

Task 15 Enabling Framework for the Development of BIPV

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# Digital BIM-based process for BIPV Digital product data models 2024



## What is IEA PVPS TCP?

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

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

The 25 IEA PVPS participating countries are Australia, Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, 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, the Solar Energy Industries Association, the Solar Energy Research Institute of Singapore and Enercity SA 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 and financial issues.

Subtask A of Task 15 is focused on the analysis of the Technological Innovation System (TIS) for BIPV on national levels in order 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. This document is one of the national TIS-analysis reports. A synthesis of national TIS-analyses will be made based on this and other national reports.

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### COVER PICTURE

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INTERNATIONAL ENERGY AGENCY  
PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

# **Digital BIM-based process for BIPV**

## **Digital product data models**

**IEA PVPS Task 15**

**Enabling Framework for the Development of BIPV**

Report IEA-PVPS T15-0:2024  
May 2024

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## LIST OF ABBREVIATIONS

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IEA	International Energy Agency
AEC	Architecture, Engineering and Construction
BIPV	Building Integrated Photovoltaics
BIM	Building Information Modelling
PVPS	Power Systems Programme
ESD	Environmentally Sustainable Design
ISO	International Organization for Standardization
IFC	Industry Foundation Classes
IDM	Information Delivery Manual
LOIN	Level of Information Need
CDE	Common Data Environment
IFD	International Framework for Dictionaries
bSDD	buildingSMART Data Dictionary
CCI	Construction Classification International
ETIM	European Technical Information Model
ECS	Engineering Consulting Services
MEP	Mechanical, Electrical and Plumbing
LOD	Level of Detail/Definition
LOG	Level of Geometry
SNV	The Swiss Standardization Association
CEN	European Standardization Committee
SIA	Swiss Society of Engineers and Architects
NATSPEC	National Building Specification
SEAL	Solar Energy Application Lab
LCC	Life Cycle Cost
LCE	Life Cycle Assessment
MVD	Model View Definitions

## EXECUTIVE SUMMARY

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The aims of this report are:

- (1) Give an overview of potentialities of BIM (Building Information Modelling) for the BIPV process and products referring to the available international standards and approaches;
- (2) Describe in a systematic way BIM-based workflows and tools in relation with the main BIPV process stages;
- (3) Present an overview of available BIM-based objects for BIPV products to describe the state of play, regulations and standards; and
- (4) Report case-studies of some BIPV projects developed with a BIM approach and/or tools to share real experiences on how to implement BIPV processes in BIM.

The overall goal is to prepare with this analysis the international work towards coherent open BIM-standards for BIPV, which will be as well supported by IEA Task 15 working groups in the period 2024-2027. An overview of the BIPV process was conducted representing the main process phases, the main activities, and the main outputs produced by the involved stakeholders.

The report reviews the concepts of BIM and openBIM®, the current BIM standards scenario, the benefits of BIM for BIPV, and how can BIM potentially affect BIPV process stage. The study also provided the national state of play about digital BIM-BIPV products in six regions, and their digital structure/schema/framework/standard for describing BIPV product and categorize BIPV data. A list of current BIM-BIPV product database, online portals and libraries is included in the report.

The study reviews the BIM tools for BIPV design, modelling, and simulation, and how digital objects are handled in these tools. Furthermore, this report reviews five specific BIM-based BIPV tools and workflows for design and simulation, three BIM-BIPV showcases and case studies, as well as seven research activities on BIM and BIPV.

As a conclusion, this report suggests preliminary inputs for BIPV product data management in a BIM-based approach, further BIM/BIPV research regarding digital product data models, pre-normative recommendations and standards, and geometrical and informative parameters to support LOIN definition.



# 1 INTRODUCTION

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Main Targeted Audience: Architects, Building Engineers, BIPV designers and consultants, researchers as well as BIPV / PV-, construction and software industry

Aims:

- 1) Give an overview of **potentialities of BIM for the BIPV process and products** referring to the available international standards and approaches;
- 2) Describe in a systematic way **BIM-based workflows and tools** in relation with the main BIPV process stages;
- 3) Present an overview of available **BIM-based objects for BIPV products** to describe the state of play, regulations and standards;
- 4) Report **case-studies** of some BIPV projects developed with a BIM approach and/or tools to share real experiences on how to implement BIPV processes in BIM.

The overall goal is to prepare with this analysis the international work towards coherent open BIM-standards for BIPV, which will be as well supported by IEA Task 15 working groups in the period 2024-2027

## 2 BIPV PROCESS: AN OVERVIEW

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*Highlight: overview of the BIPV process representing the main process phases, the main activities, and the main outputs produced by the involved stakeholders.*

The relationship among the client team, the design team, industry stakeholders, and other participants in the construction process has grown increasingly intricate in recent years. This complexity has arisen due to various strategies for enhancing procurement methods, the rise of specialized expertise in building design, and the continued complication of construction processes. In numerous countries, there exists a formalized procedure for designing structures, with clear guidelines and documentation. In contrast, some countries follow a more informal approach, passing down knowledge from one generation of professionals to the next. Globally, there are several design process frameworks and plans of action in use to guide clients through the stages of briefing, design, construction, handover, and beyond. These international plans of work exhibit notable distinctions among them.

The following overview of the BIPV process attempts to identify and describe the key phases, activities, and outputs to provide a reference framework for the analysis of BIM-based digital processes, BIM-based digital tools, and BIPV case studies developed with a BIM approach. However, considering that each building and each BIPV project is unique and that each country can have its process peculiarities, this overview doesn't pretend to be exhaustive and to be used as a reference for developing BIPV buildings.

The proposed overview has been obtained through the description of BIPV processes and related inputs provided by the IEA PVPS Task 15 experts. Specifically, the resulting BIPV process has been based on experiences coming from Australia, Italy, Spain, and Switzerland.

The BIPV process phases are described in Table 1. The ideal BIPV process stage starts with the strategic planning of the building, where the client sets building objectives, including a budget, sustainability targets, energy accreditations and incentives. Iterative conceptual design follows, and the client, architect, BIPV / ESD consultant investigate the feasibility of different BIPV solutions through conceptual drawings, preliminary data, and simulations. This iteration continues in the developed design stage where the BIPV / ESD consultant, architect and the client investigate BIPV design scenarios and BIPV product solutions in more detail to obtain a preliminary/schematic project. Once a BIPV solution has been agreed, all involved BIPV stakeholders prepare detailed technical drawings, schedules, and specifications to enable the construction of the selected BIPV design, according to the different tendering models:

- AU: the tendering is after technical design,
- CH/IT: the tendering is before the technical design stage. Thus, the BIPV manufacturer provides technical details.
- DE: there are different models for tendering depending on project type:
  - In mostly very large projects with a “general contractor” the tendering of the overall project is done according to the project design planning and client

requirements which are fixed in the “project brief”. The drawing of details and tendering of subcontractors / specialized companies is done by the “general contractor”.





- In public buildings / larger buildings with public funding there must be a “functional tendering” which is not yet product specific to allow the required competition on the market to find the cheapest offer
- In projects without such requirements there are all different forms of tenders possible including product specific tenders with the goal to identify the best price offer / installer

After the manufacturing stage is completed, based on the technical drawings the materials needed for the BIPV realization are shipped to the project site. The BIPV envelope is then built based on the technical drawings, specifications and instructions for installation, while the monitoring and controlling of the BIPV project installation process is carried out during the construction phase. Hence, testing and commissioning of the BIPV system is done and the building with BIPV project information is handed over the building operators. The latest phase before the end of life is represented by the O&M where monitoring should be conducted in order to maintain high BIPV envelope performances.

For each of these phases, main activities of key BIPV stakeholders are reported in Table 2, whereas

Table 3 describes the main outputs of the BIPV process phases.

**Table 1. Description of the main BIPV process phases**

PHASE	DESCRIPTION
 <p>1. STRATEGIC PLANNING</p>	The initial stage of the building process where the client sets building objectives, including a budget, BIPV and sustainability targets, energy accreditations and incentives
 <p>2. CONCEPTUAL DESIGN</p>	Iterative design stage where the client, architect, BIPV / ESD consultant investigate the feasibility of different BIPV solutions through conceptual drawings, preliminary data, and simulations
 <p>3. DEVELOPED DESIGN</p>	Iterative design stage where the BIPV / ESD consultant, architect and the client investigate BIPV design scenarios and BIPV product solutions in more detail to obtain a preliminary/schematic project
 <p>4. TECHNICAL DESIGN</p>	All involved BIPV stakeholders prepare detailed technical drawings, schedules, and specifications to enable the construction of the selected BIPV design. (AU: the tendering is after technical design, CH/IT: the tendering is before the technical design stage. Thus, the BIPV manufacturer provides technical details)















	5. BIPV MANUFACTURING	At this stage, materials needed for BIPV realization are produced and shipped to the project site
	6. INSTALLATION	Realization of BIPV envelope based on the technical drawings, specifications, and instructions for installation. Monitoring and controlling the BIPV project installation process. Testing and commissioning the BIPV system
	7. HAND-OVER	Handover the building with the BIPV project information to the building operators
	8. O&M	Operation, monitoring, and maintenance of the BIPV envelope, and energy management
	9. DISMANTLING	Dismantling of the BIPV installation or parts of it due to ageing / change of the project
	10. END OF LIFE	Reuse of still usable components, recycling of valuable materials, disposal of waste material

Table 2. Description of the main BIPV stakeholders' roles and activities

PHASE	STAKEHOLDERS' ACTIVITY DESCRIPTION
 <p>1. STRATEGIC PLANNING</p>	<ul style="list-style-type: none"> <li>The <b>Client</b> provides inputs about BIPV energy/sustainability targets, energy accreditations and government incentives. Moreover, the Client provides overall building idea and budgetary constraints.</li> <li>Based on the Client inputs, the <b>Architect</b> provides insight on BIPV application types and product types, sustainable and energy targets.</li> <li>The <b>BIPV / ESD consultant</b> can help the Architect to explore BIPV solutions in the market and their values/advantages.</li> </ul>

	<p>2. CONCEPTUAL DESIGN</p>	<ul style="list-style-type: none"> <li>• The <b>Client</b> provides feedback about proposed conceptual BIPV solutions, costs, and profitability.</li> <li>• The <b>Architect</b> designs the concept of the building envelope and identifies BIPV solutions (BIPV surfaces and type of installations). The Architect can be supported by the BIPV / ESD Consultant for solar analysis and identification of BIPV solutions.</li> <li>• The <b>BIPV / ESD Consultant</b> can support the Architect by performing solar analysis, by identifying suitable areas for BIPV and by collecting inputs from BIPV Manufacturer to develop techno-economic evaluations.</li> <li>• The <b>BIPV Module Manufacturer</b> can be involved for early consulting on average costs or average power of custom BIPV solutions (to support rough cost estimation and preliminary annual yield estimation).</li> </ul>
	<p>3. DEVELOPED DESIGN</p>	<ul style="list-style-type: none"> <li>• The <b>Client</b> provides feedback and approval for the proposed BIPV solutions.</li> <li>• The <b>Architect</b> develops BIPV design scenarios with the selected BIPV solutions.</li> <li>• The <b>BIPV / ESD Consultant</b> collects inputs from the Architect, and from the BIPV module Manufacturer and Envelope Engineer (if involved) to provide estimations of BIPV production, costs/profitability, impact on building performances (thermal, daylighting).</li> <li>• The <b>BIPV Module Manufacturer</b> can be involved for providing techno-economic inputs on specific BIPV products or for consulting on custom BIPV modules.</li> <li>• The <b>Envelope Engineer</b> can be involved for early consulting on mounting structures (prefeasibility and average cost). The Envelope Engineer may update the BIPV design drawings from the architect, based on the thermal and ventilation impact, daylighting and glare results provided by the ESD consultant.</li> <li>• The <b>Fire Engineer</b> can be involved in the early stages to verify the fire safety requirements of the proposed BIPV design scenarios (AU).</li> <li>• Based on the input about BIPV designs, the <b>Building Contractor</b> develops the preliminary estimations and schedules of the whole building including BIPV.</li> </ul>
	<p>4. TECHNICAL DESIGN</p>	<ul style="list-style-type: none"> <li>• The <b>Client</b> approves a specific BIPV design.</li> <li>• The <b>Architect</b> updates the architectural drawings of the BIPV envelope with specifications of the BIPV modules.</li> <li>• The <b>BIPV / EPD Consultant</b> delivers the final report of the BIPV project, including energy production, cost/profitability, impact on building performances.</li> </ul>

	<ul style="list-style-type: none"> <li>• The <b>BIPV Module Manufacturer / Supplier</b> provides technical details of the selected BIPV modules.</li> <li>• The Electrical <b>Engineer and installers</b> develop the final BIPV system's electrical system design (Wiring and cabling system design) drawings. They check the system compliance with local building codes and standards.</li> <li>• • The <b>Envelope Engineer develops</b> the structural and mechanical drawings of the BIPV envelope system considering inputs from the Architect, BIPV Module Manufacturers/ Suppliers and Electrical Engineer and installers.</li> <li>• The <b>Fire Engineer</b> develops the fire performance design based on the inputs from the Architect, BIPV module suppliers/manufacturers, Electrical Engineer and installers and the Envelope Engineer (AU).</li> <li>• The <b>Building Contractor</b> appoints electrical installers and facade/roof installers. The Building Contractor develops the project budget and project schedule of the whole building including BIPV.</li> </ul>
 <p>5. BIPV MANUFACTURING</p>	<ul style="list-style-type: none"> <li>• The <b>BIPV manufacturer</b> produces the BIPV modules.</li> <li>• The <b>Electrical Engineer</b> orders electrical equipment and ships them to project site.</li> <li>• <b>Facade/roof installer and the Engineering team</b> with the project procurement team tender/order the items required for the building envelope.</li> </ul>
 <p>6. INSTALLATION</p>	<ul style="list-style-type: none"> <li>• <b>Electrical Installers</b> connect BIPV modules and electrical equipment.</li> <li>• <b>Facade/Roof Installers</b> install mounting structures and BIPV modules.</li> <li>• The <b>Building Contractor</b> coordinates the electrical installers and facade/roof installers to carry out the BIPV installation work. The Building Contractor monitors the installation progress.</li> <li>• <b>Electrical Engineer</b> creates the physical infrastructure and the digital platform for BIPV system monitoring and O&amp;M.</li> </ul>
 <p>7. HAND-OVER</p>	<ul style="list-style-type: none"> <li>• The <b>Building Contractor</b> hands the project and documents over to the Client or Facilities Management team on behalf of the Client.</li> </ul>
 <p>8. O&amp;M</p>	<ul style="list-style-type: none"> <li>• The <b>Facility Manager and team</b> monitors the performance of the BIPV system, arranges cleaning, inspection, repair, and replacement.</li> <li>• The <b>building/community energy manager</b> optimizes the use of the solar electricity produced within the building / energy community / energy market / distribution network.</li> </ul>













	<p>9. DISMANTLING</p>	<ul style="list-style-type: none"> <li>• <b>Electrical Installers</b> disconnect BIPV modules and electrical equipment.</li> <li>• <b>Facade/Roof Installers</b> uninstall mounting structures and BIPV modules.</li> </ul>
	<p>10. END OF LIFE</p>	<ul style="list-style-type: none"> <li>• <b>The PV / BIPV-trader</b> is collecting the “second hand”-modules for a new purpose.</li> <li>• <b>The PV / BIPV-producer</b> is taking the dis-functional modules back for repair or internal recycling.</li> <li>• <b>The construction company / electrical installers</b> are moving the modules and components to a specialized place for disposal of electric waste material.</li> <li>• <b>The specialized recycling company</b> is de-constructing the BIPV-elements and is selecting material for recycling or waste disposal</li> </ul>

Table 3. Description of the main outputs of the BIPV process phases

	PHASE	OUTPUTS
	<p>1. STRATEGIC PLANNING</p>	<p>Budget, BIPV energy and sustainability targets, aesthetical appearance</p>
	<p>2. CONCEPTUAL DESIGN</p>	<ul style="list-style-type: none"> <li>• Conceptual 2D/3D model of BIPV solutions,</li> <li>• Feasibility report with BIPV energy output, rough cost estimation and profitability of the proposed solutions,</li> <li>• Planning and zoning permit (AU: planning permit including the BIPV solution)</li> </ul>
	<p>3. DEVELOPED DESIGN</p>	<ul style="list-style-type: none"> <li>• 2D schematic design drawings/3D schematic models of the chosen BIPV design</li> <li>• Report with preliminary BIPV energy production and cost estimations for the chosen BIPV design</li> <li>• Thermal &amp; ventilation impact, daylighting and glare control, structural impact, and fire safety assessment (AUS)</li> <li>• Building Permit Application (CH)</li> </ul>
	<p>4. TECHNICAL DESIGN</p>	<ul style="list-style-type: none"> <li>• Detailed drawings and/or 3D detailed models of the BIPV envelope</li> <li>• Technical drawings with specifications of BIPV modules mounting structure, electrical configuration</li> <li>• Detailed information about BIPV energy production and cost estimation for the whole BIPV envelope</li> </ul>

	<p>5. BIPV MANUFACTURING</p>	<p>Instructions for BIPV components installation, testing and commissioning</p>
	<p>6. INSTALLATION</p>	<p>As-built drawings and/or 3D detailed models of the following installed elements: BIPV modules, mounting structures, electrical equipment</p>
	<p>7. HAND-OVER</p>	<p>Handover documents: Drawings/3D models Warranties, BIPV system and product data sheets (ISO 23386/7) and manuals, commissioning, and testing certificates</p>
	<p>8. O&amp;M</p>	<p>Monitoring and controlling system of the BIPV system.</p> <p>Optimized energy management procedures</p> <p>Planned preventive maintenance procedures</p> <p>Archiving of product data sheets and system documentation including cabling and their labeling</p>
	<p>9. DE-INSTALLATION</p>	<p>Drawings and/or 3D detailed models of the installed elements to locate and deinstall them free of destruction: BIPV modules, mounting structures, electrical equipment.</p>
	<p>10. END OF LIFE</p>	<p>Documentation strategy for long term accessibility of product data sheets and installation manuals of BIPV-modules and system components.</p> <p>Detailed list of components and the incorporated materials for the purpose of reuse of components, recycling processes, reuse of materials and waste disposal.</p>



## 3 BIM FOR BIPV PROCESS AND PRODUCTS

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Highlights:

- What is BIM and openBIM®? What is the current BIM standards scenario?
- What does BIM mean for BIPV? And how can BIM potentially affect BIPV process stage?
- What is BIM for BIPV products?

### 3.1 BIM, openBIM and standards about BIM

BIM is the acronym for Building Information Modeling. The “official” BIM definition is provided by the standard ISO 19650 and explained by buildingSMART as following:

*“BIM (Building Information Modelling) is considered a strong driver of digitalisation. ISO 19650 defines BIM as “the use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions” (built assets include buildings, bridges, roads, and process plants). This standard thus refers to the three essential aspects of BIM: model, technology and processes. The core of BIM is the digital building model, which contains the information in the form of geometries and alphanumerics (non-geometric information on function, location, material, etc.). Thus, BIM provides an interdisciplinary, optimised, digital way of creating, exchanging, and maintaining digital building information. BIM promotes successful communication and collaboration between the parties involved in a construction project in all phases.”<sup>1</sup>*

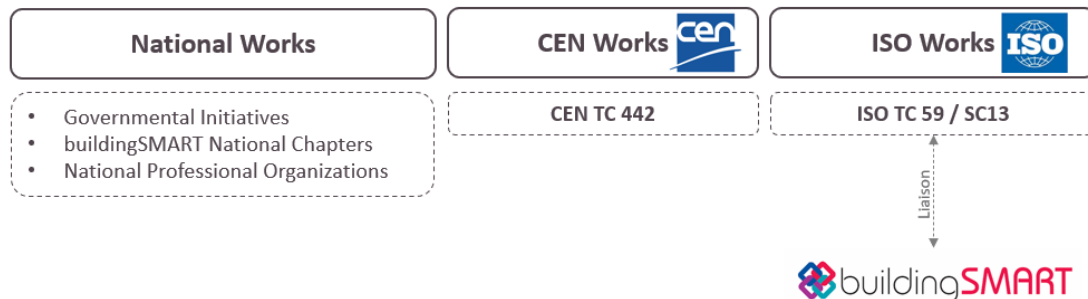
BIM is commonly considered also as “a process supported by various tools, technologies and contracts involving the **generation** and **management** of digital representations of physical and functional characteristics of places” (Hai et al., 2020), including not only buildings but also other construction projects (e.g., civil infrastructure, energy plants, process plants, ...). This means that BIM has introduced **new approaches in the design and construction** of buildings, as well as **new ways to manage built environment**, based on **shared and reliable information** and on **collaborative and cooperative ways of work**.

Different organization at different levels are developing standards and processes about BIM, as shown in Figure 1. At the national levels, there are governmental initiatives, buildingSMART National Chapters and National Professional Organizations. At the European level, the CEN/TC 442 is working for the standardization in the field of structured semantic life-cycle information for the built environments through BIM. And, finally, the ISO TC59/SC13 is focusing on international standardization of information through the whole life cycle of

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<sup>1</sup> Eichler, C.C., Schranz, C., Krischmann, T., Urban, H., Hopferwieser, M., Fischer, S., 2024, BIMcert Handbook — Basic Knowledge openBIM — Edition 2024, Mironde, Niederfrohna

buildings and infrastructure across the built environment in liaison with buildingSMART International and other committees or technical groups,



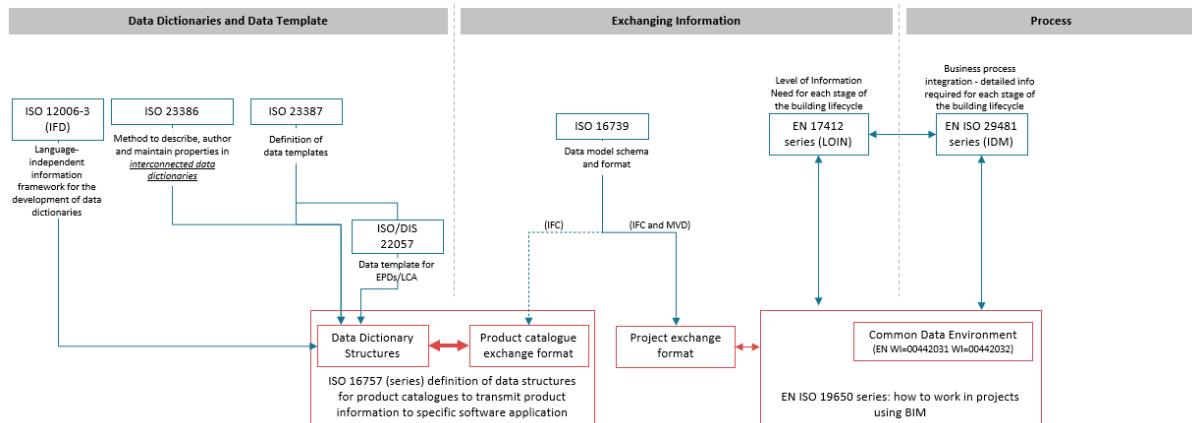
**Figure 1. Organizations working on BIM.**

buildingSMART International, as a leading global community, is committed to driving the digital transformation of the built asset environment, through the creation and adoption of openBIM<sup>®</sup> standards for infrastructure and buildings. Indeed, openBIM<sup>®</sup> extends the benefits of BIM by creating common alignment and language. On this basis, technical applications developed in accordance with openBIM<sup>®</sup> improve the management of data and eliminate disconnected workflows, through vendor-neutral formats and open data exchanges<sup>2</sup>. The adoption of BIM and specifically openBIM<sup>®</sup> in the AEC sector will provide benefits since it will enhance the collaboration for project development and delivery through better access to data created during the design and it will facilitate the development of data management strategies for the whole life cycle of the built asset. buildingSMART International developed three main openBIM standards in accordance with ISO:

- ISO 12006-3:2022 about the International Framework for Dictionaries,
- ISO 16739:2013 about the Industry Foundation Classes (IFC) format,
- ISO 29481-2:2012 about the Information Delivery Manual (IDM).

Beyond these standards, there are several other norms that are relevant to BIM. A non-exhaustive overview of BIM standards is provided in Figure 2.

<sup>2</sup> <https://www.buildingsmart.org/about/openbim/openbim-definition/>



**Figure 2. Overview of BIM standards**

The core standard about the BIM process at the international level is the ISO 19650 series that describe how to manage information over the whole life cycle of a built asset using Building Information Modelling. However, there are also other standards which support the implementation of the BIM process. Among them, the ISO 29481 part 1 and 2 “Building information models – Information Delivery Manual (IDM)” provides details about information required for each stage of the building lifecycle. At the European level, the series EN 17412 “Building Information Modelling – Level of Information Need (LOIN)” aims at supporting the definition of information to be exchanged and delivered throughout the life cycle of built assets. Alphanumeric, geometric data and documentation related to a construction project and BIM process can be stored in a digital information platform (Common Data Environment or CDE) that centralizes project data storage and access for the different stakeholders.

It's important to highlight that exchange of data and information between stakeholders who design and realize built assets and components manufacturers has to be managed in order to avoid fragmentation and allow seamless workflows. For this reason, the series ISO 16739 “Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries” has been developed. However, it is also necessary to ensure that data shared through exchange formats is universally understood by all actors and software used. Therefore, several preliminary standards have been developed with the final aim to define data dictionaries, data templates and exchange formats for products. Among them, it is important to mention:

- **ISO 12006-3:2022** “Building construction - Organization of information about construction works - Part 3: Framework for object-oriented information”. It specifies a standard language to be used for the development of a dictionary useful to the construction sector. Specifically, it establishes an open terminology standard, the International Framework for Dictionaries (IFD ) in which concepts and terms are semantically described and given a unique identification number.
- **ISO 23386:2020** “Building information modelling and other digital processes used in construction - Methodology to describe, author and maintain properties in interconnected data dictionaries”. This standard provides a methodology to define rules for defining properties used in construction and a methodology for authoring

and manage construction object characteristics for digital use among stakeholders in a BIM process to obtain fully interoperable, non-ambiguous, machine-readable, and human-understandable data along the construction lifecycle.

- **ISO 23387:2020** “Building information modelling (BIM) - Data templates for construction objects used in the life cycle of built assets - Concepts and principles”. This standard sets out the principles and structure for data templates that can be used to digitally describe any construction object within the construction works and building services. In other words, a definition of data templates for standardizing objects (components or even materials) and connecting properties is provided.
- **ISO 16757-1:2015** “Data structures for electronic product catalogues for building services – Part 1: Concepts, architecture and model”. It provides the data structures for digital product to transmit product data automatically into models of building services software applications.

**buildingSMART introduced a Data Dictionary known as “bsDD”**, which is implementing concepts covered in the ISO standards: 12006-3, 23386 and 23387. The buildingSMART Data Dictionary (bSDD) is an online service hosting classes (terms) and properties, allowed values, units, translations, relations between those and more. It provides a standardised workflow to guarantee data quality, information consistency and interoperability. bSDD is a service from buildingSMART International supporting the openBIM® workflow. The definitions from bSDD can be referenced in IFC models and IDS specifications. Based on the bsDD property sets for products can be published and used worldwide to allow a smooth communication between different softwares, such as planning and simulation. Besides national and international classification systems (e.g. Uniclass, CCI) and domain-specific standards (e.g. ETIM, IfcAirport), company-specific standards can be stored in bSDD as well<sup>3</sup>.

The provided standard scenario can be not exhaustive also considering that is constantly under development. Nevertheless, it is important to underline that BIM affects the whole lifecycle of a built asset from design to O&M.

Indeed, focusing on the project development and the design stage, the opportunity to share BIM data through technical solutions of Common Data Environment (CDE) allows different stakeholders coming from different disciplines to enhance the collaboration and coordination on specific aspects of the project. Regarding the construction stage, the adoption of BIM approach and strategies (e.g., clash detection, code checking, scheduling) allows improving the quality of construction and limiting the risk of delays and extra-costs due to mistakes or collisions in the project site. This is especially relevant in complex projects, where different companies and different installers are working together and simultaneously. The benefits of BIM adoption can be observed also in the O&M stage. Indeed, a specific dataset with defined granularity and extension of a realized asset can be transferred from the as-built model to the

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<sup>3</sup> <https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/>

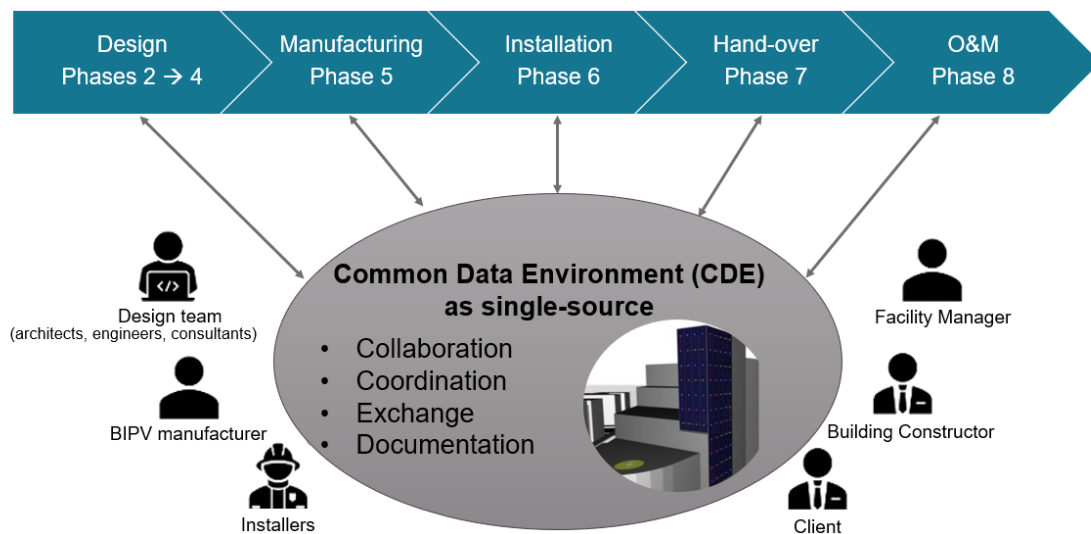
model that is needed for supporting O&M activities. In this way, a large amount of time and effort can be saved for retrieving information needed for O&M, and this stage can be optimized thanks to reliable data and information.

### 3.2 Possible BIM approaches for the BIPV process

Based on the BIPV process stages provided in chapter 2 and the recognized advantages of BIM for the AEC sector, the possible applications of BIM for BIPV and related benefits are described hereinafter.

#### BIM in the BIPV project development and technical design stages.

As introduced before, the adoption of BIM and specifically openBIM<sup>®</sup> to share data about a building project in a CDE can enhance the collaboration and coordination of the different disciplines and stakeholders involved in the project development. This goal can be achieved also because the digital process is structured since the beginning of the building process, involving all relevant stakeholders who are required to deliver specific information in specific formats.

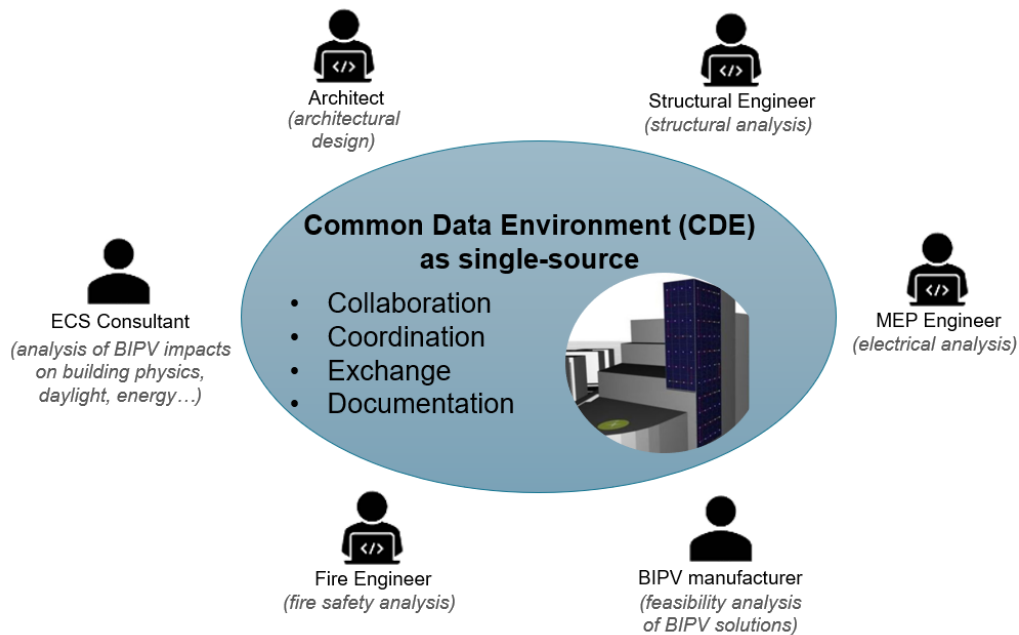


**Figure 3. BIM adoption in the BIPV process and involved stakeholders. Re-elaboration from: <https://isfh.de/bimpv/>**

Beyond typical uses, BIM can be also referred to “a model-based process of generating and managing coordinated and consistent building data that facilitates the accomplishment of established sustainability goals” (Altohami et al. 2021) and can be also a driver for BIPV.

Indeed, considering the intrinsic multidisciplinary of BIPV, the opportunity to share data about photovoltaic façades, roofs and envelope elements in a common data environment allows to create a common basis of discussion and development among the different stakeholders involved (e.g., architect, ECS consultant, MEP engineers, structural engineer, ...) with the final aim to carry out the most appropriate BIPV solutions.

In this way, BIM can favour a seamless workflow among the various actors of the BIPV design process, reducing efforts and time for coordination, limiting mistakes and risks, and considering BIPV from the initial stages of the building construction process.



**Figure 4. Examples of CDE for managing BIPV data among stakeholders, and possible BIM uses in the design stages.**

#### BIM in the BIPV manufacturing stage

When designing BIPV envelopes, two main design approaches can be adopted. On one hand, designers can rely on predefined digital BIPV objects from BIM database. On the other hand, designers want to design custom BIPV products. The adoption of custom BIPV approach typically requires a high degree of flexibility and customization during the manufacturing to realize BIPV modules and components capable to correctly suit the building envelope on every technical issue (electrical, mechanical, thermal, optical, aesthetical). Indeed, depending on the complexity of the building and the layout pattern of modules, different sizes of BIPV modules need to be produced. Another option could be to provide architects and BIPV designers with customizable BIPV parameters from the industry to make aware architects of the feasible solutions. Indeed, a strong commitment and collaboration between BIPV designers and manufacturers is crucial to reduce mistakes, repetitive work and extra-costs. In this context, the possibility to adopt a CDE allows improving the exchange of information between designers and BIPV producers. The latter, indeed, can immediately review and inform about possible bottlenecks due to a not-producible BIPV object. This knowledge supports the BIPV designer in the development of the optimal-feasible solution.

Moreover, when BIM-BIPV objects are created, the BIPV drawings and models could be used to feed an Industry 4.0 production process, even though this involves the need for production lines capable to “read” the parameters specified in the BIPV design stage to manufacture the desired BIPV product.

### BIM in the BIPV project installation stage

The benefits of BIM go beyond the design stage and can also involve the installation and construction stage for the whole building but also for BIPV building envelopes.

- Validation of BIPV design constructability

Considering the multidisciplinary expertise and resources needed to realize a BIPV envelope, developing a BIM 3D model allows visualizing better the result and associated components related to different disciplines (glass, mounting structures, electrical components, ...). This makes easier the decision-making process and the identification of the best way to construct the project.

- Definition of optimal construction phases and scheduling and reduction of extra-costs

Adopting BIM for BIPV projects can also help identify if there are any potential clashes between the different components and elements, phases, or even site features or construction site aspects before the project begins construction. In this perspective, different solutions for the construction phase can be developed and compared until a workable and convenient solution is achieved. This allows anticipating issues that can arise during the construction stage thus eliminating the need for redesign or rework while the structure is being built. Having access to detailed information from the BIM model allows for mitigating risks, optimizing construction costs, and improving construction quality.

### BIM in the BIPV project hand-over stage

Once the BIPV project is realized, the as-built model can be carried out. This as-built model with embedded information can be delivered to the client or the facility managers, rather than relying on updating as-built drawings. This allows contractors to avoid the collection of the different data and information about the building from different stakeholders, thus avoiding risks of mistakes and loss of information.

### BIM in the O&M stage for BIPV, and DT for dismantling and end-of-use

The BIM model of the BIPV building can be used during the whole building lifecycle, especially for BIPV operation and maintenance but also for any future intervention or demolition work.

Typical maintenance operations for BIPV are often implemented only when the electrical performances behave under the expected values or accidental failures occur. Only in recent times, most advanced inverters with power optimizers allow real-time monitoring of the BIPV system and modules.

Beyond this, specific O&M systems can be developed to monitor the performances and planning smart maintenance of the system, thanks to AI algorithms. This innovative concept is called Digital Twin and it is mostly used for large PV plants to anticipate failures and mitigate operational risk. However, the DT concept can be transferred also at the building level, where several DT models can be aggregated to create the DT of a building that could be used to improve energy efficiency, increase indoor well-being and so on. In this framework, a DT of the BIPV envelope can be suitable to monitor the BIPV performances and to improve maintenance to extend the BIPV life of service.

Finally, the opportunity to update the information in the DT model as the building lifecycle progresses and store it in a centralized and easily accessible environment could facilitate not only facilities management teams but also operators that will disassembly and recycle BIPV components.

### 3.3 BIM and BIPV objects

As introduced before, BIM can embrace all stages of the BIPV process, starting from modelling and design, till the O&M. BIM also offers the possibility to manage information and data of BIPV products and objects along the BIPV process stages. Indeed, when using BIPV products in the BIM-based BIPV process, associated information can differ from one stage to another depending on the expected use of the model and expected outputs.

One of the most controversial concepts when dealing with BIPV products in a BIM process is the LOD. Indeed, this acronym can be intended as both Level of Detail/Definition (to identify the quantity of geometric and informative data associated to the object, born in UK) and Level of Development (to identify the reliability of geometric and informative data associated to project phase where the object is used, born in US). The adoption of these concepts can change from country to country and each definition can be characterized by different LOD classifications (Bolpagni 2016; Harpaceas 2021; BibLusBIM 2023).

In this context, the concept of LOIN (Level of Information Needed) is introduced by **ISO 19650-1:2018** to define the following project' prerequisites or questions that are made by the client in a BIM process:

- Purpose: why is the information needed?
- Information delivery milestone: when is the information required?
- Actors: who requires and delivers information?
- Objects: what information is required for the goals?

Specific metrics to measure the information to be delivered are not defined in the LOIN concept provided by ISO 19650. However, at the European level a new standard **EN 17412** has been published in 2021 to bridge this gap. In accordance with this standard, once the purpose, the information delivery milestone, the actors, and the objects are clarified, the Level of Information Needed is defined through the identification of the information to be delivered, considering geometry, alphanumeric data and documents (e.g., unstructured information such as plans, reports, photographs and so on). For instance, the geometric data can be defined depending on different parameters, such as:

- Level of detail,
- Dimensionality,
- Location,
- Appearance,
- Parametric.

Regarding alphanumeric data, this is described by:

- Identification
- Information content.



Documentation includes different documents needed to support decisions, reviews and approvals or processes in general. Documents can be reports, specifications for components or products, manuals, photographs, hand sketches, signed documents, printouts of geometric information (e.g., floor plans) or alphanumeric information can also be viewed as documents.

From this standard, the concepts of the Level of Geometry (LOG – level of detail for the geometric and visual representation of an object), and the Level of Information (LOI – level of detail for the informative data associated to the object) can be intended as metrics to satisfy the request of information from LOIN.

Therefore, in a BIM process, the concept of LOIN should be defined by the client for the objects of the BIM project considering the purposes, the information delivery milestones, and the actors starting from the initial BIM documents about requirements (e.g., EIR). Then, the BEP will include the definition of LOIN as a combination of LOG and LOI to fulfil the requests made by the client.

Even in this constantly changing scenario, it is important to consider that properties of BIPV products are not only related to the construction domain but also to the electrical field and both will need to be included in digital BIPV objects, depending on the LOIN defined for the BIM project. Moreover, as introduced in paragraph 3.1, it is necessary to refer to standardized data dictionaries and templates in order to avoid mistakes and/or duplication of properties and attributes which could be also not readable by BIM-based software and tools.

## 4 STATE OF PLAY FOR BIM-BIPV OBJECTS

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### Highlights:

- *What is the national state of play about digital BIM-BIPV products? Are there digital structure/schema/framework/standard for describing BIPV product and categorize BIPV data?*
- *Which BIM-BIPV product database, online portals and libraries exist?*

As already mentioned, currently there are many efforts in standardizing the way to create and manage digital information in the construction sector even though several organizations in different countries have already adopted local approaches or standards to face BIM in their activities.

However, due to the novelty of this standardisation work and the changing scenario, it is interesting to also provide an overview of the current national standards and approaches adopted for digital BIPV objects by some countries, as well as the current state of play of libraries for BIM BIPV objects. Indeed, these approaches and available BIM objects will be used and adopted, while the introduction of new regulations can be expected in the next years.

### 4.1 National strategies, standards, and libraries for BIM objects including BIPV

#### 4.1.1 Italy

- *Italian standard UNI EN ISO 19650 and other standards about BIM*

UNI represents the Italian organization for standardisation that also implements the European and international standards. Regarding BIM, UNI integrated the EN ISO 19650-1 e EN ISO 19650-2 in 2018. Moreover, the EN ISO 19650-3:2021 has been adopted jointly with the Italian standard UNI 11337 “Building and civil engineering works – Digital management of the informative processes” which represents a complementary standard. Specifically, this standard came into force in 2021, and transposes EN ISO 19650-3:2020 and adopts ISO 19650-3:2020.

In particular, LOI and LOG concepts of BIM objects are defined in the third part of UNI 11337-3:2015. This standard identifies 5 levels ranging from A (schematic design) to F (quantitative and qualitative characteristics are specific for the installed product), up to level G (for each individual product, the management, maintenance and/or repair and replacement interventions to be carried out throughout the life cycle of the work are defined).

In addition to this, it is important to mention that the Italian decree DM 560/2017 defined a progressive and mandatory introduction of BIM for projects put to tender by public administrations. Specifically, starting from 2019, the use of BIM is mandatory for works defined as “complex” (e.g., economic value equal or higher than 100 million euros) with

an annual reduction of the economic threshold until 2025 when adoption is envisaged for all public construction works.

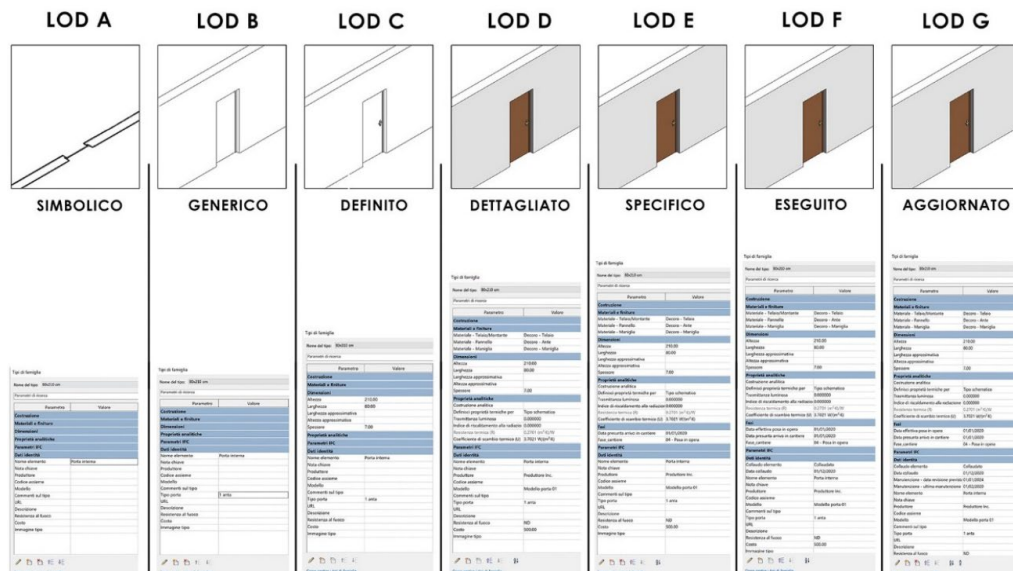


Figure 5. Italian definition of LOD in UNI 11337-3. Source: 4mgroup.it

- *Italian BIM Libraries*

When looking for Italian BIM object libraries, it arises that several Italian producers of construction elements provide their own objects in their company’s website. However, there are also non-commercial BIM libraries such as the database provided by BIM Portale (<https://www.bimportale.com/oggetti-bim/>) that allows to download Revit families and IFC format from BIM&co portal (<https://www.bimandco.com/bim/it/>).

#### 4.1.2 Switzerland

- *Swiss standard SIA 2051 and other documentation about BIM*

The Swiss Standardization Association (SNV) is a member of the European Standardization Committee (CEN) and, by virtue of this affiliation, European standards automatically become an integral part of the catalog of Swiss standards (Huber and Häubi 2020). The same principle also applies to the EN ISO 19650 series and EN ISO 16739 which have been adopted in the Swiss standard context in 2017. In addition to the above mentioned EN ISO standards, the Swiss Society of Engineers and Architects (SIA) introduced a technical leaflet SIA 2051 in 2017 “Building Information Modelling (BIM) – Basis for the application of the BIM method” to provide architects, engineers and specialists, builders and managers with a better understanding of the BIM method and the underlying terminology (SIA 2023). SIA has also published two further documents to support BIM application:

- Technical document D0270 “Application of the BIM method – Guideline for improving cooperation”,

- Technical document D0271 “Application of the BIM method – Model-based quantity determination”,

As well as a supporting agreement relating to contracts, SIA 1001/11 “BIM supplementary agreement”. This is a contractual appendix to be used if the parties have decided to carry out the project in BIM. Most recently, also the EN 17412-1:2020 has been adopted and supported with a SIA explanatory document.

Other actors in the Swiss construction industry published documentation and guidelines on BIM implementation. For instance, Bauen Digital Schweiz developed guidelines to assist parties in BIM adoption, provide practical tools, showcase best practices and provide support to all players in the construction and real estate sector (Bauen Digital Switzerland (BuildingSmart Switzerland) 2023).

With regard to BIM objects and the definition of the geometrical and alphanumeric properties, there are two main documents that can be used as references:

- SIA D0270 where the LOG and LOI are defined in a range from 100 to 500, where the available information increases from the early stage (100: schematic representation) to the later design stages (500: as-built)
- The Bauen Digital Schweiz document “Swiss BIM LOIN-Definition (LOD)” that specifies the concepts of LOIN, LOG and LOI and related responsibilities (Figure 6) and moreover, similarly to the SIA D0270, provides definition of LOG and LOI in a range from 100 to 500, including also some examples for specific building components (Figure 7).
- As a new development in January 2024 “Bauen Digital Schweiz” is introducing the LOIN – Level of Information Need as the new logic to be used, as SN EN17412-1 is fully substituting the LOG / LOI-concept with the LOIN Level of Information need.<sup>4</sup>

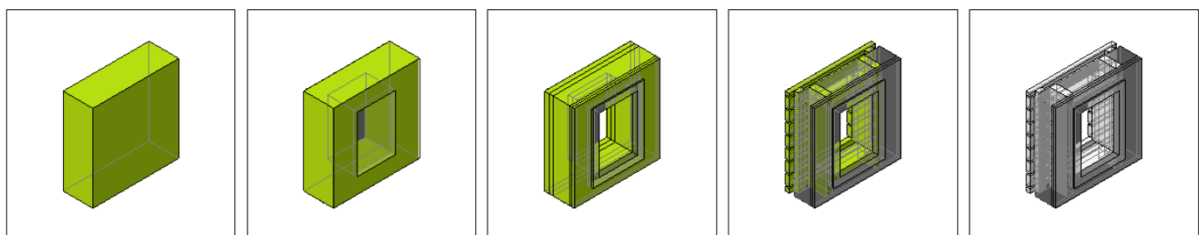


Abbildung 1: Objekt und geometrische Auflösung - Detaillierung

**Figure 6. Explanation of LOIN from Bauen Digital Schweiz**

<sup>4</sup> <https://bauen-digital.ch/assets/Downloads/de/2024-01-LOIN-Grundlagen.pdf>

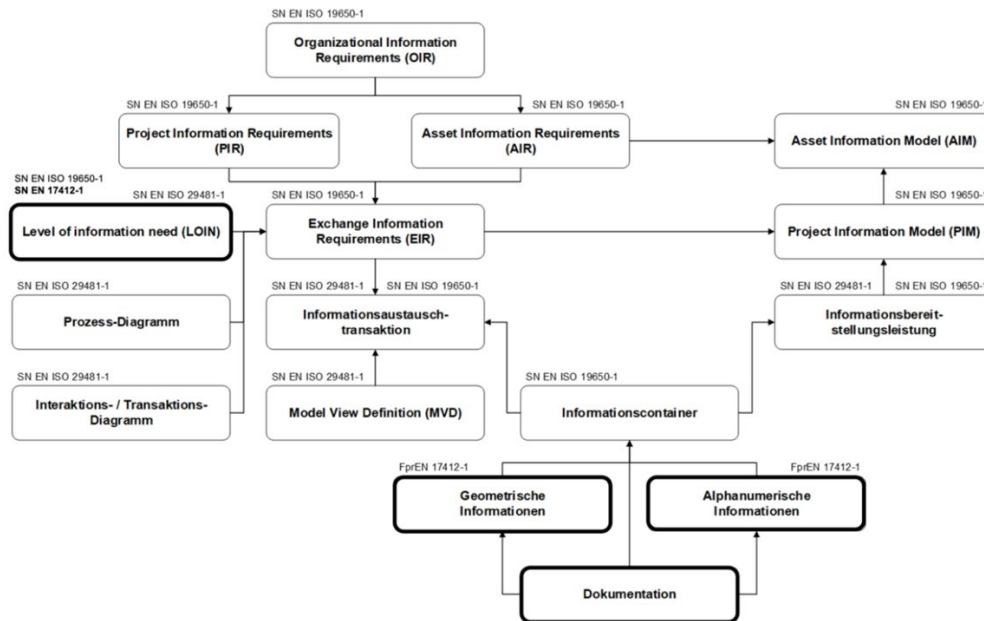


Abbildung 2: Konzeptionelle Zusammenhänge zwischen EN 17412-1:2020, EN ISO 19650-1 und SN EN ISO 29481-1 (Quelle SN EN 17412-1:2020)

**Figure 7. Contextualization of the LOIN-concept in the project and standardizationframework from Bauen Digital Schweiz 1/2024**

- *Swiss BIM Libraries*

Among libraries of construction products, one BIM library developed by a Swiss company is Buildup library. Buildup starts with the transfer of real products to digital construction product data. The goal is to act as the link for those involved along the construction value chain in the digital transformation. Specifically, this library offers different opportunities for construction sector stakeholders. Indeed, planners can find all available construction products across manufacturers through a Comprehensive Digital Library that is continuously updated (**Error! Reference source not found.**). Moreover, there is also an IFC file generator that makes available the construction product in an openBIM format. Moreover, also planners can take advantage of the digitization of their product portfolio thus providing their data directly to the workplace and into your customers' projects.

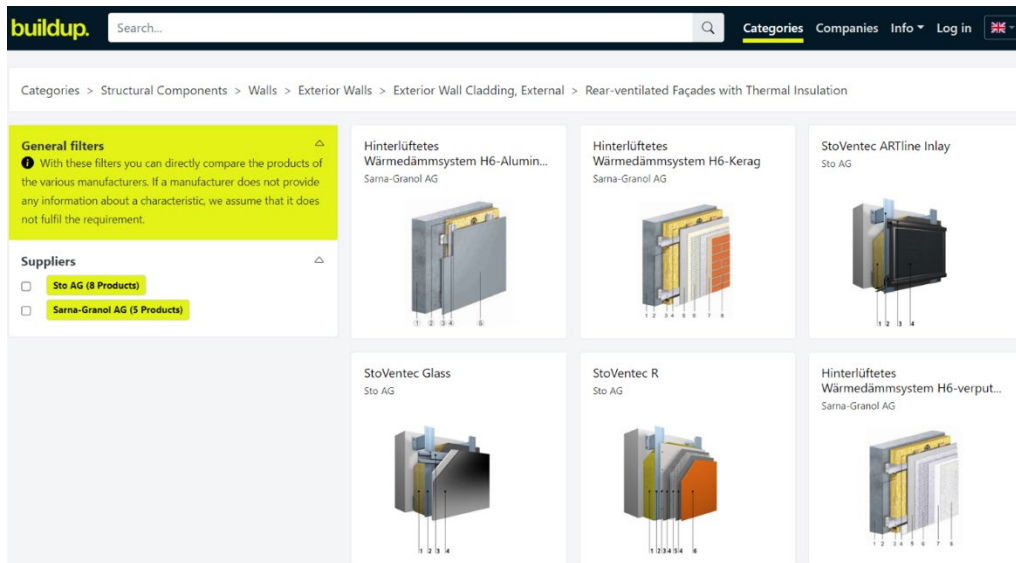


Figure 8. Buildup library. Example of rear ventilated façades category.

It is interesting to note that different Swiss manufacturers of BIPV systems for roof and façade joined the platform making available their product objects (Figure 9). Currently, some products are available for the download through an IFC file generator, and some others can be exported in the Autodesk Revit proprietary format. However, properties associated to BIPV products are not standardized and each manufacturer provides a custom set of attributes.

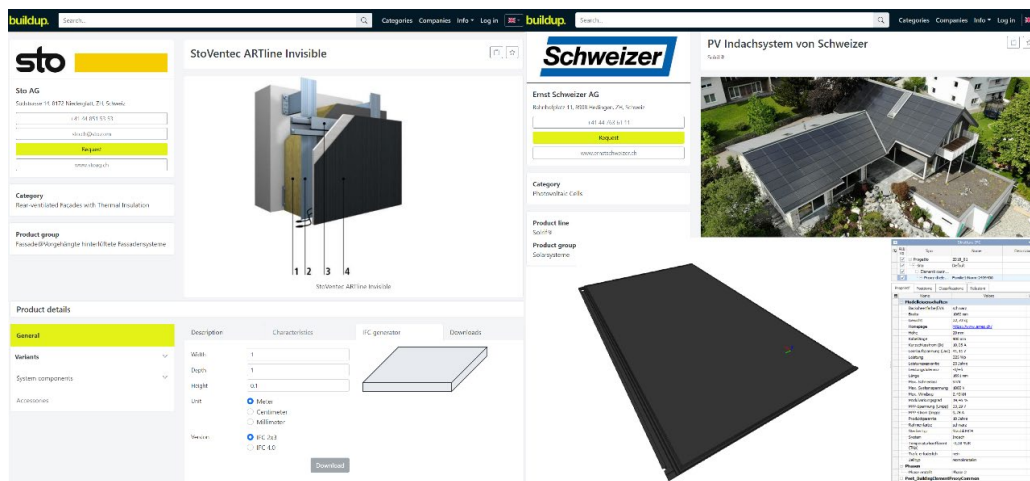


Figure 9. Example of available BIPV products in the Buildup library for BIPV façade (Sto manufacturer) and BIPV roof (Schweizer manufacturer and Arres manufacturer)

#### 4.1.3 Australia and New Zealand

- *Australian BIM standard and other documentation*

Standards Australia BD-104 is the Australian Mirror Committee of ISO TC 59/SC 13 that promotes the adoption of the AS ISO 19650 series “Organization and digitization of information about buildings and civil engineering works, including building

information modelling (BIM) — Information management using building information modelling” in 2019 and 2021 (McPherson 2022). Moreover, also AS ISO 16739-1 has been adopted in 2021. This standard establishes a data schema and an exchange file format for BIM data for use in architecture, engineering, construction, and facility management (Standards Australia 2017).

NATSPEC (National Building Specification) is a not-for-profit Australian organization that supports for architects, interior designers, landscape architects, structural engineers, service engineers and domestic owners. One of NATSPEC aim is the comprehensive national specification system endorsed by government and professional bodies. Regarding BIM, NATSPEC published the “NATSPEC National BIM Guide” that has been updated in 2022. This guide provides a set of principles that can be used to implement BIM on a project. It can be used assist building design and construction stakeholders to implement BIM in their projects in a nationally consistent manner. The guidelines define model setup and protocols, model, system, and view naming conventions. The update of the guide document, specifically, introduces key BIM concepts and principles and focuses on the strategic and managerial aspects of BIM implementation in accordance with the AS ISO 19650(NATSPEC Construction Information Systems Limited 2023a). Further, it specifies the Open BIM object standard (OBOS) to create standardized generic, manufacturer, and project-specific BIM objects. In the NATSPEC National BIM, the concept of LOIN is introduced in accordance with ISO 19650, and it is stated that “Level of information need does not completely replace LOD in the Guide, but the use of the LOD framework is confined to describing the geometrical resolution of model objects through LOD tables included in the BIM Execution Plan Template” (NATSPEC Construction Information Systems Limited 2022). Also in this country, LOD is intended as a “numerical scale applied to individual model elements or to indicate their development status at different times during the modelling process (e.g., LOD 100, LOD 200, LOD 300, etc). Its main purpose, when incorporated in responsibility matrices, LOD tables, etc, is to make it clear what each member of a delivery team is required to author in their models, at each stage, and to what extent others can rely on them. The LOD framework sits within the broader framework of level of information need. It should only be applied as a metric for describing the geometrical resolution of individual model objects”. It is interesting to note that the specific definitions of LOD for construction elements refer to the US definition provided by the BIMForum Level of Development Specification.

- *New Zealand BIM standard and other documentation*

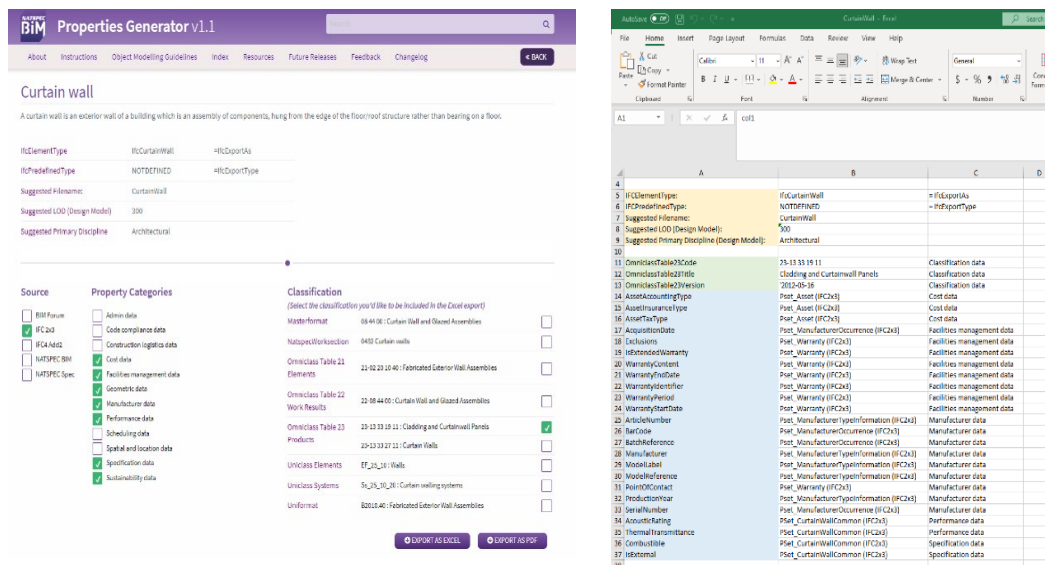
New Zealand does not have a national annex for ISO 19650. However, the BIM Acceleration Committee provides a portal with useful resources to implement BIM such as handbooks, tools and other documents. Among them, there is the NZ BIM Handbook that aims at capturing the many benefits of BIM to encourage its use by referring to the recently released standards ISO 19650 parts 1 and 2. This document addresses also the topic of LOD for model elements as a scale used to show the reliability of content likely to be included for specific model elements, at different times,

during model development. In particular, the LOD definition refers to the US definition provided by the BIMForum with some changes.

- **Australian BIM Libraries**

**Australian BIM-MEPaus object library:** This library is managed by the Air Conditioning & Mechanical Contractors’ Association (AMCA) in Australia. BIM-MEPaus provides detailed manufacturing content and objects for service-related contracts. BIM objects are available for mechanical, electrical, hydraulics, fire protection, building automation, communication, security and building transport. The BIM objects are developed under three content categories generic, manufactures and fabrication. The generic content is developed with the content to provide the minimum information required for early design and technical approval. Manufacturers contents include manufacturer specific Revit MEP content. Fabrication content developed to provide an Australian industry standard fabrication workflow (source: <https://www.bimmepaus.com.au/>). However, this library does not contain any BIM objects directly related to BIPV.

**NATSPEC BIM Properties Generator:** NATSPEC BIM Properties Generator is a tool available online for generating BIM objects properties. It includes objects based on buildingSMART’s Industry Foundation Classes (IFC). The Objects can be classified based on major systems such as NATSPEC, Uniclass, Omniclass, Masterformat and Unifomat. Further, users can select the properties based on IFC4, IFC 2x3, BIMForum LOD Specification, COBie and NATSPEC. The tool facilities to export properties of the BIM object to a pdf or excel file. Currently, the Properties Generator includes over 120 generic architectural and structural objects. BIPV related architectural objects such as curtain wall, roof, parapet, window etc. are available. An example of the properties of curtain wall is shown in Figure 10. However, mechanical, electrical, and plumbing (MEP) objects are currently not available in this tool.

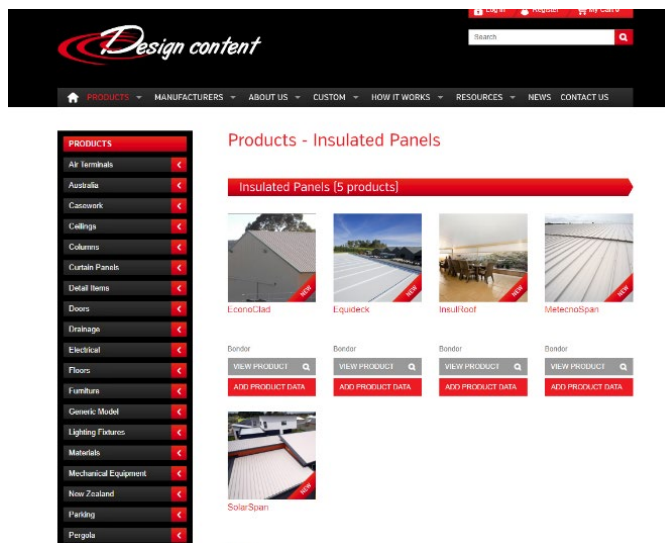


**Figure 10. Example of properties generator for BIPV curtain wall. Source : <https://www.propgen.bim.natspec.com.au/pages/329658.html>**



There are also BIM objects libraries supplied by private entities such as:

Design Content run by A2K Technologies in Australia and Productspec in New Zealand. Design Content by A2K Technologies is a popular Australian object library at present (NATSPEC Construction Information Systems Limited 2023b). It contains 2D and 3D BIM objects for Australian and New Zealand products. Its aim is to facilitate manufacturer-specific and generic libraries for architects, engineers, designers and specialist consultants/contractors.



**Figure 11. Design content library**  
Source : [www.designcontent.com.au](http://www.designcontent.com.au)

NBS National BIM Library is a UK BIM object library supported by the Australian Institute of Architects. The BIM library include generic and manufacturer BIM objects authored and certified based on NBS BIM Object Standard. The NBS BIM Object Standard defines requirements for the information, geometry, behaviour and presentation of BIM objects and gives a reassurance of quality and consistency that facilitates greater collaboration across the construction industry. The BIM objects in the library can be downloaded for free. (Source: <https://www.nationalbimlibrary.com/en-au/>)

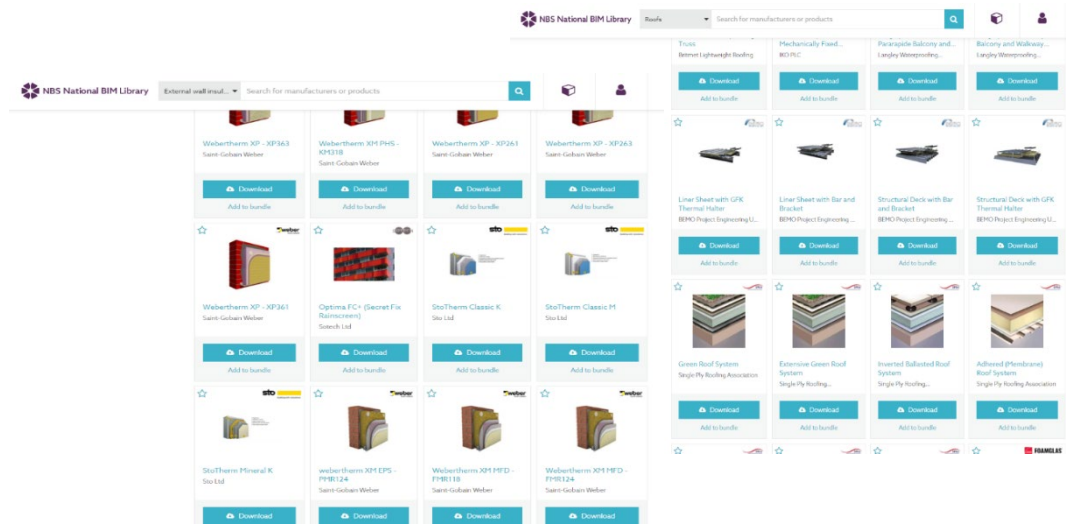


Figure 12. NBS National BIM Library

#### 4.1.4 Spain

- *Spanish standard and other documentation about BIM*

First BIM activities in Spain are reported in 2009. In 2012, the Spanish standardization organism AENOR (now UNE) created the subcommittee AEN/CTN 41/SC13 for developing standards related to civil construction works. That included BIM methodologies. Two years after, the Spanish branch of the international association buildingSMART (<https://www.buildingsmart.es/>) was born, being now part of this subcommittee.

Following the European Directives, the Government of Spain and several institutions created in 2014 a public-private discussion committee for the development of BIM in Spain, and in 2017 IFC standards started to be adopted. In 2018, the use of BIM was recommended for public works tenders, and, some months after, it became mandatory for all public works and infrastructures.

The Spanish BIM committee has established an open methodology based on the Ministry's general guidelines and receiving continuous feedback from the construction. The Ministry es-BIM project CBIM (<https://cbim.mitma.es/>) is an open system, having as participants the industry experts (companies, professionals, public administrations) and a multidisciplinary group divided into different groups. The main objective of this project is to promote and spreading BIM in the Spanish construction industry, adapting the national legislation to BIM methodologies, and developing protocols to standardize the use of BIM. Recently, the Ministry of Transport, Mobility and Urban Agenda (MITMA) has created the Interministerial Commission that should coordinate the implementation and application of BIM requirements in public tenders. However, the CBIM does not have information regarding experiences in the field of the use of BIM methodology for the integration of photovoltaic installations in buildings so far.

Regarding BIM associations and working groups, Spain is part of the international initiative BuildingSMART, that is organized by country in “Chapters”. In this sense, the Spanish Chapter is quite active (<https://www.buildingsmart.es/bssch/la-asociaci%C3%B3n/>), with a lot of interesting information that can be downloaded from their website. Then, at user level, there are multiple local user groups within international initiatives (<http://www.eubim.com/mapa/>).

There are some initiatives for the standardization of BIM objects. ECOB (<https://ecobject.com/>) is probably the most recent and most detailed. It is promoted by IteC, and it standardises the way in which the attributes of BIM objects are defined, although probably it is still not widely used nowadays. GDO-BIM is also a similar initiative proposed by Bimetica. There might be some other initiatives, but none of them has really caught on. Moreover, in certain tenders, each administration proposes its own guide or style guide with their own requirements.

In general, the knowledge and use of BIM has grown in recent years, as well as its demand in public projects, but the generalised use of standards such as IFC or standardised nomenclatures of BIM objects is still some way off.

- *Spanish BIM Libraries*

The most representative BIM object databases used in Spain are Bimetica (<https://www.bimetica.com/es/busqueda-bim>) and Saltoki (<https://bim.saltoki.com/#/>). Also BimObject (<https://www.bimobject.com/es>), that is present internationally. Usually BIM objects are in native formats (mostly Revit families) although there are more and more possibilities to download in IFC standard.

#### 4.1.5 France

- *French standard and other documentation about BIM*

On the French governmental authorities’ side, BIM was promoted from 2014 via the PTNB initiative, now PLAN BIM 2022. The PLAN BIM 2022 brings every construction representative actor committed to digital transition and sustainable development to a national strategy. This strategy defines 2 main targets:

1. Generalize BIM in public and private procurement in the construction sector,
2. Disseminate BIM into all then French territories and for every actor, via adapted tools.

A part from governmental initiatives, there are also BIM associations and communities that support the adoption of BIM. Among others, Mediaconstruct and HexaBIM.

MEDIACONSTRUCT<sup>5</sup> is a nonprofit association that holds the BuildingSMART International roadmap for the french context and promotes the IFC standardisation in openBIM. It gathers openBIM users (architects, engineers, professional and

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<sup>5</sup> [MEDIACONSTRUCT](#)

educational practitioners), with solutions developers and providers (software editors, libraries editors). The main strategic focuses are:

1. Operational BIM: openBIM for all! BuildingSMART France-Mediaconstruct supports the acceleration and exploitation of nearly mature technologies regarding the market and professionals needs. Actions are mainly: promotion, awareness campaigns, support to education, labeling of training programs and training organizations (EDUBIM), development of methodologies, guides, technical and user specifications from dedicated workshops and experimentations, standardization committee in 3 levels (data, machine, process) with a strong focus on BIM libraries (partnerships between industrial leaders and software editors). The BIM practices observatory was created to monitor opinions, practices, projects, and feedbacks throughout the different professional colleges.
2. Prospective BIM: a 360° BuildingSMART vision. The prospective vision is mainly supported by the scientific and technical committee, managing an active technical and strategic intelligence:
  - based on R&D + Innovation watch,
  - focusing on standardization works, interoperability around the data management (from smart cities to smart buildings),
  - including IoT and BIM interactions,
  - anticipating interoperability between GIS, infrastructure and IFC openBIM,
  - developing the new PPBIM standard for construction products and catalogs interoperability (prEN ISO 23386) together with the promotion of generic objects.
3. Communication. The ambition is to maintain a permanent flow of incoming and outgoing information related to BIM practices, success stories, uses cases, barriers, bottlenecks, and consequently organize specific workshops and events. Partnerships have been made with the major events (BIM tour, BIM World, Batimat) and with professional press (Le Moniteur, Batiactu, BIMTv).

On the BIM community side, it is relevant to mention HEXABIM. This is now the main media platform, supporting the largest community of players with recent information, tips, links and material in France.

- *French BIM libraries*
  - datBIM was the first to develop a new BIM library 100% compliant with the PPBIM standard in France. However, solar PV is poorly addressed and BIPV is not mentioned <https://open.datbim.com/Produit-COMPOSANTS-1510136689107.html>
  - BIM&Co. This is the main BIM objects platform in France. It provides openBIM IFC objects and native (.rfa) Autodesk REVIT families. Users can directly download objects for free or use specific plugin (REVIT) to keep connected to the updated

data from the products providers. Manufacturers, providers, can subscribe to specific facilities such as PIM2BIM tool that manages the data and pushes updated information to the users in real time: this a Product Data Management approach. BIPV is not really addressed, but some PV modules are available for download.

#### 4.1.6 Austria

- Austrian standard and other documentation about BIM

In Austria, the ÖN A6241 standardisation group exists. ÖN 6241-2 forms the basis of the Austrian BIM standards. It was published in 2015. ÖN 6241-2 was published before ISO 19650-1. As a result, the terms between the standards are different. ÖNORM A 6241-2 regulates the technical implementation of a uniform, structured, multidimensional data model for building structures based on Building Information Modelling Level 3-iBIM. This ÖNORM creates the basis for a comprehensive, uniform, product-neutral, systematised exchange of graphical data and the associated factual data based on IFC and bSDD. The first section of the standard defines general terms. A description of the project model follows this. A project model is created based on the client's requirement (AIA). This project model consists of sub-models (technical models), which can be divided into sub-models. In the following sections, services and levels of detail are described according to the life phases of a structure. These life phases were defined in accordance with EN 16310. The last section of the standard describes the IFC data schema (at that time, still IFC2x3) as the software manufacturer-independent standard for exchanging information in the construction industry. The annexe also contains a modelling guideline, which includes definitions of geographical location, storey structure, and component structures (single-layer, multi-layer).

The Austrian state standardization institute "Austrian Standard Institut ASI" has launched an initiative to publish an "ASI-Merkmalserver" (ASI property server) in German language. The ASI property server is described in ÖNORM A 6241-2. This is a type of national property server. The definition of characteristics including description, discipline affiliation, type, project phase etc. takes place in the ASI characteristics server. These characteristics are linked to the international property server (bSDD) using the bSDD-GUID.

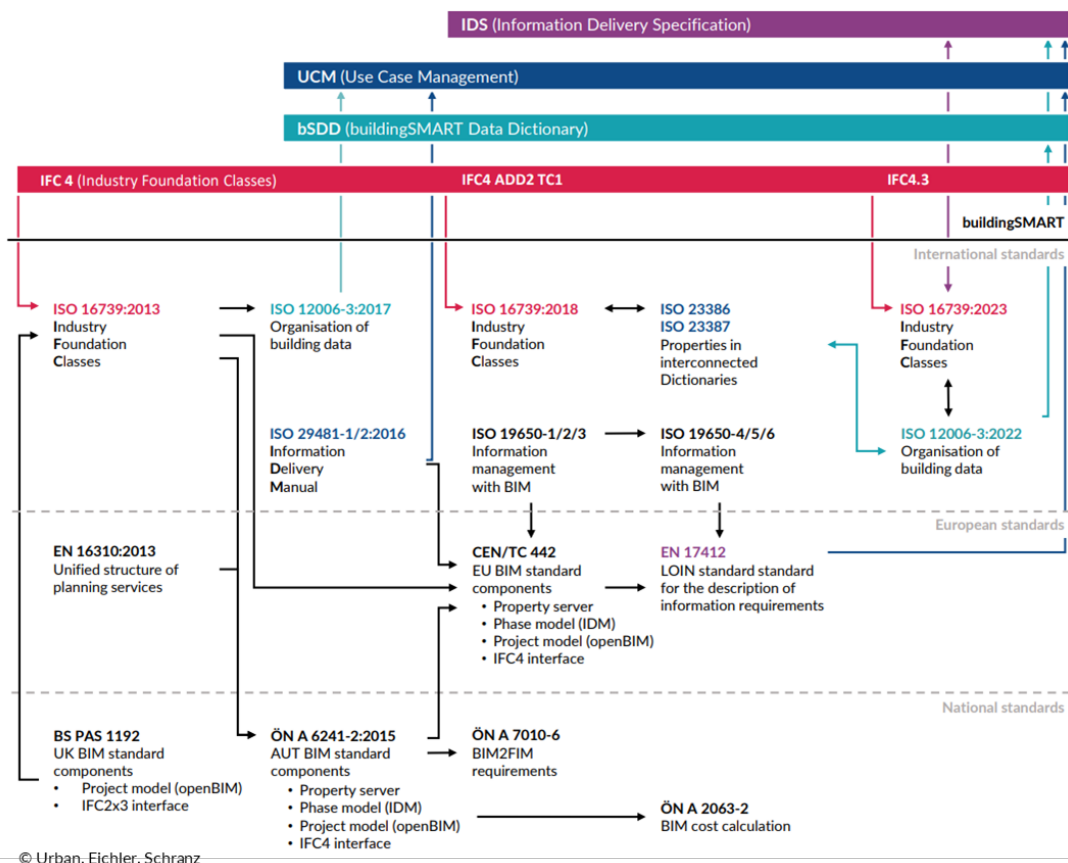
The ASI property server is described in ÖNORM A 6241-2. This is a type of national property server. The definition of characteristics including description, discipline affiliation, type, project phase etc. takes place in the ASI characteristics server. These characteristics are linked to the international property server (bSDD) using the bSDD-GUID. In future, the data will be published as a .csv file for easy further use.

ÖN A 7010-6 was published in 2019 and describes the information needs of clients and operators for BIM projects. This description is provided generically in tabular form for typical site elements (such as plots, buildings, and floors) and operationally relevant equipment elements (such as doors, windows, and relevant components of ventilation systems/fire alarm systems). All relevant details required for maintenance, care, inspection, repair, or replacement are defined. The subsequent description of the

specific implementation based on the IFC specification will occur in the planned ÖN A 6241-3.

ÖN 2063-2 regulates the structure of data sets that are exchanged in an automated manner between all parties involved in the phases of tendering, awarding and invoicing, such as LB issuers, EK issuers, planners, clients, bidders or contractors. ÖN 2063-2 describes the structure of an element catalogue for use in tendering. This catalogue is intended to represent the link between the standard bill of quantities in Austria and the IFC data schema.

The following figure shows the national and international standards and their interrelationships. A detailed description of the standards and their interrelationships is described in the BIMcert Handbook (source: BIMcert Handbook 2023 (buildingsmart.co.at)).



- Austrian BIM libraries

There are no national standardised BIM project databases in use in Austria. buildingSMART Austria recommends using BIM libraries based on the buildingSMART Data Dictionary (bSDD) and international standards (ISO 23386/7). International standards should therefore be used and no national data structures should be defined in the area of product data. For example, a generic (product-neutral) database was developed in the timber construction sector in accordance with ISO 23386/7 in link with bSDD (Eichler et al. 2024). Component structures

can be downloaded from this web service as IFC files and used directly in some software applications.<sup>6</sup>

## 4.2 Overview of BIM BIPV products in libraries and online portals

The state of the art of BIPV objects was evaluated by analysing the different products available in online BIM libraries. It is not common to find BIM BIPV products, as most of them are add-on modules and not made for being integrated in the building envelope. A total of 22 BIM BIPV objects were identified from 3 online BIM libraries (bimobject, BuildUp, BIMPortale) and 1 BIM library of BIPV system manufacturer. Only a single product typology for each manufacturer has been selected in order to avoid the collection of BIM BIPV products which are very similar and show small changes in some parameters.

In order to show the results of the analysis on the identified BIM objects, several objects parameters have been considered such as:

- the name of the object and manufacturer
- the source: it informs on which online library the identified objects are downloadable
- the BIPV category of the object: indicates what type of BIPV component the object is in accordance with the Report IEA-PVPS T15-12:2021 “Categorization of BIPV applications”
- the certification of the BIPV object if any
- the available BIM format of the object
- the BIM classification of the object: in which type of BIM classification the BIPV product has been categorised.

The BIM-BIPV products and these parameters are analysed in Table 4. Specifically, different products for BIPV roofs (15 discontinuous roof and 1 continuous roof) have been found whereas few products represent canopy (3), solar shading product (2) and rainscreen façade (1).

Regarding the geometrical and informative modelling, it has been decided to provide only a qualitative description of LOG (Level of geometry) and LOI (Level of information), providing also a description of the option to customize the related geometrical and informative parameters. This qualitative description is mainly due to the continuous changing scenario in this topic and the different definitions of LOD / LOG and LOI that have been developed in different countries and by different organizations. The table below shows the results of the analysis.

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<sup>6</sup> [Katalog bauphysikalisch und ökologisch geprüfter Holzbauteile – dataholz.eu](https://dataholz.eu)

**Table 4. BIM-BIPV products available online**

Source	BIPV category	Certification	BIM format	Classification system for BIM objects				
				Uniclass (UK)	Omniclass (USA+CA)	NBS	IFC	COBie
1	BIMobject	Discontinuous roof	rvt, ifc				Ifc Building Element Proxy	
2	bimobject	Discontinuous roof	rfa, archicad	icf	Solar Collectors		Solar Collectors	Solar power plants
3	bimobject	Canopy	rvt	Photovoltaic Modules	Photovoltaic Collectors / Solar Flat Plate Collector		Energy Conversion Device	
4	bimobject	Discontinuous roof	rvt, gsm					
5	bimobject	Continuous roof	rfa					
6	bimobject	Discontinuous roof	rvt, ifc, gsm	Solar panel fields	Solar Panels			
7	bimobject	Solar shading	rvt, rfa, ifc, gsm		Solar Panels			



8	bimobject	Discontinuous roof	rvt, rfa
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	Source	BIPV category	Certification	BIM format	Classification system for BIM objects				
					Uniclass (UK)	Omniclass (USA+CA)	NBS	IFC	COBie
9	Buildup	Discontinuous roof		ifc, rfa				ifc Building Element Proxy Type	
10	BIMstore	Canopy		rfa		Translucent Roof Assemblies		ifc Building Element Proxy Type / ifc Roof Type	
11	<a href="https://mssystem.pl/bim-library/?lang=en">https://mssystem.pl/bim-library/?lang=en</a>	Solar shading		rvt		Photovoltaic Array		ifc Solar Device	
12	<a href="https://mssystem.pl/bim-library/?lang=en">https://mssystem.pl/bim-library/?lang=en</a>	Rainscreen I		rfa		Photovoltaic Array		ifc Solar Device	
13	<a href="https://mssystem.pl/bim-library/?lang=en">https://mssystem.pl/bim-library/?lang=en</a>	Discontinuous roof		rfa					

14	BIMPortale	Discontinuous roof	rfa	Solar Collectors	
15	<a href="https://mlsystem.pl/bim-library/?lang=en">https://mlsystem.pl/bim-library/?lang=en</a>	Discontinuous roof	rfa	Car Shelters	Ifc Solar Device

	Source	BIPV category	Certification	BIM format	Classification system for BIM objects				
					Uniclass (UK)	Omniclass (USA+CA)	NBS	IFC	COBie
16	<a href="https://mlsystem.pl/bim-library/?lang=en">https://mlsystem.pl/bim-library/?lang=en</a>	Discontinuous roof		rfa					
17	<a href="https://mlsystem.pl/bim-library/?lang=en">https://mlsystem.pl/bim-library/?lang=en</a>	Discontinuous roof		rfa					
18	NBS Library	Discontinuous roof	<a href="http://www.nationalbimlibrary.com/cert/niyyxgwb">www.nationalbimlibrary.com/cert/niyyxgwb</a>  Degree of protection: To BS EN 61140, Class II	rfa, ifc	Photovoltaic modules		Photovoltaic modules		Photovoltaic modules
19	Polantis	Canopy		rfa	Canopy Systems		Canopy Systems		

20	caddetails	Discontinuous roof	rfa
21	archello	Discontinuous roof	rfa, ifc
22	<a href="https://en.solrif.com/solarmodule">https://en.solrif.com/solarmodule</a>	Discontinuous roof	stp

**Table 5. Investigation of the LOG and LOI of the BIM-BIPV products (disclaimer: the list is not meant to be exhaustive and is used for only indicative purposes)**

	<b>LOG</b>	<b>Geometrical customization</b>	<b>LOI</b>	<b>Informative customization</b>
<b>1</b>	frames, cells and substructures	No	Materials, load, dimensions, manufacturer	No
<b>2</b>	no frames, cells, fixing system	yes	Materials, dimensions, manufacturer data	Yes, only some parameters
<b>3</b>	no frames, cells, fixing system	only some parameters	-	-
<b>4</b>	substructures, frames	No	electrical data, materials, manufacturer	Yes
<b>5</b>	no cells, substructures, frames	No	Electrical data	Yes, only some parameters
<b>6</b>	frames, cells, substructures	No	only manufacturer data	Yes, only some parameters
<b>7</b>	frames, cells and substructures	No	only manufacturer data	No
<b>8</b>	frames, substructures, PV cells	No	manufacturer, cells number, electrical data, dimensions	Yes, only some parameters
<b>9</b>	Only frames and cable	No	manufacturer, electrical data, max load, dimensions, warranties	Yes, only some parameters
<b>10</b>	frames, substructures, no cells	No	manufacturer data, electrical data, warranties	Yes, only some parameters

	LOG	Geometrical customization	LOI	Informative customization
11	frames, cells, busbars, ribbons and substructures	No	manufacturer data, materials, electrical data	Yes, only some parameters
12	frames, cells, busbars + ribbons and substructures	only number of vertical/horizontal modules	manufacturer, dimensions, power, materials	Yes, only some parameters
13	only roof, no PV module	no	manufacturer data, nominal power	no
14	frame of the model and substructures	No	Materials, power, max load	Yes, only some parameters
15	frames, cells, busbars, ribbons and substructures	yes	manufacturer data, electrical data	Yes, only some parameters
16	frames, cells, ribbons	No	manufacturer data, materials	Yes, only some parameters
17	frames, cells, ribbons	No	manufacturer data, materials	Yes, only some parameters
18	3D shape only	No	manufacturer data, electrical data, warranties, NBS data	Yes, only some parameters
19	frames and substructures	No	manufacturer data, power	Yes, only some parameters
20	frames, cells, substructures	No	manufacturer data, electrical data	Yes, only some parameters
21	frames, cells, substructures	No	Only electrical data	Yes, only some parameters
22	frames, cells	No	-	

## 5 STATE OF PLAY OF BIM TOOLS AND WORKFLOWS FOR BIPV PROCESS

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### Highlight:

- Which are the BIM tools for BIPV design, modelling, and simulation?
- How are digital objects handled in these tools?

Nowadays, **BIM and BIPV are towards integration mainly in the design stage, where modelling and simulation of BIPV envelopes are carried out.** For this reason, this chapter provides an **overview of BIM tools for BIPV design referring to the phases from 2 to 4 of the BIPV process.**

Tools, software, applications are intended as BIM if they allow generating parametric objects, for designing their information, structuring them, and managing them. As other building elements and components, also BIPV products and systems can be developed, modelled, and managed in the BIM environment. However, digital tools developed for designing BIM-BIPV systems are very few nowadays in comparison to the plenty of software and applications for designing and simulating conventional PV systems. By the way, some BIM tools and interoperable applications are emerging to support the implementation of BIPV in digital building models developed in a BIM environment.

Thanks to the collaboration of Task 15 experts, research in SCOPUS database and online research, 12 tools for supporting the design and simulation of BIPV in the BIM environment have been identified (Figure 13). These tools have been categorized in:

- **BIM-based tools**

Such tools refer to plugins, apps, modules developed for specific BIM authoring software (software that create and modify the BIM).

- **openBIM® interoperable tools**

Such tools refer to software, application developed in accordance with openBIM® standards. Through the adoption of these vendor-neutral formats identified in ISO standards, data can be efficiently exchanged between software, eliminating disconnected workflows. In this case, the research has been focused on two main openBIM® formats:

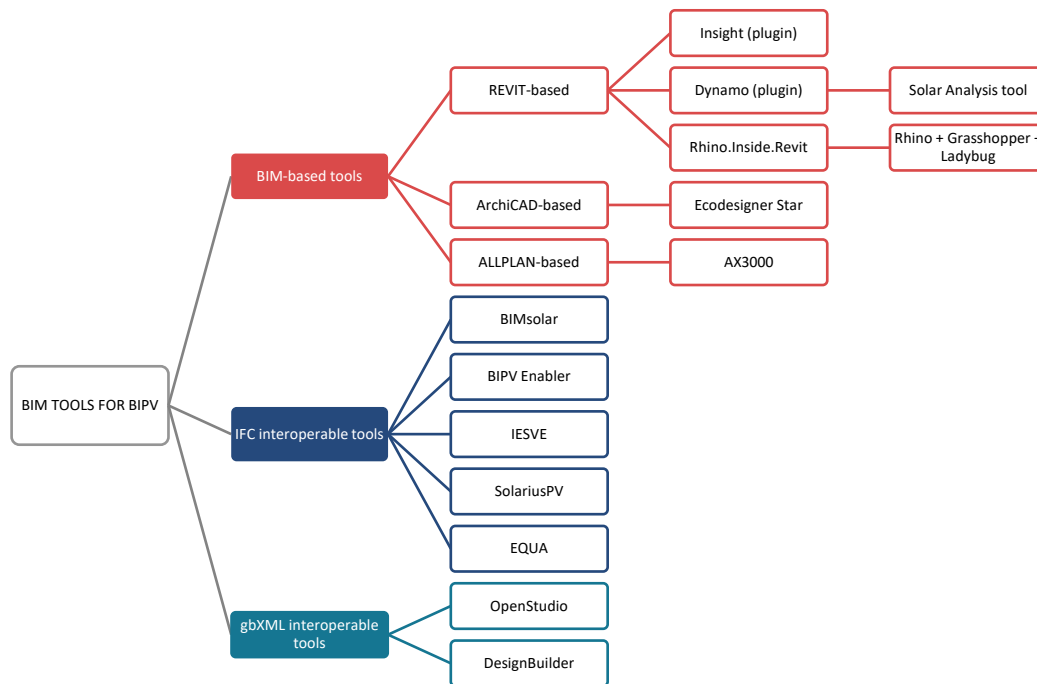
- Industry Foundation Classes (**IFC**) defined in the ISO 16739-1:2018<sup>7</sup>,
- Green building XML (**gbXML**) developed based on the XML (Extensible Markup Language) format. This is “a robust, non-proprietary, persistent, and verifiable file format for the storage and transmission of text and data both on

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<sup>7</sup> New version under publishing at the date of the report

<sup>8</sup> <https://www.iso.org/standard/70303.html>

and off the Web”<sup>9</sup>. The gbXML schema, indeed, is open and accessible to developers<sup>10</sup>.



**Figure 13. Overview of BIM tools for BIPV design stages**

Table 6 provides a short description of the investigated tools and functionalities, as well as other information such as:

- BIM authoring tool, the BIM software that is used to generate the BIM model,
- Design stage, the stage where the BIPV tool is mainly used (conceptual, developed, technical, in accordance with the BIPV process stages described in Chapter 2),
- Type of simulation, BIPV simulation can refer to different analysis. This column specifies the analysis carried out for the BIPV project (e.g., solar irradiation, PV output, economic analysis, ...)
- Time scale of the simulation, to describe whether the simulation is carried out at the annual, monthly, daily, hourly, sub-hourly step,
- BIPV module object. The last three columns refer to the possibility to model the BIPV module in the BIM environment and/or import it from a database, as well as the possibility to use BIM BIPV module object in the simulation. With regard to BIM BIPV objects, Chapter 6 provides a detailed insight on this topic.

<sup>9</sup> [http://www.ibpsa.org/proceedings/bs2007/p363\\_final.pdf](http://www.ibpsa.org/proceedings/bs2007/p363_final.pdf)

<sup>10</sup> <https://www.gbxml.org/>



Table 6. Overview of BIPV tools for BIPV design stages

Tool category	BIM authoring tool	Tool name	Short Description	Stage	Type of simulation	Timescale	BIPV module modeling in the BIM environment	BIPV module importation from the tool to the BIM environment	Simulation considering BIPV module object parameters
BIM based tools	Revit	Insight	Insight is a tool integrated within Revit. It allows running solar and PV potential analyses on building surfaces within the Revit environment	Conceptual	Solar irradiation PV ROI	Annual	Yes (through Revit / Dynamo)	No (objects are already in the BIM environment)	
BIM based tools	Revit	Dynamo + Solar Analysis tool	Dynamo, as a plugin for Revit, is a graphical programming interface. Thanks to Solar Analysis tool, solar potential analyses on building surfaces can be carried out within the Revit environment	Conceptual	Solar irradiation	Annual	Yes (through Revit)		No (objects are already in the BIM environment)
BIM based tools	Revit	Rhino.Inside.Revit + Grasshopper + Ladybug	Rhino.Inside.Revit is add-on for Revit that allows integrating Rhino and Revit.	Conceptual	Solar irradiation	Annual Monthly Daily Hourly	Yes (through Revit / Rhino)	No (objects are already in the BIM environment)	Yes, only if the user defines specific workflows and simulation algorithms
BIM based tools	Revit	BIMsolar	BIMsolar, as plugin of Revit, can allow exporting Revit geometries to BIMsolar standalone software in a proprietary format. Then, it permits to import BIPV systems designed in BIMsolar through a proprietary format.	Conceptual / Developed / Technical	Solar irradiation PV ROI	Annual Monthly Daily Hourly	No (objects are modelled in BIMsolar and can be imported in Revit through BIMsolar plugin)	Yes (through BIMsolar plugin)	Yes, only if BIPV objects are generated within the BIMsolar environment
BIM based tools	Revit	BIPV.world	BIPV.world, as plugin of Revit, enables the design of BIPV façades within the Revit environment. The plugin provides direct insight into the costs and revenues as a function of the design	Conceptual / Developed / Technical	PV ROI Performance	Annual	YES (the user can import all elements from the BIPV.world database. Design can be exported to the latest BIM standards)	No (objects are already in the BIM environment) Design can be exported to IFC	Yes (for BIPV modules from the database)
BIM based tools	ArchiCAD	Ecodesigner Star	EcoDesigner STAR is an Archicad extension providing a full BIM to BEM workflow. It allows BAPV simulations	Conceptual	PV	Annual Monthly Daily Hourly	No, the user can only define some electrical characteristics of standard PV modules within the tool	No	Yes, only for PV modules defined in the Ecodesigner Star tool
IFC interoperable tools		BIMsolar	BIMsolar, as standalone software, allows importing IFC file. Moreover, it allows importing Revit models through a proprietary format. It permits analysis of solar potential irradiation and the design and simulation of BAPV and BIPV systems	Conceptual / Developed / Technical	Solar irradiation PV ROI	Annual Monthly Daily Hourly	Yes, BIPV objects are modelled in BIMsolar	No (BAPV/BIPV objects can be imported in Revit only through BIMsolar plugin)	Yes, only for BIPV objects generated within the BIMsolar tool





<b>IFC interoperable tools</b>		BIPV Enabler	BIPV Enabler allows export BIPV designs created in BIPV Enabler via IFC.	Conceptual	Solar irradiation PV ROI Wind load Optimisation	Annual Monthly Daily Hourly	Yes (Includes a BIPV products database. BIPV modules can be modeled based on the scalable BIPV product database).	No	Yes, for objects created in the BIPV Enabler tool.
<b>IFC Interoperable tools</b>		IESVE + SunCast tool + Apache	IESVE is a BEM software that allows importing projects in IFC format. Thanks to the SunCast tool, shading analysis and solar potential studies can be carried out. Moreover, BAPV potential analysis can be performed through Apache engine tool	Conceptual / Developed	Solar irradiation PV	Annual Monthly Daily Hourly	No (the user can select commercial PV modules from a database within the tool)	No	Yes, only for BIPV objects within the IESVE tool
<b>IFC interoperable tools</b>		SolarusPV	SolarusPV is a standalone software that allows importing projects in IFC format to design and simulate PV and BAPV systems	Technical	Solar irradiation PV ROI	Annual Monthly Daily Hourly	No (the user can select commercial PV modules from a database within the tool)	No	Yes, only for BIPV objects within the Solarus tool
<b>IFC interoperable tools</b>		IDA-ICE	IDA-ICE is a standalone software that allows importing projects in IFC format to design and simulate PV and BAPV systems	Developed / Technical	Solar irradiation PV	Annual (solar irradiation) Annual / monthly / daily / hourly (PV)	No (the user can select commercial PV modules from a database within the tool)	No	Yes, only for BIPV objects within the IDA-ICE tool
<b>gbXML interoperable tool</b>		OpenStudio	OpenStudio is a BEM software that allows importing projects in gbXML format to design and simulate PV and BAPV systems	Technical	PV	Annual Monthly Daily Hourly	No (the user can select commercial PV modules from a database within the tool)	No	Yes, only for BIPV objects within the OpenStudio tool
<b>gbXML interoperable tool</b>		DesignBuilder	DesignBuilder is a BEM software that allows importing projects in gbXML format to design and simulate PV and BAPV systems	Technical	PV	Annual Monthly Daily Hourly	No (the user can select commercial PV modules from a database within the tool)	No	Yes, only for BIPV objects within the DesignBuilder tool



## 6 REVIEW OF SPECIFIC BIM-BASED BIPV TOOLS AND WORKFLOWS FOR DESIGN AND SIMULATION


### Highlight:

- Insight of some BIM-based tools for BIPV design, modelling, and simulation.
- Description of digital BIPV objects modelling

This chapter is aimed at providing a more detailed description of some BIM-based tools and workflows that can be adopted by architects, engineers, designer, and consultants to carry out BIPV projects when a BIM approach is adopted.

Indeed, specifications about input data, location definition, context/building/BIPV module modelling, irradiation and PV calculation are provided, as well as simulation results and outputs. Hence, a summary table is provided together with a description of how the tool can be used. This review has been made by Task 15 participants that currently use these tools in R&D activities, and/or by the software developers.

### 6.1 Revit Insight

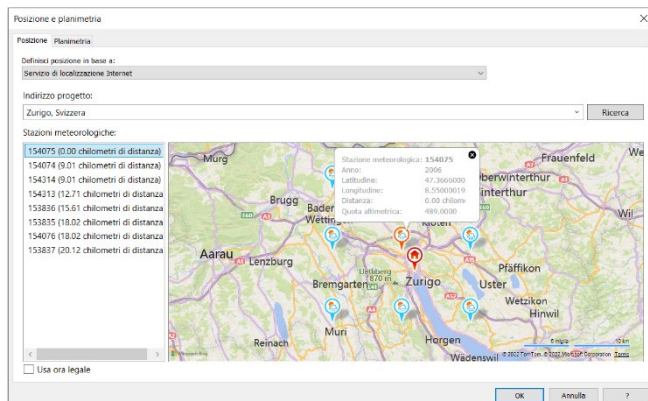
Autodesk Revit + Insight add-in		v.2023
BIPV Process Stage		
Conceptual	✓	
Developed		
Technical		
Description		
References	<p><a href="https://knowledge.autodesk.com/support/revit/learn-explore/caas/CloudHelp/cloudhelp/2021/ENU/Revit-Analyze/files/GUID-15701517-EB11-460D-9BC9-EDEC7AE68BB9-htm.html">https://knowledge.autodesk.com/support/revit/learn-explore/caas/CloudHelp/cloudhelp/2021/ENU/Revit-Analyze/files/GUID-15701517-EB11-460D-9BC9-EDEC7AE68BB9-htm.html</a></p>	



Functionalities	
<b>Input data</b> Proprietary format IFC gbXML Other	<b>Irradiation calculation</b> Horizon Nearby objects Albedo Time-step
<b>Location definition and weather file</b> Internal database External database	<b>PV output calculation</b> Module level String level System level Time-step
<b>Context modelling</b> Nearby buildings Building envelope Vegetation Other	<b>Simulation results</b> PV production Load matching Payback time analysis Others
<b>Building Element modelling</b> Building objects (openings, chimneys, ...) BIPV structural elements Others	<b>Outputs:</b> IFC gbXML Other
<b>BIPV modules modelling</b> Predefined products Custom products	

Revit is a BIM software that enables users to create, edit and manage building project properties, including both geometrical and informative data.

Regarding solar and PV analysis, it is possible to run some preliminary assessment. The first step is the importation of the building geometry from proprietary format or from the IFC format. Also, nearby buildings and objects can be modelled and/or imported to represent the surroundings. Then, the user can define the location thus setting the background weather data that can be chosen by selecting one of the 8 weather stations that are closest to the specified location.

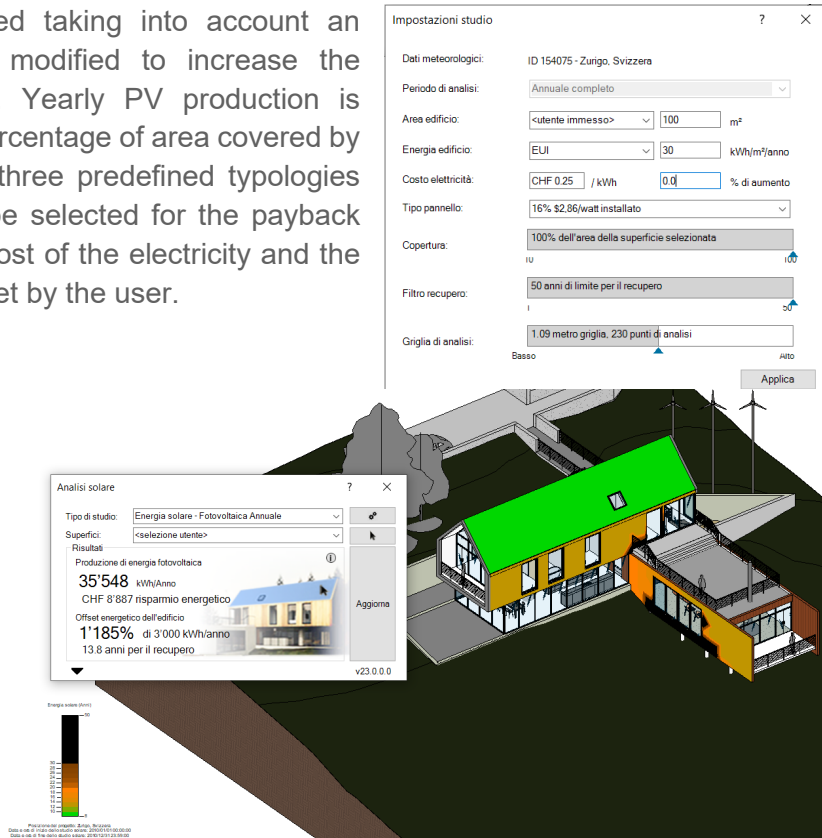




Even if the building envelope and BIPV structural elements can be modelled with high level of details, this kind of information is not used to run the BIPV performance prediction. Indeed, the Insight Solar tool provides a preliminary yearly analysis of the solar radiation over building surfaces and the production of these surfaces when covered with photovoltaic products.

Solar irradiation is calculated taking into account an analysis grid that can be modified to increase the accuracy of the evaluation. Yearly PV production is calculated considering the percentage of area covered by PV or BIPV modules. Only three predefined typologies with pre-defined costs can be selected for the payback time analysis, whereas the cost of the electricity and the building energy use can be set by the user.


Results are displayed within the Revit environment as graphical representation to visualise the total solar radiation, the PV energy production, or the payback time. Moreover, a specific tab provides an overview of these values.



<http://knowledge.autodesk.com/support/revit/learn-explore/caas/CloudHelp/cloudhelp/2021/ENU/Revit-Analyze/files/GUID-15701517-EB11-460D-9BC9-EDEC7AE68BB9-htm.html>



## 6.2 Grasshopper + Ladybug

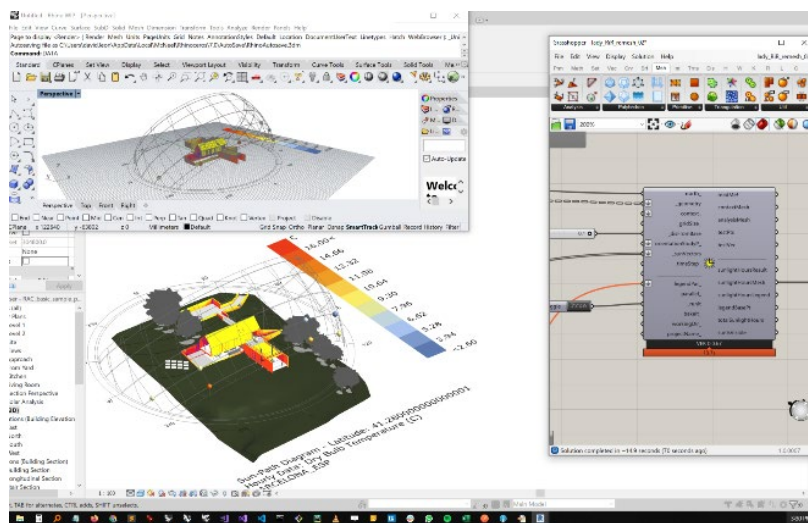
Autodesk Revit + Rhino.Inside.Revit + Grasshopper + Ladybug		v.2022
<p><b>BIPV Process Stage</b></p> <p>Conceptual ✓</p> <p>Developed</p> <p>Technical</p>	 <p>Rhino.Inside®.Revit</p>	
<p><b>Description</b></p> <p>Rhino.Inside.Revit is an add-on for Autodesk Revit® that allows to bring Rhino and Grasshopper functionalities within the Revit environment. Hence, it is possible to perform solar and PV potential analyses on building surfaces thanks to Ladybug tool.</p>		
<p><b>References</b></p> <p><a href="https://www.rhino3d.com/inside/revit/1.0/">https://www.rhino3d.com/inside/revit/1.0/</a></p>		
Functionalities		
<p><b>Input data</b></p> <p>Proprietary format ✓</p> <p>IFC ✓</p> <p>gbXML</p>	<p><b>Irradiation calculation</b></p> <p>Horizon</p> <p>Nearby objects ✓</p> <p>Albedo</p> <p>Time-step year</p>	
<p><b>Location definition and weather file</b></p> <p>Internal database</p> <p>External database .epw</p>	<p><b>PV output calculation</b></p> <p>Module level</p> <p>String level</p> <p>System level ✓</p> <p>Time-step Year</p>	
<p><b>Context modelling</b></p> <p>Nearby buildings ✓</p> <p>Building envelope ✓</p> <p>Vegetation ✓</p> <p>Other: ...</p>	<p><b>Simulation results</b></p> <p>PV production ✓</p> <p>Load matching</p> <p>Cost analysis</p>	
<p><b>Building Element modelling</b></p> <p>Building objects (openings, chimneys, ...) ✓</p> <p>BIPV structural elements ✓</p> <p>Others: ...</p>	<p><b>Outputs</b></p> <p>IFC</p>	
<p><b>BIPV modules modelling</b></p>		



Predefined products	✓	gbXML	
Custom products	✓	Other	✓

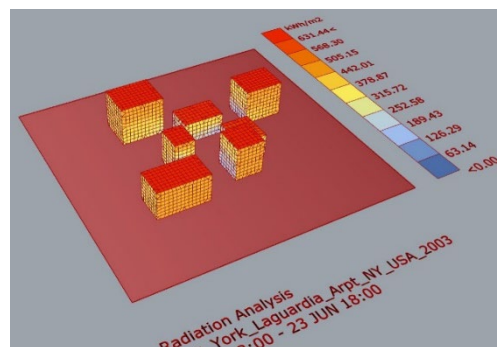
Rhino.Inside.Revit is an add-on for Autodesk Revit® that allows to bring Rhino and Grasshopper functionalities within the Revit environment, where the geometrical and informative data of a building project can be modelled and managed. Specifically, the visual programming tool Grasshopper can profit of the Ladybug tool for environmental analysis such as the solar potential analysis.

Indeed, the building geometry, nearby buildings and objects of the Revit environment can be represented in the Rhino environment and managed to simulate the solar radiation potential through Ladybug tool. Ladybug imports standard EnergyPlus Weather files (.EPW) to establish radiation studies over building surfaces.



A specific component, indeed, permits the calculation of the radiation falling on the selected geometries considering the nearby objects and context using a sky matrix. However, this tool doesn't include reflections of sunlight in the radiation analysis.

Solar irradiation is calculated taking into account an analysis grid that can be modified to increase the accuracy of the evaluation. The analysis can be made at different time steps, ranging from hourly to monthly analysis.



PV or BIPV electrical performances can be then calculated by setting an ad-hoc workflow with Grasshopper components in order to include PV output evaluation. The same approach can be also adopted for cost analysis, where inputs should be provided by the user.

Results are displayed within the Revit environment as graphical representation to visualise the total solar radiation, the PV energy production, or the payback time.

Even though this kind of tools doesn't provide standard outputs, they have a huge potential for customizing the analysis considering different aspects and for running automated and iterative analysis, as well as to perform optimization analysis.



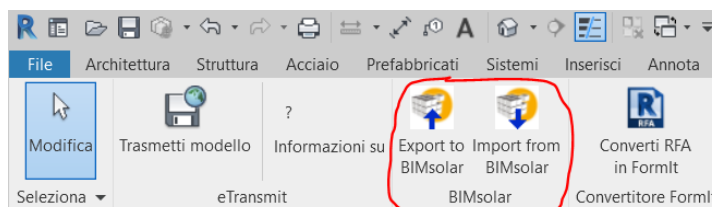
## 6.3 BIMSolar

Autodesk Revit + BIMSolar plugin / IFC + BIMSolar		v.1.3.0 rc 63	
<b>BIPV Process Stage</b> Conceptual ✓ Developed ✓ Technical ✓			
<b>Description</b> BIMSolar is a solar simulation software for BIPV. It allows importing an IFC file from BIM software or to export a BIM workflow from and to Revit where BIPV objects can be modeled and simulated with high degree of detail			
<b>References</b> <a href="https://www.bim-solar.com/en/bimsolar-4/">https://www.bim-solar.com/en/bimsolar-4/</a>			
Functionalities			
<b>Input data</b> Proprietary format ✓ IFC ✓ gbXML Other		<b>Irradiation calculation</b> Horizon Nearby objects ✓ Albedo ✓ Time-step Y, M, D, H	
<b>Location definition and weather file</b> Internal database ✓ External database .epw .tmy		<b>PV output calculation</b> Module level ✓ String level ✓ System level ✓ Time-step Y, M, D, H	
<b>Context modelling</b> Nearby buildings Building envelope Vegetation Other		<b>Simulation results</b> PV production ✓ Load matching ✓ Payback time analysis ✓ Others	
<b>Building Element modelling</b> Building objects (openings, chimneys, ...) BIPV structural elements			



Others		<b>Outputs</b>	
BIPV modules modelling		IFC	
Predefined products	✓	gbXML	
Custom products	✓	Other (.rvt; .csv)	✓

A BIM-based software tool called BIMsolar has been developed by EnerBIM for the design and simulation of BIPV systems. This stand-alone software allows importing .IFC file from any BIM software. Therefore, the BIM model of the building can be used to investigate the solar potential, the potential energy production of BIPV systems and the economic impact. Another interesting workflow is represented by the BIMsolar plugin for Revit. This plugin exports the building project and all related objects (e.g., building envelope, building elements, nearby buildings, and vegetation) to BIMsolar. Then, once the BIPV project is finalized, the plugin allows importing the developed project within the Revit environment where the BIPV modules can be integrated as BIM objects.



BIMsolar integrates different functionalities for BIPV analysis and implementation. The first one is the detailed radiation analysis that can be done by setting the location and the weather file, as well as the local albedo factor. In this way, the user can investigate the building surfaces which can be more suitable for BIPV.

The following step is represented by the definition of the BIPV modules. The user is also able to develop own BIPV components using BIMsolar configurators, save to personal database, then integrate into architectural projects. Therefore, custom BIPV objects can be created to obtain the module design that fits the most the BIPV project. The user indeed can also create a personal database with PV cells and BIPV modules.




Once BIPV modules are modeled, they can be integrated in building surfaces (both opaque and transparent) to define the electrical layout of the system. In this way, the electrical AC output can be calculated. Then, the user can evaluate in detail the results of the BIPV project, ranging from the irradiation over single modules to the production of the whole BIPV system, selecting the different time scales for the analysis (monthly, daily, or hourly). This data can be then exported as .csv file to deeper the analysis.





## 6.4 BIPV Enabler

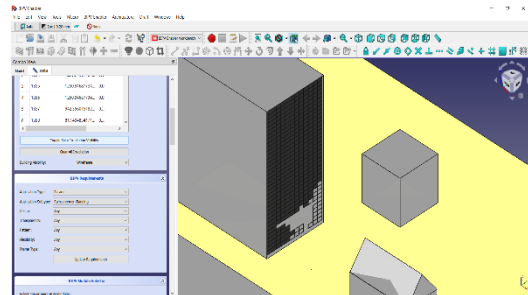
BIPV Enabler		v.01
<b>BIPV Process Stage</b> Conceptual ✓ Developed Technical	 <p>Solar Energy Application Laboratory BIPV Enabler 0.1</p>	
<b>Description</b> BIPV Enabler is a platform that integrates product, regulation, technical, economic and construction data to create optimum BIPV solutions in conceptual building design stage.		
<b>References</b> <a href="https://www.rmit.edu.au/about/schools-colleges/property-construction-and-project-management/research/research-centres-and-groups/solar-energy-application-laboratory/projects/bipv-enabler">https://www.rmit.edu.au/about/schools-colleges/property-construction-and-project-management/research/research-centres-and-groups/solar-energy-application-laboratory/projects/bipv-enabler</a>		
Functionalities		
<b>Input data:</b> Proprietary format ✓ IFC gbXML Other	<b>Irradiation calculation</b> Horizon Nearby objects ✓ Albedo Time-step Y,M,D,H	
<b>Location definition and weather file</b> Internal database ✓ External database ✓	<b>PV output calculation</b> Module level String level System level ✓ Time-step Y, H	
<b>Context modelling</b> Nearby buildings ✓ Building envelope ✓ Vegetation ✓ Other	<b>Simulation results:</b> PV production ✓ Load matching	
<b>Building Element modelling</b> Building objects (openings, chimneys, ...) ✓	Payback time analysis ✓ ✓	



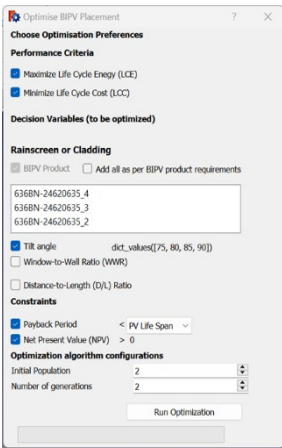
BIPV structural elements	✓	Others: Carbon emissions, wind load simulation, design optimisation	
Others		<b>Outputs:</b>	
BIPV modules modelling:		IFC	✓
Predefined products	✓	gbXML	
Custom products	✓	Other (.fc; .csv; .pdf)	✓

BIPV enabler is a tool developed by the Solar Energy Application Lab (SEAL) at RMIT University, Australia. This tool integrates product, regulation, technical, economic and construction data to create optimum BIPV solutions in the conceptual building design stage. The platform uses FreeCAD as the primary CAD tool for creating 3D building models. In this tool, the users can 1. select building type and project location using an interactive map; 2. Create the building model with the 3D geometric building shapes library or default arch and/or draft workbenches in FreeCAD; 3. Visualise the solar irradiance on the building envelope; 4. Select BIPV module(s) from the product database, generating a report on the energy output of the BIPV design(s) and economic and environmental considerations, and automatic and manual placement of the BIPV modules; 5. estimate the wind load of the BIPV design 6. Optimise the BIPV designs per tilt angles, BIPV product, window-to-wall, and distance-to-length ratios.

First, the project setup is done by selecting the building type and selecting the location to determine the weather file. Then the building designing process can be done in two ways: 1. Using the 3D geometric building shapes library to input the shape of the buildings directly. The building dimensions, colours and orientations can be controlled per user requirements or 2. Use the default Arch and/or draft workbenches to create the building. The building dimensions, colours and orientations can be controlled per user requirements. Once the design is created, the user can perform solar irradiation and shading analysis. The solar irradiation and shading analysis are facilitated by hourly weather data and can be performed for the user-defined date range.




After the solar irradiation and shading analysis, the users can select the BIPV modules from the BIPV product database. The BIPV product database consists of seventy-three (73) Australian and international BIPV module information. The module data are presented with 13 major attribute categories and 136 sub attribute categories of BIPV products based on the local and international building design and construction related regulatory requirements. The database includes the cost of BIPV modules and their maintenance cost. Furthermore, the users are provided with the option to create custom BIPV modules. The user can select one or more BIPV modules for the economic analysis or the optimisation process.



The users can select or define parameters for the economic analysis, such as building energy consumption, discount factors, interest rates, energy prices and feed-in tariff prices, cost of alternative materials etc. The simulation results show system size, life cycle cost, life cycle energy generated, the payback period, net present value, LCOE and life cycle carbon emissions avoided for the selected BIPV modules. The user can choose the BIPV module type that matches their requirement and visualise them on the building surface. The users can export the results into a pdf file. Furthermore, the users can export the building design with the BIPV modules as an ifc file to be used in ifc enabled platforms.

BIPV enabler can also perform multi-objective optimisation. The optimisation process is based on the non-dominated sorting genetic algorithm (NSGA-II). The optimisation process generates feasible BIPV design solutions based on design variables, objective functions and constraints defined by the user. The user can export the optimised results into a CSV file. Furthermore, the BIPV enabler can calculate the wind load of a selected BIPV design. The wind load calculation is based on AS1170.2: Structural design actions—Wind actions.

## 6.5 BIPV.world

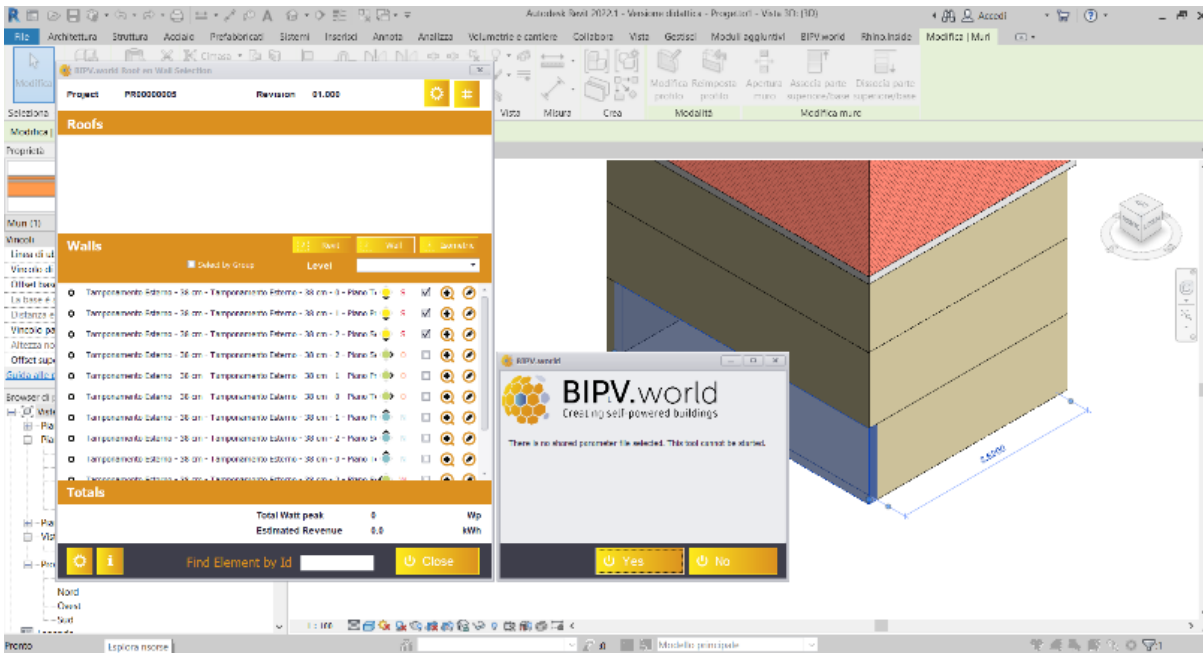
BIPV Enabler		v.2023
BIPV Process Stage		 <b>BIPV.world</b> Creating self-powered buildings
Conceptual	✓	
Developed	✓	
Technical	✓	
Description	The BIPV.world tool is a plug-in for Revit. The tool is aimed at designing BIPV buildings, and it is connected to a web-platform for cost analysis.	
References	<a href="https://bipv.world/">https://bipv.world/</a>	
Functionalities		
Input data:		Irradiation calculation
Proprietary format	✓	Horizon
IFC	✓	Nearby objects
gbXML		Albedo



Other		Time-step	
<b>Location definition and weather file</b>		<b>PV output calculation</b>	
Internal database		Module level	
External database		String level	
<b>Context modelling</b>		System level	
Nearby buildings	✓	Time-step	
Building envelope	✓	<b>Simulation results:</b>	
Vegetation	✓	PV production	✓
Other	✓	Load matching	
<b>Building Element modelling</b>		Payback time analysis	✓
Building objects (openings, chimneys, ...)	✓	Others	
BIPV structural elements	✓		
Others		<b>Outputs:</b>	
<b>BIPV modules modelling:</b>		IFC	✓
Predefined products	✓	gbXML	
Custom products	✓	Other (.rvt)	✓

BIPV.world was born as a products and services platform for European supply chain and building professionals. Among services, the BIPV.world plugin for Revit is a tool that helps developers to model BIPV façades in the architects/designers own Revit/BIM environment.

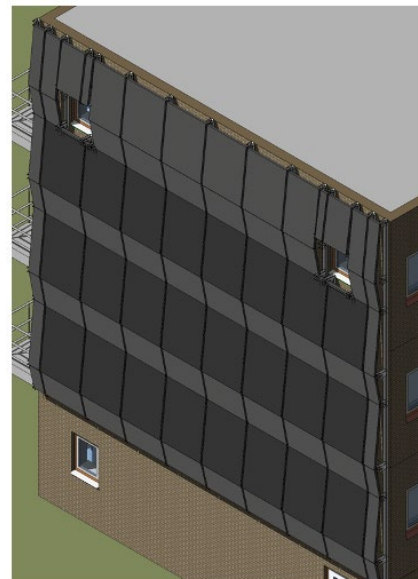
The BIPV project has to be linked to a project in the web-platform. Then, the building project can be created thanks to the Revit functionalities. Thus, building envelope surfaces (e.g., rear walls, roofs, etc.) can be modelled and edited, as well as building elements (e.g., chimneys, balconies, windows, etc.), nearby buildings and trees. When the building project is made, the user can run BIPV.world to add BIPV systems (fully automatic or manual design). Indeed, the plugin allows the selection of the surfaces where the BIPV modules should be placed.



An automatic placement tool allows selecting the BIPV product from a product database, as well as dummies (glass, aluminium composite cassettes or other façade materials) products. Depending on the BIPV product dimension, an automatic grid is created over the selected surfaces. However, the user can change the grid to obtain the needed design.

Thanks to the defined grid, the BIPV modules and mounting structures can be placed on the building surfaces as BIM objects, so that they are integrated in the Revit environment. Moreover, the tool provides an overview of the total watt peak installed and an estimation of the yearly electrical production.

The innovation introduced by the BIPV.world is the possibility to export the data (not the BIPV design) to the web-platform and automatically obtain a cost and revenue indication for the BIPV project.





## 7 BIM-BIPV SHOWCASES AND CASE STUDIES.

*Highlight: small collection of BIPV showcase and case-study to show how BIM tools and workflows can be used in practice.*


Beyond the description of the BIM-based tools and workflows, it is important to show how these tools have been already implemented to realize BIPV buildings where the BIM approach has been adopted. However, since BIM-BIPV is a niche market, this section includes 3 showcases (already realized BIPV buildings) and 1 case study (not yet realized BIPV projects / not existing BIPV buildings which have been studied in research projects).

Each case is presented by providing a description of the building itself and by specifying BIPV and energy characteristics. Moreover, the adopted workflows and tools, as well as data management strategies are described. This description has been obtained thanks to Task 15 participants who circulate a survey to collect relevant information from architects and BIPV stakeholders involved in the BIPV project development. However, for the sake of length, this section shows only a synthesis of the collected inputs.

Contributions:

- Franklin College-- Switzerland (SUPSI)
- Shuifa Singyes R&D Building-- China (Shuifa Singyes)
- RMIT Design Hub-- Australia (RMIT)

### 7.1 Franklin College-- Switzerland

NEW CAMPUS-- FRANKLIN UNIVERSITY SWITZERLAND	
	<p><b>Address</b></p> <p>Via Ponte Tresa, 6924 Sorengo, Switzerland</p>
	<p><b>Location</b></p> <p>45.99 N, 8.94 E</p>
	<p><b>Description</b></p> <p>The “Campus 3” project includes an auditorium that stands like a beacon of light within the overall complex. An orientable system of white photovoltaic lamellas has been developed to shade the interior and to follow the orientation of the sun to maximize energy yield at the same time.</p>



<b>BUILDING CHARACTERISTICS</b>	
Building typology	Educational
Construction type	New
Year of construction	2022
Gross floor area	Area above ground: 7500 sqm. Area underground: 2600 sqm.
Energy index	Cooling: 248 kW; Heating 99 MJ/m2; Lighting: 16.8 kWh/m2.
Energy labelling	None
<b>BIPV ENVELOPE</b>	
BIPV surface	about 170 sqm
BIPV surface ratio	17%
Building skin application	Vertical shading louvres
Product	Custom BIPV modules
Manufacturer	Sunage
Cell technology	Mono-crystalline
Front glass type/customization	Coloured front glass (white)
Dimensions	Louvers are 360 mm large and 4630 mm height (1 <sup>st</sup> floor) or 3670 mm height (2 <sup>nd</sup> floor)
Power density	110 Wp/sqm
<b>ENERGY PERFORMANCES</b>	
Peak power	16.5 kWp
Energy production	Depends on louvres elements handling
Self-consumption	n.a.
<b>CONTACTS</b>	
Architect	Flaviano Capriotti Architeti
Installer	AIL SA (Alsolis-Kummler+Matter)
Other relevant contact	AFRY (General Contractor), KU+MA & Poretti&Gaggini (BIPV louvre system)



- BIM ADOPTION

The new building complex of the Franklin College has been designed by the Italian firm Flaviano Capriotti Architetti. The exterior appearance of the main building represents the profile of a book and hosts residential apartments for students. Next to this construction, there is a lantern-like building made of vertical photovoltaic louvers to produce energy.

The realization of this new building complex has been coordinated by the Swiss company AFRY. The decision to adopt BIM was made by AFRY, without any request from the client because of the recognized benefit of this methodology as stated by Umberto Ceccarelli, AFRY manager of this project:



**Figure 14. BIM model of the new building complex of the Franklin College. Source: AFRY**

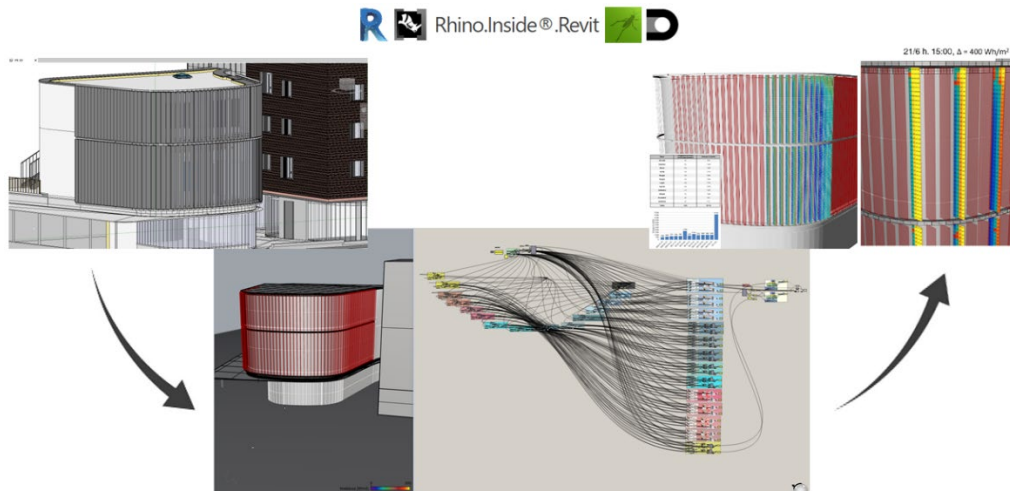
*“Our design thinking approach together with the BIM methodology allowed us to carry out the project with a clear organization from the very beginning. We have put our experience in the management of complex projects and in the executive planning of the architecture in symbiosis with Flaviano Capriotti Architetti, always with the aim of achieving the client’s objectives” (AFRY 2021)[REF].*

- DESCRIPTION OF ADOPTED TOOLS AND WORKFLOW

AFRY developed the project with Autodesk Revit and by using the BIM360 Autodesk construction cloud to promote collaboration along the project development among different team members.

Regarding the lantern-like building, SUPSI has been commissioned to carry out a feasibility study for the integration of photovoltaics in the vertical louvres. Therefore, the BIM model developed by AFRY has been retrieved and imported in the Rhinoceros environment through the Rhino.Inside.Revit plug-in. This has allowed to transfer geometries in a seamless way without losing data and information. Therefore, thanks to Grasshopper plug-in of Rhinoceros and Ladybug and DIVA components, the preliminary BIPV analysis has been carried out.





**Figure 15. Workflow developed by SUPSI for the preliminary BIPV analysis of the shading vertical PV louvres.**

- DESCRIPTION OF INFORMATION AND DATA MANAGEMENT FOR BIPV

As already introduced in the previous paragraph, a set of tools and a specific workflow has been adopted for the BIPV conceptual design stage to provide the client and other stakeholders with information about the feasibility of the white BIPV vertical louvres.

Thanks to the importation of the geometries in Rhinoceros from Revit through Rhino.Inside.Revit, it has been possible to model BIPV elements and generate algorithms for their handling. Indeed, in accordance with the client, the BIPV louvres are envisioned as sun-tracking elements to provide shading within the building rooms. By means of Ladybug and DIVA components the sun-tracking has been defined and the hourly irradiation simulation on the vertical louvres has been defined for a single representative day of each month. Moreover, a simplified model has been integrated in the Grasshopper environment to simulate the DC energy generated by the white BIPV vertical louvres. From these analyses, several recommendations arose for the definition of the BIPV system layout and the BIPV module layout. These recommendations have been shared with other stakeholders (e.g., electricians, BIPV module manufacturer, ...) to enable the BIPV development design stage.

Regarding the information and data management, in this initial phase of the BIPV process, the focus has been put on geometrical data. Indeed, the goal was to identify the best system and module layout depending on the irradiation conditions. Therefore, the LOG of the objects has been defined in the value of 200, meaning that BIPV louvres have been modelled with schematic quantities, size, shape, location, and orientation, without representing details such as PV cell's location and size, specific mounting structures or specific stratigraphy of the BIPV module.

The whole workflow and information management approach are shown in Figure 16.

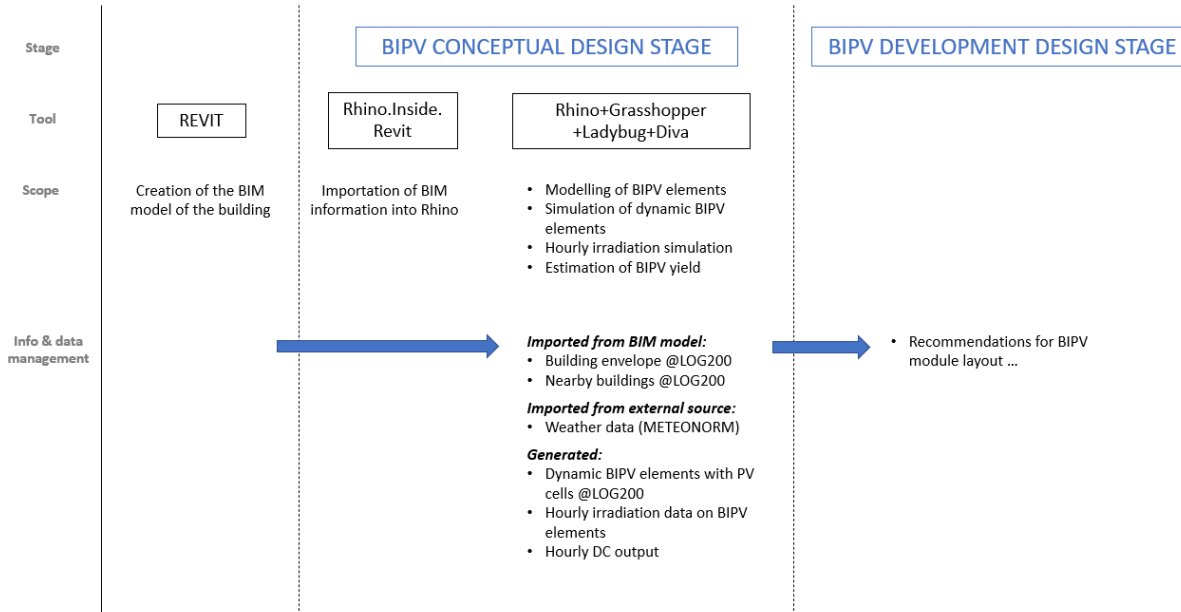


Figure 16. Workflow and information management approach for the BIPV feasibility study of the Franklin College project. Source: SUPSI

## 7.2 Shuifa Singyes R&D Building – China

SHUIFA SINGYES R&D BUILDING – CHINA	
	<p><b>Address</b></p> <p>No. 9, Jinzhu Road, Science and Technology Innovation Coast, High-tech Zone, Jinding Town, Zhuhai City, Guangdong Province</p>
	<p><b>Location</b></p> <p>42.39 N, 113.55 E</p>
	<p><b>Description</b></p> <p>This is a 17-storey low-carbon energy-saving building. It has low energy demand, and the environmental protection value is outstanding. It received several awards: the country's first net zero energy building operation logo, G20 International Energy Conservation and Innovation Award, International Eco-Design Award, Award Sino-US Clean Energy Joint Research Center Research and Demonstration of Key Technologies for Net Zero Energy Buildings</p>
	<p><b>BUILDING CHARACTERISTICS</b></p>



Building typology	Office
Construction type	New
Year of construction	Built in 2017
Gross floor area	23546 m <sup>2</sup>
Energy index	34.3 kWh/m <sup>2</sup> y (electricity)
Energy labelling	China's three-star green building design certificate (for design and operation). US LEED BD+C NC platinum certification
<b>BIPV ENVELOPE</b>	
BIPV surface	n.a.
BIPV surface ratio	n.a.
Building skin application	Roof, Facade, Canopy, Louvre
Product	4 custom made products
Manufacturer	Singyes Solar
Cell technology	Monocrystalline silicon
Front glass type/customization	Standard front glass
Dimensions	Custom
Power density	n.a.
<b>ENERGY PERFORMANCES</b>	
Peak power	210.6 kWp (130 kWp façade shading system, 78.8 kWp roof, 17.5 kWp canopy, 8.5 kWp louvre parapet)
Energy production	140'000 kWh/y
Self-consumption	n.a.
<b>CONTACTS</b>	
Architect	Mr. Adam Huang
Installer	Singyes Solar
Other relevant contact	Deng Xin, technical engineer, Shuifa Singyes

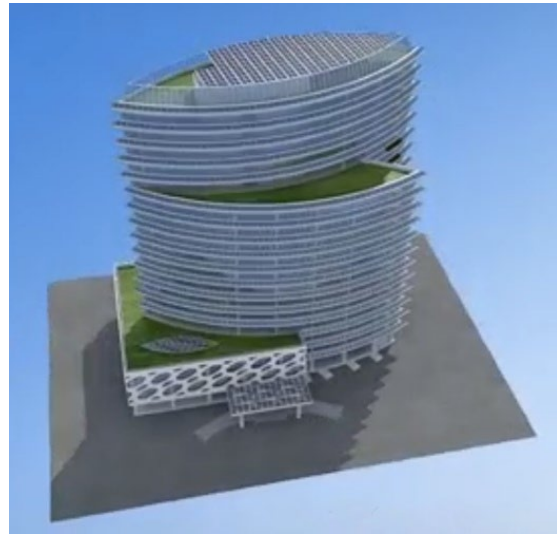
- BIM ADOPTION



This building is a key project of Xing Ye Group. In this project, BIM plays a central role in the construction process, playing a huge role in curtain wall design, on-site construction, collision check and construction simulation.

The introduction of BIM technology in a project requires careful planning and preparation according to the characteristics and circumstances of the project. The BIM application planning includes the application objectives, the agreement of BIM model standards, the determination of the application scope, the construction of the organizational framework and the information exchange methods.

BIM application in the process of selecting software should not only consider meeting the design requirements and time requirements but also consider the transfer of the building information.



**Figure 17. BIM model of the Shuifa Singyes R&D Building. Source: Shuifa Singyes**

- DESCRIPTION OF TOOL USED AND INFORMATION AND DATA MANAGEMENT

Revit and Navisworks are the main BIM software used in this project. Based on the Revit software for the façade, the photovoltaic glass curtain wall system, the HVAC system and the fire system have been designed. From the model, it is possible to derive the bill of materials, work quantities, elevations and planes, details, and other drawings. The model can be imported into Navisworks software for collision checking, construction simulations, etc. Regarding the solar analysis, Ecotect has been used for the insulation analysis and the monthly surface irradiance.

- DESCRIPTION OF BIPV MODELING AND SIMULATION

Though BIM tools (i.e. Rhino and Ladybug), the total efficiency of the grid-connected photovoltaic power generation system has been calculated considering the irradiation and the efficiency of the photovoltaic array, the efficiency of the inverter and the line efficiency. Specifically, the power generation of the photovoltaic grid-connected power generation system has been evaluated for each inverter.

Specifically, the irradiation analysis has been performed for the different BIPV systems installed in the building: the podium canopy, the spandrels of each floor, top blinds, the main roof and the daylight roof as shown in Figure 18.

Roof

Daylighting roof

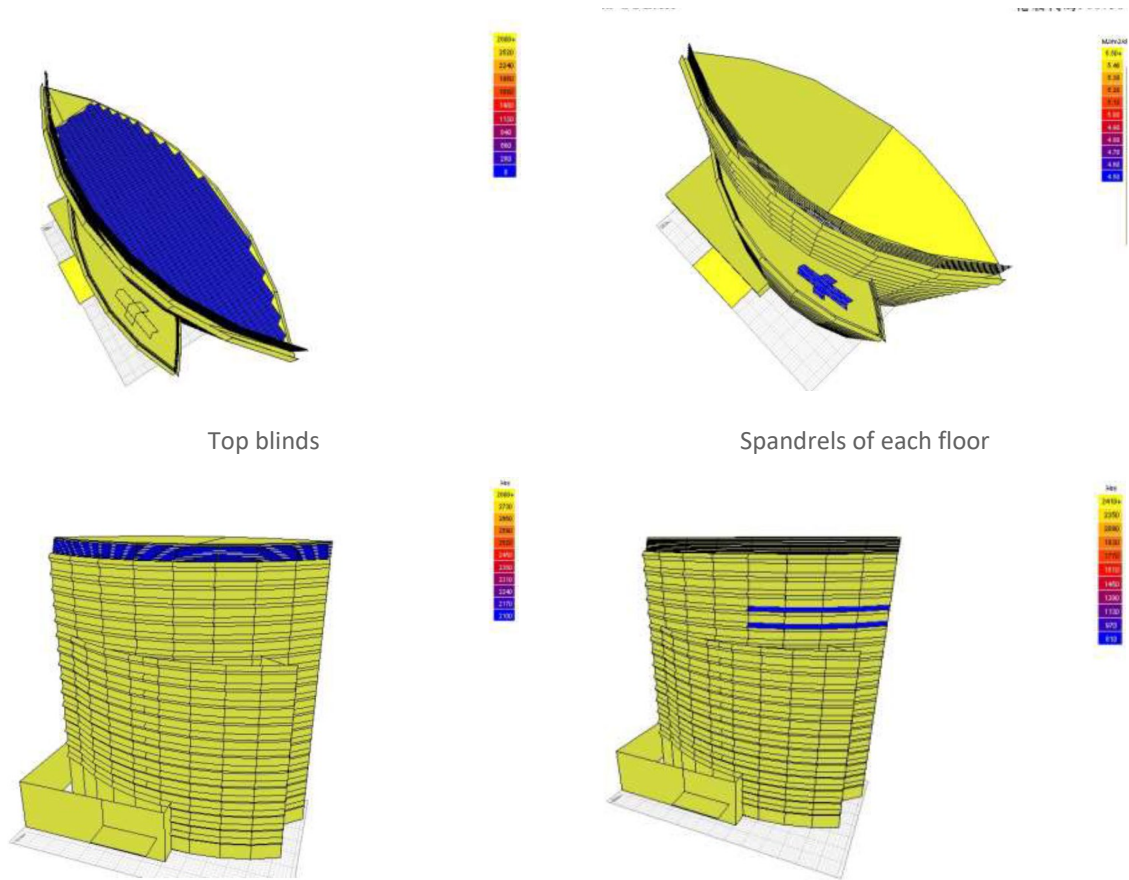


Figure 18. Irradiation analysis carried out on the different BIPV system. Source: Shuifa Singyes

### 7.3 RMIT DesignHub-- Australia

RMIT Design Hub-- Australia	
	<p><b>Address</b></p> <p>150 Victoria St, Carlton Victoria 3000, Australia</p>
	<p><b>Location</b></p> <p>-37.8064,144.9627</p>
	<p><b>Description</b></p> <p>RMIT Design Hub is used for research and postgraduate education in the fields of fabric, fashion design, architecture, aeronautical engineering, industrial design, landscape architecture, and urban design. It has eight floors and a flat roof, and the building façade consists of a rain screen façade.</p>
	<p><b>BUILDING CHARACTERISTICS</b></p>

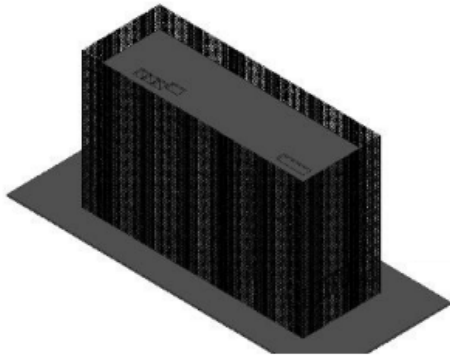


Building typology	Higher Education
Construction type	Retrofit
Year of construction	2017
Gross floor area	14,218.96 m <sup>2</sup>
Energy index	n.a.
Energy labelling	5-Star Green Star Design Rating (Education v1) - Green Building Council Australia
<b>BIPV ENVELOPE</b>	
BIPV surface	n.a.
BIPV surface ratio	n.a.
Building skin application	Rain screen
Product	16W semi-transparent module
Manufacturer	Sunjoule
Cell technology	Monocrystalline silicon
Front glass type/customization	6mm extra clear heat strengthened glass
Dimensions	396mm x 50mm
Power density	n.a.
<b>ENERGY PERFORMANCES</b>	
Peak power	5.84 kW (inverter capacity) 6.34 kW (array size)
Energy production	5,000 kWh/ year (estimated)
Self-consumption	n.a.
<b>CONTACTS</b>	
Architect	Sean Godsell Architects, Peddle Thorp Architects
Installer	AGC
Other relevant contact	Inverter manufacturer: Enphase

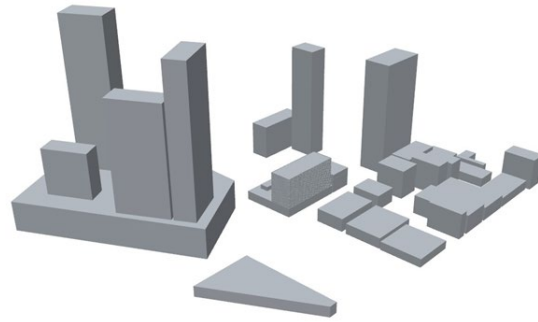
- BIM ADOPTION AND PROCESS DESCRIPTION
- BIM ADOPTION



BIPV application in RMIT design hub has been done as a retrofit project. Solar Energy Application Group (SEAL) at RMIT university applied the BIM technology to explore the potential impact of installing BIPV panels in the design hub building.



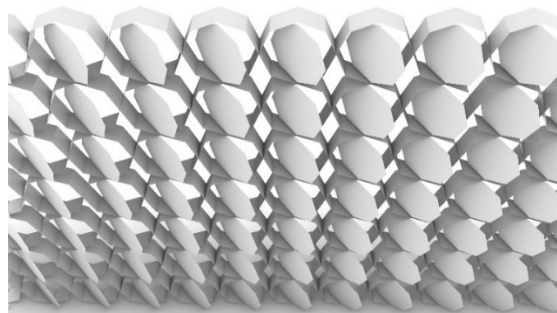
**Figure 20. BIM model of the RMIT design hub building using Autodesk Revit.**  
Source: Wijeratne (2021)



**Figure 19. BIM model of the RMIT design hub building using Rhino**

- DESCRIPTION OF TOOL USED AND INFORMATION AND DATA MANAGEMENT

Rhino and Autodesk Revit were used as the main BIM software as shown in Figure 19 and Figure 20. For an example, the floor plan was imported into the Rhino and each floor has been traced to the appropriate dimensions. After the initial modelling of the case study building using Rhino, the program and construction set of the building were assigned using Grasshopper for further modelling according to the material specifications. The prototype of the BIPV module was also modelled in Rhino as shown in Figure 21.



**Figure 21. Modelling of the BIPV panel using Rhino**

- DESCRIPTION OF BIPV MODELING AND SIMULATION IN CONCEPTUAL DESIGN

BIPV enabler was used to create conceptual BIPV designs. This tool utilizes hourly weather data to facilitate solar irradiation and shading analysis, which can be performed for a user-



defined date range. Following the completion of the solar irradiation and shading analysis, BIPV modules were selected from the BIPV product database. This database encompasses information on seventy-three (73) BIPV modules from both Australian and international sources. After the selection of the BIPV modules the economic feasibility was calculated and the BIPV panels were visualised on the building surface as shown in Figure 20.

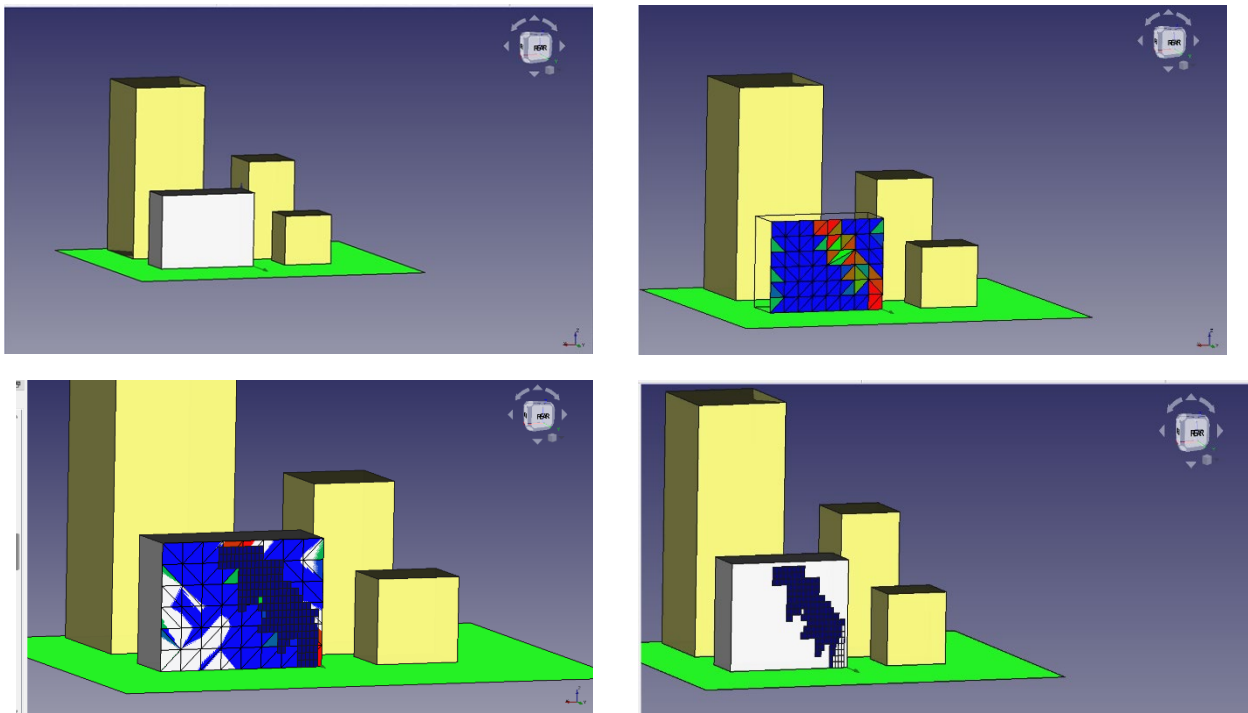


Figure 22 Irradiation analysis and BIPV placement - Source RMIT

- BIPV KINETIC FAÇADE SIMULATIONS

Furthermore, the kinetic solar façade assessment was carried out by analyzing the performance of the RMIT design hub building under three main criteria namely, building energy consumption (kWh), daylighting (lux), and PV energy output (kWh) (Figure 23 & 24). Since BIPV Enabler cannot handle kinetic design (i.e. changing tilt angles of the panels with the change of sun position), BIM tools and MATLAB were applied. The existing design hub building has no BIPV installed, and the study aimed to compare the effect of BIPV in the four scenarios to identify the potential impact of installing BIPV panels on the building. The four scenarios include the original design hub building with and without BIPV and the kinetic facade with and without BIPV. The assessment process involved four stages starting with the data collection stage which included the selection of appropriate tools as well as building and BIPV product data collection.

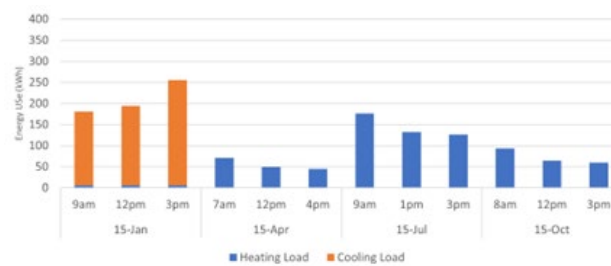
Rhino platform was used for modelling the design hub building based on the collected specifications. Grasshopper was used to assign the heat loads, schedules, and construction



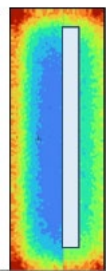


types for the modelled building. Ladybug plugin was used in the grasshopper for visualising and analysing the solar incident radiation on the building and facade by considering the weather data. Honeybee uses Energy Plus and Open Studio for energy simulation. Climate studio tool was used to analyse and evaluate the illuminance levels with different scenarios through daylight analysis. A programmed MATLAB module was used to determine the PV energy yield from the Kinetic PV façade during different scenarios.

Next, the parametric modelling of the 4 cases was conducted. Then, the assessment of the parametric models based on the three main criteria was performed. Since the kinetic BIPV panels tilt their angle based on the sun’s movement, it is a tedious process to specify the sun’s path and energy analysis period simultaneously. Therefore, the point-in-time approach by considering particular times of day has been used to compare the different cases.



**Figure 23. Heating, Cooling loads in different seasons**



**Figure 24, Daylighting levels of the kinetic facade with BIPV**

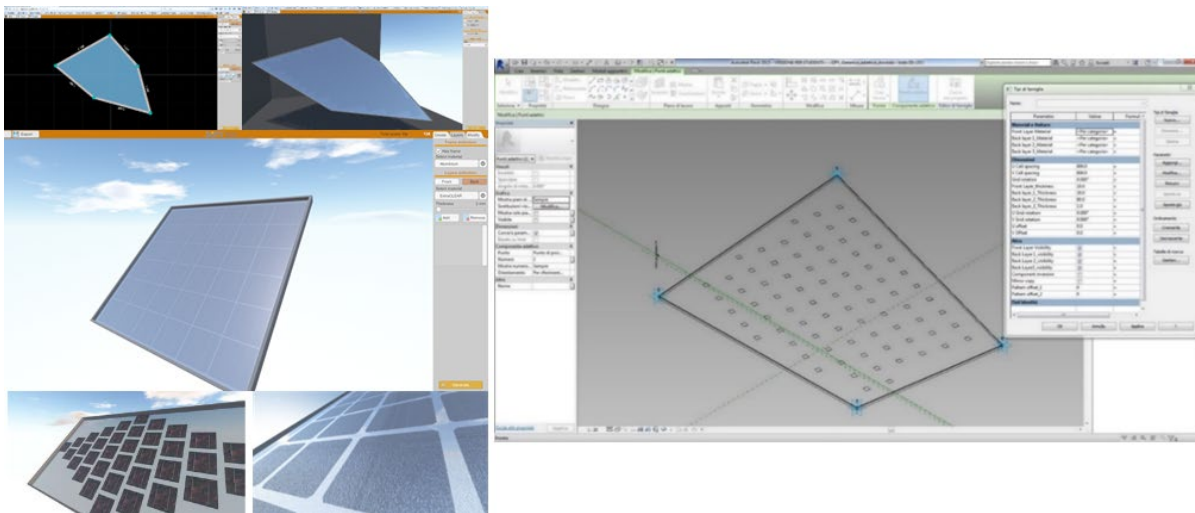


## 8 RESEARCH ACTIVITIES ON BIM AND BIPV

The above-mentioned tools are already in the market. However, it is important to highlight that there are also **research and development activities about BIM tools for BIPV**. In the following paragraphs, a non-exhaustive description of research projects on BIM and BIPV is presented.

### 8.1 Construct PV

The project Construct-PV (CONSTRUCT 2011) offered a first development in the field on BIM-based BIPV objects. The product customization was addressed thanks to a versatile software design environment and able to evaluate energy, architectural and construction aspects. The software tool and workflow had the goal to allow stakeholders in connection with a BIM-based design approach a “creation process” of customized BIPV components beginning with the Early Design Stage. The web-tool allowed a real time visualization and customized editing of the BIPV object created by the user considering the different module’s materials, glass types and finishings, cell’s arrangements, transparencies, etc. by also preliminarily assessing the relative influence on the final power of the front layer main features. The transition to a BIM-based process became strategic to support the penetration of BIPV within the real Architectural, Engineering and Construction (AEC) process so that the Interoperability was ensured through a plug-in allowing exchange of components as native BIM objects in BIM environment.



**Figure 25. Left: A screenshot of the Construct-PV webtool for defining the layout of the BIPV glazed component in terms of layering, material, shape, and transparency. Right: Adaptive BIPV module with parametric features in Revit. Source: SUPSI.**

Autodesk Revit platform was used as BIM authoring tool since it also provided IFC import, and export based on buildingSMART openBIM standard, thus not limiting the applicability in the construction sector. Specifically, the Family Editor of Revit has been used to create the adaptive BIPV families. The “Adaptive Component” functionality is designed to handle cases where components need to flexibly adapt to different boundary conditions needed for



integration in the building envelope. For example, adaptive BIPV components can be used on wall/roof/curtain wall/skylight component surfaces in design environment, with their own informative parameters. It is typically useful for singularly customized building elements with every instance different by each other (Bonomo et al. 2018).

Many applications can be accomplished using these objects in BIM projects, since the Early Design Phase to Design Development stage, since many customization options will be available, such as: module customized shape (free shape and number of vertices), shape adaptability in design environment (adaptive model), layering (n-layer can be added, also choosing thickness, material), frame (different frames can be eventually included to the family template prototypes), cell level (type of cell, spacing, cell rotation, grid disposition, material), parametric behaviour of the main features available for user in design environment, and adaptive component in design environment (Frontini, Bonomo and Hecker 2017).

## 8.2 BIPVBOOST

The European H2020 project BIPVBOOST (BIPV BOOST 2018) was aimed at transferring a BIM-based digital approach from the construction sector to the whole BIPV process, thus achieving a substantial reduction of the cost along the value chain (from design to installation). Specifically, it provided a clear definition of the reference BIPV process, including its information management, optimization strategies and KPIs for cost-reduction. Indeed, the three main topics addressed within this project are the following:

- The development of an information management strategy that consists in a framework for managing all the information categories which need to be digitalized and embedded in each stage of a BIM-based BIPV process, as well as KPIs about project results and performances,
- The definition of an information modeling strategy that describes the approach for including all the required geometrical and informative data of BIPV objects to be used in a BIM-based BIPV process,
- The integration of optimization algorithms to manage quantities of data and scenario into the BIPV workflow to support decision and design from the early stages.

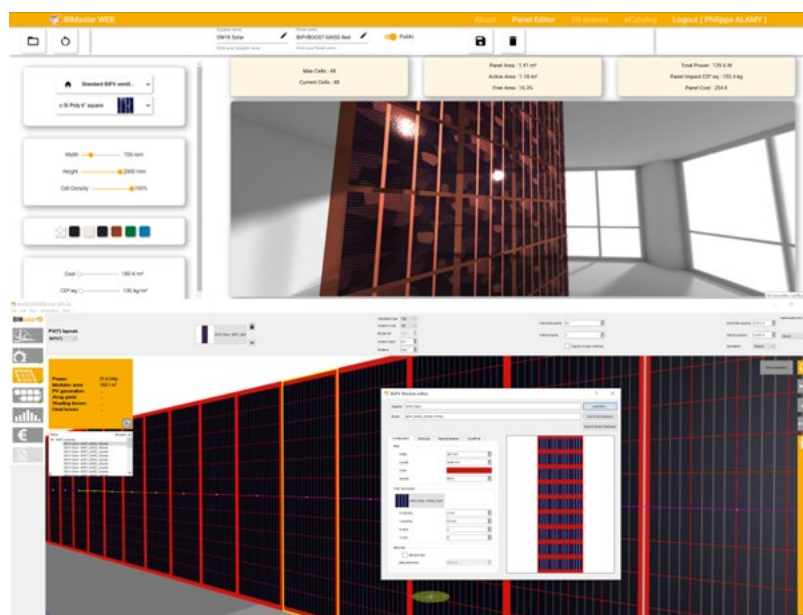
In this context, the existing BIM-based SaaS (Software as a Service) platform, namely BIMsolar<sup>®</sup>, has been enhanced with new features to ease the integration of BIPV systems in buildings from concept design stage to installation, including pre-design of BIPV materials and connections to manufacturing lines (Figure 26). Among new features, there are:

- Definition of BIPV modules in a new web-based “BIMsolar eCatalogs” to address the BIPV industry with a BIM and Product Lifecycle Management perspective. Indeed, this tool allows generating LOD 200 “macro-types” BIM objects. Several parameters can be customized such as, cell type, module size, building application thus generating a BIPV object with information about energy, cost and CO<sub>2</sub> equivalent emissions. The online database of macro-types is then synchronized with the BIMsolar desktop database to a complete BIM object integration within desktop software. In this way, it



is possible to start BIPV simulation within BIMsolar and digital objects bring properties to BIM & BEM workflows in open IFC, as REVIT families and soon in gbXML.

- Integration of optimization algorithms for the BIPV layout of macro-types based on energy and costs models, to reduce costs and increase energy KPIs,
- Development of a proof of concept for AR/MR (augmented reality/mixed reality) application to involve potential investors through a BIPV architectural scenario on a building in its proposed real-world location, helping them understand how the BIPV modules will be integrated with its surroundings as well as to estimate preliminary energy production.



**Figure 26. Enhanced version of BIMsolar developed in the BIPVBOOST project. Top: web-based “Panel Designer” to generate macro-types. Bottom: BIPV modules imported in BIMsolar for simulation.**



### 8.3 Vitality District

AT FFG Vitality District project (funded by the Austrian Research Promotion Agency-FFG) (Vitality District 2022), which focuses on the early planning phase of resilient, energy-efficient neighbourhoods. Within this project, a tool (Vitality District tool (Food4Rhino 2023)) was developed, aiming to support the “design and optimization of photovoltaic planning, coordinated with consumption profiles, building topology and solutions for energy communities, storage and greening”. With the purpose of enabling the tool to interact with existing BIM tools, a suitable strategy was identified and set up. An initial tools’ review led to establish the reference format to consider (.ifc) and the existing tools able to translate the Vitality District outputs in that format. Among many, the IFCOpenShell open-source tool REF was selected. It allowed the development of a new component to add into the Vitality District tool modelling and simulation environment (i.e. Rhinoceros (Robert McNeel & Associates 2023) + Grasshopper (Grasshopper Docs 2023)). This component, written in Python programming language, converts objects in BIM format, assigning them the properties required in addition to the 3D features (i.e. related to time or project schedule, cost management, structure management, sustainability). Figure 27 shows an example of a generated BIM object, a photovoltaic module with specific properties (e.g., IFC Entity, Name, Area, Height, Volume, Efficiency, Technology, Transmittance, etc.).

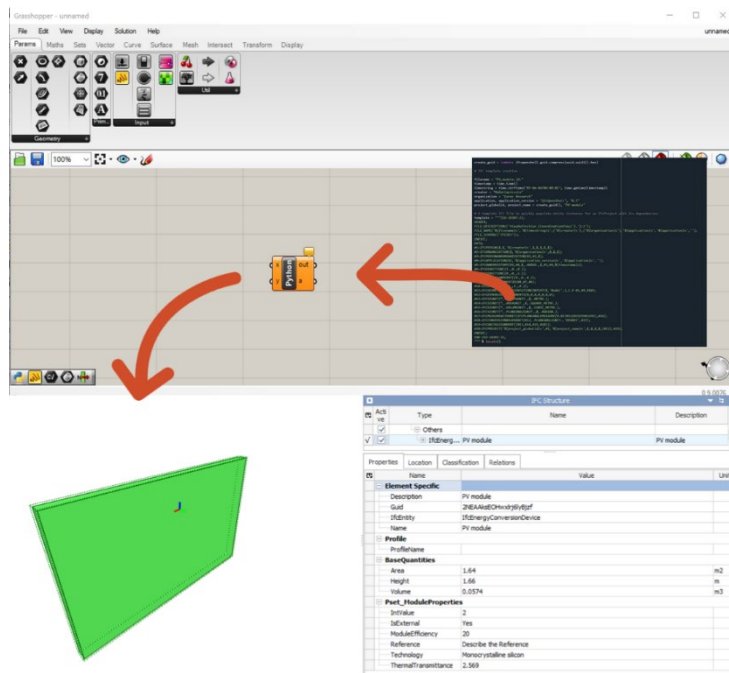


Figure 27. Example of generation BIM BIPV module with specific properties. Source: AT FFG Vitality District project

Figure 27 shows an example of a generated BIM object, a photovoltaic module with specific properties (e.g., IFC Entity, Name, Area, Height, Volume, Efficiency, Technology, Transmittance, etc.).



## 8.4 INFINITE

EU H2020 INFINITE project (Infinite 2021) relies on the “Renovation 4.0” approach, which combines digitalisation and industrialisation to offer high-quality, tailor-made, sustainable solutions for the building retrofit designed to last. Within the project, the BIM-collaboration platform named BIM-P will be connected to a set of different plugins related to buildings O&M, LCA, LCC and photovoltaic system design. The aim of the photovoltaic optimization plugin is to support the designer (user) in the early-stage design of the photovoltaic plus battery system. The plugin will be connected to the BIM platform through an API which will enable the input-output exchange. The tool will profit of the integration with the BIM platform by collecting the required inputs such as surface properties, geographic information and all data required for the techno-economic photovoltaic optimization directly from the BIM model and used as input for the calculations. As a result, the photovoltaic optimization plugin will calculate for the user the optimal number of modules installed on each surface and the optimal battery capacity.

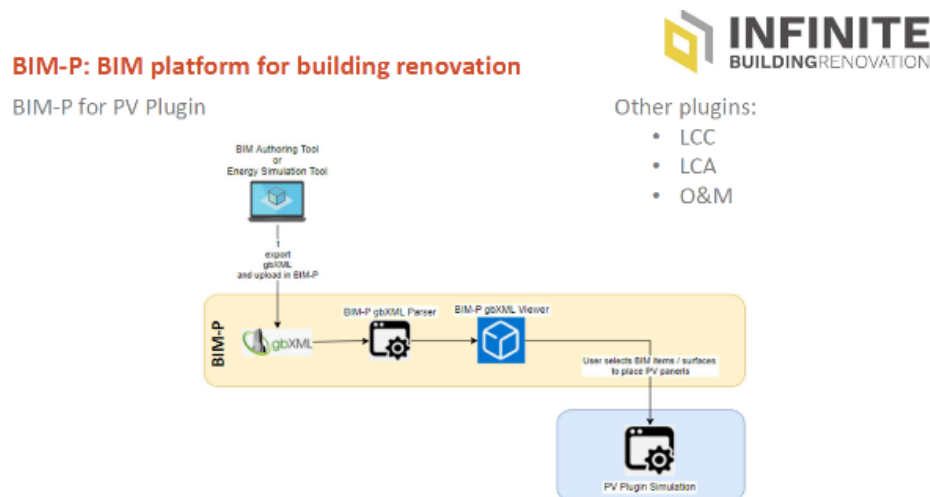


Figure 28. Framework of the BIM-P platform. Source: EU H2020 INFINITE Project

## 8.5 BIPV Enabler

The BIPV enabler research project was funded by the Australian Renewable Energy Agency’s Commercialisation of R&D Funding Initiative Pilot and RMIT University Research and Innovation. The objective of this initiative was to transform intricate technical details of the BIPV design process into a user-friendly platform that seamlessly incorporates product, regulatory, technical, economic, and construction data as shown in Figure 29. This platform is designed to craft the optimal Building-Integrated Photovoltaics (BIPV) solution tailored to conceptual design of BIPV projects. The key functions of the BIPV enabler platform include:

1. Initiating the project setup which include selection of the building type and project location using a map;
2. Creating the building model with the 3D geometric building shapes library or default arch and/or draft workbenches in FreeCAD;



3. Visualising the solar irradiance on the building envelope;
4. Selection of BIPV module(s) from the product database (73 BIPV product information were collected through local and international BIPV product suppliers and manufacturers), generating report on the energy output of the BIPV design(s) and economic and environmental considerations, and automatic and manual placement of the BIPV modules;
5. Estimation of the wind load of the BIPV design
6. Optimisation of BIPV designs as per tilt angles, BIPV product, window to wall ratio and distance to length ratio.

The simulation and optimisation process in the prototype is facilitated by hourly weather data from the pvlib- python’s weather library, the database with standard energy prices and feed in tariff prices, the database with cost of alternative materials and the BIPV product database. The optimisation process is based on the non-dominated sorting genetic algorithm (NSGA-II).

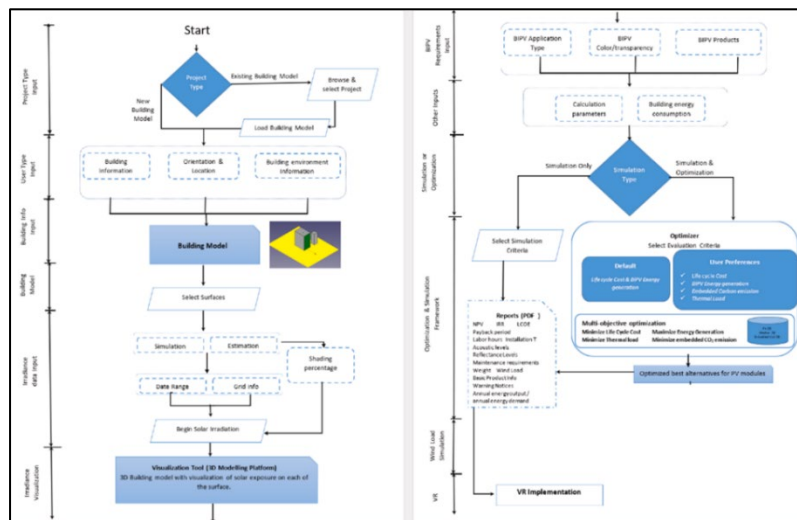


Figure 29 Flowchart of BIPV Enabler platform

Source: Yang et al. (2023)

## 8.6 Inputs for BIM-BIPV tools and interoperability

The absence of digitalization in BIPV products and limited research into BIPV digital product data models for seamless integration with BIM platforms is evident (Pajkic et al. 2019). Therefore, further investigation is needed to identify and validate an appropriate representation and interoperability approach for BIPV products under the IFC schema by integrating BIPV digital product models with BIM to facilitate BIPV design simulation applications (Zang, Yang and Boukamp 2022). A study by Zang, Yang and Boukamp (2022) at RMIT, Australia investigated a case to demonstrate the processes of developing a Model View Definition (MVD) for BIPV digital products in the Australian context. This study is part of a larger project focused on creating a MVD for Building-Integrated Photovoltaics (BIPV) digital product representation



to support Building Information Modeling (BIM) data exchange in Australia. The study follows buildingSMART's recommended methodology for developing MVDs and applies it specifically to BIPV products during the technical pre-design phase. It involves conducting interviews with industry professionals to gather use case information and develop process maps that define information exchange requirements. The research presents a sample use case related to "technical pre-design consideration" to illustrate the process from identifying use cases to developing MVDs. It also highlights some challenges in MVD development, particularly in accurately representing certain aspects like "fire certificates" and "integration methods" within the initial proposed MVD. While the Industry Foundation Classes (IFC) schema covers many BIPV product exchange requirements, ensuring correct semantics and meaning in digital representation remains a challenge to be explored further. To address these challenges, the researchers in Australia propose to consider the results as an input for the next version of MVD to be published by buildingSMART international.

## 8.7 BIM4BIPV

The research project "BIM4BIPV – Future aspects of Building Integrated Photovoltaics (BIPV) for the interdisciplinary BIM-Planning process" is funded by the the Austrian Research Promotion Agency-FFG and initiated by the TU Wien architectural department. The project BIM4BIPV aims at establishing a fluent interdisciplinary planning process for BIPV. The goal is to place openBIM BIPV elements directly into the architectural design model *for the planning and simulation* of power generation, daylighting, shading, energy certificate and aesthetic appearance. Specifically, the reasons to support the integration of openBIM BIPV elements in the BIM model are the following:

- BIM-3D-model = "Digital Twin" of the overall project – including BIPV
- accurate simulation of the solar yield – especially regarding bifacial modules and near shading
- detail specific integration of PV / BIPV into complex building and environment geometries
- Interdisciplinarity = use of the BIPV-system representation / -model for PV-system design, architectural design, daylighting calculation, energy certificate, structural and energy engineering – for the whole life cycle including O&M, re-use, dismantling and recycling
- Inclusion of the PV-System into forecast and tools for energy management

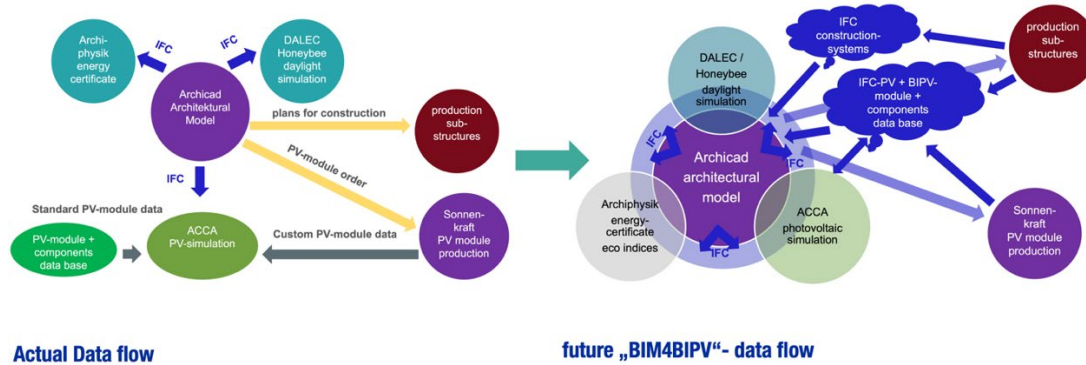
To achieve the project goal, it is necessary to identify interfaces, standards, tools and information needed to generate BIPV-BIM-elements and to use them for interdisciplinary planning, visualization, simulation, facility management and reuse and circularity or disposal. The digital prototypes shall be tested and optimized on exemplary planning tasks.

The overall expected result is the contribution to the development of an open BIM-IFC Data-Template, which enables the worldwide generation and use of interdisciplinary data of BIPV-elements.





## DATA FLOW IN BIPV / PV-SIMULATION AND PROJECT PLANNING



**Goal: Planning of Photovoltaic systems / BIPV directly in the architectural model with BIM-solar moduls with complex informations suitable for PV-, energy- and daylight simulation , calculation of energy certifiactes and eco balances, architectural design, visualization and use of the model for energy management, operation, maintenance, repair, reuse, disposal and circularity**

BIM4BIPV

Quelle Graphik: BIM4BIPV – Astrid Schneider, TU Wien

FFG

**Figure 30**

The project partners are coming from the different disciplines: PV-simulation (ACCA software), Daylighting (Bartenbach), Energy certificate / building physics (Archiphysik), Solar Module production (Kioto Photovoltaics – today renamed “Sonnenkraft GmbH”), Architecture (Treberspurg and Partners), IFC-BIM-standardization (buildingSMART), education of architects and engineers and research (TU Wien faculty of architecture and faculty of civil and environmental engineering: institute for digital construction processes). In collaboration with stakeholder groups – as represented in “buildingSMART”, and the IEA PVPS Task 15 – a worldwide effort shall be made to develop an accepted and coordinated data format (data template) for IFC-BIPV-BIM-elements. The software of the project partners who are already working in the above-mentioned disciplines shall be adapted and tested regarding interoperability. The purpose is that architects and engineers can plan their buildings, urban infrastructure, Agri-PV or even greenfield systems with PV-modules as integral part of their detailed construction planning. Professional CAD-tools are as well much more capable of precise planning than PV-tools used today. The PV and BIPV-modules shall be placed by the planners with their different BIM authoring software directly into place within their BIM-designs and constructions. By using a worldwide standardized IFC- / BIM-format it shall be enabled, that BIPV- and PV-module producers provide IFC-models of their products, which can be directly used by drag and drop in the planning. Worldwide databases as in use today for PV-system planning and simulation can then evolve based on the IFC-format to be widely used. As BIM will be the planning standard of the future in construction and infrastructure the generation of a common data open BIM-standard for PV / BIPV will be useful. The mostly geometrically complex models incorporating the PV-modules can then be used to carry out PV-system, energy, daylighting and other disciplines planning and simulation directly with the construction model developed in the authoring software, as it already contains the relevant interdisciplinary information.



## 9 OUTLOOKS FOR BIM-BASED BIPV PROCESS AND PRODUCTS

### Highlights:

- Preliminary inputs for BIPV product data management in a BIM-based approach and recommendations for further BIM/BIPV research regarding digital product data models, pre-normative recommendations, and standards
- Geometrical and informative parameters to support LOIN definition.

### 9.1 Inputs for BIM-BIPV product standardization

As introduced in chapter 4, it arises that some BIM libraries provide BIPV products, among other objects. However, the level of geometric and informative data associated to these BIM objects is usually low and can significantly differ depending on the BIM object producer since there is not a clear standardization. In addition to this, BIPV products properties and characteristics can be defined with different nomenclature, and different data dictionaries seem to be present.

Furthermore, considering that BIPV products are not only electrical devices but also building components that require to fulfill construction performances in accordance with their use and application in the building envelope, it arises that a product data template should be defined for this type of product to enable their efficient BIM digitalization. Specifically, such a product data template should refer both to IEC and construction standards, in accordance with the existing standards ISO 23386 and ISO 23387. In this way, information about digital products could be shared without ambiguous terms and properties.

The below image shows a possible example of how a BIPV cladding data template can be developed in accordance with current standards and state of the art. BIPV elements and related components should firstly be identified with non-ambiguous terms, as well as properties.

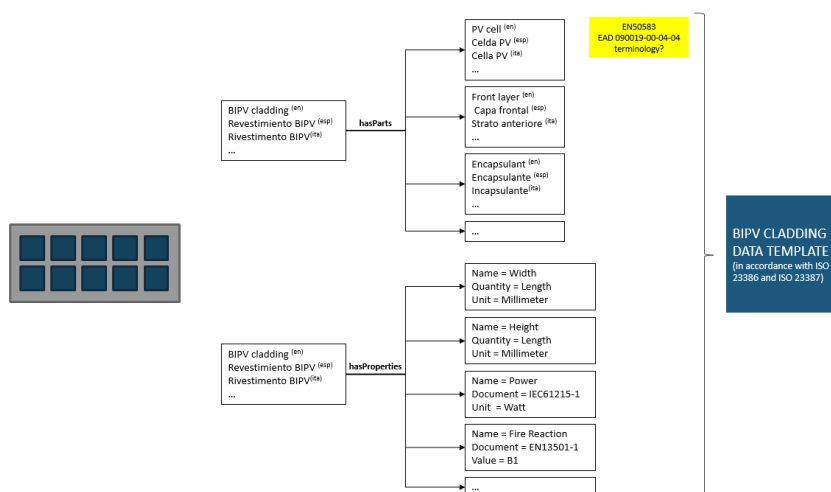


Figure 31. Example for setting up a data template for a BIPV cladding template.



It can be easily understood that this is only a preliminary step in the definition of a data template for a BIPV object. Indeed, this example is intended to provide some inputs for the discussion that should be made between BIPV stakeholders, BIM actors and standardization bodies (both in the field of construction and electrical devices). Only through multidisciplinary discussion it will be possible to develop an efficient and useful data template for the large variety of BIPV products.

## 9.2 Inputs for LOIN definition strategy of BIM-BIPV objects in the BIPV process stages

As introduced in previous chapter, the introduction of the **Level of Information Need (LOIN)** in the EIR provides clients with a methodology to define the prerequisite of a BIM project and its objects by identifying the information to be delivered at the different process stages, considering geometry, alphanumeric data, and documents. The definition of prerequisite is an essential step to ensure that client needs are efficiently included in the next stages of the BIM process and, specifically, in the BIM Execution Plan. The LOIN concept intrinsically refers to the concepts of LOI and LOG for each construction component that should satisfy the request of information made with LOIN and should be specified by the contractor in the BIM Execution Plan for a specific BIM project.

Guidelines for BIM-BIPV objects can be developed to support the LOIN definition for such building components in the building project. Starting from the EN 17412-1 and the Digital Adoption Plan BIPVBOOST (SUPSI 2019), an example of definition of the LOIN for a BIPV cladding object in the developed design stage is shown in the below table. This table is developed starting from the framework provided by the EN 17412-1 and it is filled in as an example for the developed BIPV project stage.

**Table 7. Example of LOIN definition for the developed BIPV design stage, based on the framework of the EN 17412-1**

Delivery milestone:	Developed BIPV project stage
<b>Scope:</b>	Coordination
<b>Actor:</b>	BIPV consultant
<b>Object:</b>	BIPV cladding
<b>Geometric information</b>	
• <b>Detail:</b>	Detailed geometry (e.g., referring to a generic LOG300)
• <b>Dimensionality:</b>	3D
• <b>Position:</b>	Related to other objects, such as mullions of the substructure
• <b>Aesthetical appearance:</b>	Consistent colour of materials
• <b>Parametrization:</b>	Partial (e.g., only some characteristics can be parametrized instead of the whole geometry)
<b>Alphanumeric information</b>	



• <b>Identification:</b>	Cladding type (unique designation or key that allows clearly identifying the object)
• <b>Informative content:</b>	Depending on attributes and properties of the cladding type (e.g., in IFC) <ul style="list-style-type: none"> <li>- Electrical data</li> <li>- Manufacturer data</li> <li>- Geometric data</li> <li>- Materials</li> <li>- Thermal properties</li> </ul>
<b>Documentation</b>	
• <b>Set of documents:</b>	IEC certifications, BIPV analysis report, BIPV product datasheet

The provided example is not intended to be exhaustive and does not cover all possible scenarios that can rise in a real BIM-BIPV project. It serves as a starting point in the current standard scenario to facilitate the potential benefit of LOIN also for the BIM-BIPV project and products.



## 10 CONCLUSIONS

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Digitalization in the AEC sector is gaining more and more attention because it offers numerous benefits, including reduced project delays, improved cost control, enhanced collaboration and better decision-making not only in the initial stages of the project but also during its operation. In this context, BIM represents a starting point of the digitalization of the AEC sector. This involves that the realization of buildings, including BIPV buildings, should be coherent with the BIM approach. For this reason, the goal of this report was not only to give an overview of the **potential of BIM for the BIPV process and products**, but also to present existing **BIM-based workflows and tools**, as well as available **BIM-BIPV objects and products**.

From this review of the state of art about normative efforts and standards, and from the analysis of the state of play about BIM-BIPV tools and products, it arises that BIPV processes and products are currently in an initial stage. Indeed, even though different BIPV processes, workflows, tools, and products have been developed recently to allow designing BIPV as part of the BIM process, it emerges that **there is a huge need for BIM standardization of the BIPV products and processes**. This is partially due to the continuous changing scenario related to international standards and approaches. However, **this lack of definition and standardization** at the international (and sometimes national) level **can be an opportunity for the BIPV process, tools, and products to be included in the BIM discussion**. Indeed, it is fundamental that BIPV stakeholders, BIM actors and standardisation bodies will work together to find out common strategies for BIM-BIPV approaches.

This report concludes with some **outlooks for future multidisciplinary discussions that could support the adoption of BIM also for BIPV**. Specifically, some examples and inputs have been identified with specific regard to the BIM-BIPV product standardization, the development of BIM-BIPV tools and their interoperability of workflows, and the definition of LOIN for BIM-BIPV products. These aspects are not intended to be exhaustive but are aimed at identifying a starting point to facilitate the discussion for future development and implementation of BIM-BIPV approaches.

IEA Task 15 will focus on the next phase from 2024-2027 with the Subtask of Digitalization on the development of a proposal to develop an IFC-standard representation for BIPV-products and systems as an input to a smooth integration of PV and BIPV into digitally designed construction processes based on BIM.



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