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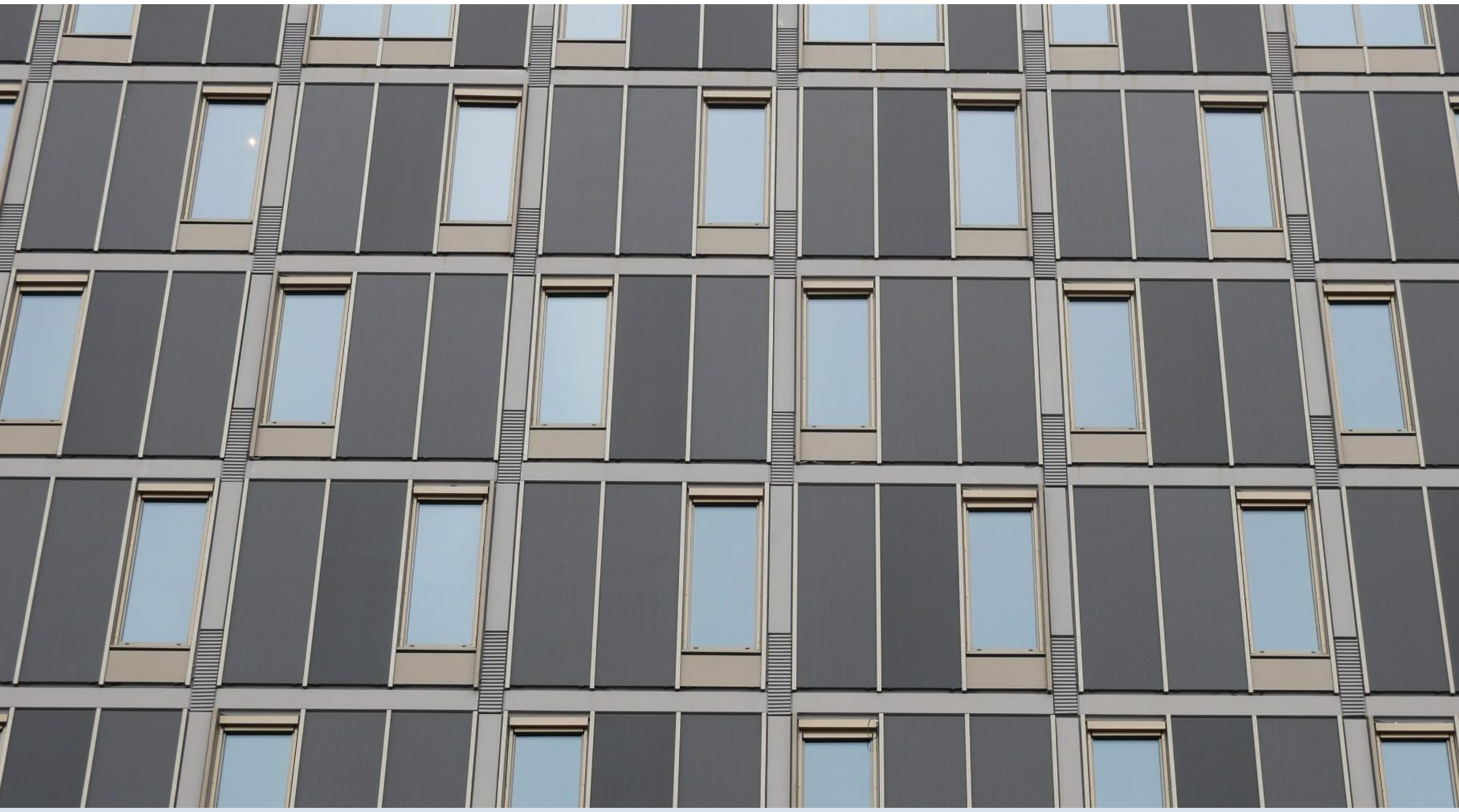

PVPS

Analysis of Technological Innovation Systems for BIPV in Different IEA Countries 2025

Report IEA-PVPS T15-23:2025

What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

The IEA PVPS participating members are Australia, Austria, Belgium, Canada, China, Denmark, Enercity SA, European Union, Finland, France, Germany, India, Israel, Italy, Japan, Korea, Malaysia, Morocco, the Netherlands, Norway, Portugal, Solar Energy Research Institute of Singapore (SERIS), SolarPower Europe, South Africa, Spain, Sweden, Switzerland, Thailand, Türkiye, United States.

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What is IEA PVPS Task 15?

The objective of Task 15 of the IEA Photovoltaic Power Systems Programme is to create an enabling framework to accelerate the penetration of BIPV products in the global market of renewables, resulting in an equal playing field for BIPV products, BAPV products and regular building envelope components; respecting mandatory issues, aesthetic issues, reliability issues, and financial issues.

Subtask A of Task 15 is focused on the analysis of the Technological Innovation System (TIS) for BIPV on national and multi-national levels to identify systemic problems and recommend actions for industry and/or policymakers that want to support the development of the BIPV market and innovation system.

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COVER PICTURE

House of Choice, Solna (Sweden) - property owner: Fabege; architect: White Architects; BIPV supplier: Solkompaniet & ML Systems; Photo: M. van Noord

INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Analysis of Technological Innovation Systems for BIPV in Different IEA Countries

IEA PVPS
Task 15
Enabling Framework for the Development of BIPV

Report IEA-PVPS T15-23:2025
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LIST OF ABBREVIATIONS

IEA	International Energy Agency
BAPV	Building Applied/Attached Photovoltaics
BIM	Building Information Modeling
BIPV	Building Integrated Photovoltaics
CENELEC	European Electrotechnical Committee for Standardization
CPR	Construction Products Regulation (European normative)
FiT	Feed-in tariff
FiP	Feed-in premium
IEC	International Electrotechnical Commission (iec.ch)
IFC	Industry Foundation Classes (for BIM)
IEA	International Energy Agency
NABERS	National Australian Built Environment Rating System
LVD	Low Voltage Directive (European normative)
nZEB	Net Zero Energy Building 2021-2030
PPA	Power Purchase Agreement
PVPS-IEA	Photovoltaic Power Systems Program of the International Energy Agency
TIS	Technological Innovation System
RVO	the Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland)
RES	Renewable Energy Sources
GSE	Gestore dei Servizi Energetici
RE	Renewable Energy
PV	Photovoltaics
EV	Electric Vehicles
AT	Austria
AU	Australia
FI	Finland
IT	Italy
NL	the Netherlands
ES	Spain
SE	Sweden

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EXECUTIVE SUMMARY

This report compiles and compares the results of seven national technological innovation systems (TIS) analyses for building integrated photovoltaics (BIPV), in Spain, Finland, Sweden, Italy, Australia, Austria and the Netherlands. All these analyses were performed within Subtask A of the IEA PVPS Task 15 and built upon the guidelines published earlier by the same task. The data for the national analyses were gathered from (national or international) databases on projects, publications, patents and regulations; interviews, workshops and/or surveys with representatives along the BIPV value chain; and websites, press and literature review.

Analysing the structures of the national innovation systems has identified research and education actors to be a driving force in most of the countries, together with BIPV manufacturers. For Austria, the Netherlands, Spain, and Sweden, policymakers have also been found to have a relevant impact on the innovation systems' development. Industry associations are typically less active in BIPV, giving them low importance for the TISes in all countries except Austria and Australia.

The formal institutional framework (i.e. regulations, standards, etc.) for BIPV is still underdeveloped or unspecific. BIPV is typically not considered as a building product and guidance on how to comply with building code regulations is limited, which complicates implementation of BIPV. Incentives are generally directed towards PV in buildings or towards renewable energy in general, which puts BIPV in a competing situation, primarily with BAPV. In this competition BIPV is typically a less mature option, with higher complexity and costs. In the informal institutional framework (i.e. culture, habits, etc.) there is support for PV and BIPV at a higher level, while at a more practical level, BIPV is hindered by a cultural gap between the solar energy and the construction industries.

Within the current structures of actors and formal or informal frameworks, niche markets for BIPV have evolved in all countries. For all countries except Spain, a main sub-market exists for roof systems with regular sized modules. In Spain, façade solutions with PV glazing are the most developed sub-market, while Austria has a combination of the two.

Analyses of applied and granted patents show that Italy and the Netherlands are the two most active countries in BIPV intellectual properties, followed by Spain. The application types that are targeted in the patents generally correspond to the main sub-markets for each country.

In order to advance from a niche market to a commercial market, a TIS must function properly. This is assessed using eight TIS-functions. Out of these eight, all countries have at least three (and up to eight) functions with insufficient fulfilment for a commercial market growth. All suffer from insufficient knowledge dissemination (to the construction industry, the market, public administration and/or supporting actors) and insufficient market formation (through market push, market pull or market incentives). Furthermore, the creation of social capital is low in six of seven countries, which hampers many other aspects such as legitimation, resource mobilisation and entrepreneurial experimentation.

The underlying problems for insufficient functional fulfilment are listed and discussed. The main issues are a limited engagement of certain actor groups, such as actors originating from the construction industry and product manufacturers; the industry's difficulties in reducing prices sufficiently or convincing customers of the benefits of BIPV; and the lack of BIPV-specific policy incentives to mitigate differences in matureness between BIPV and competing technologies.

Also, limited social interaction between actors in the BIPV and adjacent value chains, and the lack of educational resources, are important barriers in many countries.

Recommendations to facilitate BIPV market development are mostly similar from country to country and the main recommendations can be grouped into:

- Engaging new actors in the TIS to fill gaps and increase diversity, for example through assessing and communicating market potential.
- Increasing interactions between actors in the value chain, through collaborative actions on roadmaps, market creation, knowledge dissemination, etc.
- Bridging gaps between the solar and construction sectors (cultural and interactional), e.g. by requiring such cooperations in tenders or funding calls.
- Stimulating further innovation and development, in areas like rationalisation of production and scalable solutions for retrofitting.
- Improving regulations, standardisation, and increasing technical guidance for BIPV, for instance through acknowledgement of BIPV-products as construction products.
- Stimulating BIPV market(s), which could be done through regulatory incentives or requirements.
- Increasing education, training, and knowledge transfer.

Since many of the overarching problems and recommendations are similar for the studied countries, there is a clear potential for multi-lateral cooperation by industry actors and for international policy initiatives. In topics like knowledge dissemination or technical guidance, IEA PVPS Task 15 has the potential to make a difference.

1 INTRODUCTION

BIPV is the abbreviation for “building-integrated photovoltaic” [1], and refers to the dual function of BIPV devices producing electrical energy and serving as a building component. To better understand their constructive role, if BIPV elements are removed from a building, fully functioning building components must substitute them. In addition to the technical requirements of BIPV, there are aesthetical integration needs for this technology; diversity of colouring, surface finishing, sizes and shapes have shown the versatility of the BIPV industry to adapt to such requirements [2]. Examples of BIPV products are façade components of rainscreens or curtainwalls, and solar tiles. Figure 1 shows the role of BIPV modules in different architectonic applications.

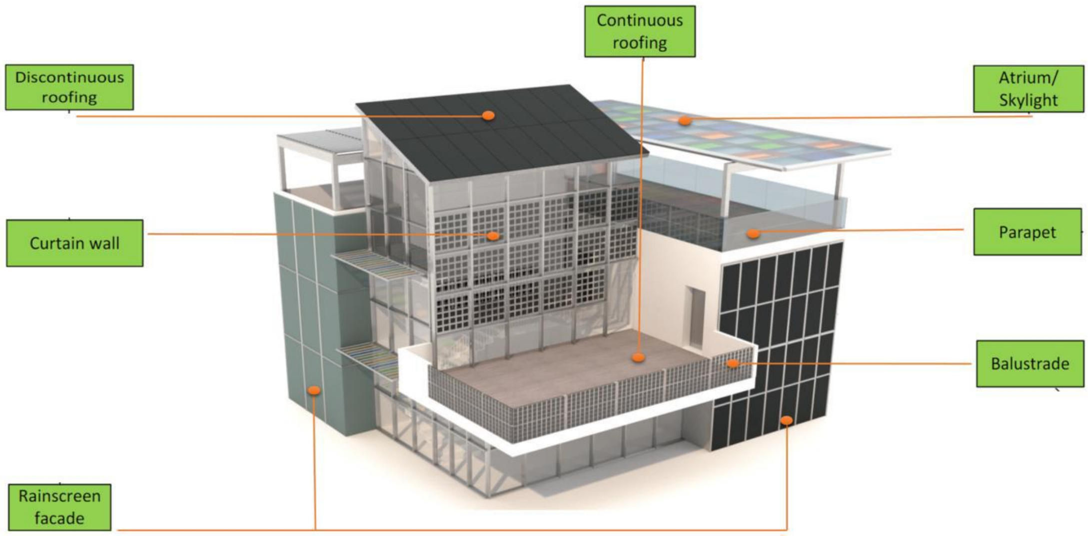

Figure 1: Examples of BIPV systems in a building case (source: SUPSI)

In this report, BIPV’s technological and market development is assessed using the technological innovation system (TIS) framework. The TIS framework and its concept of functional dynamics was developed in the 2000’s to better describe the dynamics of innovation systems around new technological developments, and to do so in a structured, multi-disciplinary approach. Functional analysis of a TIS should make innovation system analysis results more comparable and make it easier for policy makers to extract key policy issues and set policy goals [3], [4]. As such, TIS-analyses have been utilized in research and policy development for renewable energy technologies, primarily in the Netherlands and Sweden.

The aim of the TIS-analysis framework described above, corresponds well to the overall objective of IEA PVPS Task 15: to create an enabling framework to accelerate the penetration and deployment of BIPV products in the global market of renewable energies and in the construction sector. Literature exists for BIPV drivers and impediments in numerous countries, but most studies were conducted with a specific perspective and varying methodologies, making it hard to benchmark. For that reason, Subtask A in phase 2 of Task 15 (2020-2023) was dedicated to performing TIS-analyses for BIPV in a number of participating countries. This subtask was a distinctive one, amongst the mostly technically oriented activities and community of Task 15. Initially, only Sweden, the Netherlands, and a possible third country were set to analyse their national innovation systems for BIPV. However, more countries joined as the activity proceeded and the concept and benefits of TIS-analyses became clearer. In the end, seven countries participated actively in Subtask A and performed analyses for their respective BIPV TISes. Australia [5], Austria [6], Italy [7], the Netherlands [8], Sweden [9], and Spain [10] performed a full TIS-analysis, according to the Task 15 guidelines, and Finland [11], [12] performed a similar analysis with a somewhat limited scope.

Performing a TIS-analysis can be a challenging effort, but it provides a broader understanding and new insights on the development of BIPV markets. Furthermore, having several national analyses (in parallel) gives a benchmarking perspective that is highly useful. Internal benchmarking was done during national TIS-analyses, through benchmarking workshops, but the main benchmarking process was through compilation of this report. It is the authors' hope and expectation that this report can provide readers from both industry and government agencies a better understanding of the challenges and opportunities for BIPV – and how they themselves could contribute in their roles to making the future of BIPV brighter.

2 METHOD

This report presents comparisons and results based on the analysis of seven national technological innovation systems (TISes) for building integrated photovoltaics (BIPV). These analyses were conducted within the framework of IEA PVPS Task 15, following the method outlined in Task 15's guide for BIPV TIS-analysis [13].

In brief, the Technology Innovation System framework is employed to evaluate the weaknesses and strengths of the national innovation systems for BIPV – for their functioning and structure. The data and knowledge used for these assessments are collected from various sources, such as:

- market statistics (where available),
- project and publication databases,
- patent application databases, and
- interviews with relevant stakeholders.

Data collection through interviews and/or questionnaires was primarily carried out during 2021 and 2022. This means there may be some discrepancies between the institutions (i.e. regulations, norms, etc.) that influenced respondents' answers and the institutions currently in place. Chapter 2 presents the most relevant institutions that were active during the interviews/questionnaires, with notes added if changes have occurred since.

The authors of the national TIS-analyses, who are mostly experienced in BIPV research and development, have contributed additional insights on the national markets to their reports. Most of these authors have also participated in writing this synthesis report.

This report compiles and compares the main results from the national TIS-analysis reports, covering structural and functional analyses, as well as the identified systemic problems and opportunities for BIPV in the respective countries. The focus of this synthesis is on identifying relevant similarities and differences between countries, particularly in terms of systemic problems. The discussion of similar problems, or weaknesses, is contextualized within the structure of the TISes, such as policy frameworks and actor involvement. Additionally, recommendations from the national levels are compiled and discussed to derive more general recommendations for enhancing BIPV development and deployment, and to identify measures that could be taken at a bi- or multi-lateral level, by industry or policymakers.

In the subsequent subsections of this chapter, more details are provided on the data sources used for the national studies. All national TIS-analyses are published as separate Task 15 reports, except for Finland. Instead, the Finnish TIS-analysis was published as two separate Bachelor's theses. References to the national reports can be found in the following subsections. In the rest of the report, data from the national reports is used without further referencing, with few exceptions.

2.1 METHODOLOGICAL CHOICES AND DATA SOURCES IN THE NATIONAL ANALYSES

Different countries and different researchers have different preconditions and therefore there are also certain differences in how data has been gathered for the national report TIS-analyses. The following subsections describe the specifics for the respective countries.

2.1.1 AUSTRIA (AT)

The authors of the Austrian TIS-analysis report [6] utilized a combination of data sources to identify TIS actors: their own market intelligence (from prior research and business intelligence activities), database searches (for projects, publications, and patents), and web searches (for educational actors). For the functional analysis, interviews with 17 representatives of the BIPV and adjacent TISes served as the primary data source, supplemented by the aforementioned sources. To provide additional depth or background to certain parts of the analysis, desktop research was conducted, covering actor websites, market reports, energy statistics, and hard institutions (e.g. regulatory documents). National IEA PVPS Task 15 experts contributed to several parts of the report. All data were analysed according to the requirements of TIS-analyses.

2.1.2 AUSTRALIA (AU)

The information for the Australian analysis [5] was collected from publications, interviews, and workshops. Regarding publications, this study reviewed articles, books, official websites, newspapers, magazines, and national reports that referenced the BIPV contexts in Australia. Additionally, the study analysed 50 semi-structured interviews. Interview participants were building and PV stakeholders who have been involved and are interested in BIPV technologies. Two workshops were held in Melbourne, Australia, to discuss the adoption of BIPV and its technical, economic, and social parameters. Stakeholders from the building industry, PV industry, academia, regulatory bodies, renewable energy authorities, and fire department were invited to the workshops to discuss BIPV adoption, safety, benefits, drawbacks, and requirements for future uptake. All data were analysed according to the requirements of the TIS-analysis.

2.1.3 FINLAND (FI)

The TIS-analysis for Finland was conducted with a limited scope through two Bachelor’s theses at Aalto University [11], [12]. The first thesis focused on structural analysis and relied on online research, supplemented by insights from two expert interviews. The second thesis centred on functional analysis and was based on information gathered from four interviews. These interviews were conducted with representatives from various aspects of the Finnish BIPV landscape, including a research university, a manufacturer of solar cells and modules, a provider of photovoltaic (PV) systems, and a company involved in the production of solar modules and the planning and installation of PV systems. Due to the constraints of this limited scope, the Finnish TIS-analysis did not strictly adhere to the Task 15 TIS guidelines but utilized a streamlined approach to data collection and analysis.

2.1.4 ITALY (IT)

For the Italian TIS-analysis report [7], TIS actors were identified among stakeholders who have a long standing relationship with Gestore dei Servizi Energetici (GSE, the Italian energy services operator) resulting from years of incentive schemes and public support of renewable energy sources (RES), along with a detailed market analysis. Additionally, databases of regulations, publications, projects, and patents were exploited. Special attention was given to patent applications/patents analysis, considering the importance that Italian Feed-in Tariff (FiT) decrees attributed to innovation in the BIPV sector. The results of the patent analysis influenced the entire report, especially the functional analysis. Around 40 stakeholders from different categories, i.e., PV/BIPV industry, associations, universities, research centres, were interviewed directly, sometimes more than once, when necessary, to clarify emerging topics and issues. Questionnaires and interviews were supplemented with results of other works, interviews, and data annually prepared for the reports of the Italian participation in IEA PVPS Task 1.

2.1.5 THE NETHERLANDS (NL)

The author of the Dutch TIS-analysis report [8] utilized a combination of data sources to identify TIS actors: their own RVO market intelligence (from prior research and business intelligence activities), the RVO database search (for projects, publications, and patents), several national roadmaps for BIPV, and interviews conducted by scholars and published in “Solar Magazine” over the years. The report builds upon these findings, with additional attention given to the changing perceptions of BIPV over time and the varying interest of different government bodies presented in policy documents. The functional analysis is based on two main publications [14], [15] which contain interviews with representatives of the BIPV, construction, and the solar sector. To provide more context, general policy goals and monitoring figures were utilized.

2.1.6 SPAIN (ES)

The Spanish team consulted various databases of publications, research projects, and patents to develop the Spanish TIS-analysis report [10]; however, the most significant source of information for their study was the 111 responses received from tailored surveys addressing each of the 15 stakeholder groups involved in BIPV technology and six additional detailed interviews conducted with experts in the field. The surveys were disseminated directly or through national networks (associations, platforms, social networks).

2.1.7 SWEDEN (SE)

The authors of the Swedish TIS-analysis report [9] utilized a combination of data sources to identify TIS actors: their own market intelligence (from prior research and business intelligence activities), database searches (for projects, publications, and patents), and web searches (for educational actors). For the functional analysis, interviews with 24 representatives of the BIPV and adjacent TISes served as the primary data source, supplemented by the aforementioned sources. Additionally, interviewees were asked to list main actors and suggest additional interviewees, leading to the identification of several additional actors. To provide additional depth or background to certain parts of the analyses, desktop research was conducted, covering actor websites, market reports, energy statistics, and hard institutions (e.g., regulatory documents).

3 COMPARISON OF NATIONAL RESULTS

In this chapter, results from the seven national TIS-analyses are compiled for comparison and discussion on similarities and differences. These compilations and comparisons are divided into the same main sections as the individual TIS-analysis reports. The structural analyses, describing the actors, networks and institutions that comprise the innovation systems, are compared in section 3.1. The functional analysis results are presented in section 3.2. Systemic problems and opportunities identified for the studied countries are listed and compared in section 3.3, and national recommendations in section 3.4.

3.1 STRUCTURAL ANALYSES AND BIPV APPLICATIONS

The structural analyses describe the actors, networks, and institutions in the studied countries. For this synthesis, the focus is on the relative strength of different types of actors within each national TIS and on the institutions present. In this context, institutions are defined as the "rules of the game", consisting of both hard (formal, regulatory) and soft (informal, cultural) institutions. To provide additional background for each of the countries' BIPV markets and innovation systems, the relative market development of different BIPV application types is compared, as well as the number of patents and patent applications related to BIPV.

3.1.1 ACTORS IN THE NATIONAL TISES

Table 1 summarizes the main actor types in the national BIPV value chain in a relative comparison within each country. Typically, research and education actors are seen as the main driving actors in the national BIPV value chains and have a significant influence on the BIPV value chain in all countries, except for Swedish education. All countries have at least one BIPV product manufacturer. Concurrently, policy- and decision-makers have also played a direct or indirect role in BIPV development. In some countries, construction companies and BIPV installation manufacturers have also been active players in the value chain.

The marking of actor groups in Table 1 represents a relative strength and does not indicate whether the existing actor group is sufficient in number and quality for the BIPV TIS to reach a commercial growth market.

Table 1: Main actor types in each national BIPV value chain[1]

	BIPV-product manufacturers	BIPV-mounting manufacturers	Real estate developers and their advisors	PV suppliers and installers	Construction companies	Research	Education	Politics and policymakers	Intermediaries and supporting organisations
Austria	x	x			x	x	x	x	x
Australia	x		x	x	x	x	x		x
Finland	x	x				x	x		
Italy	x	x		x		x	x		
The Netherlands	x	x				x	x	x	
Spain	x					x	x	x	
Sweden	x	x	x	x		x		x	

3.1.2 INSTITUTIONS IN THE NATIONAL TISES

Hard institutions make up the regulatory framework that BIPV should fit within or co-exist with. This includes legislation but also industry standards, codes, etc. that form a de facto standard for the application of BIPV.

3.1.2.1 SYNTHESIS OF MAIN FORMAL (HARD) INSTITUTIONS DISCUSSED IN THE NATIONAL BIPV TISES

The main hard institutions for each of the studied countries are listed in the tables in Appendix A. Results for the main legislative institutions (Table A1) indicate that PV in buildings is supported by national and regional measures in most countries. However, this causes BIPV to compete with BAPV, which typically does not economically favour BIPV. Certain BIPV characteristics, such as superior visual integration possibilities, make it the preferred choice for some historical and high cultural heritage projects. In other such instances, the fact that BAPV can more easily be removed, restoring the original status of the building, can make it the preferred option. Some regulations, such as those supporting PV canopies over regular BAPV, have also aided BIPV.

However, no international or national regulation recognizes BIPV modules as construction products. Consequences are, for example, the ineligibility of BIPV products in energy renovation actions although acting as construction products.

[1] x-es mark the main national actor groups, this does not imply that the actor group is strong enough to support a development of the TIS to commercial growth.

The underlying reason is that, so far, BIPV standards are not harmonised, so they are not compulsory and they do not provide a technical basis to assess the performance of BIPV modules as construction products. Harmonised standards in Europe come from European Directives or Regulations.

Since BIPV is also part of the construction, the costs of the investments and the benefits often do not accrue to the same parties. This complicates the decision-making process or even disqualifies BIPV as an option to consider.

All countries support PV through various economic incentives, particularly aimed at PV self-consumption and RE storage projects, and there is also support for the energy rehabilitation of buildings. In many countries, there are aids for replacing asbestos with PV roofs. Generally, all countries support PV in buildings and PV self-consumption (and electric vehicles and storage). There are various types of incentives, such as subsidies, tax reductions, rebate schemes, and soft loans for PV in buildings, often subject to certain conditions (e.g., energy efficiency improvement, self-consumption schemes). However, generally, there is no specific economic support for BIPV.

Further hard institutions, which are not laws but rather technical codes, industry standards, etc. (Table A2, Appendix A) show that every CENELEC country in Europe has adopted the EN 50583 BIPV standard for BIPV products and systems, while the remaining countries refer to the equivalent international standard IEC 63092. However, none of those standards are compulsory (there is no harmonized BIPV standard in any country). In addition, there are harmonized standards and rules derived from the Low Voltage Directive (LVD) and the Construction Products Regulation (CPR) which are to be applied to BIPV in EU countries. Equivalent regulations exist in other countries, such as Australia. Green labels for the buildings and the origin of electricity benefit from PV in buildings, but not necessarily from BIPV. Regarding the technical building codes, some have indirectly supported BIPV, although the building codes do not explicitly mention BIPV.

3.1.2.2 SYNTHESIS OF MAIN CULTURAL (SOFT) INSTITUTIONS DISCUSSED IN THE NATIONAL BIPV TISES

Cultural (soft) institutions refer to the non-legal, intangible norms, practices, and social conventions that shape behaviour, interactions, and relationships within a society or a particular cultural group. These institutions encompass a wide range of aspects, including values, beliefs, traditions, customs, and social norms. They play a significant role in influencing how individuals and communities perceive BIPV, make decisions about investing in BIPV, and engage with one another in the processes leading to the decisions. The soft institutions also influence the creation of economic, environmental, and technical regulations such as standards and building codes (hard institutions) that guide the adoption of new technology.

The national BIPV TIS-analyses examined various soft institutions, such as, awareness and acceptance, aesthetic requirements, non-formalized public procurement practices, and the stakeholders' conduct/practice, and found similarities between the countries. The national TIS reports discussed the main cultural institutions at different levels of granularity and systemics. Consequently, a synthesis is presented in a written form, focusing on the supporting, and not supporting institutions that can be considered common to all the analysed countries although the relative significance of the institutions can vary.

Several cultural factors support the wider adoption of BIPV. These include a strong social acceptance of renewable energies, particularly photovoltaics, along with a heightened awareness of the climate emergency. Additionally, homeowners are increasingly trying to increase energy self-sufficiency and lower electricity costs by self-generation. Furthermore, there is growing concern about the environmental and visual impact of utility-scale PV plants, leading to increased interest in integrating solar power into existing structures. These cultural institutions and societal attitudes collectively contribute to the advancement of BIPV adoption in the studied countries.

However, significant cultural institutions hinder or fail to support the wider adoption of BIPV. A major barrier is that the construction sector and the solar energy sector are distinct industries with different cultures. The construction industry, driven by a risk-averse culture, views innovative solutions like BIPV with scepticism, often seeking proof of safety, reliability, and sustainability, which the PV industry frequently fails to adequately provide. With BAPV dominating the built environment, the reluctance to change and the lack of mutual understanding between the two sectors create barriers. Architects and construction professionals typically exclude solar energy expertise in early planning phases, preferring to treat PV as an add-on feature rather than considering fundamental design changes. Furthermore, the construction industry prioritizes upfront cost reduction over lower lifetime costs, which is problematic for BIPV. Builders bear the economic burden of investment, while the subsequent benefits accrue to building owners and managers. An economic instrument or business model that bridges this gap has yet to emerge or gain widespread adoption. Conversely, PV installers tend to stick with BAPV, even when clients initially prefer BIPV, to avoid engaging with construction practices and guarantees. This preference for simplicity aligns with the broader acceptance of BAPV among contractors and property owners, providing little incentive to address the cultural differences between the two sectors.

Although aesthetics is acknowledged as a pertinent factor favouring advancement of BIPV, the significance of aesthetics of BIPV in comparison to BAPV is not unequivocally held by all stakeholders. In many countries BAPV is already an integral, and accepted, part of the urban landscape. Because PV is generally regarded as an important part of solutions for decarbonizing energy production, which, too, is widely held an important goal, most people accept BAPV in urban environment, even if they would consider it less aesthetic than BIPV in relative terms.

3.1.3 BIPV MARKETS AND MAIN APPLICATIONS

Most of the studied countries lack statistics on the market size for BIPV, but indications suggest that Italy is the market with the highest accumulated installed capacity, with more than 2.5 GWp installed. This leading role is likely due to five different historical feed-in tariff schemes with BIPV bonuses, in combination with a large PV market in general. Among other countries, the Netherlands has an estimated total installed BIPV capacity of about 0.15 GWp (2021). Austria had an estimated annual installed capacity of 0.029 GWp (29 MWp) in 2021 [16], while the same figure for Australia was estimated to be <1 MWp. For other countries, no estimates exist on the BIPV market size, but the market sizes for building mounted PV (BAPV + BIPV) were estimated at around 2.64 GWp for Spain in 2023 [17], 0.76 GWp for Sweden in 2022 [18], and at 0.08 GWp for Finland in 2019 [19].

BIPV comprises a number of applications and sub-technologies (see also [20]). Market development for BIPV is generally considered to be in a niche market phase for all studied countries, but BIPV roof solutions with regular-sized modules (sometimes called “in-roof systems”) might be on the verge of commercial growth in some countries. Other applications, especially parapets and balustrades, more often remain in a demonstration phase.

An absolute benchmarking of market development for different applications in all countries is nearly impossible (given the lack of market statistics). Therefore, Table 2 presents relative comparisons within each country on the most relevant and well-developed applications or sub-markets.

Table 2: Main BIPV applications in the national BIPV TIS, categorized according to [20]. Colours indicate relative market activity within each country and should not be used to compare market development between countries. Finland results are not available.

Nr.	Categories[1]	Austria	Australia	Italy	the Netherlands	Spain	Sweden
A1.r	Discontinuous roofing, regular modules	highest	highest	highest	highest	low	highest
A1.s	Discontinuous roofing, tiles	medium	medium	medium	medium	low	medium
A2	Continuous roofing	medium	medium	medium	medium	low	medium
B1	Atrium/Skylight	highest	medium	highest	highest	highest	medium
C1	Rainscreen façade	highest	medium	medium	medium	highest	medium
C2	Masonry wall				medium		medium
C/D3	Double skin façade	highest		low	medium	low	medium
D1	Curtain wall	highest	low	low	medium	highest	medium
D2	Window	low	low	low	low	highest	medium
E1	Parapet	low	low	low	low	low	low
E2	Balustrade	low	low	low	low	low	low
E3	Canopy	low	low	medium	medium	highest	low
E4	Solar shading	low	low	medium	low	highest	low

Relative market activity (within each country)

existing, low activity
highest activity

Colour codes not benchmarked between countries

The findings in Table 2 indicate that BIPV solutions for discontinuous roofing using regular PV module sizes are a leading application in all markets except for Spain. Moreover, it appears that some national markets lean towards BIPV roofs (Australia, Italy, Sweden, and the Netherlands), while other markets favour BIPV façades (Spain) or both (Austria).

For Spain and Italy, the market inclination is clearly tied to previous policies (so-called "hard institutions"). In Spain, the tendency towards BIPV façades stems from an historical obligation to install PV in tertiary buildings, requiring a minimum amount of installed PV power rather than a percentage of PV electricity production. Furthermore, installation on building façades was only permitted if modules were architecturally integrated (BIPV), so BAPV was not allowed on façades but only on better-positioned surfaces (e.g., roofing). Thus, since available roof area was not always apparent in typical multi-storey tertiary buildings, the market developed BIPV façade solutions. In Italy, historical feed-in tariff schemes implemented bonuses for BIPV applications, and for BIPV installation combined with the removal of asbestos, or with building energy efficiency refurbishment.

The other countries do not have such a clear link between leading application types and policy frameworks. A plausible hypothesis is that an historically stronger market development of distributed PV (mostly residential BAPV rooftop systems) in Australia, Austria, the Netherlands and Sweden [18], [21], [22], [23] has led to the current BIPV market bias towards roof applications. The fact that Spain, with a clear historical market focus on centralized PV and to some extent commercial buildings [24], is the only country without high activity for BIPV roofs reinforces this hypothesis. Italy also had a strong focus on centralized PV in the past [25], but had specific incentives for BAPV and BIPV applications, as mentioned above.

The two countries with the most distinct market opportunities towards façade applications (Spain and Austria) both have local manufacturers of photovoltaic glass (i.e., semi-transparent BIPV glass-glass PV laminates and/or PV-integrated double/triple insulated glass) that are also active internationally. The same markets tend to have higher activity for BIPV atrium (also skylight) applications, where similar BIPV products can be used as in BIPV curtain wall façades.

3.1.4 PATENTS AND PATENT APPLICATIONS

Data and documents on the websites of the European Patent Office (EPO), World Intellectual Property Organization (WIPO) and on national databases have been exploited for an intellectual property analysis concerning BIPV. Main results of the patent analysis are summarized in Table 3.

The Netherlands and Italy are the countries with the highest number of patent applications/patents. With respect to Italy, the number is primarily due to the booming effect of past Feed- in Tariff Law which required a European patent for the mounting systems of one of the two product categories incentivized, and the effect of these requirements still persists today. In Italy, the historical architecture and urban heritage have led to significant research, within innovation, of special BIPV tiles to be integrated in historical contexts. In light of the above, most of the inventions are focused on roof applications. The main actors involved in innovations today in Italy are the PV/BIPV industry, research centres, universities, and to a lesser extent the construction industry.

Other countries than Italy did not experience subsidies for BIPV patented products. The inventions of their patent applications/patents are thus more diverse, and focused also on walls, windows with transparent modules, and others. For the Netherlands, the high number of inventions is focused mostly on roofs and façades, as is the case for BIPV patent applications in Australia and Austria. Regarding the actors, it is important to emphasize, especially in Spain and in Sweden, the contribution of architects as patent applicants in BIPV innovation, along together with the construction industry and PV/BIPV industry. In Australia, innovation is led predominantly by BIPV industry.

Table 3: Insight in patent applications for the national BIPV TISes[2]

	Austria	Australia	Italy	the Netherlands	Spain	Sweden
BIPV patents incentivized	**No**	**No**	**2010-2013**	**No**	**No**	**No**
Total no. of applications	**27**	**20**	**100**	**112**	**51**	**10**
Patents	22	20	96	112	38	10
Utility Models	5	n/a	4	0	13	n/a
Of which granted[3]	16	9	41	80	42	4
Of which under proceeding	2	1	6	0	0	1
Exploited in production (incl. historically)	**(no data)**	**4**	**48**	**(no data)**	**(no data)**	**5**
Of which in current production		1	21		5	3
Main Product Type						
Roofs	x	x	x	x	x	x
Roof tiles		x	x	x		x
Façades	x			x	x	
Walls	x	x				x
Transparent modules		x				
Windows				x		
Main Typology of Building						
Residential	x		x	(no data)	x	x
Industrial			x			
Urban Design					x	
All	x	x				x

[2] Patent applications analysis updated to July 2023 except for Spain which ended the analysis in March 2022.

[3] Patent applications are marked as granted when granted on any level (national/European) even if not granted or withdrawn on other level.

The type of buildings targeted in the patent applications is mainly residential with pitched roofs, even though there are solutions for industrial buildings. The product types are largely consistent with the main application types per country (compare Table 2). There is a primary focus on roofs for Austria, Italy, the Netherlands, and Sweden, even though Spanish patent applications also include roof products. For façades and walls, Austria and Spain (mostly glass façade applications) have active markets and also focus on patent applications. Countries with medium market activity in façades and walls, the Netherlands and Sweden, also see a significant share of their patents for these product types. Australia's market and patent applications are both more evenly distributed over different product types.

3.2 FUNCTIONAL ANALYSES RESULTS

All national TIS-analyses have assessed the functional fulfilment for the set of eight TIS-functions. The fulfilment scores indicate how each of the functions is performing relative to a set target, which can be summarized as: BIPV transitioning from the niche market phase to a commercial growth phase. The results are displayed in Table 4 and Figure 2 below.

Table 4: Functional scores for all functions the national BIPV TISes

Nr	Function	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden	Average
F1	Knowledge development	3	2	3	3	4	3,5	3	**3,1**
F2	Knowledge dissemination	2	2	1,5	2,5	2	2	2	**2,0**
F3	Entrepreneurial experimentation	3	2	2	3	3	2,5	2	**2,5**
F4	Resource mobilisation	3	2	2,5	2,5	2	2	2,5	**2,4**
F5	Development of social capital	2	2	2	3	2	2	2	**2,1**
F6	Legitimation	3	2	2	2,5	3	3	2	**2,5**
F7	Guidance of the search	3	2	1,5	3	3	2,5	1,5	**2,4**
F8	Market formation	2	2	2	2	2	2,5	2,5	**2,1**

Legend

1	absent
2	weak
3	moderate
4	strong
5	excellent

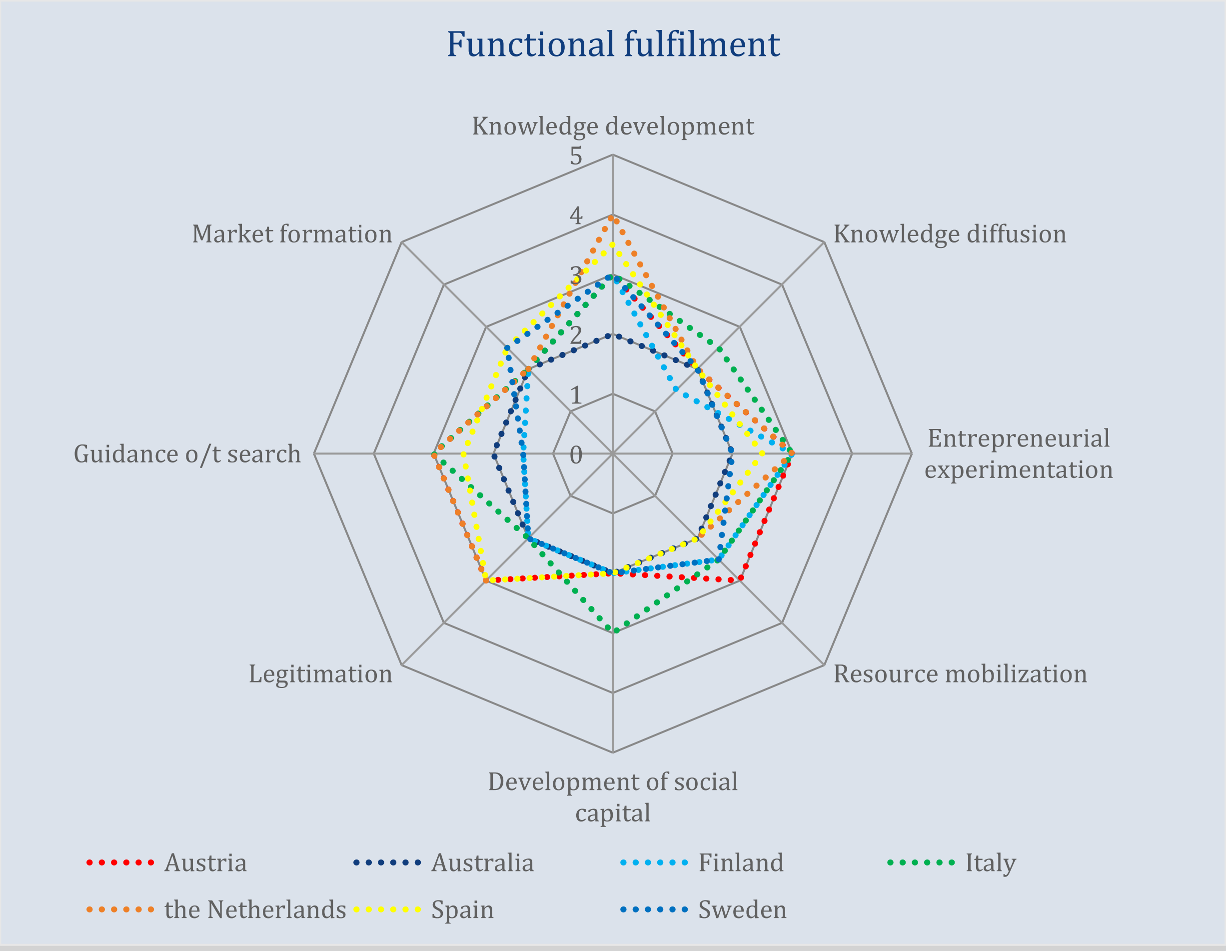

Figure 2: Results of the fulfilment assessment of the TIS-functions. Numbers indicate the degree of fulfilment: 1 – absent; 2 – weak; 3 – moderate; 4 – strong; 5 – excellent.

As noted by [26], the primary functions for a niche market to further evolve are F3, followed by F4 to F8, with less emphasis placed on knowledge-related functions (F1, F2). Consistent with this, we observe that for the studied countries (apart from an overall "weak" fulfilment for all the TIS-functions in Australia), the function F1 "Knowledge Development" is considered as (one of the) strongest for all countries, with moderate or stronger fulfilment. Moderate fulfilment can be interpreted as such that the mere development of new knowledge is not the main obstacle to overcome for further market development.

On the other hand, F2 "Knowledge Dissemination" is not adequate in any of the countries, even though Italy is close to a moderate level (due to a stronger BIPV market in the past). When delving into detailed descriptions of dissemination-related problems, they are often linked to other, prioritized, functions. For instance, we find low knowledge levels among market actors (hampering F8), construction sector (hampering F3), public administration (impacting F6, F7 and F8), and the financial sector (hampering F4 and F6). This suggests that the knowledge that has been developed and is available, nationally or internationally, is not reaching value chain actors and other stakeholders to the extent and/or quality needed to support other functions. Weak dissemination towards the construction industry, technical consultants and architects, and potential clients is common among all countries.

Another function that stands out negatively is F5 “Development of Social Capital”, with weak fulfilment for all countries except Italy. Lack of mutual trust, as well as lack of networks and meeting places for BIPV, and discrete relationships between PV and building sectors are identified in multiple countries. This is indicative of the early development phase of the TIS and might be amplified by the fact that other adjacent TISes within the greater PV-area are much stronger (i.e., BAPV and/or utility scale PV). It is also logical that Italy, with its history of a strong BIPV market, scores better on this function.

For the remaining functions, there is no clear trend for all countries. “Resource Mobilisation” is weak due to limited financial or human resources in some countries. Other countries see larger weaknesses in “Guidance of the Search” where there is often a lack of roadmaps and (national) strategies for BIPV, no market statistics, and stronger guidance towards the BAPV TIS than to BIPV.

Weak levels of F6 “Legitimation” for BIPV, in multiple countries, could partly be related to weak knowledge dissemination, for example when policy makers are unaware of potential benefits of BIPV over other PV application technologies, or when market actors consider BIPV to be more complex and riskier (in terms of performance and project delays) than BAPV. Furthermore, most countries lack (formal) technical guidance on design, installation, and operation of BIPV. Weak legitimation can also be related to permitting issues (as is the case in Italy in historical centres) or performance issues for existing projects.

Low awareness and knowledge levels also indicate a weakness in market creation from the BIPV industry side, which impacts “Market Formation” assessments. There are also some issues here for governments’ contribution to market creation, where a lack of legitimacy and knowledge might be a reason that policy regulations are unaware of BIPV or sometimes counter-productive. The split-incentives between building owners, who have to make the investment, and building users (renters), who get most of the benefits, can also be a hindrance for market development in certain market segments.

For F3 “Entrepreneurial Experimentation”, the crucial function for niche markets to evolve into commercial growth, approximately half of the countries observe moderate fulfilment (Austria, Italy, Netherlands). These are countries that have several BIPV application-types with higher market activity (see Table 2). Spain is weak to moderate, while the remaining countries (Australia, Finland, Sweden) have weak fulfilment. Effective entrepreneurial experimentation is linked to knowledge development and dissemination, but also to the social capital engaged for the technology (F3), and the attractiveness and potential of the TIS and its sub-applications, that is expressed in F7 “Guidance of the Search”. The latter is also found to be very weak to fairly weak for four out of seven countries.

Examining the overall functional fulfilment patterns, Italy has the strongest TIS but weaknesses in F8 “Market formation” and to some extent in F2, F4, and F6. The Netherlands and Austria display quite similar patterns as Italy for their main functional weaknesses (F8, F2). However, their challenges are somewhat stronger for F5 “Development of social capital” and, in the case of the Netherlands, also F4 “Resource mobilisation”. Spain also has a quite similar pattern, most like the Netherlands, with main weaknesses in F2, F4, and F5. Sweden and Finland differ from the previously mentioned countries in such a way that they are facing larger problems with F6 “Legitimation” and F7 “Guidance of the search”. Finally, Australia has an overall weak fulfilment and is likely in an earlier stage of TIS development, also generally ranking application activities at a low level (see Table 2).

In the next section, more details are presented on the underlying problems for the functional weaknesses.

3.3 SYSTEMIC PROBLEMS AND OPPORTUNITIES

This section and its subsections present the systemic problems (i.e., the root causes in the structure of the TIS) that lie behind the weaknesses in functional performance. It also introduces the opportunities in the systemic structures. The systemic problems and opportunities are categorized into:

1. Actor-related problems
2. Institution-related problems
3. Interaction-related problems
4. Infrastructure-related problems

A full overview of the main systemic problems and opportunities presented in each country's TIS-analysis report is provided in Appendix B. Despite some efforts to group and compile the individual problems, certain overlaps remain.

3.3.1 ACTOR-RELATED PROBLEMS AND OPPORTUNITIES

The overview of actor-related systemic problems and opportunities (Table B1) reveals that nearly all countries list several presence-related problems, in the form of a deficiency or low number of a certain type of actors. For the Netherlands, this deficiency is confined to multinational companies, but other countries identify multiple types of actors to be scarce. This is sometimes articulated at a higher level, such as in four countries (AU, IT, ES, SE) that mention the need for more BIPV-specialized actors. But also at a more granular level, in the form of lacking BIPV product manufacturers (AT, AU, FI, IT, ES), installers and suppliers (AT, FI) or actors originating from the construction industry (AU, IT, NL, ES, SE). Beyond supply-side actors, a low engagement of education actors (AT, ES, SE) and of lead-customers (AU, FI, ES) is perceived as a problem in some countries.

Austria, Australia, Italy, and Sweden are observing some early initiatives that merge PV installation companies with construction companies, which appear promising. Another positive trend is the growing interest from architects in BIPV, observed in Austria, Italy, and Spain.

In terms of the quality performance of actors, the most frequently mentioned problem is the industry's difficulties to sufficiently reduce prices. This could be associated with other quality issues indicating needs for further innovation, such as a lack of focus on solutions for easy replication (ES, SE), or on specific market sectors, such as retrofit solutions in Spain, or historical buildings in Italy.

Generally, presence- and capacity-related problems like those mentioned above could indicate a low functional fulfilment for guidance of the search, which aligns with low functional scores for countries like Australia, Finland, and Sweden (scores: 1.5-2) and possibly Spain (2.5). If legitimacy is weak at the same time, as in Australia, Finland, Sweden, and possibly Italy, that might also be an underlying problem for the lack of "guidance". In countries with moderate "guidance" and similar Legitimation (the Netherlands, Austria, and Italy) the challenge may be more on the function of market creation.

Regarding guidance of the search, the industry is said to do too little to improve this by formulating a common vision, in Italy, Spain, and Sweden. Furthermore, initiatives from the industry on communicating the benefits and legitimacy of BIPV are assessed as insufficient in Australia, Italy, Spain, and the Netherlands.

3.3.2 INSTITUTION-RELATED PROBLEMS AND OPPORTUNITIES

An institutional problem emphasized across six out of seven countries is the lack of direct support for BIPV despite national support for renewable energy. For instance, Australia is actively promoting rebates for residential solar PV applications to meet its renewable energy goals, yet BIPV lacks recognition due to its complexity and limited public acceptance. By categorizing BIPV and BAPV under the same support mechanisms, it overlooks that BIPV-development is in an earlier stage than BAPV.

Similarly, the absence of appropriate standards and building codes is a common issue among these countries. While many conform to European standards, there is a significant lack of national regulations or codes specifically for BIPV. Some countries reference standards for traditional PV applications but building codes do not consider BIPV requirements. Additionally, the lack of technical guidance on BIPV implementation is a problem for some countries that has contributed to its low adoption rate. On the positive side, the ongoing revision of the European BIPV standard (EN 50583) and the forthcoming guidebook on BIPV by IEA PVPS Task 15 are noteworthy. At the same time, functional and safety requirements from standards and national building codes apply to BIPV products used as construction products but are not always considered in equivalent BAPV solutions posing similar risks and challenges. Under those circumstances, the implementation threshold for BIPV becomes higher than for BAPV.

Furthermore, a key institutional issue is the scarcity of BIPV products meeting the BIPV standards. Most serial-produced BIPV modules are not certified as building products, but only as electrical PV products according to IEC/EN 61730. Moreover, a considerable number of customised products are not even certified according to this electrical safety standard. For market entry within the EU, all PV products (except for those intended for applications below 75 V_{DC}) must conform to the EN 61730 requirements, as it is a harmonized standard under the Low Voltage Directive, yet there is no formal demand for third party certification.

Several countries prioritize PV over BIPV, viewing the latter as less of a value addition. Australia, Austria, Italy, Spain, and Sweden focus on PV due to higher demand, resulting in limited attention to BIPV. Some nations even experience competition over BIPV solutions. The reluctance of authorities to incorporate BIPV early on, combined with public reluctance due to a lack of understanding of the technology, remains a significant challenge. Austria and Australia specifically cite this lack of awareness as a problem. Moreover, BIPV is not recognized as a building material element, possibly due to insufficient awareness or trust.

The construction industry's resistance to new technologies is also an institutional problem. Some practitioners prioritize risk elimination and resist additional burdens from new applications. Countries like Sweden and Spain highlight the construction industry's focus on minimizing upfront costs rather than considering the total cost of ownership. Similarly, the Netherlands points out the lack of incentives for building owners to invest in BIPV when renters reap most of the benefits. Both these aspects can lead to the rejection of BIPV despite its long-term benefits.

For countries in the European Union, the recently published EU directives related to energy and buildings are an opportunity that could significantly impact BIPV by setting standards for energy efficiency (EED, Energy Efficiency Directive), renewable energy usage (RED, Renewable Energy Directive), and energy requirements for buildings (EPBD, Energy Performance of Buildings Directive). The EPBD, published May 8, 2024, includes requirements for including solar energy into society and building design. This is likely to increase the demand for BIPV systems, especially because the construction industry and the solar energy industry will have to cooperate early in the planning stage.

EPBD revision will promote stricter measures to increase the renovation rate and achieve the objectives set by the Renovation Wave [27]. This initiative, launched in 2020, identified large-scale building renovation as a decisive tool for reducing buildings' greenhouse gas emissions in 2030 by 60%, their final energy consumption by 14%, and energy consumption for heating and cooling by 18%, compared to 2015. The strategy focused on tackling energy poverty and worst-performing buildings, improving the energy efficiency of public buildings, and decarbonising heating and cooling. Including BIPV in renovations combines the energy efficiency improvement in buildings with local renewable energy production, making them more sustainable and economically and energetically resilient. The latest revision of the EPBD requires EU member-states to renovate the 16% worst-performing non-residential buildings by 2030 and the worst-performing 26% by 2033.

Additionally, directives aimed at reducing carbon emissions and promoting sustainable development in general may further incentivize the adoption of BIPV technology.

In Australia, the federal government’s whole-of-economy plan to achieve net zero emissions by 2050 drives the role of Australia’s building sector in carbon emission reduction. The Australian Government supports the establishment of standards, programs, and other innovative measures to improve energy efficiency in commercial, residential and government buildings. Although BIPV may obtain more opportunities during these processes, the market is still under development.

For a complete overview of institution-related systemic problems and opportunities, refer to Table B2 in Appendix B.

3.3.3 INTERACTION-RELATED PROBLEMS AND OPPORTUNITIES

An interaction-related problem observed across all countries pertains to insufficient communication among supply chains. There is a lack of collaboration among manufacturers, builders, construction companies, and planners, leading to fragmented interactions. This lack of cross-sector collaboration particularly impacts the integration between the PV and construction sectors, where a shared language is currently lacking. Some countries note that BIPV is not recognized as an integral part of building systems, negating its potential multifunctionality. Inadequate interaction of the construction sector at all levels is also reported by several countries. Furthermore, there are fewer, or no communities focused on BIPV, with countries lacking a common platform for knowledge and information sharing. Currently, only Australia and the Netherlands have a dedicated BIPV association or BIPV group under the larger PV association. Insufficient networking opportunities for both practitioners and the public contribute to this issue, resulting in limited social cohesion—a problem identified among multiple countries – and a weak voice in advocating for the technology. Additionally, the prevalence of the “lock-in effect” of BAPV over BIPV is highlighted, where BAPV has established a strong market presence over the years, limiting the adoption of BIPV.

Table B3 in Appendix B lists all the identified interaction-related systemic problems and opportunities for the studied countries.

3.3.4 INFRASTRUCTURE-RELATED PROBLEMS AND OPPORTUNITIES

The primary infrastructure-related problem highlighted across the countries is the lack of adequate financial support schemes. Most nations lack direct financial assistance specifically tailored for BIPV, making its deployment less feasible. Another infrastructure-related challenge involves the scarcity of educational resources, including training facilities, workshops, and apprenticeships. Both government and private sector entities are currently inactive in initiating such programs, leading to a shortage of expertise in this sector. Several countries emphasized the absence of a skilled or professional workforce. Finland and Sweden specifically highlighted an ongoing concern regarding grid capacity.

An opportunity for BIPV in some countries (mentioned for Italy and Spain, but also valid for Sweden) arises with the urgent need to renovate large parts of the existing building stock to improve energy efficiency performance. For all identified infrastructure-related systemic problems and opportunities, refer to Table B4, Appendix B.

3.4 NATIONAL RECOMMENDATIONS

In the following paragraphs, the recommendations from the different national Technological Innovation System analyses are briefly summarized.

The **BIPV TIS in the Netherlands** is currently in a niche phase (NHL TIS p 28) and has been for the last ten years. (NHL TIS p 22). Recommendations include networking, identifying new markets, involving and training all actors, shifting business cases to “energy ownership”, adopting legislation, initiating large demonstration projects followed by building codes and financial incentives, developing digital tools and standardisation, and finally ramping up European production. These recommendations fall under the umbrella of new market formations and should focus on societal issues, long-term benefits, and high visibility. [8, pp. 28–29]
The **BIPV TIS for Austria** is also in a niche phase. Recommendations include visible successful implementation projects, training architects and planners together, involving BIPV early in the planning process, industry-launched advertising programs, harmonized standards and construction codes, development of easy-to-install BIPV systems, governmentally stipulated PV in obligatory building specifications, and a law which requires every sealed area to be checked for dual use with (BI)PV. [6]
The **BIPV TIS for Spain** is also in a niche market. Recommendations include the national building code to include BIPV, BIPV-specific incentives, demonstration projects of public buildings, using BIPV in building rehabilitation, increased communication between solar and construction sectors, and incentives to encourage interaction among BIPV stakeholders. [10]
The **BIPV TIS for Australia** is in both a niche and demonstration market. Key recommendations include the BIPV alliance for creating a common platform for actors to collaborate, introducing live lab testing modules and systems, developing building codes, particularly on fire safety, and government intervention to support both upstream and downstream actors. [5]
The **BIPV TIS for Italy** is in a niche market. Recommendations include BIPV in the national decrees, training of public administration, involving finance in the BIPV models, standardisation and certification, and financial support in patent and/or certification fees. They end by raising the question “is standardisation the answer, when local authorities and architects are asking for a “solar language” rather? [7, p. 38]
The **BIPV TIS for Sweden** is in a niche market with some applications close to commercial market development. “The report concludes with recommendations for industry actors to increase cooperation between PV and construction industry actors; engage in demonstration projects; apply for external financing of lab tests and verifications; or collaborate on road-mapping public campaigns, or market reports. Market actors (public or private) can join collaborative efforts with industry; engage in demonstration projects or innovation procurement for reproducible BIPV concepts; or require cross-sector cooperation in tenders. Public authorities can investigate how to address the unlevel regulatory playing field; encourage BIPV in municipal planning; or support other actors’ initiatives such as demonstrations, tests and

verifications, workshops, etc. Supporting actors can also investigate the unlevel playing field, organize technical or scientific workshops; run BIPV courses for professionals or students; and support demos, tenders, lab tests, etc." [9, p. 10]

A full list of recommendations given in the national TIS reports, with a comparison across countries, is presented in Appendix C. . It comprises a broad range and a significant number of recommendations. While some of them are mentioned for only one or two countries, 26 are shared by three or more. These can be categorized into the following groups, related to the main shared problems:

- Engaging new actors in the TIS, to fill gaps and increase diversity (R2-4, R11)
- Increasing interactions between actors in the value chain (R3, R5-6, R18-21)
- Bridging gaps between the solar and construction sectors (cultural and interactional) R1, R3, R5, R7, R18-19),
- Stimulating further innovation and development,(R8-10, R12-13, R25)
- Improving regulations, standardisation, and increasing technical guidance for BIPV (R11, R13-14, R16, R26, R29)
- Stimulating BIPV market(s) (R2, R6, R8, R12, R15, R20-21, R23, R27, R29)
- Increasing education, training and knowledge transfer (R15, R17-20)

These groups partly overlap in purpose and, as can be seen, many recommendations are relevant for multiple groups. Still, the categorisation helps to create a clearer purpose and overview of recommendations.

The most commonly recommended actions, endorsed by five or more out of seven countries, are discussed below.

The first widely held recommendation is to initiate partnerships between solar and construction companies, which could be done voluntarily or incentivised by requirements in tenders or funding calls (R1).

Another frequent recommendation is to compile and publish BIPV market potential reports (R4) to attract new actors, including supporting and financing actors. As was proposed in the TIS-analysis for the Netherlands, such reports help to identifying lower-end markets for BIPV, with a focus on societal values [8, pp. 28–29]. In that way, innovation directions are pointed out and legitimation for BIPV can be increased.

This links to the next broadly recommended action: developing and demonstrating reproducible and scalable BIPV solutions with extensive knowledge dissemination (R10) which could be designed for, and applied throughout multiple countries, allowing for economies of scale. Prefabrication and rationalisation of production could be possible ways forward. One target application could be retrofitting existing buildings with energy renovation needs. Although the scale and scope can vary, some countries explicitly recommend large-scale demonstration of applicable concepts [8, p. 29], ideally on a European scale.

Reproducibility and scalability can also benefit from the common recommendation to increase standardisation (in production but also through industry standards) (R13). Historically, other construction products have been accelerated by standardisation, making the recommended action of "product standardisation" sensible. However, this might not be enough. Italy concludes its TIS-analysis with the question "Could standardisation be an issue for local authorities and architects who are loudly asking for a "solar language" capable of taking into account different materials, architectures, landscapes?" [7, p. 38]. One of the benefits of BIPV is aesthetic integration, so achieving standardisation without losing aesthetic values and the possibility of architectural expression would be desirable. Here, standardisation in production, or of sub-products, might be a way forward.

International submarkets are beneficial for economies of scale, but some countries might require locally oriented solutions for BIPV to make an impact. As illustrated above, Italy – with its extensive cultural heritage – is such an example. Apart from aiming at a certain standardisation, many countries therefore recommend to (financially) support verification, certification and/or patent applications, especially for this type of smaller, niche applications (R12).

Finally, the most recommended action across all groups is to acknowledge BIPV modules as building products in the (national) building codes, thereby clarifying the requirements for BIPV (R14). The fact that BIPV is not yet recognized as a construction product is a common issue, hindering many acceleration aspects, starting from the construction sector's trust in BIPV but also impacting the eligibility for economic incentives for renovation. This recommendation is related to the need for proper standards and building codes, as claimed by most countries. It would aid the further development of the BIPV manufacturing industry and enhance user trust and general acceptance of BIPV. The situation is being improved by an ongoing revision of the European BIPV standard (EN 50583-1), aiming for a harmonized standard. However, this standard revision still leaves certain (non-glass-based) applications uncovered.

Not one single recommendation on education, training and knowledge transfer is recommended by five or more countries. Still, there is a clear agreement that there is a need for more BIPV trainings, workshops, and knowledge dissemination between solar and construction industries and to public administration employees. This could also facilitate many of the other recommendations to become impactful.

3.4.1 ON THE COMPLETENESS OF RECOMMENDATIONS

A relevant check to perform is to see whether the recommendations presented address the functional weaknesses of the different national TISes, or if some functional weaknesses are left rather unattended. To check this, the number of recommendations linked to a certain function are presented in Table 5 for each country and for all countries summarised. As seen in Sections 3.2 and 3.3, the most problematic functions in general are F5 (Creation of social capital), F8 (Market creation),) and F2 (Knowledge dissemination), with the latter often linked to F3 (Entrepreneurial experimentation), F4 (Resource mobilisation), F6 (Legitimation), and F7 (Guidance of the search) that also show weak scores for about half of the studied countries. To consolidate all this information into one table, the colour indications of the functional fulfilment scores are added to Table 5.

Overall, it is observed that F2, F6, and F8 are addressed by the highest number of recommendations, even though the number alone does not provide a complete picture as some recommendations can be quite similar. Generally, there is a notable inverse correlation between the degree of functional fulfilment and the number of recommendations addressing that function. This means that functions performing poorly (indicated by yellow to red colours) receive more attention in recommendations than those performing better (indicated by green) – which is as expected. Exceptions to this trend are primarily seen for F3, F4, and F5 (e.g., Finland, the Netherlands, and Spain). Possible explanations could be that these functions are influenced by other functions that receive more attention. For instance, the lack of financial resources in the Netherlands is analysed to be due to the absence of solid business cases, which are addressed through recommendations on F5 and F6. Finland, likely in an earlier niche phase than other countries, is expected to see an increase in entrepreneurial experimentation

(F3) when Legitimation (F6) and Guidance of the search (F7) improve. In Spain, it is known that recent steps have been taken to integrate BIPV into construction sector events to enhance social capital development.

Table 5: Distribution of recommendations over addressed TIS-functions, per country and total. Cell colours indicate functional scores, where red means "absent to weak" (1.5/5) and dark green means "strong" (4/5).

Addressing:	F1	F2	F3	F4	F5	F6	F7	F8
Austria	4	11	6	3	5	16	6	10
Australia	4	13	7	5	8	17	7	13
Finland	1	5	1	1	2	5	4	4
Italy	1	2	2	2	1	7	2	5
The Netherlands	2	4	3	1	4	6	2	4
Spain	2	3	3	3	1	5	2	3
Sweden	2	7	4	3	5	12	6	7
Total	**5**	**15**	**8**	**5**	**9**	**21**	**8**	**15**

4 DISCUSSION AND CONCLUSIONS

The most apparent similarity among all the national BIPV TISes is that BIPV typically exists in a niche market phase, even though some niche markets (for instance, Italy) are significantly more developed than others (such as Australia).

On the supply side, there appears to be a blend of internationally and locally active actors. A smaller number of larger producers, primarily for c-Si glass-glass BIPV modules (for façades and skylights) and BIPV mounting systems, supply to many countries. In addition, there are numerous smaller companies that primarily operate in their own country, although some are exploring international expansion.

Architects or engineering consultants with BIPV experience are predominantly national, as are users, such as real-estate companies.

International policymaking is generally strong within the European Union (EU) but for BIPV its main effect is that BIPV's status as a building product is ambiguous within EU regulations. Otherwise, the primary hard institutional drivers or barriers for BIPV are typically nationally based. In the near future, the role of the EU might strengthen with forthcoming renewed directives addressing energy performance of buildings and energy markets.

Research actors frequently participate in international networks, while education is typically organized nationally or locally. Given the general weakness of the "Knowledge development" function (F2) in all studied countries, there should be opportunities and benefits for cooperation in educational activities and infrastructure. This opportunity is addressed by IEA PVPS Task 15 in its workplan for 2024-2028.

From several of the national TIS-analyses, it appears that BIPV sub-markets could be divided into two tracks. One track involves ambitious architectural integration of the PV system in a building or local environment, often with unique architectural qualities (such as historical environments or new flagship projects). BIPV solutions in this track tend to have a high degree of customisation. Typical applications within this path are discontinuous roofs with tile-sized BIPV modules or curtain walls – especially on existing buildings. Projects in this track are often lighthouse projects where public relations or image is an important argument. From here on, this track will be referred to as the *high-level* integration track, where "high-level" refers to architectural qualities, customisation, and customer segments.

The other track is one where the architectural integration can be less ambitious, with the focus more on the use of regular and/or mass-produced module sizes. Typical applications in this path are discontinuous roofs with regular module sizes and, to some extent, rainscreen façades, most likely in new constructions. This will be referred to as the *low-level* integration track.

Most countries have some commercial basis for the *high-level* track to exist as a (small) niche market, but even there, expansion to a commercial growth market would require more standardized solutions. Ideally, such solutions are created in a way that is feasible for multiple countries, in order to facilitate economies of scale. Since construction sector practices and architecture are to a certain extent regional or national, standardisation could be relevant at a product or at a sub-product level. Along with this, the development of an architectural "solar language" could facilitate the acceptance (legitimation) of BIPV.

The topic of digitalisation has arisen during the concluding works of this report. In most of the TIS studies by included countries, except for the Netherlands, it didn't appear as a topic by either analysis or as a result from interviews. However, with regard to the multiple industries (e.g. construction industry) which surround BIPV and where digitalisation is ongoing, it has potential to affect the implementation of BIPV, although more work is needed. IEA PVPS Task 15 has addressed challenges and opportunities of digitalisation with previous publications on design workflows and methods [28] as well as on a BIM-based process for BIPV digital product data [29]. There is also ongoing work in Task 15 to develop an IFC-Scheme for BIPV products and to describe BIM-based simulation and optimisation processes for BIPV projects.

4.1 MOTORS OF INNOVATION

The discussion of the results in this section is based on the theory of "Motors of Sustainable Innovation" by Suurs [30] to identify currently functioning motors or possibilities to activate these motors. The original theory defines and describes functional patterns, drivers, and barriers for:

- four positive motors of innovation:
  - Science and Technology Push Motor (STP)
  - Entrepreneurial Motor (E)
  - System Building Motor (SB)
  - Market Motor (M)
- one category of negative motors:
  - Motors of Decline (D)

In the original definitions and descriptions by Suurs, a slightly different set of TIS-functions (and alternative function numbering!) is used than in the Task 15 reports. This includes a function "Support from advocacy coalitions" and excludes "Development of social capital" and "Legitimation". However, there is a certain overlap between the two alternative function sets as good legitimation and social capital are key assets for a well-functioning advocacy to adapt the institutional configuration of the TIS. Even though the two functions used within Task 15 are broader than just the advocacy aspect, they will be used mainly as a substitute here to recognize and apply the main principles and ideas of the motors of innovation to our results.

All positive motors rely on decent fulfilment of F1 *Knowledge development*, F2 *Knowledge dissemination*, F4 *Resource mobilisation*, and F7 *Guidance of the search* (see Table 6). For the knowledge-related functions, all studied countries except for Australia have at least a moderate fulfilment for F1, but for F2 the fulfilment is assessed as (rather, to very) weak. This could be taken as a hindrance for all motors of innovation to operate in the national TISes. However, the fulfilment scores are mostly based on the weak dissemination to demand-side actors and supporting actors (e.g., government agencies), while dissemination to supply-side actors, especially producers originating from the PV sector, is generally found to be sufficient. Therefore, the F2 fulfilment is assumed to be sufficient for motors that rely on good knowledge dissemination to a smaller number of supply-side actors, such as the STP and E motors.

Table 6: TIS-function assessments and their role as drivers for the *Motors of Innovation*. Main drivers are marked with 'x', secondary drivers with '(x)'. Cell colours indicate functional scores, where red means "absent to weak" (1.5/5) and dark green means "strong" (4/5).

Nr	Function	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden	STP Motor	E Motor	SB Motor	MM Motor
F1	Knowledge development	3	2	3	3	4	3,5	3	x	x	x	x
F2	Knowledge dissemination	2	2	1,5	2,5	2	2	2	x	x	x	x
F3	Entrepreneurial experimentation	3	2	2	3	3	2,5	2	(x)	x	x	x
F4	Resource mobilisation	3	2	2,5	2,5	2	2	2,5	x	x	x	x
F5	Development of social capital	2	2	2	3	2	2	2	(x)	x	x	(x)
F6	Legitimation	3	2	2	2,5	3	3	2	(x)	x	x	(x)
F7	Guidance of the search	3	2	1,5	3	3	2,5	1,5	x	x	x	x
F8	Market formation	2	2	2	2	2	2,5	2,5			x	x

The anticipated outcomes of a period with a functioning STP motor in its early development, include a shared vision (F7), an increased number of scientists (F1) and supply-side companies (F3), and the establishment of some supportive hard institutions like R&D programs or demonstration projects (F1, F2, F4) [30]. These conditions are generally present in the studied BIPV markets. There is an overarching vision for BIPV as a technology that provides locally-generated renewable energy, architecturally integrated into buildings, requiring no additional land use, and improving resource, climate, and economic efficiency (compared to BAPV). More detailed visions, regarding the part of the building stock where BIPV is applicable (new or existing buildings) or potential volumes, are open for debate or undefined. Overall, scientific activity (*knowledge* development) is assessed to be sufficient, and all countries have several active supply-side companies, though the numbers are typically too low to cater for commercial growth. Thus, a general need to stimulate STP motors cannot be identified for these countries.

The E motor leads to a broad base of actors along the value chain and supporting actors (F1, F3), formation of (still poorly coordinated) networks (F5), stronger demand-side (market) actors with good connections to the industry (F4) and knowledge infrastructure (F2), technological progress in costs and/or performance (F1, F3, F4, F6), and further alignment of hard institutions like certifications and safety or quality standards (F7) [30]. These characteristics are not present in all countries. Leading customers are few, and all national analyses mention low knowledge levels among market actors – indicating weak connections or access to knowledge infrastructure – and often poor connections to industry actors. Networks do exist but are often weak or encapsulated in PV networks (apart from the Netherlands and Australia). Technological progress has surely occurred (e.g., in colouring) but especially progress in cost reductions seems slow (see e.g., [8]). In other words, engagement (or prolongation) of E motor activity would be beneficial for all countries, maybe with Italy being the exception to the rule. Italy has had at least aspects of an SB motor in place during the (later) FiT periods and – despite a period with possible *Motors of Decline* (D) – still has a considerably strong structure and fulfilment of the TIS-functions necessary for the E motor, especially for *low-level* integration. Drivers for the E motor are in place for *low-level* integration in Austria, the Netherlands, likely in Sweden, and possibly Australia. For *high-level* integration, Austria, Spain, and possibly Finland have E motor drivers in place. Otherwise, the promise of a commercial environment and willingness from e.g., governments to provide financial resources could be to low due to a lack of legitimacy and low knowledge levels.

Currently, *low-level* roof integration could be nearing commercial conditions for a portion of the market in several countries, although it often still faces an unaligned institutional framework. *High-level* integration largely depends on formal institutions to create commercial conditions for a significant portion of the building stock. Such kind of institutions are currently only in place in Austria and Finland. Spain and Italy have historically had such institutions, but currently only provide support for niche applications. The other countries studied (i.e., Australia, the Netherlands, Sweden) lack institutional benefits directed more specifically to BIPV installations.

4.2 OPPORTUNITIES FOR INTERNATIONAL COOPERATION

The institutional framework needed for long-term commercial conditions (to initiate the SB motor) could be established at the national level, but for countries within the European Union, there are shared opportunities in the forthcoming revisions of EU directives, particularly the Energy Performance of Buildings Directive that will set requirements for solar energy on buildings. The exact formulation and especially the implementation of the revised directive is yet to be defined, and BIPV actor networks could cooperate in advocating the role of BIPV.

Another opportunity is to identify which national market segments in the different countries could be served by the same or highly similar BIPV solutions. The conditions for commercial markets might be challenging to meet without economies of scale, and national markets are mostly too small to achieve these.

The point on economies of scale touches upon opportunities for standardisation in design, but also standardisation for quality and safety (e.g., fire) is needed. This is an ongoing process, but more work will be required. IEA PVPS Task 15 is actively participating in this work, mainly regarding characterisation methods for quality and safety.

Finally, there is a significant need for knowledge dissemination towards governments and market actors, as well as to ensure properly skilled professionals. This opportunity is seized by IEA PVPS Task 15, and TIS actors in all countries are advised to participate in these activities.

To reach the market development phase of *commercial growth*, a *System Building* motor would be needed in all countries. For this, coordinated networks (F5) are needed that can disseminate knowledge (F2) and campaign towards governments and markets and increase the legitimacy of BIPV (F7). This likely requires addressing technical questions like fire safety, societal topics like environmental benefits and economic feasibility. Once a sufficient level of legitimacy is present, the conditions can be met to set up institutions that can offer long-term commercial conditions.

4.3 MAIN CONCLUSIONS

BIPV is in a niche market phase in all countries. For all countries, except Spain, *low-level (architectural, customisation and customer segment)* roof integration is the most advanced BIPV sub-market, not so far from becoming a commercial growth market. In Spain, and to some extent Austria, *higher-level* façade integration is the main sub-market.

Despite differences between countries, all national TISes face similar challenges in knowledge dissemination, too low numbers of certain actor types in the value chain (especially construction industry actors and product manufacturers); limited legitimacy for the technology; little to no support in policies and regulations; cultural differences between PV and construction industries; limited trust, communication and collaboration between TIS actors; lack of trained professionals and of training opportunities.

In light of the above, it makes sense for industry actors and policymakers to increase international cooperation and focus on the following, recommended topics:

- Engaging new actors in the TIS, to fill gaps and increase diversity
- Increasing networking and collaboration between actors in the value chain
- Bridging (cultural and relational) gaps between the solar and construction sectors
- Stimulating further innovation and development (rationalising production and application)
- Improving policy regulations, standardisation, and increasing technical guidance for BIPV
- Stimulating BIPV markets
- Increasing education, training, and knowledge transfer on BIPV

For examples on concrete actions for each of these topics, see Section 3.4 and Appendix C.

For several countries there is also a need to increase legitimacy, through knowledge dissemination on societal benefits (e.g. role in climate change mitigation) and through strengthening social networks and social capital.

Performing TIS-analyses in multiple countries in parallel is a useful method to benchmark national technological innovation systems and to identify international patterns. A balance must be found between flexibility of the method for varying conditions between countries and level of detail in method standardisation. A somewhat higher level of standardisation than used in Task 15 Subtask A (in categorising and describing actors and institutions, systemic problems and opportunities, and recommendations) could be beneficial to improved benchmarking possibilities.

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APPENDIX A MAIN FORMAL (HARD) INSTITUTIONS IN THE NATIONAL BIPV TECHNOLOGICAL INNOVATION SYSTEMS

Table A1: Main legislative institutions in the national BIPV TIS, grouped by specific BIPV support, support for PV in buildings, no specific BIPV/PV in buildings support

Country	Specific BIPV support	PV in buildings support	General PV support	Explicit Barriers
Austria	Subsidy for particularly innovative systems, for which an additional 30% of the investment costs of the system are subsidized. Innovative systems include BIPV, among others.	In the Viennese building code an obligation to install renewable energy sources on all new buildings (E.g. 100 m^2 / 1kWp) Incentives for PV in buildings coupled with building energy efficiency refurbishment and zero energy buildings (some regional different requirements).	Capital subsidies for PV systems (+30 % for innovative PV Systems) Tenders or PPA: Yes P > 1 MW Tax free for PV self-consumption. Financial green loans for renovation, regional dependent. Support for special projects, cultural heritage etc. (*PV-Leuchttürme v2*)	BIPV products are not considered construction materials.

Country	Specific BIPV support	PV in buildings support	General PV support	Explicit Barriers
Australia	BIPV and PV benefits from government support programs to renewable energy adoption. BIPV benefits from low-cost loans for PV products improving energy efficiency in dwellings.	Some specific support programs to PV rooftops Support for replacing asbestos by PV roofs. Capital subsidies for PV in buildings (and batteries), solar rebate schemes, interest-free loans.	FiT – FiP for PV, variable among states and retailers. PPAs for RE. Dedicated financial green loans for all RE Other support measures for special projects, cultural heritage Social housing renovation scheme Self-consumption scheme: Net- metering or net-billing scheme Support for storage, eventually coupled with BI(PV)	

Country	Specific BIPV support	PV in buildings support	General PV support	Explicit Barriers
Finland	25% energy allowance for investment of costs of PV window glass	Commitments to EU climate or renewable energy goals. One of the key methods listed for increasing the energy efficiency of the building stock is installation of solar panels. Tax reductions for the installation of PV in households (from 40% reduction, up to 2250 €). Energy allowance for renovation of a residential building in a way that improves energy efficiency, available for private persons and housing companies. E.g. 10% for PV systems with roof renovation, 25% for PV window glass, and 50% on planning costs.	Energy aid to larger renewable energy projects from the Ministry of Economic Affairs and Employment of Finland. Granted for companies or municipalities for new projects that promote the use of renewable energy or improve energy efficiency. Priority for new technologies not previously used in Finland. For PV, the aid is 15% of investments costs.	

Country	Specific BIPV support	PV in buildings support	General PV support	Explicit Barriers
Italy	Regional tender for PV and BIPV in public administration buildings	National: - Renewable energy obligation in refurbishment and new buildings (PV included). Tax deduction/Fiscal incentives for PV in buildings (50%), and for PV coupled with building energy efficiency refurbishment (so-called superbonus)	National: - Feed-in Law, Gestore dei Servizi Energetici (GSE) -Tax deduction : Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA). -Net-billing scheme (even if a gradual phase out is foreseen), dedicated withdrawal (GSE).	BIPV products are not considered construction materials.

Country	Specific BIPV support	PV in buildings support	General PV support	Explicit Barriers
The Netherlands	BIPV benefits from the government support for innovation and solar technologies R&D.	Support for replacing asbestos roofs with PV roofs, especially in farms. VAT exemptions for PV in/on buildings for residential systems. Dedicated financial green loans (for renovation etc.)	VAT reduction of 10% for PV products. Self-consumption (real time) Net-billing for PV self-consumption (up to 500 kW) based on energy and services. Direct self-consumption allowed. Dedicated withdrawal of electricity. Tax credit for storage coupled with PV. Collective self-consumption, solar communities (support granted for 20 years)	Parties investing in BIPV (e.g. property owners) are often not those who get the benefits (e.g. users, renters), which limits the incentives to invest.

Country	Specific BIPV support	PV in buildings support	General PV support	Explicit Barriers
Spain	BIPV benefits from the increase in self-consumption subsidy if the installation is a canopy. Capital subsidies for self-consumption increase if the PV system is installed/integrated in a canopy.	The government economically supports PV self-consumption. Municipalities establish tax reductions for PV in buildings. The Building Technical Code requires to new buildings and integral retrofit actions a minimum RE electricity. Building permit requirement to install PV modules in buildings is suppressed throughout Spain since July 2023. Support for replacing asbestos roofs with PV roofs. Tax reduction by some municipalities up to 50% for PV in buildings.	Net-billing scheme for PV self-consumption. Collective self-consumption allowed. Capital subsidies for self-consumption investment. Energy rehabilitation subsidies for buildings. Public tenders (PPA) for RE. Support for RE storage.	BIPV material is not eligible in energy renovation of buildings, unlike conventional materials.

Country	Specific BIPV support	PV in buildings support	General PV support	Explicit Barriers
Sweden	Detailed plans at municipal level can require roofs or façades in particular colour for areas of higher cultural heritage. Same plans can also prohibit (BI)PV.	Tax deduction for house owners. Tax deduction for consumers investing in PV on/near buildings, electrical storage, EV charging stations.	FiP designed as a tax deduction on income tax, for all RE (prosumers only). Previously active supports for energy efficiency renovations in multi-family dwellings stopped in 2022. Self-consumption scheme: No energy tax for RE installations up to a generator capacity of 100 kW (for PV this is translated to 500 kWp, DC).	Building permit exceptions for BAPV are much more extensive than for BIPV. (Government investigation foreseen). Compulsory climate declarations (for new buildings) should cover BIPV, while BAPV is currently excepted. New proposal suggests a level-playing field for BAPV and BIPV.

Table A2: Main technical codes, standards, etc. in the national BIPV TIS, grouped by specific BIPV support, support for PV in buildings, no specific BIPV/PV in buildings support

Country	Specific BIPV support	PV in buildings support	Support not specific for BIPV nor PV in buildings	Barriers
Austria	OVE EN 50583 (parts 1 and 2): 2016 is a BIPV national standard.		Green certificate of guarantee of origin of energy. Harmonised standards and rules established by the Low Voltage Directive (LVD) and the Construction Products Regulation (CPR)	There are currently no harmonized standards that allow the simple mounting of standard modules on building objects.
Australia	The IEC 63092 has not been adopted as a national standard especially in the building industry, but it is serving as a starting framework to develop future national BIPV related requirements.	The National Construction Code (NCC) supports PV adoptions in buildings, but there are limited specific rules, codes, and standards relevant to PV in buildings.	Green certificate of guarantee of origin of energy (NABERS) Codes and standards imposed by the Australian Building Codes Board (ABCB) and the Standards Australia. National Construction Code (NCC) sets the minimum required level for the safety, health, amenity, accessibility, and sustainability of certain buildings (ABCB, 2019). The Australian PV sector follows the relevant IEC standards related to PV	Australian building industry does not have BIPV specific rules, codes, and standards.
Finland	SFS-EN 50583 (parts 1 and 2): 2016 is a BIPV national standard.		Green energy certificate for buildings: Energy efficiency class and E-rating. PV improves the E-rating. Harmonised standards and rules established by the Low Voltage Directive (LVD) and the Construction Products Regulation (CPR).	

Country	Specific BIPV support	PV in buildings support	Support not specific for BIPV nor PV in buildings	Barriers
Italy	CEI-EN 50583 (parts 1 and 2): 2016 is a BIPV national standard.		Energy performance label of the building	
The Netherlands	NEN-EN 50583 (parts 1 and 2): 2016 is a BIPV national standard.		Harmonised standards and rules established by the Low Voltage Directive (LVD) and the Construction Products Regulation (CPR).	
Spain	UNE-EN 50583 (parts 1 and 2): 2016 is a BIPV national standard.		The Technical Building Code requires renewable energy electric power in new buildings and integral renovations (also residential since June 2022). Green energy label for buildings: PV adds to label qualification. Harmonised standards and rules established by the Low Voltage Directive (LVD) and the Construction Products Regulation (CPR).	BIPV is not explicitly named in the building code.

Country	Specific BIPV support	PV in buildings support	Support not specific for BIPV nor PV in buildings	Barriers
Sweden	SS-EN 50583 (parts 1 and 2) PV in buildings is a BIPV national standard.	SIS HB 537 BAPV mounting on roofs (not covering BIPV). CEN/TR 16999 Requirements for structural connections to solar panels (BAPV).	Building regulations or building code (BBR): Defines (functional) requirements of buildings and building parts. Nothing specific on BIPV. Electrical Code for low voltage electrical installations (SEK 4364000), including PV chapter 712. Green Certificates of green electricity: Certificates of origin with market based price level; Previously green certificate system was present, but target is met and system has stopped. Harmonised standards and rules established by the Low Voltage Directive (LVD) and the Construction Products Regulation (CPR)	

APPENDIX B SYSTEMIC PROBLEMS AND OPPORTUNITIES FOR TIS DEVELOPMENT IN THE NATIONAL BIPV TECHNOLOGICAL INNOVATION SYSTEMS

The checkmarks in the tables in this appendix are based on the assessment of the main problems by the authors for the national reports and full-proof benchmarking of the importance and size of similar problems between countries was not possible. What this implies is that unticked problems are not necessarily absent in a country (but they are assessed as of minor importance) and that ticked problems can be of somewhat varying importance.

Table B1: Actor-related systemic problems and opportunities for TIS development and their presence (marked by "x") in the national BIPV TISes.

Nr.	Actor-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SP1	**Systemic problems**							
SP1.1	Few BIPV manufacturers	x	x	x	x		x	
SP1.2	Few installers and suppliers working with BIPV	x		x				
SP1.3	Low engagement of construction industry		x		x	x	x	x
SP1.4	Few BIPV-specialized actors		x		x		x[4]	x
SP1.5	Few or no multinational companies actively engaged		x			x		
SP1.6	Little engagement by education actors (BIPV courses)	x					x	x

[4] Refers especially to BIPV consultants.

Nr.	Actor-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SP1.7	Few industry actors focus on products for historical heritage areas				x			
SP1.8	Few industry actors focus on retrofit solutions with BIPV						x	
SP1.9	Few industry actors focus on service of BIPV-installations						x	
SP1.10	Few lead-customers		x	x			x	
SP1.11	Industry has not succeeded in bringing down the prices and/or upfront costs sufficiently		x		x	x	x	x
SP1.12	Lack of easily reproducible solutions						x	x
SP1.13	Lack of holistic façade and roof solutions including BIPV		x					x
SP1.14	No proper communication on BIPV benefits by BIPV industry actors		x		x			
SP1.15	Industry actors fail to convince market of BIPV legitimacy		x		x	x	x	x
SP1.16	Supporting actors (e.g. research) contribute little to creation of legitimacy							x
SP1.17	Industry actors fail to communicate a clear status and vision for BIPV		x		x		x	x
SP1.18	Small BIPV manufacturers lack financial means to push research	x	x					
SO1	**Systemic opportunities**							
SO1.1	Increasing interest in adjacent TISes (centralized PV, BAPV) might be an opportunity in the long run when those stagnate.							
SO1.2	Initial examples of combining PV suppliers/installers and construction companies (or close collaboration between the two) seem to be falling out well. Others might follow suite.	x	x		x			x

Nr.	Actor-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SO1.3	A few building owners are starting to accept BIPV technology, creating a positive demand		x					
SO1.4	Two producers that share more than half of the market have the necessary financial means to push the research.	x						
SO1.5	Many actors in the BIPV value chain	x	x					
SO1.6	Value chain actors help each other to understand BIPV through pilot projects							
SO1.7	Platforms exist that stimulate and improve knowledge exchange	x			x			
SO1.8	New interest of local public authorities to integrate BIPV in historical city centres (due to RES and EPB targets)				x			
SO1.9	Increasing interest from architects in BIPV (especially new generations)	x			x		x	

Table B2: Institution-related systemic problems and opportunities for TIS development and their presence (marked by "x") in the national BIPV TISes.

Nr.	Institution-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SP2	**Systemic problems**							
SP2.1	Aversion to use of new technologies/methods -risk aversion (in construction/building sector)		x				x	x
SP2.2	PV is highly focused and BIPV is not seen as a value-adding technology	x	x		x		x	?
SP2.3	National support is for renewable energy, not directly to BIPV development	x	x	x	x	x	x	
SP2.4	Not considered as building product	x			x		x	
SP2.5	Lack of technical guidance on BIPV implementation		x		x		x	x
SP2.6	Reluctant to include BIPV in the early design stage				x		x	x
SP2.7	Experienced competition over BAPV solutions		x		x	x	x	x
SP2.8	Less understanding on the technology	x	x					
SP2.9	A few standardized BIPV modules					x		
SP2.10	None or no proper standards or building codes	x	x	x	x		x	x
SP2.11	Constructions industry focus on minimizing upfront costs rather than total costs of ownership		x				x	x
SP2.12	Financial support lacks awareness of BIPV development phase (relative to e.g. BAPV)							x
SP2.13	Technical and safety requirements for BIPV are generally not asked for in BAPV, even thought they might be used in similar applications							x

Nr.	Institution-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SO2	**Systemic opportunities**							
SO2.1	Architects and most of the general public prefer aesthetical and sustainable solutions (where BIPV is considered to have a better potential than utility scale PV and to some extent better than BAPV).				x			x
SO2.2	The European "BIPV standard" EN 50583 is currently (2023) being revised, providing improved technical guidance.							x
SO2.3	An extensive technical guide on BIPV is currently under development in IEA PVPS Task 15.	x	x					x
SO2.4	The current government is planning to investigate removing building permit requirements for BIPV.		x					x
SO2.5	A new report by the responsible government agency suggests creating uniform rules for BAPV and BIPV							x
SO2.6	New/updated regulation (2021) introduces some simplifications for permitting BIPV				x			
SO2.7	The EU initiatives of the Solar Energy Strategy, upcoming updates of the Energy Performance of Buildings Directive together with the New European Bauhaus (beautiful, sustainable, together), could boost Guidance of the search and maybe also Legitimation.				x			x
SO2.8	Public Administrations have the commitment to lead as an example in how they manage their buildings, which should also be valid for BIPV.				x			
SO2.9	Support for BIPV is now offered from multiple ministries					x		

Table B3: Interaction-related systemic problems and opportunities for TIS development and their presence (marked by "x") in the national BIPV TISes.

Nr.	Interaction-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SP3	**Systemic problems**							
SP3.1 SP3.2	Lack of communications/collaborations between actors (producers, planners, and construction companies)	x	x	x	x	x	x	x
SP3.3	PV sector and building sector work separately and lack common language		x		x	x	x	x
SP3.4	A low number of jobs in the market	x						
SP3.5	BIPV is not a part of an integral system of buildings	x			x		x	
SP3.6	Limited social cohesion							x
SP3.7	PV is dominating over BIPV (lock-in effect)		x		x	x	x	x
SP3.8	Interaction with the construction sector is not sufficient in every level		x		x	x	x	
SP3.9	No or less community and opportunities for network		x				x	x
SP3.10	Lock-in effects existing (BA)PV and construction/building sector							x
SP3.11	Lock-in of relations between BIPV entrepreneurs and Solar PV research institute		x			x		
SO3	**Systemic opportunities**							
SO3.1 (also SO1)	Initial examples of combining PV suppliers/installers and construction companies (or close collaboration between the two) seem to be falling out well. Others might follow suite.							x
SO3.2	Presence of a BIPV association		x			x		

Nr.	Interaction-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SO3.3	Presence of PV platforms/associations promoting interaction	x						
SO3.4	Some public authorities' initiatives increase communities and communication channels		x					
SO3.5	Increasing concentration of relationships centring around research institutes		x		x	x		
SO3.6	Recent efforts to include BIPV products in BIM database					x		
SO3.7	Governmental organisations can support network building for SMEs			x				

Table B4: Infrastructure-related systemic problems and opportunities for TIS development and their presence (marked by "x") in the national BIPV TISes.

Nr.	Infrastructure-related problems and opportunities	Austria	Australia	Finland	Italy	the Netherlands	Spain	Sweden
SP4	**Systemic problems**							
SP4.1	Lack of skilled/trained workers	x	x			x	x	x
SP4.2	Limited education infrastructure (training places, apprenticeships, workshops)	x	x	x			x	x
SP4.3	No specific/improved incentives nor direct financial support schemes	x	x	x	x	x	x	x
SP4.4	No proper facilities for onshore manufacturers		x					
SP4.5	Grid capacity could become a problem			x				(x)
SO4	**Systemic opportunities**							
SO4.1 (also SO2)	The EU initiatives of the Solar Energy Strategy, upcoming updates of the Energy Performance of Buildings Directive together with the New European Bauhaus (beautiful, sustainable, together), could boost Guidance of the search and maybe also Legitimation.	x			x			x
SO4.2	Strong electrical grid infrastructure	x					x	
SO4.3	Many financing options for BIPV installations	x						
SO4.4	Existing educational infrastructure for BIPV can be expanded relatively easy	x						
SO4.5	Strong research infrastructure	x						
SO4.6	Many existing buildings in need of energy rehabilitation				x		x	(x)
SO4.7	Available land and surfaces are very limited - also some surfaces are more suitable for BIPV than BAPV				x	x		

APPENDIX C LIST OF RECOMMENDATIONS FROM THE INDIVIDUAL COUNTRY REPORTS, THEIR LINKS TO SYSTEMIC PROBLEMS AND MAIN TARGET GROUPS, AND THEIR IMPLEMENTATION STATUSES

Target groups are indicated as: I(ndustry), M(arket), P(olicy makers), O(thers). Implementation statuses are indicated as: R(ecommended), C(urrently implemented), H(istorically implemented), or N/A.

Some grouping or categorisation has been done while compiling the table below. Also, be aware that a recommendation could have relevance for more countries than those marked. The lack of a mark for a country indicates that this particular recommendation was not considered or was not prioritised by the authors of that national TIS-analysis.

Nr	Recommended actions	Main target group	Main target functions	Austria	Australia	Finland	Italy	The Netherlands	Spain	Sweden
R1	Initiate partnerships between PV and construction companies (voluntary or in tenders or funding calls)	I	F2, F3, F5	R	R		C	R	R	R
R2	Involvement of financial institutes in BIPV	M	F4	R	R		R		R	
R3	Collaborative road-mapping initiatives;	I	F5, F7	C	R			R		R
R4	Market potential reports;	I, M, P, O	F7	R	R	R		R		R
R5	Implement collaboration and mobility schemes for industry experts and researchers;	I	F2, F5	R	R					R

Nr	Recommended actions	Main target group	Main target functions	Austria	Australia	Finland	Italy	The Netherlands	Spain	Sweden
R6	Report on and campaign against disadvantages for BIPV in current institutions, compared to (BA)PV;	I	F6	R	R					R
R7	Organize BIPV networking events aimed at (BI)PV, construction, and real-estate industries.	I, M	F2, F5, F7, F8	C	R	R				R
R8	Specific BIPV research funding	P	F1, F4	R	R			R	R	
R9	New solar language according to different materials, architectures, landscapes	O	F1, F2, F3	R			R		R	
R10	Develop and demonstrate reproducible BIPV concepts (with extensive knowledge dissemination);	I, M	F1, F2, F3, F6	R	R	R		R		R
R11	BIPV technology to be explicitly indicated in the RES national decrees	P	F6, F7	R	R	R			R	
R12	Grant a support to cover (part of) product verification or certification costs and/or patent fees, especially for small producers of niche products	P, O	F4 (F3, F6)	R	R		R		R	R
R13	Product standardisation (in production, but also industry standards)	I	F6, F8	R	R		R	R	R	
R14	Including BIPV in the national building codes as building products and solutions, thereby clarifying the requirements for BIPV	P	F6, (F7, F8)	R	R	R	R		R	R
R15	Develop LCA reports or Environmental Product Declarations for BIPV products and systems;	I (O)	F6	R	R		R			R
R16	Investigate building permit exceptions for BIPV (or ending exceptions for BAPV).	P	F6, F8	R			R			R

Nr	Recommended actions	Main target group	Main target functions	Austria	Australia	Finland	Italy	The Netherlands	Spain	Sweden
R17	Training about RES, BIPV and building energy efficiency for Public Administration employees	O	F2, F5, F6	R	R		R	R	H	
R18	Organize technical and scientific workshops on BIPV;	I, M, O	F1, F4	H	R			R		R
R19	Develop and provide trainings on BIPV for professionals, preferably in multi-disciplinary groups;	I	F2, F5	R	R			R		R
R20	Dissemination of existing relevant information and experience among stakeholders to increase their trust in BIPV	P, M, I	F2, F6	H	R	R			R	R
R21	Joint campaign, by BIPV-actors, to highlight the technology's benefits.	I	F8, (F2, F6)	R	R	R				R
R22	Arrange workshops, training programmes/ apprenticeships to increase the number of expertise and distribute the knowledge to a broader community	I, O	F2, F5	O	R					
R23	Public buildings as leading examples: their new projects or retrofit actions should include BIPV	P	F8	R	R		R		R	
R24	Establish harmonized (EU) standards or product certifications for (non-glass) BIPV (preferably based on the European Construction Products Regulation [45]);	I	F6	R						R
R25	Innovation procurement for mass-customized BIPV-solutions;	M	F3, F8	R	R					R
R26	Investigate which building product-originated requirements also are relevant to (some) BAPV;	I, P	F6	R	R					R

Nr	Recommended actions	Main target group	Main target functions	Austria	Australia	Finland	Italy	The Netherlands	Spain	Sweden
R27	Investigate economic incentives (or bonuses) for BIPV installations, e.g. Feed-In Tariff (FIT) or tax reduction;	P	F4, F8	C	R	R				R
R28	Develop (and communicate) an industry-bridging perspective on BIPV in the implementation of upcoming EU regulations (Solar Strategy, EPBD, …) to seize opportunity SO 8;	I	F6, F7	R						R
R29	Encourage (or demand) BIPV solutions in urban planning (e.g. detailed development plans, land allocation agreements), wherever a significant interest from real-estate developers makes this feasible.	P	F6, F7, F8	R	R		R			R
R30	Creation of a network of BIPV value chain members	I (O)	F2, F5	R	C	R				
R31	Publishing technical guidebooks, industry reports, articles, and newsletters	I, O	F2, F6	R	R					
R32	An easily accessible BIPV product database	I	F2, F8	R	R					
R33	A live lab that can test and demonstrate all types of BIPV products based on its applications is essential for Australia	O (I)	F1, F2, F6, F8	R	R					
R34	Government authorities to take the lead in disseminating knowledge covering various aspects such as technical, scientific, economic, etc.	P	F6	R	R					
R35	The government to provide reimbursements for upstream and downstream actors to encourage the development of BIPV	P	F3, F7, F8	R	R					
R36	Existing network (academia, start-ups, and consultancies) to start networking with local government to address societal issues	I	F5, F6		R			R		

Nr	Recommended actions	Main target group	Main target functions	Austria	Australia	Finland	Italy	The Netherlands	Spain	Sweden
R37	Identify new markets addressing societal needs, bring together different stakeholders to negotiate business cases	I, P, O	F3, F6, F8		R			R		
R38	Identify new markets and business cases that require new legislation	P	F6, F8					R		
R39	Industrialisation of the building process by using digital tools.	I	F2, F3, F8		R			R		

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