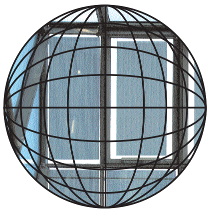


Large ground-mounted photovoltaic plants are increasingly becoming the norm. Yet isn't one of the real benefits of PV the fact that it can be integrated into the fabric of buildings – the ultimate in decentralized generation? **Thomas Nordmann** argues that it is and that photovoltaics should ideally be used in this way.

Built-in future

Integration, technical and market-development issues for PV

In 2004, Germany's popular political weekly magazine *Der Spiegel* launched an attack on the extensive use of wind power, following a discernible shift in public support for that technology.[1] Photovoltaics however, still have considerable support among the public, yet might the technology be opening itself up to criticism regarding land use and aesthetics, as multi-megawatt installations are set up in the fields of Germany?[2] Today, Germany is the European front-runner in the rapid development of the grid-connected photovoltaics market.

Building integrated PV (BIPV) is an application of the technology that has zero land consumption. Yet even under the favourable conditions of Germany's Renewable Energy Sources Act (EEG), which guarantees system owners a good rate of payment for power they feed into the grid, real BIPV accounts for too small a fraction of the market.

> **Building integrated PV is an application of the technology with zero land consumption**

THE SITUATION IN GERMANY AND OTHER IEA COUNTRIES

In the developed world, where there is an existing power grid infrastructure, PV in buildings is regarded as a major application area for photovoltaics. Taking Germany as an example, the PV grid-connected market for 2004 shows dramatic development (Table 1), with a growth rate between 2003 and 2004 of nearly 100%.[4] However, a deeper analysis of the split between the three major market segments (BIPV, roof-mounted PV and ground-mounted PV) shows a real imbalance in market development

TABLE 1. German PV market development

New PV installations in 2004	360 MWp
Total installed capacity by the end of 2004	758 MWp
Number of new installations in 2004	40,000
Market value of new installations in 2004	€1.7 billion
Number of jobs in sector	20,000
New roof-mounted installations in 2004	253 MWp (70%)
New ground-mounted installations in 2004	104 MWp (29%)
New BIPV installations 2004	3 MWp (1%)

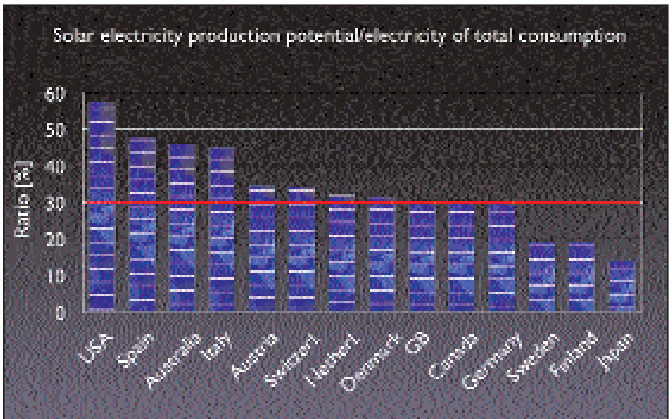
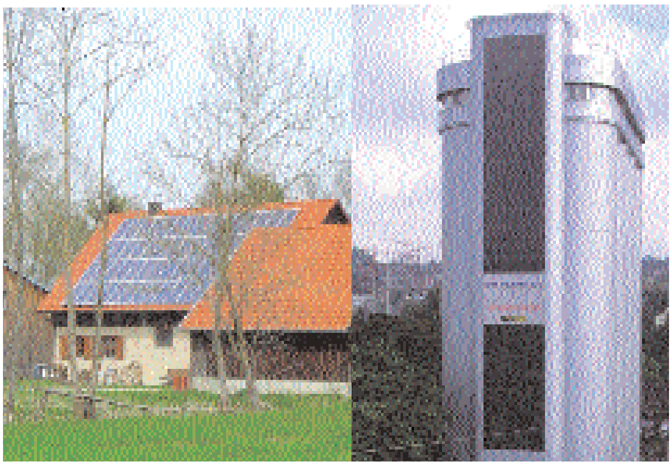


FIGURE 1. Potential for BIPV for selected IEA countries

Photovoltaic glass in the winter garden of a private house in Germany RWE SCHOTT SOLAR



Different systems for integrating PV into buildings

(Table 2). Roof-mounted PV is still in the lead with 70% of the market. With several multi-MW installations, ground-mounted PV

> **PV in buildings is seen as a major application of photovoltaics in the developed world**

is taking a big part of the fast-growing market, occupying 20%–29% in 2004 (and new plants constructed in or announced

TABLE 2. Issues considered in a survey of key European experts – also see Figure 2

Topic	Parameters considered
Cost and economics	Cell and module
	Inverter
	Balance of systems (BOS)
	Project development
	Financial engineering
Technology	Best possible orientation/yield
	Best possible plant size
	Best cell/module technology and size
	Best size of inverter
	Best availability BOS solutions
Market	Highest added value for PV
	Highest market potential for PV
	Best image for client
	Highest relevance for PV industry
	Best market-development incentives
Values	Lowest construction costs
	Lowest market price for investor
	Highest payback price for PV owner
	Highest PV added value
	Least know-how and training needed

for 2005 suggest that this proportion will have increased significantly by the end of 2005). BIPV, in which the photovoltaic elements actually form part of the roof or facades, lags far behind with a market share in Germany of just 1%.[5]

Yet BIPV can deliver much more. The potential for PV in buildings in selected International Energy Agency (IEA) member countries was evaluated by members of 'Task 7 – 'Photovoltaic Power Systems in the Built Environment' of the IEA Photovoltaic Power Systems (IEA PVPS) Programme.[6]

Figure 1 shows the fraction of total national electricity use that could technically be covered by BIPV. That fraction is calculated at over 55% in the case of the US, but the average fraction across all the countries examined is 30%. This represents a very high application target.

The application of BIPV today is still very low; in 13 central European countries (Austria, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden Switzerland and UK), only 0.02 m²/capita of PV is integrated into buildings, in

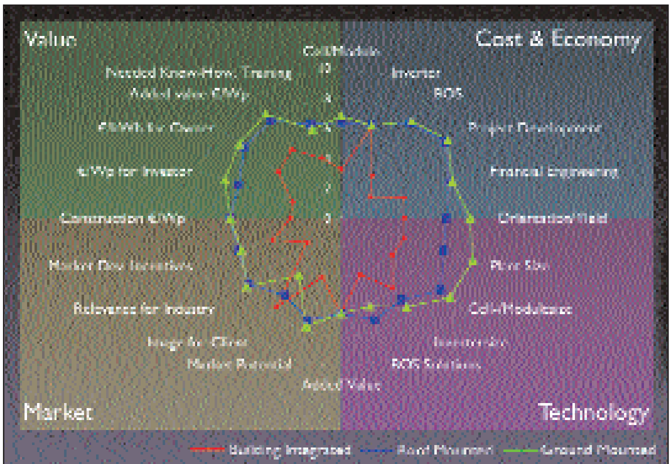


FIGURE 2. Survey findings: investment costs and financial engineering

TABLE 3. The PV 'tower of Babel' – non-standard sizing examples

Brand	Type	Power (Wp)	Length (mm)	Width (mm)	Height (mm)
Sharp	NT 175 EI	175	1575	826	46
BP Solar	BP 7175	175	1593	790	50
Shell Solar	Power Max Ultra 175	175	1613	814	56
Sanyo	HIP-180BE3	180	1319	894	35
RWE Schott Solar	ASE-190 GT-FT	190	1600	800	50

TABLE 4. Investment options for a PV installation of less than 30 kWp located in Freiburg, Germany, in 2004

	Rates (€c/kWh)	Yield/year (kWh/kWp year)	Cash in (€/year kWp)	German market share (%)
Roof-mounted	57.4	850	488	70
Ground-mounted[a]	45.7	900	411	29
Facade-integrated BIPV	62.4	595	371	1

[a] Typically, ground-mounted systems are, of course, larger than 30 kWp, thus this serves only as an illustration

sharp contrast with the 18.5 m²/capita for PV mounted on roofs and 6.5 m²/capita mounted on facades.[7]

THE VIEWS OF PV EXPERTS

Why do we see such unbalanced market development, even under ideal economical conditions as available in Germany today? To help answer this question, a survey was carried out among a small number of key experts in the European PV community, half of whom are PV-dedicated architects.[8] The survey addressed the market segments of BIPV, roof-mounted PV and ground-mounted PV with respect to cost and economics, technology, market and value indicators. The survey examined a number of different parameters (shown in Table 2). Its findings are summarized in Figure 2 on page 238.

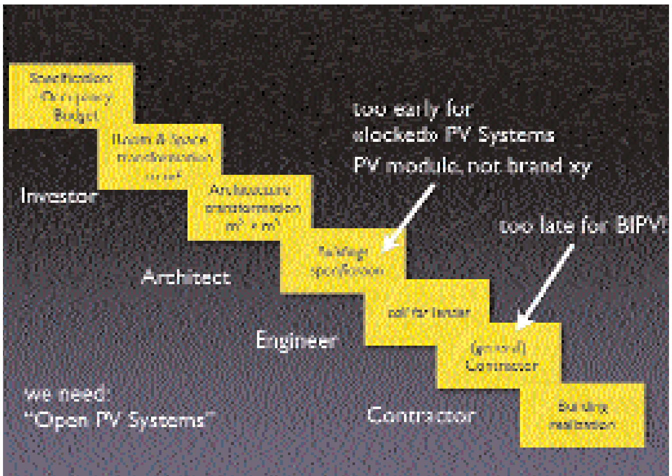


FIGURE 3. The problem of 'locked' PV systems in building processes

The unbalanced situation between BIPV and the other major applications of PV cannot be blamed on one single cause. Comparison of the rating lines (Figure 2) of the three market segments highlights those areas in which there are major differences. BIPV falls far short of roof-mounted and ground-mounted applications with respect to a number of criteria. Three critical cases are discussed below.

> The different suppliers in the PV industry produce and market their modules in non-standard sizes

THREE CRITICAL CASES

Does BIPV share construction costs?

The question highlighted here is the impact of investment costs on project development. Compared with an ordinary roof-mounted installation, which is placed on top of a conventional roof, part of the basic concept of a true BIPV installation is to share the cost of the building envelope because the installation has a double function. Thus the use of solar roofing material, for example, removes the need for conventional roofing material.

But can these double functions actually work in practice? The main potential of double function in the area of balance of systems (BOS) is in the area of module costs and installation costs, where it should be 30% of the total system cost. While

Typical PV roof installation

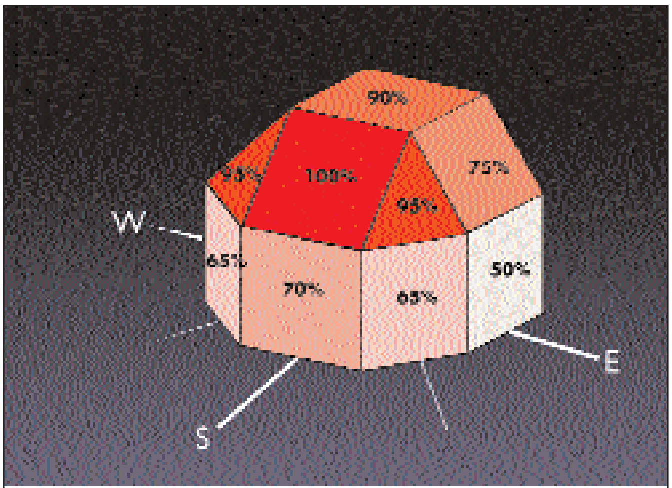


FIGURE 4. The sky is 'tolerant' – efficiency of PV by mounting angle

this overlap of cost can be described theoretically, in practical terms it cannot be achieved in an actual project development.

The dilemma of 'locked' PV systems

The different suppliers in the PV industry produce and market their modules in individual, non-standard sizes. Each company has its own layout depending on the cell type and technology it uses. While they all optimize the physical sizes of the modules to achieve the best 'fill factor', direct comparison of similarly rated modules shows that their physical layout differs by a few centimetres – the modules are *almost* the same, but not *exactly* the same size. This lack of consistency contrasts strongly with the approach of today's construction industry, in which building components are available in standardized dimensions. It demonstrates the immaturity of today's fledgling PV industry.

The approach across most of the building industry is for many elements to be specified by size, then become part of the tendering process. Unfortunately, the PV industry does not allow this procedure to be followed, leading to the dilemma of what I call the dilemma of 'locked' PV systems in the building planning process (Figure 3). This means that PV tends not to be taken into account by the planning team for the tendering process. Because each PV brand has its individual size for modules, the planning team is forced to design its application in favour of a certain product *before* the call for tender. (Non-standard sizing also makes it difficult to replace broken modules during their operating life if their supplier has goes out of business or has changed the sizes again.)

The sky is 'tolerant' – solar radiation on inclined roofs versus facades

In a BIPV application, how effective is a vertical wall facade installation compared with an inclined roof? Maximum available irradiation is received by a roof inclined at the optimum angle for its latitude. Assuming this number is 100%,

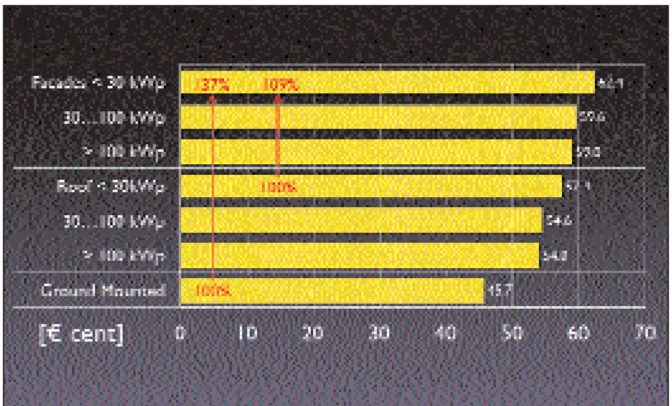


FIGURE 5. German feed-in tariffs for various applications of PV

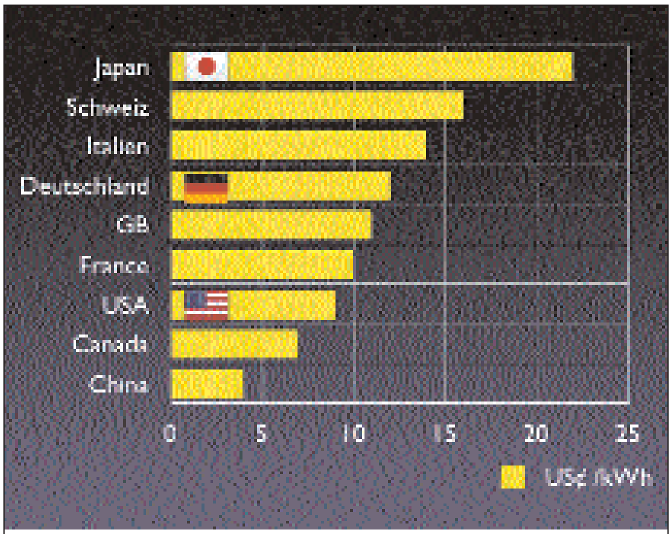


FIGURE 6. Japan has high retail power prices. This helps PV in the domestic market

the amount of radiation received, for example, by a vertical wall facing south would be just 70% (see Figure 4).

However, Germany's EEG law[3] does not compensate fully for this. For, although the difference in radiation – and thus performance – between a roof installation and a facade is 30%, the difference in feed-in tariff between an inclined roof (57.4 Eurocents) and facade (62.4 Eurocents) is only 9% (Table 4, Figure 5). So although facade installations receive a higher rate, this does not compensate well enough to encourage facade installations, as the market demonstrates.

Table 4 compares three investment options for PV plants of less than 30 kWp in Freiburg, southern Germany, in 2004 – for roof-mounted PV, ground-mounted PV and BIPV installations.

THE VALUE OF PV IN A UTILITY GRID

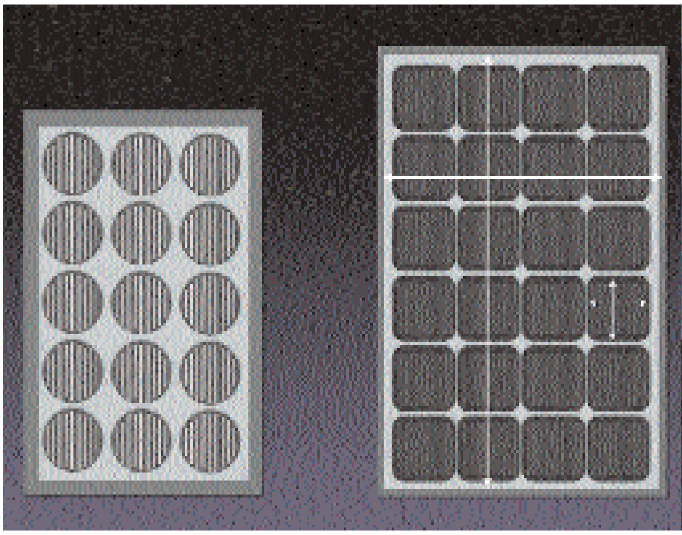
Why is roof-mounted PV or BIPV the better economic approach in the long run? The cost of electrical power delivered to the final power consumer is higher than the cost of centralized generation, because of the costs of transmission and distribution, and transmission losses that occur.

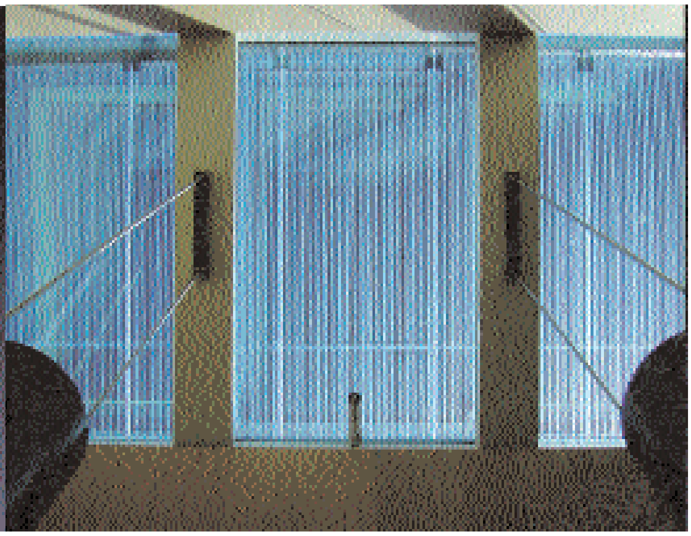
Yet utilities compare the different renewable energies with

> For a specific business case, the cost of reference electricity is as important as the annual available radiation

the centralized electricity only in terms of their production cost. This does not take into account the fact that PV is produced on-site, on the roof of the power consumer. Therefore, the reference price should not be the *production* price for the utility, but rather the price that individual building owners pay for electricity.

The EU spot market price for electric power is around



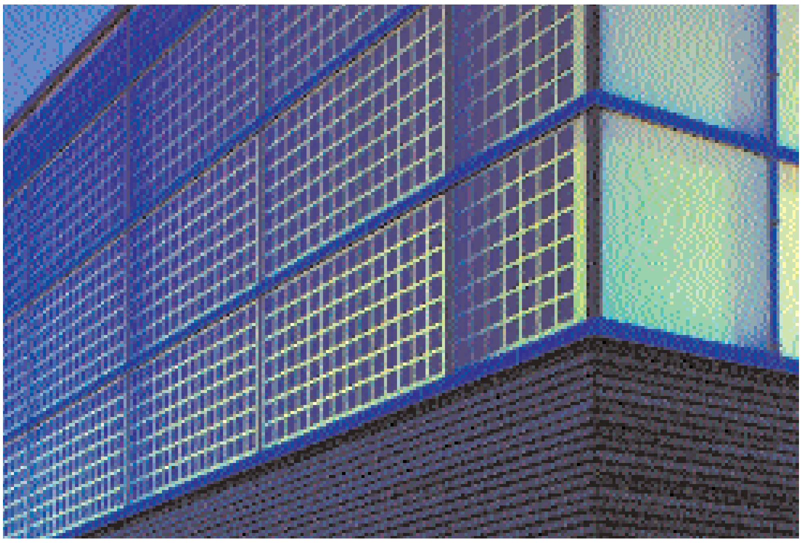


ABOVE LEFT PV module design evolution from the cell to the frame … from inside to outside **ABOVE RIGHT** Glass with integrated PV could soon become standard

three Eurocents/kWh. All the main traditional production technologies are in this range. However, new renewables such as geothermal power or wind may cost 5–15 Eurocents/kWh (Figure 6), depending on location. PV is the most expensive new renewable; for example, electric power costs for PV in Switzerland are equivalent to 40–50 Eurocents/kWh.

In the eyes of a utility, PV appears to cost about 16 times too much (compared with conventional generation of 1 kWh of electricity). In the eyes of the private independent PV power producers – who are customers of the utility as well – the cost of PV is just 3–4 times higher than the price per kWh that appears on the electricity bill). It makes a significant impact if the PV power is produced on the roof of a private independent power producer.

In this context, it is important to note that the kWh prices for private utility consumers vary dramatically. For example, Japan's high price of centrally generated electricity is another reason why it has developed a robust domestic PV market with relatively low subsidies from the government. In a worldwide comparison, Japanese private power consumers have to pay the highest rates (Figure 6).[8] Thus, when calculating a specific



ABOVE Typical BIPV installation **FACING PAGE** Until relatively recently, glass was seen as a luxury for the wealthy. PV is in the same stage of its development.

business case for PV, the reference cost of electricity is as important as the annual available radiation.

THE DEVELOPMENT OF BIPV

The PV industry has made dramatic progress over the last 15 years towards building-integrated solutions for inclined roofs, flat roofs and facades, and for using glass as a part of the roof or a shading device.

IN CONCLUSION

Satisfying 30–60% of our electricity demand with building-integrated PV would be easy to do. It represents a mere 2% extra of building investment. The way we make and integrate BIPV modules is still evolving. We need economic and technological progress in all three market segments – roof-mounted PV, ground-mounted PV and BIPV.

The PV industry thinks in kWp, but the building industry thinks and plans in square metres, and I am sure we are not talking the same language. Today, the industry is offering what I call 'locked' PV systems. Tomorrow, for the building industry, we need 'open' PV systems. I urge the European Photovoltaic Industry Association (EPIA) and other organizations to encourage the production of not just standard-sized modules but modules that will fit in with other industries that use – or could use – PV systems.

The PV industry is on its way and is working hard to make PV the perfect companion for a low or zero-energy building. However, we have to be careful with quality and performance. A sustainable energy source needs a sustainable product and solution. Where feed-in tariffs are established, it is important for them to take into account the yield from facades.

I believe that, with ongoing economic progress, roof-mounted PV and BIPV installations will be the next hot 'multi-gigawatt' targets. In the next 5–7 years, these installations will become cost-effective in southern Europe – even without rate-based incentives for many private electricity users.

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This article is based in part on the author's presentations to the 19th and 20th European Photovoltaic Solar Energy Conferences.9,10

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