Building Integrated Solar Technology – Evaluating 20 Years of Experience with Solar Buildings from an International Competition

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Abstract

The "Architectural Award Building Integrated Solar Technology" was established in 2000. The aim of this prize is to make exemplary solutions at the interface between architecture and solar energy accessible to a broad public. Since then, eight competitions have been held, with around 40 prize winners and almost 600 projects submitted from all over the world. The competition entries show the great potential of coherently integrated solar technology as part of ambitious architectural and energy building concepts. In the article, examples from the competitions are used to illustrate continuous further developments and, above all, design innovations in the field of building-integrated solar technology (with a focus on photovoltaics).

Keywords: Building Integrated Photovoltaics (BIPV), Solar Façade, Solar Buildings, Solar Architecture

1. Preliminary remarks on the context

The use of solar energy in and on buildings is a central aspect of energy-efficient construction – for homes, industrial and administrative buildings as well as residential complexes. The Solarenergieförderverein Bayern (SeV) [https://www.sev-bayern.de <12.10.2021>] has held eight competitions on the topic of "Building Integrated Solar Technology" with around 40 prize winners since 2000. The thematic focus and geographical orientation changed over the years. Initially, the competition only targeted PV façades in Bavaria and Germany. Then there was an opening up from photovoltaics to solar technology (including solar thermal collectors) and building envelopes. As of 2011, there are no longer any national restrictions.

The aim of the competitions is to make exemplary solutions in qualitatively demanding architecture accessible to a broad public. In the years between 2000 and 2005, only a little more than a dozen entries from Bavaria and Germany were represented at any one time. After the opening for European and worldwide submissions, a continuous increase in the number of participants can be observed. The 2020 competition attracted 159 entries, of which 146 were ultimately in the "Architectural Award" competition. In total, the eight competitions now comprise almost 600 submitted projects from 43 countries. (Fig. 1)

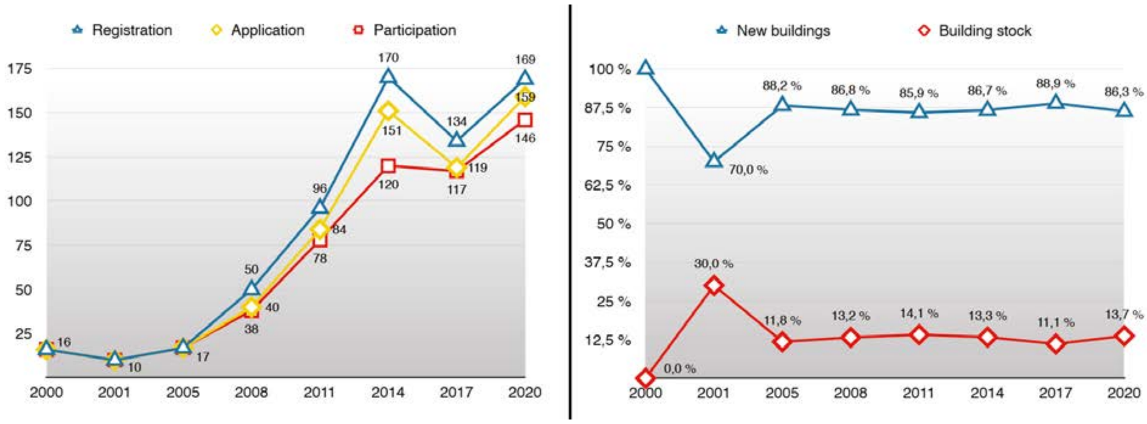

Fig. 1/2: Development of the number of participants (left) and proportion of new and existing buildings (right)

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Fig. 3/4: Nikolaus-Fiebiger-Zentrum, Erlangen (2000), Universitätsbauamt (left) and Holz-Berufsgenossenschaft, München (1999), pmp Architekten (right)

The example of the competition activities of the SeV, founded in 1997, can be used to show the increasing broad impact and establishment of the topic in the following decades. What are the continuities in the field of building-integrated solar technology and how have construction and especially design strategies changed in the last 20 years? Solar systems with a focus on photovoltaics will be examined, but in addition to roof solutions, the focus will be on PV façades, as some particularly striking developments can be identified here.

2. About the competitions

A cursory look at the first phase at the end of the 1990s – in which one can speak of "building-integrated solar technology" in a certain broader sense, beyond a few pilot projects – shows that a wide range of possible applications of solar technology has already been successfully tested in architectural practice, even if some of these projects are only known to experts.

2.1. Solar power systems and PV façades in Bavaria and Germany (2000 - 2005)

The example of the competition winners in particular can be used to illustrate very clearly strategies in the use of photovoltaics in architectural concepts. (Krippner, 2017, pp. 8-19) Due to the tender conditions, three façade solutions that are still current today were initially awarded. (SeV-Bayern, 2002 and SeV-Bayern, 25.07.2005).

In 2000, the competition is held for the first time under the title "Innovative building-integrated solar power systems in Bavaria". Among the 16 projects submitted, the Nikolaus Fiebiger Centre of the Friedrich Alexander University in Erlangen (2000; Erlangen University Construction Office, Christof Präg) demonstrates the potential of integrating PV modules. A slightly curved "solar awning" is arranged on the top floor of the south façade, while the façade of the lower structure is extensively equipped with horizontal, single-axis tracking PV glass louvres. The photovoltaics blend in perfectly with the technical aesthetics of the research building (Fig. 3).

2001, the subsequent competition "Solar Power from Façades" was announced, to which projects from all over Germany were admitted. Out of ten buildings submitted, the headquarters of the Holz-Berufsgenossenschaft (1999) in Munich by PMP Architekten was awarded 1st prize. In the almost 50 m high building, polycrystalline PV modules are arranged both in a cold façade in a narrow vertical strip and as solar protection in a partial area of the warm façade. A wider and a narrower strip extend from the third to the eleventh floor, each emphasising the vertical in the distant view, but horizontally divided by the cover strips in the near view (Fig. 4).

In 2005, the third competition was held under the title "Architecture and Solar Power - Building-Integrated Photovoltaic Systems". The competition shows a clearly higher design quality. First prize was awarded to the architects Rolf + Hotz for the renovation of two nine-storey apartment buildings (2001) in Freiburg from the second half of the 1960s. The closed south façade is characterised by a building-high, interconnected PV system. The glass-glass modules, arranged in landscape format, are attached to the aluminium substructure on the long side with visible black clamping profiles. The project shows how PV façades can be implemented in an exemplary manner, both technically and in terms of design, even in renovations (Fig. 5). (Krippner, 2015)

2.2. European and Architectural Award for Building-Integrated Solar Technology (2008 - 2020)

Since 2008, the SeV has held the competition every three years, expanding it to include solar thermal and roof systems and opening it up internationally – initially as a "European Prize".

Fig. 5/6: Punkthäuser Wilmersdorfer Straße, Freiburg (2001), Rolf + Hotz Architekten (left) and Marché International, Kemptthal (2007) Kämpfen für Architektur (right)

In the 2008 competition, the jury reviewed 38 projects from eight countries. (Becker and Krippner, 2009) The European Prize for Building-Integrated Solar Technology was awarded to a new office building for Marché International in Kemptthal (2007). This is considered to be the "first office building in Switzerland with a real zero-energy balance". In combination with a clear architectural concept and a compact structure, Beat Kämpfen succeeded in creating an exemplary solution for administrative buildings that generate the energy required for operation themselves. The monopitch roof is designed as a full-surface electricity generator and supplies 100 % of the required electrical energy. The architects succeeded in unobtrusively but extremely carefully and elegantly detailing the roof and its edges (Fig. 6).

For the first time, projects from all over the world are eligible for the 2011 Architectural Award. Even though most of the 84 entries came from German-speaking countries, the response from a total of 13 countries confirms the openness of the process. (Becker et al., 2012) With the new construction of a carpenter's workshop (2010) near Freising, this time the architecture prize is awarded to a type of building where design demands are otherwise often rare. Deppisch Architekten designed a formally reduced, elegant structure in which not only the south-facing surface (20 degrees) is fully covered with photovoltaics, but also the more gently sloping north-facing surface (10 degrees). The PV system is flush with the roof edges, resulting in a two-dimensional appearance. With a plausible overall concept, the PlusEnergy standard is achieved (Fig. 7).

In 2014, the competition underlines the topicality of the subject, both quantitatively and qualitatively, which in the meantime threatened to be somewhat lost from the field of vision of architects and building owners due to the economic problems of the solar industry. 137 projects submitted from 20 countries represent an increase of over 60 percent compared to 2011. (Krippner et al., 2015) The architecture prize was awarded to René Schmid Architekten with the UmweltArena in Spreitenbach (2012). The new building is dominated by a prismatically folded roof with 33 differently inclined and exposed sections. The long sides are oriented to the southwest and northeast, but the north-facing roof surfaces are also solar-activated with monocrystalline, frameless glass/glass modules. The solar yield exceeds the arena's own energy requirements by a factor of two (Fig. 8).

Fig. 7/8: Hall design.s, Pulling (2010), Deppisch Architekten (left) and Umweltarena, Spreitenbach (2012), René Schmid Architekten (right)

Fig. 9/10: Hof 8, Schäftersheim (2014), Architekturbüro Klärle (left) and Lycée technique pour Professions de Santé, Ettelbrück (2019), Fabeck Architectes (right)

In the 2017 competition with 119 evaluated projects, it can be seen that only a good third (≈ 34 percent) still come from Germany. Due to the strong share of submissions from Switzerland and Austria, the German-speaking region is around 77 percent. The growing number of participants from non-German-speaking countries, especially from Scandinavia and the Benelux countries, is encouraging and shows that the competition continues to gain considerable international recognition. (Krippner et al., 2018)

The prize winner, the PlusEnergy building complex “Hof 8“ in Schäftersheim, makes a contribution to a topic determined by numerous challenges in a holistically designed concept: building in rural areas. In addition to a coherent mix of uses, the use of regional products and the reuse of materials in order to minimise the proportion of grey energy in construction, photovoltaics are fully integrated into the roof surfaces of the farm ensemble. In terms of construction, a rather conventional rooftop installation is chosen, which, however, captivates through the carefully detailed treatment of the roof edges. The combination with existing quarry stone masonry and new timber façades also illustrates the design potential of commercially available solar technology (Fig. 9).

In October 2020, with 159 projects, the field of participants has almost doubled compared to 2011, and even compared to the previous competition in 2017, there has been an increase of 20 percent. The country-specific distribution also shows an increase with 26 countries, although submissions from Germany and Switzerland clearly continue to dominate, each accounting for more than a third. (Krippner et al., 2021)

This time, the “Architecture Prize“ is awarded to a school building in Ettelbruck. The four-storey building is divided by a projecting and a receding structure. The primary construction is made of wood, except for the escape staircases. Asymmetrical gable roofs vary in pitch and are fully covered with PV modules. The PV generator on the roof surfaces is carefully implemented on a wooden substructure with painted connection plates and continues familiar approaches of structural engineering practice. In the southwest and west façades, solar thermal collectors based on a post-and-beam construction are flush-mounted at the height of the opening edges. The chosen dimensions and proportions of the solar components complement the façade appearance with the vertically arranged narrow wooden strips in an excellent way (Fig. 10).

Fig. 11/12/13: Single family home, Hegenlohe (2005), Tina Volz and Michael Resch (left), opus House, Darmstadt (2007), opus Architekten (middle) and Weyerguet, Wabern (2019), Halle 58 (right)

Fig. 14/15: Bus station, Bad Wörishofen (1995), GS Schneider Architekten (left) and Carport Waste Management Corporation, München (2011), Ackermann Architekten (right)

2.3. Continuities and changes - assessments based on selected examples of projects

Using projects from all competitions, some aspects of PV roofs and façades will be discussed. In the case of roofs, over the past 20 years a broad standard of exemplary solutions can be found both in award-winning projects and in everyday architecture. (Krippner, 2019) In many cases, fully integrated systems are implemented in a technically and design-wise coherent manner in a variety of building types. But rooftop solutions, such as the one-family house in Hegenlohe by Tina Volz/Michael Resch (2005) with precisely detailed implementation, can also be convincing. An elevated PV system is located on the flat, southwest-facing gable roof. The rows of modules are slightly guided over the eaves and ridge, the punctual fastening can be read off (Fig. 11).

The issue of existing buildings still poses a challenge, especially when requirements for the protection of historical monuments have to be taken into account. (Krippner, 2017) If one disregards the first two competitions with their “special conditions“, it becomes apparent that measures in existing buildings still play only a subordinate role within the “Architectural Award“, at around 13 percent (Fig. 2). Over the years, numerous competition entries, including those that have won awards, have shown exemplary, almost self-evident implementations and demonstrate that solutions are available.

In Darmstadt, Opus Architekten realised a combined system with rather conventional solar thermal collectors and photovoltaic modules in a historical ensemble (Fig. 10). In contrast, Halle 58 architects is using red PV modules in the renovation of the historic Weyerguet farmhouse (2019) in Wabern (Fig. 11). Both projects are exemplary for energy roof solutions in which both the building concept as a whole and the detailing of the solar technology are convincing.

Large-scale roofing is also becoming important, especially in combination with electric mobility. An early example is the bus station (1995) in Bad Wörishofen. GS Schneider Architekten use semi-transparent PV modules on an elegant steel structure in the southern surfaces of the roof construction (Fig. 14). For the roofing of the carport of the waste management corporation (2011) in Munich, Ackermann Architekten choose an innovative approach with flexible modules and foil cushions as a multifunctional roof: weather protection, use of daylight and electricity generation (Fig. 15).

Fig. 16/17: Ökotec 3, Berlin (1993), SJ Planungsges. (left) and Paul-Horn-Arena, Tübingen (2004), Allman Sattler Wappner (right)

 

Fig. 18/19: Nursery +e, Marburg (2014), opus Architekten (left) and Grosspeter Tower, Basel (2017), Burckhardt+Partner (right)

While there has been continuous development of the PV roofs, there have been significant changes in the façades over the years. In addition to the solutions discussed in the area of cold façades, two projects are exemplary for early PV façades. In the Ökotec building (1993) in Berlin, natural stone cladding is combined with glass modules in the façade. Apart from the visible fastening, it is striking that the modules were designed with horizontal PV cell strips at the time (Fig. 16). The Paul Horn Arena in Tübingen (2004) shows an unusual implementation for the early 2000s in terms of surface size and detail. Allmann Sattler Wappner designed the entire south façade with vertical-format modules with green polycrystalline PV cells in four different sizes. A white edge, pronounced by the foil laminate on the back, structures each module and the overall appearance of the façade. Here, the visibly applied photovoltaics also perform an important role as a communicator for renewable energies (Fig. 17).

From 2010 onwards, a change begins. Architects are seeking to reduce the PV cell in the overall area of the module. An example is the nursery +e (2014) in Marburg by opus Architekten. The shed-like roof structure with PV strips sloping to the south continues its structure vertically in the south-west façade. Here, the monocrystalline cells recede in favour of a uniform surface effect; a perfectly detailed glass façade is revealed (Fig. 18). In the Grosspeter Tower (2017) in Basel by Burckhardt+Partner, the façade is characterised by a clear grid structure with openings that widen towards the top. The opaque façade surfaces consist of CIGS thin-film solar modules. Due to the different dimensions and architectural requirements, there are around 450 different types of façade elements, which are suspended in the substructure via support profiles on the back. The result is a homogeneous surface that is an elegant and efficient alternative to stone and metal façades (Fig. 19).

However, it is not only architects who are increasingly criticising these dark, anthracite-coloured PV modules. Colourfulness has been significant for building-integrated solar technology since the pioneering years; the widest possible range is often highlighted as a particular advantage of photovoltaics. In recent years, printed or coated modules, sometimes in combination with special glass, have also enabled solutions in other colours. For example, in the case of the apartment building (2018) in Zurich, Beat Kämpfen uses PV modules with multicoloured printing (50 percent of the surface), which gives the façade a reddish-brown appearance (Fig. 20).

 

Fig. 20/21: Multi-family home Höngg, Zürich (2018), Kämpfen Zinke + Partner (left) and Solaris, Zürich (2017), huggenbergerfries Architekten (right)

Fig. 22/23: Oskar von Miller Forum, München (2009), Herzog + Partner (left) and "Multi-family home with energy future", Zürich (2017), René Schmid Architekten (right)

In the Solaris residential building (2017), also in Zurich/CH, by huggenbergerfries Architekten, all opaque surfaces are covered with photovoltaics despite the complex geometry of the building. The architects' goal here was a "solar house that should not necessarily be recognisable as such". Monocrystalline modules are used with a prismatic front glass that is additionally colour-coated using a special printing technology. The vertical relief structure gives the glass surface a matt sheen and creates a variedly shaded, coloured play of light (Fig. 21).

In addition to colour, important issues in façade cladding are always fastenings and module dimensions or proportions. While non-visible fixings are now generally preferred, two projects show convincing solutions with visible hooks and profiles. Narrow PV louvres are arranged in front of the glazed access area at the Oskar von Miller Forum in Munich by Herzog + Partner (2009). The frameless glass-foil modules are each held in place by linear profiles on the long sides. Here, a few variations, both functional and constructive, in a clear overall structural concept result in an almost 'playful' solution (Fig. 22).

René Schmid Architekten chose a rather small-format module size for the multi-family house with energy future (2017) in Zurich. The façade planning is based on a clear modular grid, with over 1,000 monochrome glass panels of the same size, which brings cost advantages. In combination with the scaled arrangement on visible stainless steel hooks, an attractively structured division of the opaque surface is created (Fig. 23).

In a comparison of cold and warm façades, no such variance has yet been observed in the latter. The basic strategies of how crystalline cells can be used as parts of a mullion-transom construction are already shown by early examples from the SeV competitions. PV is almost naturally used in insulating glazing and often also serves as semi-transparent solar shading. Some projects also illustrate that the PV façade can also function as a status symbol, as in the SMA Solar Academy (2009) in Niestetal by HHS Planer + Architekten (Fig. 24).

In contrast, dye cells and organic photovoltaics open up different types of design. Richter Dahl Rocha & Associés used dye solar cells in this dimension for the first time worldwide at the SwissTech Convention Center (2012) in Lausanne. In the west façade, glass-glass modules with dye cells in different shades of yellow, green and red are arranged storey-high in front of the glass façade in narrow strips. These not only act as sun protection, but also create charming lighting moods in the foyer (Fig. 25).

Fig. 24/25: SMA Solar Academy, Niestetal (2009), HHS Planer + Architekten (left) and SwissTech Convention Center, Lausanne (2012), Richter Dahl Rocha & Associés architectes (right)

Fig. 26/27: Convention Center, León (2018), Dominique Perrault Architecte (left) and SIEEB, Beijing (2006), Mario Cucinella Architects (right)

3. (Interim) Conclusion – Building Culture: Architecture and Solar Technology

The Architectural Award of the Solarenergieförderverein Bayern e. V., with its focus on "Building Integrated Solar Technology", is now regarded as the leading event in its field in Europe, alongside the Swiss Solar Prize, which has been awarding prizes for buildings, best-integrated systems and architects since May 1990, and the German and European Solar Prizes, with which Eurosolar has also been honouring architects annually since 1994. Not only the award-winning examples show that in the meantime, in addition to solar thermal collectors, photovoltaics in particular have become a natural part of the building envelope of energy-efficient buildings in ambitious overall architectural concepts (Fig. 32/33/34). (Herzog et al., 2021 and Krippner, 2021)

When analysing pitched roofs, it can be seen that standard modules for on-roof or roof-integrated systems are usually chosen; only in the case of detached and semi-detached houses are special products such as solar tiles or specially shaped modules for roof integration sometimes used (Fig. 35). Very often, solar systems cover the entire roof surface, oriented towards the south, on a flat pitched roof facing south and north or as a prismatic structured building envelope.

In many buildings, the solar installation covers only partial areas of the roof. Very important for a coherent appearance is the design of the side surfaces with (colour-matching) flashings: Ridges, verges and eaves, as on the Convention Center (2018) in León. An almost 300 m long, flat-pitched roof on steel trusses spans the event and exhibition zones. The modules are mounted in single and double rows on six slightly unfolded fields of the roof surface, embedded in level maintenance corridors. Dominique Perrault Architecte from Paris thus succeeds in forming a multifaceted, large-scale energy roof of metal and glass in a historical setting. In addition, many projects now show unpretentious and carefully executed solutions that consistently follow familiar approaches from building practice (Fig. 26).

In contrast, some special features, but also problems regarding the form and character of the visual design of solar façades can be discussed. In terms of construction, applications in ventilated façades dominate - either in new buildings or in renovations. In the meantime, there are a number of projects in which PV systems are also installed in the balcony parapet area.

In terms of appearance, it can be seen over the years that crystalline PV modules with visible cells are now used rather rarely. Architects prefer modules with homogeneous surfaces, mostly in black – supplemented by anthracite-coloured thin-film modules. Modules with coloured imprints, coatings or special glasses are very common. An exception is the use of photovoltaics as (movable) sun protection, although there are instructive precursors. In the SIEEB (Sino-Italian Ecological and Energy Efficient Building) for Tsinghua University in Beijing by Mario Cucinella Architects (2006), for example, the PV lamella constructions cantilevered out floor by floor became an important element shaping the design. The institute building contains multiple overlaps of use and references to traditional Chinese symbolism. The different functional layers in the building envelope are brought to bear in terms of construction and design. In addition, there are projects with PV modules in non-ventilated façades, mostly post-and-beam constructions, in which – as a rule – the crystalline cells have a solar protection function (Fig. 27).

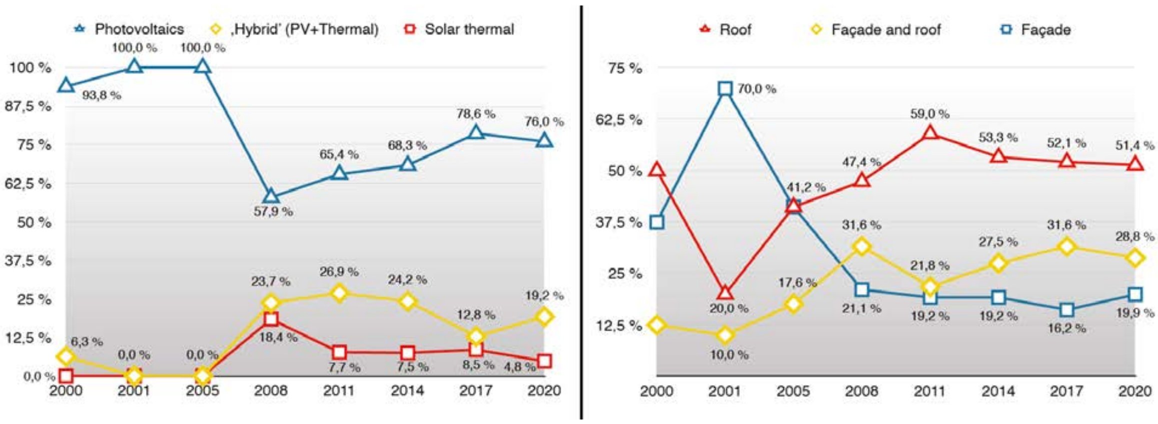

Fig. 28/29: Distribution of the solar technology used (left) and structural integration of solar installations (right)

Over a period of 20 years, it can be said that the quality of everyday architecture in the submissions has also increased significantly. The share of PV systems in the competition continues to grow, reaching more than 80 percent of the submitted projects in 2020. 14 percent of the buildings have combinations, the share with solar thermal collectors is only 5 percent. Despite the focus of the “Architectural Award" on “solar technology“ since 2008, photovoltaics continue to dominate. In the past 12 years, pure solar thermal systems have hardly played a role; nevertheless, hybrid concepts in the roof and/or façade form a large project group with an average of about 21 percent. (Fig. 28)

Looking at the integration measures on the building, the development can be seen, especially since 2008, that pure roof systems (pitched and flat roof) comprise more than half of the projects on average. In view of the large number of façade systems (almost 20 percent) in the competition over the past 20 years, the state of the art and, at least in the case of the award-winning projects, design and construction ambition can be clearly demonstrated. (Fig. 29)

To participate in the competition, in addition to general author's declarations, information about the system components as well as detailed technical descriptions of the solar system, type of installation with technical details of the building integration, electrical or thermal output and annual yield up to the contribution of the solar systems to the energy supply of the building as well as the environmental effect are requested. In practice, only little such substantial information can be found in the documents.

Many award winners and projects from the “shortlist“ are often “one-offs“ in which the players involved are breaking new ground both aesthetically and technically. In order to be able to recognize these impulses for the topic in a timely manner, the verifiable first energy delivery of the systems must generally have taken place within a period of three and a half years from the announcement of the competition, i.e. the competition takes into account projects that have only recently been completed. However, since the competition organizer is unable to provide a subsequent evaluation of any building monitoring measures, no information or experience is available on possible operating and maintenance problems in these pilot projects.

One challenge, meanwhile, is still the broad impact. As can be seen from the submissions for the 2020 competition, slightly more than three quarters of the projects come from Germany and Switzerland, supplemented by a few entries from Austria. Since 2008, German-speaking (D-A-CH: Germany, Austria, Switzerland) countries have again dominated the Architecture Award competition, accounting for a good three-quarters of the entries;; the increase in projects from Switzerland is clearly noticeable here. Among the international entries, there is a pleasingly noteworthy range of between 20 and 30 % of the submissions, whereby the country focuses within the competitions also shift again and again. (Fig. 30) The goal for subsequent competitions is to actually attract even more participants from all over the world to take part.

For decades, building culture has been a seemingly negligible factor in the everyday life of many countries. Here, architects are the decisive professional group to further develop the numerous positive examples and to try out new approaches. This also applies in particular to building-integrated solar technology. It is therefore particularly pleasing that the orientation of the competition is confirmed among the entrants. Within the “planners“ group, which also includes employees of building authorities and engineers, architects are by far the largest group with an average of 57 percent; in 2017 and 2020, numerous engineers also participated (12 and 17 percent, respectively).

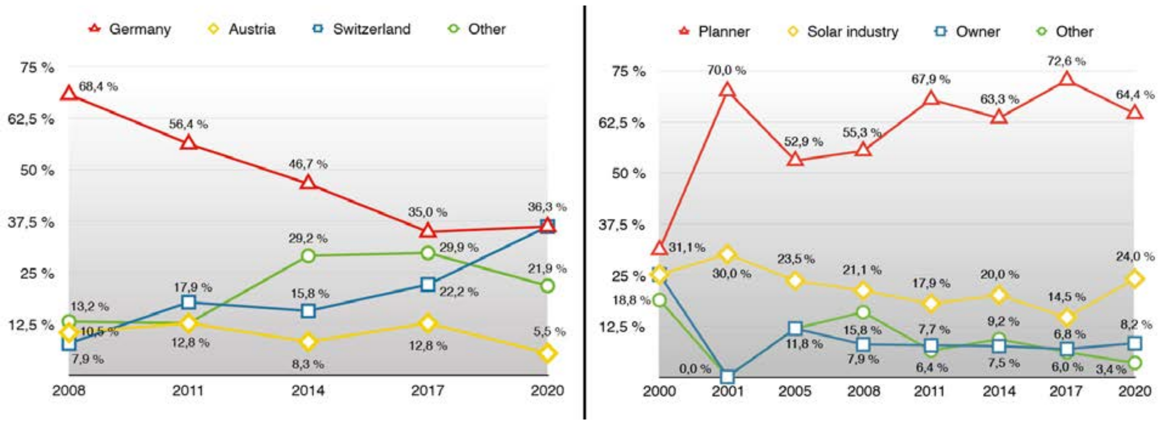

Fig. 30/31: Locations of the submitted projects (left) and submitters by group of persons and industry sector (right)

In the 2020 competition, the solar industry's stronger presence in the market is also reflected in almost a quarter of the submissions. (Fig. 31)

The current challenges, such as the energy transition and the climate crisis, require creative designers and technically competent planners in equal measure. It is a matter of daring the adventure of solar architecture, worldwide at the most diverse locations and in the most diverse climatic regions (Fig. 36-39), on a qualitative as well as quantitative level. This task is supported by the “Architectural Award Building Integrated Solar Technology“, which has established itself worldwide with a unique selling point in the field of the interface between architecture and solar technology, with important educational and informational work. (Krippner (ed.), 2017)

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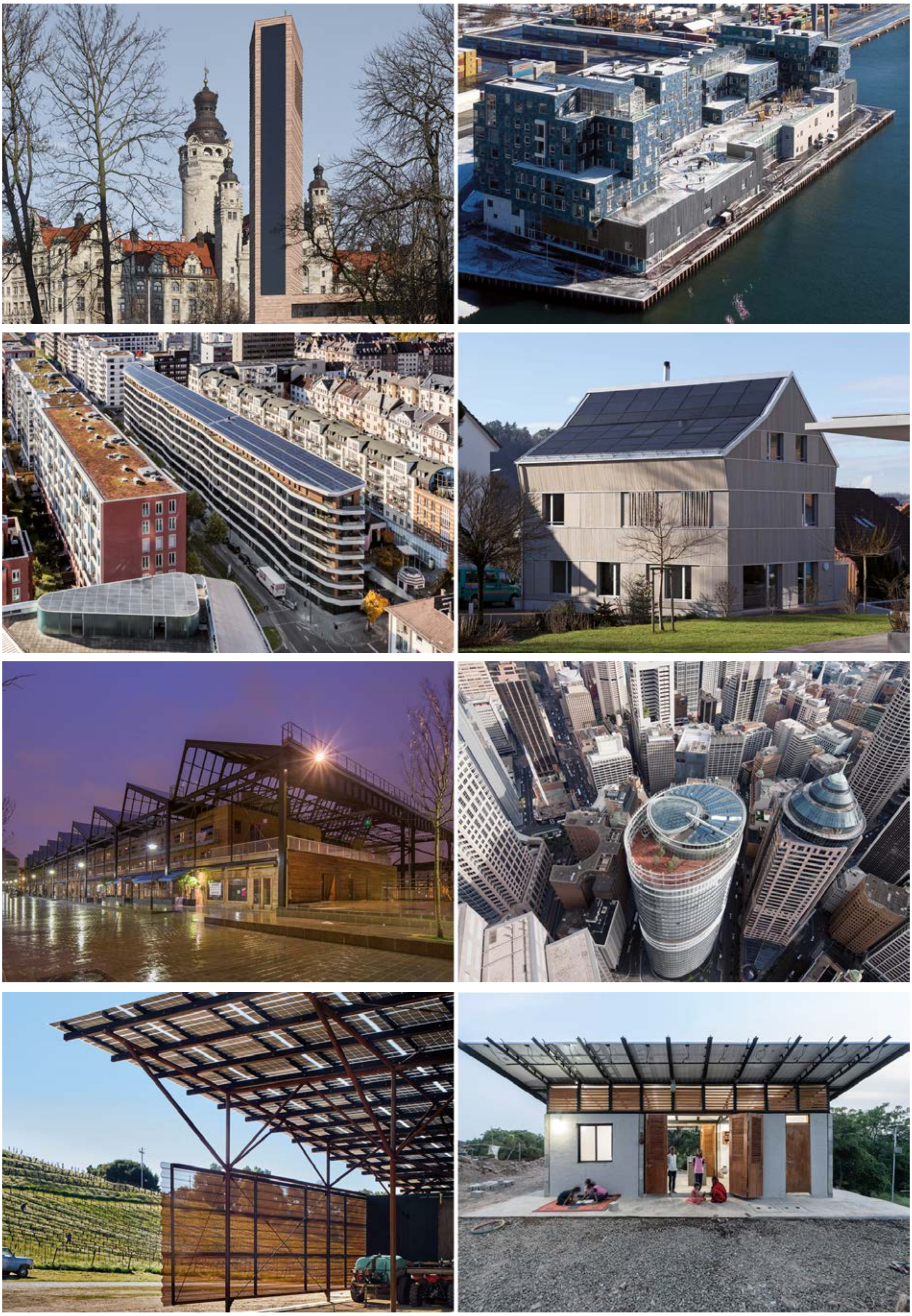

Fig. 32/33/34/359/36/37/38/39: (first row) St. Trinitatis, Leipzig (2014), Schulz und Schulz (left) and Copenhagen International School, Nordhavn (2017), C. F. Moeller Architects (right); (second row) Mühlfeldbräu, Bad Tölz (2009), Lichtblau Architekten (left) and Aktiv-Stadthaus, Frankfurt (2015), HHS Planer + Architekten (right); (third row) Halle Pajol, Paris (2013), Jourda Architectes (legt) and 1 Bligh, Sydney (2011), Ingenhoven Architects (right); (fourth row) Saxum Vineyard Equipment Barn, Paso Robles (2018), Clayton Korte Architects (left) and PowerHYDE, Mathjalgaon (2019), Architecture Brio (right)

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Credits (Photos)

Fig. 1/2: Roland Krippner
Fig. 3: Universitätsbauamt Erlangen
Fig. 4: pmp Architekten
Fig. 5: Rolf + Hotz Architekten
Fig. 6: Willy Kracher
Fig. 7: Deppisch Architekten
Fig. 8: René Schmid Architekten
Fig. 9: Brigida González
Fig. 10: Christian Aschman
Fig. 11: Tina Volz
Fig. 12: Eibe Sönnecken
Fig. 13: Halle 58
Fig. 14: Stadtwerke Bad Wörishofen
Fig. 15: Ackermann Architekten
Fig. 16: SJ Planungsges.
Fig. 17: SunTechnics
Fig. 18: opus Architekten
Fig. 19: Planeco
Fig. 20: Kämpfen Zinke + Partner
Fig. 21: Beat Bühler
Fig. 22: Verena Herzog-Loibl
Fig. 23: René Schmid Architekten
Fig. 24: Constantin Meyer
Fig. 25: Richter Dahl Rocha
Fig. 26: JMCBerlanga
Fig. 27: Daniele Domenicali
Fig. 28-31: Roland Krippner
Fig. 32: Stefan Müller
Fig. 33: Adam Moerk
Fig. 34: Constantin Meyer
Fig. 35: Mirlo Urbano Architekten
Fig. 36: Jourda Architectes,
Fig. 37: Ingenhoven Architects
Fig. 38: Casey Dunn
Fig. 39: India PHX Sebastian Zachariah