted modules on tilted roofs without extra consideration of wind loads.

The choice of mounting type is predominantly made based on the construction of the roof or façade, both among property owners and suppliers. Nevertheless, there are some property owners stating that they have primarily based their decision on recommendations from the supplier, cost, aesthetics, function, or specific requirements, such as: no penetration of the roof, shading devices, or a production profile best fitting the electricity need. Moreover, two suppliers refer to customer needs as the primary consideration, while a few others state cost as most important for this decision. It also appears that the level of potential risks that the installers will be exposed to can be decisive.

Regarding low-slope roofs, the opinions on whether it is best to mount the PV modules tilted or parallel to the roof (i.e. close to horizontal) differ among both suppliers and property owners. The arguments that were given for parallel and tilted panels respectively are shown in the following table (Tab. 2).

Tab. 2: Reasons for choosing a parallel or tilted installation on low-slope roofs as stated by property owners and suppliers

	Parallel installation (incl. integrated)	Tilted installation	It depends
Owners	The panels must not be seen from the ground		Depending on the orientation of the roof
Both	Esthetical/architectural reasons	Higher efficiency/energy yield	Depending on how low the slope of the roof is
		Dirt can run off	
Suppliers	Lower costs	Less snow coverage	Parallel for thin film
	Lower wind loads	No risk of water assembling under the panels	Parallel for locations with especially high wind loads
	Often no need for building permit	No water on top of the panels	Depending on the roofing material
	Smaller space needed, higher energy yield/m^2 roof		
	Simpler		
	Less risk for damage		

BIPV systems

As much as nearly 40% of the property owners answered that they have at least one BIPV system. PV panels in shading devices were the most common, closely followed by roof integrations. A few had PV panels installed in balconies or integrated in the façade. One of the property owners made this comment: “Works well in shading devices, fairly low additional cost compared to traditional shading devices”. Almost half of the suppliers state that they have installed a BIPV system at some point.

Experiences from the installation phase

The vast majority of the property owners seemed positive about the installation phase, with comments like “good”, “fast”, “easy” and “experienced installers”. A few did, however, give examples of issues that had occurred. For example, one owner wrote about an installation that had taken more time than expected, and another had experienced some troubles with making the installers follow rules related to work environment. A third owner wrote about the challenges to facilitate possibilities for future module replacement and to get the lead-throughs right in order to avoid future problems with moisture.

Furthermore, most of the property owners only had positive things to say about the system suppliers, although a few did have some negative experiences. There were also a couple of owners that gave advice on doing a thorough background check because of the relatively new market and high risk for bankruptcies.

Maintenance and repair

More than 80% of the property owners state that they do not maintain their PV panels. A few occasionally remove snow from the panels or clean their panels from dirt. About 25% of the property owners answer that they have a PV system that has needed repair at some point, with defects in material as the most common reason. Among these, there are three cases related to the mounting system. The material failures have been results of large snow loads and panels coming off. Occasional comments about need for repair because of vandalism, stormy weather, and installation mistakes, such as moisture in lead-throughs for cables and junction boxes, were also made.

6. Discussions and conclusions

The Swedish PV market has grown rapidly from more or less non-existing to noticeable, although still very small, in the last couple of year. This has resulted in many new suppliers and installers on the market, which in a worst case scenario could have led to a lot of beginner mistakes and bad installations. Luckily, the studies presented in this paper indicate the contrary. As a whole, the development of a Swedish PV market has been successful and the transition to more and larger installations on buildings has gone smoothly. This is in many ways thanks to a fully developed European market with a wide range of mounting systems for all kinds of roofs. First of all, this has made it possible for Swedish suppliers to find well-tried systems and techniques suitable for the Swedish market and Swedish conditions. Also, the range of products is large enough to leave room for variations and cover individual choices and needs.

The most common mounting position is steep-slope roofs, mostly pantile and metal, followed by membrane low-slope roofs. The vast majority of the systems on steep-slope roofs are mounted on top of the roof, parallel to the slop, while there are different opinions on whether the panels should be mounted parallel or tilted on low-slope roofs. The penetration of BIPV systems is fairly small and has not followed the fast increase of systems on buildings in general. Most common among the building-integrated systems are installations with PV panels in external shading devices or integrated in steep-slope roofs. Simple systems seem to be preferred. An example of this is steep-slope roof-integrated systems, where primarily full-size modules are used. Special-made building products with integrated PV cells, e.g. “PV-tiles”, are rare.

There seems to be few problems with medium sized installations and most of the property owners are satisfied with the suppliers. Nevertheless, it is clear that there are some less competent players on the market and both suppliers and property owners have expressed their concerns about this. Property owners commenting on everything from energy output to system design indicate a growing knowledge and awareness among the costumers. It should however be noted that many of the property owners participating in the study have experience from multiple PV installations, and the average costumer is most probably less informed.

Information about the current situation regarding PV systems on Swedish buildings given in this paper can hopefully be helpful to stakeholders both within the PV industry and the Swedish PV market. It is also recommended to be used as guidance for future research on the topic.

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