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Standardization needs for BIPV

Project report

CEA, Tecnalia, CTCV

September 2016

Document summary

This document describes the results of analysis activities performed in Task 1.3 of the PVSITES project in order to define standard tests needed for the fourteen (14) BIPV products to be developed in the framework of the project prior to their market introduction. A listing and a comprehensive analysis of standards concerning BIPV products is proposed. The main standards addressing BIPV systems are included from existing standards related to construction and photovoltaic sectors to the new BIPV standard EN 50583 (Photovoltaics in buildings) final content. This new standard consists mainly in a compilation and a modification of existing standards related to BIPV. Thus, the in-depth analysis focuses on synergies and deviations between existing and new standards. Also, starting from EN 50583 standard, the suitability of these standards application to BIPV products based on crystalline silicon (WP3) and thin-film (WP4) photovoltaic (PV) modules as well as to inverters (WP5) is assessed in order to identify and propose when necessary new complementary kind of tests. Based on this analysis, a specific testing plan to be applied to each BIPV product is proposed after identifying the modifications planned to increase its TRL level. The testing plan provides sequences of tests to be performed in order to assess the compliance with standards. The final goal is to ensure long term reliability and performance of the BIPV products.

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The present report was mainly prepared by PVSITES project partner CEA, with additional contributions from Tecnalia and CTCV. The report was originally submitted to the European Commission as Project Deliverable D1.3 in June 2016.

Disclaimer

About the PVSITES project

PVSITES is an international collaboration co-funded by the European Union under the Horizon 2020 Research and Innovation program. It originated from the realisation that although building-integrated photovoltaics (BIPV) should have a major role to play in the ongoing transition towards nearly zero energy buildings (nZEBs) in Europe, the technology in new constructions has not yet happened. The cause of this limited deployment can be summarised as a mismatch between the BIPV products on offer and prevailing market demands and regulations.

The main objective of the PVSITES project is therefore to drive BIPV technology to a large market deployment by demonstrating an ambitious portfolio of building integrated solar technologies and systems, giving a forceful, reliable answer to the market requirements identified by the industrial members of the consortium in their day-to-day activity.

Coordinated by project partner Tecnalia, the PVSITES consortium started work in January 2016 and will be active for 3.5 years, until June 2019. This document is part of a series of public reports summarising the consortium's activities and findings, available for download on the project's website at www.pvsites.eu.

The PVSITES consortium:

Tecnalia Research & Innovation	CTCV	FormatD2
Onyx Solar	Flisom	Vilogia
BEAR-iD	Cricursa	R2M Solution Research to Market
Nobatek	CEA	CADCAMation
Film Optics	Acciona Infraestructuras	WIP - Renewable Energies

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1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

This document summarises the activities performed in task 1.3 by CEA, TECNALIA and CTCV from month 1 to month 6 regarding the definition of the most effective test sequences for PVSITES BIPV products.

The most relevant laboratory tests needed to evaluate the performance of thirteen (13) BIPV products defined within the project, after the modifications to be performed in order to enhance their TRL level are defined and analysed. Standards in Europe applicable to BIPV systems are considered, from existing standards related to construction and photovoltaic sectors to the new BIPV standard EN 50583 (Photovoltaics in Buildings) final content. The suitability of these standards for application to BIPV products based on crystalline silicon photovoltaic (PV) modules (task 3.1 to task 3.5) and thin-film PV modules (task 4.1 and task 4.2) as well as to inverters (task 5.2 and task 5.3) is evaluated in order to identify and propose when necessary new complementary kind of tests.

The various modifications planned to increase each product TRL level are detailed, providing an optimal starting point to define the specific testing plans to be applied. Tests requirements are evaluated in order to define the most demanding tests to ensure BIPV products long term reliability and performance.

As a result, a specific test sequence is provided for each BIPV product, together with the necessary samples, estimated testing time and reference partner for the testing activities. This deliverable is therefore a key reference for tasks 3.7 and 4.4. This early definition of the standardization needs and specific requirements to be subjected to testing may also guide the manufacturers during the development phase.

1.2 Reference material

Not applicable

1.3 Abbreviation list

BIPV: Building-integrated photovoltaics

C-Si: Crystalline silicon

CIGS: Copper-Indium-Gallium-(Di) Selenide

CWCT: Centre for Window and Cladding Technology

EAD: European Assessment Documents

EN: European standard

IEC: International Electrotechnical Commission

ISO: International Organization for Standardization

IGU: Insulating glazing unit

PV: Photovoltaic

TRL: Technology Readiness Level

2 TECHNICAL RESULTS

2.1 Introduction

In order to be suitable for building integration, photovoltaic (PV) products have to satisfy both the standards of PV sector and construction sector. The requirements of these standards are most of the time related to a country or a region. Thus, a manufacturer producing a BIPV product could have to comply with different standards according to the countries of application.

In this document, considering the demonstration sites and countries involved in PVSITES project, a comprehensive analysis of main standards related to BIPV products is performed including construction and photovoltaic sectors standards as well as the EN 50583 standard (Photovoltaics in Buildings) final content. The new standard EN 50583 consists mainly in a compilation of existing standards related to BIPV with some modifications. Starting from this standard, the suitability of the application of existing standards to the type of product (BIPV modules and inverters), of PV technologies (c-Si and thin film PV modules), of integration configurations (opaque roofs, ventilated façades, curtain walls, skylights, etc.) and of integration geometry (flat or curved) to be developed within the project are examined. The results of this analysis have permitted to propose testing plans and complementary tests in order to ensure the compliance with most relevant certification requirements.

Tests sequences are defined for 13 of the 14 products to be developed within PVSITES project. Product #11 is foreseen only at design stage and will not be tested within the project. Table 2.1 includes these products, each of which has been given a code (consistently with deliverable 2.1).

Table 2.1: BIPV products to be developed within the PVSITES project

Code	Product	Developer
X1/X3	CIGS roofing shingle on metal substrate	Flisom
X2	CIGS large area flexible roofing membrane and bendable elements	Flisom
X4	CIGS large area elements on metal substrate	Flisom
X5	C-Si glazed products with hidden bus bars and L interconnections	Onyx
X6	Glass-glass products with back contact c-Si cells	Onyx
X7	Curved glass-glass, CIGS technology	Onyx
X8	Framing systems for c-Si large area glass	Onyx
X9	C-Si semi-transparent low concentration and solar control BIPV system – skylight configuration	Onyx, Tecnalia, Film Optics

X10	C-Si semi-transparent low concentration and solar control BIPV system – façade configuration	Onyx, Tecnalia, Film Optics
X11	C-Si semi-transparent low concentration and solar control BIPV system – shading element configuration	Onyx, Tecnalia, Film Optics
X12	Glazed modules treated for improved passive properties	Onyx
X13	Low cost, flexible, DC coupled PV storage inverter	Tecnalia
X14	Single-stage SiC technology based PV inverter	CEA

2.2 Qualitative analysis of standards

2.2.1 Overview of existing standards

2.2.1.1 Existing standards in the construction sector

In this subsection, the main standards used for PV modules certification related to construction sector are analysed:

- Glass standards (insulated glazing units –EN 1279 series-, laminated glass –EN 14449 and EN 12543 series- and curved glass –ISO 11485 series-)
- Curtain wall standards (EN 13830)
- Ventilated façades (ETAG 034)
- Fire classification - external fire exposure to roofs tests (EN 13501-5)
- Test methods for external fire exposure to roofs (EN 1187)
- Roof coverings - Classification, requirements and test method (EN 14963)
- Prefabricated accessories for roofing - Product specification and test methods (EN 1873)
- Transversal standards (EN 13501-1, EN 410, EN 673, EN ISO 6946 and EN 12600)

2.2.1.1.1 Glass standards (insulated glazing units, laminated glass and curved glass)

Standards of this group refer to glazing systems. The types of glass considered in these standards are:

- Insulating glazing units (IGU) (EN 1279-1 to 6)

- Laminated glass (EN 14449 and EN ISO 12543-1 to 6)

- Curved glass (ISO 11485-1 to 3)

EN 1279-5:2006 standard (Glass in building – Insulating glass units- Part 5: Evaluation of conformity) applies to IGU and specifies requirements, conformity evaluation and factory production control of insulating glass units for use in buildings. For glass products with electrical wiring or connections (as is the case of PV modules), other directives (e.g. Low Voltage Directive) apply. The main intended uses of insulating glass units are installations in windows, doors, curtain walling, roofs and partitions where there is protection against direct ultraviolet radiation at the edges. In cases where there is no protection against direct ultra-violet radiation at the edges such as structural sealant glazing systems, additional European technical specifications should be followed (e.g. EN 15434, EN 13022-1). EN 1279-5 is supported by EN 1279-1 to 4 and 6 standards, in which the specific testing procedures applicable to IGUs are described (mainly humidity penetration, gas leakage rate and gas concentration, edge sealing).

EN 14449:2006 standard (Glass in building – Laminated glass and laminated safety glass – Evaluation of conformity / Product standard) covers the evaluation of conformity and the factory production control of laminated glass and laminated safety glass for use in buildings. This standard includes references to testing standards for laminated glass.

ISO 12543 series provides specific testing method for laminated glass and consists of the following parts, under the general title “Glass in building - Laminated glass and laminated safety glass”:

- Part 1: Definitions and description of component parts
- Part 2: Laminated safety glass
- Part 3: Laminated glass
- Part 4: Test methods for durability
- Part 5: Dimensions and edge finishing
- Part 6: Appearance

ISO 11485 consists of the following parts, under the generic title “Glass in building - Curved glass”:

- Part 1: Terminology and definitions
- Part 2: Quality requirements
- Part 3: Requirements for tempered and laminated curved safety glass

Part 3 of this standard provides a reference for the testing of fragmentation and impact resistance of curved toughened laminated glass. In the case of impact resistance, a standard is ongoing and currently there is no available test procedure. However, EN 12600 standard (Glass in building - Pendulum test - Impact test method and classification for flat glass)could be used on equivalent flat glass and although this standard doesn’t present any additional requirement, it must be referred as the one related specifically with curved glass (see section 2.2.1.2.7).

2.2.1.1.2 Curtain wall standards (EN 13830)

EN 13830 specifies requirements for curtain walling kits intended to be used as a building envelope to provide weather resistance, safety in use and energy economy and heat retention, and provides test/assessments/calculation methods and compliance criteria of the related performances. This standard applies to curtain walling kits ranging from a vertical position to ± 15° from the vertical. Any sloping parts should be contained within the curtain walling kit. The standard is applicable to the whole of the curtain walling kits, including the fixings. Curtain walling according to this standard is intended to be used as part of the building envelope.

This European Standard does not include:

- Patent glazing (glazed sloping roofs) kits;
- Roof glazing constructions;
- Façades made of precast concrete panels as part of the wall (see EN 14992 standard).

NOTE 1: Precast concrete panels may be used in curtain walling kits as infill panels.

NOTE 2: Durability of structural sealed glazing infills is not covered by this standard.

NOTE 3: This standard doesn't apply to skylight products.

2.2.1.1.3 Ventilated façades (ETAG 034)

This guideline covers kits for vertical exterior wall claddings consisting of an external cladding, mechanically fastened to a framework (specific to the kit or not), which is fixed to the external wall of new or existing buildings (retrofit). An insulation layer is usually fixed on the external wall. The substrate walls are made of masonry (clay, concrete or stone), concrete (cast on site or as prefabricated panels), timber or metal frame. Insulation material is defined in accordance with an EN standard or an ETA (European Technical Assessment). Between the cladding elements and the insulation layer or the external wall accordingly, there is an air space which shall always be drained and may be ventilated or not. The cladding elements can be made of for example wood based panels, plastic, fibre cement, fibre reinforced cement, concrete, metal, laminate panels, stone, ceramic or terra cotta tiles. They are attached to the external wall using a subframe, which is made of timber or metal (steel, stainless steel or aluminium). They are usually assembled according to a specific technical design for joints and construction discontinuities, which forms part of the product description. The claddings are non-loadbearing construction elements. They do not contribute to the stability of the wall on which they are installed. The claddings will normally contribute to durability of the works by providing enhanced protection from the effect of weathering. They are not intended to ensure airtightness of the building structure. The cladding kits do not contain windows or doors.

Part I

Part I of the guideline covers only the external claddings and associated mechanical fixings intended to be used with a ventilated air space. Forming the kit are the cladding elements and their fixing devices (which fasten the cladding elements to the framework).

Part II

Part II of the guideline covers the kit of all the components of claddings (external cladding element and their fixing devices, the subframe and their fixings to an external wall, and any insulation layer) intended to be used with an air space, ventilated or not.

2.2.1.1.4 Fire classification - external fire exposure to roofs tests (EN 13501-5)

This European Standard provides the fire performance classification procedures for roof/roof coverings exposed to external fire based on the four test methods given in CEN/TS 1187:2012 and the relevant extended application rules. For the classification of a roof/roof covering, only those test methods and those application rules need to be applied for which the corresponding classification is envisaged. Products are considered in relation to their end use application.

2.2.1.1.5 Test methods for external fire exposure to roofs (EN 1187)

This European Standard specifies four methods for the determination of the performance of roofing systems against external fire exposure. Fire propagation through the external surface, propagation towards the internal side of the roof, fire penetration and production of flammable particles or melted material.

2.2.1.1.6 Roof coverings - Classification, requirements and test method (EN 14963)

This European Standard specifies requirements for continuous rooflights made of plastic materials (e.g. GF-UP, PC, PMMA, PVC) with or without bearing profiles to be used with upstands made of for example GF-UP, PVC, steel, aluminium, wood or concrete, for laying in roofs, which serve the purpose of lighting by means of daylight and, possibly, of ventilating interior spaces by means of opening devices. The standard applies to continuous rooflights without upstand. It also applies to continuous rooflights, where a single manufacturer provides all components of the rooflight with upstand, which are bought in a single purchase. Products covered by this European Standard may be supplied as continuous rooflights with and without upstand and rooflights intended to be used with an upstand, for which the upstand is specified, but not supplied.

2.2.1.1.7 Prefabricated accessories for roofing - Product specification and test methods (EN 1873)

This European Standard specifies requirements for rooflights made of plastic materials (e.g. GF-UP, PC, PMMA, PVC) and rooflights with upstands made of for example GF-UP, PVC, steel, aluminium or wood for installation in roofs. These rooflights serve the purpose of introducing daylight. This European Standard applies to rooflights with a rectangular or circular ground plan. This European Standard applies to rooflights and rooflights with upstand, where a single manufacturer provides all components of the rooflight with upstand, which are bought in a single purchase. This standard applies to rooflights with one or several translucent parts. Rooflights may be opened by means of opening devices in one or more parts for ventilation.

2.2.1.1.8 Transversal standards (EN 1991-1-3 and 4, EN 13501-1, EN 410, EN 12600, EN 673, EN ISO 6946, EAD 220025-00-0401 *and CWCT Technical note 67).*

EN 1991 Eurocode 1 – Actions on structures – Part 1-3: General actions: snow loads, gives design guidance and actions from snow for the structural design of buildings and civil engineering works. The standard provides guidance to determine the values of loads due to snow.

EN 1991 Eurocode 1 – Actions on structures – Part 1-4: General actions: wind actions, gives design guidance and actions for the structural design of buildings and civil engineering works for wind. The standard provides guidance on the determination of natural wind actions for the structural design. This includes the whole structure or parts of the structure or elements attached to the structure, e.g. components, cladding units and their fixings, safety and noise barriers.

EN 13501-1 standard provides the reaction to fire classification procedure for all construction products, including products incorporated within building elements. Products are considered in relation to their end use application. This document applies to three categories, which are treated separately in this European Standard:

- Construction products, excluding floorings and linear pipe thermal insulation products;
- Floorings;
- Linear pipe thermal insulation products.

EN 410 standard specifies methods for the determination of luminous and solar characteristics of glazing of buildings. These parameters can be used as basis for light, heating and air engineering calculations used. They allow the comparison between different glazing systems. This European Standard is applicable to both conventional glazing and to absorbing or reflecting solar control glass, used in vertical or horizontal light openings. The appropriate equations for single, double and triple glazing are given.

EN 12600 standard or Pendulum Test is the standard for classifying flat glass products by performance under impact and by mode of breakage. It is similar to the previously used swing bag test whereby a weight cushioned with two rubber tyres is allowed to swing at the glass from 3 heights. The classification has three components:

- The first component is the drop height class (i.e. 1, 2 or 3) at which the product did not break or broke in accordance with two types of breakage.

- The second component is the mode of breakage defined as:

    - TYPE A: numerous cracks appear forming separate fragments with sharp edges, some of which are large, typical of annealed glass.

    - TYPE B: numerous cracks appear, but the fragments hold together and do not separate, typical of laminated glass.

    - TYPE C: disintegration occurs, leading to a large number of small particles that ar relatively harmless, typical of toughened glass.

- The third component is the highest drop height at which the product did not break or when it broke, broke in accordance with TYPE B.

EN 673 standard specifies a calculation method to determine the thermal transmittance of glazing with flat and parallel surfaces. This European Standard applies to uncoated glass (including glass with structured surfaces, for example patterned glass), coated glass and materials not transparent in the far infrared (which is the case for soda lime glass products, borosilicate glass and glass ceramic). It applies also to multiple glazing comprising such glasses and/or materials. It does not apply to multiple glazing which include in the gas space sheets or foils that are far infrared transparent. The procedure specified in this European Standard determines the U value (thermal transmittance) in the central area of glazing. The edge effects due to the thermal bridge through the spacer of a sealed glazing unit or through the window frame are not included. Furthermore, energy transfer due to solar radiation is not taken into account. In order to apply this standard to glazing systems containing PV cells, slight modifications on the U value calculation are needed, in order to account for the modified conductivity of the system.

EN ISO 6946 international standard provides a method for the calculation of the thermal resistance and thermal transmittance of building components and building elements, excluding doors, windows and other glazed units, curtain walling, components which involve heat transfer to the ground, and components through which air is designed to permeate. The calculation method is based on the appropriate design thermal conductivities or design thermal resistances of the materials and products for the application concerned. The method applies to components and elements consisting of thermally homogeneous layers (which can include air layers up to 0.3 m thickness).

EAD 220025-00-0401 text (Cantilevered structural horizontal glazing – structural glass canopy/roof- is not publicly available yet, but it has been included in the sequences following Tecnalia know-how and internal access to the text as a suitable option for the affected product.

CWCT Technical note 67 is a test sequence for testing fragility of glazed roofs. It is applied to the whole assembly, consisting on the glass, supporting structure, fixing, glazing materials and all other components other than any single component.

2.2.1.2 Existing standards in PV sector

In this subsection, the main standards used for PV and CPV (concentrator photovoltaic) modules certification related to photovoltaics and electricity are analyzed:

- EN 61215 standard "Crystalline silicon terrestrial photovoltaic (PV) Modules - Design qualification and type approval" and EN 61646 "Thin-film terrestrial photovoltaic (PV) Modules - Design qualification and type approval".

- EN 61730-1 and EN 61730-2: "PV module safety qualification".

- EN 62108: "Design qualification and type approval of CPV modules and assemblies."

2.2.1.2.1 EN 61215 - EN 61646

Specificities (see description in deliverable D1.2)

EN 61215 standard "Crystalline silicon terrestrial photovoltaic (PV) Modules - Design qualification and type approval" and IEC 61646 "Thin-film terrestrial photovoltaic (PV) Modules - Design qualification and type approval" include the examination of all parameters which are responsible for the ageing of PV modules and describe the various qualification tests to be applied to PV modules to ensure their performance and to comply with certification requirements. They include radiation testing, thermal testing and mechanical testing.

Impact of modifications to be performed on the products in order to enhance their TRL level

In the following PV modules configurations, additional tests are not necessary: (TUV, 2016)

- *Tested model ;*
- *All models with same number of cells but with power output +/-10% respect to the tested model;*
- *All models with less cells or smaller cells respect to the tested model, if they are assembled with exactly the same list of materials;*
- *The PV modules certification is valid for the tested modules with a defined list of materials (BOM). The materials that are subject to retest are: cells; front glass (or generally any front cover material); backsheet (or generally any rear cover material); EVA (or generally any encapsulation material); frame and sealant/adhesive.*
- *Junction box, cables and connectors and sealant / adhesive / pottant;*
- *Interconnection and soldering material.*

2.2.1.2.2 EN 61730-1 and -2 Photovoltaic (PV) module safety qualification

EN 61215 and EN 61646 standards only take into account some aspects of electrical, mechanical and fire safety. Thus, to complete these tests, it is relevant to consider EN61730 standard safety requirements.

Specificities

The standard EN 61730 is required for CE marking of the PV module. It is identical to the IEC 61730 standard "Photovoltaic (PV) module safety qualification" with the exception of fire test and some minor modifications.

This standard is composed of two main parts:

- Part 1: requirement for construction;

- Part 2: requirement for testing.

In the two parts, PV modules applications are organized in three classes A, B and C equivalent to safety class II, 0 and III (see EN 61140 standard).

- Class A: general application with maximum system voltage greater than 120 VDC with no restricted access to the modules (satisfying safety requirements of class II);

- Class B: application with restricted access to the modules (satisfying safety requirements of class 0);

- Class C: low voltage application with maximum system voltage lower than 120 VDC with no restricted access to the modules (satisfying safety requirements of class III).

- Part 1: requirement for construction:

This part defines requirements for the design of the modules (small components, wiring, electrical connection, grounded connectors, wall thickness of the junction boxes, minimum distances of conductive parts from the module edges), for physical/chemical (UV-stability, thermal index, safety class…) properties of the polymeric materials (of PV modules active parts and external envelope) used on the modules as well some requirement of the documentation and labelling of the PV modules.

- Part 2: requirement for testing:

This part of the standard defines some particular additional tests to validate the electrical and mechanical safety of the modules during lifetime according to the three classes of application A, B and C. It describes requirement tests against electrical shock hazard, fire hazard, mechanical and structural safety.

The objective of this part is to provide tests sequence in order to validate safety of PV modules that have passed tests of EN61730-1 for construction aspects (See overview of EN61730 tests in annex 1.). These tests are performed both on six (6) complete PV modules and a complete frameless PV module as well as on individual module components (11 pieces of foil, 1 junction box and on 6 knockouts). The PV modules should be selected at random from various lots of products accordingly to CEI 60410 standard requirements. They should have passed the requirements of CEI 0364-5-51 standard and be adapted for operating in AB8 type environmental conditions.

Remark: This standard is defined in order to permit the combination of its tests sequence with tests sequences of EN 61215 and EN 61646 standards. Thus, performance and safety standards tests can be realized on the same samples. As example, EN 61730-2 proposes a test sequence using EN 61215 and EN 61646 standards for preconditioning tests (environmental tests: thermal cycling, humidity freeze test, damp heat and UV-exposure test) even if it doesn't cover all safety aspects (E.g. electrical shock hazard in a damaged PV module in a high voltage system is not considered).

This standard cannot be applied to AC PV module with inverter CE.

The product could obtain a test certificate (with a validity of 5 years) if all relevant requirements of EN 61730 – 1 and EN 61730 –2 tests are satisfied.

<u>**Impact of modifications to be performed on the products in order to enhance their TRL level : (Solar, 2009)**</u>

According to the standard specifications, all significant modifications concerning design or configuration of electrical or mechanical elements of a PV module which had already passed certification of EN61730-1 and tests of EN 61730-2, will lead to new controls in order to define the effects of these modifications. A supplementary test according to standard EN 61730-2 may be necessary.

Additional tests are not necessary in the following case:

- Tested model;

- All models with same number of cells but with power output +/-10% respect to the tested model;

- All models with less cells or smaller cells respect to the tested model, if they are assembled with exactly the same list of materials.

2.2.1.3 Existing standards on concentrator photovoltaics (CPV) (IEC 62108 and IEC 62688)

Specificities (Robusto and Rai, 2013)

IEC 62108 is related to design qualification and type approval of CPV modules and assemblies suitable for outdoor applications. It is based on IEC 61215(2005) standard (qualification of crystalline silicon terrestrial PV modules) comprising electrical, thermal and mechanical tests in order to validate the capacity of CPV product to withstand long period sun exposure. Nevertheless, some modifications have been added. The standard tests are realized partially indoor and outdoor. Effects of tracking alignment, high current density and rapid temperature changes are taken into account.

Tests are realized on samples of seven (7) to nine (9) CPV modules and one or two receivers according to the kind of system (non-field adjustable or field-adjustable focus-point). Prior to testing, samples have to be exposed to direct normal irradiation (DNI) of 5 to 5.5 kWh/m² (outdoor or with solar simulator). In this standard, all electrical data are measured with a DNI of 900W/m², a cell temperature of 25°C, an air mass of 1.5D (under consideration) and a maximum wind velocity of 3 m/s. During tests, CPV modules are randomly divided into seven (7) groups from A to F as well as a “control” group which indicates the test sequence to perform (see CPV test sequence in annex 1).

IEC62108 standard is the most complete standard concerning CPV products including both performance and safety tests. Thus, CPV have mainly to comply with its requirements during certification tests. Nevertheless, it could be completed with IEC62688 standard (Concentrator photovoltaic (CPV) module and assembly safety qualification) which comprises additional safety tests such as *reverse current overload, CPV temperature tests, CPV electrical parameters, dielectric voltage-withstand test, impulse voltage, sharp edges and accessibility*.

This standard has to be applied to the semi-transparent low concentration BIPV products (see task 3.1 of work programme) to be developed within the project.

Impact of modifications

All or part of standard tests should be repeated in case of modifications in the design, in materials, in components or in manufacturing method of CPV modules. Thus, an agreement could be made between the certification body and the component producer in order to define tests to be applied instead of the whole tests sequence. No more details are indicated in the standard.

2.2.1.4 New standard EN 50583 final content

EN 50583:2016 standard for BIPV modules and systems was published on January 18th 2016 in English and French. The standard has two parts:
- Photovoltaics in buildings – Part 1: BIPV modules

- Photovoltaics in buildings – Part 2: BIPV systems

It is not a harmonized standard (it does not include a ZA annex) and it is not mandatory. It does not imply an associated CE marking.

EN 50583: 2016 – Part 1

Part 1 applies to photovoltaic modules used as construction products. It focuses on the properties of PV modules which are relevant to the essential building requirements as specified in the Construction Product Regulation CPR 305/2011, and the applicable electro-technical requirements as stated in the Low Voltage Directive (LVD) 2006/95/EC or CENELEC standards. According to EN 50583 part 1, *BIPV modules are considered to be building-integrated if the PV modules form a construction product providing a function as defined in CPR 305/2011. Thus,* ***the BIPV module is a prerequisite for the integrity of the building's functionality****. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent construction product), the PV module would have to be replaced by an appropriate construction part.*

The fact that BIPV modules have to comply with requirements from two separate backgrounds (CPR and LVD) has led EN 50583 to be structured in three hierarchic levels of requirements.

Top level:

1) The electrical requirements are relevant for **all** kinds of BIPV modules **regardless** of their technology **and** composition.

2) The building related requirements are differentiated **regardless** of their technology **but** depending on **whether** the modules do **contain glass or not**.

Second level:

1) **Only for the modules that do contain glass**, general requirements for all modules regardless of their location within the building are formulated.

2) **Only for the modules that do not contain glass,** requirements are formulated regardless of their location within the building but according to their backsheet (water proofing polymer or metal sheet).

Third level:

Only for the modules that do contain glass, the categories A to E are specified that differentiate additional requirements for the modules according to the location within the building in which they are intended to be used.

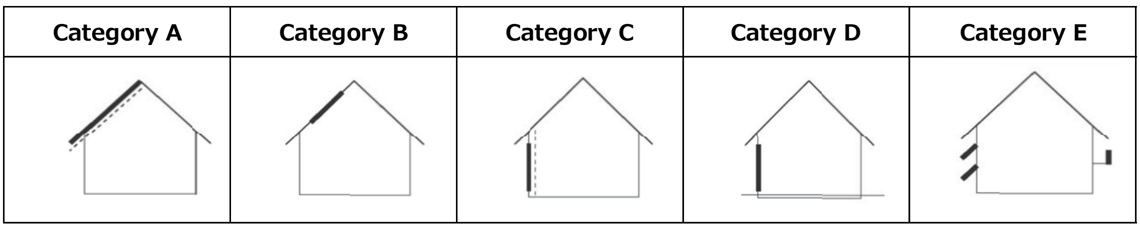

Figure 2.1: Mounting categories A-E as defined in EN 50583 standard.

The electrical and building requirements assigned by the standard in the different levels refer to CENELEC and CEN standard. Specific provisions regarding structural and rigidity calculations, post-breakage integrity tests and thermal calculations are given in Annex A of the standard.

EN 50583:2016 – Part 2

Part 2 defines photovoltaic systems as building-integrated, *if the PV modules they utilize fulfil the criteria for BIPV modules as defined in EN 50583-1 and thus form a construction product providing a function as defined in the European Construction Product Regulation CPR 305/2011.* PV systems covered by part 2 of the standard are subjected to the same hierarchy levels as PV modules (see part 1). For systems containing glass, the mounting categories are the same as those defined in part 1 of the standard. The electrical and building requirements assigned by the standard in the different levels refer to CENELEC and CEN standard. Part 2 of EN 50583 standard includes in Annex A, a specific test for BIPV roofs in category A (therefore only modules containing glass). The test evaluates the resistance to wind-driven rain of a BIPV pitched roof system including a kit of discontinuously laid BIPV modules in combination with adjacent mounting-relevant fixtures, sealants, joints and connections to regular surrounding roofing/building components. None of the products included in PVSITES is, however, affected by this annex.

In Annex 2 of this deliverable, an exhaustive and schematic analysis of EN 50583, parts 1 and 2, in terms of applicable tests to PVSITES products, is provided.

2.2.1.5 Existing standards on inverters

Concerning inverters, main existing standards are related to safety requirements (IEC 62109), grid-connection requirements (EN 50438 and IEC 62910) and overall efficiency measurement (EN 50530). These standards define testing procedures for the characterization of all these factors in laboratory. Furthermore, new standardization initiatives are arising regarding advanced inverter interoperability functions. The aim of these testing protocols is the validation of the suitable contribution of inverters to safety and security of service in distribution grids by means of communication with DSOs (Distribution System Operators).

2.2.1.5.1 Safety of power converters for use in PV power systems (IEC 62109)

The international standard IEC 62109 contains main safety requirements of power converters for use in PV power systems. Established testing procedures cover diverse aspects like thermal testing, single-fault condition testing, electrical characterization, marking and documentation, environmental requirements (temperature and humidity range, protection degree against penetration of external disturbances, etc.), dielectric strength characterization, fire resistance testing, acoustic level characterization, liquid and chemical risk evaluation, or mechanical resistance.

Its part 2 is related to particular requirements for inverters like array residual current detection, protection against electrical shock, or short-circuit and overcurrent protection.

2.2.1.5.2 Grid-connection requirements (EN 50438, IEC 62910)

EN 50438 describes EU requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks. These requests are overcurrent protection, grounding, grid voltage and frequency operating ranges, power response to over frequency, reactive power capacity and operating modes, reconnection and synchronization, and quality of service (EMC emission and immunity, THD, flicker, and DC current injection). It also includes IEC 62116 describing the test procedure of islanding prevention measures for utility-interconnected PV inverters, which is quite similar to DIN VDE 0126-1-1. Additionally, it includes a list with the particularities of each EU country.

On the other hand, the international standard IEC 62910 defines the test procedure for low-voltage ride-through measurements, which is out of the scope of EN 50438.

2.2.1.5.3 Overall efficiency of grid-connected PV inverters (EN 50530)

This EU standard provides a method for the measurement of the efficiency of the maximum power point tracking (MPPT) of inverters, which are used in grid-connected PV systems. In that case, the inverter energizes a low voltage grid with rated AC voltage and rated frequency. Both the static and dynamic MPPT efficiency are considered. Based on the static MPPT efficiency and conversion efficiency the overall inverter efficiency is calculated. The dynamic MPPT efficiency is indicated separately.

2.2.1.5.4 Advanced Inverter Interoperability Functions

Test Protocols for Advanced Inverter Interoperability Functions proposed by Sandia National Laboratories in 2013 describe test protocols to evaluate the electrical performance and operational capabilities of PV inverters and energy storage, as described in IEC TR 61850-90-7. While many of these functions are not now required by existing grid codes or may not be widely available commercially, the industry is rapidly moving in that direction. Interoperability issues are already apparent as some of these inverter capabilities are being incorporated in large demonstration and commercial projects. The test protocols are intended to be used to verify acceptable performance of inverters within the standard framework described in IEC TR 61850-90-7. These test protocols, as they are refined and validated over time, can become precursors for future certification test procedures for DER advanced grid support functions.

2.2.2 In-depth analysis of requirements (Synergies and deviations, adequacy to project needs and application)

2.2.2.1 Synergies and deviations

In this subsection, an analysis of the various standards tests listed above is conducted in order to highlight main synergies and deviations to consider within PVSITES project and to propose, when necessary, complementary tests for BIPV products to be developed. (See summary of the analysis in annex 2)

- EN 61646 standard is suitable only for flat PV modules. Thus, for curved BIPV products, some complementary tests have to be defined.

- Except, for the low concentration BIPV products, the standards tests related to Photovoltaic sector (qualification (EN 61215, EN 61646) and safety (EN 61730)) are not modified in the new EN 50583 standards. Thus, they could be applied to BIPV products in the project.

- A new version of EN 61215 standard will be released in a few months and will include tests concerning electrical insulation (Dielectric and Potential Induced Degradation (PID) tests), thermal and mechanical effects (Dynamic Mechanical Loads (DML) tests).

- In EN 61730 standard, the IEC 60364-5-51 standard is used as reference (electrical installation in buildings- part 5-51: Selection and erection of electrical equipment: Common rules). But in EN50583, the HD 60364-7-712 is used as reference (Requirements for special installations or locations: Solar photovoltaic (PV) power supply systems).

- National regulations are defined in order to comply with common objectives of IEC 60364. This standard is an attempt to harmonize national wiring standards in an IEC standard, thus it will not be applied in the project.

2.2.2.2 Requirements for PV modules long term reliability and performance

EN 61215 and EN 61646 qualification tests permit us to mainly identify initial short term reliability issues of PV modules. Ageing tests in climatic chamber and mechanical loads are also performed but it is important to note that with these tests there is no guarantee for PV modules to effectively sustain outdoor conditions and last for twenty (20) or more years. Long term reliability is a key issue for PV industries, manufacturers and end-users. Nevertheless, since the amount of collected monitoring data from PV installations with at least 20 or 25 years is still low, long term reliability issue is not always considered in standards under preparation or covered by existing standards. For long term reliability analysis, tests on PV modules are realized by simulating accelerated stress tests based on measured data collected. Typical accelerating stresses are temperature, voltage, mechanical load, thermal cycling, humidity and vibration (Marshall, 2012). Thus, in order to ensure long term reliability of PV modules, it is important to identify their installation site and to adapt, accordingly indoor tests.

Also, three standard tests are the most significant to verify PV module reliability. They are often applied in laboratories instead of the whole qualification tests sequence in order to ensure the compliance with certification requirements (EN 61215 and EN 61646 standards). (Ulrike, 2012)

1- *Damp Heat Test*: 1000 h at 85°C and at 85% RH.

The Damp Heat Test is a stress test for the quality of the used encapsulant (moisture protection).

Failures are mainly caused by delamination due to processing, contamination, material properties, back sheet adhesion loss (lamination problems) as well as corrosion.

2- Thermal Cycling Test: 200 cycles from -40°C to +85°C.

The Thermal Cycling Test is a thermomechanical stress test for cell connectors due to coefficients of thermal expansion (CTE) differences of glass, silicon (Si) wafer and copper interconnections. Observed failures can be broken cell, glass or copper ribbon, delamination…

3- Humidity Freeze Test: 10 cycles from +85°C at 85% RH and sudden drop to -40°C without relative humidity control. The Humidity Freeze Test is also a thermomechanical stress test for cell connectors due to CTE differences of glass, silicon (Si) and copper.

Moreover, to ensure PV modules long term reliability, some modifications could be applied to standard tests parameters:

- In order to guarantee the compliance of a manufacturing process with qualification standard, it is possible to extend tests duration 1.5 or 2 times compared to standard requirement.

- In order to study ageing effects or to identify degradation kinetics, it is possible to increase temperature, humidity and/or duration of tests.

- In order to consider various climates impact, it is possible to modify slightly tests: UV tests, tests in salt or ammonia atmosphere, dust tests.

Remark:

For CPV systems, these three tests are also performed to ensure long term reliability of PV modules with different durations.

1- Thermal Cycling Test: 2 or 3 months of tests;

2- Damp Heat Test: 2 or 3 months of tests;

3- Humidity Freeze Test: 1 month of tests.

Moreover, UV tests have to be realized on an additional sample.

2.2.3 Complementary tests proposal and new standard tests requirements for PVSITES products (in EN50583 final content)

Based on the analysis of the suitability of listed standards to PVSITES project BIPV products, some modifications or complements are proposed in this part to ensure long term reliability and performance.

Curved glass/glass, CIGS technology

IEC 61646 standard is suitable only for flat PV modules. Thus, for curved BIPV products, all general tests of this standard will be performed except the ageing tests which have to be realized using tests equipment (environment chamber) suitable for the component size (for example, CPV test facilities which are more adapted to systems with higher width).

Moreover, for cut susceptibility tests, according to curved BIPV products dimension, it could be necessary to modify size of equipment used since it is adapted to flat PV modules.

C-Si semi-transparent low concentration and solar control BIPV

- For low concentration products, standard related to CPV (IEC 62108 for product qualification and EN62688 for safety tests) have to be applied even if the deviation of solar radiation on to the cells is realized by lenses only during some periods of the year.

MPPT performance under heterogeneous working conditions

EN50530 describes a test procedure to measure static and dynamic MPPT efficiency of PV inverters, but established IV curves in this standard are ideal assuming the whole PV generator operates under homogeneous working conditions. However, real working conditions of BIPV generators are usually heterogeneous due to diverse mismatching effects. This means more complex IV curves including local maximum power points, so it is necessary to measure MPPT performance of PV inverters under these conditions. As a result, for BIPV inverters, the inclusion of this kind of IV curves during the test procedure measuring MPPT efficiency is proposed.

2.3 Testing plan

The testing plan proposed depends mainly on the BIPV product being tested and on the improvements planned on the products. Thus, for each BIPV product a tests sequence has been adapted by a relevant combination of PV standard tests and construction standard tests. TUV tests sequence is considered as basis for PV standard tests. Nevertheless, other tests sequences including both qualification and safety tests could be applied according to the certification organization. For a complete standard tests sequence on BIPV products including PV tests as well as construction tests, almost 2 or 3 months should be planned. For the low concentration BIPV product (X9 to X11 products in task 3.1), 3 to 15 months could be necessary to realize all tests sequence.

Although standard tests related to construction are generally realized prior to electrical standard tests, in order to consider PVSITES project time schedule, it is recommended to realize both tests sequences (PV and construction) in parallel.

Moreover, considering the limiting capacities of PVSITES projects partners research infrastructures (number of samples that could be tested simultaneously), the BIPV products will be tested in priority according to their time of provision.

The test sequences are provided at the beginning of the project (M6) and could be modified as a result of the specific development on the products. Some testing could not finally be required if manufacturers of some of the components provide previous test reports (e.g. frame manufacturer), or if the applications intended do not require a specific test.

In the following sub-chapters, an overview of the modifications planned on each product is presented. Then, for each BIPV product and inverter, tables detailing relevant information (e.g. number of samples, tests sites, and partners involved) for the performance of tests sequences are proposed. All complete tests sequences are presented in the annexes.

2.3.1 Identification of products enhancements planned (in order to increase TRL)

A summary of development modifications planned on each product is presented in Table 2.1. It is important to notice that this list is based on the information received by the partners and on the work program content. But, few tests sequences (in particular, some PV tests sequences) are defined in order to consider further modifications that were not planned on products before month 6.

Table 2.2 Main modifications planned on the BIPV products

Product	Description	Modifications description
X1 to X4	CIGS modules on metal elements for BIPV roofs and façades*	• For back encapsulation: back sheets like aluminum, anodized aluminum, steel with various organic coatings, multilayer plastic back sheets… • For front encapsulation: use of plastic sheets with high barrier properties. • bonded on curved metal sheet; • Roll-to -roll manufacturing of lightweight flexible thin film CIGS solar modules on polymer films; • Utilization of growing submodule sizes (a submodule correspond to an array of serial connected cells) in width and length which are based on a polymeric flexible foil: leading to changing electrical specifications, changing number of submodules per product, changing product sizes, changing busbar concepts… • For Flisom residential roof tile product: modification in size, shape, fixation and appearance to meet standard residential roof constructions and high aesthetics. • Modifications in electrical design expected: from junction box to power optimizer.
X5	Hidden busbars and L-interconnections for opaque BIPV	• Covering of aesthetics constrains while maintaining the performance level: o Busbars hidden by means of black conductive ribbons over the welded cells in a string; o Fully black plastic sheets integrated as interlayers to hide L-interconnections (lamination). • Fully black frit patterned rear glazing.
X6	Back-contact solar cells for see-thru glazing	• Use of back contact solar cells instead of common ones; • Development of cell to cell Sn/Cu connections;

X7	Flexible CIGS for curved BIPV glass integration	• Cold bending and low-T thermal annealing; • Fabricate PV flat laminated glass, and then, handle the cold bending process taking the samples to the mechanical limit or trying to laminate PV modules within curved glass; • Monolithically connected flexible solar module on polymer film which is bendable and suitable for curved roofs and facades.
X8	Framing systems for XL BIPV glass formats	• Mechanical aspects and hidden wiring strategies to be defined; • XL framing for canopy and double skin façade.
X9 to X11	Low concentration and solar control BIPV solutions*	• Integration of optical elements to concentrate solar radiation onto the cells: o Skylight: PMMA lenses film on glass surface #2; o Double skin: PMMA lenses attached to double skin glass external building envelope. • Shading elements: PMMA lenses hooked on PV glass curtain walling.
X12	Glazing treatments for improved passive properties	• Several treatments to be included in PV glazing systems: o Self-cleaning; o Low-e coatings on surface #4; o Frit pattern coatings on surface #2 and #3 (inner side of surface lamination); o Mass coloured glass; • Reflection hard coating on #1.

2.3.2 Definition of testing plan for each product

The following tables define the set of tests to be applied to the PVSITES BIPV products to be developed. (The details of tests to be performed are provided in annexes 1.1, 1.2 and 1.3)

In test sequences definition, the following aspects were considered:

- Product components and materials;

- Application and integration in BIPV systems;

- Issues related to European legislation applicable to construction products.

Referring to this last item, the regulation Reg EU 305/2011 especially considered– the definition of tests to be conducted by different BIPV solutions, contemplating the essential characteristics set out in Annex ZA of EN 13830 and item 8 of the ETAG 034.

Nota Bene:

- For PV tests sequences, orange cells correspond to tests which could be realized at CEA site, blue cells are tests which will be realized in sites involved in the project other than CEA site (see tables in section 2.3.2 for corresponding tests sites). Hatched cells are non-priority tests which correspond, here, to non-essential tests to assess the compliance with standards.

- For construction tests sequences, yellow cells correspond to tests which could be realized at CTCV site, white cells are tests which will be realized in Tecnalia or Flisom sites, depending on the product. Hatched cells are non-priority tests. (See tables in section 2.3.2 for corresponding tests sites)

- For CEA research equipment used for PV tests sequences, the maximum size of PV modules small tests samples is of 36x36 cm^2 and the maximum size for PV modules samples is of 120x180 cm^2.

- Partners involved in testing activities shall not be liable for delays or not completing plan test:

    - in case of products sample not compliant with size and quality requirements;

    - or in case of delay in provision of the products.

2.3.2.1 Testing plan for X1/X3 CIGS roofing shingle on metal substrate

Table 2.3 Summary of tests on the BIPV product (see annex 1.4)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	5 modules; 3 small tests samples; 1 laminate		FLISOM	FLISOM site (Switzerland)	
Construction	2 months	Impact test: 1 module Reaction to fire: 2 modules	Pull out test: 4 modules + fixing system	FLISOM	FLISOM site (Switzerland)	

Table 2.4 Summary of tests on the BIPV product (see annex 1.4)

2.3.2.2 Testing plan for X2 - CIGS large area flexible roofing membrane and bendable elements

Table 2.5 Summary of tests on the BIPV product (see annex 1.4)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	6 modules (+1 eventually); 3 small tests samples; 1 laminate		FLISOM	FLISOM site (Switzerland)	For PV tests, in the new version of EN 61215, DML tests could be necessary
Construction	2 month	Impact test: 1 module Reaction to fire: 2 modules	Pull out test: 4 modules + fixing system	FLISOM	FLISOM site (Switzerland)	

2.3.2.3 Testing plan for X4 - CIGS large area elements on metal substrate

Table 2.6 Summary of tests on the BIPV product (see annex 1.4)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	5 modules; 3 small tests samples; 1 laminate		FLISOM	FLISOM site (Switzerland)	
Construction	1 month	Impact test: 1 module Reaction to fire: 2 modules	Pull out test: 4 modules + fixing system	FLISOM	FLISOM site (Switzerland)	

2.3.2.4 Testing plan for X5 - C-Si glazed products with hidden bus bars and L interconnections

Table 2.7 Summary of tests on the BIPV product (see annex 1.5)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	6 modules (+1 eventually); 3 small tests samples; 1 laminate		CEA	INES site (France)	For PV tests, in the new version of EN 61215, DML tests could be necessary
Construction	3 months	Radiation test: 3 specimens (300x300mm) Humidity test: 3 specimens (100x300mm) High temperature test: 3 specimens (100x300mm) Impact resistance test: 4 specimens (1938x876mm) – if necessary 8 more specimens		CTCV (radiation, humidity, high T and impact tests) TECNALIA (optical properties)	CTCV site (Portugal) TECNALIA site (Spain)	

		Optical properties determination: 1 sample (50x100 mm).				

2.3.2.5 Testing plan for X6 - Glass-glass products with back contact c-Si cells

Table 2.8 Summary of tests on the BIPV product (see annex 1.6)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	6 modules (+1 eventually); 3 small tests samples; 1 laminate		CEA	INES site (France)	For PV tests, in the new version of EN 61215, DML tests could be necessary
Construction	3 months	Radiation test: 3 specimens (300x300mm) Humidity test: 3 specimens (100x300mm) High temperature test: 3 specimens (100x300mm) Impact resistance test: 4 specimens (1938x876mm) – if necessary 8 more specimens Optical properties determination: 1 sample (50x100 mm).		CTCV (radiation, humidity, high T and impact tests) TECNALIA (optical properties)	CTCV site (Portugal) TECNALIA site (Spain)	

2.3.2.6 Testing plan for X7 - Curved glass-glass, CIGS technology

Table 2.9 Summary of tests on the BIPV product (see annex 1.7)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	6 modules (+1 eventually); 3 small tests samples; 1 laminate		CEA	INES site (France)	For PV tests, in the new version of EN 61215, DML tests could be necessary
Construction	3 months	Radiation test: 3 specimens (300x300mm) Humidity test: 3 specimens (100x300mm) High temperature test: 3 specimens (100x300mm) Impact resistance test: 4 planar specimens (1938x876mm) – if necessary 8 more specimens Optical properties determination: 1 planar specimen (50x100 mm).		CTCV (Glass standards radiation, humidity, high T and impact tests) TECNALIA (optical properties)	3 months	

2.3.2.7 Testing plan for X8 – Framing systems for c-Si large area glass

Table 2.10 Summary of tests on the BIPV product (see annex 1.8)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	3 modules; 3 small tests samples; 1 laminate		CEA	INES site (France)	For PV tests, in the new version of EN 61215, DML

						tests could be necessary
Construction	2 months	Impact resistance: 1 module	**Canopies:** Snow and wind load: roof kit with fixing system, 2 modules of representative size Pull out test: 4 modules plus fixing system **Double skin façades:** Air permeability, water tightness, wind load resistance: Façade kit - 4 elements of representative size	TECNALIA	TECNALIA site (Spain)	

2.3.2.8 Testing plan for X9 – C-Si semi-transparent low concentration and solar control BIPV system – skylight configuration

Table 2.11 Summary of tests on the BIPV product (see annex 1.9)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
CPV	3-15 months	7 modules; + 1 module (UV tests)	2 receivers+1 special receiver+1 special module	CEA	INES site (France)	Tests could be completed with UV tests
Construction	3-4 months	Long term humidity test: 15 specimens (350x500mm) Impact resistance: 1 module Optical properties: 1 sample (50x100 mm)		CTCV (long term humidity) TECNALIA (impact resistance, optical properties)	TECNALIA site (Spain) CTCV site (Portugal)	

2.3.2.9 Testing plan for X10 – C-Si semi-transparent low concentration and solar control BIPV system – façade configuration

Table 2.12 Summary of tests on the BIPV product (see annex 1.9)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
CPV	3-15 months	7 modules; + 1 module (UV tests)	2 receivers+1 special receiver+1 special module	CEA	INES site (France)	Tests could be completed with UV tests
Construction	2 months	Optical properties: 1 sample (50x100 mm)	Wind load, impact resistance: façade kit – 4 modules-	TECNALIA	TECNALIA site (Spain)	

2.3.2.10 Testing plan for X11 – C-Si semi-transparent low concentration and solar control BIPV system – shading element configuration

Table 2.13 Summary of tests on the BIPV product (see annex 1.9)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
CPV	3-15 months	7 modules; + 1 module (UV tests)	2 receivers+1 special receiver+1 special module	CEA	INES site (France)	Tests could be completed with UV tests
Construction	2 months	Optical properties: 1 sample (50x100 mm)	Snow and wind load, impact resistance: 1 module plus fixing system Pull out test: 2 modules plus fixing system	TECNALIA	TECNALIA site (Spain)	

2.3.2.11 Testing plan for X12 – Glazed modules treated for improved passive properties

Table 2.14 Summary of tests on the BIPV product (see annex 1.10)

Sector	Duration (months)	Nb. of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
PV	2-3 months	5 modules; 3 (+1) small tests samples; 1 laminate		CEA	INES site (France)	Adhesion tests to be added on small PV samples (size lower than 40mmx40mm)
Construction	3 months	Radiation test: 3 specimens (150x300mm) Humidity test: 3 specimens (100x300mm) High temperature test: 3 specimens (100x300mm) Impact resistance test: 4 specimens (1938x876mm) – if necessary 8 more specimens Optical properties determination: 1 specimen (50x100 mm).		CTCV (radiation, humidity, high temperature, impact) TECNALIA (optical properties)	TECNALIA site (Spain)	

2.3.2.12 Testing plan for X13: Low cost, flexible, DC coupled PV storage inverter

Table 2.15 Summary of tests on the BIPV product (see annex 1.11)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
Inverter	3 months	1 inverter	-	TECNALIA/ CEA	TECNALIA site (Spain) INES site (France)	TECNALIA site / INES site

2.3.2.13 Testing plan for X14: Single-stage SiC technology based PV inverter

Table 2.16 Summary of tests on the BIPV product (see annex 1.11)

Sector	Duration (months)	Number of PV modules samples needed	Number of PV system (or integration structure) samples needed	Partners involved	Site of tests (country)	Comments
Inverter	3 months	1 inverter	-	TECNALIA/ CEA	TECNALIA site (Spain) INES site (France)	TECNALIA site / INES site

2.4 Conclusions

In this document, an in-depth analysis of existing standards in comparison with new standard EN 50583 standard final content (PV in buildings) was realized. The results have shown that even if deviations exist between photovoltaic standard and building standard requirements, the EN 50583 provides a good compromise for the certification of BIPV products. Nevertheless, for some innovative configurations of products, some adaptations of standard tests or proposals of complementary standard tests are necessary. Thus, for low concentration BIPV product and curved glass/glass product in the PVSITES project specific recommendations were proposed in order to adapt standard tests to their configuration and properties. In order to contribute to ensure products performance and long term reliability, test sequences were defined for each product (BIPV products and inverters) based on the above in-depth analysis and on the list of modifications planned on PV modules. The objective of these tests is to permit compliance with standards. Then, the test sequences proposed in this document are composed of a relevant combination of photovoltaic and construction standard tests. For both kinds of standard tests (PV and construction), which have to be performed in parallel most of the time, the document includes the main useful information such as number of samples, duration of tests and PVSITES partners involved in the testing.

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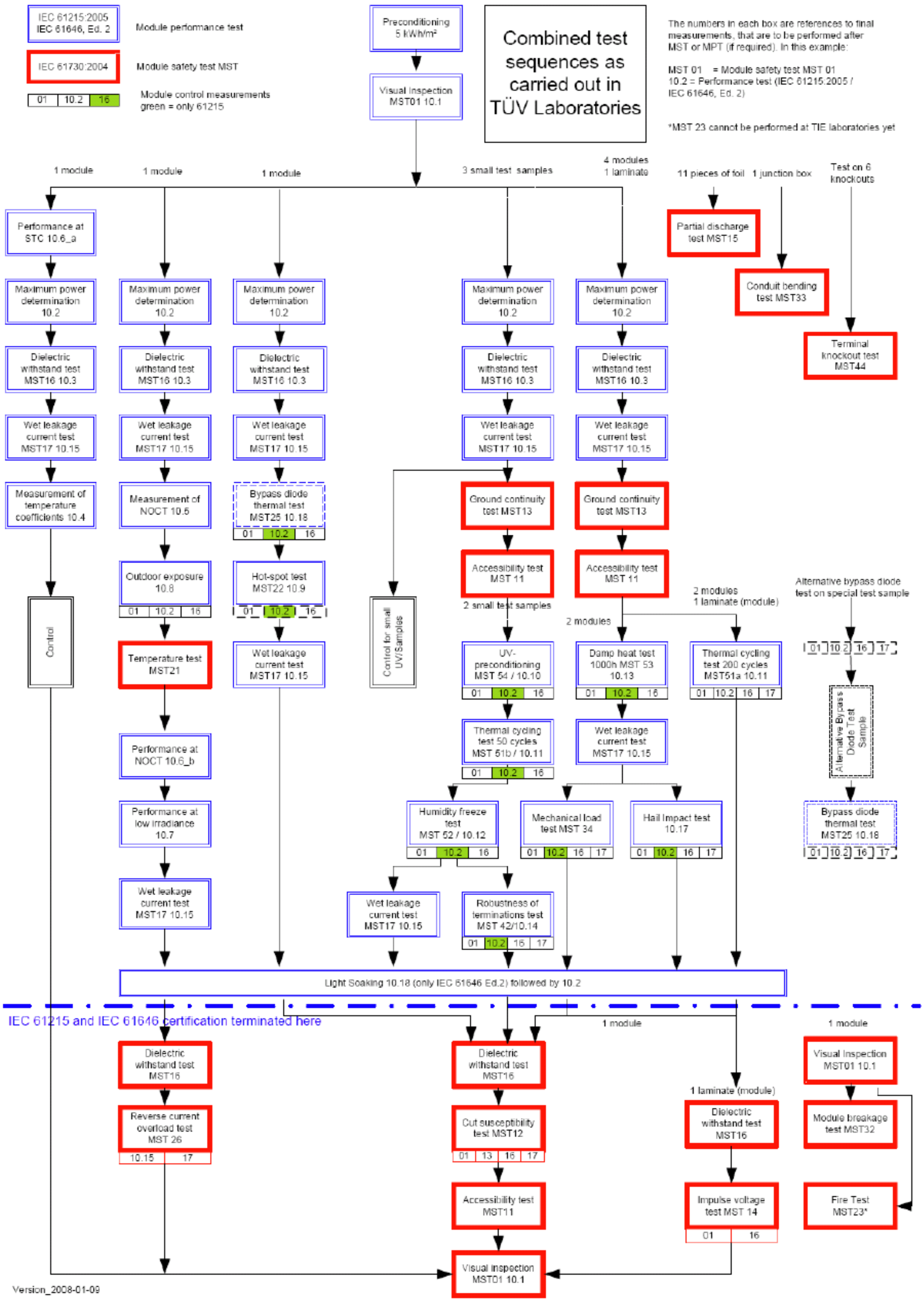
4 ANNEXES

Annex 1: Test sequences for BIPV products

Annex 1.1: Overview of qualification tests according to IEC 61730-2 (application class A)

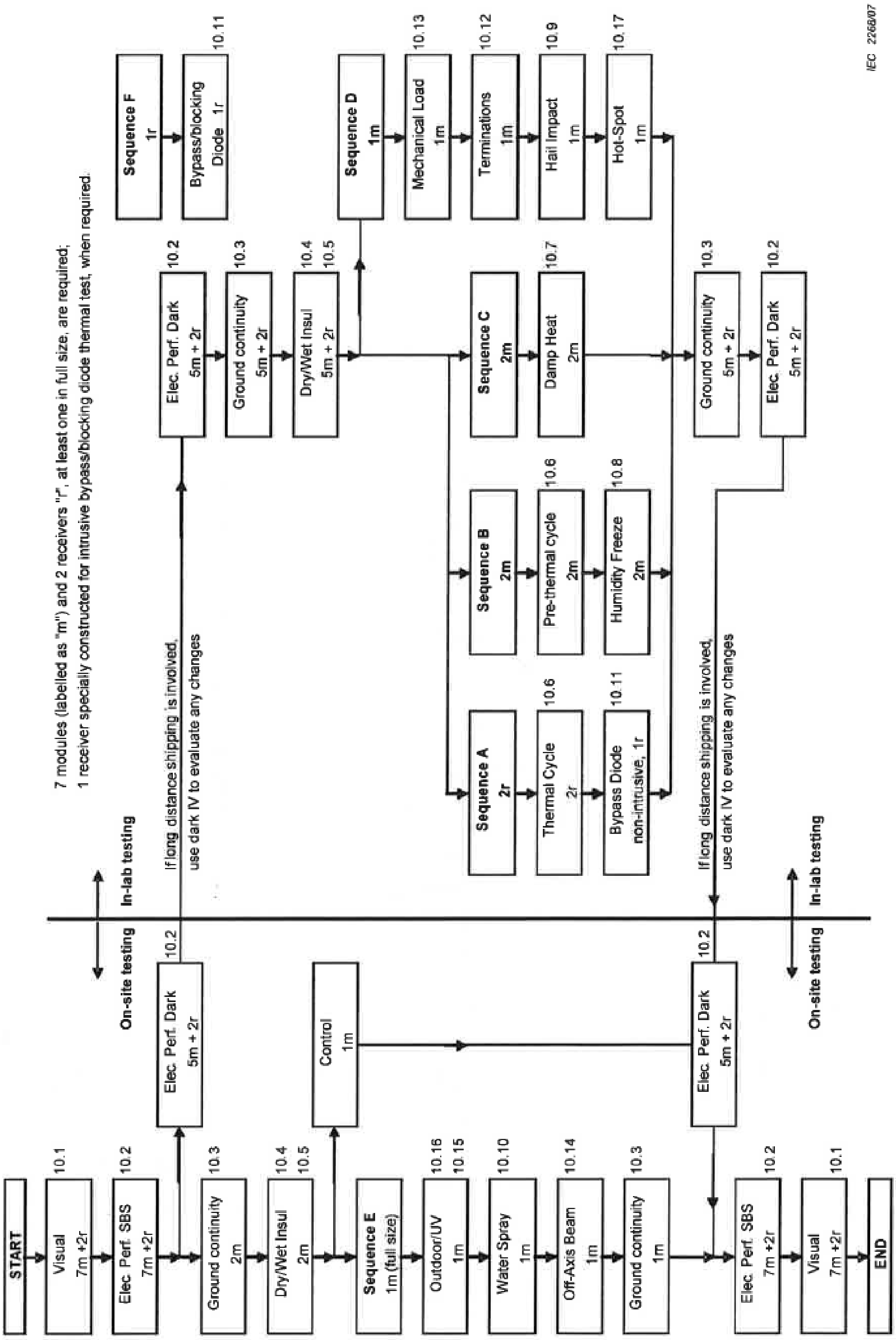
Code	Test name	Test description / Pass criteria
MST 01	Visual inspection	According detailed inspection list
MST 11	Accessibility test	Resistance always >1 MΩ between test fixture (acc. IEC 61032) and module life parts
MST 12	Cut susceptibility test	Meet insulation requirements after defined cutting on module backside film
MST 13	Ground continuity test	Resistance < 0,1 Ω between marked grounding point and frame points in distance at a current that equals 2,5 times the maximum over-current protection rating of the module (for a minimum of 2 minutes)
MST 14	Impulse voltage test	High voltage impulse depending on selected application class and max. system voltage with a laminate wrapped in copper foil
MST 15	Partial discharge test	Determination of the partial discharge behaviour of the modules backside foil
MST 16	Dielectric withstand test	High voltage test with 2000 V DC + 4 x max. systems voltage at STC for 1 min (Leakage current <50µA),
MST 17	Wet leakage test	Evaluation of insulation of the module under wet conditions; measurement of leakage current at 500 V DC
MST 21	Temperature-test	Compliance of the measured material temperatures with the max. permissible values given in IEC 61730, Table 9 under >700 W/m² irradiation, wind speed < 1 m/s, environmental temp. 20 – 55 °C
MST 22	Hot-Spot test	5 hour exposure to > 700 W/m² irradiance in worst-case hot-spot condition
MST 23	Fire test	Proof according to ANSI/UL790, that the module meet the minimum fire resistance rating of Class C
MST 25	Bypass diode thermal test	Asses adequacy of thermal design of by-pass diodes at a current of 1.25 x Isc running through the diodes at module temperature of 75°C
MST 26	Reverse current overload test	Reverse current through the module equal to 135 % of the module's over-current protection rating for 2 hours
MST 32	Module breakage test	Mechanical impact by a test-bag with a weight of 45,5 kg (ca. 540 J kinetic energy); Requirements for breakage (shards < 6,5 cm²)
MST 33	Conduit bending test	Test of the ability of a possible conduit fixed to the junction box to withstand a bending force (220 to 49 N, depending on diameter)
MST 42	Robustness of Terminations	As in IEC 60068-2-21
MST 44	Terminal knockout test	Test of the suitability of terminal knockouts
MST 51 a/b	Thermal Cycling	50 and 200 cycles -40°C to +85°C
MST 52	Humidity Freeze Test	10 cycles -40°C to +85°C, 85% RH
MST 53	Damp Heat	1000 h at +85°C, 85% RH
MST 54	UV-exposure test	Min.15 kWh/m² UV-radiation (280 - 400 nm) with 7.5 kWh/m² UV-radiation (280 - 320 nm) at 60°C module temperature

Annex 1.2: Combined tests sequence for EN IEC 61215/61646/IEC 61730

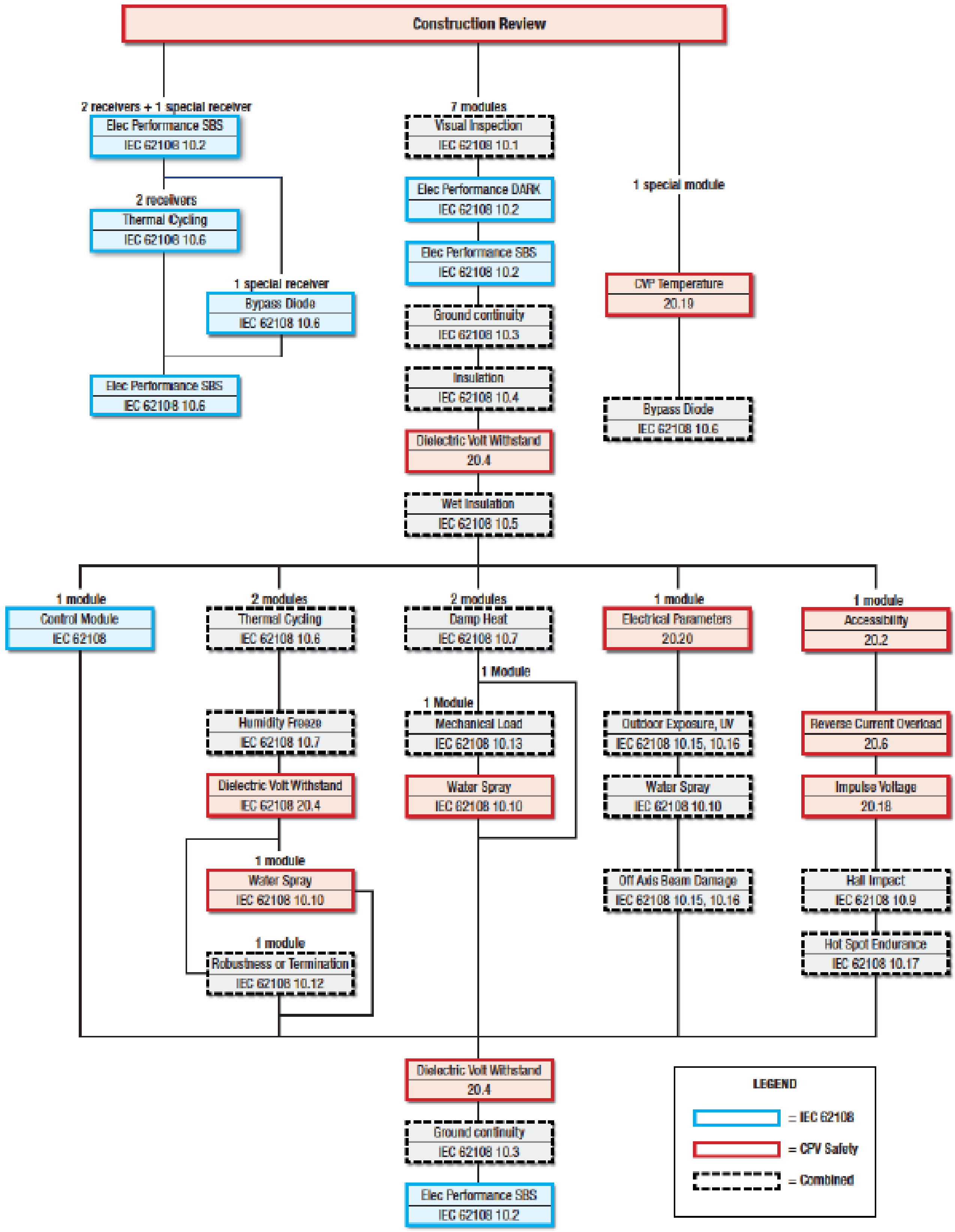


Annex 1.3: Tests sequences for CPV modules

- Tests sequence for IEC 62108 (qualification and type approval of CPV modules)

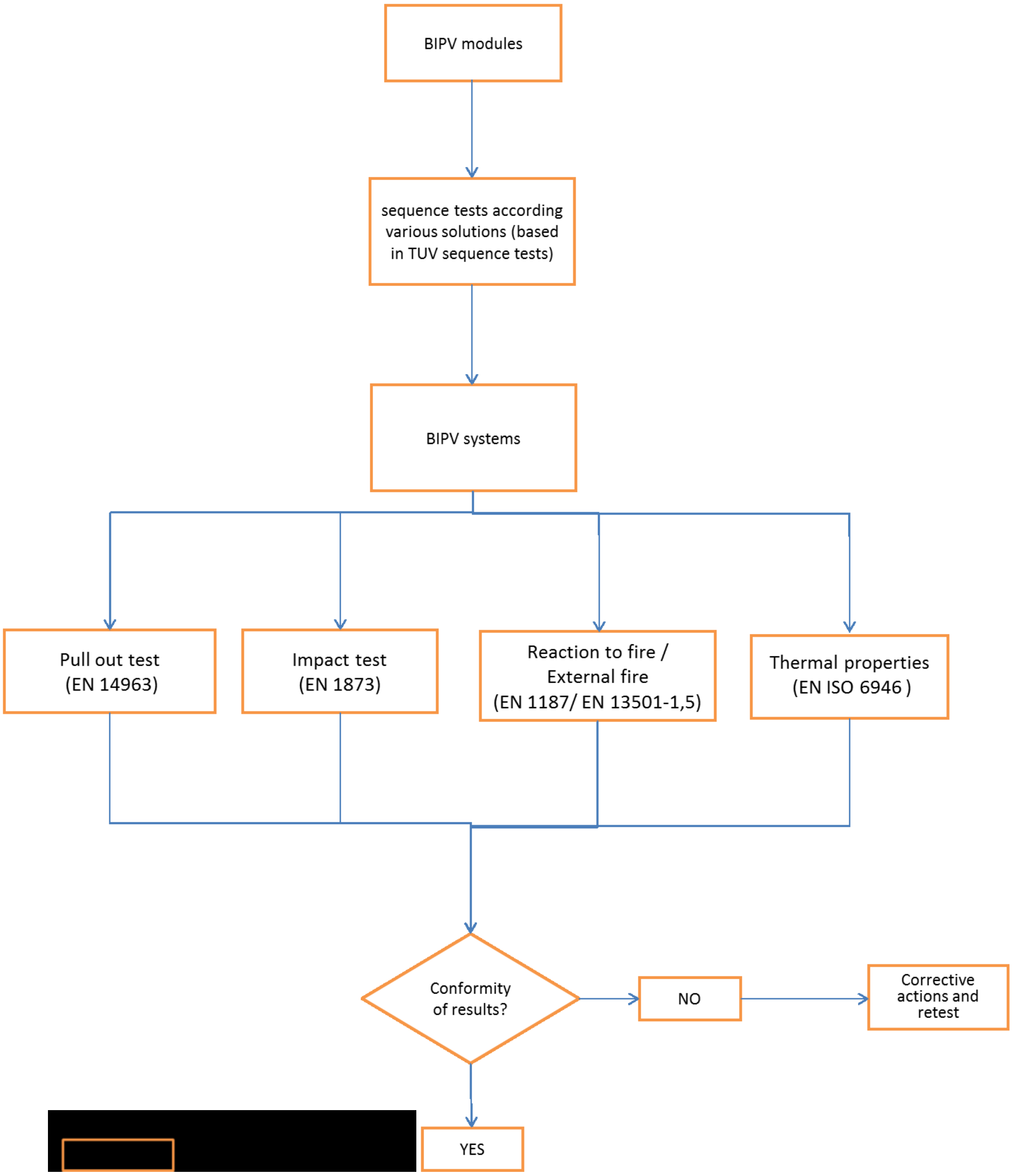


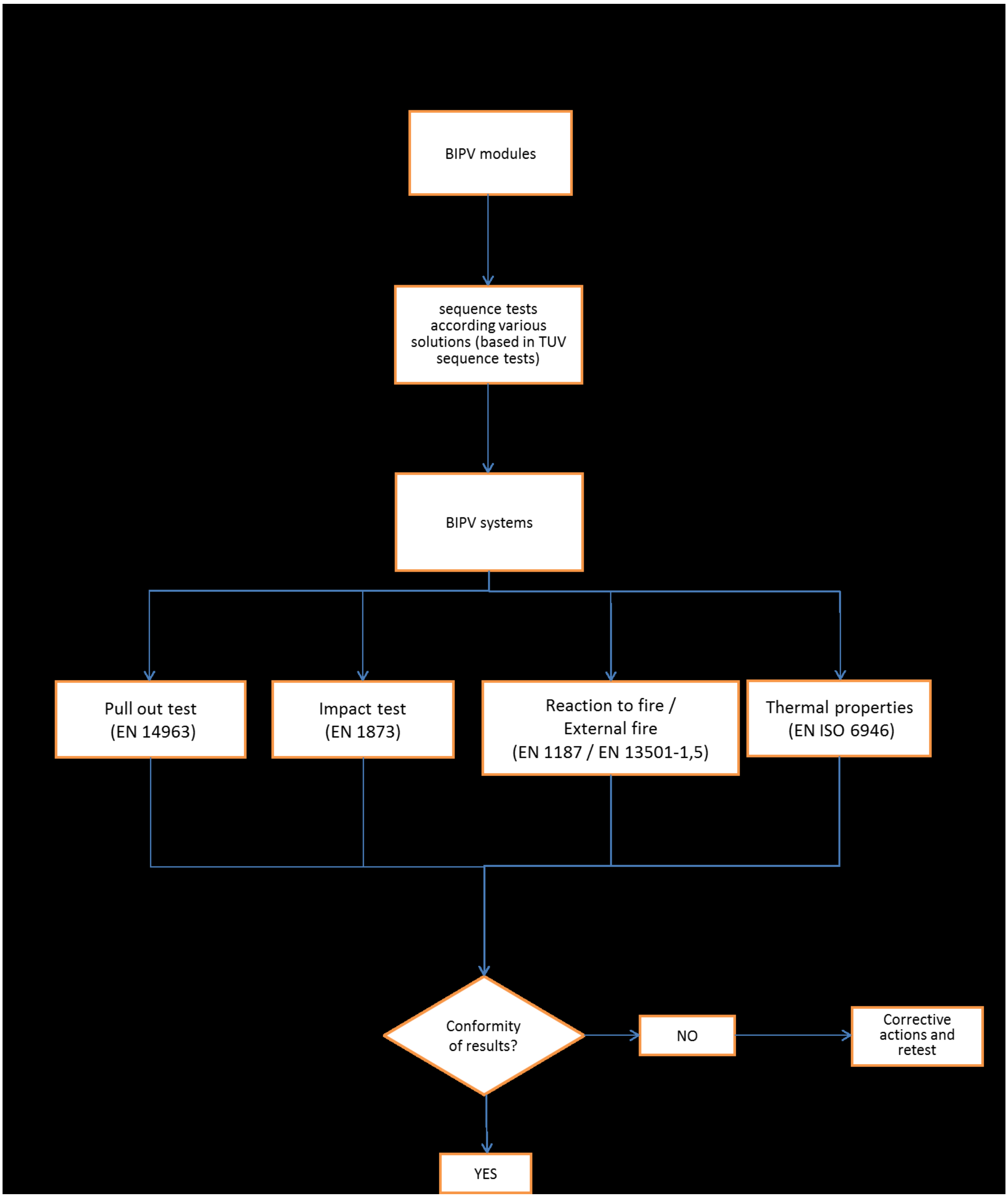
- Combined tests sequence including IEC62108 (qualification) **and IEC 62688** (safety) **standards** (Robusto and Rai, 2013)

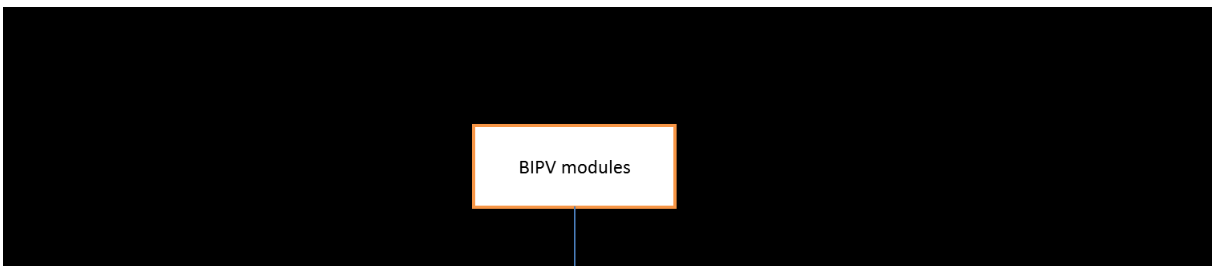


Annex 1.4: Tests sequences for X1/X3, X2 and X4 BIPV product (task 4.1)

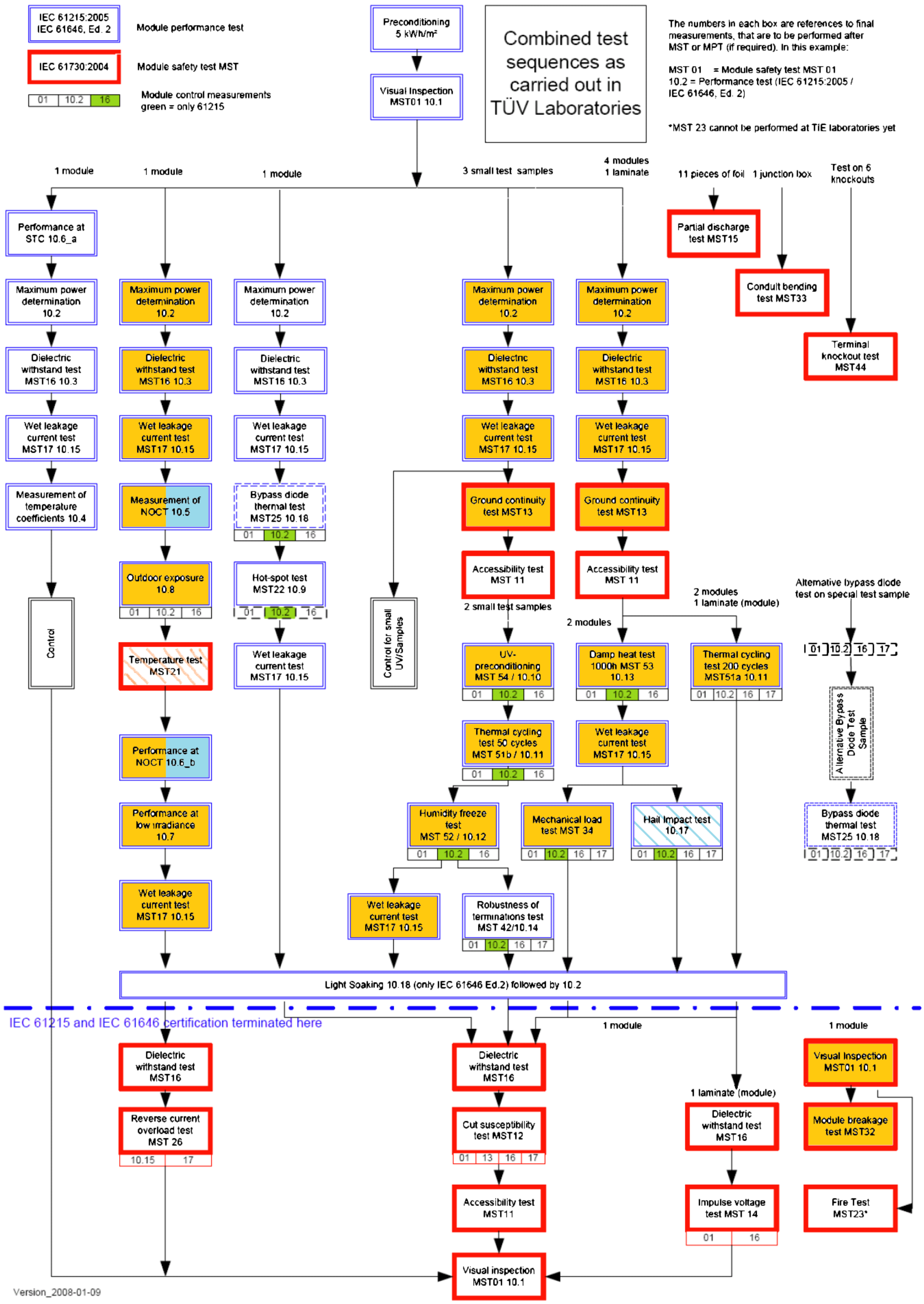
X1 / X3 - CIGS roofing shingle on metal substrate



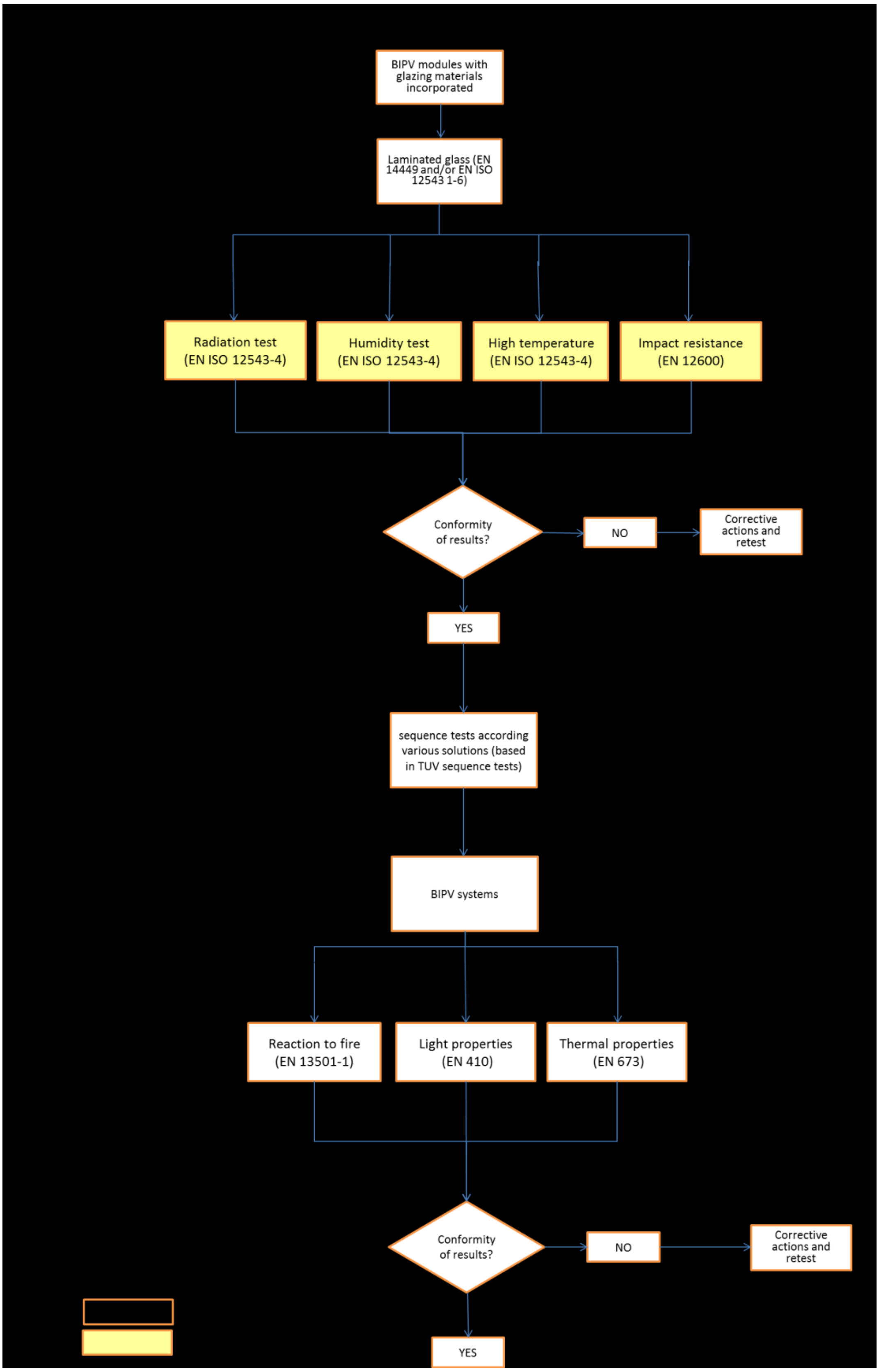

BIPV modules
sequence tests according various solutions (based in TUV sequence tests)
BIPV systems
Pull out test (EN 14963)
Impact test (EN 1873)
Reaction to fire / External fire (EN 1187 / EN 13501-1,5)
Thermal properties (EN ISO 6946)
Conformity of results?
NO
Corrective actions and retest
YES


BIPV modules

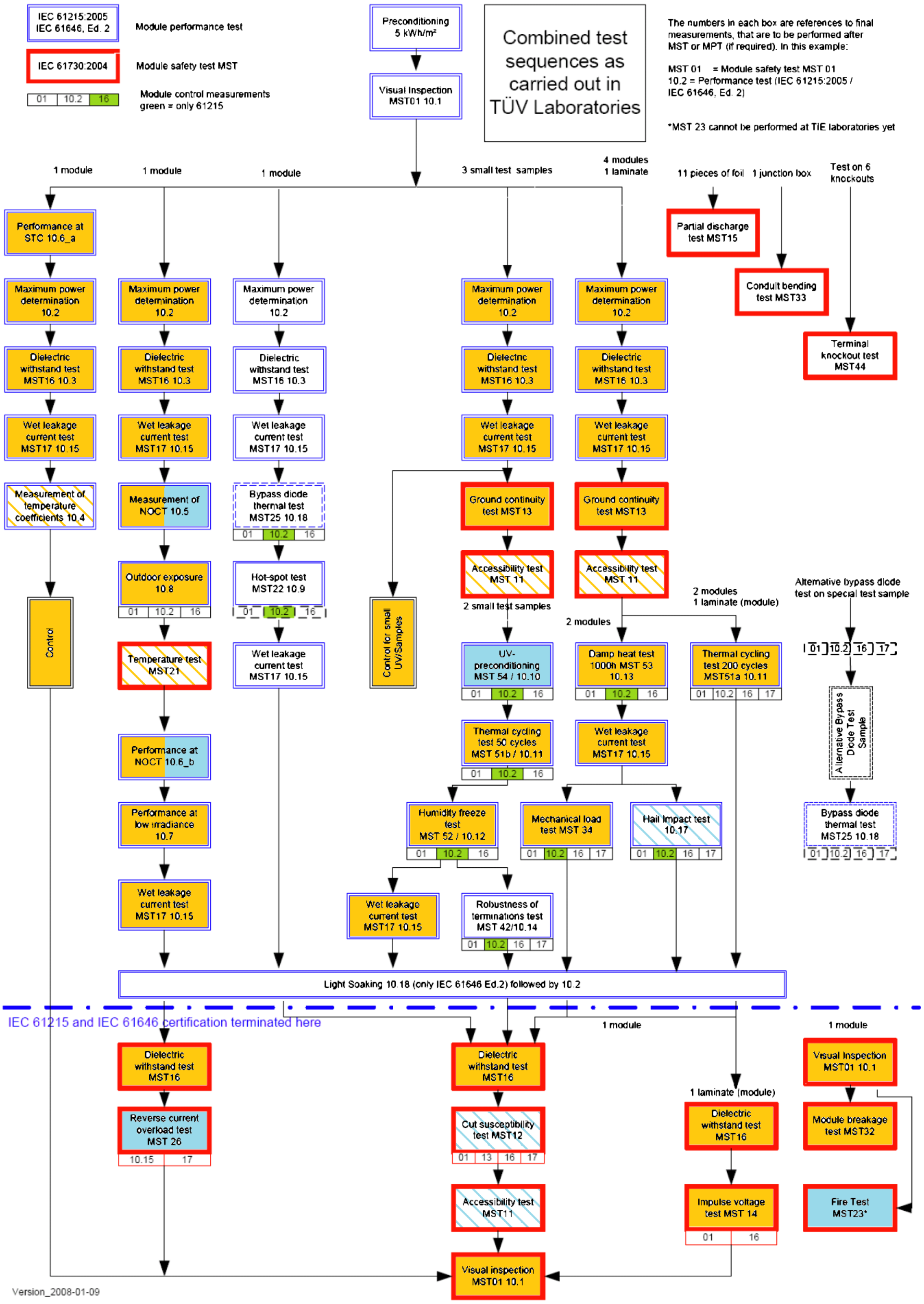
Combined Test-sequence for EN IEC 61215/61646/IEC 61730



Annex 1.5: Tests sequences for X5 BIPV product (task 3.2)

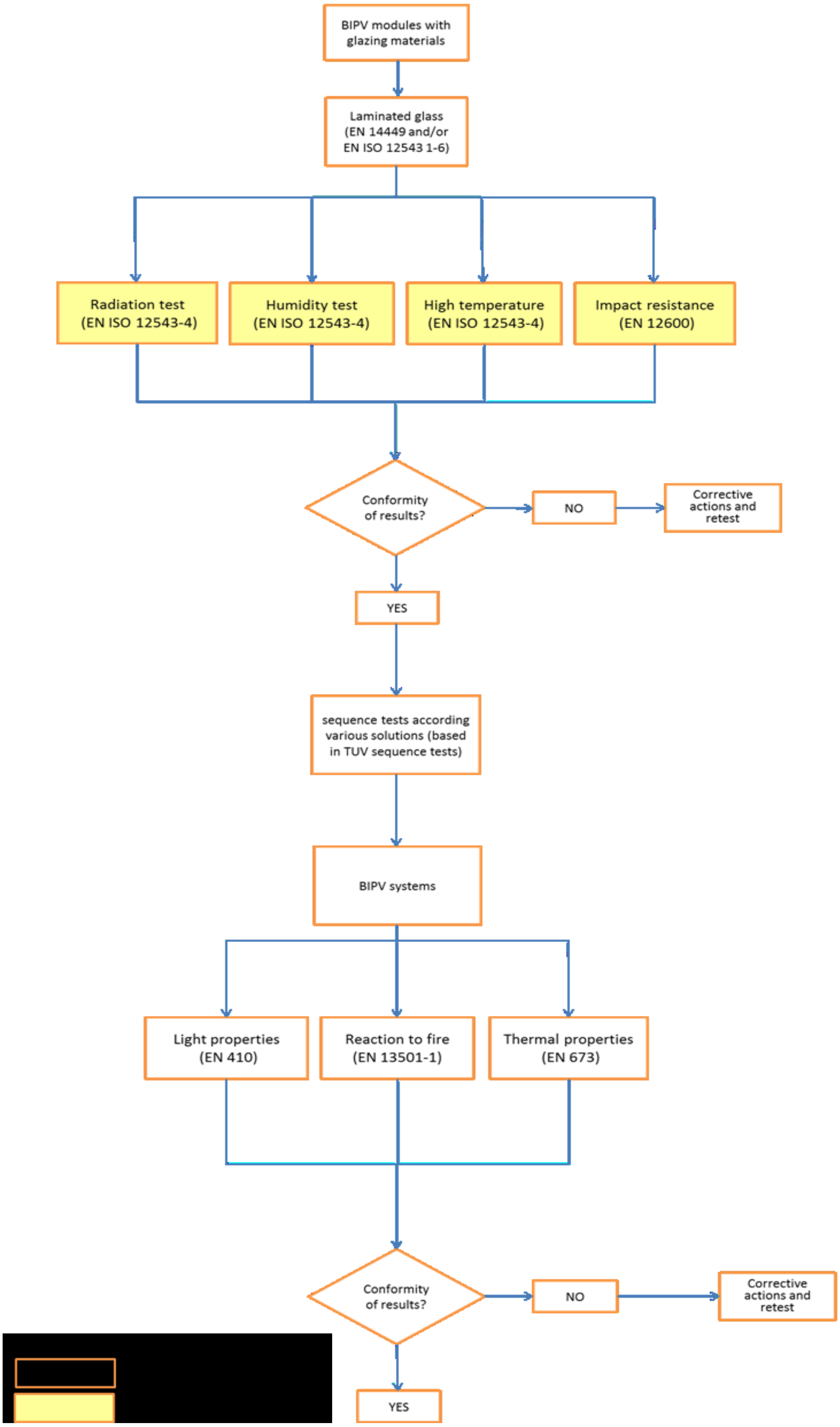


Combined Test-sequence for EN IEC 61215/61646/IEC 61730

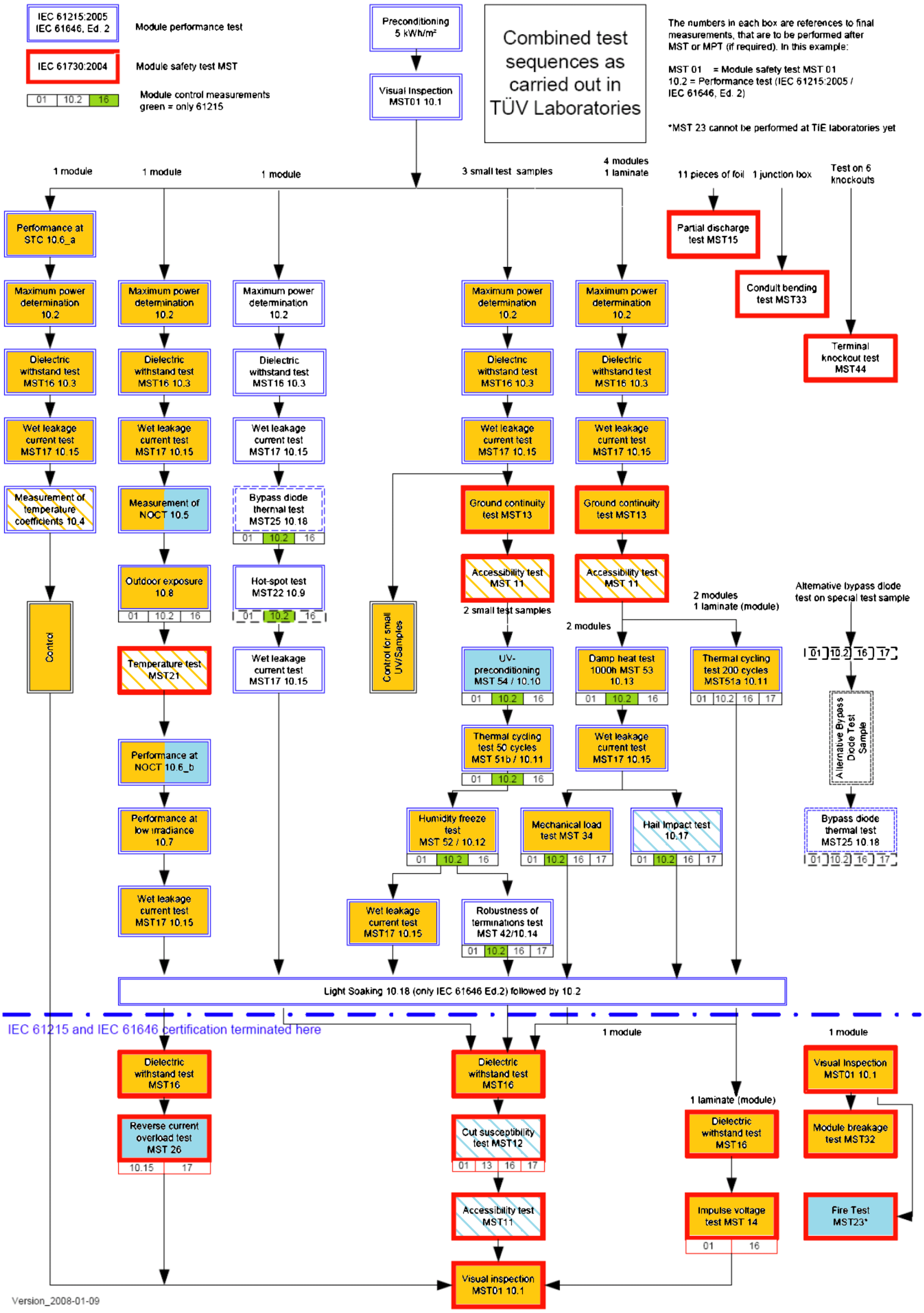


Annex 1.6: Tests sequences for X6 BIPV product (task 3.3)

X6 - Glass-glass products with back contact c-Si cells

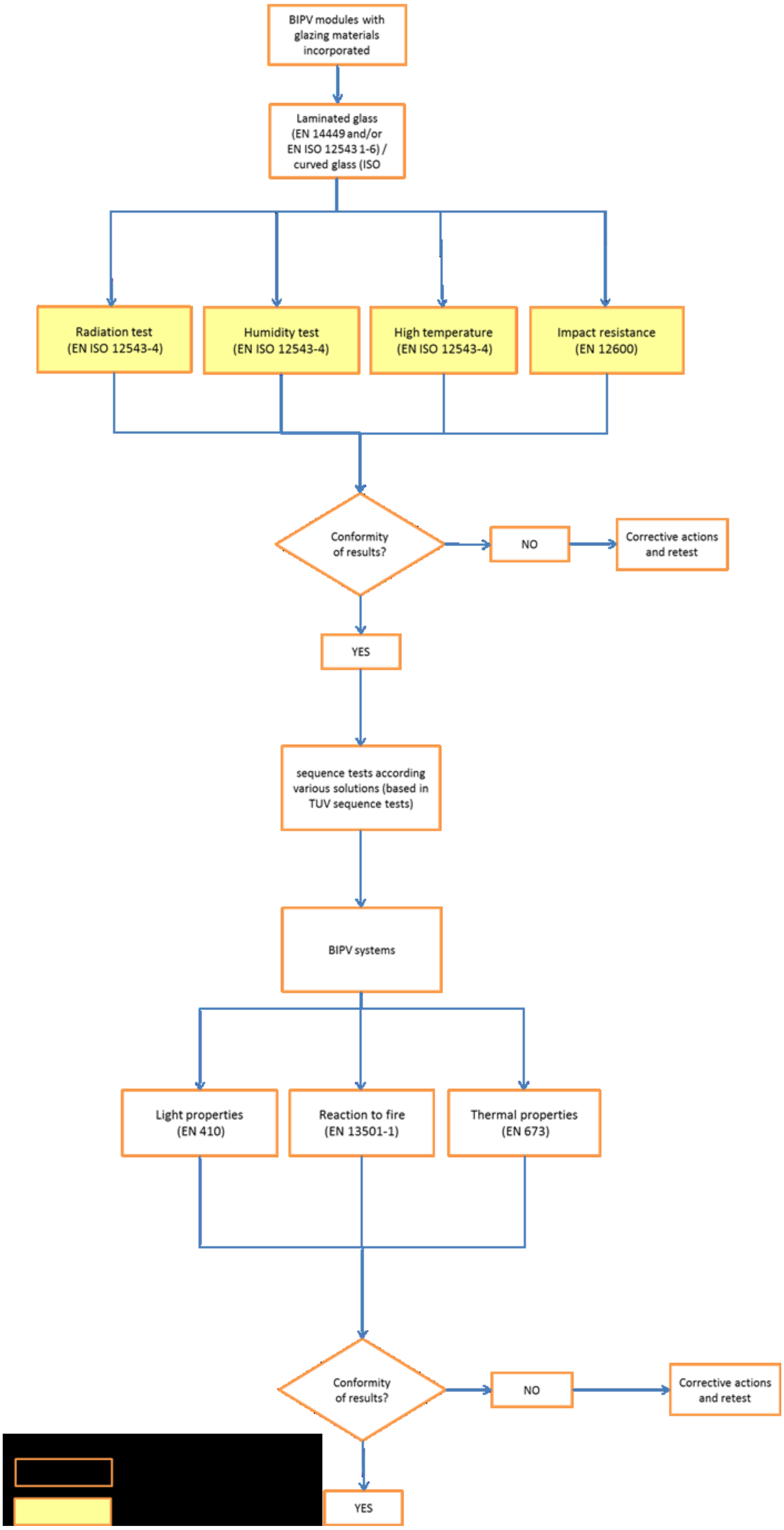


Combined Test-sequence for EN IEC 61215/61646/IEC 61730

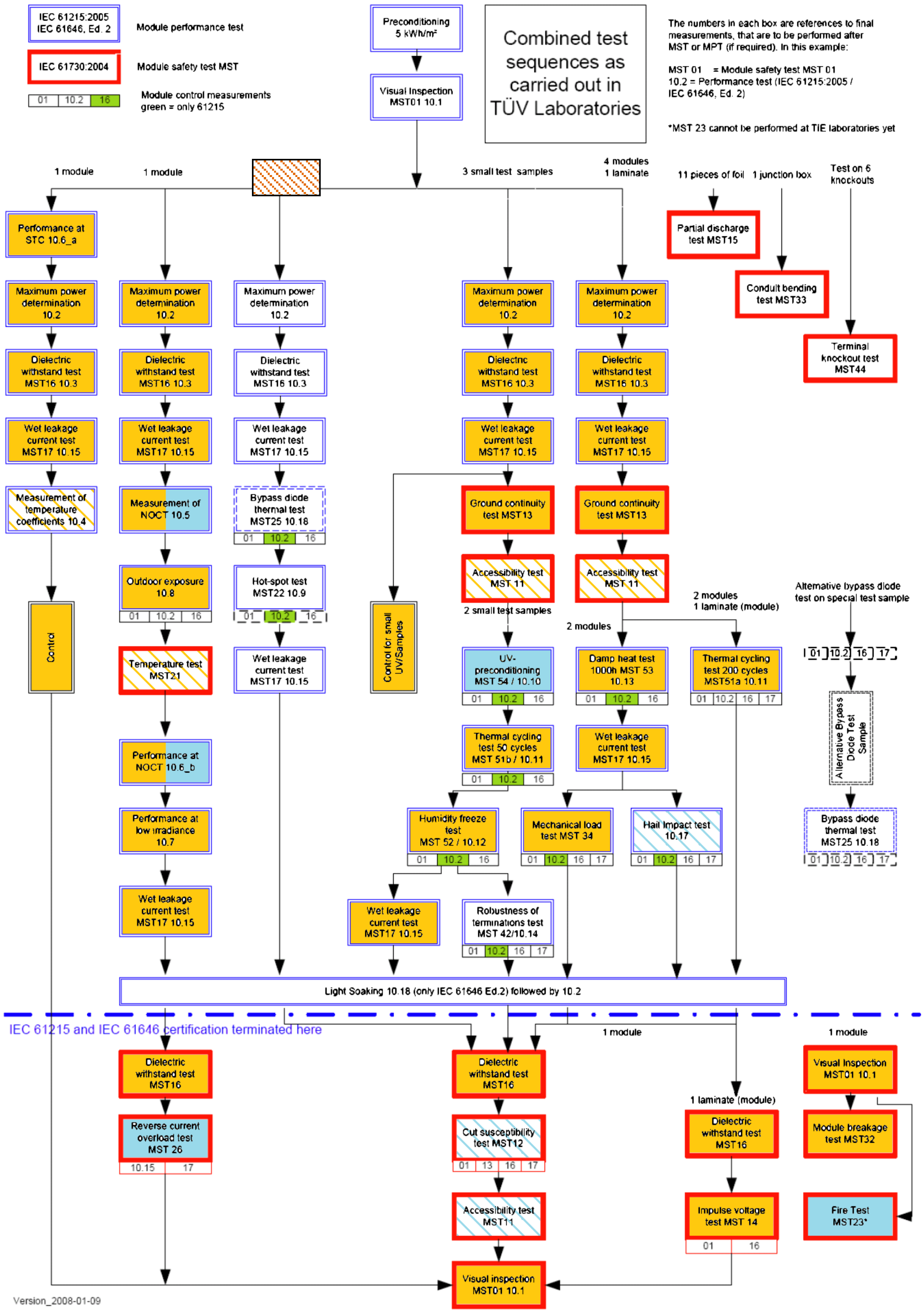


Annex 1.17: Tests sequences for X7 BIPV product (task 4.2)

X7 - Curved glass-glass, CIGS technology

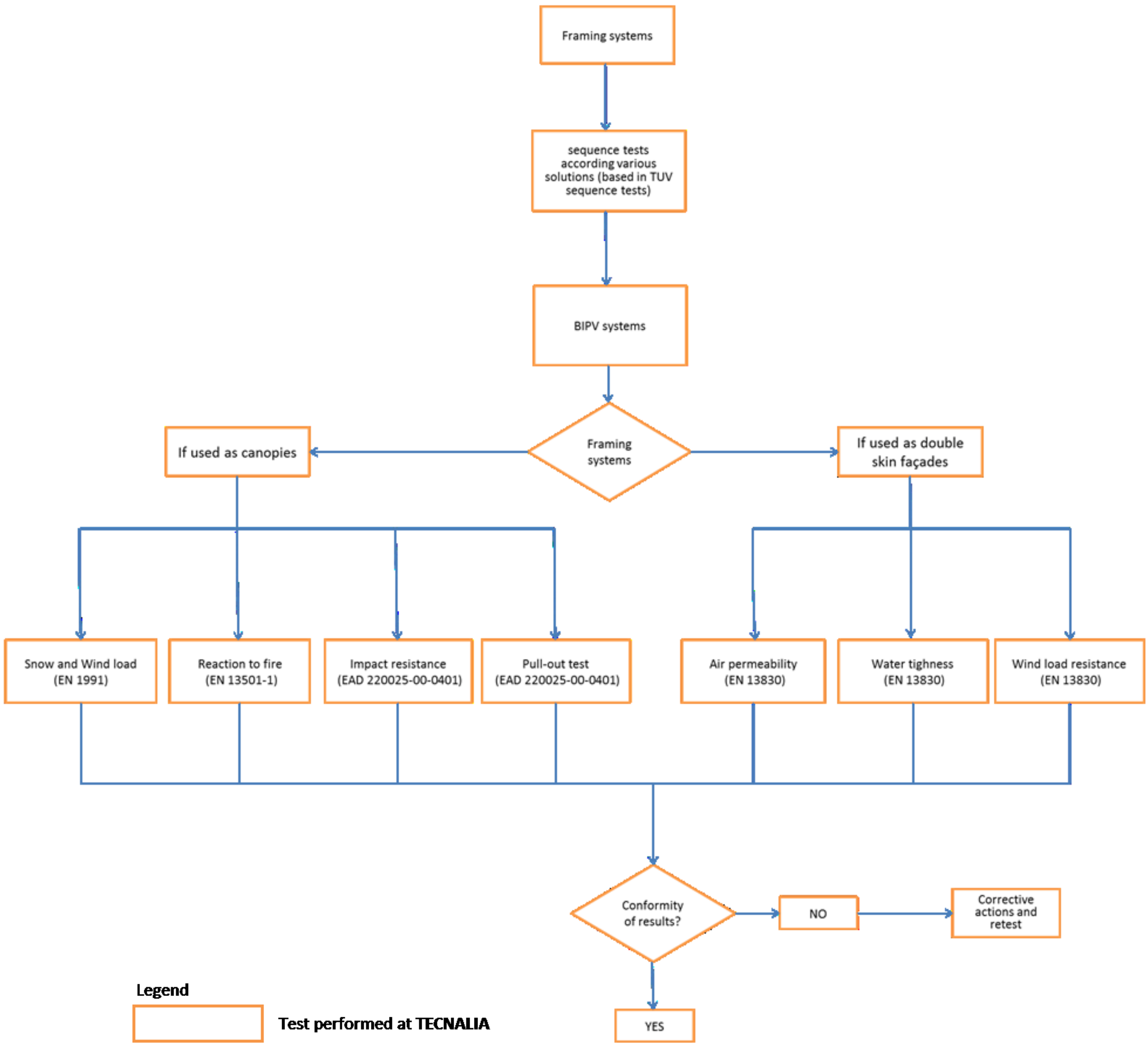


Combined Test-sequence for EN IEC 61215/61646/IEC 61730

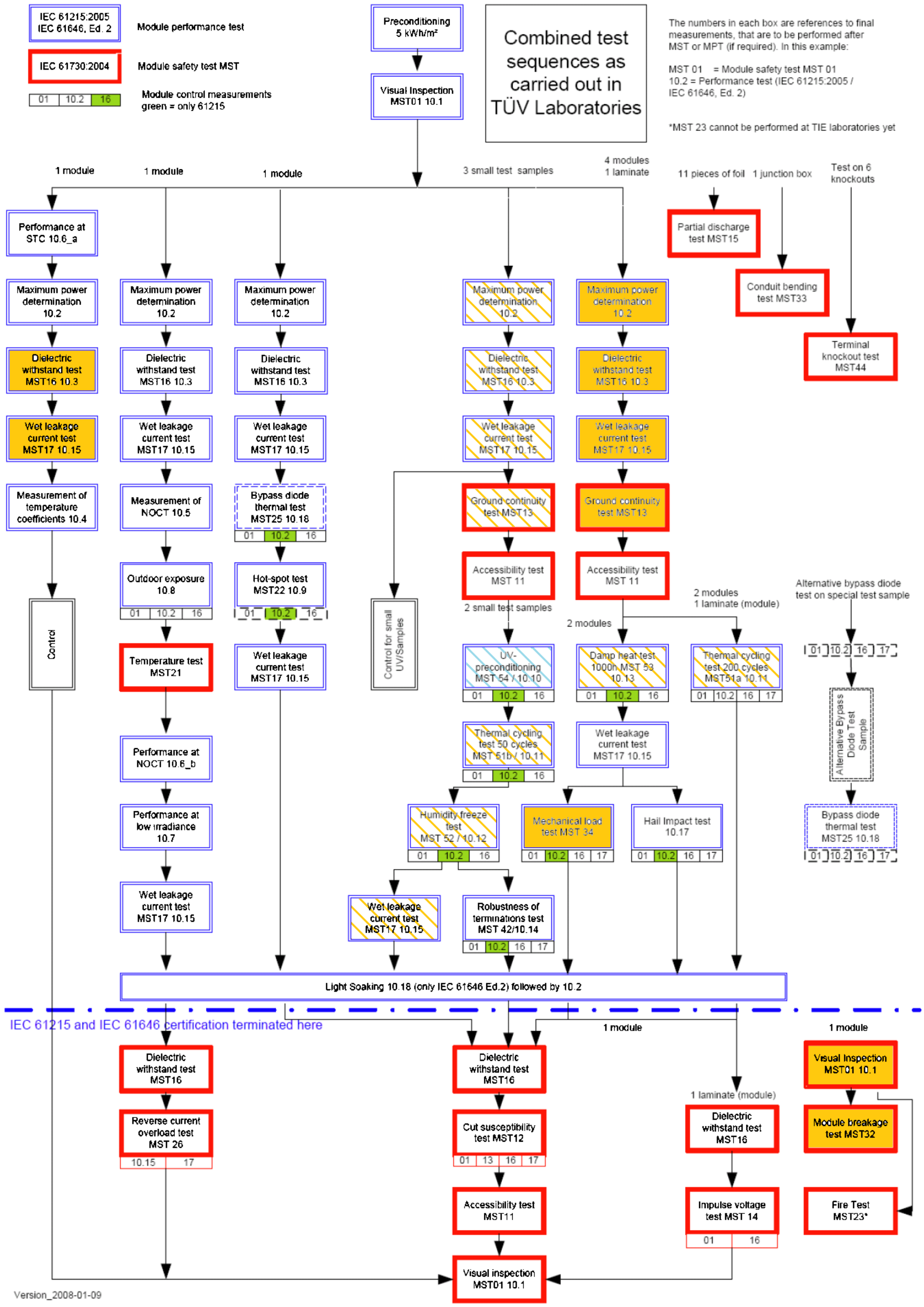


Annex 1.8: Tests sequences for X8 BIPV product (task 3.4)

X8 - Framing systems for C-Si large area glass

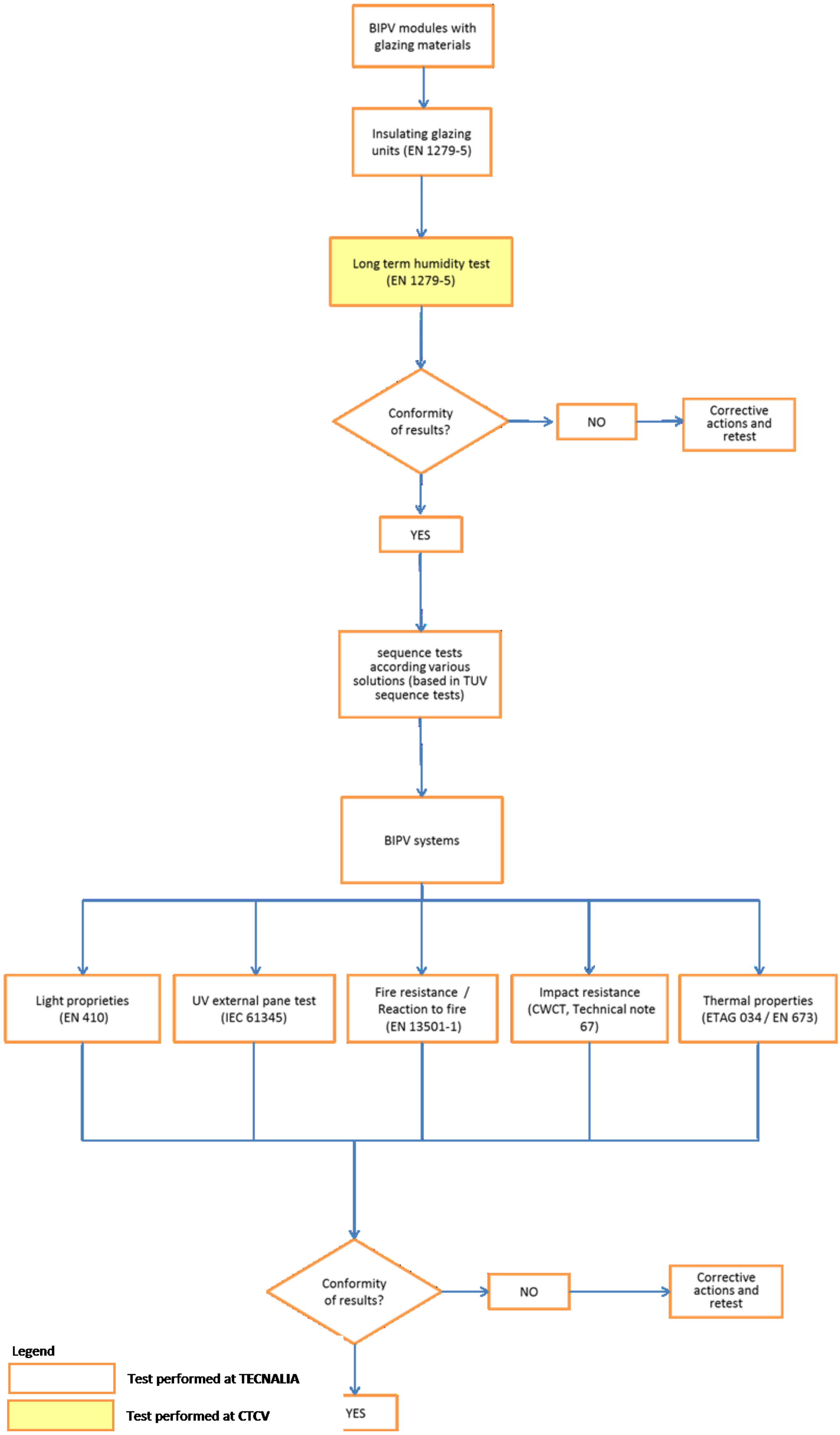


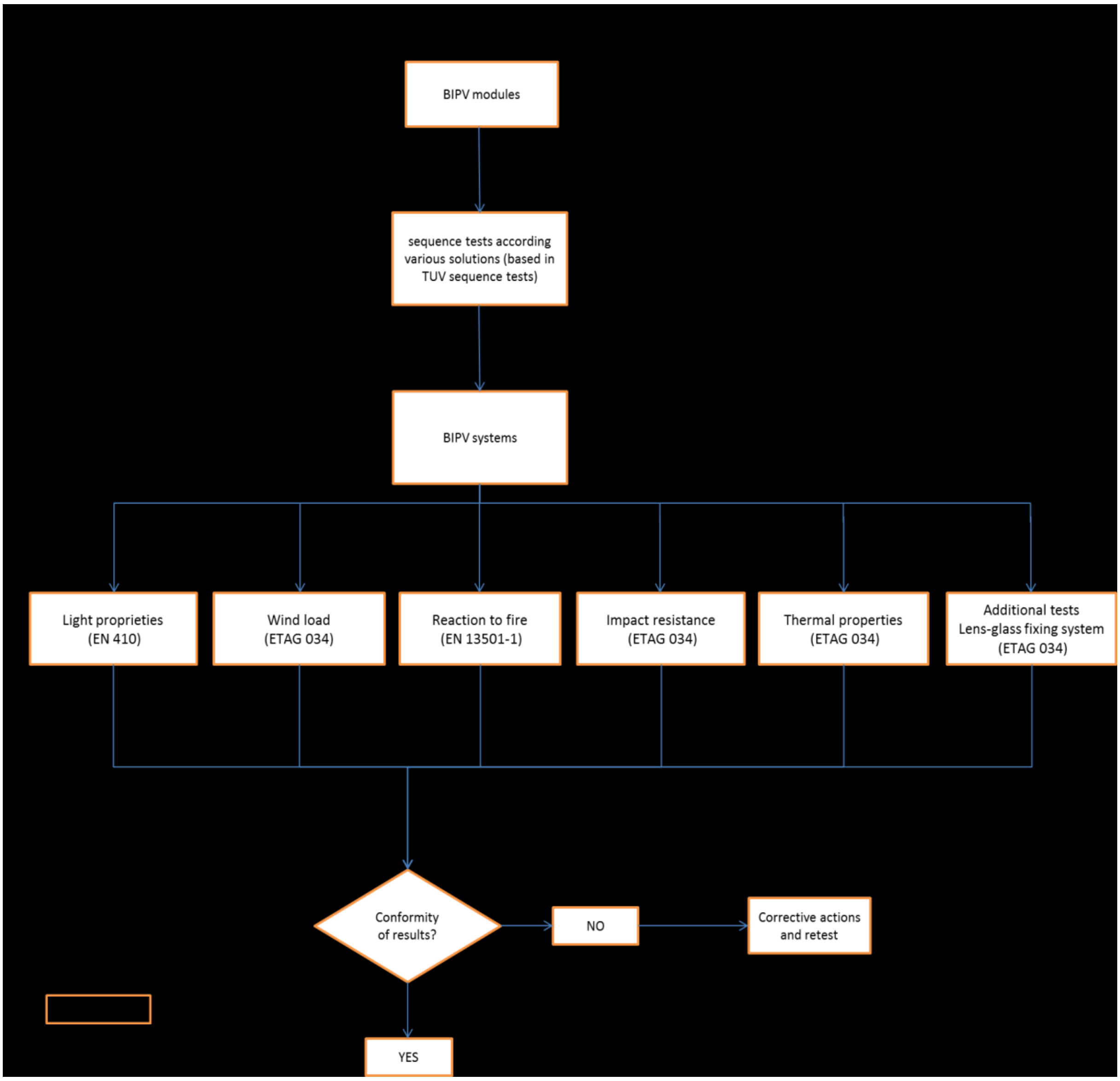
Combined Test-sequence for EN IEC 61215/61646/IEC 61730

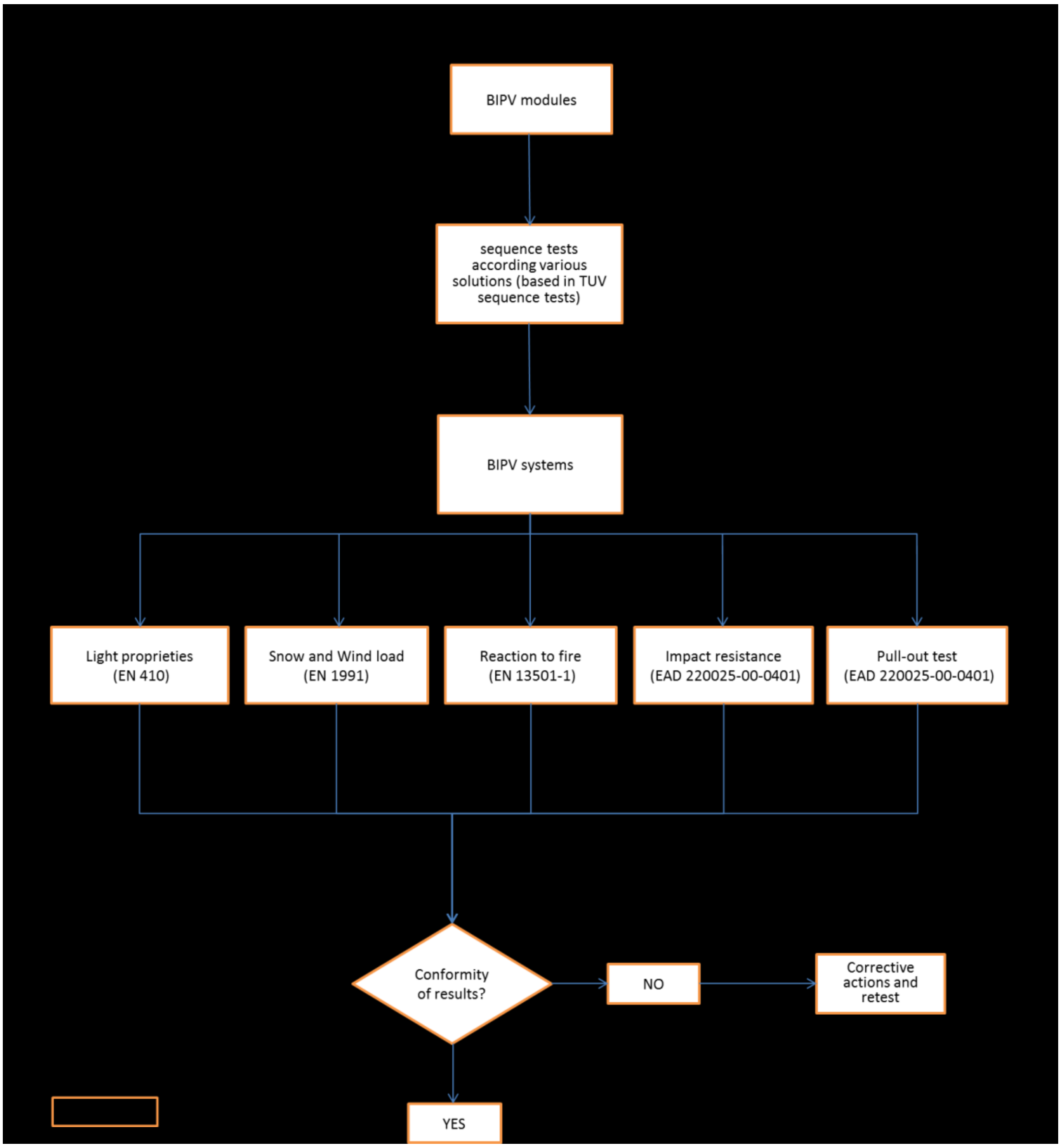


Annex 1.9: Tests sequences for X9 (skylight), X10(façade), X11 (shading element)

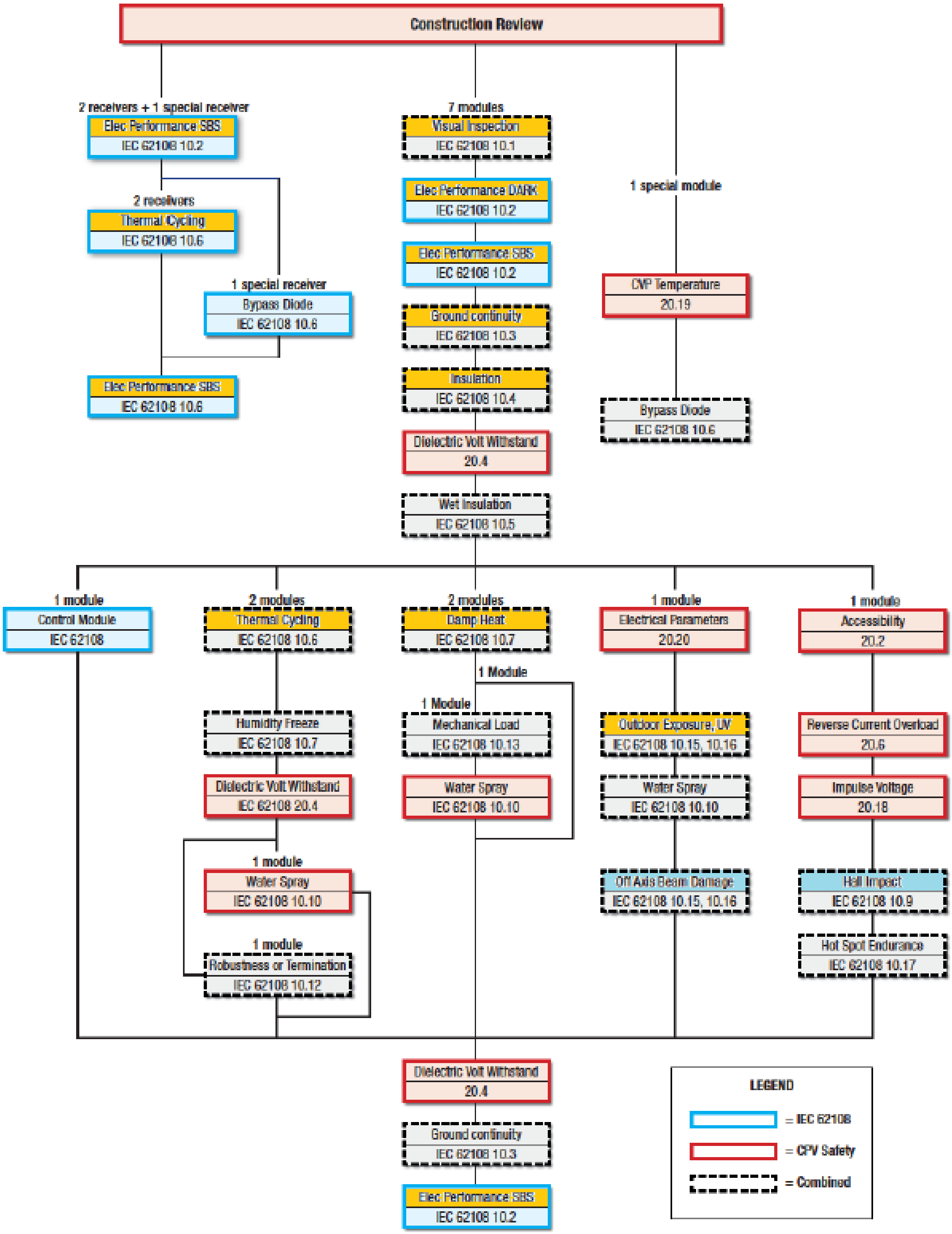
X9 - C-Si Low concentration system in skylight configuration



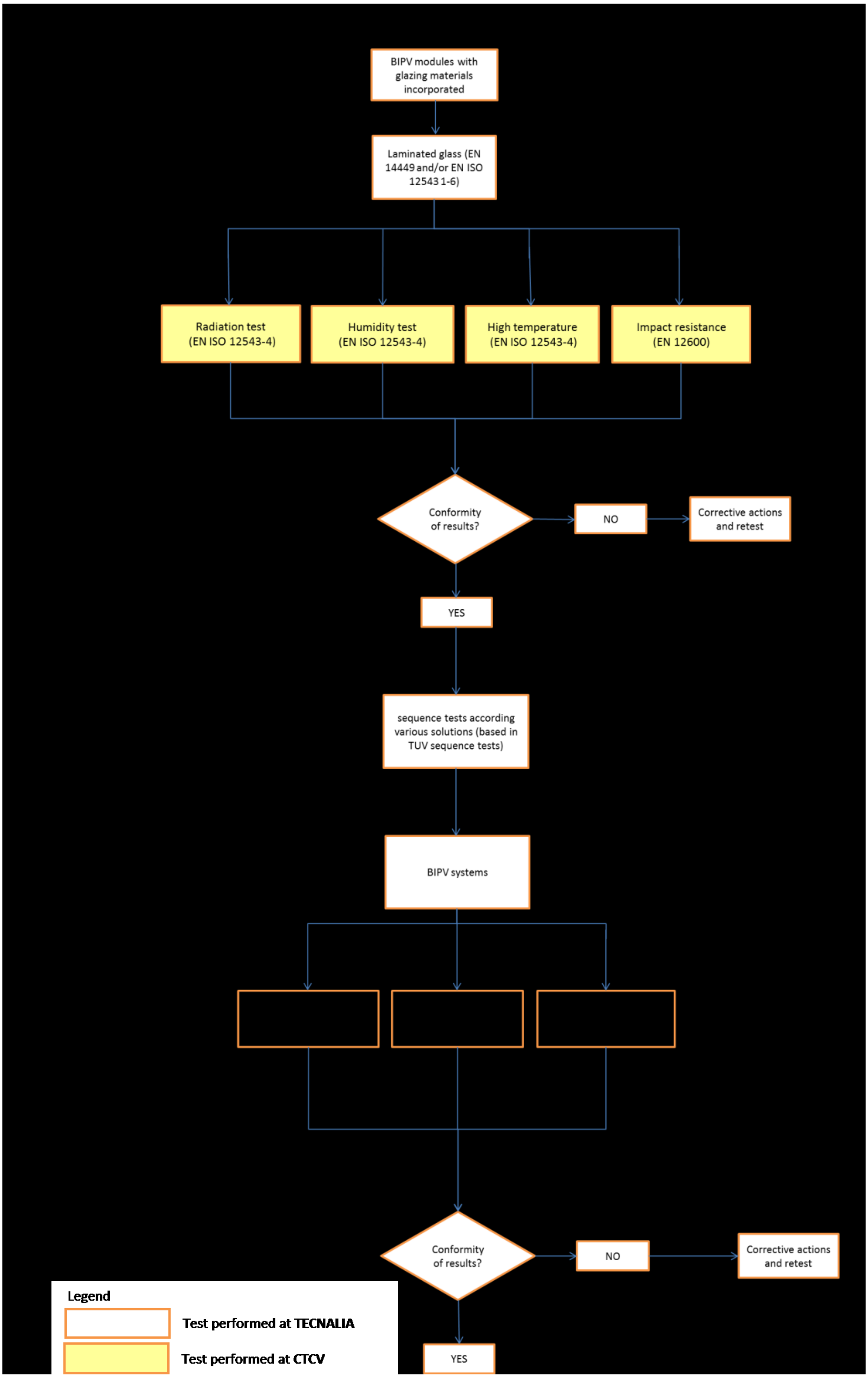

BIPV modules
sequence tests according various solutions (based in TUV sequence tests)
BIPV systems
Light proprieties (EN 410)
Wind load (ETAG 034)
Reaction to fire (EN 13501-1)
Impact resistance (ETAG 034)
Thermal properties (ETAG 034)
Additional tests Lens-glass fixing system (ETAG 034)
Conformity of results?
NO
Corrective actions and retest
YES


BIPV modules
sequence tests according various solutions (based in TUV sequence tests)
BIPV systems
Light proprieties (EN 410)
Snow and Wind load (EN 1991)
Reaction to fire (EN 13501-1)
Impact resistance (EAD 220025-00-0401)
Pull-out test (EAD 220025-00-0401)
Conformity of results?
NO
Corrective actions and retest
YES

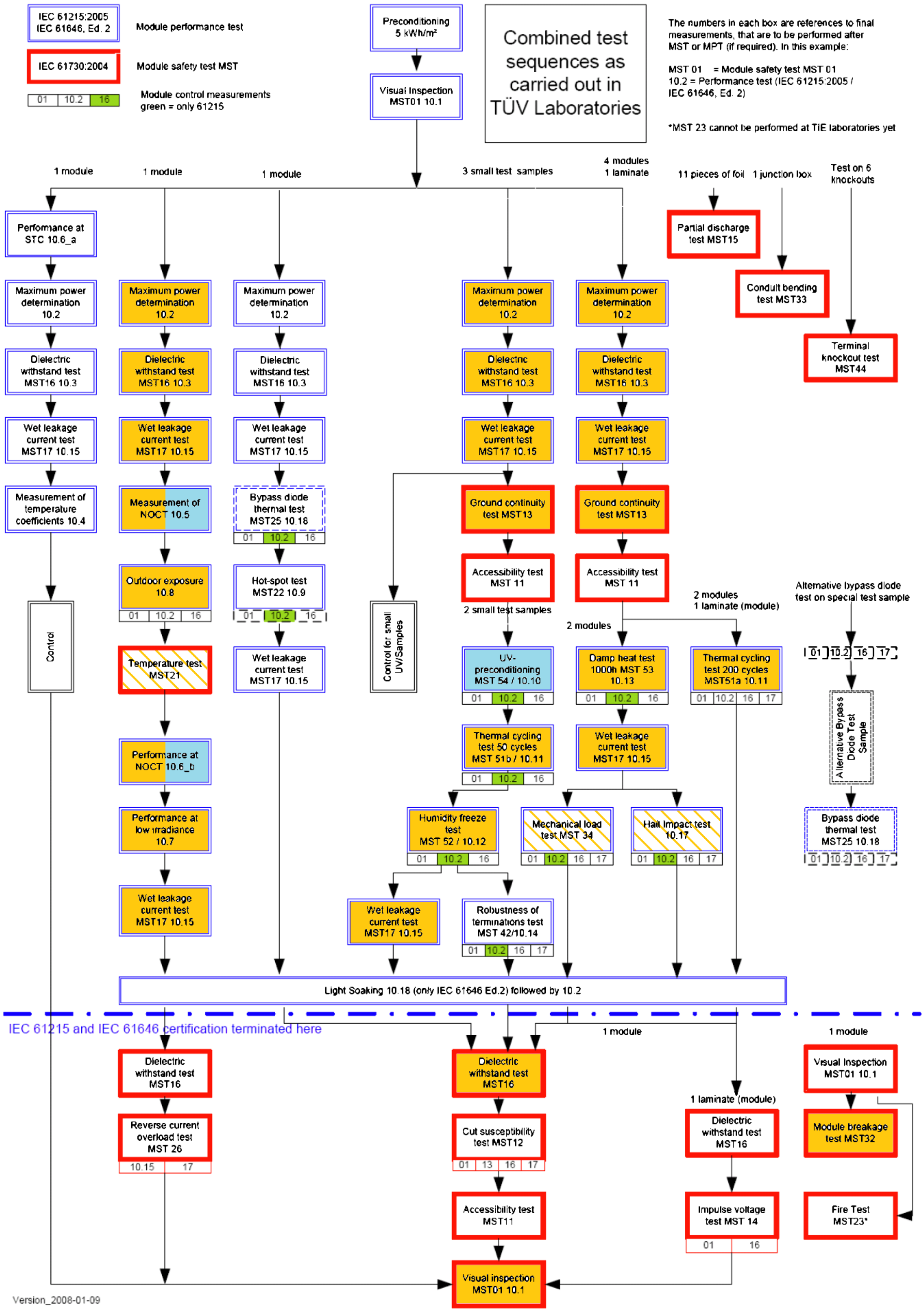
Combined Qualification/Safety Test Flow for CPV Modules



Annex 1.10: Tests sequences for X12 BIPV product (task 3.5)



Combined Test-sequence for EN IEC 61215/61646/IEC 61730



Annex 1.11: Tests sequences for X13 and X14 inverters (task 5.3)

Test description	Facility	Responsible
Insulation resistance (IEC 62109:1)	Electrical Equipment Laboratory	Tecnalia
Dielectric strength (IEC 62109:1)	Electrical Equipment Laboratory	Tecnalia
Voltage impulse (IEC 62109:1)	Electrical Equipment Laboratory	Tecnalia
PV array insulation resistance detection (IEC 62109:2)	Electrical Equipment Laboratory	Tecnalia
Residual current detection (IEC 62109:2)	Electrical Equipment Laboratory	Tecnalia
Maximum and minimum variations in grid voltage and frequency (EN50438)	Inverter Testing Laboratory	Tecnalia
Active power regulation (EN 50438)	Inverter Testing Laboratory	Tecnalia
Reactive power regulation (EN 50438)	Inverter Testing Laboratory	Tecnalia
Connection and reconnection conditions verification (EN 50438)	Inverter Testing Laboratory	Tecnalia
THD measurement (IEC 61000-3-2)	Inverter Testing Laboratory	Tecnalia
Voltage fluctuations and flicker measurement (IEC 61000-3-3)	Inverter Testing Laboratory	Tecnalia
Direct current injection measurement (EN 50438)	Inverter Testing Laboratory	Tecnalia
Islanding prevention measures (IEC 62116)	Inverter Testing Laboratory	Tecnalia
LVRT measurements (IEC 62910)	Inverter Testing Laboratory	Tecnalia
Overall efficiency of grid-connected PV inverters (EN 50530)		CEA
Measurement of MPPT performance under heterogeneous working conditions		CEA
Sandia test protocols for Advanced Inverter Interoperability Functions (INV1, INV2, INV3, INV4, VV, FW, L/HVRT, L/HFRT)	Inverter Testing Laboratory	Tecnalia
Sandia test protocols for Advanced Functions of grid-connected storage (R21-1-SS, R21-1-AI)	Inverter Testing Laboratory	Tecnalia

Annex 2: Analysis of EN50583 "PV in Buildings"

Product		System for demonstration	Relevant standards according with EN 50583:2016	
X1/ X3	CIGS roofing shingle on metal substrate	Roofing shingles	IEC 61646 a-Si	TF modules - Design qualification and type approval
			EN 61730	PV module safety qualification
			50583-2 Annex A	PV in buildings. Rain penetration test
			EN 13501 - 1	Fire - Classification from reaction to fire tests
X2	CIGS large area flexible roofing membrane and bendable elements	Roofing membrane	IEC 61646 a-Si	TF modules - Design qualification and type approval
			EN 61730	PV module safety qualification
			**EN 13363-1	Solar protection devices - Light & Solar
			50583-2 Annex A	PV in buildings. Rain penetration test
			EN 13956	Flexible sheet for waterproofing
			EN 13501 - 1	Fire - Classification from reaction to fire tests
			EN 16002	Flexible sheets for waterproofing - Resistance to wind load
X4	CIGS large area elements on metal substrate	Large area tiles façade Roof tiles on metal Large area roofing shingles	IEC 61646 a-Si	TF modules - Design qualification and type approval
			EN 61730	PV module safety qualification
			EN ISO 6946	Construction - Thermal transmittance
			EN 14782-3	Self-supporting metal sheet (roofing, cladding, lining)
			EN 14783	Supported metal sheet and strip for roofing, cladding, lining
			EN 13501 - 1,2,5	Fire - Classification from reaction to fire tests
			**EN 13116	Curtain walling - Resistance to wind load - Requirements
			**EN 12179	Curtain walling - Resistance to wind load - Test
X5	C-Si glazed products with hidden bus bars and L interconnections	Ventilated façade	EN ISO 12543 1-6	Glass in building - Laminated glass and laminated safety glass
			EN 14449	Laminated glass
			IEC 61215 c-Si	c-Si modules - Design qualification and type approval
			EN 61730	PV module safety qualification
			EN 13501 - 1,2	Fire - Classification from reaction to fire tests
			**EN 13116	Curtain walling - Resistance to wind load - Requirements
			**EN 12179	Curtain walling - Resistance to wind load - Test
X6	Glass-glass products with back contact c-Si cells	Ventilated façade	IEC 61215 c-Si	c-Si modules - Design qualification and type approval
			EN 61730	PV module safety qualification
			*EN 410	Glass - Light & Solar
			*EN ISO 12543 1-6	Glass in building - Laminated glass and laminated safety glass
			*EN 12758	Glass in building - Sound insulation
			*EN 12600	Glass in building - Pendulum test
			*EN 13501 - 1,1	Fire - Classification from reaction to fire tests
			**EN 13116	Curtain walling - Resistance to wind load - Requirements
			**EN 12179	Curtain walling - Resistance to wind load - Test
X7	Curved glass-glass, CIGS technology	TBD	EN ISO 12543 1-6	Glass in building - Laminated glass and laminated safety glass
			EN 14449	Laminated glass
			EN 61730	PV module safety qualification
			EN 673/674/675	Glass in building - U Value

			EN 12758	Glass in building - Sound insulation
			EN 13501 - 1	Fire - Classification from reaction to fire tests
X8	C-Si framing for large area glass	TBD	EN 61730	PV module safety qualification
			EN ISO 12631	Curtain walling - Calculation of thermal transmittance
			EN 13022-1	Glass in building - Structural sealant glazing (SSG)
			**EN 13116	Curtain walling - Resistance to wind load - Requirements
			**EN 12179	Curtain walling - Resistance to wind load - Test
X9 to X11	C-Si semi-transparent low concentration and solar control BIPV system	Skylight	EN 1279-5	Glass in building - Insulating glass units - Conformity
			**EN 13830	Curtain walling - Product standard
			IEC 62108	CPV - Design qualification and type approval
			EN 410	Glass - Light & Solar
			**EN 13363-1	Solar protection devices - Light & Solar
			EN 673/674/675	Glass in building - U Value
		Façade	EN 12758	Glass in building - Sound insulation
			EN 13501 - 1	Fire - Classification from reaction to fire tests
			**EN 13116	Curtain walling - Resistance to wind load - Requirements
			**EN 12179	Curtain walling - Resistance to wind load - Test
X12	Glazed modules treated for improved passive properties	TBD	***EN ISO 12543 1-6	Glass in building - Laminated glass and laminated safety glass
			***EN 14449	Laminated glass
			EN 410	Glass - Light & Solar
			EN 673/674/675	Glass in building - U Value
			IEC 61215 c-Si	Design qualification and type approval
			EN 61730	PV module safety qualification

* Just if another plastic sheet is included

** If required for application

*** If surface treatments in contact with encapsulants