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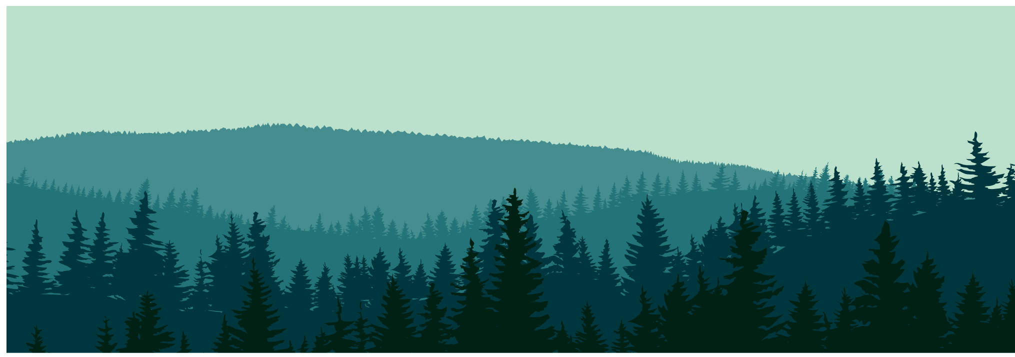

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"It Would Be a Shame if We Did Not Take Advantage of the Spirit of the Times ..."

An Analysis of Prospects and Barriers of Building Integrated Photovoltaics

Adoption of building integrated photovoltaics is slow. Nevertheless, expectations of experts are running high that markets will grow. Moreover, the technology is likely to gain considerable momentum with the new European Building Directive.

Johann Koinegg, Thomas Brudermann, Alfred Posch, Maximilian Mrotzek

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Abstract
Building integrated photovoltaics, a special form of photovoltaics, is still a niche market with a relatively low number of installations worldwide. Although it is considered a promising technology, especially in Europe where land for large-scale photovoltaic plants is rare, several factors continue to constrain its widespread adoption. This paper investigates the prospects for, and barriers to, building integrated photovoltaics adoption in the European context, building on a series of interviews with experts in the field. The results indicate that the main problems relate to cost calculations, to the existing gap between the photovoltaic and the building industry, and to the lack of expertise and knowledge concerning the potential of the technology among important stakeholders. However, with the implementation of the new *European Building Directive* 2010/31/EU that demands "nearly zero-energy buildings" by 2020, building integrated photovoltaics is likely to gain considerable momentum.

Keywords
building industry, European Building Directive, photovoltaic industry, zero-energy buildings

Great Potentials, Slow Adoption

Within the last few years, photovoltaics (PV) as a relatively young technology has received a lot of support in the form of guaranteed feed-in tariffs and other forms of subsidies in different European countries, especially in Germany. This has led to extremely fast growth in the market for PV and has helped to bring down the cost of PV installations to a competitive level. The European PV sector now generates considerable revenue and employment. Using the sun as "fuel" means that PV costs are likely to decline further and the potential for sectoral growth appears to be enormous. PV is well on the way to making a major contribution to European and global energy supply.

One special field of photovoltaics application is building integrated photovoltaics (BIPV). Integrating photovoltaic modules into a façade or other part of a building structure is relatively straightforward. As an integrated module can substitute for other materials, the cost reductions so achieved can contribute to improving overall efficiencies for the photovoltaic system (Jelle et al. 2012). In addition, glass-glass modules can perform several functions simultaneously, for example, heat insulation, noise protection, weather protection, provision of shade, etc. They also offer several aesthetic possibilities. Figure 1 (p. 40) illustrates potential applications. Buildings engage in decentralised electricity generation, and in contrast to large-scale PV plants there is no need to deprive other sectors, such as agriculture, of land. As land is a relatively scarce resource in many European countries, BIPV thus appears to be a promising alternative (or complement) to large-scale operations (Nordmann 1997).

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Contact: *Johann Koinegg, M. S.* | E-Mail: johann.koinegg@inode.at

Dipl.-Ing. Dr. Thomas Brudermann (corresponding author) |
Tel.: +43 316 3807336 | E-Mail: thomas.brudermann@uni-graz.at

Prof. Dr. Alfred Posch | E-Mail: alfred.posch@uni-graz.at

Dr. Maximilian Mrotzek | E-Mail: maximilian.mrotzek@uni-graz.at

all: University of Graz | Institute of Systems Sciences, Innovation and Sustainability Research (ISIS) | Merangasse 18/I | 8010 Graz | Austria

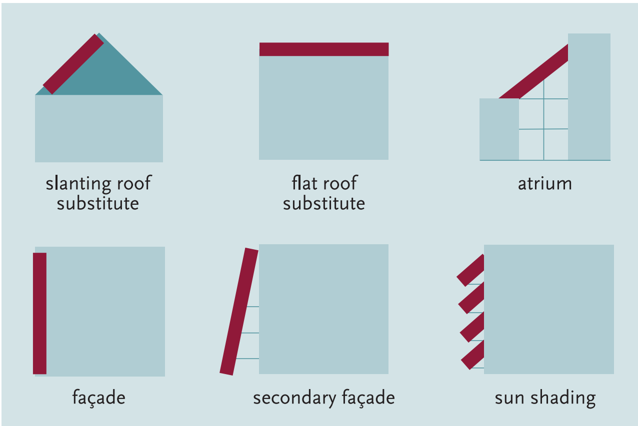


FIGURE 1: Possible applications for BIPV in roofs and façades (based on Fechner et al. 2009).

The potential for BIPV needs to be considered within the context of the new *European Building Directive* from 2010 (Directive 2010/31/EU), which is of special relevance with respect to achieving European renewable energy goals. The directive aims at improving the energy performance of buildings within the European Union (EU). Today, the building sector accounts for roughly 40 percent of total energy consumption. The directive also suggests the use of renewable energy sources for buildings: Article 9 states that all new buildings in the EU have to meet the requirements for "nearly zero-energy" buildings by the end of 2020.[1] If possible, the minimal energy still required should originate from renewable sources ideally situated on or near the building. While the directive lays more emphasis on the need for a life-cycle approach when considering building energy requirements, the European Commission continues to harbour reservations with respect to the development of a power sector based completely on renewables (Hey 2012).

A report of the International Energy Agency (IEA 2002) indicates that huge potential is available for electricity production in buildings with PV and BIPV once one considers the available façade and rooftop areas and the respective levels of irradiation. As calculations show, up to one third of electricity consumption could be met by PV and/or BIPV. A recent study on the technical potential for photovoltaics on buildings in the EU-27 (Defaix et al. 2012) concluded that 22 percent of the expected European 2030 annual electricity demand could be generated via BIPV. This is a major argument in favour of BIPV. In countries where wind energy is limited and/or space for large-scale PV plants is scarce, BIPV represents an interesting alternative in renewable energy production.

Energy payback times of PV systems are currently calculated to be approximately 1.5 to 2.5 years. The expected future developments in module efficiency and production technology indicate that payback time is likely to decrease to less than one year (Fthenakis and Kim 2011). In comparison, the yield for BIPV is lower, energy payback times are thus higher (Lu and Yang 2010, Hammond et al. 2012).[2] In fact, they still remain way below module lifetime, which usually is guaranteed to be 20 to 25 years. However, when cost calculations are adjusted to take account of substitution effects, synergy effects, etc., BIPV can become justifiable in terms of both cost and carbon footprint, even today (James et al. 2009).

Though prospects look good, the diffusion process of BIPV is slow. Apart from design or technical constraints (Scognamiglio and Røstvik forthcoming), there are several other factors that hinder the adoption of BIPV. The aim of this paper is therefore to systematically analyse how experts see the overall development potential of BIPV and what can be learned from existing projects. With a focus on façade and shading applications (figure 1, second row), our main research questions are as follows:

- What barriers and problems arise concerning an increased use of BIPV systems?
- How do experts and practitioners anticipate future developments in this field?
- Which role does the *European Building Directive* play in the diffusion of BIPV?

First, we provide details of our methodological approach and our sample. We then present the results of the interviews by ordering them thematically. In conclusion, we offer a system-theoretical discussion of the outcome of our study.

Methods and Study Design

The need to establish a suitable link between the PV industry and the construction industry is critical when attempting to implement BIPV projects. In a BIPV project, planners, installers, building developers, architects, module producers and end users all have to collaborate closely in order to be effective. The necessary channelling or distribution structures are quite different to those used in standard PV, as indicated in figure 2.

We used the structure in figure 2 as a starting point for our research design and conducted semi-structured interviews with experts and practitioners representing these fields. Additionally, we interviewed experts from governmental and research institutions. Some of the 18 interviewees were able to represent several fields simultaneously. The study hence offers a rather broad view on the topic. However, the sample is clearly biased in terms of nationality, since all but two interviewees were Austrian. Compared to standard PV, BIPV so far is less dependent on national characteristics, especially in terms of solar radiation and subsidies, because the purpose of BIPV is not only to produce energy,

1 In this context, "zero energy" does not equal autarky, but balance between electricity drawn from and fed into the grid. Buildings owned by public authorities have to meet the requirement by the end of 2018.

2 Hammond et al. (2011) calculated an energy payback time of 4.5 years for a specific BIPV roof tile system in the UK. Taking into consideration the embodied energy of all system components, a time of 7.3 years was calculated for a roof-mounted BIPV system installed in Hong Kong and of 13.3 years for a south-facing façade installation in the same location (Lu and Yang 2010).

but also to substitute other construction materials – and/or aesthetic aspects. We thus consider our results to be of relevance for other EU member states as well. As all interviewees are in some respect connected with the field of PV, it is not surprising to notice that they have a very positive attitude towards the technology. This has to be borne in mind when interpreting the results.

The interview guidelines were established on the basis of insights gained from earlier studies and reports as well as on key assumptions derived from the literature mentioned above. The nature of the topic led us to choose a qualitative approach. Quantitative studies only make sense at later stages of BIPV diffusion. All interviews were recorded and transcribed in order to facilitate qualitative content analysis.

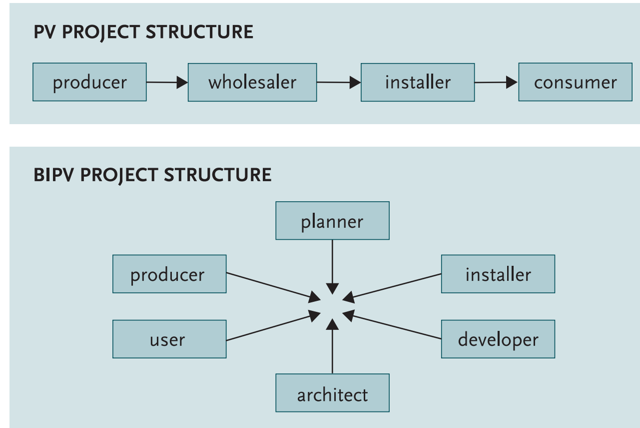


FIGURE 2: Linear structure of PV projects versus open structure of BIPV projects (based on Fechner et al. 2009).

Diffusion of BIPV: Prospects and Barriers

In the following, the results of the interviews are summarised, organising them along five major topics: cost issues, local value generation, the gap between PV and building industry, the role of the *EU Building Directive,* and additional aspects of BIPV adoption.

BIPV and the Cost Argument

BIPV is still a niche product. Despite its potential, existing applications are mostly limited to showcase or prestige projects where builders and other stakeholders may be motivated by considerations other than pure cost effectiveness (e.g., the desire to demonstrate a green image). While such projects are generally considered to be important for the development of the BIPV market as a whole, some interviewees point out their down side: more often than not they tend to indicate that BIPV is not beneficial in financial terms when in reality financial benefits can be quite possible.

Cost is obviously a major concern when it comes to the adoption of a new technology such as BIPV. However, system prices are not as high as it is generally perceived; some calculations already show that BIPV can be an appealing alternative to other types of façade. As one expert from academia stated, prices of approximately 600 euros per square metre for simple glass, ceramic or simple stone façades are not very different from the cost of a PV façade at about 700 to 800 euros. Polished stone façades are priced at well over 1,000 euros, and their high weight often leads to problems in statics. Here, BIPV is likely to be a cheaper alternative. Another expert confirmed that BIPV may be indeed advantageous, though he added that ordinary glass façades are still considerably cheaper. However, the benefits of a PV façade in terms of electricity yield are not included in this comparative calculation.

In successful projects either money did not play a role or the PV façade was already cheaper than the other options under consideration (e.g., polished stone). Whatever the case, by its very nature façade construction lies at the end of the building process. Where financial resources are limited from the beginning, the situation can hardly improve as the project proceeds, and the temptation to cut BIPV installation altogether is likely to become ever greater as the project proceeds. In larger investor projects, regardless of whether they concerned new construction or refurbishment, the most frequent cause of project failure was excessive cost. In contrast, for smaller projects, where the idea for BIPV normally comes from an architect, nearly all projects achieve completion. Where BIPV is largely motivated by the desire to demonstrate "greenness", projects are often scaled down such that PV modules take up only a few square meters of the façade or roof.

The question of aesthetics also seems to be important for BIPV and the cost argument. In a standard PV system, the focus lies on energy production, while doing one's best not to spoil the appearance of the building on which the system is applied. In BIPV applications, aesthetic considerations play a much more crucial role. Unfortunately, there is often a conflict between the desire to meet aesthetic requirements and the desire to maximise the energy yield generated by the system. This has a clear impact on cost efficiencies. When asked for their opinions regarding the right balance between yield and aesthetics, experts unanimously stated that, while system appearance has to be taken into account in all cases, finding the "correct" balance will vary from case to case. Some users of BIPV prioritise yield characteristics, while others are willing to sacrifice some fraction of yield in order to gain what they consider to be a more pleasing appearance. Such deliberations can hardly be mapped in purely financial terms.

The Importance of BIPV for Local Markets

One expert in our sample points out that policy makers need to show considerable interest in BIPV. After all, whether to support small-scale PV or large-scale projects is a decision which has a direct bearing on value creation in the PV industry. When building a large-scale PV plant, modules and other BOS (Balance of System) components are more likely to be imported from low-income countries, whereas smaller individual projects lead to the use of more components from local industries.

As the costs for glass-glass modules and the price of all the BOS components are higher than for standard PV, development of the BIPV market requires a higher level of financial support. An expert from the *Austrian Climate and Energy Fund* sees a close >

link between success in PV and success in BIPV. When PV is doing well, BIPV also does well. The *Climate and Energy Fund* places special emphasis on BIPV, since the home economy derives relatively more benefit from such projects, and a country like Austria could play a key role in this niche segment. Another expert stated that this is exactly why, in small countries, the focus of funding schemes should be completely on building integration rather than on standard PV. Although from the point of view of energy policy, such a limited form of support is not at all desirable, the attempt to strengthen a specific location by targeting such a niche segment does appear to be quite a natural response.

According to the complaints of an expert from a PV company, funding policy is, however, not always consistent with the need for higher support for BIPV. For example, regulations in Vienna require of a PV system an electricity output of 900 kilowatt-hours per kilowatt-peak in order to be eligible for direct support. Such a performance is almost impossible in a façade, thus making such an alternative financially unattractive.

BIPV between Two Chairs

BIPV projects require close cooperation between two distinct, but as yet unrelated industries: the building industry and the PV industry. The experts interviewed acknowledged this division to be in fact one of the most important issues that needs to be addressed in order to foster the BIPV market.

One of the main problems is simply the lack of mutual understanding and knowledge concerning everyday practice. All interviewees agree that communication and professional exchange are crucial in this context. The practice of implementation offers a good example. The PV industry persists in trying to use existing products in construction projects, despite their numerous constraints (in terms of size and appearance). The building industry would much prefer to see the PV industry design new products in façade or roof applications, which are devoid of such constraints and resemble products common in the glass industry they are used to work with. Some module manufacturers have now begun to address this issue and are attempting to develop a market niche by introducing customised modules for building integration.

All in all, the players in the BIPV market still have to learn how the respective partner industries work and what their needs are. Many actors in the building industry are not yet aware of the full potential of BIPV products and, according to experts in the PV industry, they remain very sceptical. One representative of a major construction conglomerate did nevertheless mention that the building industry could be quite open to BIPV, if only the architects and potential users would demand it.

Additionally, the building industry is described as being very inert and as lacking sufficient innovative drive. According to the architects and façade constructors in our sample, companies in this business simply prefer to continue building, using the same tried and tested techniques they have always used. An example is the experience gained during the emergence of passive houses. The new technology and new construction techniques led to initial fear and uncertainty in the early stages of development. Potential customers remained highly sceptical. But as time passed and innovators built passive houses which actually worked, a considerable market emerged and prices subsequently fell.

Apart from the need for greater cross-sectoral information exchange, showcase projects, like the Saubermacher headquarter (figure 3), are also of particular importance, since they serve to make the technology tangible for both experts and a wider public audience. Considerable effort, time and information exchange are all essential in order to bring the PV and the building industry closer together.

The second major problem is the planning and construction process itself. As a result of their practical experience, architects and façade constructors are particularly aware of it. A new trade is needed in the process of construction when BIPV comes into play. As the construction industry already has to deal with problems concerning time and money constraints as well as with logistical issues, they are not in a favourable position to accept the demands of organising a new trade. Here, façade constructors, and in particular specialised planning offices, are of major importance. The planning offices can bundle the issues facing both industry branches and help deal with problems arising at various interfaces.

The interface and information problems are likely to diminish, as time passes. If the market for building integration grows due to increasing demand, and assuming changes to existing legal frameworks will enable the technology to spread, the construction industry will eventually learn to use the new BIPV technology. According to two experts, the big Austrian construction companies are already closely following developments regarding BIPV and intend to be active in this segment. It is just not the right time for them yet.

A third crucial problem emerges from the different standards and regulations currently existing in the building and in the PV industries. The PV industry has to comply with norms concerning module manufacturing, the building industry has to comply with norms concerning construction. There are no interconnections. Hence BIPV has to comply with electro-technical standards but at the same time be compatible with existing building codes and specific safety requirements. Additional complexity results from varying building codes and regulations between different countries. Attempts to develop universal European standards are not yet complete.

However, among our interviewees a certain amount of controversy reigned concerning the importance or necessity of BIPV standards. While academics see the need for more standards, practitioners view the absence of regulations and standards as far from being a market barrier. Some are even glad about the lack of comprehensive norms, since they believe that such standards would in fact impede the realisation of various projects. The claim that projects may not be realised due to the lack of standards is explicitly rejected by several experts. Decisions on implementation of BIPV projects are mostly made on a case-by-case basis, since questions concerning statics are a crucial point. A structural engineer has to evaluate the particular project and decide which materials and glass thicknesses are needed. Only then the module manufacturer can produce the right modules.

One product manager of a steel building company stressed the fact that knowledge about the technology is the only key factor: "[A BIPV module] is a standard building component like a window or a door. Actually a window is more complex in this respect".

The Role of the *European Building Directive*

What effect will the new *European Building Directive* (Directive 2010/31/EU 2010) have on the adoption on BIPV? Most interviewees agree that the directive[3] is very ambitious and can be expected to have a significant impact on the building landscape as well as on renewable energies as a whole. However, it is likely to take several years before the full impact is felt.

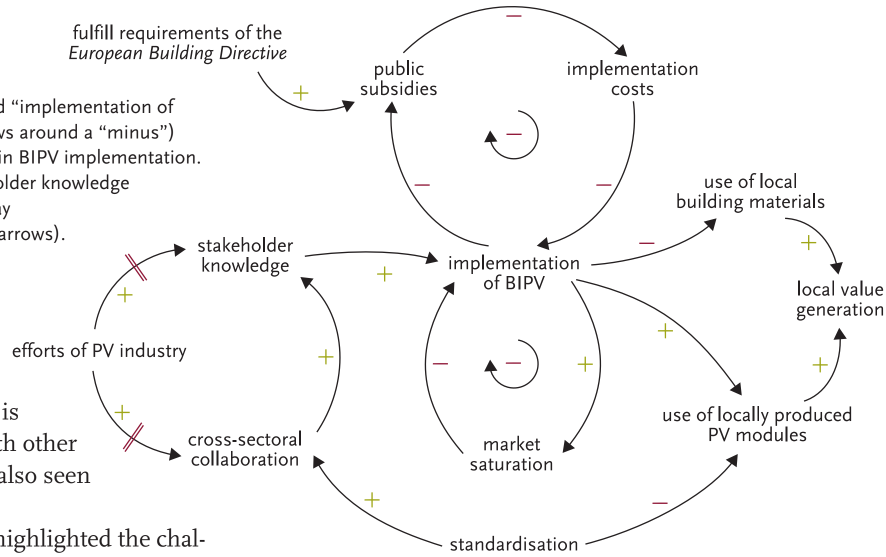
Some parts of the directive are considered to provide too much leeway in that they allow for fairly generous interpretation. For example, the term "near zero" is considered to be too vague and possibly dangerous, because it may become subject to manipulation. As previously observed, similar objectives were often picked to pieces and delayed by the member states – for example, the 2002 *EU Directive on the Energy Performance of Buildings* (Directive 2002/91/EC 2002). The new directive still has to be translated and implemented into national laws. While some member states have a tradition of "watering down" European directives, implementation is unavoidable in the end. Based on prior experience, it is likely that time limits will be stretched as long as possible. As already mentioned, the slowness of the construction industry together with the relative lack of institutional standardisation are both obstacles in terms of speeding up implementation.

When it comes to zero-energy housing, active energy production is required. While it is possible to design a building in such a way that passive energy is sufficient to fulfill the requirements for heating, this is not true with respect to meeting the demand for electricity. Even if electricity-saving measures are implemented, electricity for the building still has to be produced somehow. For this reason, all interviewees see renewable sectors such as wind, geothermal, solar thermal and PV as being beneficiaries of the building directive. It is further desirable to focus on more than just one or two technologies. Whether a technology is appropriate depends on various factors, for example, the available natural potential or the use of the building. However, our interviewees regard PV as central, since it is – integrated or not – the only tech-

3 The question whether the directive would foster the utilisation of BIPV was dealt with by asking the interviewees to describe their experience regarding other building directives as well as their general assumptions. The interviewees were given a short description of the content of the directive during the talk. They were in general familiar with it, but not always in detail.

FIGURE 3: BIPV installation at the headquarters of Saubermacher Dienstleistungs AG, a private waste disposal company, near Graz, Austria.

FIGURE 4: The *Causal Loop Diagram* systemises prospects and barriers of BIPV diffusion. The two balancing feedback loops "public subsidies – implementation costs – implementation of BIPV" and "implementation of BIPV – market saturation" (indicated by circular arrows around a "minus") have a stabilising effect and hinder excessive growth in BIPV implementation. The efforts of the PV industry positively affect stakeholder knowledge and cross-sectoral collaboration, albeit with time delay (represented by delay marks – dashes – in these two arrows).



nology possible for many buildings. In particular, office buildings, which exhibit very high daytime electricity consumption, are an area where PV definitely is the best option. The combination of PV with other technologies, for example, heat pumps, is also seen as a desirable solution.

A managing director of a PV company highlighted the challenges faced in conurbations where buildings are built very close to each other and have a high effective area in relation to the surface area. BIPV is of particular significance here, as there is no choice but to use the façade to produce energy. However, zero-energy or plus-energy houses in congested urban areas are hard to achieve.

As questions concerning implementation possibilities, performance calculations and cost optimisation are still open, lobbying for PV is going to be essential according to some experts in our sample. In their opinion, interest groups rather than single companies have to take on this task. As one project manager put it: "No industry can sit back passively and wait for things to fall into their lap".

Additional Aspects of BIPV Adoption

According to the interviewees, it is imperative that BIPV be considered right from the very beginning of any project. Those projects that did not reach fruition nearly always failed as a result of introducing the idea of building integration at too late a stage of the project life. This created immediate problems with respect to dealing with the various interfaces between the trades. As one interviewee pointed out, "in 99 percent of all cases" buildings are designed without any consideration of energy issues. When in a later stage of the project somebody comes up with the idea of implementing BIPV, it is doomed to fail. As architects and planners often simply lack sufficient knowledge concerning the technical and economic possibilities of BIPV, it is mostly not even considered in the process of planning a new building.

Technically, the integration of a PV glass-glass module into a façade or a roof is no longer a problem. The module technology is mature. Installation, apart from cabling and some other minor points, is now a standard procedure and not much different from normal façade construction.

When asked to identify the initiator behind BIPV, the interviewees named architects as the major driving force over the last five years. Unfortunately, there are only a handful of architects in Austria who have sufficient expertise in the field and who put emphasis on sustainable architecture. Recently, the desire for BIPV has started to emerge among building owners, developers and investors. Interest in the technology is clearly growing.

Promising Future: The *European Building Directive* and Growing Markets

Developments in BIPV cannot be viewed separately from developments in the PV sector as a whole. Both are likely to profit when the new version of the *European Building Directive* on energy-efficient buildings is implemented. Given the characteristics of Europe in terms of population density and land availability, there is clearly a huge potential for BIPV. It can be a highly attractive solution, in particular for office buildings, where daytime electricity demand is high. For residential buildings, additional forms of electricity production or short-time storage systems will be needed in order to meet electricity demand in the evening hours.

From a systems science perspective, the *Causal Loop Diagram (CLD,* figure 4) systemises the main results of our study. The realisation of BIPV projects is associated with high initial costs and this is a major barrier to adoption in practice. But system prices are falling continuously. BOS costs make up a very high share in BIPV projects and are expected to decrease rapidly once a significant market has developed. Respective subsidies, which can be expected to be introduced as the new *European Building Directive* comes into effect, might also help to solve the cost issue. In later stages of BIPV diffusion, subsidies are likely to decrease again.

The price argument is not the sole obstacle to increased use of BIPV. Lack of expertise and knowledge among stakeholders are also a great problem. The key players involved in the beginning of the planning process – particularly architects and project developers – have to be informed in depth regarding the possibilities of BIPV. The fact that PV integration is often not considered until too late a stage in the building process is a further factor dampening market development. To overcome this problem, increased cooperation between the building and the PV industry is clearly necessary. Indeed, considerable effort is currently being made in this direction. These efforts will eventually close the gap between the industries and increase knowledge about the possibilities of BIPV. After all, information transfer and cross-sectoral collaboration are of crucial importance in the development of BIPV.

The possibility of substituting BIPV modules for standard construction materials means that they may be associated with certain cost advantages. This serves to contribute to the view of BIPV being an important and acceptable technology. This view also emerges, because BIPV is much more individual than standard PV, leading to significantly higher local value creation. However, these claims have to be seen critically, as BIPV modules might well replace building materials, which are locally produced, too. Moreover, ongoing international standardisation attempts will eventually lead to module standards. Although the issue is seen controversially by practitioners, standardisation is very likely to facilitate cross-sectoral collaboration. At the same time, standardisation might reduce the use of locally produced modules, resulting in a decrease of local value generation.

The variable "stakeholder knowledge" includes knowledge of users about BIPV, knowledge of architects about how to design buildings considering BIPV, and knowledge of builders on how to implement BIPV. All these aspects will contribute to increased adoption rates. Other aspects are not explicitly considered in the *CLD,* such as the decrease in implementation costs as products and processes mature as well as the role of word of mouth and marketing in the diffusion process. The effects BIPV adoption will have on the electricity mix and the challenges decentralised electricity generation brings along for grid operators, are also beyond the scope of this paper.

Despite the problems mentioned above, our analysis reveals that the market for BIPV is expected to grow considerably in the near future, mainly due to increasing knowledge about technology and projected cost reductions. Currently, feelings of optimism and creativity appear to be dominant among the players in the field. The prevalent mood can be described in the words of one interviewed façade constructor: "It would be a shame if we did not take advantage of the spirit of the times. It shows us again and again that there is no future in fossil fuels".

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Johann Koinegg

Born 1981 in Graz, Austria. Bachelor in environmental systems sciences, 2012 joint master's degree in Sustainable Development from the University of Graz. Research interests: building integrated photovoltaics, green innovation and the adoption of renewable energies.

Thomas Brudermann

Born 1981 in Wolfsberg, Austria. Master in informatics, 2009 PhD in psychology. Since 2011 post-doctoral researcher at the Institute of Systems Sciences, Innovation and Sustainability Research (ISIS), University of Graz. Research interests: decision-making, agent-based modelling and human-environment interactions.

Alfred Posch

Born 1966 in Heiligenkreuz, Austria. Associate Professor at the Institute of Systems Sciences, Innovation and Sustainability Research (ISIS), University of Graz. Working experience in the industry. Research interests: innovation and transition towards sustainability, industrial ecology, transdisciplinary processes of knowledge generation and integration.

Maximilian Mrotzek

Born 1979 in Heidelberg, Germany. Bachelor in business administration, master in industrial engineering, 2009 PhD in mathematics. Since 2010 post-doctoral researcher at the Institute of Systems Sciences, Innovation and Sustainability Research (ISIS), University of Graz. Research interests: resource scarcity (topic) and system dynamics (method).