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Glass in building — General technical requirements of building integrated photovoltaic modules recycling

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Foreword

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This document was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 1, *Product considerations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Glass in building — General technical requirements of building integrated photovoltaic modules recycling

1 Scope

This document specifies requirements for the recycling of building integrated photovoltaic (BIPV) modules. It is suitable for crystalline silicon PV modules and thin film modules.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 472, *Plastics — Vocabulary*

ISO 11469, *Plastics — Generic identification and marking of plastics products*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
waste photovoltaic module
waste PV module
photovoltaic module that the holder discards, or intends to discard, or is required to be discarded

3.2
laminated solar photovoltaic glass
laminated solar PV glass
double glass photovoltaic module
double glass PV module
laminated glass that integrates the function of photovoltaic power generation

Note 1 to entry: This term covers both laminated glass (see ISO 12543-3) and laminated safety glass (see ISO 12543-2).

[SOURCE: ISO/TS 18178:2018, 3.1, modified — Photovoltaic has been changed to PV.]

3.3
hazardous material
item, element or substance with a potential for harm in terms of human injury or ill health (both short and long term), damage to property, damage to the environment, or a combination of these

[SOURCE: ISO 30000:2009, 3.5]

3.4
collection
logistical process of moving waste photovoltaic module from its source to a place where it can be recovered

[SOURCE: ISO 472:2013, 2.1682, modified — Domain of application has been deleted, and "plastics waste" has been changed to "waste photovoltaic module".]

3.5
storage
temporary storing activity of waste photovoltaic modules at a special place which meets the requirements for the purpose of *collection* (3.4), transportation, *treatment* (3.10) and *disposal* (3.11)

3.6
disassembly
set of activities of demounting and disintegrating waste photovoltaic modules by a manual or mechanical way for the convenience of *treatment* (3.10)

3.7
re-use
use of a product more than once in its original form

[SOURCE: ISO 472:2013, 2.1708, modified — Note to entry has been deleted.]

3.8
recycling
processing of waste materials for the original purpose or for other purposes, excluding energy recovery

[SOURCE: ISO 472:2013, 2.1706]

3.9
recovery
processing waste material for the original purpose or for other purposes, including energy recovery

[SOURCE: ISO 472:2013, 2.1704]

3.10
treatment
set of activities of decontamination, *disassembly* (3.6), comminution and *recycling* (3.8) of waste photovoltaic modules

3.11
disposal
set of activities for diminishment or elimination of the danger of waste photovoltaic modules

Note 1 to entry: This can be by means of changing physical, chemical and biological characteristics.

Note 2 to entry: The activities of final placement for waste photovoltaic modules in a place or facility that meets the requirements for environmental protection.

3.12
termination
component that is used to extract the direct current from photovoltaic module

3.13
photovoltaic laminate
PV laminate
portion of a photovoltaic module consisting of substrate, encapsulant, complete photovoltaic cell circuit, and superstrate

Note 1 to entry: A photovoltaic module includes a laminate and a junction box. A frame and other accessories can also be added.

[SOURCE: IEC/TS 61836:2016, 3.1.50, modified — The preferred term has been changed to photovoltaic laminate.]

3.14
photovoltaic modules that lose safety performance
PV modules that lose safety performance
photovoltaic modules that have structural, electrical and other types of the safety risk

3.15
recovery rate
ratio of the weight of the recovery materials or components to the whole weight of the waste photovoltaic modules

4 Fundamental principles

4.1 The fundamental principles are the maximizing of resource utilization and the minimizing of environmental pollution.

4.2 The treatment shall be conducted according to the following order: re-use, recycling and energy recovery. The re-use and energy recovery should meet the requirements of related standards or specifications.

4.3 Treatment and disposal shall adopt the current optimal feasible technology. All necessary measures shall be employed in order to ensure that the effect of recycling process on personnel and the environment are in accordance with relevant standards during treatment and disposal.

4.4 The participants, including dismantlement, transportation and recycling organizations, shall establish appropriate information statistic systems for the collection, treatment and disposal of waste PV modules. The relevant data/information (see Table A.1) shall be saved and be available to competent departments or organizations.

4.5 Waste PV modules should not be landfilled or burnt directly.

4.6 Recovery materials or components should be used in PV modules.

4.7 Matters needing attention for recycling should be given (see Annex B) in the documentation of PV module.

5 Classification

5.1 It can be classified according to the type of cell:

a) Crystalline silicon PV module;

b) Copper indium gallium selenide (CIGS) PV module;

c) Cadmium telluride (CdTe) PV module;

d) Silicon-based thin film PV module;

e) Other types of PV module.

5.2 It can be classified according to the structure of encapsulation:

a) Single glass PV module;

b) Laminated solar PV glass;

c) Multi-layer glass PV module.

5.3 It can be classified according to abandoned condition:

a) PV module that lose safety performance;

b) PV module with damaged appearances, but the power generation performance works properly;

c) PV module where the power generation performance shows obvious attenuation, but the appearances are not damaged;

d) PV module with undamaged appearances and proper power generation performance, which the holder discards, or intends to discard for other causes.

NOTE Such PV modules can be reused without recycling.

6 Dismantlement

6.1 Dismantlement of waste PV modules shall avoid excessive emissions of pollutants, such as screw, rubber and metal components.

6.2 According to the methods of ISO 15928, the safety level of building after dismantlement of waste PV module should not be lower than that of building before dismantlement.

6.3 The electrical safety of the whole dismantlement should conform with the requirements of IEC 60364-7-704, IEC 60364-5-54 and IEC 60364-5-55.

6.4 The requirements related to the dismantlement of waste PV module can be found in national or local building safety codes.

6.5 Structure safety of buildings and safety of users shall be ensured during dismantlement process.

6.6 The system shall be electrically isolated before dismantlement, and it shall not be powered on until the whole system is repaired after being partly dismantled.

6.7 Safety nets should be installed in the working area to avoid tools and materials falling. Workers should be equipped with the safety devices such as safety helmets, safety ropes, safety shoes and safety clothes.

6.8 The integrity of PV modules should be ensured during the dismantlement process.

6.9 In order to avoid electric shock accidents, after the waste PV module is separated from the inverter, the cables of the module and inverter shall be insulated with insulating materials.

6.10 For cracked module, in order to prevent electric shock, the surface of the cracked waste PV module should be insulated in advance, if it is necessary to dismantle in rain and snow weather. Condition a) and b) should not be met at the same time:

a) sunlight irradiates directly on module illumination side;

b) human gets in contacts with the internal electrode of module directly or through conductive fluid.

6.11 For cracked module, before dismantlement, safety measures should be set to prevent the broken parts from falling.

6.12 The inner side of the building where waste PV module is disassembled shall be properly secured.

6.13 According to the disassembly height of the waste PV module, the appropriate size of the no walking area on the ground shall be set referring to Table 1.

Table 1 — Determination of the size of the no walking area

Dismantlement height, h m	No walking area radius m
$2 \leqq h \leqq 5$	3
$5 < h \leqq 15$	4
$15 < h \leqq 30$	5
$h > 30$	6

6.14 During the entire dismantlement process, safety measures for waste PV module should be taken to avoid accidents such as module falling, severely swinging, and bursting, caused by operation, wind and rain, etc.

6.15 For waste PV module on the side of the building, if conditions permit, dismantlement work should be operated from the interior of the building rather than from outside the building.

6.16 If traffic is too heavy, the operation time should select the daytime period when traffic is not heavy. If the above condition cannot be met, the road can be temporarily closed, or the radius of the no walking area can be expanded.

6.17 In the case of wind speed greater than 10 m/s or other bad weather such as rain, thunder, snow and fog, the waste PV module dismantlement work should not be operated, unless authorized by national or local regulations.

6.18 Before dismantlement, workers shall clean the work area, and remove water, snow, oil, dust and other slippery materials from the surface of waste PV module components.

6.19 Before dismantlement, a safety plan shall be set according to building conditions. The workers shall track the safety of both the tool and the dismantling worker in real time during dismantlement process, avoiding accidents such as tool falling, rope breaking, unstable fixed point. The communication between the workers shall be clear.

6.20 Safety and construction equipment shall be fully prepared before waste PV module dismantlement work.

6.21 If the building of disassembled waste PV modules is in use, it should install new BIPV modules or materials with building function to repair the building immediately.

6.22 The dismantled modules should be recorded into the information statistics system to form a complete information system with the transportation and recycling parts.

6.23 The dismantlement of photovoltaic insulating glass units with PV power generation should avoid glass breakage caused by operation.

6.24 The accessories of BIPV modules should be removed during the dismantlement processing. If the accessories cannot be removed on the spot, these modules should be collected separately, and the accessories should be removed before recycling processing.

6.25 The requirements related to dismantlement work can be found in national or local regulations for work at height.

NOTE Refer to Annex C for common requirements for work at height.

7 Collection, transportation and storage

7.1 General provisions

7.1.1 In the process of collection, transportation and storage, the harm caused by electric leakage of solar cell shall be prevented.

7.1.2 For PV modules that lose safety performance, these shall be classified prior to collection, transportation and storage. This shall be conducted in a manner that ensures personal injury is avoided.

7.1.3 For PV modules having risk of heavy metals leakage, these shall be classified prior to collection, transportation and storage. This shall be conducted in a manner that ensures environmental pollution is avoided.

7.1.4 PV modules shall avoid secondary pollution influencing the recycling, such as oil pollution and saline-alkali corrosion.

7.1.5 Sort waste PV modules according to the size and shape of waste PV modules before transportation and storage.

7.2 Collection

7.2.1 Waste PV modules shall be prohibited from being mixed with domestic garbage or industrial solid waste.

7.2.2 Collected waste PV modules shall be stored according to the requirements of 7.4.

7.2.3 Collector shall deliver collected waste PV modules to qualified organizations for disassembly and treatment.

7.2.4 Protection measures shall be set up to avoid harming of modules and broken components falling in the process of collection, such as broken glass, interlayer, termination, cable and solar cell, which can cause injury or pollute the environment.

7.3 Transportation

7.3.1 The waste PV module should be recorded in the statistical information management system before transportation.

7.3.2 In the process of transportation, unauthorized disassembly and treatment to waste PV modules shall not be conducted in any form.

7.3.3 Protective measures shall be set up to avoid harming of modules and broken components falling in the process of transportation, such as broken glass, interlayer, termination, cable and solar cell, which can cause injury or pollute the environment.

7.3.4 Secondary pollution to waste PV modules shall be prevented in the process of transportation, especially oil pollution and saline-alkali corrosion. Transportation organization should connect with a

recycling organization to ensure whether the recycling process requires avoiding secondary damage to PV modules or other requirements.

7.4 Storage

7.4.1 Requirements for the storage site of waste PV modules can be found in the relevant regulations, i.e. national and local laws and regulations.

7.4.2 All kinds of waste PV modules shall be classified prior to storage and all module types (see 5.1) shall be appropriately marked at prominent positions.

7.4.3 It shall be guaranteed that pollutants, such as broken glass, solar cell, termination and cable, cannot drop down during storage, avoiding pollution to environment.

7.4.4 Secondary pollution, especially oil pollution and saline-alkali corrosion, should be prevented during storage. Storage organization should connect with a recycling organization to confirm whether the recycling process requires avoiding secondary damage to PV modules or other requirements.

8 Disassembly

8.1 General provisions

8.1.1 It shall be strictly prohibited to discard any part of waste PV modules, which are taken out in advance.

8.1.2 Materials and all the taken-out parts shall be stored in appropriate classified containers and be marked clearly. Hazardous material should be classified correctly and stored carefully avoiding dangers to personnel and pollutants to environment.

8.2 Termination

8.2.1 The gas containing dust, which is produced in the process of sorting and crushing, shall be dealt with by the waste gas processing system. After treatment, waste gas should conform with the relevant requirements shown in Table D.1.

8.2.2 After the treatment of scrap wire and cable, all metals, plastic and rubber shall be recycled.

8.2.3 Termination waste should not be landfilled directly.

8.2.4 Waste water, produced in the process of waste termination cleaning, should be dealt with by the waste water treatment system, and should be recycled. After treatment, waste water should conform with the relevant requirements shown in Table D.1.

8.3 Frame

8.3.1 The frame should be mechanically disassembled before other recycling processing.

8.3.2 Mechanical disassembly shall be performed in a manner that prevents disassembled metal components from hurting workers.

8.3.3 After disassembly, the metal components that can be directly recycled should be subjected to cleaning, polishing and edge grinding.

8.3.4 After disassembly, the metal components that cannot be directly recycled shall be subjected to other environmentally friendly processes, e. g. melting, extraction, etc., and the processes shall guarantee no leakage.

8.4 PV laminate

8.4.1 Hot-melt methods or chemical techniques can be used to decompose interlayer while recycling PV laminate. Then the glass or organic back sheet should be peeled from the PV laminate. The integrity of the PV laminate should be ensured as far as possible.

8.4.2 A mechanical or chemical method can be used to separate the welding strip and the solar cell.

8.4.3 A mechanical method can be used to break the left PV laminate parts into small pieces. A dust collection system should be used during this process.

8.4.4 Multi-layer glass PV modules should be disassembled to glasses and laminated solar PV glass, then following the recycling processing of laminated solar PV glass.

8.4.5 The disassembly of photovoltaic insulating glass units should take the desiccant collection into consideration, avoiding desiccant pollution to environment. If the heat method is adopted, the disassembly should also consider poisonous gases during the high temperature processing during which the following should not be adopted: too high temperature or poisonous gases treatment.

9 Treatment

9.1 General provisions

9.1.1 When a hot-melt method and other heating methods are used to treat waste PV modules or parts of PV modules, waste gas treatment facilities shall be employed and the emissions of pollutants should meet the relevant requirements shown in Table D.1.

9.1.2 When an incinerating method is used to treat waste PV modules or parts of them, the emissions of pollutants should meet the relevant requirements shown in Table D.1.

9.1.3 Waste water and liquid produced in the process of treatment shall be disposed, and the emission of pollutant should meet the relevant requirements shown in Table D.1.

9.2 Glass

9.2.1 In the treatment process of thermal decomposition of glass, waste gas treatment system shall be employed to control the amount of impurity in waste gas. Any contaminants/pollutants produced should meet the relevant requirements shown in Table D.1.

9.2.2 When incinerating or hot-melt method is used to process glass, waste gas treatment facilities shall be employed. The emissions of pollutants should meet the relevant requirements shown in Table D.1.

9.3 Interlayer

9.3.1 After peeling the interlayer, it shall not be sent to land fill directly.

9.3.2 When an incinerating or hot-melt method is used to process interlayer, waste gas treatment facilities shall be equipped. And the emissions of pollutants should meet the relevant requirements shown in Table D.1.

9.3.3 After the hot melting of interlayer, the residue shall be recycled according to its physical and chemical characteristics.

9.4 Solar cell

9.4.1 In the recycling treatment of crystalline Si or Si thin film solar cells, there should be no polymer materials residue, and silicon solar cell may be recycled as silicon powder or silicon wafer according to the damaged condition.

9.4.2 Silver, aluminum and other metal impurities can be removed from silicon powder by a chemical method, and the emission of pollutants should meet the relevant requirements shown in Table D.1.

9.4.3 Entirety recycling uses chemical method for cleaning, corroding the surface coating, and finally for the polishing treatment. The discharge of waste water of the recycling process should meet the relevant requirements shown in Table D.1.

9.4.4 When an acid dissolution method is used to process solar cells, it shall be guaranteed that there is no leakage. Acid gas produced in reaction time shall be treated, and the emission of pollutants should meet the relevant requirements shown in Table D.1. After the treatment of waste liquid, the emission of pollutants should meet the relevant requirements shown in Table D.1.

9.4.5 When the heat treatment method is used, waste gas treatment facilities shall be employed. The emissions of pollutants should meet the relevant requirements shown in Table D.1.

9.4.6 When precious metal materials are extracted from solar cells, it shall be guaranteed that there is no leakage. Acid gas and waste liquid produced in reaction time shall be treated, and the emission of pollutants should meet the relevant requirements shown in Table D.1.

9.4.7 Protection measures should be set up to avoid polluting the environment or harming human health in the process of treatment.

9.5 Welding strip

9.5.1 The recycling of welding strip can generally use heat method or chemical etching to remove the surface tin and lead, in order to obtain high-purity copper. For aluminum welding strip used in thin film modules, it can be directly recycled in order to obtain high-purity aluminum.

9.5.2 The recovery purity of copper should attain 99,5 %. For aluminum welding strip used in thin film modules, the recovery purity of aluminum should attain 99,5 %. For the welding strip with known weights of copper and aluminum, the recycling technologies should attain 90 % recovery rate for each of these metals.

9.5.3 When lead of the welding strip is removed by chemical etching method, the treatment of the solution should meet the relevant requirements shown in Table D.1.

9.5.4 When tin of the welding strip is removed by chemical etching method, the treatment of the solution should meet the relevant requirements shown in Table D.1.

9.5.5 When extracting precious metal materials by chemical solution method, it shall be guaranteed that there is no leakage. Acid gas produced in reaction time shall be treated, and the emission of pollutants should meet the relevant requirements shown in Table D.1. After the treatment of waste liquid, the emission of pollutants should meet the relevant requirements shown in Table D.1.

9.5.6 After treatment, the discharge of waste gas and liquid, which are produced in the process of waste copper recycling, should meet the relevant requirements shown in Table D.1. Protection measures should be set up to avoid sharp metal strip causing injury, metal component falling and polluting the environment.

9.5.7 In the process of waste metal collection, transportation, storage and disassembly, suitable measures should be taken to avoid causing secondary pollution to the environment.

9.5.8 The copper after treatment can be divided into different categories according to the physical form and the name. Each kind of copper is divided into different groups according to different types of production, and each group is distinguished between different levels according to the name of the scrap copper. If copper recycled shows different quality in terms of purity or alloy component, it should be classified in accordance with EN 12861.

9.5.9 Tin and tin alloys should be classified by scrap purchasing enterprises in terms of different chemical component, physical form and existing way.

9.6 Plastic back sheet

9.6.1 If peeling back sheet by heating method, the heating temperature of the back sheet containing fluoride should not be too high according to the materials of back sheet, in order to prevent the production of poisonous gas like hydrogen fluoride.

9.6.2 Peeled back sheet materials shall not be discarded arbitrarily. Requirements for their recycling can be found in national or local treatment regulations for halogen-containing plastic products. The treatment of materials that cannot be recycled shall be in accordance with the treatment requirements of general industrial solid waste.

9.6.3 When an incinerating method is used to treat back sheet (containing fluoride or not), waste gas treatment facilities shall be employed, and the emissions of pollutants should meet the relevant requirements shown in Table D.1. When landfill is used for treatment, the emission of pollutants should meet the relevant requirements shown in Table D.1.

10 Recovery

10.1 Semiconductor materials recovery

10.1.1 The recovery of silicon materials generally uses a chemical method to remove the positive and negative electrodes, antireflection film, p-n junction and so on, in order to obtain recyclable high-purity silicon materials.

10.1.2 For modules with a known weight of silicon, the recycling technologies should attain 90 % recovery rate for silicon.

10.1.3 Silicon powder, which is purified twice according to the relevant requirements, can be suitable for semiconductor industry, and it may be treated by landfill when no heavy metals are contained.

10.1.4 Undamaged recovery silicon wafer may be used again in the photovoltaic industry.

10.2 Metal materials recovery

10.2.1 The purification of precious metals in solar cells may generally use the method of reduction after solvent corrosion for regeneration.

10.2.2 The purity of silver should attain 99,5 %. For modules with a known weight of silver, the recycling technologies should attain 90 % recovery rate for silver.

10.2.3 The purity of copper, indium, gallium and selenium should attain 90 %. For CIGS thin film modules with known weights of copper, indium, gallium and selenium, the recycling technologies should attain 90 % recovery rate for each of these metals.

10.2.4 For CdTe thin film module, the purity of cadmium and tellurium should attain 98 %. For CdTe thin film modules with known weights of cadmium and tellurium, the recycling technologies should attain 95 % recovery rate for each of these metals.

10.2.5 After treatment, the discharge of waste gas and liquid, which are produced in the process of scrap metal recovery, should conform with the relevant requirements shown in Table D.1.

10.2.6 Requirements for recovery metal products can be found in national or local regulations for metal products.

10.2.7 Requirements for the discharge of waste water can be found in relevant local standards.

10.3 Glass recovery

10.3.1 After treatment, light transmittance and strength of undamaged glass should conform with the requirement of re-use purpose. If re-used in the production of PV modules, it should follow the usual requirements of glass for PV modules.

10.3.2 Requirements for recycled and undamaged glass can be found in national or local regulations for glass products.

10.4 Polymer materials recovery

10.4.1 In the recovery treatment of waste PV modules, the waste gas and liquid produced in the treatment process of polymer materials should be collected and be treated in a harmless way. After that, waste plastics shall be classified for re-use.

10.4.2 Waste plastic containing flame retardants can only be applied to plastic products raw materials containing flame retardants.

10.4.3 Requirements for recovery plastic products or materials can be found in national or local regulations for plastic products. A recovery logo shall be marked on the surface and conform with the relevant requirements of ISO 472 and ISO 11469.

10.4.4 In the production process of recovery plastic products or materials, chloro-fluoro-carbons shall not be used as foaming agent. Poisonous and harmful chemical additives shall not be utilized to improve recycle raw material plastic characteristic when the final product could come in contact with human being.

11 Management

11.1 Recycling organizations shall establish a system of record for the whole recycling process.

11.2 Recycling organizations shall keep records of treatment related to waste PV modules, pollutant monitoring and other relevant processes for at least three years. They can also be required to be inspected by local authorities.

11.3 Recycling organizations shall have the corresponding environmental protection facilities, including waste water treatment, waste gas treatment, dust treatment and noise reduction devices, and the discharges of pollutants shall meet the relevant national standards. The pollutant concentration in the discharge of waste water and waste gas should be monitored regularly. The noise at the boundary of the industrial premises should be monitored regularly. Requirements for its level can be found in national and local laws and regulations.

11.4 Recycling organizations shall establish emergency handling procedures, and have a complete protective equipment system and measures. Requirements for the operation can be found in national and local laws and regulations.

11.5 New workers shall conduct pre-service training or operation under the guidance of the technician.

11.6 The operation and management of the recycling organization should meet the requirements of ISO 14001, ensuring that the discharge of the three wastes meets the national or local standards, the recycling operation information is fully monitored, and the potential dangers of personal safety and environmental pollution are avoided.

Annex A
(informative)

Data collected for the information statistic system

Table A.1 — Data collected by different participants for the information statistic system

	Dismantlement organization	Transportation organization	Recycling organization
1	date of dismantlement	date of transportation	date of recycling
2	building function of waste PV module	location of waste PV module collection	recycling material category
3	BIPV project location	destination	weight of recycling materials
4	module type	module type	module type
5			module size
6			module weight
7			greenhouse gases of recycling process
8			date of manufacture
9			BIPV manufacturer
10			BIPV project location
11			reason of discard
12			date of dismantlement
13			date of transportation

NOTE 1 The data in the table or other data are optional for the information statistic system.

NOTE 2 Building function of waste PV modules can be curtain wall, sunroof, handrail, carport and roof.

NOTE 3 Recycling materials categories can include Si, Ag, Cu, In, Ga, Se, Al, Te, Cd, glass, etc.

NOTE 4 Greenhouse gases emission management of organization and project level should conform with ISO 14064.

NOTE 5 For module type, see 5.1 and 5.2 for reference.