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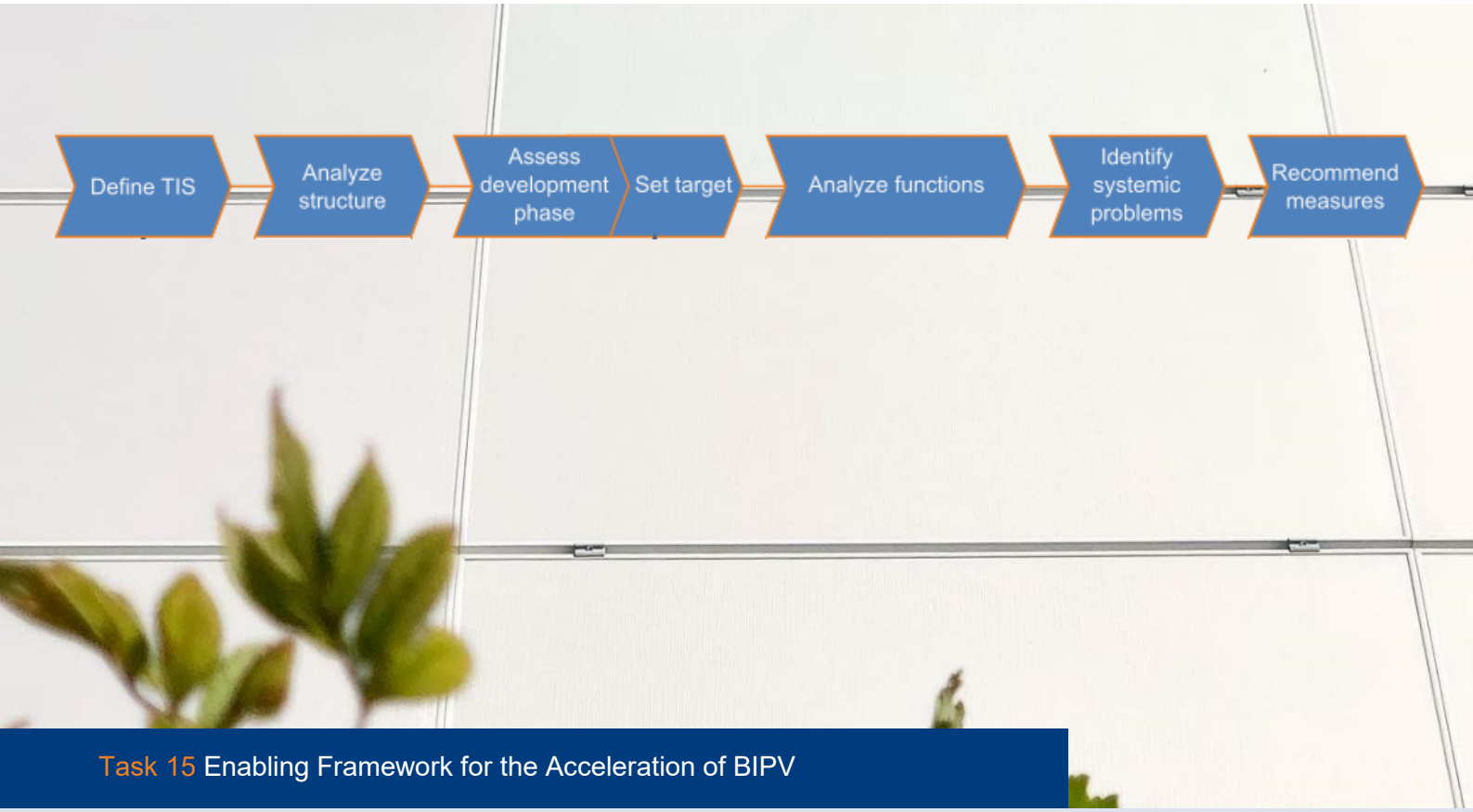

Task 15 Enabling Framework for the Acceleration of BIPV

PVPS

Guide for Technological Innovation System Analysis for Building-Integrated Photovoltaics 2023

Report IEA-PVPS T15-16:2023

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 TCPs 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 countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Copper Alliance are also members.

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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

Photo: @solcellsarkitektur, Malin Unger; Flowchart: Michiel van Noord

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INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Guide for Technological Innovation System Analysis for Building-Integrated Photovoltaics

IEA PVPS
Task 15
Enabling Framework for the Development of BIPV

Report IEA-PVPS T15-16:2023
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LIST OF ABBREVIATIONS

BAPV	Building Applied Photovoltaics
BIPV	Building Integrated Photovoltaics
EE	Entrepreneurial Experimentation
IEA	International Energy Agency
NGO	Non-Governmental Organisation
nZEB	Near-Zero Energy Building
Org.	Organisation
RE	Renewable Energy
TIS	Technological Innovation System

EXECUTIVE SUMMARY

This Guide for Technological Innovation System (TIS) Analysis for Building-Integrated Photovoltaics offers hands-on support on theory and methods for those who want to analyse the innovation system for BIPV in their country. It describes the general process steps to perform a TIS analysis and the specific choices and methods used by Subtask A of IEA PVPS Task 15. In this way it allows for future TIS-analyses to be made in a comparable way to the national studies published by Task 15, either by covering new countries or by timely updates of the TIS in the same countries.

Apart from being a guidebook for the analyser, this document can also be used as a template for a final TIS-analysis report – using the same (sub-)chapters, tables, and graphs.

The initial definition of the common scope of the TIS studied consists of Building Integrated PV modules and systems as well as PV modules and systems for aesthetical integration. Where relevant, national studies can adjust or deepen the scope by separately analysing different market segments or by excluding certain sub-technologies or application types. The latter can be relevant for example due to cultural or historical reasons.

Starting from the scope defined, this guide describes how to analyse and describe the structure of the TIS, through its actors, networks, and institutions (regulations, cultural norms, etc.). Based on that structure and the market situation, an assessment is to be made of the market development phase for BIPV in general or for different application types. Next, a development target should be defined so that the current TIS can be evaluated in relation to that target.

The main part of the TIS-analysis is performed after defining the target, by analysing the performance of eight functions of the TIS: Knowledge development, Knowledge dissemination, Entrepreneurial experimentation, Resource mobilization, Development of social capital, Legitimation, Guidance of the search, and Market formation. The meaning of each function is explained and key indicators, as well as assessment questions, are listed. These indicators and questions assist the reader in her/his assessment of whether the function is sufficiently fulfilled for the TIS to achieve the set target.

For those functions that are not fulfilling the target requirements, guidance is given on how to identify systemic problems that either relate to actors, institutions (hard and soft), interaction between actors, or to infrastructural deficits.

Finally, the guide describes the need of, and some advice on how to arrive at recommendations for a possible overcoming of problems and weaknesses in order to reach the set target. Recommendations should address both industry actors and policy makers.

1 INTRODUCTION

This document is a guide developed by IEA PVPS Task 15 Subtask A for those who intend to perform an analysis of the technological innovation system (TIS) of Building integrated photovoltaics (BIPV). The guide consists of a preliminary heading structure and describes a well-established analysis procedure based on a methodology presented in more detail by e.g. Bergek et al. [1], Hellsmark et al. [2] and Hekkert et al. [3]. Under each heading, a number of instructions, suggestions and questions are listed that are meant to support the implementation of a TIS analysis. Originally this guide was developed for internal use within Task 15 only, but by publishing it we want to support other actors to perform comparable analysis reports for additional countries, or to update the Task 15 national analysis reports.

TIS analyses have been applied to analyse innovation systems for different energy technologies, primarily in Sweden and the Netherlands, which was one of the reasons Task 15 partners from these two countries proposed this as a main activity in Task 15. Drivers and barriers for BIPV have been analysed in many countries in several earlier projects, and this will be helpful when carrying out the Task 15 TIS analyses. However, we believe that previous analyses were primarily carried out from a specific perspective, defined by the people performing them, and therefore are of limited value for broader use. The TIS framework provides a tool that enables a structured and more objective perspective on the entire value chain of BIPV, including the interaction between its parts and its stakeholders. Additionally, the TIS framework is specifically aimed to analyse the main barriers that hamper acceleration of technologies, such as BIPV, which is another reason why the framework is useful for the goals set out in Task 15 (i.e. to accelerate market uptake of BIPV).

The first target group for this guide consists of all partners of Task 15 who intend to carry out a TIS analysis for BIPV in their country or region, within Subtask A. We also hope that the guide will serve as a first introduction to the methodology and, as such, encourage more partners to join the work and perform their own analyses. After several national analyses, Subtask A will eventually provide a synthesis analysis of the national studies that were performed in Task 15, and based on that, develop recommendations for more extensive policies. With multiple country analyses, the synthesis will gain both relevance and momentum, and is expected to have a big impact.

Whereas most historical TIS analyses have aimed their findings and policy recommendations to public government and organisations, and decision makers, an intention for this study is to broaden the focus and present findings and recommendations to private organisations and businesses, along with policy recommendations. In this context, the interactions between the (BI)PV and the building industry, as well as real estate owners, are of particular interest. The building industry is here considered as a broad range of actors, including not just construction companies but also architects, consultants, building product manufacturers, etc.

The main objectives of the Task 15 TIS analyses are to facilitate and support implementation of BIPV, and support innovation and industrial development of BIPV solutions.

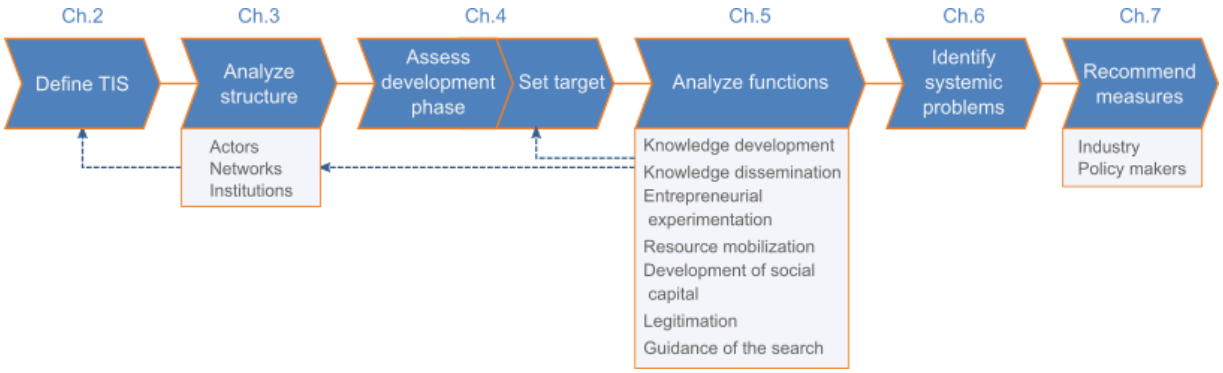


Figure 1: Process overview for the TIS analysis (adapted from [1])

The process of performing a TIS analysis is summarized in Figure 1 (above) and will be described in more detail in each of the following chapters. The structure and headings of this guide are intended to be used for TIS analysis reports in the same way as presented in this report. Each chapter and sub-chapter starts with **a short description in bold text** of what should be the content of that section in a final report. Following are more detailed descriptions of TIS theory, work approaches, etc. as well as suggestions and templates for presentation of results in graphs and tables.

2 DEFINITION OF THE TIS FOR BUILDING-INTEGRATED PHOTOVOLTAICS

The first step of a TIS analysis is to define the considered innovation system as well as giving a historical background to it. Therefore, this chapter defines the common scope of our analyses, including possible limitations, and explains what developments in time are relevant to describe.

2.1 Scope of this analysis

In this section, the scope of the TIS and its analysis is defined. This scope should be kept as similar as possible for all national studies, thus starting in a broader scope and allowing only for limitations of that scope.

For the purpose of the TIS analysis focusing on innovation and markets, we see a need to use a somewhat broader scope than the BIPV definitions that were previously recommended for use within Task 15 concerning BIPV standards [4]:

> *A BIPV module is a PV module and a construction product together, designed to be a component of the building. A BIPV product is the smallest (electrically and mechanically) non-divisible photovoltaic unit in a BIPV system which retains building-related functionality. If the BIPV product is dismounted, it would have to be replaced by an appropriate construction product. [4]*

> *A BIPV system is a photovoltaic system in which the photovoltaic modules satisfy the definition above for BIPV products. It includes the electrical components needed to connect the PV modules to external AC or DC circuits and the mechanical mounting systems needed to integrate the BIPV products into the building. [4]*

An adaptation is considered necessary to better account for market situations where products for “solely aesthetic” integration are competing with, and targeting, the same niche markets as products with an aesthetic, functional and constructive integration. Both product types play a similar role in the innovation system for BIPV. Aesthetic integration is here defined in accordance with the IEA-SHC Task 41 description of formal (aesthetic) integration [5], implying coherency and/or compatibility with the building design for:

- position and dimension of the PV field(s);
- material surface texture(s) and colour(s);
- module size and shape;
- jointing types.

A “solely aesthetic” integration implies an integration where dismounting the PV product would not create the need for replacement by an appropriate construction product. See also the text box below for illustrative examples of products for “solely aesthetic” integration.

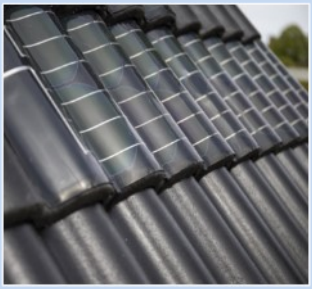
The following common scope is therefore defined for all national TIS analyses, using the definitions and descriptions above:

BIPV scope:
BIPV modules and systems as well as PV modules and systems for solely aesthetical integration.

Illustration of the scope: BIPV and non-BIPV solutions

The following solutions for integration with roof tiles all target the same, or very similar, markets, but not all are BIPV modules and BIPV systems according to the recommended Task 15 definitions.

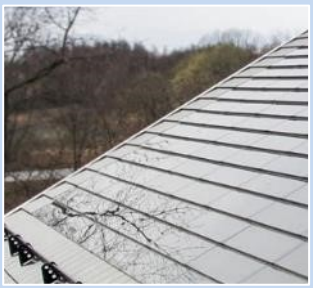
Solely aesthetical integration



Flexible CIGS-module on top of roof tiles (image: Midsummer)

Aesthetical and constructional integration:

CIGS-integrated roof tile module (image: Hanergy)



CdTe-integrated roof tile module (image: Soltech Energy)

Although these products are competitors on the market, the technological challenges could be quite different. When comparing these kinds of solutions from an economical or technological perspective, a system functionality approach should be used: consistently include all system components (incl. construction products) that are required to deliver the same functionality as the BIPV system.

Starting from the common BIPV scope, a further national delimitation of the scope of the TIS analyses can be made, excluding those BIPV technologies and applications that are irrelevant for the specific country. Definition of such delimitations should be made using the categories defined in [6], see Figure 2.

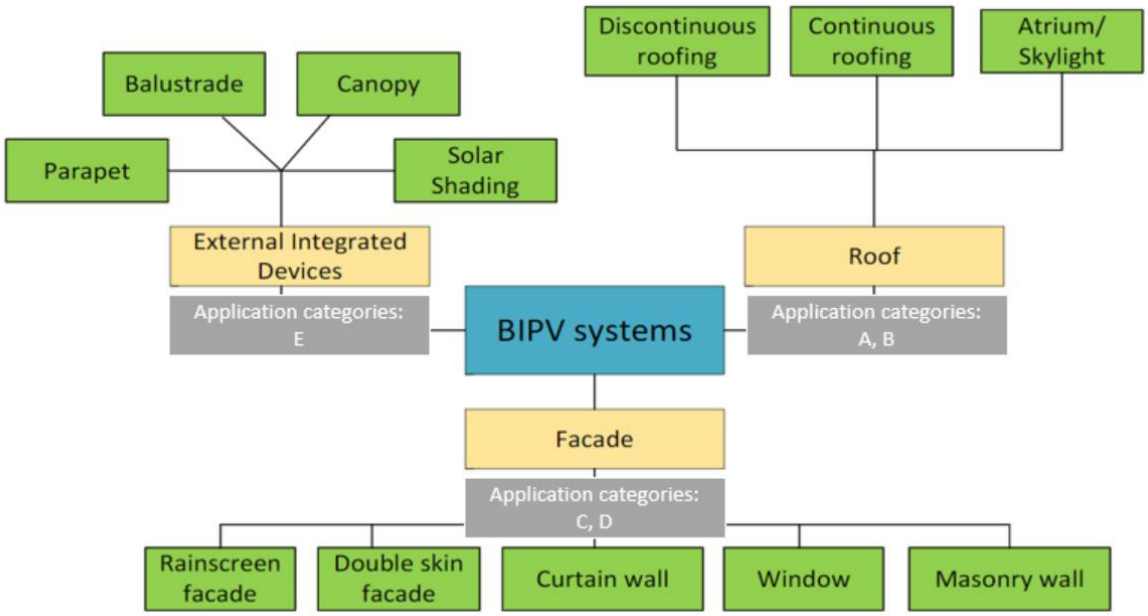


Figure 2: BIPV system categorization (from [6])

2.2 Historical technological development

In this section, briefly describe the historical development of technology (i.e., solutions, products, materials) in the country. This description provides a general introduction and background to the TIS analysis, as well as arguments for any delimitations of the scope compared to the common scope.

2.3 Historical development of the innovation system

In this section, briefly describe the historical development of the innovation system in the country, i.e. the actors, networks and institutions that have been active within the scope.

Describe important milestones or events for the national BIPV market development. Focus only on the most important actors/networks/institutions that can explain why the market has developed as it has. Also, keep in mind that the current status will be described and analysed in the next Chapter, so do not cover that here.

Please keep in mind that in a TIS context, “institutions” are defined as the rules of the game describing why actors act as they do. They can be roughly divided into soft and hard institutions, where the hard ones are laws, rules, standards, support schemes, etc. and soft ones are norms, cultural values, beliefs, etc.

The descriptions in this section should serve two purposes:

- Providing an introduction and background to the BIPV TIS and market for those readers that are not familiar with these for the relevant country.

- Providing background and arguments for any delimitations of the scope as compared to the common scope.

Historical milestones or clusters of events with significant importance for the development of the TIS can be presented in a timeline figure (optional).

For an example of a (more extensive) historical description of developments of a TIS, refer to example I in Appendix C – Illustrative example studies.

3 STRUCTURAL ANALYSIS

In this chapter we leave historical developments behind us and present the current status of the technological innovation system, and describe it using the same elements as in the previous chapter (in line with [1]): technology; actors and networks; and institutions.

BIPV is an overarching term for multiple applications and products that could well target different customers and end-users. These end-user groups also make substantial contributions to the development, diffusion, and societal embedding of these technologies in the country considered. When analysing such multifaceted technologies, Dewald and Truffer [7] propose to add sub-system structures to the overarching TIS structure to be able to take specific market segments into account (see Figure 3 below). If the BIPV market and end-user groups in the studied country are clearly segmented into multiple market segments you can use this sub-system approach. If so, start with defining market segments according to what is relevant for this country, and then present the structural analysis for each of the segments.

A BIPV-market segmentation could for example be defined per building type (private housing, social housing, offices, etc.) or building owner/user (real estate developers, homeowners, community of owners, housing corporations, etc.).

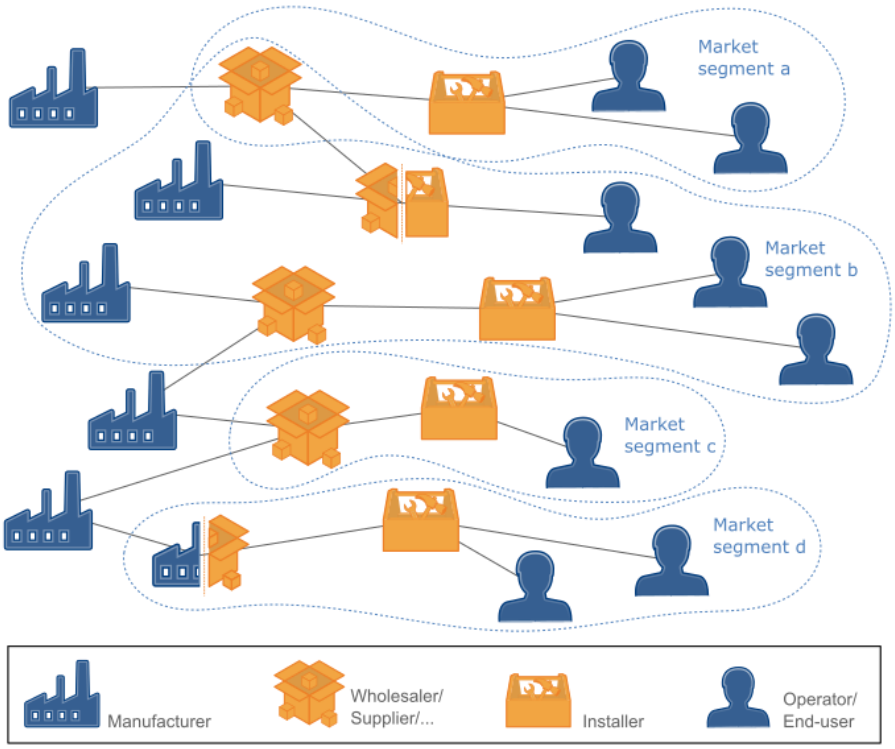


Figure 3: Schematic illustration of market actors and market segments (a, b, c, d) in a TIS (adapted from [7])

When describing the structure, it is important to also capture whether certain system elements are lacking. This could be the case for non-existing or misaligned institutions, certain types of actors, etc.

For examples of TIS structure descriptions, refer to examples III and V, but also example IV in Appendix C – Illustrative example studies.

Future synthesis work will have to identify a proper way of collaborating on the international parts of the value chains. Co-operation on this point will benefit the speed of common efforts and the resulting quality.

3.1 Technology

Describe which technologies and areas of knowledge are included in the innovation system in the specific country. For example, knowledge of solar cells but also building design and architecture.

Consider the scope of the analysis, i.e. focus on such technologies and areas specific for BIPV and ignore those that are just as relevant for ground-mounted PV as for BAPV / BIPV.

Where relevant, complete with country-specific limitations of the scope (based on cultural, historic or market reasons) as discussed in section 2.1.

Typical knowledge areas with relevance for BIPV include:

- Architectural integration
- Moisture safety
- Fire safety, electrical safety
- Civil engineering / building construction
- BIPV energy production
- Building energy needs
- User behaviour and acceptance
- Environmental life cycle analysis
- Economic life cycle cost analysis
- Business development and innovation support
- Glass constructions, glass coatings
- Thermal insulation
- Operation and maintenance
- Project development and financing

For a more in-depth analysis of relevant technologies and knowledge areas, the Task 15 reports on “Categorization of BIPV Applications “ [6], “Analysis of requirements, specifications and regulation of BIPV” [8], and “Multifunctional Characterization of BIPV - Proposed Topics for Future International Standardization Activities” [9] could be helpful to identify technologies and knowledge areas. However, such an in-depth analysis is optional.

3.2 Actors and networks

Describe the current actors and networks present and make sure your description answers the following questions.

- What does the value chain look like? See Figure 4 for a general example.
- Which stakeholder groups are involved? Use the categories defined below as inspiration, see also Figure 4.

  There are several ways of identifying actors and practice may be adapted to the authors' background. Internet searches for actor websites mentioning "BIPV" or "building integrated photovoltaics" (possibly in local language) can be used, although they risk including actors not actually active. Authors with good insight in the national BIPV TIS can likely identify many of the actors but can easily miss some that entered the TIS more recently. Database searches (patents, projects, scientific articles) can be helpful. Also, (a selection of) interviewees or other experts can be asked to see over a list of actors and add missing ones – or be asked a more open question to list the main actors. A combination of several methods is recommended. We do not aim for full coherence in the methods used, but it is good practice to include in the report what methods have been used.

  - Industry: Actors involved in the supply of BIPV systems or upstream in manufacturing, for example:
    - BIPV-targeted cell manufacturers
    - BIPV-product manufacturers
      - BIPV-module or integrated product manufacturers
      - BIPV-mounting manufacturers
    - BIPV suppliers
      - Wholesalers
      - Construction companies
      - Installation companies

        Note that it could be relevant to categorize BIPV installation companies into different levels of matureness/experience, e.g., based on national certification schemes.
  - Market: Actors creating demand of BIPV systems directly or indirectly through support, or downstream activities such as:
    - Real estate developers and supporting actors, e.g.:
      - Architects
      - Engineering consultants/ planners/ designers
    - Real estate owners and supporting actors, e.g.:
      - Service or Operation & Management consultants
      - End user segments - represented by current or historical lead-users.

Lead users are actors in the innovation system that, through their articulation of demand for particular types of solutions based on their needs, contribute to the development of a new technology. In some cases, they also participate in the development of the technology. Through their engagement, these lead users can influence the direction of search [10]. *Lead users are ahead of most other users in a TIS and expect to reap benefits from taking novel solutions into use. Their articulation of needs comes about because users might not find what they require on the market, and therefore articulate demand towards potential suppliers, or themselves become enrolled in the development process* [11]. *Indeed, an important source of technology improvement and adaption stems from the differences between what users require and what solutions de facto supply* [12].

- Utility companies

  Utilities can have several roles including as suppliers, customers or issuing hard institutions.

- What other actors and networks are relevant for the development of BIPV technology? For example, universities, research institutes, consultants for knowledge development and demonstration projects.
  - Research: actors involved in developing knowledge, both fundamental and applied.

    Research actors can for example be identified through searching for keywords (at least "bipv") and authors' affiliation country in databases for scientific publication, such as SCOPUS, or Science Citation Index, Google Scholar. Also, EU's CORDIS database and national project databases, such as Swecris in Sweden, can be useful.

  - Education: actors involved in dissemination of knowledge through education and training, both academic and vocational.
  - Politics and policymakers: actors initiating, defining and/or deciding on institutions (legislation, regulations, etc.).

    Keep this description brief and forget about trying to analyse the complete political process. One can start with what hard institutions exist for BIPV and identify the policymakers behind them. Include also political actors and policymakers that have an influence on the TIS besides or apart from hard institutions they define, for example those influencing cultural norms or overarching strategical principles.

  - Funding organisations, e.g.
    - Public funding programs
    - Risk-capital
  - Intermediaries and supporting organizations: actors that try to engage collaboration between different partners or act to support and facilitate development of the TIS, including e.g., industry associations (PV associations, Green Building Councils, etc.), networks, etc.

Apart from national networks, consider the national relevance of the following networks:

- Relevant EU projects, amongst others:
  - https://www.pvsites.eu/
  - http://www.constructpv.eu/
  - https://summit-project.eu/
  - https://bipvboost.eu/
- EPIA => Solar Power Europe with BIPV Task Force https://www.solarpowereurope.org/?s=BIPV
- IEA-PVPS Task 15
- IEA SHC Tasks
- European Technology and Innovation Platform for Photovoltaics (ETIP PV)

Next, consider where all the listed actors and networks are located geographically. Focus on the studied country but consider links between the development of technology and the innovation system in that country and what happens in other countries. E.g., collaborations, ownership relations, etc. Limit the international part to such that is directly relevant for your analysis, using, for example, the following questions.

- Is this actor/network relevant for the development of BIPV in the country assessed?
- Is this actor/network relevant for local production of BIPV products?
- Is this actor/network relevant with respect to local regulations and cultural differences?

Finally, additional network analyses can be made on the actor group. Also, geographical analysis can be relevant to show cluster formation.

Figure 4 below can be used as a template to present a quick overview of the structure of the TIS.

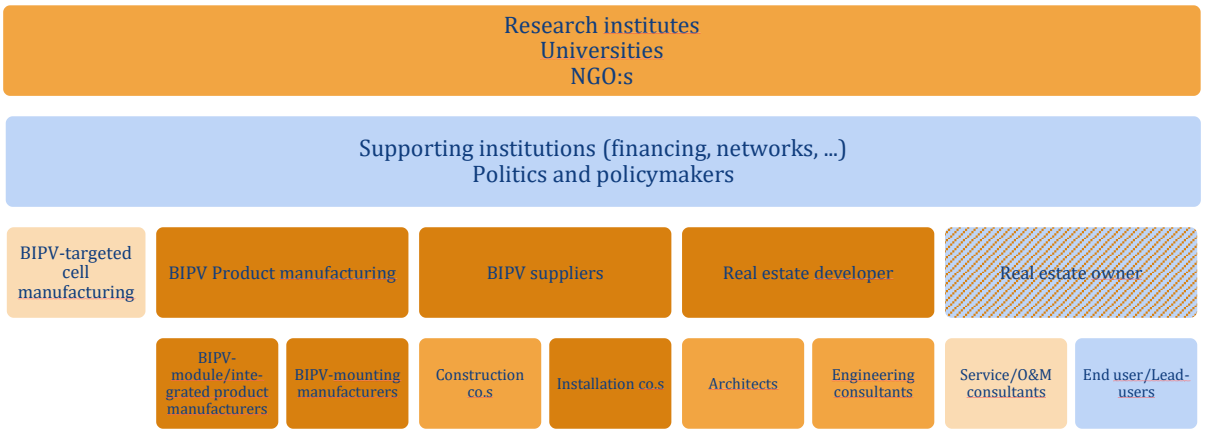


Figure 4: [Template and example] Overview of the TIS value chain for BIPV. Orange colour intensity can be used to indicate the approximate number of actors actively

involved in the BIPV TIS. Adjust colour intervals to national conditions, e.g. light = 0-1; medium = 2-5; dark = 6-10; darker = 10+. A blue colour indicates that the actor group is to diverse to quantify, e.g. where private house owners are included.

3.3 Institutions

This section is used to list and describe current institutions influencing the TIS. Recall that institutions can be defined as the rules of the game that describe why actors act as they do.

Describe the current institutions using the questions and suggestions below.

- Which institutions influence (positively or negatively) the development of BIPV technology in the country?

  Institutions can represent either driving forces or obstructive forces.

- Take support by thinking of hard institutions, such as laws, regulations and standards, and soft institutions, such as norms and culture. Consider the following types:
  - Soft:
    - Aesthetic requirements
    - Awareness of climate change (private and public authorities)
    - Public procurement practices (non-formalized)
    - Project developers conduct/practice.
  - Hard
    - Government support programs
    - Public procurement regulations
    - Codes and standards, national/international, e.g.:
      - IEC 63092
      - EN 50583
        A good starting point for European countries – giving guidance on which electrical or building component standards are relevant for the BIPV-products (part 1) and systems (part 2). Additional (non-harmonized) requirements may exist depending on national differences.
      - Building codes or similar, including:
        - Moisture and water safety
        - Fire safety
          This area is known to have higher requirements than EN 50583 referenced standards in some countries.
        - Roof safety
      - Grid codes, e.g.:
        - RfG (COMMISSION REGULATION (EU) 2016/631) including regionally/nationally defined parameter settings.
      - Electrical safety, such as national electrical installation codes.

- For identification of (hard) institutions Task 15 reports covering regulations [8] and business models [13] can be useful. Also, national guidelines or handbooks for BIPV and PV as well as tender documents often include a list of relevant regulations and standards.

Please keep in mind to include only international institutions that are implemented in or influencing the situation in the country considered.

Another important note is that this section might describe ongoing developments, but the analysis should refrain from jumping to conclusions about the effects in the long run.

4 PHASE OF DEVELOPMENT AND TARGET DEFINITION

In this chapter, an assessment of the phase of development of the TIS is to be presented in text and in a graph according to the template in Figure 5. Based on the current phase (or phases, see more below) an analysis target is to be defined that is used in the remaining steps of the TIS analysis (see remaining chapters).

With the innovation system's historical development and current structure described in the previous chapters, there is a base for assessing and describing what development phase the system is in. The different development phases are defined in Table 1, where definitions are translations of the definitions in [2, p. 18] (Swedish only). Technology Readiness Levels (TRL's) can be used in combination with the table, to differentiate between initial development phases.

Table 1: Development phases for the TIS (from [2])

Development Phase	Description of additional aspects in each phase
Concept-development	New concepts, prototypes and models are developed and tested on a limited or small scale.
Demonstration	Prototypes and concepts are further developed into functional units and systems that illustrate the technology's functionality in environments that enable feedback from potential customers and society at large.
Niche-market	The technology is launched in naturally occurring (i.e., from customers with specific needs) or politically constructed (e.g., via investment subsidies or other types of support) niche markets. In these markets the technology is not fully exposed to competition from other mature technologies and can yet receive valuable feedback from paying customers and users.
Commercial growth	The technology becomes competitive with established alternatives and is starting to spread in mass markets. The step from niche market(s) to commercial growth can be challenging as it involves establishing the first commercial scale applications in parallel to facing competition with mature alternatives.
Mature market	The technology replaces existing technologies to a significant degree, thereby causing a restructuring of society's production and consumption systems.

Typically, a technology is mainly in one development phase, but within one innovation system different sub-technologies can be in different development phases, see example for Sweden in Figure 5. Moreover, the development of a technology does not always follow a linear process from one phase to the next, rather the activities in one phase continue as the technology moves in to the next.

Use this chapter to briefly describe the current development phase for the technology, or the development phases for the different sub-technologies.

Development phases for relevant sub-technologies should be presented in a figure like Figure 5. The sub-technology categories used can be chosen based on relevance for the studied country but must always be explained in the figure text. Furthermore, categorizations should be in line with [6].

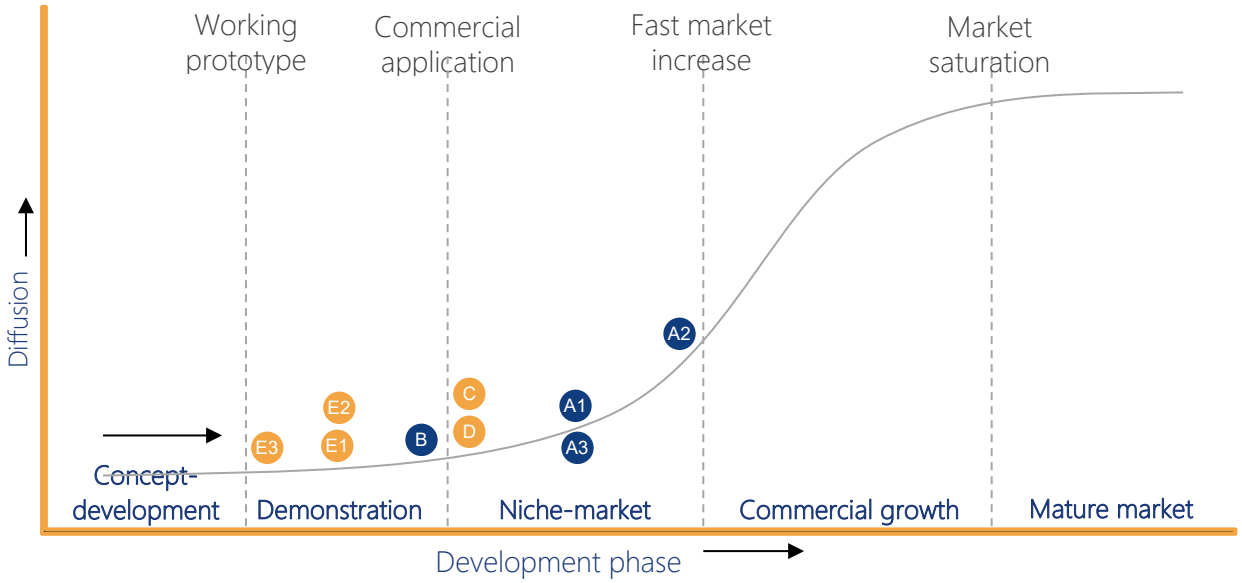


Figure 5: [Template and example] Assessed development phases for BIPV in the studied country. Blue circles are used for roof-integrated solutions and canopies, while orange circles indicate other external integrated devices (than canopies) and façade-integrated solutions (see the BIPV system categorization (from [6]) in Figure 2). <u>Example data:</u> The following sub-division is indicated by the circle texts: A1. discontinuous roof, tiles; A2. Discontinuous roof, regular modules; A3. Continuous roofs, large modules; B. Skylights; C. Rainscreen and masonry wall façades2; D. Curtain wall, windows, and double skin façades; E1. Parapets and balustrades; E2. Canopy; E3. Solar shading.

Conclude on the main phase of development for BIPV in the studied country, starting from the descriptions given above. To be as consistent as possible in the assessments for different countries it is key to provide a clear and sound argumentation for your conclusion. That argumentation may well be qualitative and where possible backed with quantitative arguments. Also, national experts can help with defining or verifying the development stage of different products. For instance, preliminary assessment results can be discussed when doing interviews for the functional analysis.

A draft of the conclusion on the current development phase of the BIPV innovation system and the underlying argumentation should be benchmarked against other TIS analyses, preferably against (upcoming) Task 15 national TIS analyses reports. For TIS analyses conducted within Subtask A of Task 15 special benchmarking and verification workshop will be organized for each national analysis, where experts from different countries are participating.

If you have chosen to analyse the TIS-structure for different market segments you need to describe and define the development phase for each of these, according to the instructions given above.

It is good practice to verify the label put on the development phase in this step, after the analysis of the functions is concluded. If necessary, feel free to adjust your conclusions here.

The chapter is to be concluded with the definition of a target for further analysis of the TIS. This analysis target should relate to the current development phase.

Examples of typical target definitions are:

- continued development;
- development in niche market;
- market expansion to X % of total PV market/of total PV on buildings market.

This target is now used as a reference for the remaining analysis: what future development is needed in the different areas in order to achieve the target?

Once again, if you have chosen to analyse the TIS-structure for different market segments you need to refer to these in your target definitions and, where relevant, set different targets for each segment.

5 FUNCTIONAL ANALYSIS

This chapter should present assessments of how well the eight TIS functions (as defined below) are fulfilling the needs of the current TIS, with regard to the analysis target set in the previous chapter. Use the defined sub-chapters to describe the data sources, your analysis of the data, your assessment of the function strength and a clear and sound argumentation for your assessment for each of the functions. A short introduction or general findings and remarks can be presented in this initial chapter section.

The TIS functions represent the key processes that should exist within a well-functioning innovation system. By describing their status and assessing them, you can identify what is challenging a further development of the technological innovation system. In Task 15 STA we use the following functions [2, pp. 20–22] (Swedish only):

- Knowledge development
- Knowledge dissemination

- Entrepreneurial experimentation
- Resource mobilization
- Development of social capital
- Legitimation
- Guidance of the search
- Market formation

For your convenience, a more thorough description of each function is provided in the following sub-chapters together with a description of the assessment focus and key indicators, etc., (Table 2 - Table 9) all based on literature [1]–[3], [14].

In your analyses of the different functions, relate primarily to the quality of the function, e.g. "What is missing, or what would be required, in these functions (in order to reach our target)?" "Are the right stakeholders involved? (rather than: "How many stakeholders are involved?"). Also, try to avoid describing the same things as already described in the structural analysis.

Finally, each function analysis should result in one of the pre-defined assessment scores:

1. Absent
2. Weak
3. Moderate
4. Strong
5. Excellent

Your analysis text is supposed to present the background to the final assessment score, but many times it can be relevant to add one or a few sentences explaining how you arrived at this score and/or to argument for your case. For example, such explanations can clarify how and why you weighted different aspects of the function the way you did.

To be able to do a good comparison of different national TIS-analyses it is crucial that the analyses are based on a common method and understanding of how to assess these functions, where interviews with relevant actor representatives should play a key role. Due to the varying preconditions for different countries and authors (i.e., country size, market development phase, authors' backgrounds and social networks, available resources, etc.) it is practically impossible to perform all national TIS analyses using the exact same method. Rather than aspiring one single method, your method should be based on the same foundations as much as possible. Furthermore, method choices or deviations should be clearly described and explained. In this way the reader can do their own evaluation of the comparability from one national report to another.

The common foundation of analysis consists of the definitions in this guide in general and the descriptions, assessment focuses, and indicators listed for each function in particular. Additionally, an interview guide including a long-list of interview questions is included in Appendix A – Interview Guide TIS Analysis BIPV. A relevant selection of the questions listed should be used for each interview, where the selection is based on the interviewees position and experience in the BIPV value chain. Also, the same questions can be used in questionnaires, preferably with a stakeholder-group-based selection of questions (see the same Appendix).

A draft of the argumentations and function assessments for the BIPV innovation system should be benchmarked against other TIS analyses, preferably against the (upcoming) Task 15 national TIS analysis reports. For TIS analyses conducted within Subtask A of Task 15 special benchmarking and verification workshop will be organized for each national analysis, where experts from different countries are participating. These workshops are/were organized by the subtask leader in cooperation with the authors after notification by the latter.

For additional examples of descriptions and analyses of TIS functions, refer to examples I, II, III, IV and V in Appendix C – Illustrative example studies. Note that example V is the only exemplification of using the function Development of social capital.

5.1 Knowledge development

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 2: Description, assessment focus and key indicators for the function Knowledge development

	Knowledge development
Description	This is the function that is normally placed at the heart of a TIS in that it is concerned with the knowledge base of the TIS (globally) and how well the local TIS performs in terms of its knowledge base and its evolution. The function captures the breadth and depth of the current knowledge base of the TIS, and how it changes over time. For some types of knowledge e.g., the scientific, the development over time is likely to occur as an iterative interaction between fundamental research, applied research and practical experiences, which makes a good synergy between this function and knowledge dissemination is important.
Assessment focus, questions	Different types of knowledge, e.g., scientific, technological, production, market, logistics and design knowledge, will be relevant to assess and their relative importance will differ depending on the boundary conditions of the study and the phase of development of the TIS. Which types of knowledge to focus on could thus be tentatively determined in the TIS definition phase. Furthermore, different sources of knowledge development can be used, for example R&D, learning from new applications, production, and imitation. In order to support the construction sectors' embracement of BIPV this sector could be one focal point.

	• What types of knowledge are currently considered most critical for reaching the target set above? • Which actors are asking for what type of knowledge? • Which actors are developing this knowledge? • Which market actors are joining efforts to develop new knowledge? • Is the amount of knowledge development sufficient for the development of the innovation system? • Is the quality of knowledge development sufficient for the development of the innovation system? • Does the type of knowledge developed fit with the knowledge needs within the innovation system? • Does the quality and/or quantity of knowledge development form a barrier for the TIS to move to the next phase?
key-indicators, data etc.	The current level and dynamics of the function could be measured by a range of indicators, including for instance: • bibliometrics (citations, volume of publications, orientation); • number, size, and orientation of R&D projects; • number of professors; • number of patents; • assessments by managers and others; • learning curves for cost or performance. Quantitative indicators for knowledge development on e.g., applications, market- and business development are hard to find, and the mapping must be based primarily on qualitative sources as: • interviews with e.g. construction companies, architects, building component manufacturers, real estate owners etc.; ○ Choose respondents in accordance with outcome of TIS definition phase. Several different roles within each sector may be relevant. • trade press.

Results of a patent search, according to the description in Appendix B – Standardized Patent search, are to be presented and discussed in this section.

5.2 Knowledge dissemination

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should

conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 3: Description, assessment focus and key indicators for the function Knowledge dissemination

	Knowledge dissemination
Description	This function describes how the knowledge developed in the system is diffused and combined in the system. Knowledge diffusion includes not only theoretical diffusion (conferences, workshops, publications, etc.) but also practical diffusion such as demonstration projects. For some types of knowledge e.g., the scientific, the development over time is likely to occur as an iterative interaction between fundamental research, applied research and practical experiences. Therefore, a good knowledge diffusion is also key for further knowledge development, as well as entrepreneurial experimentation.

Assessment focus, questions	• How is knowledge shared to those who need it?
	• How has knowledge from pilot and demo-installations developed and diffused?
	• Is there enough knowledge exchange between the relevant actor groups? For example, between:
	  ○ science and industry
	  ○ users and industry
	• Is there sufficient knowledge exchange across geographical borders?
	• Are there problematic parts of the innovation system in terms of knowledge exchange?
	• Is knowledge exchange forming a barrier for the innovation system to move to the next phase?

key-indicators, data etc.	Assessment of knowledge dissemination must be based primarily on qualitative sources as: • interviews with e.g. construction companies, architects, building component manufacturers, real estate owners, etc.; ○ Choosing respondents in accordance with outcome of TIS definition phase. Several different roles within each sector may be relevant.

	• some partially quantitative indicators might be obtained by analysing BIPV-attention in scientific-, industry- and market-focused press or conferences/events, as well as in general media.

5.3 Entrepreneurial experimentation

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 4: Description, assessment focus and key indicators for the function Entrepreneurial experimentation

	Entrepreneurial experimentation (EE)
Description	A TIS evolves under considerable uncertainty in terms of technologies, applications, and markets. This uncertainty is a fundamental feature of the development and is not limited to early phases in the evolution of a TIS. From a social perspective, the main source of uncertainty reduction is EE, which implies a probing into new technologies and applications. Many will fail, some will succeed, and a social learning process will unfold. A TIS without vibrant experimentation will stagnate. An extensive EE is particularly important if the TIS is still in a formative phase.
Assessment focus, questions	Focus on quality rather than quantity i.e., was the EE up to now taking place in the most appropriate contexts and was it carried out by the most appropriate actors? • Which are the most important drivers and barriers for a vivid EE? • Which are the actors or actor constellations behind the majority of the (publicly accessible) EE? • Are these the most relevant actors? • are there sufficient industrial actors in the innovation system? • are industrial actors hampered in their innovation pace? By what? • are the industrial actors focusing on the proper scale of production for the set target? If not: what is hindering them? • Could the market development benefit from other actors engaging in EE? • What are the perceived risks, and what risk mitigation strategies are being used by the involved actors?

key-indicators, data etc.	As an analyst you need to map the number and variety of experiments taking place in terms of, for example: • number of new entrants, including diversifying established firms; • number of different types of applications; • the breadth of technologies used, and the character of the complementary technologies employed; • number of pilot and demo-installations. Complete with qualitative data, like interviews with e.g., BIPV entrepreneurs, R&D managers at diversifying established firms, public research, and innovation funding agencies etc

5.4 Resource mobilization

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 5: Description, assessment focus and key indicators for the function Resource mobilization

	Resource mobilization
Description	This function seeks to understand the extent to which the TIS is able to mobilize: *competence/human capital* through education in specific scientific and technological fields as well as in entrepreneurship, management and finance, *financial capital* (seed and venture capital, diversifying firms, etc.), and *physical infrastructure and/or complementary assets* such as complementary products, services, network infrastructure, etc
Assessment focus, questions	Focus on identifying important resources (as learnt from the analysis of all functions), their respective "bottlenecks" and how they evolve over time? • Are there sufficient human resources? • Are there sufficient financial resources? • Are there expected physical resource constraints that may hamper technology diffusion?

	• Is the physical infrastructure developed well enough to support the diffusion of technology?
key-indicators, data etc.	There are various ways to measure resource mobilization, such as: • rising volume of capital; • increasing volume of seed and venture capital; • changing volume and quality of human resources (e.g., number of university degrees); • changes in complementary assets (through interviews); • ease of access to capital through public or private funding (through interviews).

5.5 Development of social capital

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 6: Description, assessment focus and key indicators for the function Development of social capital

	Development of social capital
Description	Social capital development is about creating and sustaining social relations. It focuses on the non-formal side of networks and institutions: common understanding, trust, mutual recognition, etc. Social capital is strongly linked to other functions such as formal networks and knowledge dissemination. Where social capital catalyses the other functions, but also depends on or can be hampered by these other functions. Social capital's role in development of a TIS is often larger than that of formal networks and institutions.
Assessment focus, questions	Assessment should focus on mapping the development of actors' mutual trust, mutual understanding of their cultures and targets, as well as on common social standards and values. • Who trusts who and why?

	• How does mutual trust impact development of value chains, leaning processes and political influence?
key-indicators, data etc.	• Interviews with representatives from all actor-groups. • Observation of actor interactions (at meetings, conferences, etc.). • Statements in press/media and strategical documents. • Also, network analyses can be useful to identify weak social links.

5.6 Legitimation

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 7: Description, assessment focus and key indicators for the function Legitimation

	Legitimation
Description	Legitimacy is a pre-requisite for a TIS to develop and is all about social acceptance and compliance with institutional frameworks. Once a TIS has established legitimacy it becomes easier to mobilize resources and acquire political strength. Legitimacy also positively influences guidance of the search. There are three typical strategies to gain legitimacy. • Manipulation – of the rules in the existing institutional framework (often needed when the new TIS competes with established TIS). • Conformance – to the existing institutional frameworks, e.g., standardization. • Creation – of a new institutional framework.
Assessment focus, questions	Analyse the legitimacy as perceived by relevant actors and stakeholders, as well as internal activities to increase the legitimacy. • How strong is BIPV legitimacy in form of alignment with current legislation and acceptance by industry and society? • How does this level of legitimacy influence demand, legislation, and behaviour? • What/who influences legitimacy, and how (positive/negative)?

	• What is the average length of a project? Is there a lot of resistance towards the new technology, the set-up of projects/permit procedure? • If yes, does it form a barrier?
key-indicators, data etc.	Indicators/data sources: • analysis of media and press studies; • analysis of legislative proposals and statements in official consultation rounds; • studies on changes in attitude; • studies on permit processes; • changes in technologies (e.g., adaptations to existing standards); • length of projects from application to installation to production; • most important regulations/policies (present or lacking); • activity of actors working to influence these institutions.

5.7 Guidance of the search

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 8: Description, assessment focus and key indicators for the function Guidance of the search

	Guidance of the search
Description	This function includes two types of guidance that should be analysed: 1. Guidance towards the BIPV innovation system in general, and 2. guidance to specific technologies, applications, markets, etc. within the TIS. Guidance typically consists of expected business potential, expressed customer demand, policy, and regulations, but also the status of other TISs (e.g., crises in related market segments)
Assessment focus, questions	Which factors have (had) influence on the choices and strategies chosen by actors in the system, regarding different technical solutions, applications, markets, business models, etc.?

	• What drives or hampers actors from entering the TIS?
	• Is there a clear vision on how the industry and market should develop?
	  ○ In terms of growth
	  ○ In terms of technological design
	• What are the expectations regarding the technological field?
	• Are there clear policy goals regarding this technological field?
	• Are these goals regarded as reliable?
	• Are the visions and expectations of actors involved sufficiently aligned to reduce uncertainties?
	• Does this (lack of) shared vision block the development of the TIS?

key-indicators, data etc.	Key-indicators: • beliefs in growth potential, e.g. from development in other countries; • incentives from factor/product prices, e.g. taxes and prices in the energy sector; • the extent to which economic incentives are specifically or effectively directed to the technology; • the extent of regulatory pressures, e.g., regulations on minimum level of adoption ("green" electricity certificates, building codes etc.) and tax regimes; • the articulation of interest by leading customers. Typical data sources: • Interviews • Reports on expected BIPV market growth • Public policies and goals (national, EU) • Reports identifying technical barriers

5.8 Market formation

This sub-chapter should present an analysis of how well this function is performing, based on relevant data gathered (both qualitative and quantitative). The analysis should conclude in a well-argued assessment score (1-5) for the functions' fulfilment in relation to the analysis target from Chapter 4.

Use the information in the table below for the analysis and data gathering, in combination with Appendix A – Interview Guide TIS Analysis BIPV.

Table 9: Description, assessment focus and key indicators for the function Market formation

	Market formation
Description	A well-developed market is often lacking for emerging TIS. Generally, three market development phases can be defined: • Nursing markets – creating a learning space for TIS actors, • Bridging markets – where volumes and the number of actors are increasing, and • Mass markets – large volumes. The development from nursing to mass market often takes several decades. With regard to the aim of our studies focusing on implementation (i.e., market) we choose to put some extra effort into this function. Therefore you should separately investigate the roles for different actor types and analyse their functioning. We define the following three main actor groups, developing from recommendations by [15], in order to streamline the analysis towards recommendations on both policy and industry or market actions: a. Market formation by the government. Consisting mainly of institutional support (e.g., market regulations, tax benefits and regulations, support schemes), or the lack of those. b. Market formation by entrepreneurs. Representing "market push", including individual and collective actions to e.g., raise user awareness, create demand, user involvement in development processes. There is a clear link to the Entrepreneurship-function, but we prefer to describe these activities under "market formation" and focus more on the quantity, quality, and boundary conditions of/for entrepreneurial experimental under "entrepreneurship". c. Market formation by lead-users. Representing "market pull", where pro-active customers (groups) turn to the supply side of the market to deliver the BIPV solutions they would like to implement. This could apply for both public and commercial procurement.
Assessment focus, questions	Analyse the actual market development and the driving and restraining forces behind market formation. The latter requires in-depth knowledge of the BIPV TIS. • Is the current and expected future market size sufficient for an increasing number of actors, and for further development of the technology? Or does the size of the market form a barrier for the development of the innovation system?

	Focus on assessing: <u>General level:</u> • Market phase (nursing, bridging, mature) • Commercial competitiveness • Type of users ("user groups") and their purchasing processes <u>a. Government-driven</u> • Existing institutional stimuli or hindrances (or current discussions on introducing new stimuli or removing hindrances) • Are the existing stimuli well-known and easy to use? <u>b. Entrepreneur-driven</u> • Are user groups sufficiently aware of the technology and its benefits? • What is the demand profile – is this clearly articulated, and by whom? Do existing products/solutions meet these? • Common standardization and certification activities • Marketing and lobbying activities <u>c. User-driven</u> • Are user groups using their customer power? • Do user groups know where to turn to when purchasing (new) BIPV solutions? • Are project sizes and/or future replication potential appropriate to attract manufacturer and/or supplier interest?
key-indicators, data etc.	Indicators/data sources: • market statistics • Studies on buyer's preferences • Data on price/performance-ratio development • Studies and interviews on actors' activities for market formation, e.g., strategies, purchasing processes, standardization efforts, perceptions of what drives/or hampers the formation of markets?

5.9 Summary of the functional analysis

This section summarizes the results of the functional analysis from sections 5.1 to 5.8 in a spider diagram (Figure 6) and a summary table (Table 10), according to the templates provided.

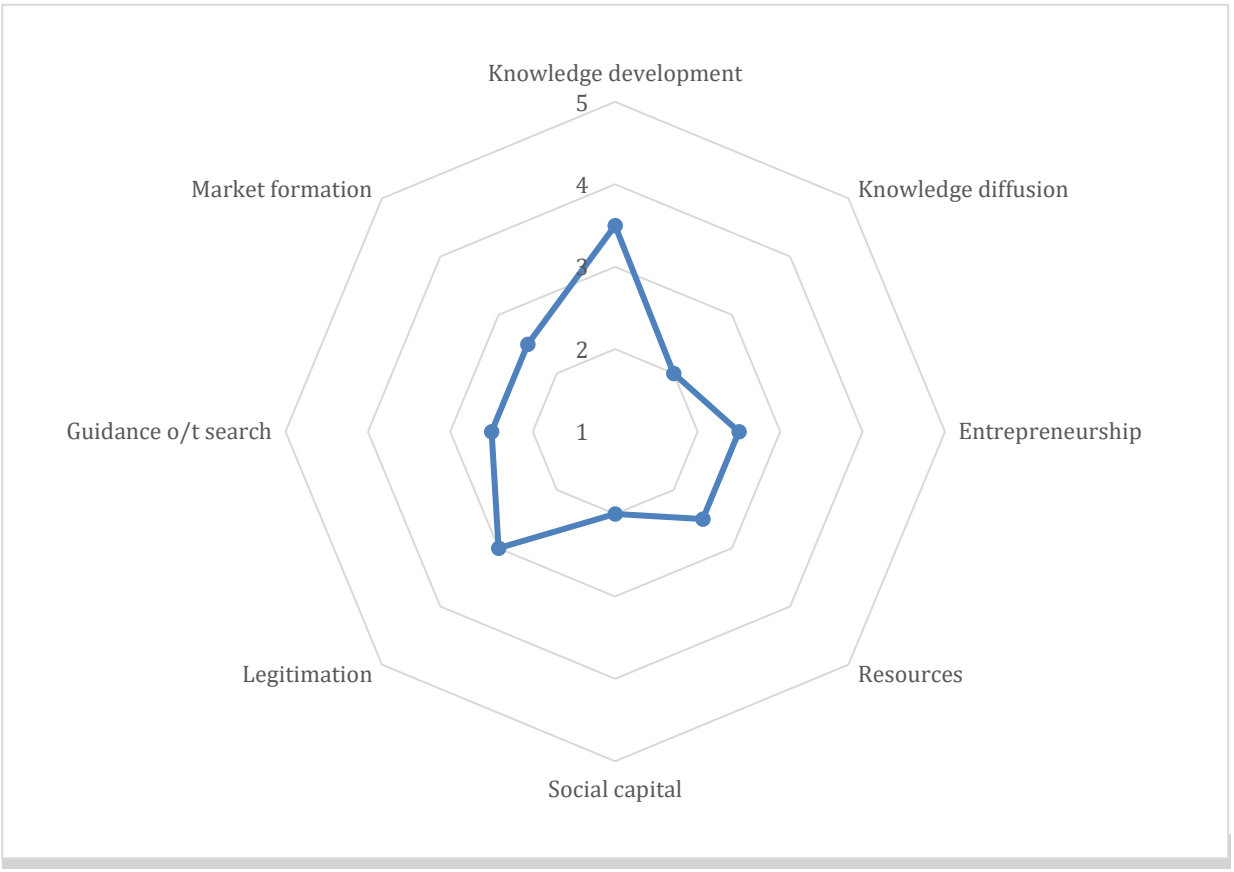


Figure 6: [Template and example] Results of the fulfilment assessment of the TIS functions. Numbers indicate the degree of fulfilment: 1 – absent; 2 – weak; 3 – moderate; 4 – strong; 5 – excellent. Example data for Spain [16].

Table 10: [Template and example] Summary of the results of the functional analysis. Example data from Spain [16].

Functions	Strengths/Opportunities	Weaknesses	Assessment
F#. Function name **[Template row]**	• Strength/ Opportunity 1 • Strength/ Opportunity 2 • …	• Weakness 1 • Weakness 2 • …	**Degree of fulfilment** Optional comment/explanation.

Functions	Strengths/Opportunities	Weaknesses	Assessment
F1. Knowledge development	• Scientific knowledge is relevant: 50 BIPV publications in peer reviewed journals. • 19 European projects (ongoing or finished in 2020) with Spanish participation; 9 of them coordinated by Spain. • 22 Spanish patents related to BIPV.	• Low number of technological development publications. • Few current BIPV national projects. • Weak technological, production and market knowledge. • 40% of the architects claim the need for complete digitization of databases and specific calculation tools/software for BIPV calculations.	**Moderate to strong** Knowledge development has sufficient quality, but it is quite limited to the scientific field. The innovation system needs more technological, production and market knowledge.
F2. Knowledge dissemination	• Several dissemination events in PV sector fairs, and energy-related magazines. • Some dissemination papers and webinars by architecture and construction magazines.	• 60% of the architects and building engineers do not have sufficient knowledge. • Not sufficient knowledge exchange between BIPV manufacturers and/or suppliers and architects. • Few dissemination activities addressed to architects and especially to the construction industry. • Bad connection between the technical platforms of different sectors. • Not much feedback from the architects.	**Weak** Although most of the architects interviewed have sufficient or some knowledge to implement BIPV, they claim more knowledge from the manufacturers and suppliers. Knowledge dissemination is especially low between PV and construction sector.

Functions	Strengths/Opportunities	Weaknesses	Assessment
F3. Entrepreneurial experimentation	• Some construction companies are starting to develop BIPV solutions. • Some small new companies interested in BIPV (consultancies, designers). • Half of the BIPV patents are developed by or with the industry.	• Low number of BIPV companies. • Low number of pilot or demo installations. • Low variety of products. • No solutions for rehabilitation for BIPV.	**Moderate to weak** Entrepreneurial experimentation is growing, but slowly.
F4. Resource mobilisation	• There are national and regional funds for R&D&I projects (research and technological centres and industry), and BIPV projects can benefit from them. • Self-consumption is becoming profit business for many companies (especially growing in the residential sector). • Subsidies for self-consumption have been recently approved and favour PV in/on pergolas. • Good network infrastructure (grid line capability).	• There are no specific funds for BIPV, which has to compete in costs with BAPV. • Lack of BIPV competency. • Few BIPV specialized testing labs (construction testing labs are not adapted to BIPV).	**Weak** Trust and good communication are limited to the known stakeholders. Communication initiatives are necessary (PV should meet construction).
F5. Social capital development	• Good communication among already known stakeholders.	• Distrust among not known stakeholders. • Low interaction between PV sector	**Weak** Trust and good communication are limited to the known stakeholders. Communication

Functions	Strengths/Opportunities	Weaknesses	Assessment
		and construction sector.	initiatives are necessary (PV should meet construction).
F6. Legitimation	• Architects' perception of BIPV is good in general. • Good acceptance from the public. • BIPV uses urban space, and not additional land (no impact on nature). • Recently, UNEF succeeded in eliminating the planning permission in in most Spanish regions. • The standard UNE- EN 50583 adds value to the development of BIPV. Good representation of Spain in the development of national and European standards.	• Most architects, consultants and promoters find some resistance to the inclusion of BIPV technologies (main reasons: costs, real final cost uncertainty, administrative barriers). • In many BIPV projects, delay can occur in the design phase. • Low number of published real practices. • Standard UNE- EN 50583 still needs to be further upgraded.	**Moderate** Although there is good acceptance and perception of BIPV, there are two main barriers (cost and administrative) that increase customer resistance to include BIPV.
F7. Guidance of the search	• There are national policies that promote the integration of Renewable Energy in buildings, and nZEB. • BIPV is considered a relevant solution in order to achieve the set objectives.	• Difficult to obtain the required information from laws and regulations. • BIPV is not considered specifically as a solution for nZEB. • BIPV does not appear in the	**Moderate to weak** Although general framework is favourable to BIPV development, no specific attention is paid to it. BIPV is not explicitly mentioned in any regulation document.

Functions	Strengths/Opportunities	Weaknesses	Assessment
	• The emerging boost of renovation and PV self-consumption is expected to bring opportunities to BIPV. • Ongoing support for the energy rehabilitation of buildings in Europe and Spain provides good opportunities for BIPV. • CTE now includes the requirement of production of electricity with RE sources.	Technical Building Code (CTE). • Low Information policies on BIPV technology, education, and training of the construction sector • No financial incentives for owners to include BIPV. • Lack of specific funds for BIPV	
F8. Market formation	• BIPV market in Spain is growing, although it is still a niche market. • There is a sound Spanish BIPV company, Onyx Solar (globally 350 projects and staff 51 p.; in Spain, 65 BIPV projects and staff 50 p.). • There is a big potential for BIPV in retrofit actions. • There are good expectations for all the interviewees. • BIPV is seen as an innovative and attractive solution.	• BIPV market is still small. • BIPV market formation by the Spanish government lays on the current support schemes for renewable energies and energy efficiency in buildings where BIPV modules are not eligible costs). • Market formation by entrepreneurs is not still playing a key role in raising user awareness. • Potential users are not yet sufficiently motivated.	**Moderate to weak** Market is slowly growing but with good future perception. The market size may increase significantly if addressed to building retrofit actions.

6 IDENTIFYING SYSTEM WEAKNESSES AND STRENGTHS

This Chapter presents the analysis of systemic weaknesses and strengths that are underlying causes for the current fulfilment of the eight TIS functions (see Chapter 5).

When the TIS's structure and functions have been analysed you are able to identify system weaknesses that obstruct its development. These underlying weaknesses in the system can usually be described either by a lack of presence, or a lack of quality/capacity in one of the following aspects: actors, institutions, interactions, or infrastructure. This could be, for example, a weak or undeveloped network, or regulations that prevent technological development or limit certain applications. A single system weakness can impact multiple functions, and a single function can be obstructed by multiple system weaknesses.

To structure and facilitate the analysis, start with the summary of the functional analysis in Table 10 and describe the reasons for weaknesses (and strengths) in form of lack of presence or quality. Please categorize the systemic problems according to [17, Ch. 4] into the four categories described in each sub-chapter below. Take advantage of the short descriptions in these sub-chapters for certain typical problems.

Identifying the system weaknesses and their impacts allows you to be more spot-on in proposing effective measures (in the next Chapter) that address/mitigate these weaknesses and help reach our target.

For example studies that summarize TIS systemic strengths and weaknesses refer to examples I, II, III, IV and V in Appendix C – Illustrative example studies.

6.1 Actors' problems and opportunities

In this section, describe problems (and opportunities) related to the presence or lack of presence (in sufficient numbers) of a certain type of actors, or related to the (lack of) capacity of present actors to fulfil their roles within the innovation system [17, Ch. 4.2.1].

6.2 Institutional problems and opportunities

In this section, describe problems (and opportunities) related to the (lack of) presence of institutions (soft or hard), or related to the (lack of) quality of present institutions. Quality problems are typically either too stringent institutions (i.e. not opening up for new solutions or actors) or too weak institutions (i.e. lack of support for new solutions) [17, Ch. 4.2.2].

6.3 Interaction problems and opportunities

In this section, describe problems (and opportunities) linked to actor relations and networks, related to either the (lack of) presence of interactions between actors, or the (lack of) quality of actor interactions. Quality problems typically involve either too strong network ties between certain actors (e.g. strong actor(s) guiding other actors in a wrong direction, or in practice hindering these other actors from establishing interaction and knowledge exchange with third actors), or too weak network ties hindering mutual learning and innovation [17, Ch. 4.2.3].

6.4 Infrastructural problems and opportunities

In this section, describe problems (and opportunities) linked to infrastructure and available resources, i.e., physical infrastructure, knowledge infrastructure and financial infrastructure. Problems relate to either the (lack of) presence of infrastructure or (lack of) quality of present infrastructure [17, Ch. 4.2.4].

7 RECOMMENDATIONS

This final chapter presents recommendations on which actions policy makers or value chain actors can take to support, facilitate, and enhance the development of the BIPV TIS. If the number of recommendations is extensive, it can be useful to add separate sub-chapters for different target groups, e.g., policy makers, industry actors and market actors.

When more functions are found to be strong it will likely lead to a better performance of the TIS. This eventually leads to higher chances for successful development and diffusion of BIPV. Moreover, it is also important to consider how functions interact. The different system functions can influence and reinforce each other, which results in different functional patterns [18], [19]. For instance, when a prototype (or premature commercial application) of a technology is ready, new entrants or diversifying existing actors start experimenting (Function 3), resulting in positive expectations by industry actors and policymakers (Function 7). This in turn leads to lobby activities (Function 6) for support from other TIS actors (e.g., government or industry actors) to mobilize resources (Function 4). This then leads to more firms entering the market, which results in overall more entrepreneurial activities (Function 3).

By assessing the TIS functions as well as how they influence one another, more insights can be provided regarding the specific drivers and barriers (systemic problems) that are present in the TIS. Therefore, both should be considered when recommending measures to support further BIPV development and implementation.

The best strategy for recommended measures (to overcome system weaknesses) is to target change in the TIS structure, rather than tweaking the functions. Function measures would require consistent action, but structural change can improve the function from within. Therefore, recommendations should target the systemic problems (weaknesses) identified in the previous Chapter.

Depending on which market development phase the TIS is in, varying priorities should be given to get particular functions up to strength. Table 11 lists the most important functions for the different development phases, as described in [3] and completed with the authors' assumptions for the development phase "mature market" and the function "development of social capital". The assumptions for the latter are based on the importance of social networks for building structure (especially networks) and system affinity, and its key role in knowledge dissemination [14]. Through network building, the creation of social capital is deemed important also for influencing the direction of development of the institutional framework of the TIS and for mobilizing resources. Therefore, social capital development is assumed prioritized in case any of the following functions is prioritized: knowledge dissemination, creation of legitimacy and resource mobilization.

Table 11: Prioritized functions for different TIS development phases (based on [3] and authors' assumptions)

Development Phase	Most critical function (underlined) and influencing functions that must be of sufficient strength
Concept-development	Knowledge development, knowledge dissemination, guidance of the search and resource mobilization
Demonstration	Entrepreneurial experimentation and all other functions
Niche-market	Entrepreneurial experimentation, development of social capital, legitimation, guidance of the search, resource mobilization and market formation
Commercial growth	Market formation, entrepreneurial experimentation, development of social capital, resource mobilization and guidance of the search.
Mature market	(No guidance from [3] is provided here, but based on the matureness the majority of functions are expected to require at least mature fulfilment. Possibly the knowledge related functions are of less importance.)

Proposed measures can be of different nature. Some of the system weaknesses can be coped with by industry and/or market actors, other system weaknesses will require government incentives, regulations, etc. Measures can also be directed towards ongoing processes (e.g., policies). Table 12 lists different types of instruments or measures for a number of possible desired systemic changes, which were originally published in [17].

For examples that summarize TIS strengths and weaknesses as well as bring up recommendations for further development, refer to examples I, II, III, IV and V in Appendix C – Illustrative example studies.

Table 12: Examples of instruments aiming at specific systemic changes - from Wieczorek & Hekkert, Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars, Science and Public Policy, 2012, vol. 39, issue 1, pp 74–87, by permission of Oxford University Press.

Systemic change goals	Examples of individual instruments
Stimulate and organise participation of actors	Clusters; new forms of Public Private Partnerships, interactive stakeholder involvement techniques; public debates; scientific workshops; thematic meetings; transition arenas; venture capital; risk capital
Create space for actors' capability development	Articulation discourse; backcasting; foresights; road-mapping; brainstorming; education and training programmes; technology platforms; scenario development workshops; policy labs; pilot projects
Stimulate occurrence of interactions	Cooperative research programmes; consensus development conferences; cooperative grants and programmes; bridging instruments (centres of excellence, competence centres); collaboration and mobility schemes; policy evaluation procedures; debates facilitating decision-making; science shops; technology transfer
Prevent too strong and too weak ties	Timely procurement (strategic, public, R&D-friendly); demonstration centres; strategic niche management; political tools (awards and honours for innovation novelties); loans/guarantees/tax incentives for innovative projects or new technological applications; prizes; Constructive Technology Assessment; technology promotion programmes; debates, discourses, venture capital; risk capital
Secure presence of (hard and soft) institutions;	Awareness building measures; information and education campaigns; public debates; lobbying, voluntary labels; voluntary agreements
Prevent too weak or too stringent institutions	Regulations (public, private); limits; obligations; norms (product, user); agreements; patent laws; standards; taxes; rights; principles; non-compliance mechanisms
Stimulate physical, financial and knowledge infrastructure	Classical R&D grants, taxes, loans, schemes; funds (institutional, investment, guarantee, R&D), subsidies; public research labs
Ensure adequate quality of infrastructure	Foresights; trend studies; roadmaps; intelligent benchmarking; SWOT (strengths, weaknesses, opportunities and threats) analyses; sector and cluster studies; problem/needs/stakeholders/solution analyses; information systems (for programme management or project monitoring); evaluation practices and toolkits; user surveys; databases; consultancy services; tailor-made applications of group decision support systems; knowledge management techniques; Technology Assessments; knowledge transfer mechanisms; policy intelligence tools (policy monitoring and evaluation tools, systems analyses); scoreboards; trend charts

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APPENDIX A – INTERVIEW GUIDE TIS ANALYSIS BIPV

Preparation

Ahead of the interview it is recommended to send an email to the interviewee, and to have her/him confirm that she/he has read it. This email can contain a short introduction to the project and a brief explanation of the objective of your study, including the main themes of the interview questions. The term “innovation system” should be explained and the main actor groups of the BIPV TIS listed. This may in the best case “prime” the interviewee to start thinking about the interview topics. You can find an example text of such an introductory email in the textbox below.

Example text for introductory email to interviewee

Currently [organization name] is conducting a study on building integrated photovoltaics (BIPV). Our main goal is to identify relevant actions that can speed up the implementation of BIPV in [your Country] and support innovation and industrial development of BIPV solutions. We have selected [interviewees organization, or "you"] as a key actor for BIPV deployment and/or development and would like to include your insights and thoughts on BIPV in our study.

What we ask from you is to participate in an interview by one of our experts, during which we will discuss the innovation system for BIPV. The innovation system is the whole ecosystem around innovation of, and market development for BIPV: consisting of industry and market actors, research institutes and academia, networks, standards, and regulations, etc. Typical topics we will touch upon are how knowledge is developed and spread; how innovative and user-focused entrepreneurs are; to what extent BIPV is accepted as a feasible technology; and how well the market is developing.

By participating you can share your expertise, raise the obstacles you consider most important and come with suggestions on what actions are needed. Together with the input from other key actors (e.g., product manufacturers, installers, technical experts, end customers) this will lead to suggestions to policymakers, industry, and market actors on effective measures to accelerate the development of BIPV technologies and markets.

Funding for this study is provided by [your funder].

We value your personal privacy and integrity and follow the rules and principles defined here: [link to privacy policy for your study, e.g. according to GDPR for European countries]

Background check and identification of interview focus

Ahead of the interview, do a quick background check of the interviewees professional responsibility and experience using e.g., their organization's website and their LinkedIn-profile. Also include information on the organization that the interviewee represents. Note down the information listed in Table A1.

Table A1: Relevant information to gather before the interview

Background information on interviewee
Organization / department
Title / Role
Area of responsibility within the organization
Relevant historical positions (interviewee)
Geographical scope of activities (Regional/National/International/…)
Manufacturing and / or development? If so, where does it take place?
Historical milestones (organization)
Organization ownership

Then ask yourself:

- On what functions or sub-topics do you expect the most valuable input from this person? For example, it is likely that supply chain actors could elaborate more on implementation issues, whereas policymakers could elaborate more on the institutional barriers or drivers. List or mark these functions.
- Is there any specific question you want to ask the interviewee? For example, to get a second opinion on an answer from a previous interview, or on preliminary findings of your own. Or regarding a specific national regulation or support scheme.

How many interviews?

The number of interviews should reflect the diversity of the actors within the TIS and some perspectives from actors outside of the TIS, or with low engagement. Typically one should aim for reaching saturation – when additional interviews do not (or hardly) give any additional insights.

Conducting the interview

Conducting an interview requires keeping track of several aspects: Is the interviewee at ease? Is she/he saying something especially interesting that needs further discussion? Have all relevant topics been addressed? Are we keeping our time schedule? …

Try to always pose questions in a neutral way and not as leading questions. It can be relevant to ask second opinions or reflections on perspectives or opinions expressed by other interviewees, or from media, etc., but do this in a transparent way.

It is beneficial if you can split up responsibilities between two persons, with one responsible for the interview/conversation and one responsible for documentation. This is especially useful during the first couple of interviews.

As a back-up it is recommended to record the interview for your own reference. Please make sure that you have the interviewees explicit consent for this.

Introduction

After the obligatory introduction, as an “icebreaker”, you can do a quick double check on the background information gathered or fill in eventual gaps in what you found.

You will also have to introduce the interviewee to your analysis target, so that she/he can relate to that while answering questions about sufficiency.

Furthermore, it might be a good idea to bring along and introduce a flow-chart of the BIPV value chain (like Figure 4 in Chapter 3) and a chart with BIPV applications and development phases in the start of the interview (like Figure 5 in Chapter 4). This creates a common starting ground and could be helpful when asking more detailed questions.

Interview questions

Table A2 below lists relevant interview questions to start with, to dive into each TIS function and to conclude with. The questions are based on the diagnostic questions described by [3], [20] with additions based on experience of the authors of this guide. Although all questions listed are relevant for the in-depth functional analysis work that you will have to perform, going through all questions in each interview would be too cumbersome for both parties in the interview. Therefore, you should have listed the most relevant questions and/or functions for each specific interview in advance (see Section Background check and identification of interview focus). Some more advice to use while conducting the interview is given next.

- Start with the most relevant functions based on your background check.
- In general, it is easier to get the conversation going when starting with a function that is easier to grasp (i.e. less theoretical), such as entrepreneurial experimentation, market formation or legitimation. Hopefully, this will also trigger thoughts and insights that are relevant for other functions such as knowledge development and dissemination, resource mobilization, etc.
- For each function, start asking (one of) the introductory questions (bold font). This should get the interviewee talking about the function more broadly, probably focusing on what they find most important or relevant. The interviewee might cover several aspects listed in the more specific questions. In many cases these first answers also give an indication whether the interviewee has some depth on this topic. Afterwards, use a selection of the function-listed questions to deepen or broaden the dialogue if needed.

Many questions assume some kind of assessment from the interviewees side, for example to assess if something is sufficient. It can be useful to repeatedly relate "sufficient" to your national target defined in Chapter 4.

Table A2: Interview questions sorted per interview section and TIS function. Introductory questions for each TIS function are printed in bold font and numbered 0.

Section/Functions	Interview questions
General questions (G)	
1	Look at the value chain flow chart. Do you find anything important (actor group, organization) missing?
2	Look at the BIPV applications. Do you find anything important missing? What development phase would you say BIPV and applications are in?
3	How have you and your organizations worked with/for BIPV?
4	Thoughts or targets on size of the BIPV-market?
5	What would you say is/are the main hindrances for BIPV to reach the presented goal?
Knowledge development (F1)	**0. Do you (and does your organization) have the knowledge needed when it comes to BIPV implementation or development?**
1	What main actors do you think are watching / driving so that the knowledge about BIPV increases / develops?
2	Do you think the amount and quality of knowledge is appropriate and sufficient for further development of the BIPV sector? [Is knowledge lacking in certain areas, e.g., technical, institutional, market preferences…? Or among certain actors?]
Knowledge dissemination (F2)	**0a. How is developed knowledge being used and reaching the right actors? What are you doing to spread knowledge to other actors in the value chain?** **0b. Do you know where to find knowledge? What are you doing to spread knowledge to other actors in the value chain?**
1	Is there sufficient knowledge exchange between BIPV manufacturers and suppliers? [How could this be improved?]
2	Describe the knowledge exchange between BIPV industry and actors in the construction sector. [Specific actors missing? Important knowledge missing?] And other adjacent industries (e.g., real estate owners, energy sector)? [How could this be improved?]
3	Is there sufficient knowledge exchange across geographical borders? What does it look like?
4	Are there sufficient networks and/or connections between parties through which knowledge can be exchanged? [Which actors should be more connected? How/ where could this happen?]
5	*For innovation nerds:*

Section/Functions	Interview questions
a	- Are there problematic parts of the innovation system in terms of knowledge exchange?
b	- Is knowledge exchange forming a barrier for the IS to move to the next phase?
Entrepreneurial experimentation (F3)	**0a. Which businesses are driving BIPV development and innovation (technical and commercial)?** **0b. Does BIPV fit into typical business models in the construction sector?**
1	What is the scale of your business and where do you see it five years from now?
2	If relevant, how would you describe your activities in entrepreneurship and/ or innovation (regarding BIPV)?
3	What are the perceived risks related to BIPV, and what risk mitigation strategies are being used by you?
4	Are there sufficient and suitable types of actors contributing to entrepreneurial experimentation? [If not: which ones are missing?]
5	From which sectors do the firms active in the BIPV sector originate (e.g., construction or PV sector)?
6	How would you characterize construction projects in which BIPV is applied, pilot/demonstration projects or mature/fully commercial projects? [What type of project should be initiated more? Who should initiate and/or execute this type of project?]
7	To what extent do BIPV firms align their products to other solutions used in the built environment (compatibility, interfaces, software, etc.)? [How could this be improved?]
8	Does development/experimentation take place in [country] or mostly abroad?
9	Are you aware of the BIPV related standards? Do you see them an aid for BIPV innovation and product development? If not: why?
10	Does the development of BIPV solutions require additional efforts compared to conventional PV solutions? Why?
Resource mobilization (F4)	**[no proposed introductory questions. We find the questions below to be clear and sufficient.]**
1a	Are there sufficient financial resources available for the further development of the BIPV market? [How could this be improved?]

Section/Functions	Interview questions
1b	If no, what kind of financial resources are lacking and what form or conditions would you prefer?
1c	Are these financial resources easy enough to get a hold on?
2	Are there sufficient suitable and well-trained employees available to be able to develop and implement BIPV? [How could this be improved?]
3	Is the physical infrastructure developed well enough to support further diffusion of technology (e.g., production capacity, test beds, or energy network)? [How could this be improved?]
Development of social capital (F5)	**0. Think about the people active within BIPV. Do you trust that people are knowledgeable, experienced? Do you have good relationships within the BIPV-actor group?**
1	How would you describe the general confidence and well-functioning cooperation between actors in the BIPV value chain? Who trusts (or does not trust) whom, and why?
2	For an area to develop, it is important that you can have confidence in others. What does your confidence look like for other actors in the BIPV area?
3	Would you say that a common understanding and language, mutual recognition etc. exists in the business to a sufficient extent to facilitate collaboration? [If not: explain deficiencies etc…]
Legitimation (F6)	**0a. What attitudes towards BIPV do you meet within your own and other actor groups (e.g., potential customers, architects, technical consultants, authorities)?** **0b. What are the main problems with BIPV?**
1	Is there a conflict of interest between conventional PV (BAPV or utility scale PV) and BIPV?
2	How much resistance is present towards the implementation of BIPV technologies during the initiation and execution of construction projects, i.e., negative talk, do construction projects take longer if BIPV is applied? [During what phase(s) of the project does it occur?]
3	What positive attitudes towards BIPV are present?
4	Do BIPV manufacturers and suppliers sufficiently contribute to the legitimacy of BIPV? E.g., by publishing finished projects and best-practices [How could this be improved?]
5a	Do formal and informal institutions sufficiently contribute to the legitimacy of BIPV? E.g., inclusion of BIPV-solutions in standards, guidelines; aesthetic guidelines? [How could this be improved?]
5b	How does this differ between different projects (e.g., new construction versus renovation projects, residential versus commercial buildings)? [How could this resistance be removed?]

Section/Functions	Interview questions
6	Considering that the photovoltaic amount of installed power will significantly increase during the next years, do you consider that BIPV is the best option, or would you prefer the big PV increase? Do you see these PV plants increase as a threat for the landscape and the preservation of nature?
Guidance of the search (F7)	**0. Do you see BIPV as a promising market/technology? Why/Why not - do you have any concrete indications?**
1	What are the visions and expectations of the industry (BIPV, construction) on how BIPV technologies should develop towards the future in terms of growth and technological design? Are the visions and expectations of the different actors within the industry sufficiently aligned? How does this compare to adjacent sectors (e.g., energy sector or the already established PV-business)? [How could this be improved?]
2	What are the expectations on BIPV from the demand side?
3	Are there any public policies on BIPV in [country] and if so, what are the goals?
4	Do the public policies of [country] offer sufficient direction and clarity about the future of BIPV and the application of BIPV in the built environment? [How could this be improved?]
5	Do standards and product certification play a role for the BIPV development in [country]? [Is it mainly hampering or supporting the development? How could this be improved?]
6	Do you think that the (National) building code includes or considers BIPV sufficiently? (Structure)
7	Do you see the renovation support in Europe (and your country) as a good opportunity for the BIPV to grow? What do you miss?
General market formation (F8)	**0. Can you briefly describe the BIPV-market? Maturity, type of projects, stability, …**
1	In what phase of development do you consider the BIPV market to be? (Explain: Nursing, bridging, mature)
2	Do you consider BIPV in general, or in certain niches, to be commercially competitive?
3	Can you describe the type of users (“user groups”) your company addresses and their purchasing processes
4	Is the current size of the BIPV market (financially) sufficient for firms to be able to continue to innovate/develop?
5	What is your perspective on the future market of BIPV?
6	What impedes upscaling of the BIPV market?

Section/Functions	Interview questions
7	Which buildings or projects are most suitable for upscaling the BIPV market (residential buildings, commercial/utility buildings, or public buildings)? How does this differ between new construction and renovation projects?
Government/ policy driven market formation (8)	**What policy stimuli (regulations, subsidies, public purchasing etc.) are present? Think wide (indirect).** **What policy barriers are present?**
9	What are your views on existing institutional stimuli or hindrances (or current discussions on introducing new stimuli or removing hindrances)
10	Are the existing stimuli well-known and easy to use?
Business driven market formation (11)	**Could (or should) business actors (incl. Industry associations) do more to stimulate the BIPV-market?**
12	Are there sufficient and suitable types of actors contributing to up-scaling?
13	What actions could entrepreneurs implement to further develop the BIPV market?
14	What actions could entrepreneurs deploy in terms of business model development?
15	Are BIPV products sufficiently standardized (for easy application/implementation)? [How could this be improved?]
16	Do you think the current standards (i.e., EN 50583) are being considered for developing BIPV products? What standards do your products comply with?
User-driven market formation (17)	Are user groups using their customer power?
18	Do user groups know where to turn to when purchasing (new) BIPV solutions?
19	Are project sizes and/or future replication potential appropriate to attract manufacturer and/or supplier interest?
Conclusion of interview (C)	**[All of the below questions are always good to ask]**
1	Of the previously mentioned barriers, what are the largest barriers that hamper further development and diffusion of BIPV technologies?
2	What are the largest opportunities that could possibly foster further development and diffusion of BIPV technologies?
3	Would you like to add anything that was not discussed during this interview?
4	Could you suggest some people you consider important in the context discussed here, as potential interviewees?

After the interview

It is a good idea to take some time directly or shortly after the interview to note down your reflections from the interview, such as:

- main takeaway points;
- follow-up points (e.g., any facts, statistics, etc. that you promised to look up, or that you should look up to check a statement by the interviewee; send an e-mail with a question that the interviewee promised to discuss with a colleague);
- reflections on the authority of the interviewee in general or certain answers in particular. This can be both raising importance (e.g., “well-thought-through insights regarding resource mobilization”) or lowering it (e.g., “interviewee had little practical experience with BIPV”, or “unsure if interviewee properly understood the questions about social capital”).

Using questionnaires with listed interview questions

Apart from interviews, questionnaires can be a suitable supplement to the data gathering process. This can be a way forward when facing difficulties to find key representatives willing to be interviewed, but also to broaden perspectives or get some statistical data. By nature, questionnaires are less interactive, and they should be comprehensible in size, therefore a selection of the interview questions can be used, adapted to different target groups.

A first page of the questionnaire can be used to collect the most important background information from Table A1.

After that a selection of interview questions is posed. For the TIS analysis of BIPV in Spain the following selections have been used. Using (partly) the same questions in other countries makes it possible to do more detailed analyses and comparisons.

Table A3: Suggested selection of interview questions for 15 target groups. Questions are referred to by section/function indicators and question numbers (see Table A2).

Target group	G	F1	F2	F3	F4	F5	F6	F7	F8	C
PV and BIPV manufacturers	3, 5[1]		2	2, 9	2		1, 4	0, 1	6[1], 15	3
Manufacturers of mounting systems, etc.				2, 7, 10			0b, 1, 5a	0, 1	15	3
Building product manufacturers & suppliers		2		2, 7	2	0		0, 3, 4, 7	2, 8, 16	2, 3
Solar PV suppliers & installers				0a, 2, 3, 5	3	3	1, 4	0, 2, 7	11	3
Construction companies			2	0b, 6, 7		3[2]		1	7[1]	3
Technical consultants		0	4	9	1a-c	1	3, 5a		0, 12	3
Architects			2	6			0[3], 1[1]	0, 5	7, 15	3
Real estate owner					1a-b		0b, 6	0, 2[1], 7	9	3
Consumers / Consumer organizations	5[1]	0	0[1]				0[4], 6		6[1], 11[1]	3
Research & Academia	4	0, 1	0, 2	0a, 5, 8	1a				1	3
Education (academic & vocational)	5[1]	2	0[1], 3		1a	3	0a[5]		4	3
Networks, industry org.s, NGOs					1a-c	0	0a[6]	5	8, 9, 13, 14	1, 3
Promoters				0, 6, 7			2	1, 6	7[1]	3
Financing org.s (public & private)	4				1a-c	1			2	2, 3
Policy makers	5[1]		3		3		1[1]	3, 6, 7	6[1], 8	3

[1] Slightly adapted formulation

[2] Formulated specifically for relations between the BIPV and construction sector.

[3] Formulated more specific:" Do you find BIPV to be simple or easy to implement at a design level, compared to conventional construction products?"

[4] Formulated more specific:" What do you think about the idea to integrate solar energy in a more aesthetic and architectural way in buildings?"

[5] Formulated more specific:" Are companies, persons, organisations that are not aware of BIPV initially showing interest when you present the technology?"

[6] Formulated more specific:" Do you consider BIPV to be a technology with potential for the energy transition?"

APPENDIX B – STANDARDIZED PATENT SEARCH

For comparison and benchmarking of BIPV development amongst different countries, but also over time, it is found useful to define a patent search term that can be used by each country.

There are no obvious search terms that include all BIPV-related patents and exclude everything else, so our aim is to find a common search term/method that:

1. covers the majority of BIPV-related patents (applied for from a specific country);
2. requires a reasonable effort to review the list and exclude patents not at all relevant; and
3. could give relevant trend data for an analysis over time.

After an initial analysis of keywords and classifications used in a selection of BIPV-related patents, and a test of three different search terms for three countries, the search method described below was found to be most appropriate. There is no guarantee that this method will include all BIPV-related patents for each country, as a matter of fact we know that it does not, but it covers the majority and is reproducible so that comparisons can be made.

If the patent search described here is completed with additional search methods, e.g., asking interviewees, or searching on company names, then the results of the search method according to this Appendix should be presented separately in order to allow for comparison studies.

Use the following search and analysis method:

Patent searches are performed using the worldwide search portal of the European Patent Office (https://worldwide.espacenet.com/) that included results from national patent offices in Europe and should be performed as follows:

- Perform a global search with the following search terms:[1]
    - EITHER:
        - Classification (IPC or CPC) is:
            - EITHER: H02S20/20 (Supporting structures for PV modules directly fixed to an immovable object) including sub-classes;
            - OR: Y02E10/50 (Energy generation through renewable energy sources – Photovoltaic [PV] energy) including sub-classes.
        - AND Claims contain:
            - EITHER: "roof";
            - OR: “facade”;
            - OR: “building".

[1] To apply a search with the listed search conditions on Espacenet, you can also use the following link: https://worldwide.espacenet.com/patent/search?q=%28%28cl%20%3D%2Flow%20%22h02s20%2F20%22%20OR%20cl%20%3D%2Flow%20%22y02e10%2F50%22%29%20AND%20claims%20any%20%22roof%20facade%20building%22%29%20OR%20cl%20%3D%2Flow%20%22y02b10%2F10%22&queryLang=en%3Ade%3Afr

  - OR: Classification (IPC or CPC) is Y02B10/10 (Integration of renewable energy sources in buildings – Photovoltaic [PV]).
- Filter on "Applicants – country" for the studied country.[2]
- Go through the result list and remove all patents completely unrelated to BIPV. Start with the title and if necessary, check the figures and claims. Keep in mind that patents are considered to be relevant if they are specifically BIPV-targeted, or if they offer a clear potential in/for BIPV-applications.
- For the resulting list: Mark the status of the applications. These statuses are typically marked by a single letter, often followed by a number, at the end of the document number. Here you need to check the complete patent family, i.e., all published documents for that particular application. The following statuses are relevant to distinguish:
  - granted application, mostly marked by the letter **B** (in some countries also: **C**);
  - utility model, mostly marked by the letter **U** or **Y**;
  - application only, i.e., not (yet) accepted, mostly marked by the letter **A**.

  As the focus of our patent analysis is knowledge development and to some concern identification of actors, there is no need to check whether granted patents are still active, i.e., whether all fees have been paid. It is enough to know whether the patent was granted (as patent or as utility model) or not.

In the further analysis of the patent search results it can be relevant to consider the total number of applications and granted patents, but also the ratio of granted/applied (e.g., ca 50% in Italy) and the possible explanations to it (for Italy the requirements of patents to be eligible for a specific feed-in tariff). Differences between utility models and patents should also commented, if relevant.

[2] To directly filter search results on Espacenet for a specific country, add &f=publications.pac%3Ain%3D[CC] to the link in the previous footnote, where [CC] should be replaced by the country's two-letter country code according to WIPO Standard ST.3 [21].

APPENDIX C – ILLUSTRATIVE EXAMPLE STUDIES

I. TIS-analysis for BIPV development in the Netherlands by Vroon et al. [22]

This publication describes the historical development and current status of the TIS for BIPV in the Netherlands. Its objectives are highly similar to that of Subtask A, but there are slight differences in the method, being mainly that the function "Development of social capital" is not included in this example. Furthermore, there is a larger focus on development over time and therefore more emphasis on the history of the TIS.

Basically, all parts that are described in this guide are also included in the example study, though the structural analysis is presented more briefly. Functional analysis for the current status as well as systemic problems are discussed, and recommendations are presented in the Discussion and Conclusion sections. Analyses of patent applications, projects and social networks are included in the work. As such this example is a very useful example.

Please note that the function numbering in the example study differs from that presented in this guide.

II. TIS-analysis for offshore wind energy in different North-Western European countries by Wieczorek et al. [20]

This study analyses and compares the innovation systems for offshore wind energy in the UK, the Netherlands, Germany, and Denmark. It is explanatory since it covers four countries and therefore includes a broader exemplification of strengths and weaknesses than a single country TIS. It is also relevant for the work in Subtask A because of its multi-national nature.

This study does not explicitly describe or assess the structure of the TIS. The TIS' functions are analysed and scored on a 5-point scale for each of the countries included. It also presents several policy recommendations, that are directed to policymakers but actually go beyond that and are relevant also for industry and market actors.

Please note that the study uses a different function ordering than in our guide and that the function Development of social capital (see section 5.5) is not considered.

The article presents the analysis of the innovation system functions per function, rather than per country. For a short summary of the results per country including graphical illustration, please refer to [23, Ch. 4].

III. TIS-analysis for the deployment of building-applied photovoltaics in Sweden by Palm [24]

This example study analyses the Swedish innovation system for deployment of building-sited solar PV. As it focuses on the deployment it has similarities in its main objective with the first part of the Subtask A aim, i.e., to facilitating BIPV implementation, but it does not cover the second part of our aim, which is to also support innovation and industrial development of BIPV solutions.

The study includes quite extensive descriptions of structure and analysis of functions of the TIS, with concluding recommendations. Recommendations are policy-targeted and do not include recommendation for market or industry actors.

The study is useful as an illustration of how structure and functions of a TIS can be described and analysed. Unfortunately, this study lacks the assessment steps of deciding a development phase (Chapter 4 of this guide) and scorings for function strengths.

Also note that the function ordering is different from that in this guide. Knowledge development and diffusion are defined as a single function and the function Development of social capital (see section 5.5) is not included in the study.

IV. TIS-analysis for photovoltaics in Japan and the Netherlands by Vasseur, Kamp and Negro [25]

This study compares the Japanese and Dutch innovation systems for PV, describing both the structure and the functions of the TIS in both countries. The study lacks the assessment steps of deciding a development phase (Chapter 4 of this guide) and scorings for function strengths but includes written assessments of the functions per country. Recommendations on how to strengthen the TIS are included and embrace both policy- and industry/market-directed actions.

The study is useful as an example of how to describe and analyse structure and functions of a TIS. Do note that the function ordering is different from that in this guide and that the function Development of social capital (see section 5.5) is not included in the study.

V. TIS-analysis for marine energy in Sweden – including social capital development by Andersson, Perez Vico, Hammar and Sandén [26]

A study covering the innovation system for marine energy in Sweden. It clearly describes both structure and functions of the TIS and also includes some international context. The study lacks the assessment steps of deciding a development phase (Chapter 4 of this guide) and scorings for function strengths but includes written assessments of the functions.

The main purpose of this listing is to exemplify the use of the function Development of social capital (see section 5.5), but it is also relevant as an example for descriptions of structure, functions and blocking factors, as well as policy recommendations.

Trans-national analyses

VI. Broadened analysis of TISs for offshore wind energy in North-Western Europe by Wieczorek et al. [23]

Based on the study presented in section I above [20] this study exemplifies how connections between different national TISs can be analysed. They use two main concepts:

- trans-national linkages – being the involvement of or the flow of actors, knowledge, capital, institutions or technology from one nation to another (as defined in [27]);
- institutional embeddedness – defined as the constraints that territorial (often national) institutions have on different types of innovations and market developments. As an example, they mention how coordinated market economies tend to support incremental

innovation, whereas liberal market economies are more likely to boost radical innovation.

VII. Analysis of the historical development of the PV TIS in China and Germany by Quitzow [28]

This study is not so much a relevant example for a TIS-study as such, as it describes historical developments rather than the current status, but it is relevant as an example that includes analyses of trans-national linkages for China and Germany.

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