Understanding the Impact of Climate Change on Building Façade-integrated Photovoltaic Durability Testing: A Review

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Abstract

Building-integrated photovoltaic (BIPV) systems blend energy generation with traditional architectural functions, promoting the development of zero-energy buildings by reducing energy consumption, lowering greenhouse gas emissions, and enhancing aesthetic value. Despite these benefits, the integration of photovoltaic technology into building materials introduces challenges, notably in ensuring structural integrity, maintaining thermal performance, and securing long-term durability under diverse environmental conditions. This review examines current standards and building codes relevant to BIPV windows, highlighting the necessity for testing protocols that encompass combined stressors from extreme weather events exacerbated by climate change. Through a case study focused on Singapore, the review underscores the rising frequency of combined heat and wind events, advocating for robust standards and adaptive policies. The paper identifies critical research gaps and proposes future directions to enhance the reliability and performance of BIPV systems, aiming to solidify their role in sustainable building practices.

Introduction

Building-integrated photovoltaics (BIPV) have evolved from niche technology to a cornerstone of sustainable architectural design, merging traditional building materials with energy production capabilities (Simon and Nicolò, 2009). This integration not only enhances building aesthetics but also significantly reduces energy consumption and greenhouse gas emissions, contributing to the development of zero-energy buildings (Kapsalaki & Leal, 2011). However, integrating PV technology into building materials not only promises energy self-sufficiency but also introduces complex challenges. Ensuring structural integrity, maintaining thermal performance, and achieving architectural aesthetics requires overcoming significant technical and regulatory hurdles (Agathokleous and Kalogirou, 2020). Additionally, the long-term durability of these systems is compromised by environmental factors, as materials degrade under conditions such as UV exposure, temperature fluctuations, and mechanical loads (King et al., 2000). Existing standards and building codes play a crucial role in guiding the development and implementation of BIPV windows. Key standards for BIPV systems include EN 50583, which covers general requirements, electrical performance, and safety aspects, and IEC 63092, which defines requirements for PV modules and their integration into buildings(Pellegrino et al., 2013). Additionally, ISO 18178 specifies requirements for laminated solar PV glass used in buildings. These standards ensure that BIPV systems perform reliably under specified environmental conditions. When BIPV windows are integrated into building designs, they must also comply with building codes and standards for fenestration systems. Standards such as ASTM E330/E330M, which evaluate structural performance under wind pressures, and EN 1279, which defines requirements for IGU, are crucial. These standards ensure that BIPV windows provide adequate insulation and maintain thermal performance, which is critical for energy efficiency and occupant comfort.

Meanwhile, climate change has led to an increase in the frequency and severity of extreme weather events, such as hurricanes, heavy rain, and temperature fluctuations. The escalating severity of climate change presents significant challenges for building materials, as increased moisture, temperature extremes, and heightened storm activities accelerate material deterioration (Stewart et al., 2011; Lacasse et al., 2020). For BIPV systems, the implications are particularly dire; they must withstand not only the usual environmental stressors but also intensified conditions such as increased UV exposure, more frequent thermal cycling, and stronger wind loads, which collectively compromise their durability and functional integrity(Sharma et al., 2013;Tawalbeh et al., 2021). Traditional durability testing protocols often focus on single stressors, such as wind or rain, but real-world scenarios typically involve multiple, simultaneous environmental stressors. This necessitates the development of combined durability testing procedures that can accurately simulate the harsh conditions BIPV windows may face. Fedorova et al., (2021) conducted studies showing that BIPV systems need to withstand complex environmental conditions that include simultaneous exposure to wind, rain, and temperature fluctuations. Furthermore, a report by the International Energy Agency (IEA) underscores the importance of developing testing methods that consider these combined stressors to improve the reliability and lifespan of BIPV windows(IEA 2022).

The goal of this review paper is to understand the standards and building codes relevant to solar-integrated building systems, particularly BIPV windows. It aims to explore how existing standards, codes, and policies address the challenges posed by extreme weather conditions and to identify gaps where further research and policy development are needed. By focusing on the combined effects of environmental stressors, this review seeks to provide a comprehensive understanding of the durability and performance requirements for BIPV windows, ensuring their long-term reliability and contribution to sustainable building practices. In summary, this paper will 1) review existing standards and building codes on BIPV windows, 2) highlight the critical role of standards and codes in the deployment of BIPV systems, 3) examine the challenges posed by extreme weather conditions, and 4) propose directions for future research and policy to enhance the resilience and performance of BIPV windows in the face of evolving environmental challenges.

Existing Standards and Codes on Durability

Existing standards and codes about durability assessment are essential for guiding the development and implementation of BIPV windows. These standards address a range of individual stressors, durability parameters, and policy concerns to ensure that BIPV systems perform reliably under varying weather conditions. This section introduces the relevant standards, codes, and policies for individual stressors such as temperature, humidity, wind load, and solar/UV radiation, as well as for combined stressors(IEA 2022).

Temperature variations are a critical factor affecting the durability and performance of both traditional building window systems and BIPV windows. Several standards address the requirements for withstanding thermal cycling to ensure long-term reliability. ISO 18178 specifies requirements for laminated solar PV glass used in buildings, ensuring durability under temperature changes by maintaining structural integrity and safety, with the PV glass tested to withstand thermal cycles typically ranging from -40°C to 85°C. IEC 63092 outlines requirements for BIPV modules and systems to endure temperature variations, ensuring that PV modules can maintain their electrical performance and structural stability under thermal stress, often tested within a similar temperature range. Additionally, ISO 12543 provides specifications for laminated glass and safety glass, emphasizing the need for these materials to resist degradation at high temperatures, typically up to 200°C, to ensure long-lasting durability and safety.

Humidity and moisture ingress can significantly affect the performance and longevity of BIPV windows, and several standards ensure that materials and systems can resist these conditions effectively. ASTM E2188 tests the performance of insulating glass units(IGU) under temperature changes and moisture ingress, evaluating durability by ensuring that materials can resist thermal stress and moisture penetration, often under conditions of up to 85% relative humidity. ASTM E2189 evaluates the resistance of IGU to fogging caused by humidity and temperature fluctuations, ensuring visibility and performance are maintained in high humidity conditions, typically tested at up to 100% relative humidity. ASTM E2190 outlines performance criteria for IGU, focusing on durability under environmental stressors, including humidity and moisture ingress, often tested in environments with humidity levels up to 95%. ASTM E331 evaluates water penetration resistance of exterior windows, skylights, doors, and curtain walls by applying a uniform static air pressure—typically 300 Pa—while spraying water at a rate of 204 liters per hour per square meter, simulating wind-driven rain conditions. ASTM E547 evaluates resistance to water penetration under cyclic static air pressure differences, ensuring that windows can withstand fluctuating pressures, with similar water spray and pressure conditions as ASTM E331. EN 1027 defines the water-tightness test method for windows and doors, ensuring resistance to water penetration under specified conditions, commonly tested with pressure differences ranging from 50 Pa to 600 Pa, depending on the performance class. These standards collectively ensure that BIPV windows can endure high humidity and rainy conditions, maintaining their structural integrity and functionality.

High wind pressures can exert significant mechanical stress on window systems, and standards addressing wind load ensure that windows can withstand these conditions without structural failure. ASTM E330/E330M evaluates the structural performance of exterior windows, doors, skylights, and curtain walls under uniform static air pressure differences, simulating wind loads. This standard ensures that window systems can resist deformation or structural failure under high wind pressures, with tests typically applying pressures up to 2400 Pa to verify safety and integrity. ASTM E1886 tests the performance of exterior windows, curtain walls, doors, and storm shutters under missile impact and cyclic pressure differentials, simulating conditions such as those experienced during hurricanes. This standard assesses the ability of window systems to withstand both impact and fluctuating pressures, with missile impact tests involving projectiles traveling at speeds up to 80 feet per second and cyclic pressure tests applying pressures up to 9600 Pa. ASTM E1996 specifies performance criteria for exterior windows, curtain walls, doors, and storm shutters impacted by windborne debris in hurricanes. It ensures that these components can resist damage from debris impacts during high wind events, with tests involving projectiles like wooden boards impacting at speeds of up to 34 meters per second, which is crucial for maintaining safety in hurricane-prone areas. These standards collectively ensure that BIPV windows can endure high wind loads, maintaining their structural integrity and functionality during extreme weather events.

Prolonged exposure to solar and UV radiation can degrade materials over time, and several standards ensure that materials used in BIPV windows can withstand these conditions effectively. IEC 61215 provides qualification requirements for PV modules, including tests for UV exposure. It ensures that PV modules can withstand prolonged UV radiation without losing efficiency or structural integrity, typically testing modules for 60 kWh/m^2 of UV exposure to simulate extended sunlight exposure, which is vital for their long-term durability and performance. IEC 61730 outlines safety qualification requirements for PV modules, including UV testing. This standard ensures that encapsulant materials and other components of PV modules can resist degradation due to UV exposure, maintaining both safety and functionality, with UV exposure tests typically involving 15 kWh/m^2 to assess the resistance of materials to UV-induced damage. ISO 12543 specifies requirements for laminated glass and safety glass, including testing for durability under solar and UV radiation. It ensures that laminated glass can maintain its structural integrity and visual clarity despite prolonged exposure to sunlight, often involving exposure to UV radiation equivalent to 50 kWh/m^2, to ensure the glass can withstand solar radiation without significant degradation. These standards collectively ensure that BIPV windows can endure prolonged solar and UV radiation, maintaining their structural integrity and functionality over their expected lifespan.

Policy and Building Code Considerations for BIPV Windows

Building-integrated photovoltaic (BIPV) systems are significantly influenced by local and international building codes and policies, which dictate aspects ranging from system integration to safety and aesthetic standards. A comprehensive review by Curtius (2018) outlined the current landscape of these regulations, demonstrating the diverse approaches taken by different regions to incorporate renewable energy technologies into their building practices. This review highlights both the facilitative policies that have encouraged BIPV adoption and the restrictive regulations that have impeded its broader integration(Curtius 2018). Policies require compliance with standards like ASTM E1996 for hurricane-prone areas, which ensures that windows, including BIPV systems, can resist windborne debris and withstand high wind pressures. ASTM E1996 involves testing with projectiles such as wooden boards impacting at speeds of up to 34 meters per second, simulating the effects of debris during hurricanes. This compliance enhances the safety and resilience of buildings equipped with BIPV windows during extreme weather events, thereby protecting both the structure and its occupants. Moreover, building codes incorporating standards like ASTM E2188 emphasize the importance of energy-efficient IGU, while evaluating the performance under temperature changes and moisture ingress, ensuring that these units can maintain their insulating properties and reduce energy consumption in buildings. This aligns with broader sustainability goals and regulatory requirements aimed at promoting energy conservation, thus contributing to lower energy costs and reduced environmental impact. Furthermore, policies promoting sustainable building practices often reference standards such as ISO 15392 and ISO 15686-1, which provide general principles for sustainability in building construction. These standards offer guidelines for minimizing environmental impact and optimizing the lifespan of building components, thereby supporting the integration of BIPV systems into green building initiatives..

While existing standards provide a solid foundation, there are several limitations that need to be addressed to ensure the comprehensive durability and performance of BIPV windows. Many existing standards and testing protocols concentrate on single environmental stressors, such as wind load or humidity. This approach may not adequately simulate real-world conditions where multiple stressors occur simultaneously. For instance, a BIPV window might be exposed to high winds, heavy rain, and temperature fluctuations all at once during a severe storm(Breivik et al., 2013), with possible damage to insulation(Zhang et al., 2023). Therefore, the current single-stressor focus highlights the need for more comprehensive testing protocols that consider combined stressors to ensure realistic durability assessments. This gap necessitates the development of new testing methods that can replicate the complex interactions of multiple environmental factors. Additionally, integrating PV technology into traditional building components introduces new complexities that existing standards may not fully address(Maghrabie et al., 2021). BIPV windows serve dual functions: generating electricity and providing structural integrity as part of the building envelope. Ensuring compatibility between electrical performance and structural integrity requires careful consideration and may necessitate the development of new or revised standards(Shukla et al., 2017). For example, the materials and designs used in BIPV windows must balance the requirements of efficient energy production with those of maintaining weather resistance and structural support, a challenge not fully covered by current standards. Moreover, current standards may not fully account for the increasing frequency and intensity of extreme weather events due to climate change. As weather patterns become more erratic and severe, BIPV windows must be capable of withstanding more extreme conditions than those typically covered by existing standards. This underscores the importance of adaptive testing protocols that can simulate the combined effects of various environmental stressors, such as high winds, heavy rain, and temperature fluctuations.

Extreme Weather Conditions on Durability Testing

The first aspect related to extreme weather conditions is the combined stressors, such as simultaneous exposure to temperature variations, humidity, wind load, and UV radiation, which present significant challenges to the durability and performance of BIPV windows(Özkalay et al., 2024). Real-world scenarios frequently involve multiple environmental stressors occurring together, which can exacerbate the effects on materials and systems. For the latest combined stress testing, DuPont developed the module accelerated sequential testing(MAST) with temperature, humidity, UV, and wind load on both sides of the PV module and reported a significant reduction in total test time(Gambogi et al., 2019). NREL introduced the combined accelerated sequential testing(C-AST) with 2 by 2 mini-modules of Tessolar construction that could outperform the other two reference construction samples(Hartman et al., 2019). Luo used the in-situ degradation method to demonstrate the environmental impact of various p-type multi-Si PV technologies and analyze their energy payback time and greenhouse gas emissions(Luo et al., 2018). Addressing these combined stressors through comprehensive testing is crucial for ensuring the long-term reliability and functionality of BIPV systems.

Meanwhile, standards addressing combined stressors ensure comprehensive durability testing, providing a more realistic assessment of the module's long-term performance under varied environmental conditions. For example, IEC 61215 includes combined environmental stress testing for PV modules, ensuring they can withstand multiple simultaneous stressors such as thermal cycling, humidity freeze, and UV exposure. It specifically tests modules with thermal cycles ranging from -40°C to 85°C, humidity freeze tests at high humidity levels around 85% at -40°C, and UV exposure up to 60 kWh/m². These rigorous tests ensure that PV modules maintain their performance and structural integrity under real-world conditions. Similarly, IEC 61730 covers safety qualifications for PV modules under combined stressors, testing modules for their ability to resist degradation from simultaneous environmental stressors like mechanical load combined with temperature cycling and UV exposure. These tests typically involve applying mechanical loads of up to 2400 Pa while cycling temperatures between -40°C and 85°C and exposing modules to UV radiation levels of 15 kWh/m², ensuring both safety and functionality. EN 50583 addresses both BIPV modules and systems, specifying general requirements for electrical performance and safety, including provisions for combined environmental stress testing. This standard ensures that BIPV systems integrated into building windows can endure real-world conditions involving multiple simultaneous stressors, maintaining their functionality and safety. Together, these standards ensure that BIPV windows are rigorously evaluated for durability and performance under the combined effects of various environmental stressors, enhancing their reliability and lifespan in diverse and challenging environments.

The second aspect of extreme weather conditions is related to the exacerbated situations caused by climate change, posing significant challenges to the durability and performance of BIPV windows. These conditions often involve the simultaneous occurrence of multiple environmental stressors, which can severely test the structural integrity and functionality of BIPV systems. Hurricanes and typhoons are characterized by high wind speeds, heavy rainfall, and flying debris. These events can subject BIPV windows to extremely high wind pressures, which cause significant mechanical stress on window structures. Standards such as ASTM E330/E330M and ASTM E1996 address these concerns by evaluating the structural performance of windows under simulated wind loads, typically applying pressures up to 2400 Pa to verify safety and integrity. Additionally, intense rainfall associated with hurricanes can lead to water ingress, challenging the watertightness of window systems. Standards like ASTM E331 and ASTM E547 test the resistance of windows to water penetration under pressure differences, commonly simulating rain conditions with pressure differences of 300 Pa and water spray rates of 204 liters per hour per square meter. Furthermore, the combination of high winds and heavy rain exacerbates the stress on BIPV windows, as wind-driven rain can penetrate gaps and seams while high wind pressures weaken the structure, making it more susceptible to water damage.

Heatwaves involve prolonged periods of extremely high temperatures, which can cause thermal expansion and contraction in materials, potentially leading to material fatigue and failure. Standards such as ISO 18178 and IEC 63092 ensure that BIPV modules can withstand thermal cycling, typically tested within a temperature range of -40°C to 85°C without significant degradation. Moreover, increased exposure to UV radiation during heatwaves accelerates the degradation of materials like encapsulants and coatings. Standards like IEC 61215 and ISO 12543 include provisions for UV testing, exposing materials to UV radiation levels up to 60 kWh/m² to ensure long-term durability under intense sunlight. Thus, simultaneous exposure to high temperatures and UV radiation can significantly impact the lifespan of BIPV windows, necessitating comprehensive durability testing to ensure their reliability.

Severe storms and heavy rainfall can lead to increased moisture levels and water ingress, challenging the moisture resistance of BIPV systems. Standards such as ASTM E2188 and EN 1027 address the performance of IGUs under high humidity and rain conditions, ensuring they can resist moisture penetration and maintain their insulating properties. ASTM E2188 evaluates the durability of IGUs under moisture ingress and thermal stress, ensuring that they can maintain performance in conditions of up to 85% relative humidity. Additionally, EN 1027 defines the water-tightness test method for windows and doors, ensuring resistance to water penetration under specified conditions, commonly tested with pressure differences ranging from 50 Pa to 600 Pa.

High wind speeds during storms exert mechanical stress on windows, testing their structural resilience. Standards like ASTM E1886 ensure that windows can withstand debris impacts and fluctuating pressures typical of storm conditions, with tests involving projectile impacts at speeds up to 80 feet per second and cyclic pressures up to 9600 Pa. Therefore, the combination of wind, rain, and humidity during severe storms creates complex stress conditions that are difficult to replicate individually, necessitating comprehensive testing protocols that consider these combined effects to ensure reliability.

Cold waves and snowstorms involve low temperatures and heavy snowfall, which can cause thermal contraction in materials, potentially leading to brittleness and failure. Standards like ISO 12543 ensure that laminated glass can withstand low temperatures, typically down to -40°C, without losing integrity. Snow and ice can lead to water ingress when they melt, challenging the watertightness of window systems. Consequently, the combined effects of low temperatures and moisture from melting snow create unique challenges for BIPV windows, as the materials must resist both thermal contraction and water ingress simultaneously. Ensuring the materials maintain their structural integrity and performance under these combined stressors is crucial for their reliability.

Case Study: Combined Events of Intense Heat and Intense Wind Load in Singapore

Climate change has significantly impacted weather patterns worldwide, with cities like Singapore experiencing an increase in the frequency and intensity of extreme weather events. This case study focuses on the combined events of intense heat and intense wind load in Singapore, analyzing their historical occurrences and predicting future trends based on the dataset provided by Machard et al. (2024).

Historically, Singapore has experienced numerous instances of extreme weather events characterized by high temperatures and strong winds. The dataset provided includes detailed records from 2001 to 2020, highlighting the frequency and severity of these combined events. During this period, the number of days experiencing both high temperatures (above 30°C) and high wind speeds (exceeding 6 m/s) was relatively infrequent but notable. Using projections from the regional climate model (RCM) bias-corrected datasets, future scenarios were analyzed for two periods: the mid future (2041-2060) and the long future (2081-2100). The projections indicate a significant increase in the frequency and intensity of combined heat and wind events in Singapore. For the mid-term future (2041-2060), the number of days with temperatures above 30°C and wind speeds exceeding 6 m/s is projected to increase by approximately 30% compared to the historical period, attributed to rising average temperatures and changes in wind patterns due to climate change. For the long-term future (2081-2100), the projections are even more concerning, with a predicted increase of up to 60% in the frequency of these combined events, as temperatures are expected to rise by an average of 2-3°C, and wind speeds during extreme events may increase by 10-20%. As shown in Figure 1, A method of identifying intense events is used with the dataset. A sample combined intense event(day) is identified and showed in figure 1, left, it represented one intense day in the long future and both of its temperature and wind speed is exceeded the 99.5 percentile of the historical data(intense), and figure 1, right indicated its increasing trend of occurrence on both typical and intense weather predictions.

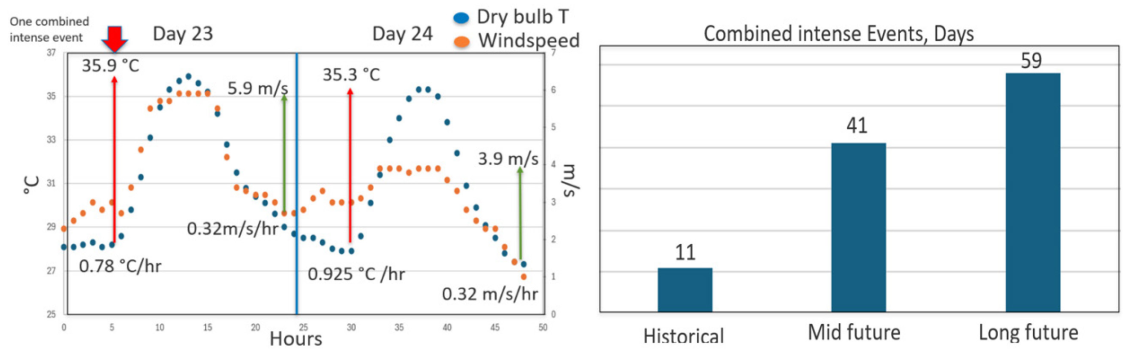

Figure 1. Identified intense events.

Research Gaps

Despite significant advancements in standards and testing protocols for BIPV windows, several research gaps remain that need to be addressed to ensure the long-term durability and performance of these systems under extreme weather conditions(Tamer et al., 2024; Özkalay et al., 2024; Skandalos et al., 2022). Identifying these gaps and proposing future research directions is essential for advancing the field and enhancing the reliability of BIPV windows. One significant research gap is in combined stressor testing. While existing standards often focus on individual stressors, there is a lack of comprehensive testing protocols that simulate combined environmental stressors. Real-world conditions involve multiple simultaneous stressors, such as temperature fluctuations, high humidity, wind loads, and UV radiation(Fedorova et al., 2022). Therefore, research is needed to develop and validate testing methods that accurately replicate these complex interactions.

Furthermore, understanding material degradation mechanisms remains crucial. Although there is some knowledge of how materials like encapsulants, sealants, and PV cells degrade under individual stressors(Owen-Bellini et al., 2021; Sinha et al., 2021), there is limited understanding of long-term degradation under combined stressors. Studies focusing on simultaneous exposure to temperature, humidity, and UV radiation are needed to develop more durable materials. Additionally, the lack of field performance data is a significant gap. Most current data comes from laboratory testing, which may not fully capture the real-world performance of BIPV windows. Long-term field studies are needed to collect data on the performance of BIPV systems in different climatic conditions, providing insights into actual degradation patterns and failure modes(Hartman et al., 2019).

Conclusion

BIPV windows are pivotal in the evolution of sustainable architecture, merging energy production with the structural and aesthetic functions of traditional building materials. This review underscores the vital role of existing standards and building codes, such as EN 50583, IEC 63092, and ISO 18178, in ensuring that BIPV systems withstand typical environmental stressors. Additionally, standards like ASTM E330/E330M and EN 1279 are crucial for integrating these systems into building designs, ensuring adequate insulation and thermal performance. However, the increasing severity and frequency of extreme weather events due to climate change present unprecedented challenges to the durability and performance of BIPV systems. Traditional testing protocols, often focused on single stressors, are inadequate in today's climate scenario, where multiple simultaneous environmental stressors are the norm. The review highlights the urgent need for comprehensive testing protocols that accurately simulate these harsh conditions. Despite progress in standards and testing protocols, significant research gaps remain, necessitating a deeper understanding of material degradation mechanisms, more robust field performance data, predictive modeling, and standardized practices across regions. Future research should focus on developing advanced materials and innovative testing protocols, conducting lifecycle analyses, and enhancing field monitoring. This paper calls for interdisciplinary collaboration among researchers, industry experts, policymakers, and building professionals to advance the field of BIPV windows, making them more reliable, durable, and integral to sustainable building practices.

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Appendix I

The list of all the standards used in the paper:

Title	Name
ASTM E2188	Standard Test Method for Insulating Glass Unit Performance.
ASTM E2189	Standard Test Method for Testing Resistance to Fogging in Insulating Glass Units.
ASTM E2190	Standard Specification for Insulating Glass Unit Performance and Evaluation
ASTM E330/E330M	Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Uniform Static Air Pressure Difference.
ASTM E331	Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
ASTM E547	Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference
ASTM E1886	Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials
ASTM E1996	Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes
EN 50583	Photovoltaic systems - Requirements for testing, documentation, and maintenance - Part 1: Grid-connected systems - Documentation, commissioning tests, and inspection
EN 1279	Glass in building - Insulating glass units - Part 2: Long term test method and requirements for moisture penetration
EN 1027	Windows and doors - Water tightness - Test method
IEC 63092	Photovoltaic (PV) systems - Requirements for testing, documentation, and maintenance - Part 1: Grid-connected systems - Documentation, commissioning tests, and inspection
IEC 61215	Terrestrial photovoltaic (PV) modules - Design qualification and type approval.
IEC 61730	Photovoltaic (PV) module safety qualification - Requirements for construction and testing.
ISO 12543	Glass in building - Laminated glass and laminated safety glass.
ISO 15392	Sustainability in building construction - General principles.

ISO 15686-1	Buildings and constructed assets - Service life planning - Part 1: General principles.
ISO 18178	Laminated glass and safety glass - Durability requirements, including testing methods for laminated glass used in buildings.