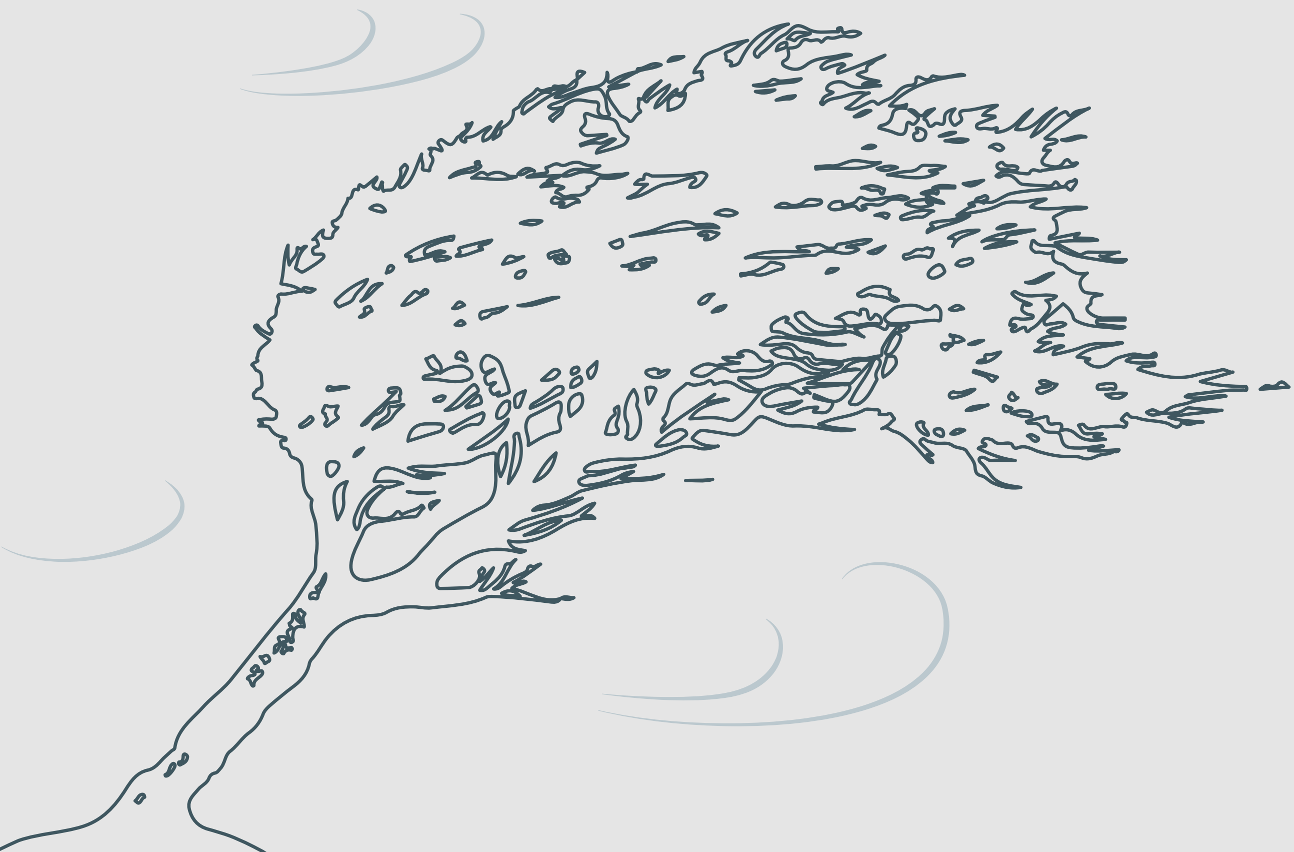
REDi™

Resilience-based Design Initiative
for the Next Generation of Buildings

EXTREME WINDSTORMS



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Glossary of Terms

Back-up Systems

The capacity of back-up systems must be adequate to operate Owner-designated systems at Owner-designated performance levels. This capacity may be substantially lower than that required for normal full operation but must be reasonable. For example, the capacity of back-up power required while utilities are disrupted can be based on operating the lighting for a reduced number of hours or keeping the temperature within a broader, but still reasonable, range than in 'normal' conditions.

Design-Level Event

This is a wind event with a mean recurrence interval (MRI) of 700, 1700, or 3000 years, depending on the desired REDi™ rating level. This is consistent with the ASCE 7 design standard for Risk Category II, III and IV buildings respectively. If the building type has a different ASCE 7 Risk Category than the one associated with its REDi™ rating, then the larger MRI of the two shall be used.

REDi™ Silver: 700-year MRI wind event

REDi™ Gold: 1700-year MRI wind event

REDi™ Platinum: 3000-year MRI wind event

Downtime

Downtime is the time required to achieve a defined recovery state after a severe wind event has occurred. Three such recovery states were defined by the Structural Engineers Association of Northern California (Bonowitz, 2011): re-occupancy of the building, functionality, and full recovery. The downtime resilience objectives of the REDi™ Extreme Windstorms guide focus on the first two: re-occupancy and functional recovery.

Section 4 - Resilience Assessment provides general guidelines for evaluating realistic downtime estimates that account for the time required to undertake repairs to the building (see "Repair Time" below), the time before repairs can be started (see "Impeding Factors" below), and utility disruption (see "Utility Disruption" below). A complete component-based extreme windstorm risk methodology, adapted from REDi™ Seismic, will be included in an upcoming version of REDi™ Extreme Windstorms.

Full Recovery

Full recovery follows functional recovery, when repairs required primarily for aesthetic purposes (such as painting and other finishes) restore the building to its original condition prior to damages from the windstorm. Since these repair measures are minor and do not hinder building function, they may be undertaken at a time best suited to the owner and occupants. For that reason, it is not included as a REDi™ baseline resilience objective.

Functional Recovery

In general, functional recovery represents the time required to establish re-occupancy and regain the facility's primary function (analogous to "operational" or "operable" in some building codes). A building is functionally recovered when the majority of its area can be used for its intended purpose, though there may be limited areas of the building which require more time to be completely restored to the pre-storm condition.

For all commercial occupancy types, this will require restoring power, water, fire sprinklers, lighting and HVAC systems while also ensuring that elevators are back in service. Back-up systems may also be used in the interim to provide a pre-defined state of functionality agreed by the Owner (potentially at reduced capacity, see "Back-up Systems" in Glossary of Terms) until the municipal utilities are restored and able to provide for full capacity.

In residences, functional recovery is related to regaining occupancy and livable conditions: lights are on, water flows, and heating and air conditioning are operating if necessary. Residential re-occupancy may take place for a limited time (e.g., days to weeks) before all services are restored if suitable temporary sources are available.

Functional recovery also indicates the time required for resumption of specific functions particular to a certain occupancy. Examples include emergency and typical services in hospitals, business activity in offices and retail, or classes in educational facilities.

Repairs to prevent deterioration of the building (such as sealing damaged, leaky pipes for mold prevention or ensuring the building envelope is weatherproof) must also be completed for the majority of the building, including the business critical areas, to achieve functional recovery.

Impeding Factors

The delay between the wind event and the initiation of repairs can sometimes be significant. These delays are referred to as 'impeding factors' and include the time needed to complete post-hazard building inspections, secure financing for repairs, mobilize engineering services, obtain permitting, mobilize a contractor and necessary equipment, and for the contractor to order and receive the required components including "long-lead time" items. Other considerations, such as the time needed for a competitive bidding process for contractors, is also included for heavily damaged buildings. The REDi™ downtime estimates assume that the Owner's decision-making process or regulatory uncertainty does not contribute to downtime.

Life Safety

Life safety refers to the protection and preservation of human life during emergency events and any building system failures. Building code requirements account for and prioritize life safety in structural design. Non-essential facilities must be designed to meet minimum code design requirements.

Physical injury or fatalities associated with extreme windstorms are generally caused by collapse or by components falling on persons inside or outside a building. However, the code does not directly address several sources of causalities in major storms, such as injury associated with trees, wind-borne debris, or other non-structural objects, which may fail when subjected to loads from a design windstorm. The REDi™ framework includes provisions for securing building contents to mitigate hazards of this type as well as reducing damage to the building fabric.

Apart from tornadoes, extreme windstorms generally have significant advanced warning 'lead time'. Therefore, the key to occupant safety is the development of emergency response plans (ERPs). As the importance of ERPs is highlighted for all REDi™-rated buildings, all REDi™-rated buildings will sufficiently protect occupants from injury.

Casualties associated with tornadoes can be reduced with the provision of adequate shelter. Casualties from hurricanes and thunderstorms are difficult to predict in a quantitative manner and are best mitigated by holistic design and adhering to best practices, such as the ones contained in this guide.

Mean Recurrence Interval (MRI)

The Mean Recurrence Interval (MRI), sometimes referred to as the return period, is the average length of time between occurrences of a wind storm of a certain magnitude. The inverse of the MRI can represent the likelihood of occurrence of an event with a given intensity within one year. Referencing extreme windstorms by their MRI allows for consistent representation of storm intensities and probabilities of occurrence, even across different regions and storm hazards.

Operational-Level Event

Also referred to as the service-level wind event, the operational-level event is a wind event with a mean recurrence interval of 100, 200, or 500 years, depending on the desired REDi™ rating level. This wind event is used to design building systems and envelope components against the impacts of wind and to allow for the continued functionality of mechanical components.

REDi™ Silver: 100-year MRI wind event

REDi™ Gold: 200-year MRI wind event

REDi™ Platinum: 500-year MRI wind event

Probabilities

Various similar terms are used throughout the guideline to express the probabilities associated with the direct financial loss and downtime estimates.

The REDi™ downtime objectives are associated with 75% probability of non-exceedance. For example, Gold buildings have a 75% probability that the time required to achieve functional recovery would not exceed 2 weeks.

The Owner is encouraged to discuss higher probability levels with the engineer and design team, if desired, to achieve even better performance than the REDi™ resilience objectives. For example, Probable Maximum Loss is the 90% confidence level of direct financial loss that many windstorm insurance policies are based upon.

Probable Loss

Probable loss is the estimated financial loss to a building in a given wind event, expressed as a percentage of the total building replacement cost. This value is specified for each REDi™ Rating Level in the REDi™ Resilience Objectives section.

Re-occupancy	Re-occupancy can occur when the building is deemed safe enough to be used for shelter. If significant damage is apparent, this typically requires an inspection by a qualified professional. Re-occupancy can occur once a Green Tag is awarded, given that any damage to structural and non-structural components is minor and does not pose a threat to life safety and egress paths are undamaged (ATC-45). A Green Tag allows unrestricted access and re-occupancy to all portions of the building, though clean-up and/or minor repairs to some non-structural components may be required to clear egress paths. If visible damage is minor, the Owner may decide to forego inspection, allowing the building to be re-occupied almost immediately after the wind hazard at his/her discretion. It is still recommended that the Owner retains a qualified professional to perform post-event inspection (see 1.4.1) to avoid long delays associated by inspections performed by the jurisdiction. The jurisdiction also has the power to require inspection if it is felt to be necessary, but this process is unlikely to be initiated if the damage is minor. Re-occupancy can occur before functionality is restored. Lighting, heating/air-conditioning, and water may be unavailable, so the use of flashlights, blankets or heavy clothing, operable windows, bottled water, and waste disposal may be needed. Discrete portions of a building may be re-occupied before others (i.e. "Yellow Tagged"); however, the re-occupancy objectives in REDi™ are associated with the time to re-occupy the entire building. In certain cases, emergency response and business continuity plans may call for ride-out teams to remain in the building during an event. This is common for hurricanes and allows essential building systems to remain operational and damage, such as breaching, to be identified and quickly mitigated where possible. In this case, the ride-out team must be provisioned for continuous occupancy.
Repair Class	"Repair Classes" describe how the extent of severity of damage to particular types of building components may hinder specific recovery states. This is used as part of the downtime methodology, which will be included in an upcoming version of REDi™ Extreme Windstorms.
Repair Time	Repair time is the total amount of time required to repair or replace all damaged building components to restore the building to a specific recovery state (re-occupancy or functionality), assuming that the labor, equipment, and materials required are available (see "Impeding Factors" below). For example, the repair time required to achieve re-occupancy is the time needed to repair major structural damage, but not the time needed to repair slightly cracked partitions, since that would not stop the building from being re-occupied.
Resilience	Resilience is the ability of the built environment to adapt to changing conditions and to withstand and recover positively from shocks and stresses. It includes both the physical built asset and the organization that occupies it.
Ride-Out	A ride-out team consists of trained building maintenance personnel who remain in the building during the storm, ready to respond should any critical infrastructure have issues or fail.
Risk	Risk is the possibility of adverse effects due to a hazard event in the future. It is derived from a consideration of both the hazard and its likelihood of occurrence, the vulnerabilities of the considered built asset, and the consequence should the event occur.
Total Building Value	Total Building Value is defined as the hard costs only (including labor) required to replace the building at today's price. Direct financial loss should be expressed as a proportion (%) of the Total Building Value. The hard costs should be obtained from a construction cost estimate (including at minimum all structural and non-structural components) plus the value of damageable building contents if they are known. Markups such as liability, material cost uncertainty, demolition, design/management, and profit/overhead should not be included. For existing buildings, the total insured value may be a starting point, but depreciation must be considered if insured value is used.

Utility Disruption	Utility disruption is likely to occur in a design-level wind event depending on geographical location and must be considered for all REDi™-rated buildings. In most cases, functional recovery will require utility services to be available. Back-up systems are required to achieve the 48 hours functional recovery target for REDi™ Platinum buildings. If on-site storage of the back-up capacity necessary for the duration of the estimated utility disruption is not feasible, contingency plans for re-fueling generators, re-filling water tanks and emptying wastewater tanks should be in place to allow continued functionality (see Section 1.2 for details).
Vulnerability	Vulnerability is the propensity of the considered built asset to suffer adverse effects when impacted by a hazard event. In the context of buildings, it includes both the building's physical robustness and the organization's operational procedures and preparedness.


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INTRODUCTION

Motivation

Traditionally designed buildings have repeatedly shown a lack of resilience in the face of extreme windstorm events. Year after year, such storms result in many billions of dollars of losses to the building stock and massive disruptions in their aftermath. This damage stretches from individual buildings to entire communities, and often includes systemic factors that extend beyond the design of any individual building.

Code-Based Design

Current building codes exist largely to ensure a minimum level of human life safety during extreme loading events. Their main objective is to minimize structural risk, but they do not always provide a reliable level of performance for all building components at every storm severity level. Further, building codes do not properly address the integrity of non-structural elements and exterior equipment, nor do they consider the damage potential of external wind-borne debris during a storm. Building codes do not currently account for climate change's effect of augmenting extreme windstorm hazards with each passing year.

The annual losses due to extreme wind events clearly illustrate that the building codes do not provide adequate protection against property damage and downtime. Without these considerations, severe damages (largely to non-structural components) have been observed in structures ranging from single family houses to those of critical societal importance, such as hospitals. This is a particularly concerning trend for building owners, insurers, and wider society as climate change leads to greater risks to structures.

Performance-Based Design

As a supplement or alternative to the prescriptive nature of typical building codes, performance-based design may be employed to enhance the design of individual structures. This approach establishes certain performance criteria for the building, often requiring more sophisticated design techniques to validate its performance. Features of performance-based wind design include the evaluation of a building at various return periods (intensities), enhanced building envelope design, non-linear response history analysis, wind tunnel testing, and site-specific wind climate assessments. Although this method has been widely used in seismic engineering circles for more than a decade and early adoption has begun in wind engineering, there is limited, if any, code language in most jurisdictions to permit such approaches.

While performance-based design yields a better understanding of the structural and non-structural performance of the building, it does not create holistic building resilience. Both code-based and performance-based design approaches do not currently include elements such as building systems performance, emergency response planning, site and community resilience, and risk assessments.

Resilience-Based Design

The goal of resilience-based design is simple: follow a design approach which results in a desired level of physical robustness, enhanced safety, and a faster return to operations post-event, relative to a typical design. Further, resilient buildings are sustainable buildings, as reducing potential building damage engenders a longer usable lifetime, conserving reconstruction material, energy, and waste in the long term. Code-based approaches do not claim to provide this holistic performance, and performance-based design only addresses some of the root causes of building damage and downtime.

Resilient design principles include consideration of structural and non-structural components, along with operational and ambient features, to address the key drivers of building damage and downtime. A loss assessment is used to evaluate the building's resilience and verify that objectives are achieved. The REDi™ suite of guidelines serves to outline this process and certify buildings for meeting these objectives, with the aim of enabling a more holistically resilient built environment.

Wind Effects and Damages

The following list summarizes some of the damage mechanisms which lead to losses in major storms. These must be addressed in any resilience-based approach to building design.

A. ENVELOPE AND NON-STRUCTURAL DAMAGES

The envelope of a building, its roof system, and its non-structural components are often the first to be damaged by aerodynamic pressures, lift (suction) forces, fatigue damage under fluctuating loads, or wind-borne debris, as later introduced in Part C. In many cases, damage occurs not only during the most extreme windstorms, but also during more common wind events.

Building envelope failures represent the majority of damage in large buildings during extreme wind events. For example, breached areas of the façade or roof expose the building to one of the most significant damage mechanisms in hurricanes: rainwater penetration. Careful attention is required to provide adequate protection against water intrusion. Further, broken elements of the façade may become wind-borne debris and result in cascading damages and failures. Exterior mechanical equipment may become separated from the building or damaged if not properly affixed.

B. DAMAGE OUTSIDE THE BUILDING

Strong winds cause damage to trees, powerlines, fencing, and other components which are not generally considered during building design. These items are often a barrier to site access and operation in the aftermath of storms. A building cannot be reoccupied or resume normal operation as long as safe access cannot be established. These factors must be anticipated and mitigated to ensure the safe and speedy return of building occupants.

C. WIND-BORNE DEBRIS

Strong winds have the potential to turn any debris in the surrounding environment into dangerous flying projectiles. This wind-borne debris, which can include tree limbs, ballast from roofs, or unsecured objects located upstream, may impart impact loads and penetrate the building envelope. This penetration in turn leads to detrimental effects, such as allowing rainwater into the building or increasing internal pressurization. Projectiles may also pose a safety threat to occupants. Beyond the structure, wind-borne debris may impede access to critical systems and facilities, resulting in losses of functionality or repair delays.

D. STRUCTURAL RESPONSE AND FAILURE

Dynamically sensitive structures such as high-rise buildings or slender towers may exhibit large or prolonged deflections and accelerations in reaction to extreme windstorms (e.g. vortex-induced vibrations, galloping and flutter instability). These responses may lead to serviceability issues; for example, the halting of elevators due to excessive floor accelerations, popping out of glazing elements, or people on the top floor perceiving the motion. In extreme cases, inelastic deformation and collapse may occur. For low-rise structures, internal pressures, acting together with external aerodynamic loads, may cause roof failures if entries have been breached.

Storms with less energy may not cause damage to the building, but may be perceived by occupants and sensitive equipment. This may result in a number of negative outcomes, including occupants’ concerns about structural safety, evacuations, loss of use, and/or downtime.

(A) Façade damage on a building caused by Typhoon Mangkhut, © Arup / (B) Road debris left behind by Hurricane Katrina, © Arup / (C) Debris generated by Hurricane Katrina, © Arup / (D) Collapse of a 5-storey brick building following Hurricane Katrina, © Arup

Wind Mechanisms

Wind is generated by a variety of climate phenomena. Understanding the dominant mechanism in the site's region is important when designing for resilience.

A. SYNOPTIC WINDS / LARGE DEPRESSIONS

Synoptic winds generated by large depressions (for example, extra-tropical cyclones) have scales spanning hundreds to thousands of kilometers. They take several days to pass, occur at or above the mid-latitudes, and are typically described as "straight-line winds".

B. TROPICAL CYCLONES / HURRICANES

Tropical cyclones are rotating, low-pressure storm systems that form over the tropical seas and last a period of days. They can be referred to as hurricanes, typhoons, and cyclones. Though their vortex structures are more well-defined compared to synoptic storms, the winds from tropical cyclones are treated as straight-line since their scales are over hundreds of kilometers wide. They are often accompanied by severe flood risks and intense rainfalls.

C. THUNDERSTORMS

Thunderstorms are convective, local storms that are typically tens of kilometers wide with typical durations between 30 to 60 minutes. Thunderstorms can produce severe, hurricane-force winds in the form of derechos, downbursts, and tornados. Derechos are widespread, straight-line windstorms associated with a group of severe thunderstorms. On a scale of less than ten kilometers, downbursts are vertical downdrafts of air, released from a thunderstorm cloud, that rapidly spread out at ground level.

D. TORNADOS

Tornados can be produced from both hurricane and thunderstorm systems. Typically with diameters spanning hundreds of meters, they are violently rotating columns of air. In addition to their extreme cyclonic winds, they have strong updrafts that can carry large amounts of wind-borne debris.

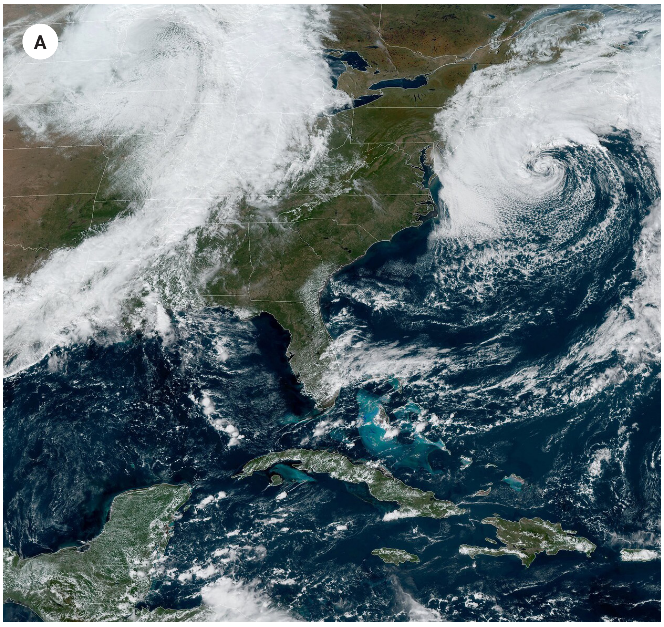
E. DOWNSLOPE WINDS

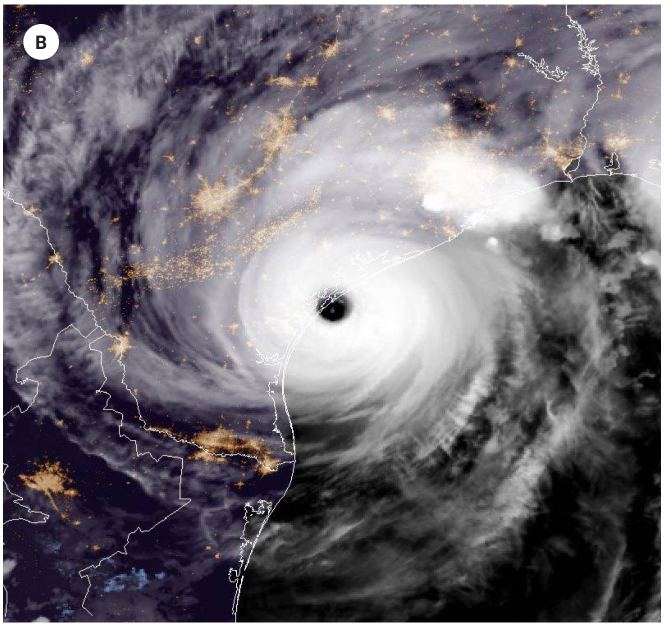
Downslope winds are flows directed down a mountain slope. With the potential to produce high wind speeds, they affect small, "special regions" that are designated in codes and standards. In dry conditions, they have the potential to increase wildfire risks. A well-known example of the downslope wind mechanism is the Santa Ana winds in California, USA.

F. EFFECTS OF CLIMATE CHANGE

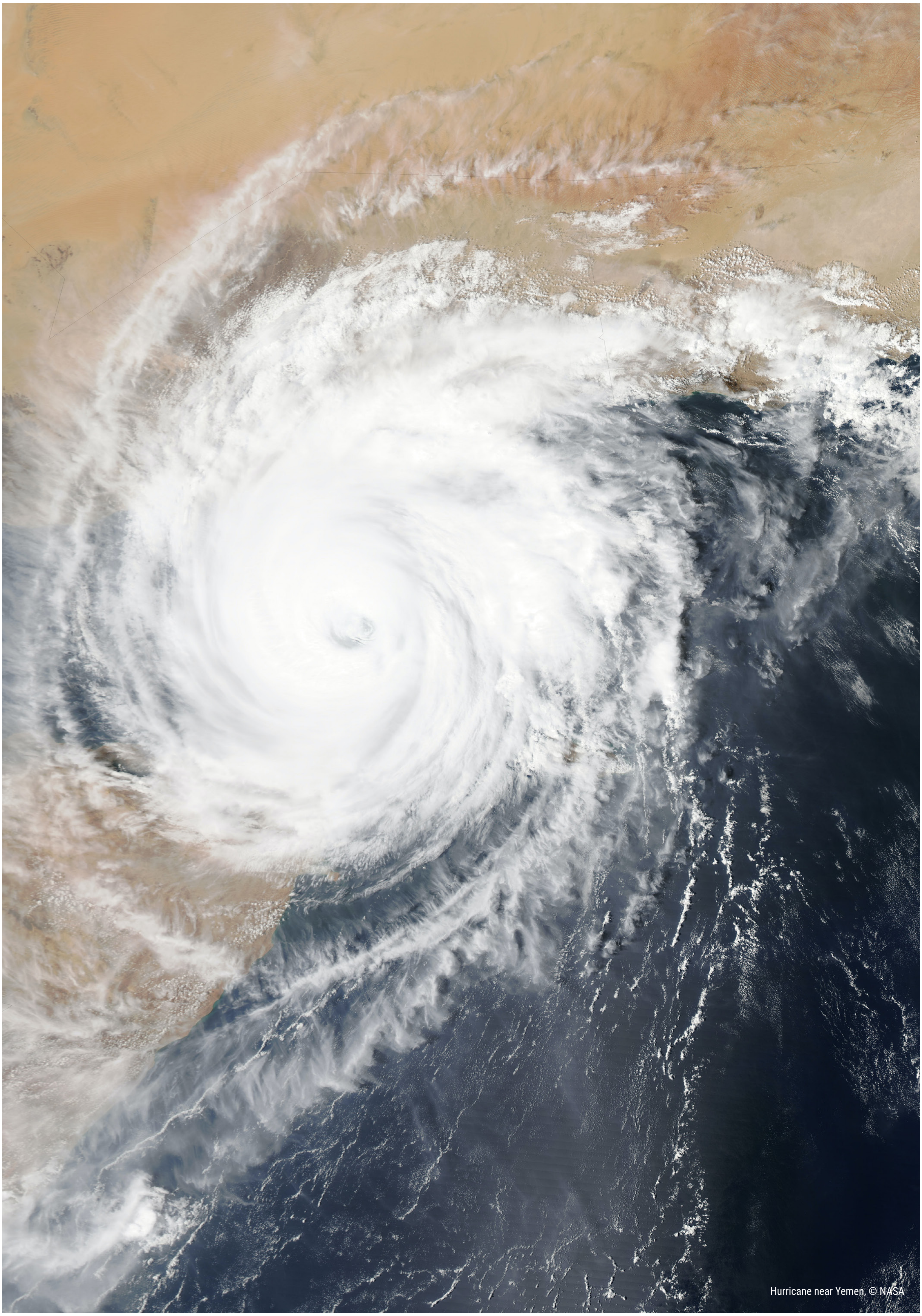
As the expected life cycle of a building is typically 50 years or greater, climate change effects are important to consider in any new building's design. A warming climate is expected to increase the intensity of tropical cyclones, leading to a proportional increase in the frequency of very intense (Category 4 and 5 on the Saffir-Simpson Hurricane Wind Scale) hurricanes. NOAA has found an increase in hurricane wind speeds of up to 10 percent in a 2 degree Celsius global warming scenario.

For other wind mechanisms, such as thunderstorms and tornadoes, the influence of climate change on frequency and severity remains uncertain and will vary by region.





(A) Two large storm systems over North America, © NOAA / (B) Hurricane Harvey, © NOAA / (C) Supercell thunderstorm in Nebraska, U.S., © NOAA / (D) Tornado in Nebraska, U.S., © NOAA / (E) Downslope winds, © Alberto Varela, Flickr.com (Licensed under CCPL)


Hurricane near Yemen, © NASA

REDi™ Roadmap to Resilience

Overview

The REDi™ framework recognizes that holistic design and planning is the key to achieving a truly resilient building. To qualify for a REDi™ rating, (Platinum, Gold, or Silver) it is necessary to satisfy required criteria for that tier in each of three Resilient Design and Planning categories - Operational Resilience, Building Resilience, and Ambient Resilience. In addition, a Resilience Assessment must be performed to verify that the REDi™ resilience objectives associated with each rating (located on page 22) - measured in terms of downtime and financial loss - are achieved. The framework also includes requirements to evaluate multiple hazards when applicable.

The general concepts which form the REDi™ Roadmap to Resilience are summarized in the figure below and described in more detail on the next page. To qualify for a REDi™ Rating, the criteria for each of the Resilient Design and Planning and Evaluation categories must be satisfied.

> The REDi™ roadmap to resilience will allow owners to resume business operations and provide functional conditions quickly after a major storm.

REDI™ FRAMEWORK

Minimize expected damage to structural, architectural, and MEP (mechanical, electrical, and plumbing) components through enhanced design

Contingency planning for utility disruption and business continuity

Reduce risks from external hazards that may cause building damage or restricted site access

Evaluate financial losses and downtime to evaluate success of the design and planning measures in meeting the resilience objectives

Operational Resilience

Contingency planning for utility disruption and business continuity

Disruption resulting from major wind events is rarely limited to physical building or site damage. Municipal power, water, and sewer systems are often interrupted for a period of a few days up to several months, and may substantially delay an otherwise operational building's resumption of operations. Adaptive capacity is the ability to respond and recover from unanticipated risks that may stress operations.

Contingency planning and emergency preparedness are integral to a resilient facility, as many aspects of resilience are reliant on proper maintenance and operation of the facility after construction.

Depending on the extent of advanced warning, there are various operational strategies that considerably hasten disaster recovery when implemented correctly. Having preparedness plans in place for post event action often supports improved resilience.

PROJECT EXAMPLE:
MOMA PS1 HY-FI SCULPTURE

The Hy-Fi experimental sculpture was installed in the New York Museum of Modern Art (MoMA) PS1 location during the summer of 2014. The outdoor sculpture stood 13 m tall, constructed of 10,000 compostable bricks - an innovative new material made from farm waste and fungus culture, grown in brick shapes. Due to the temporary nature of the structure, it was exempt from adherence to local building codes. Therefore, Storm Action Plan was developed to enhance the sculpture's resilience to extreme windstorms. The Storm Action Plan clearly outlined explicit mitigation actions to implement, at ranges of wind speeds increasing in intensity. This allowed MoMA to respond appropriately to high-intensity wind, ensuring visitor safety and increasing resilience.

Building Resilience

Minimize expected damage to structural, architectural, and MEP components through enhanced design

The design of buildings to resist wind forces has traditionally been prescriptive, based on code parameters and occasionally modelled using wind tunnel testing.

Recently, there has been considerable development in the field of performance-based design (PBD) approaches for wind. Enhanced design approaches are an important component to resilient building performance and must be applied for various building elements (structural, building envelope, etc.) and at various hazard levels to be most effective. This approach goes beyond the prescriptive code to design the entire building, including its non-structural elements, to be relatively undamaged in extreme windstorms. This guide intends to capitalize on recent progress in PBD for wind, some of which will be included in the upcoming ASCE 7 code cycle.

PROJECT EXAMPLE:
181 FREMONT TOWER

Standing at 244 m tall in the high-density Transbay corridor in San Francisco, California, the 181 Fremont Tower is a prime example of the holistic resilience-based design that can be achieved with the principles of the REDi™ guidelines. Innovative approaches in both structural and non-structural design were adopted to meet enhanced sustainability and resilience objectives, far surpassing the requirements of local building codes. These included a state-of-the-art viscous damping system used to mitigate wind vibrations and a façade system that would remain air- and water-tight at more stringent drift requirements than specified by code. Pre-disaster contingency planning and a supplementary loss assessment further informed design strategies so that immediate re-occupancy could be achieved, disruptions to functionality would be limited, and financial losses would be minimized in an extreme hazard event.

Site Resilience

Reduce risks from external hazards that may cause building damage or restricted site access

In built-up environments during major storms, damage is often triggered by adjacent sites. The failure of simple details such as roof aggregate on a neighbouring building can cause extensive damage.

Building hardening alone is not always sufficient to address these scenarios. Assessing and mitigating risks beyond the property line is crucial to achieve building resilience.

PROJECT EXAMPLE:
LOMA LINDA HOSPITAL REPLACEMENT

The Loma Linda University Medical Center campus revitalization included a complete replacement academic adult hospital and a partial replacement pediatric hospital. Currently in construction, the project's design breaks new ground in areas of pediatric and adult program development, open core nursing unit design, and near-fault seismic design for vertical motion. As a holistically resilient building, the hospital considers a number of factors in its emergency planning, including multiple redundant forms of communication and sourcing of backup utilities (such as power, water, sewage, and more) for 72 hours. These considerations of 'outside-the-wire' impacts allow it to maintain operations throughout a hazard event.

Resilience Assessment

Evaluate financial losses and downtime to evaluate the success of the design and planning measures in meeting the resilience objectives

The success of the resilience-based design approach in satisfying the REDi™ resilience objectives is measured through a resilience assessment. There are numerous frameworks available for conducting risk and loss assessments, several of which are required for REDi™ resilience objectives.

A high-level loss assessment at the building level can be conducted with publicly available risk estimation tools, such as FEMA's HAZUS. Though it is primarily designed for census-tract-level loss assessments, this approach of extrapolating past hazard data to estimate individual building losses are is appropriate for some projects and resilience objectives.

The most detailed probabilistic assessment currently used in the industry is a component-level loss and downtime assessment. This takes a component-by-component approach to calculating building loss and downtime and is capable of developing detailed, actionable quantitative risk information. Important aspects of this approach are described in Section 4.1.2. Future versions of REDi™ Extreme Windstorms will include a detailed procedure for executing the component-level assessment.

PROJECT EXAMPLE: **DATA CENTER RISK ASSESSMENTS**

With society's growing reliance on digital technologies such as cloud computing, data centers have become an integral component of infrastructure. They are essential to the continued operation of many facilities and organizations, such as hospitals and universities. Comprehensive risk assessments of existing and potential data center sites are typically used to better understand these risks. These risk assessments include quantification of various climate hazards, the vulnerability of the existing or proposed structure, and the consequence, measured in damage and downtime losses, of each hazard. The assessment can range from a high-level desktop study to an in-depth probabilistic analysis.

REDi™ Resilience Objectives

BASELINE RESILIENCE OBJECTIVES

The resilience objectives below are to be evaluated at the REDi™ Level Wind Event, an extreme storm with a 500 year Mean Recurrence Interval (MRI).

Platinum

Downtime:
Continuous Occupancy
Functional recovery < 48 hours

Property Damage:
Probable Loss < 1%

Occupant Safety:
Physical injury due to failure of building components unlikely

Gold

Downtime:
Immediate Re-Occupancy
Functional recovery < 2 weeks post occupancy

Property Damage:
Probable Loss < 5%

Occupant Safety:
Physical injury due to failure of building components unlikely

Silver

Downtime:
Re-occupancy in < 2 weeks
Functional recovery < 2 months post occupancy

Property Damage:
Probable Loss < 10%

Occupant Safety:
Physical injury due to failure of building components unlikely

The resilience objectives are to be evaluated at the REDi Level Wind Event, an extreme storm with a 500 year Mean Recurrence Interval (MRI). The expected performance during this event of a building designed to each REDi Rating Level is described below:

Platinum buildings are expected to sustain very little or no damage, such that the entire floor is able to be used for its intended purpose once functionally recovered. Platinum is recommended for ASCE Risk Category IV buildings: essential facilities such as hospitals, emergency responder facilities, utility generators and stations, and hazardous waste facilities.

Gold buildings are expected to sustain minimal damage at isolated locations, such that the vast majority of the floor space is able to be used for its intended purpose once functionally recovered. Gold is recommended for ASCE Risk Category III buildings: important facilities such as community centers, schools, and non-emergency health care facilities.

Silver buildings may potentially sustain sufficient damage to cause building shut-down for an extended period. However, the holistic resilience provisions within REDi Extreme Storms will result in much more capacity to quickly recover than one designed solely to code. Silver is recommended for ASCE Risk Category I and II buildings and structures: most residential, commercial, and industrial buildings.

The baseline resilience objectives above have been calibrated based on experience of building performance, post-damage assessments, and client expectations for various levels of resilience. For example, a REDi™ Silver-rated building would perform structurally slightly better than a standard (risk category II) building designed to code, and a Platinum-rated building would perform slightly better than a risk category IV building designed to code. REDi™ further addresses many non-structural elements not considered in the code. As such, the holistic, non-structural performance of any REDi™-rated building will be much better than that of a code-compliant building.

The specifications in the sections below have been carefully determined for the expected level of resilience corresponding to each rating. However, in some instances they may not intuitively match up to the resilience objectives listed here. If so, they may be adjusted to fit design factors unique to each project.

Note: these resilience objectives do not apply directly to tornadoes. REDi™-rated buildings will perform better than typical construction in tornados, but will not achieve the performance objectives stated above.

GUIDELINES AND CRITERIA

Guiding Principles for Criteria

The prescriptive requirements contained in the REDi™ Guidelines and Criteria were developed to achieve the general intent for each rating tier, distinguished by the key guiding principles summarized below. Referenced building performance is taken at the REDi™ Level Wind Event.

Platinum

- Conduct workshops with the project team to establish project resilience priorities.
- Enhance design of structure and building envelope components such that the building exterior suffers only minimal aesthetic damage and the building interior is undamaged/unaffected.
- Provide back-up for critical systems to enable continued operation of essential functions for one week if utilities fail.
- Protect mechanical, electrical, and plumbing (MEP) components and other critical systems, particularly those exposed to the environment.
- Pre-identify contingency plans to provide water, fuel, and waste removal in the event of extended utility disruption.
- Adopt operating plans appropriate for achieving continuous occupancy during extreme windstorms and functional recovery shortly thereafter.
- Retain contractors and engineers to support clean-up and any component repairs or replacements immediately after an event.
- Conduct robust peer-reviews of the design and construction.

Gold

- Conduct workshops with the project team to establish project resilience priorities.
- Enhance design of structure and building envelope components such that critical locations needed to achieve functional recovery remain unaffected.
- Provide back-up for critical systems to enable continued operation of essential functions for 72 hours if utilities fail.
- Protect MEP components and other critical systems or guarantee that they are replaced/ repaired within 2 weeks.
- Pre-identify contingency plans to provide water, fuel, and waste removal in the event of extended utility disruption.
- Adopt operating plans appropriate for achieving re-occupancy shortly after extreme windstorms and functional recovery within two weeks thereafter.
- Retain contractors and engineers to support clean-up and any component repairs or replacements immediately after an event.
- Conduct robust peer-reviews of the design and construction.

Silver

- Conduct workshops with the project team to establish project resilience priorities.
- Enhance design of structure and building envelope components such that envelope leakage is minimal and that any damage to the envelope is easily repaired after an event.
- Provide back-up for critical systems to enable continued operation of essential functions for 48 hours if utilities fail.
- Adopt operating plans appropriate for achieving re-occupancy within two weeks after critical events and functional recovery less than two months thereafter.
- Retain contractors and engineers to repair/ replace minor envelope damage, replace damaged mechanical components shortly after an event, and to support any necessary internal clean-up.

How to use REDi™ Guidelines

SUMMARY OF CRITERIA

Summary of Criteria helps you to quickly identify required and recommended criteria for the desired REDi™ Rating Level (Platinum, Gold, Silver).

REDi™ Rating Level Platinum, Gold, Silver

●●● Required

○○○ Recommended

Lead responsible for criteria implementation. Wherever the Owner is indicated as a lead, the design team should provide advice and recommendations to the Owner.

E Engineer A Architect O Owner

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	○	O	1.2.3	**Back-up Communications**	If dependent on communication for functionality, establish a communication system back-up in the event that cell phones, landlines, and internet services are interrupted. This requirement may be satisfied by having a dual communication connection.

In this example: criteria is required for the Platinum and Gold tiers and recommended for the Silver tier; the Owner should lead criteria implementation

CRITERIA PAGES

Criteria details will help you to prepare an implementation plan and assign roles.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	○	O	**1.2.3 – Back-up Communications** If dependent on communication for functionality, establish a communication system back-up in the event that cell phones, landlines, and internet services are interrupted. This requirement may be satisfied by having a dual communication connection.	*1.2.3* *Communication can be the most critical utility in a natural disaster. Lifelines and other critical facilities (such as companies providing financing or insurance) should ensure connectivity during an event. Maintenance of internet services may also be crucial. Require communications providers to share reliability information with Owner and design team.*

Summary of Criteria

All measures listed below are, at minimum, recommended for all tiers. If the circle is solid and filled in, meeting the criteria is required to achieve that rating.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
0. Multi-Hazard Resilience						
0.1 Multi-Hazard Events						
●	●	●	E	**0.1.1**	**Extreme Windstorms with Flooding**	Many extreme windstorms can also lead to flooding, whether from significant precipitation, riverine flooding, coastal storm surge, or a combination of the above. Depending on the topography surrounding the site, it may be reasonable to expect that flooding will become a salient hazard in addition to severe wind. The designer shall evaluate the potential risk of flooding at the site, and if the risk is present, a REDi™ Flood assessment shall be conducted. In the REDi™ Flood assessment, a rating that is at least equivalent to the one selected from REDi™ Extreme Windstorms must be achieved.
●	●	●	E	**0.1.2**	**Winter Storms**	In areas susceptible to winter storms, assess the effects and risks posed by strong winds in conjunction with snow accumulation, snow drift, and ice accretion on exposed systems and structures.
●	●	●	E	**0.1.3**	**Wildfires**	Assess the risk of wildfires with the potential for wind to spread fires or spark them indirectly, for example by wind-whipped power lines. Plans for evacuation and business continuity (Sections 1.5.1 and 1.5.2) are required.
1. Operational Resilience						
1.1 Resilience Planning						
●	●	●	E A O	**1.1.1**	**Resilience Workshop**	Conduct at least two workshops with the Owner, led by a qualified facilitator, with the facilities team, engineers, and the broader design team if applicable. The first workshop, occurring at project inception, should establish resilience objectives for the project (building and site), review the high level context of hazard and risk with the Owner and design team, and develop goals for managing that risk. Investigate issues including but not limited to those listed in the commentary. A formal Resilience Plan document, which identifies how each resilience objective will be achieved and identifies remaining potential risks, is to be written by the Design Team and approved by the Owner. Hold a concluding workshop at the close of the design process to ensure that resilience objectives have been met, supported by the resilience assessment (See Section 4). Ideally, interim workshops should also be held around key decision points, during which the Resilience Plan is reviewed and the design is adjusted as necessary.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	O	1.1.2	**Organizational Resilience**	In collaboration with the Owner, the design team shall prepare an organizational resilience summary which captures how the design contributes to building, community, and operational resilience. Reflect on insight gathered in the Resilience Plan and integrate this knowledge into broader organizational planning around building operations. Consider including initiatives including but not limited to those listed in the commentary.
●	●	●	E	1.1.3	**Risk Assessment**	Conduct a risk assessment consistent with the resilience objectives for the building. See Section 4 for further details regarding loss assessment requirements, which satisfy this requirement.

1.2 Essential Utility Reliability

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	1.2.1	**Back-up Utilities**	For each utility listed below, provide back-up systems and necessary fuel storage and refueling contracts, where applicable. Use scenario planning to estimate the length of disruption for each utility. Scenario planning should consider the loss of transportation or access to on-site back-up systems and supplies. The time requirements below are minimums; the length of time determined by scenario planning should be used if greater. **Silver buildings:** • Provide sufficient generators and fuel storage on-site to power essential systems for 48 hours post-event. • Maintain potable water supplies on-site for storm ride-out teams for 48 hours post-event. • If essential systems are powered by natural gas, provision back-up systems/fuel for 48 hours post-event. **Gold buildings:** • Provide sufficient generators and fuel storage to power all building systems for 72 hours post-event. An uninterrupted power supply (UPS) is required for all essential systems. • Maintain potable water supplies on-site for storm ride-out teams for 72 hours post-event. • If essential systems are powered by natural gas, provision back-up systems/fuel for 72 hours post-event. • Establish contracts to supply fuel, potable water, and waste removal after 72 hours, or employ alternative off-grid technologies. **Platinum buildings:** • Provide sufficient generators and fuel storage on-site to power essential systems for one week post-event. An uninterruptible power supply (UPS) is required for all essential systems. • Maintain water supplies on-site for one week post-event of full building services, except cooling water. • Essential systems shall not be powered by natural gas. Back-up or on-site storage shall be provided for all non-essential systems powered by natural gas. • Establish contracts to supply fuel, potable water, and waste removal after one week, or employ alternative off-grid technologies.
●	○	○	E	1.2.2	**Underground Utility Lines**	The site does not solely rely on above-ground utility lines. Underground utility lines should be able to provide power to systems and equipment needed for operation of the building or facility.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	○	O	1.2.3	**Back-up Communications**	If dependent on communication for functionality, establish a communication system back-up in the event that cell phones, landlines, and internet services are interrupted. This requirement may be satisfied by having a dual communication connection.
●	●	●	O	1.2.4	**Supply of Consumables**	For owner-occupied buildings with a dedicated storm ride-out team, determine the necessary amount of reserve food, potable water, and fuel to be stored on site. The supply of consumables should be adequate for, at minimum, three days of storm ride-out. For Platinum-rated buildings, a supply of all necessary consumables for functional operation of the facility must be stored on site. These can include medical supplies and gases for hospitals or critical reagents and other supplies for pharmaceutical companies.

1.3 Proactive Utility Measures

Platinum	Gold	Silver	Lead	Index	Item	Criteria
○	○	○	E	1.3.1	**Microgrid Technology**	Provide closed-loop systems and/or utilize a microgrid such that the building's water and energy supplies are not grid-reliant.
○	○	○	E A O	1.3.2	**Reduced Energy and Resource Consumption**	Utilize appliances and fixtures that minimize water and energy use. Maintain occupant comfort of the building using passive means where possible. This includes ample natural daylight, proper ventilation, and temperature conditioning without artificial lighting and air conditioning.
●	●	○	E O	1.3.3	**Data Protection**	Ensure that loss of power does not cause electronic data loss and that a plan exists for quick re-booting of server systems, if applicable. Adopt a cloud migration plan to reduce dependence on on-site data storage.
●	●	○	E O	1.3.4	**Security**	Ensure that loss of power does not cause security systems to become inactive, or ensure that manual over-ride is available (e.g., keys).

1.4 Mitigate Impeding Factors

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	○	O	1.4.1	**Post-Event Evaluation**	Retain a qualified professional on an annual basis to conduct a safety evaluation of the facility immediately after a severe wind event in accordance with ATC-45 procedures. The evaluation will result in a placard that indicates whether the building is safe to be occupied. As a general guideline, evaluation is needed following any event that approaches the site's design level.
●	●	●	O	1.4.2	**Contractor/ Engineer Mobilization**	Retain a contractor and/or engineer on an annual basis if the estimated damage from the design-level event would require their services.
●	●	○	O	1.4.3	**Assessment of Financing Requirements**	Identify sources of funding for the repairs necessary to ensure functional recovery within the time specified for the REDi™ Rating Level (i.e., 48 hours for Platinum and 2 weeks for Gold). Determine the funding sources' lead times. Either budget for the cost of the repairs necessary to achieve functional recovery or plan to ensure quick access to private or other financing.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	1.4.4	**Long-Lead Time Items**	For Platinum- and Gold-rated buildings, protect critical 'long-lead time' items which would hinder re-occupancy or building functionality if they sustain irreparable damage. For Silver-rated buildings, either protect the 'long-lead time' items as described for Platinum and Gold, or account for expected procurement times in the "Downtime Assessment" in Section 4.4.1 if they are expected to sustain damage requiring replacement.
○	○	○	E O	1.4.5	**Instrumentation**	Include sensor instrumentation that will provide post-event data.

1.5 Business Continuity

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	○	O	1.5.1	**Business Continuity Plan**	Develop a Business Continuity Plan (BCP). At a minimum, a site-specific BCP should reference extreme windstorms as a hazard and list emergency contacts and emergency procedures in the event of such a storm. This BCP should also reference and be consistent with an organization-wide BCP.
●	●	●	O	1.5.2	**Preparedness Plans**	At an organizational level, establish plans for evacuation of non-essential personnel, or for all personnel if storm ride-out is not proposed.
●	●	●	O	1.5.3	**Preparedness Kits**	Provide preparedness kits for all staff anticipated to be on site during an event.
●	●	○	E O	1.5.4	**Early Warning Systems**	Communicate the arrival of an extreme windstorm in an appropriate amount of time to allow for execution of any preparedness plan, inspection of critical items, and evacuation if required.
●	●	○	O	1.5.5	**Storm Ride-Out Policies**	Establish organizational policies for the maintenance of critical operations in the event of storms. Specify the safest location(s) to stay during the storm, and include at least one alternate location should problems with the primary location arise. Further, supply adequate resources for any critical personnel that must ride-out the hazard event to maintain operation (Section 1.5.3).
●	○	○	O	1.5.6	**Emergency Preparedness Training of Staff**	Conduct training for tenants and employees to become familiar with preparedness plans and emergency response measures and resources. These plans of action should be refreshed periodically along with the training procedure. For Platinum-rated buildings, conduct regular tabletop exercises with local emergency response authorities.
●	●	●	O	1.5.7	**Critical Personnel**	Work with critical personnel after an event to enable them to arrive to the site, continue their work, and carry out the recovery process. Establish a critical staff list in the Emergency Response Plan and train staff to call these personnel during an event.
●	●	○	O	1.5.8	**Review of Emergency Protocol**	Schedule routine reviews of critical items, backup power systems, and safety shelters and rooms to be used by critical personnel that must ride-out the storm or are unable to evacuate. Items to be reviewed include supply of emergency kits (e.g. Section 1.5.3), integrity of tornado and hurricane shelters and safe rooms (Section 2.4.1), and operability of early warning, communication, and emergency response systems (Sections 1.5.4, 1.2.3, 1.2.1).

Platinum	Gold	Silver	Lead	Index	Item	Criteria

2. Building Resilience

2.1 Wind Hazard

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	2.1.1	**Design-level Wind Hazard**	The design-level wind event is one with an MRI of 700, 1700, or 3000 years, depending on the desired REDi™ rating level. If local codes nominated by the Authority Having Jurisdiction (AHJ) dictate a different wind event, the larger MRI of the two shall be used. See Section 3.1.1.
●	●	●	E	2.1.2	**Site-Specific Climate Assessment**	Conduct a site-specific wind hazard analysis to determine the design wind hazard. The analysis should be statistically robust, and the analytical approach's validity should be assessed relative to the mean recurrence interval of interest and the particular wind hazard. Rare meteorological phenomena will require different statistical analyses (e.g., Monte Carlo simulations).
●	●	●	E	2.1.3	**Special Wind Conditions**	Follow the unique design considerations for tornados, tropical cyclones, and downslope winds.
●	●	●	E	2.1.4	**Building Performance against Combined Effects**	Assess the risk of multi-hazard events and ensure that building performance is adequate against their combined effects. Refer to Section 0 for multi-hazard requirements. **Winter Storms** Mechanical ventilation systems must not be clogged due to snow drift. Building access may be disrupted. Follow Sections 1.2 and 1.3 to reduce the risk of disruption to utility services if power lines fail due to ice accretion (Section 0.1.2). **Hurricanes** Consult REDi™ Flood and protect against damages due to flood and water penetration. Consider factors such as rainfall rate and volume of water. See Section 2.3.2 for further requirements for wind-driven rain intrusion. (Section 0.1.1)
●	●	●	E	2.1.5	**Climate Change Impact**	As part of the hazard assessment, mid-century climate projections should be considered. Any probable increases or decreases in extreme windstorm wind speeds and frequency due to climate change should be included in the resilience assessment. For Platinum ratings, use the late-century time horizon.

2.2 Enhanced Structural Design

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	2.2.1	**Minimize Structural Damage**	Design the building for elastic performance so that wind loads do not cause yielding under the design-level event in the structure's main wind force resisting system (MWFRS), unless Performance-Based Wind Design is used and inelastic responses are expected.
●	●	●	E	2.2.2	**Code Minimum Requirements**	Ensure the design conforms to the requirements of the local jurisdiction. Where the local codes of practice are under-developed and/or inadequate, use an international consensus standard such as ASCE 7.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	2.2.3	**Wind Consultant Review**	Employ a wind engineering consultant for advice related to the building in question. The wind consultant should advise, at a minimum, on the suitability of the code of practice to correctly establish the wind loads for design. They should also provide input on the decision to conduct wind tunnel testing and its scope.
●	●	●	E	2.2.4	**Wind Tunnel Testing**	Appropriately conducted wind tunnel testing will lead to a better understanding of the reliability of the structure. Wind tunnel testing is required if any of the following criteria are met: • Building is Platinum-rated • Testing is required by the AHJ • 150 mph design-level wind event • Constructed in a dense urban environment • 6:1 slenderness ratio and structural frequency of < 0.5 Hz
●	●	●	E	2.2.5	**Finite Element Analysis (FEA) Model**	Develop a representative, three-dimensional mathematical model of the structure, including all structural elements. Structural modelling assumptions should follow best practice, including appropriate levels of concrete and damping ratios of the order of 1% for operational and 2% for ultimate limit state (ULS) design. If the wind consultant deems the structure to be sensitive to wind-induced vibrations, conduct dynamic analysis, explicitly including dynamic and buffeting effects. Otherwise, a rationale should be put to the design team suggesting why a dynamic analysis is not necessary.
●	○	○	E	2.2.6	**Performance-Based Wind Design (PBWD)**	Conduct performance-based wind design for Platinum-rated structures. PBWD is recommended, not required, for Gold and Silver buildings.
●	●	●	E	2.2.7	**Minimize Drift-related Damage**	During wind events, limit peak story drift to H/400 - H/500 for operational performance mean recurrence intervals. Story drift is defined to include both horizontal and vertical deformations.
○	○	○	E	2.2.8	**Motion Control**	To reduce wind dynamics, supplementary damping systems such as tuned mass dampers (TMDs), tuned liquid dampers (TLDs), active vibration, or integrated damping systems may be installed. In general, their impact cannot be considered for strength design. However, under certain rare circumstances, distributed/integrated damping may be permissible for structural control when acceptable levels of reliability and redundancy can be achieved.

2.3 Enhanced Non-Structural Design

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	2.3.1	**Equipment Integrity**	Any mechanical equipment exposed to wind shall be certified to the design wind speeds and inspected to ensure the ability to withstand those speeds. See also the inspection requirements in Sections 2.54 and 2.5.6.
●	●	●	E	2.3.2	**Envelope Design**	Design all exterior, non-structural building components to withstand damage at the operational wind speeds for each REDi™ tier (Section 2.1.1). These components typically include roofing, wall cladding, doors, and fenestration, which should be designed to withstand both design wind pressures and wind-driven rain. At a minimum, follow the requirements of FEMA P-424, Chapter 6.3.3. For Platinum- and Gold-rated buildings, use robust roof, fenestration, and wall and cladding systems that have been demonstrated to be resilient to damage and failures.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E A	2.3.3	**Wind-borne Debris**	Consider potential wind-borne debris as a demand on the façade including doors and wall assemblies and as a safety concern for building users. Mitigate appropriately. Prevent leakage of roof assemblies if they are penetrated by wind-borne debris. This criteria must be considered in areas defined by the International Building Code (IBC) as wind-borne debris regions. It may also be considered in other regions according to the judgment of the design engineer.

2.4 Egress and Shelter

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E A O	2.4.1	**Tornado and Hurricane Shelter and Safe Rooms**	For Platinum and Gold buildings located where tornados pose a threat, provide a shelter or refuge area on each floor. For hurricane environments, due to the added flexibility given by longer advanced warning, provide at least one shelter or safe room for the entire building. Shelters and safe rooms should be designed following best practice. For Silver-rated buildings in tornadic environments, a safe room for the entire building should be designed following FEMA P-361.
●	●	●	E A	2.4.2	**Preservation of Egress Routes**	Ensure integrity of egress routes including doors, exits, and stairwells. At a minimum, comply with the required number of egress routes as required by the IBC.

2.5 Peer Review and Quality Assurance

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	○	○	E	2.5.1	**Hazard Peer Review**	Conduct a site-specific, wind climate hazard assessment peer review. A peer review will be required if there is any measurable (~5%) reduction in the design wind speeds being considered, compared to the code of practice.
●	●	○	E	2.5.2	**Structural Peer Review**	Analysis and design are subject to a formal structural peer review process. The structural peer review should cover: • Review assumptions and characteristics of the structural model • Review of acceptance criteria for non-structural components and systems to withstand the calculated force and deformation demands • Review of the Resilience Plan detailed in Sec. 1.1 above For Platinum-rated buildings, peer reviews should be carried out in accordance with the Prestandard for Performance-Based Wind Design (Charles Pankow Foundation). Otherwise, if mandated by the AHJ, then the required procedure for peer review should be followed. The wind tunnel testing results should also be peer-reviewed by qualified experts to ensure the following of best industry practice. **Building Envelope Peer Review** Building envelope design is subject to a formal peer review. For Gold- and Platinum-rated buildings, peer review should be carried out in accordance with the AHJ. Additionally, for Platinum-rated buildings, peer reviews should be carried out in accordance with the Prestandard for Performance-Based Wind Design (Charles Pankow Foundation).

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	○	○	E	**2.5.3**	**MEP Review**	Conduct the peer review of the design, redundancy, and sealing of mechanical, electrical, and plumbing systems in accordance to the building code specified by the AHJ. Where possible, test the MEP systems with appropriate loads to verify conformance to the desired resilience objectives established in this document. Specific requirements for the three ratings are listed in Section 1.2.1.
●	●	●	E	**2.5.4**	**Inspection of Envelope and MEP During Construction**	By inspection, review the building envelope for quality of installation and conformance with construction documents. By inspection, review exterior-mounted equipment for fixity and anchorage quality and conformance with construction documents. Additionally, include instructions for inspection to verify correct installation of non-structural components in the General Notes of the construction documents. Inspection and testing during construction is important for envelopes and rooftop equipment to achieve good performance. An inspection should be carried out immediately following building completion.
●	●	●	E	**2.5.5**	**Periodic Inspection of Envelope and MEP**	Following project completion, the building envelope and MEP systems should be inspected as needed to meet the expected design performance of non-structural building components (Section 2.3) by persons knowledgeable of these systems and materials. During inspection, special attention should be given to both the building envelope and the anchorage of exterior-mounted equipment.

3. Site Resilience

3.1 Site Vulnerability

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	○	E A O	**3.1.1**	**Site Planning**	Site location, orientation, and surroundings have a significant impact on resilience for wind storms. Extreme windstorms should be considered during site selection and climate risk should be incorporated into site selection and master-planning decisions.
●	●	○	E A O	**3.1.2**	**Scenario Planning**	Emergency response planning should include considerations for 'outside-the-wire' impacts such as interruptions in utility service, transportation, communications, etc.
●	●	○	E A	**3.1.3**	**Site Access**	Evaluate the likely site access by workers, residents, and emergency response teams via functional transportation systems during and after an event. Evaluate the implications to recovery if such systems are not accessible.
●	●	●	E	**3.1.4**	**Vulnerability Assessment of Utility Network**	Identify which parts of the utility network are vulnerable to failure or periods of shutdown due to wind or combined multi-hazard effects.
●	●	○	E	**3.1.5**	**Assessment of Surrounding Buildings**	Provide a qualitative assessment of the wind performance of adjacent buildings or structures to avoid any cascading effects. The likelihood of potential issues such as structural collapse / poor performance, generation of wind-borne debris (see Section 2.3.3), or the presence of tower cranes should be considered.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	3.1.6	**Assessment of Surrounding Non-Building Structures**	Identify any non-building structures located on the site which, if damaged, may compromise the resilience objectives of the facility or structure. Additionally, pursue mitigation measures of these potential damages and impediment sources.

3.2 Advocacy for Community Level Resilience

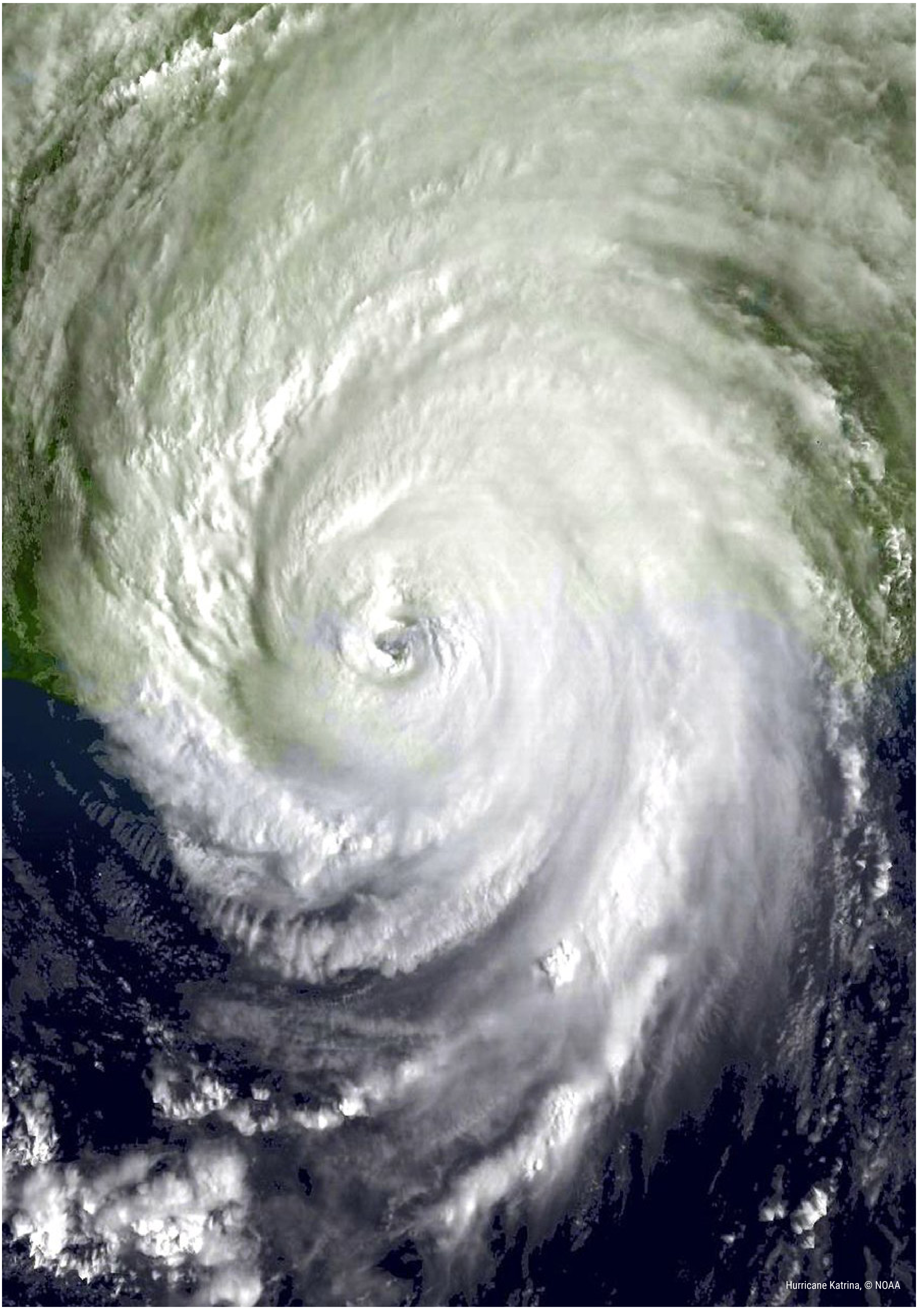
Platinum	Gold	Silver	Lead	Index	Item	Criteria
○	○	○	O	3.2.1	**Improvements to Infrastructure**	Communicate to local and state representatives, officials, and utility and transportation departments the desire for enhanced infrastructure that can withstand the effects of natural disasters.
○	○	○	O	3.2.2	**Diverse Community Mobility**	Facilitate the use and operation of public transit and active transportation in and out of the surrounding area including the site (Section 3.1.3) and enhance the sense of community in response to a natural disaster.
○	○	○	O	3.2.3	**Civic Engagement**	Promote active participation within the organization and the community to strengthen social and economic networks.
○	○	○	O	3.2.4	**Community Education**	The site should serve as a resource in the community for resilience-based initiatives and be a known source of wind and natural disaster information. The site leadership can facilitate discussions around resilient-minded development.

4. Resilience Assessment

4.1 Resilience Assessment Guidelines

Platinum	Gold	Silver	Lead	Index	Item	Criteria
●	●	●	E	4.1.1	**General Resilience Assessment Guidelines**	Conduct a risk assessment consistent with the resilience objectives for the building. Any method used must quantitatively include multiple hazard scenarios, vulnerability, and consequence. For Silver and Gold ratings, this includes a short qualitative assessment and a building-level loss assessment using HAZUS or a similar assessment technique. For Platinum-rated buildings, carry out a probabilistic, component-level assessment to establish losses, casualties, and downtime.
●	○	○	E	4.1.2	**Detailed Resilience Assessment Guidelines**	The following components should be included in a robust probabilistic building loss and downtime assessment: • Site-specific hazard data, including the effects of climate change, is used to establish the magnitude of the REDi™ Level Wind Event (500 year MRI). • The expected loss results (50% probability of non-exceedance) are used at a minimum. • Loss calculations are performed using the actual amount and location of damageable structural and non-structural components and contents where possible. This can be accomplished with component-level fragility and consequence functions (similar to those for seismic hazard in FEMA P-58). Where the default fragility curves and consequence functions are not provided for a particular component or would not provide an adequate representation of damage and consequence, they should be developed based on engineering judgment, empirical analysis, FEMA Restoration Tables, or obtained from peer-reviewed literature. A complete component-based extreme windstorm risk methodology, adapted from REDi™ Seismic, will be included in an upcoming version of REDi™ Extreme Windstorms.

Platinum	Gold	Silver	Lead	Index	Item	Criteria
4.2 Life Safety Assessment						
●	●	●	E	**4.2.1**	**Life Safety**	The best way to maximize life safety during extreme windstorms is to create a robust structural design according to the building code, to implement enhanced design of non-structural components, and to establish thoughtful Emergency Response Plans. An assessment review should be conducted of the Owner's/ operator's ERPs to ensure that they include best-practice health and safety approaches.
4.3 Direct Financial Loss Assessment						
●	○	○	E	**4.3.1**	**Direct Financial Loss Assessment**	Direct financial loss is derived through an assessment methodology similar to HAZUS, while incorporating component fragilities. The losses are expressed as the repair cost divided by the Total Building Value (see Glossary of Terms). This does not consider indirect financial loss such as business interruption.
●	○	○	E	**4.3.2**	**Valuable Building Contents**	Include valuable building contents in the loss assessment, such as medical equipment and machine servers, desktop electronics, art installations, and inventory that exceed more than 10% of the Total Replacement Value.
4.4 Downtime Assessment						
●	○	○	E	**4.4.1**	**Downtime Assessment**	Carry out an assessment of downtime for the building, including consideration of the factors below: **Impeding Factors** Quantify the cost and effect of delays to initiation of post-windstorm repairs caused by 'impeding factors'—inspection, access to financing, engineering review or re-design, contractor mobilization, and permitting. **Utility Disruption** Account for utility disruption in the downtime associated with functional recovery. **Long-Lead Time Items** Include the time associated with procuring any 'long-lead time' components in the downtime calculations if they are expected to be damaged. **Critical Building Contents** Include building contents, which, if damaged, would hinder re-occupancy or functional recovery.


Hurricane Katrina, © NOAA

0

MULTI-HAZARD RESILIENCE REQUIREMENTS

Incorporate other natural disaster threats in the resilience-based design approach when a site is exposed to multiple, correlated hazards

0.1 Multi-Hazard Resilience

Intent: Based on the specific geographical location and its climate, assess the combined risk from multi-hazard events such as hurricanes, winter storms, and wildfires and design accordingly.

Major natural disasters often include the effects of multiple damage mechanisms such as wind, flood, snow and ice, and wildfire. In the examples listed below, wind acts in conjunction with the other hazards.

The resilience objectives in this design guideline are only achieved with respect to damage from wind. For certain sites, achieving the resilience objectives for multiple hazards means incorporating design recommendations from multiple sources of guidance. A consistent importance level should be used when considering multi-hazard events. In the event of conflicting guidance for different hazards, engineering judgement should be used.

Resilience-based design approaches may not be fully developed for some hazards noted herein. It is expected that the designer will make a reasonable effort to incorporate resilient design approaches for correlated hazards and document these as part of their REDi™ rating.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E	**0.1.1 – Extreme Windstorms with Flooding** Many extreme windstorms can also lead to flooding, whether from significant precipitation, riverine flooding, coastal storm surge, or a combination of the above. Depending on the topography surrounding the site, it may be reasonable to expect that flooding will become a salient hazard in addition to severe wind. The designer shall evaluate the potential risk of flooding at the site, and if the risk is present, a REDi™ Flood assessment shall be conducted. In the REDi™ Flood assessment, a rating that is at least equivalent to the one selected from REDi™ Extreme Windstorms must be achieved.	*0.1.1* *High-speed winds with large amounts of precipitation are the primary drivers of damage in both hurricanes and severe thunderstorms. Wind and precipitation may cause internal water damage when a façade is breached. Indirect impacts include the failure of power supply lines or potable water infrastructure.* *In addition to the guidelines provided herein, REDi™ Flood must be consulted for adequate assessment and mitigation of the combined impact from wind and flood.* *A desktop flood assessment shall be undertaken for the site to determine whether flood risk is present. The assessment should include a review of publicly available riverine flood maps, historic flood event records, local intensity-duration-frequency precipitation data, coastal inundation maps, and consider best-available climate change information.* *References:* - *REDi™ Flood* - *FEMA P-424: Design Guide for Improving School Safety in Earthquakes, Flood, and High Winds*

Platinum Gold Silver Lead

CRITERIA | COMMENTARY

● ● ● E

0.1.2 – Winter Storms

In areas susceptible to winter storms, assess the effects and risks posed by strong winds in conjunction with snow accumulation, snow drift, and ice accretion on exposed systems and structures.

0.1.2

With freezing temperatures, winter storms bring strong winds and substantial precipitation in the form of snow, mixed snow and rain, or freezing rain. The interaction of this frozen precipitation and the building is important to consider.

The direct impacts of a winter storm are primarily due to the accumulation of ice and snow, which can lead to failure of utilities, MEP systems, structures, and building members. Snow and ice accumulation on roofs must be carefully considered in design to avoid structural damage and impact hazards to pedestrians.

The accumulation of ice and snow on transportation roads may also block access to damaged systems and structures, impeding post-storm recovery and repair.

Utilities are particularly vulnerable to winter storms due to the prevalence of overhead transmission and vulnerability of power generation to cold weather.

Reduced visibility in windy and snowy conditions may also create dangerous operating conditions, limiting transportation access or impeding any required outdoor maintenance or mitigation actions.

References:

- *FEMA (Ready) P-957 Snow Load Safety Guidance*
- *FEMA Playbook: Prepare your Organization for a Winter Storm*

0.1.3 – Wildfires

● ● ● E

Assess the risk of wildfires with the potential for wind to spread fires or spark them indirectly, for example by wind-whipped power lines. Plans for evacuation and business continuity (Sections 1.5.1 and 1.5.2) are required.

0.1.3

The highest wildfire hazard is posed in conditions of high temperatures, low humidity, prolonged low precipitation for part of the year, and high winds. In these climates, substantial risk may be posed either by direct contact with wildfires (locations in the wildland urban interface, or WUI) and/or by degraded air quality. Operational risks are also increasingly common in high-risk wildfire areas.

It is important to consider the local historical wilfire context in the risk assessment, including the identification of the likely ignition sources. During a wind-driven wildfire, embers can be lofted ahead of the main fire, creating new fires. Ember showers pose a significant threat to structures in WUI areas because of their ability to ignite both the exterior of structures and interior spaces, entering attics and basements through eaves and vents. Once a building is ignited, it in turn increases the risk of fire spread to any neighboring structures. Mitigations to reduce building wildfire vulnerability include vegetation control near the building and the use of fire-resistant building envelopes.

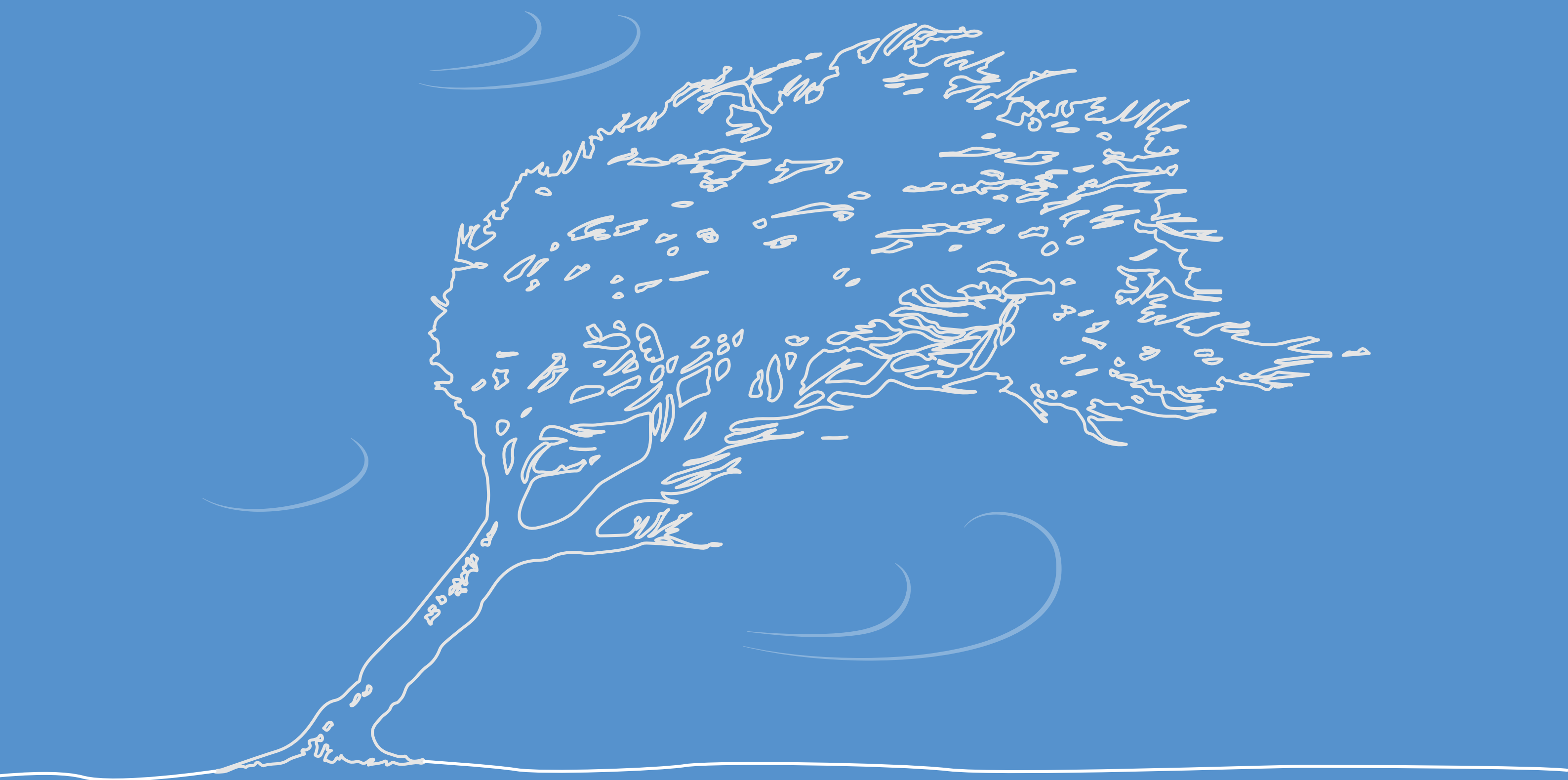
Wildfires often temporarily reduce air quality and increase smoke pollution in the surrounding area. Exterior building openings (doors, windows, vents, gaps in construction, etc.) must be properly sealed, filtered, and designed to protect occupant health and comfort and to protect sensitive electronics and equipment. Wildfires may also impede transportation access due to road blockage and decreased visibility from smoke and/or cause prolonged utility outages.

References:
- *FEMA P-737: Home Builder's Guide to Construction in Wildfire Zones*
- *FEMA (Ready) Playbook: Prepare your Organization for a Wildfire*
- *International Wildland-Urban Interface Code*

1

OPERATIONAL RESILIENCE

Establish contingency plans for business continuity and utility disruption



1.1 Resilience Planning

Intent: Identify risk drivers and establish a resilience plan to ensure that all aspects of the design contribute to reducing the risk in accordance with the Owner's resilience objectives.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY

● ● ● E A O

1.1.1 - Resilience Workshop

Conduct at least two workshops with the Owner, led by a qualified facilitator, with the facilities team, engineers, and the broader design team if applicable.

The first workshop, occurring at project inception, should establish resilience objectives for the project (building and site), review the high level context of hazard and risk with the Owner and design team, and develop goals for managing that risk. Investigate issues including but not limited to those listed in the commentary. A formal Resilience Plan document, which identifies how each resilience objective will be achieved and identifies remaining potential risks, is to be written by the Design Team and approved by the Owner.

Hold a concluding workshop at the close of the design process to ensure that resilience objectives have been met, supported by the resilience assessment (See Section 4). Ideally, interim workshops should also be held around key decision points, during which the Resilience Plan is reviewed and the design is adjusted as necessary.

1.1.1

Review the Context of Risk

- *What could go wrong? What potential hazards could interrupt building operations? How likely are these hazards to occur and how severely might they affect the project?*
- *Who is most vulnerable? What populations served by the facility or organization will need support?*
- *What are the underlying stresses that might amplify the impact of a hazard on the project/system it relies on?*

Set Goals and Priorities

- *What mission-critical systems and valuable contents should be prioritized for protection during disruption?*
- *How will decisions be made regarding managing risk? What targets should be set for casualty, re-occupancy, functionality, and financial loss objectives?*
- *What level of formal business continuity and risk assessment is required? (Section 1.5.1)*
- *What should be written into fit-out contracts with tenants to satisfy the resilience objectives?*
- *What level of occupant or community support will be provided during times of disruption, and how long will these functions need to be accommodated?*
- *Which climate change scenario(s) will be used in the wind hazard projections? (Section 2.1.5)*

Platinum Gold Silver Lead

CRITERIA | COMMENTARY

1.1.2 - Organizational Resilience

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In collaboration with the Owner, the design team shall prepare an organizational resilience summary which captures how the design contributes to building, community, and operational resilience.

Reflect on insight gathered in the Resilience Plan and integrate this knowledge into broader organizational planning around building operations. Consider including initiatives including but not limited to those listed in the commentary.

1.1.2

Resilience includes not just the physical systems of a building but also non-structural systems such as policies and practices. Examples are listed below.

- Leadership and Business Strategy*: Inform capital and operational plans and policies in core areas such as governance practices, strategic visioning, CAPEX and OPEX planning and investment, maintenance and investment, financing and insurance, and technology application.*
- Infrastructure and Operations*: Apply knowledge of risk and resilience to infrastructure and environmental systems and to inform data collection and analysis, and then use the understanding gained to influence operational decisions related to risk management and security.*
- People and Relationships*: Inform policies and communication with employees/staff and relationship and practices with partners/ suppliers to build resilience awareness and put in place contingency planning.*

1.1.3 - Risk Assessment

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Conduct a risk assessment consistent with the resilience objectives for the building. See Section 4 for further details regarding loss assessment requirements, which satisfy this requirement.

1.1.3

This rating system provides design guidance for increasing the resiliency of a given project. Assessment is essential to validate that the design approaches successfully achieve the desired resilience objectives.

1.2 Essential Utility Reliability

Intent: Utility outages are one of the most significant contributors to loss of building functionality as a result of extreme weather. Provision of back-up utilities and communication supports continued operation and faster recovery of buildings of all types.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY

● ● ● E

1.2.1 - Back-up Utilities

For each utility listed below, provide back-up systems and necessary fuel storage and refueling contracts, where applicable.

Use scenario planning to estimate the length of disruption for each utility. Scenario planning should consider the loss of transportation or access to on-site back-up systems and supplies. The time requirements below are minimums; the length of time determined by scenario planning should be used, if greater.

Silver buildings:

- Provide sufficient generators and fuel storage on-site to power essential systems for 48 hours post-event.
- Maintain potable water supplies on-site for storm ride-out teams for 48 hours post-event.
- If essential systems are powered by natural gas, provision back-up systems/fuel for 48 hours post-event.

Gold buildings:

- Provide sufficient generators and fuel storage to power all building systems for 72 hours post-event. An uninterrupted power supply (UPS) is required for all essential systems.
- Maintain potable water supplies on-site for storm ride-out teams for 72 hours post-event.
- If essential systems are powered by natural gas, provision back-up systems/fuel for 72 hours post-event.

1.2.1

Electric grids are especially vulnerable to extreme windstorms. Wind with ice can also create an amplified hazard that can cause utility disruptions, as described in Section 0.1.2.

Resilient buildings should include back-up power (commonly in the form of generators), and in the case of critical systems, should be supplemented with UPS. In cases where power reliability is critical, dual grid connections should be considered. Dual supplies from resilient sub-stations is a best practice approach and is recommended where possible.

All generators should be tested regularly to ensure back-up system readiness. Comply with local environmental regulations when providing fuel storage on-site. Refill points must be located above the design flood elevation (see REDi™ Flood). Establishing fuel contracts is a best practice approach to protect against persistent outages; though this is only required for Gold- and Platinum-rated buildings, Silver-rated buildings should also consider this measure. Fuel storage capacities should exceed required volume for emergency storage by 20% to allow for testing and routine maintenance without compromising a site's emergency preparedness.

Depending on the configuration, solar panels may be relied on for a portion of back-up power. Demonstration of robustness of assumptions is required.

Gold buildings, cont.:

- Establish contracts to supply fuel, potable water, and waste removal after 72 hours, or employ alternative off-grid technologies.

Platinum buildings:

- Provide sufficient generators and fuel storage on-site to power essential systems for one week post-event. An uninterruptible power supply (UPS) is required for all essential systems.
- Maintain water supplies on-site for one week post-event of full building services, except cooling water.
- Essential systems shall not be powered by natural gas. Back-up or on-site storage shall be provided for all non-essential systems powered by natural gas.
- Establish contracts to supply fuel, potable water, and waste removal after one week, or employ alternative off-grid technologies.

If water is required on site for safe occupancy (e.g., for fire-fighting), then non-potable backup is required.

Platinum-rated building owners should be a resource in the community for resilience information and advocates for measures that increase the robustness of local utilities.

References:

- *FEMA P-1019: Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability*
- *NFPA 110: Standard for Emergency and Standby Power Systems*

Platinum Gold Silver Lead

CRITERIA | COMMENTARY

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1.2.2 - Underground Utility Lines

The site does not solely rely on above-ground utility lines. Underground utility lines should be able to provide power to systems and equipment needed for operation of the building or facility.

1.2.2

In some areas, underground lines are fed from overhead lines which may be subjected to high wind loads in winter storms and severe hurricane, thunderstorm, and tornado events. Utility outages can also be caused by ice and snow accumulation (See Section 0.1.2). The failure of these overhead lines may affect underground systems and should be considered.

Reference:
- *FEMA P-1019: Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability*

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1.2.3 - Back-up Communications

If dependent on communication for functionality, establish a communication system back-up in the event that cell phones, landlines, and internet services are interrupted. This requirement may be satisfied by having a dual communication connection.

1.2.3

Communication can be the most critical utility in a natural disaster. Lifelines and other critical facilities (such as companies providing financing or insurance) should ensure connectivity during an event. Maintenance of internet services may also be crucial. Require communications providers to share reliability information with Owner and design team.

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1.2.4 - Supply of Consumables

For owner-occupied buildings with a dedicated storm ride-out team, determine the necessary amount of reserve food, potable water, and fuel to be stored on site. The supply of consumables should be adequate for, at minimum, three days of storm ride-out.

For Platinum-rated buildings, a supply of all necessary consumables for functional operation of the facility must be stored on site. These can include medical supplies and gases for hospitals or critical reagents and other supplies for pharmaceutical companies.

1.2.4

For immediate re-occupancy objectives, food and water should be made available for at least the first three days after a severe windstorm. For critical facilities like hospitals, water for sanitation requirements and for fire sprinklers should also be available.

Developers should provide this advice to their tenants and facilitate its implementation, for example via their occupancy agreements.

If the site's function or provided services change to additionally accommodate surrounding community members during a hazard event, the amount of reserve supplies should be increased accordingly.

1.3 Proactive Utility Measures

Intent: The following measures and the extent to which they are implemented may vary based on several factors including, but not limited to, geographic site location, the demand during the hazard event and the desired level of service. These measures are in addition to those presented in Section 1.2 to achieve the required level of resilience.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
○	○	○	E	**1.3.1 - Microgrid Technology** Provide closed-loop systems and/or utilize a microgrid such that the building's water and energy supplies are not grid-reliant.	*1.3.1* *The most resilient buildings are those that can continue to function without the support of a large-scale utility grid, which may be vulnerable to wind events. The Living Building Challenge (LBC v3.1 2016), among others, outlines recommendations for closed-loop water and energy supplies. Water may be supplied via rainwater harvesting, on-site wells, or other natural closed-loop systems. Power may be supplied through on-site renewable energy sources such as wind turbines, PV panels, solar heating, and more. Special attention must be given to the design and installation of PV panels, as these elements are liable to blow away in extreme windstorms or be damaged by debris. Additional resilience may be achieved by using microgrids. Composting toilets and waterless urinals can be used to reduce solid waste and wastewater demands.* *References:* - *Living Building Challenge 3.1 (2016): A Visionary Path to a Regenerative Future* - *FEMA P-2021, Mitigation Assessment Team Report: Hurricanes Irma and Maria in the U.S. Virgin Islands - Building Performance Observations, Recommendations, and Technical Guidance, Recovery Advisory 5: Rooftop Solar Panel Attachment*

Platinum Gold Silver Lead

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1.3.2 - Reduced Energy and Resource Consumption

Utilize appliances and fixtures that minimize water and energy use.

Maintain occupant comfort of the building using passive means where possible. This includes ample natural daylight, proper ventilation, and temperature conditioning without artificial lighting and air conditioning.

1.3.2

For example, low-flow water fixtures and energy efficient appliances reduce the required capacity of back-up systems or elongate their duration.

See LEED v4 (2019) for New Construction for more details on low-use energy and water fixtures and appliances.

Designing the building for occupant comfort provides liveable conditions in the absence of utilities. Manually operable windows may be considered for natural ventilation if they are designed and properly installed to withstand determined wind loads.

Reference:

- *LEED v4 for Building Design and Construction (2019)*

E

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1.3.3 - Data Protection

Ensure that loss of power does not cause electronic data loss and that a plan exists for quick re-booting of server systems, if applicable. Adopt a cloud migration plan to reduce dependence on on-site data storage.

1.3.3

An un-interruptible power supply system may be required to guarantee that all data units can be backed up and maintained until back-up power systems turn on.

Alternatively, fully cloud-based working can be an effective measure to mitigate data loss due to hazard events.

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1.3.4 Security

Ensure that loss of power does not cause security systems to become inactive, or ensure that manual over-ride is available (e.g., keys).

1.3.4

Additional security measures may require back-up power supplies for electronic systems or locks. Critical personnel should still have access to rooms, equipment, and items needed to maintain operation of the facility if loss of power impairs the security systems. Consideration should be given to allow access to first responders and emergency services via a knox box or other emergency key box. Local life safety codes and regulations should be followed to ensure that compliance with egress requirements are always met, even during loss of power or emergency conditions.

1.4 Mitigate Impeding Factors

Intent: Reduce delays to initiation of the post-event repairs required for re-occupancy and functional recovery.

Platinum | Gold | Silver | Lead — CRITERIA — COMMENTARY

1.4.1 - Post-Event Evaluation

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Retain a qualified professional on an annual basis to conduct a safety evaluation of the facility immediately after a severe wind event in accordance with ATC-45 procedures. The evaluation will result in a placard that indicates whether the building is safe to be occupied. As a general guideline, evaluation is needed following any event that approaches the site's design level.

1.4.1

Post disaster evaluation should be carried out by a licensed engineer who can professionally certify that the building is fit for re-occupancy using standard methodology, such as ATC-45. The agreement with the retained engineer should explicitly mention response times and availabilities.

Efforts exist to promote the understanding of building damage from extreme windstorms such as the Structural Extreme Events Reconnaissance (*StEER) Network, who produce detailed post-disaster reports. Consider participating in such programs by sharing data and system failures with professional entities that specialize in post-event evaluations. This will improve the effectiveness of resilience measures taken against future hazard events.*

1.4.2 - Contractor/Engineer Mobilization

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Retain a contractor and/or engineer on an annual basis if the estimated damage from the design-level event would require their services.

1.4.2

This criterion is most relevant to Silver-rated buildings, which are expected to suffer damage requiring skilled contractors and potential engineering services. Contractors and engineers will likely be in scarce supply after a major event, so retaining them for post-event repairs on an annual basis can save weeks of downtime. Also consider signing a pre-approval contract with the contractor which guarantees the contractor some pre-identified financial compensation to begin repairs in case financing is not immediately available (see Section 1.4.3).

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	○	0	**1.4.3 - Assessment of Financing Requirements** Identify sources of funding for the repairs necessary to ensure functional recovery within the time specified for the REDi™ Rating Level (i.e., 48 hours for Platinum and 2 weeks for Gold). Determine the funding sources' lead times. Either budget for the cost of the repairs necessary to achieve functional recovery or plan to ensure quick access to private or other financing.	*1.4.3* *The time to access financing may be the most uncertain 'impeding factor'. Financing from insurance claims or private-backed loans have historically varied considerably (several weeks to several months or longer). In addition, insurance companies often require insurance deductibles that may be higher than the estimated losses. The most reliable method is to limit the expected financial losses so that the repairs necessary for functional recovery can be financed within the normal operating budget of the facility. REDi™-rated buildings may not rely on government grants as a funding source.* *As Platinum- and Gold-rated buildings are designed to sustain only minor and non-structural damage, component repairs would not hinder functional recovery and financing may not be required for the design-level event. However, it is prudent to plan for the scenario in which wind-induced damages are more severe than expected (due to a beyond-design event).*

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY

1.4.4 - Long-Lead Time Items

Platinum ● Gold ● Silver ● Lead: E

For Platinum- and Gold-rated buildings, protect critical 'long-lead time' items which would hinder re-occupancy or building functionality if they sustain irreparable damage.

For Silver-rated buildings, either protect the 'long-lead time' items as described for Platinum and Gold, or account for expected procurement times in the "Downtime Assessment" in Section 4.4.1 if they are expected to sustain damage requiring replacement.

1.4.4

'Long-lead time' items are critical components that can take months to procure if they cannot be repaired. Wind damage to buildings commonly involves failure of façade panels in particular.

For this reason, Platinum- and Gold-rated buildings should protect these types of components (i.e. allow no more than cosmetic damage) to meet their short recovery objectives.

To reduce dependency on the supply chain following an extreme windstorm, REDi™-rated buildings should have a stock of replacement façade panels and/or other critical components stored off-site and sheltered from exposure and damages. Alternatively, these components can be allowed to be damaged if the time required to procure them does not prevent the downtime objectives from being satisfied.

The 'long lead-times' should be quantified from information provided by manufacturers, maintenance professionals, contractors, and/or cost estimators.

1.4.5 - Instrumentation

Platinum ○ Gold ○ Silver ○ Lead: E, O

Include sensor instrumentation that will provide post-event data.

1.4.5

Consider installing additional measuring equipment to provide post-event data, improve inspection, and promote quicker recovery and repair.

1.5 Business Continuity

Intent: Identify risks and necessary actions to aid owner in event preparation, ride-out, and recovery.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	○	0	**1.5.1 - Business Continuity Plan** Develop a Business Continuity Plan (BCP). At a minimum, a site-specific BCP should reference extreme windstorms as a hazard and list emergency contacts and emergency procedures in the event of such a storm. This BCP should also reference and be consistent with an organization-wide BCP.	*1.5.1* *Business continuity plans aim to recover business functions and reduce downtime costs following an extreme windstorm. They include relocation plans, workarounds to technological and operational disruptions, exploration of recovery strategies, and staff training to support the recovery process and supply food, water, medical items, and other reserves needed for the consumption of critical employees and personnel.* *Business continuity planning should interface with local emergency management to ensure plans are aligned and consistent and that channels of communication are established during an emergency.* *Examples of business continuity plans are provided in the following references:* *- NFPA 1600: Standard on Continuity, Emergency, and Crisis Management* *- ASIS SPC.1-2009 - Organizational Resilience: Security, Preparedness, and Continuity Management Systems - Requirements with Guidance for Use* *- ISO 22301:2019 - Security and resilience - Business continuity management systems* *- FEMA Ready Business Continuity Plan https://www.ready.gov/business/implementation/continuity* *- FEMA Ready Business Continuity Resource Worksheet https://www.ready.gov/sites/default/files/2020-03/business-continuity-resource-worksheet.pdf* *- Agility Recovery Business Continuity Checklist https://www.agilityrecovery.com/resources/business-continuity-checklist/*

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	0	**1.5.2 - Preparedness Plans** At an organizational level, establish plans for evacuation of non-essential personnel, or for all personnel if storm ride-out is not proposed.	*1.5.2* *Preparedness plans focus foremost on the safety of non-essential personnel during and after an extreme windstorm. Emergency Response Plans (ERPs) and Business Contuinity Plans (BCPs) should consider building occupants and employees of all abilities and mobility requirements.* *For examples, see:* - *FEMA Ready for Business* *https://www.ready.gov/business*
●	●	●	0	**1.5.3 - Preparedness Kits** Provide preparedness kits for all staff anticipated to be on site during an event.	*1.5.3* *A preparedness kit provides supplies such as food, water, and medical and other resources needed in response to an emergency. They must be ready on hand and distributed proportionately to staff on site. The following links provide a list of items that are strongly recommended to be included in each preparedness kit.* **Supply kits:** - *FEMA Ready Emergency Supply List* *https://www.ready.gov/sites/default/files/2021-02/ready_checklist.pdf* **First Aid kits:** - *OSHA 1910.266 App A* *https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.266AppA* - *American Red Cross, Anatomy of a First Aid Kit* *https://www.redcross.org/get-help/how-to-prepare-for-emergencies/anatomy-of-a-first-aid-kit.html*

Platinum Gold Silver Lead

CRITERIA | COMMENTARY

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1.5.4 - Early Warning Systems

Communicate the arrival of an extreme windstorm in an appropriate amount of time to allow for execution of any preparedness plan, inspection of critical items, and evacuation if required.

1.5.4

Warnings and advisories provided in local and federal announcements (e.g., local radio and television stations, Wireless Emergency Alerts) must be heeded. Tornados typically require an immediate evacuation to safe areas, whereas hurricanes may have a lead period of several days or up to more than a week. The links below present more details on what can be expected for each type of announcement:

- *https://www.weather.gov/safety/hurricane-ww*
- *https://www.weather.gov/unr/Warning_Systems*

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1.5.5 - Storm Ride-Out Policies

Establish organizational policies for the maintenance of critical operations in the event of storms. Specify the safest location(s) to stay during the storm, and include at least one alternate location should problems with the primary location arise. Further, supply adequate resources for any critical personnel that must ride-out the hazard event to maintain operation (Section 1.5.3).

1.5.5

Comparable staffing plans can be sourced from hospitals, police, and fire departments whereby a calendar of rotating "shifts" is established for on-call duties.

Duties assigned to ride-out teams should prioritize mission-critical duties specific to the property type. A major responsibility of the ride-out crew is to close any operable openings in the building envelope, where possible, to avoid building pressurization during the event.

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1.5.6 - Emergency Preparedness Training of Staff

Conduct training for tenants and employees to become familiar with preparedness plans and emergency response measures and resources. These plans of action should be refreshed periodically along with the training procedure.

For Platinum-rated buildings, conduct regular tabletop exercises with local emergency response authorities.

1.5.6

Developers should provide this advice to their tenants and facilitate its implementation, for example via their occupancy agreements.

Platinum Gold Silver Lead

CRITERIA | COMMENTARY

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1.5.7 - Critical Personnel

Work with critical personnel after an event to enable them to arrive to the site, continue their work, and carry out the recovery process.

Establish a critical staff list in the Emergency Response Plan and train staff to call these personnel during an event.

1.5.7

Support with a farther reach (i.e. community restoration), beyond simply arriving to work, may be necessary if damages and losses are widespread and the availability of food, water, and basic amenities are at risk.

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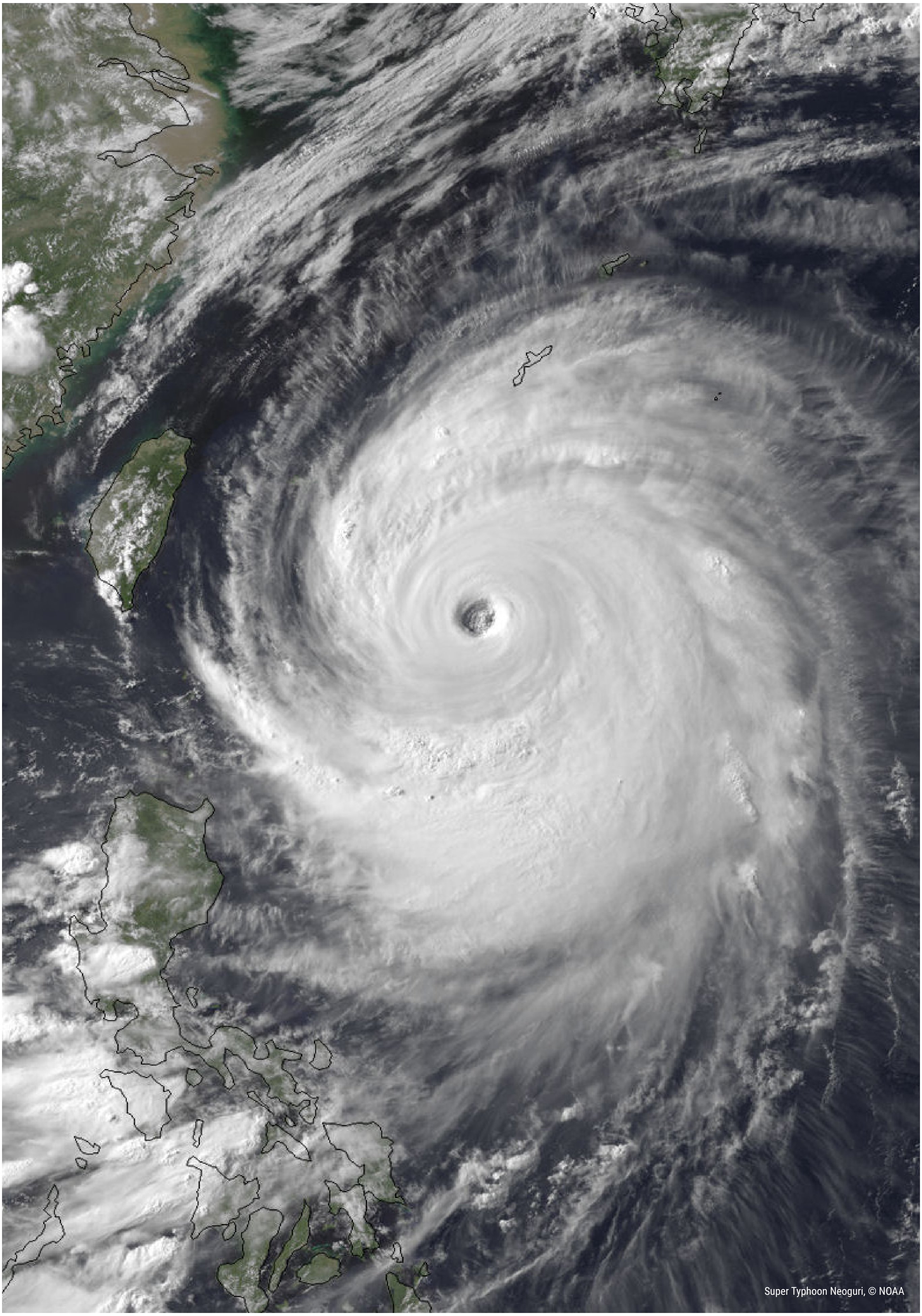
1.5.8 - Review of Emergency Protocol

Schedule routine reviews of critical items, backup power systems, and safety shelters and rooms to be used by critical personnel that must ride-out the storm or are unable to evacuate. Items to be reviewed include supply of emergency kits (e.g. Section 1.5.3), integrity of tornado and hurricane shelters and safe rooms (Section 2.4.1), and operability of early warning, communication, and emergency response systems (Sections 1.5.4, 1.2.3, 1.2.1).

1.5.8

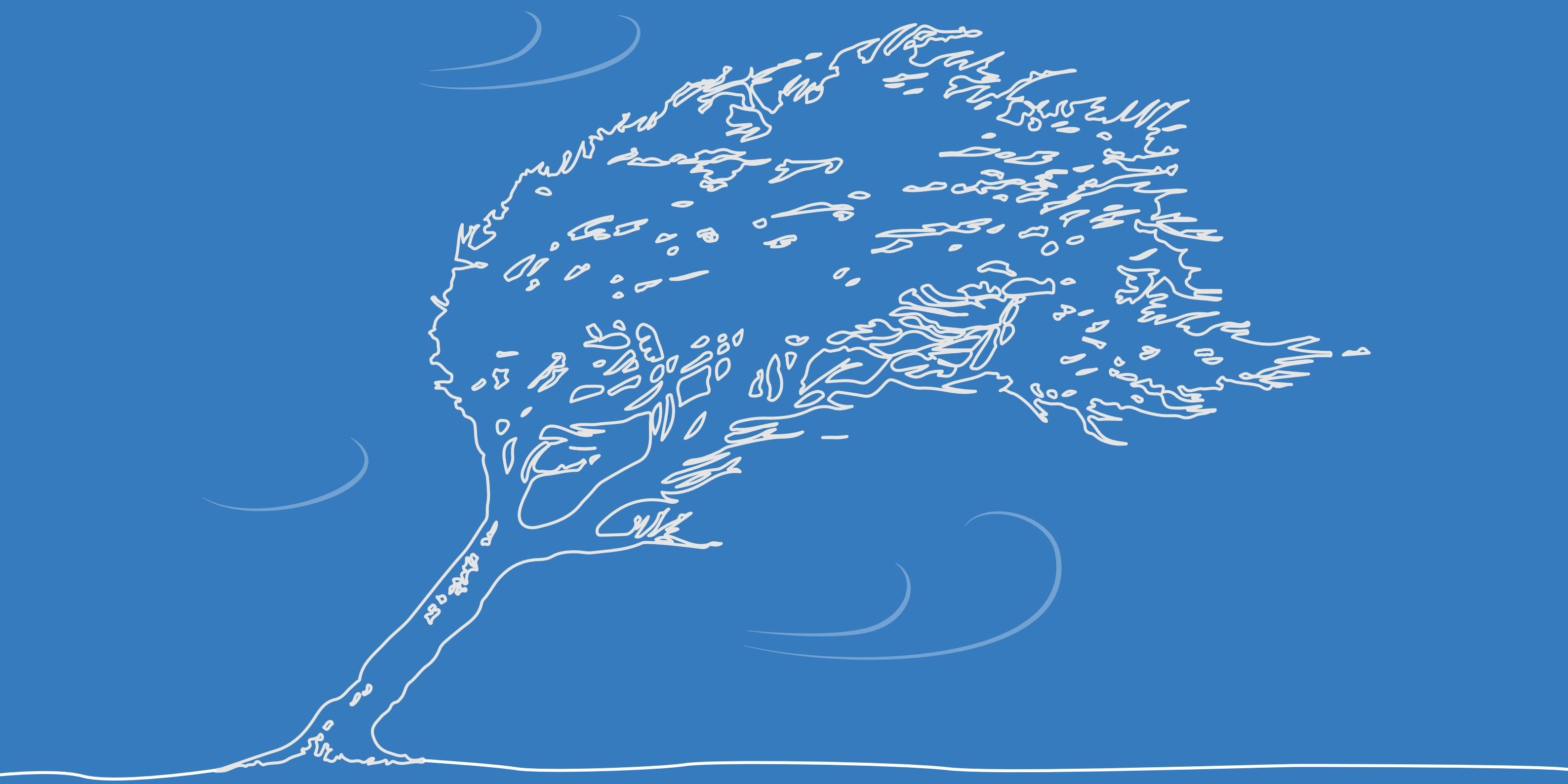
Reviews should be conducted by a professional with experience in disaster response and emergency planning. Documents should be compared to best practice and amended accordingly.


Super Typhoon Neoguri, © NOAA

2

BUILDING RESILIENCE

Minimize expected damage to structural, architectural and MEP components through enhanced design



2.1 Wind Hazard

Intent: Identify the site-specific wind hazard, reduce the building's exposure to these wind effects, and increase confidence in the building performance by designing for realistic Wind Design Parameters.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E	**2.1.1 - Design-Level Wind Hazard** The design-level wind event is one with an MRI of 700, 1700, or 3000 years, depending on the desired REDi™ rating level. If local codes nominated by the Authority Having Jurisdiction (AHJ) dictate a different wind event, the larger MRI of the two shall be used. See Section 3.1.1.	*2.1.1* **Ultimate Limit State Design-Level** *MRIs are referenced from ASCE 7:* *Silver: Risk Category II, 700-year MRI* *Gold: Risk Category III, 1700-year MRI* *Platinum: Risk Category IV, 3000-year MRI* **Operational/Serviceability-level** *Silver: 100-year MRI* *Gold: 200-year MRI* *Platinum: 500-year MRI* *References:* - *ASCE Prestandard for Performance-Based Wind Design (Charles Pankow Foundation)* - *ASCE Manual of Practice 143: Design and Performance of Tall Buildings for Wind*

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2.1.2 - Site-Specific Wind Hazard Assessment

Conduct a site-specific wind hazard analysis to determine the design wind hazard.

The analysis should be statistically robust, and the analytical approach's validity should be assessed relative to the mean recurrence interval of interest and the particular wind hazard. Rare meteorological phenomena will require different statistical analyses (e.g., Monte Carlo simulations).

2.1.2

The wind hazard analyses should account for all windstorm types relevant to the MRIs of interest (Section 2.1.1) using locally-measured historical wind data and/or storm simulations and classifying the effects of terrain and topography. In areas subjected to tropical cyclonic activity, Monte Carlo simulations (which develop hundreds of thousands of storm tracks for a specific site based on historical cyclone tracks) are necessary to understand the site wind conditions. Climate change effects should be incorporated into the site-specific wind hazard assessment (Section 2.1.5).

If the windstorm includes snow, snow drift, or other winter storm effects, see Section 0.2.

References:

- *ASCE Prestandard for Performance-Based Wind Design Chapter 5.2 (Charles Pankow Foundation)*

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2.1.3 - Special Wind Conditions

Follow the unique design considerations for tornados, tropical cyclones, and downslope winds.

2.1.3

Where tornados pose a threat, conduct an assessment of likely tornadic wind speeds. For areas subjected to downslope winds, simulations determining the influence of local and regional topography are likely required. The new (at the time of writing) ASCE 7-22 standard includes guidance on tornadoes and can be referenced.

Reference:

- *ASCE 7-22*

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2.1.4 - Building Performance against Combined Effects

Assess the risk of multi-hazard events and ensure that building performance is adequate against their combined effects. Refer to Section 0 for multi-hazard requirements.

Winter Storms
Mechanical ventilation systems must not be clogged due to snow drift. Building access may be disrupted. Follow Sections 1.2 and 1.3 to reduce the risk of disruption to utility services if power lines fail due to ice accretion (Section 0.1.2).

Hurricanes
Consult REDi™ Flood and protect against damages due to flood and water penetration. Consider factors such as rainfall rate and volume of water. See Section 2.3.2 for further requirements for wind-driven rain intrusion. (Section 0.1.1)

2.1.4

Major climate disasters often include the effects of multiple damage mechanisms such as wind, flood, snow and ice, and fire.

The resilience objectives in this design guideline are only achieved with respect to wind damage. For certain sites, achieving the multi-hazard resilience objectives requires the incorporation of design recommendations from multiple sources of guidance.

See Section 0 for further guidance regarding multi-hazard and combined effects.

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2.1.5 - Climate Change Impact

As part of the hazard assessment, mid-century climate projections should be considered. Any probable increases or decreases in extreme windstorm wind speeds and frequency due to climate change should be included in the resilience assessment.

For Platinum ratings, use the late-century time horizon.

2.1.5

Evidence suggests an increase in the frequency and the global mean intensity of cyclonic events which will indicate that stronger winds (and higher flood risks) are to be expected. Winter storms with greater volumes of freezing precipitation should also be considered. Design under these enhanced conditions (see Section 2.2 and 2.3) may be necessary.

At the time of publication of these guidelines, the United Nation's Intergovernmental Panel on Climate Change's AR6 report gives six pathways of CO_2 emissions and potential climate changes. At a minimum, include the emissions scenario following Shared Socioeconomic Pathway (SSP) 7.0 (typically referenced as the 'Business as Usual' estimate). More aggressive scenarios (e.g., SSP8.5) may be considered based on the Resilience Workshops' findings (Section 1.1.1).

See Section 0 for more on multi-hazard resilience.

2.2 Enhanced Structural Design

Intent: Increase confidence in the building performance by using best practice, beyond code design approaches.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E	**2.2.1 - Minimize Structural Damage** Design the building for elastic performance so that wind loads do not cause yielding under the design-level event in the structure's main wind force resisting system (MWFRS), unless Performance-Based Wind Design is used and inelastic responses are expected.	*2.2.1* *Structural damage is time-consuming to repair as it involves many impeding factors and time-consuming removal and reinstatement of finishes. For this reason, significant structural damage precludes achieving the resilience objectives in all but the most optimistic scenarios.* *Detailed analysis, justification, and downtime assessment must be completed to justify any inelastic response.*
●	●	●	E	**2.2.2 - Code Minimum Requirements** Ensure the design conforms to the requirements of the local jurisdiction. Where the local codes of practice are under-developed and/or inadequate, use an international consensus standard such as ASCE 7.	*2.2.2* *Some storm-prone jurisdictions have poorly-developed standards which do not conform with international norms of wind engineering. Exercise judgment as to whether the local code requirements are sufficient to achieve desired life safety performance.*
●	●	○	E	**2.2.3 - Wind Consultant Review** Employ a wind engineering consultant for advice related to the building in question. The wind consultant should advise, at a minimum, on the suitability of the code of practice to correctly establish the wind loads for design. They should also provide input on the decision to conduct wind tunnel testing and its scope.	*2.2.3* *The wind engineering consultant shall have specific training or experience in the area of wind engineering and design. They may be associated with a wind tunnel. They should be a licensed professional in their jurisdiction.*

2.2.4 - Wind Tunnel Testing

Appropriately conducted wind tunnel testing will lead to a better understanding of the reliability of the structure.

Wind tunnel testing is required if any of the following criteria are met:

- Building is Platinum-rated
- Testing is required by the AHJ
- 150 mph design-level wind event
- Constructed in a dense urban environment
- 6:1 slenderness ratio and structural frequency of less than 0.5 Hz

2.2.4

If wind tunnel testing is conducted, best industry practices or test specifications must be followed. This includes preparation of written reports.

Aeroelastic testing should be considered for dynamically sensitive structures where the wind consultant has suggested the potential for negative aerodynamic damping.

References:

- *ASCE 49-12: Wind Tunnel Testing for Buildings and Other Structures*
- *ASCE Prestandard for Performance-Based Wind Design Chapter 5.3 (Charles Pankow Foundation)*

2.2.5 - Finite Element Analysis (FEA) Model

Develop a representative, three-dimensional mathematical model of the structure, including all structural elements. Structural modelling assumptions should follow best practice, including appropriate levels of concrete and damping ratios of the order of 1% for operational and 2% for ultimate limit state (ULS) design.

If the wind consultant deems the structure to be sensitive to wind-induced vibrations, conduct dynamic analysis, explicitly including dynamic and buffeting effects. Otherwise, a rationale should be put to the design team suggesting why a dynamic analysis is not necessary.

2.2.5

If inelastic structural responses or nonlinear force-deformation or force-velocity relationships (e.g. from added damping systems) are predicted to occur, then nonlinear response time history analysis is required.

References:

- *ASCE Prestandard for Performance-Based Wind Design Chapter 6 (Charles Pankow Foundation)*
- *ASCE Manual of Practice 143: Design and Performance of Tall Buildings for Wind*

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY

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2.2.6 - Performance-Based Wind Design (PBWD)

Conduct performance-based wind design for Platinum-rated structures. PBWD is recommended, not required, for Gold and Silver buildings.

2.2.6

PBWD is either a supplement or alternative to prescriptive, code-based design. By adopting this enhanced design procedure, reliability of the building and its envelope is expected to be achieved in a more financially capable and sustainable manner. See Section 2.3 for the enhanced non-structural design.

References:

- *ASCE Prestandard for Performance-Based Wind Design Chapter 6 (Charles Pankow Foundation)*

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2.2.7 - Minimize Drift-Related Damage

During wind events, limit peak story drift to H/400 - H/500 for operational performance mean recurrence intervals. Story drift is defined to include both horizontal and vertical deformations.

2.2.7

When buildings move in the wind, damage to internal components can occur. Internal partition walls can exhibit cracks or the elevator shaft can fall out of plumb, rendering the elevator incapable of full vertical travel. In some extreme cases, drift can cause windowpanes to slip out of their mullions and fall. The requirements of this clause can be waived if PBWD demonstrates that the resilience objectives can be achieved with higher drifts.

References:

- *ASCE Prestandard for Performance-Based Wind Design (Charles Pankow Foundation)*
- *FEMA P-424: Design Guide for Improving School Safety in Earthquakes, Flood, and High Winds, Section 6.3.4*
- *ATC Design Guide 3: Serviceability Design of Tall Buildings under Wind Load (2019)*
- *ASCE Manual of Practice 143: Design and Performance of Tall Buildings for Wind*

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2.2.8 - Motion Control

To reduce wind dynamics, supplementary damping systems such as tuned mass dampers (TMDs), tuned liquid dampers (TLDs), active vibration, or integrated damping systems may be installed. In general, their impact cannot be considered for strength design. However, under certain rare circumstances, distributed/integrated damping may be permissible for structural control when acceptable levels of reliability and redundancy can be achieved.

2.2.8

Damping systems are typically introduced into buildings to reduce dynamic excitation that is perceptible to building occupants or controlling drift levels. Selection of damping systems for motion control should consider all available technologies and be done with the advice of a qualified professional.

Under certain, rare circumstances, fully integrated systems may be permissible for structural control if they have been properly designed, their usage for this purpose has been peer-reviewed, and redundancies have been incorporated into the structure. The ASCE Prestandard for Performance-Based Wind Design can be referenced for floor acceleration limits. Stricter criteria may be adopted as needed by the design.

References:
- *ASCE Prestandard for Performance-Based Wind Design Chapter 6 (Charles Pankow Foundation)*
- *FEMA P-424: Design Guide for Improving School Safety in Earthquakes, Flood, and High Winds, Section 6.3.4*

2.3 Enhanced Non-Structural Design

Intent: Extreme windstorms can cause significant damage to building envelope and exterior mechanical components. This section addresses these risk factors via enhanced design to improve building resilience.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E	**2.3.1 - Equipment Integrity** Any mechanical equipment exposed to wind shall be certified to the design wind speeds and inspected to ensure the ability to withstand those speeds. See also the inspection requirements in Sections 2.54 and 2.5.6.	*2.3.1* *Damaged equipment may become wind-borne debris if not properly installed or anchored. General guidance for non-structural exterior-mounted equipment is provided in FEMA P-424 Chapter 6.3.4 and in Chapter 8 of the Prestandard for Performance-Based Wind Design.* *Snow drift (Section 0.1.2) due to wind can cause clogging of MEP systems and equipment. Electrical equipment is also especially vulnerable to water damage and should be located within the building away from building envelope areas prone to damage and out of flood-prone areas. See Section 0 for more on multi-hazard resilience.* *Although solar panels are not required to achieve functional recovery as described in the resilience objectives, they must be designed to remain attached such that they do not become projectiles in a design level wind event (Section 2.1.1, 2.3.3).* *References:* - *FEMA P-424: Design Guide for Improving School Safety in Earthquakes, Flood, and High Winds, Section 6.3.4* - *FEMA Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 2: Attachment of Rooftop Equipment in High-Wind Regions* - *ASCE Prestandard for Performance-Based Wind Design (Charles Pankow Foundation), Chapter 8*

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2.3.2 - Envelope Design

Design all exterior, non-structural building components to withstand damage at the operational wind speeds for each REDi™ tier (Section 2.1.1). These components typically include roofing, wall cladding, doors, and fenestration, which should be designed to withstand both design wind pressures and wind-driven rain. At a minimum, follow the requirements of FEMA P-424, Chapter 6.3.3.

For Platinum- and Gold-rated buildings, use robust roof, fenestration, and wall and cladding systems that have been demonstrated to be resilient to damage and failures.

2.3.2

The building envelope plays a significant role in building resilience to extreme windstorms. Enhanced envelope design are essential to building performance.

The designer will find that the REDi™ operational wind speeds are higher than the IBC wind speeds for similar risk categories. This difference is due to envelope failures' outsize contribution to losses and downtime.

Prevention of water intrusion is a key element in the REDi™ suite and is important to consider. The designer should anticipate the possibility of envelope openings such as doors and any operable windows being open during the event. Certain locations require impact testing to protect against wind-borne debris. See Section 2.3.3.

References:

- *ASCE Prestandard for Performance-Based Wind Design Chapter 8 (Charles Pankow Foundation)*
- *FEMA P-424: Design Guide for Improving School Safety in Earthquakes, Flood, and High Winds, Section 6.3.4*

Platinum Gold Silver Lead

CRITERIA	COMMENTARY

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2.3.3 - Wind-Borne Debris

Consider potential wind-borne debris as a demand on the façade including doors and wall assemblies and as a safety concern for building users. Mitigate appropriately. Prevent leakage of roof assemblies if they are penetrated by wind-borne debris.

This criteria must be considered in areas defined by the International Building Code (IBC) as wind-borne debris regions. It may also be considered in other regions according to the judgment of the design engineer.

2.3.3

Ambient sources of wind-borne debris include material shed from the roof (e.g. gravel, pavers, and loose access panels on rooftop equipment) of the building itself or from other surrounding sources (Sections 3.1.5 and 3.1.6). Any potentially loose objects should be adequately anchored to their supporting structures. Openings in the building may be protected through the use of shutters or by tested laminated glazing or polycarbonate assemblies.

An impact test of the building component's capability to resist puncture by wind-borne debris may need to be conducted. Brittle roof coverings should be avoided since they may be susceptible to damage by wind-borne debris.

References:

- *ASCE Prestandard for Performance-Based Wind Design Chapter 8 (Charles Pankow Foundation)*
- *ASTM E1886-19: 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 E1996-20: Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*

2.4 Egress and Shelter

Intent: Increase levels of life safety by maintaining serviceable egress paths and providing cover for occupants.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E O	**2.4.1 - Tornado and Hurricane Shelter and Safe Rooms** For Platinum and Gold buildings located where tornados pose a threat, provide a shelter or refuge area on each floor. For hurricane environments, due to the added flexibility given by longer advanced warning, provide at least one shelter or safe room for the entire building. Shelters and safe rooms should be designed following best practice. For Silver-rated buildings in tornadic environments, a safe room for the entire building should be designed following FEMA P-361.	*2.4.1* *Extensive guidance for planning, design, construction, and operation of safe rooms and shelters resilient to tornado and hurricane wind effects is provided through ICC 500, FEMA P-361, and FEMA P-431. For specific requirements or best practices (e.g. minimum required usable shelter floor area per occupant), refer to these guides.* *References:* - *ICC 500: Standard for the Design & Construction of Storm Shelters* - *FEMA P-361: Safe Rooms for Tornadoes and Hurricanes - Guidance for Community and Residential Safe Rooms* - *FEMA P-431: Tornado Protection - Selecting Refuge Area in Buildings*
●	●	●	E	**2.4.2 - Preservation of Egress Routes** Ensure integrity of egress routes including doors, exits, and stairwells. At a minimum, comply with the required number of egress routes as required by the IBC.	*2.4.2* *Exposed egress doors should be designed to survive a design-level wind event. Damaged or inoperable doors may compromise the security of the facility.* *Reference:* - *2021 International Building Code (IBC)*

2.5 Peer Review and Quality Assurance

Intent: The decisions made during the design and installation process should be evaluated by a competent professional knowledgeable in the area under review to ensure structural and non-structural resilience.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	○	○	E	**2.5.1 - Hazard Peer Review** Conduct a site-specific, wind climate hazard assessment peer review. A peer review will be required if there is any measurable (~5%) reduction in the design wind speeds being considered, compared to the code of practice.	*2.5.1* *The peer review should ensure that the wind hazard and the design wind speeds by wind direction, as a function of probability of exceedance, have been adequately considered and assessed. In some cases, an independent analysis may be required. Other elements of the hazard assessment include exposure determination and the site's climate specific to the identified hazard.* *References:* - *ASCE Prestandard for Performance-Based Wind Design Chapter 5, 9 (Charles Pankow Foundation)*

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2.5.2 - Structural Peer Review

Analysis and design are subject to a formal structural peer review process. The structural peer review should cover:

- Review assumptions and characteristics of the structural model
- Review of acceptance criteria for non-structural components and systems to withstand the calculated force and deformation demands
- Review of the Resilience Plan detailed in Sec. 1.1 above

For Platinum-rated buildings, peer reviews should be carried out in accordance with the Prestandard for Performance-Based Wind Design (Charles Pankow Foundation). Otherwise, if mandated by the AHJ, then the required procedure for peer review should be followed.

The wind tunnel testing results should also be peer-reviewed by qualified experts to ensure the following of best industry practice.

Building Envelope Peer Review

Building envelope design is subject to a formal peer review.

For Gold- and Platinum-rated buildings, peer review should be carried out in accordance with the AHJ.

Additionally, for Platinum-rated buildings, peer reviews should be carried out in accordance with the Prestandard for Performance-Based Wind Design (Charles Pankow Foundation).

2.5.2

Review of the structure's performance should include examination of the structural analysis FEA model.

The building envelope peer review should be carried out to assess the performance of the envelope system and to ensure performance against target levels.

Effects of any combined effects from multi-hazard events should be suitably reviewed by the peer review team (Section 0).

References:

- *ASCE Prestandard for Performance-Based Wind Design Chapter 9 (Charles Pankow Foundation)*

Platinum Gold Silver Lead

CRITERIA | COMMENTARY

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2.5.3 - MEP Peer Review

Conduct the peer review of the design, redundancy, and sealing of mechanical, electrical, and plumbing systems in accordance to the building code specified by the AHJ.

Where possible, test the MEP systems with appropriate loads to verify conformance to the desired resilience objectives established in this document. Specific requirements for the three ratings are listed in Section 1.2.1.

2.5.3

This requirement can be satisfied by meeting Tier 3 or better of the Uptime Institute standards for Data Centers (Uptime Institute 2010).

The peer review should focus on internal distribution strategies (such as dual distribution) that contribute redundancy to the MEP systems. Enhanced commissioning to address the post-wind event performance of MEP systems may be considered.

Reference:
- *Uptime Institute Standards for Data Centers*

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2.5.4 - Inspection of Envelope and MEP During Construction

By inspection, review the building envelope for quality of installation and conformance with construction documents. By inspection, review exterior-mounted equipment for fixity and anchorage quality and conformance with construction documents. Additionally, include instructions for inspection to verify correct installation of non-structural components in the General Notes of the construction documents.

Inspection and testing during construction is important for envelopes and rooftop equipment to achieve good performance. An inspection should be carried out immediately following building completion.

2.5.4

Improper installation fo the building envelope and of exposed MEP equipment (e.g. on the rooftop) will increase the susceptibility of the envelope and of the roof to water intrusion and damage in wind events.

Appropriate documentation supplied by the contractor to the designer of record, mockups, and physical testing reports of materials should be included in the review.

Contractors with experience in the installation of resilient building components or post-wind damage repairs are highly recommended to conduct the inspections if possible.

References:
- *ASCE Prestandard for Performance-Based Wind Design Chapter 8.4, 8.5, 8.6, 9 (Charles Pankow Foundation)*
- *FEMA 4399-DR: Hurricane Michael Preliminary Damage Report*

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E	**2.5.5 - Periodic Inspection of Envelope and MEP** Following project completion, the building envelope and MEP systems should be inspected as needed to meet the expected design performance of non-structural building components (Section 2.3) by persons knowledgeable of these systems and materials. During inspection, special attention should be given to both the building envelope and the anchorage of exterior-mounted equipment.	*2.5.5* *Proper documentation and scheduling for maintenance, repair, or replacement of any items should be kept.* *Reference:* - *FEMA P-2062: Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities*

3

SITE RESILIENCE

Reduce risks from external hazards that may cause building damage or restricted site access

3.1 Site Vulnerability

Intent: Ensure the building is not impacted by third party threats

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	○	E A O	**3.1.1 - Site Planning** Site location, orientation, and surroundings have a significant impact on resilience for wind storms. Extreme windstorms should be considered during site selection and climate risk should be incorporated into site selection and master-planning decisions.	*3.1.1* *Reflecting on insight gained from the resilience workshop and the Resilience Plan, careful analysis and selection of a site for development, and consideration of programming and planning decisions are foundational factors that influence the extent to which the project itself is resilient.* *Factors may include project location and elevation, site features and development, availability of and access to infrastructure and services, and building sizing, massing, and orientation.*
●	●	○	E A O	**3.1.2 - Scenario Planning** Emergency response planning should include considerations for 'outside-the-wire' impacts such as interruptions in utility service, transportation, communications, etc.	*3.1.2* *Outside-the-wire factors are those that influence the resilience of the building indirectly and are often not in the control of the Owner.*
●	●	○	E A	**3.1.3 - Site Access** Evaluate the likely site access by workers, residents, and emergency response teams via functional transportation systems during and after an event. Evaluate the implications to recovery if such systems are not accessible.	*3.1.3* *Transportation networks and roadways are typically the first infrastructure to be operational after an event, though regaining this capacity may still take days. Consider redundancies in the road network and in access to public transportation, prioritization of debris cleanup on blocked travel paths, or alternative means of accessing the site or facility (i.e. boat dock, helipad, etc.). Consider the potential limits on electric vehicle (EV) charging if electrical power is interrupted.*

Platinum Gold Silver Lead | CRITERIA | COMMENTARY

3.1.4 - Vulnerability Assessment of Utility Network

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Identify which parts of the utility network are vulnerable to failure or periods of shutdown due to wind or combined multi-hazard effects.

3.1.4

Meeting the guidelines outlined in Sections 1.2 and 1.3 will improve operational resilience and reduce the risk of disruptions to the utility network that can impede operation and functional recovery of the facility. The assessment should also include the redundancy of infrastructure systems, where they exist.

These vulnerabilities should be considered in the resilience assessment in Section 4, specifically Section 4.4

3.1.5 - Assessment of Surrounding Buildings

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Provide a qualitative assessment of the wind performance of adjacent buildings or structures to avoid any cascading effects. The likelihood of potential issues such as structural collapse / poor performance, generation of wind-borne debris (see Section 2.3.3), or the presence of tower cranes should be considered.

3.1.5

Surrounding buildings can be a source of wind-borne debris if equipment is not anchored properly or if roofing panels strip off.

3.1.6 - Assessment of Surrounding Non-Building Structures

E

Identify any non-building structures located on the site which, if damaged, may compromise the resilience objectives of the facility or structure. Additionally, pursue mitigation measures of these potential damages and impediment sources.

3.1.6

Non-building structures may include water tanks, trees, heavy light posts, traffic lights, solar panels, and retaining structures. Assessment of the impact of these structures is critical to holistic resilience because damage to objects outside the building almost always occurs before damage to the building or its contents.

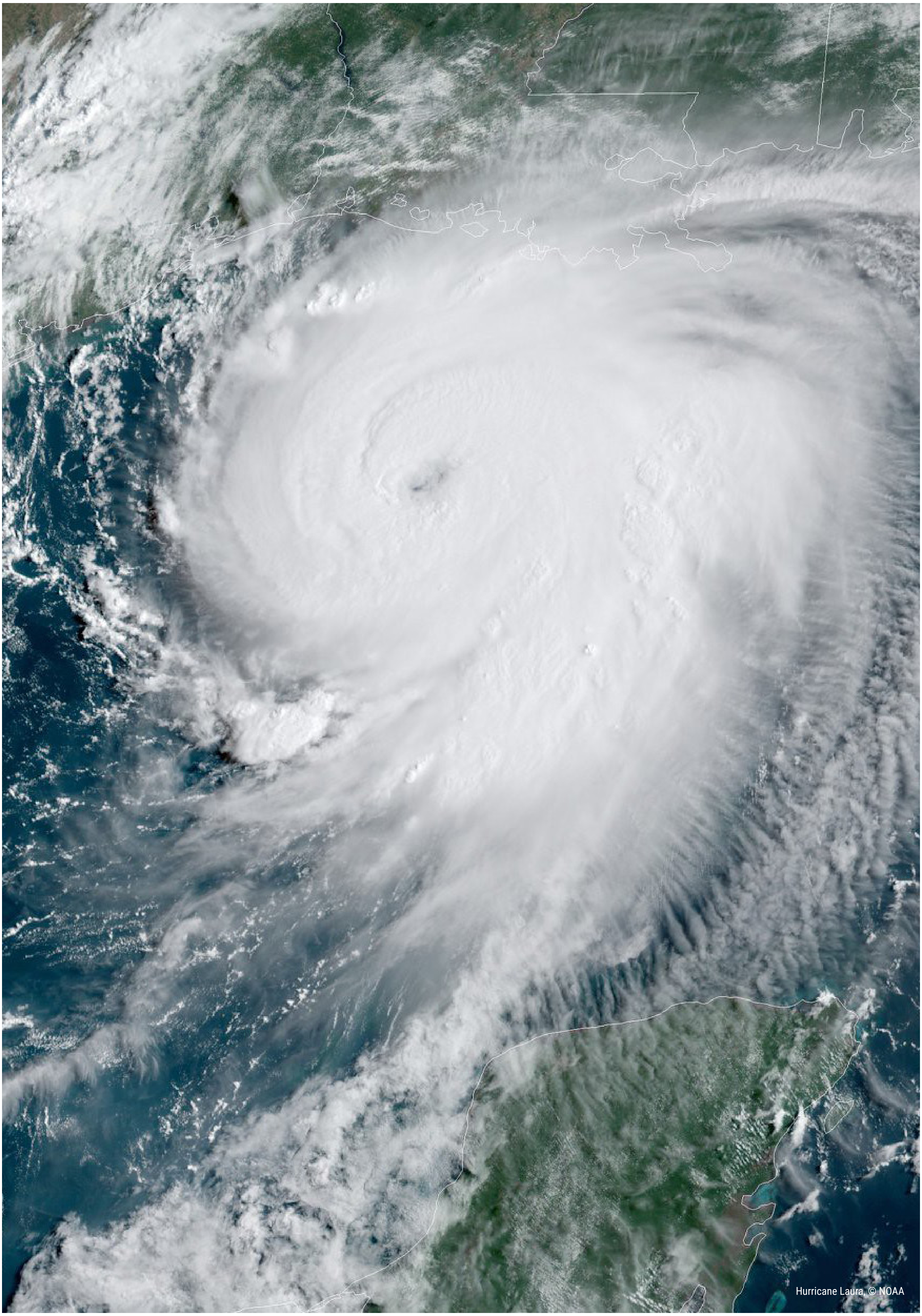
Landscaping design should be carefully planned so that large trees are not positioned near the building, potentially impeding site access.

3.2 Community Level Resilience

Intent: Collaborate with the Owner to advocate for improvements to the community's ability to recover after a severe wind event, as resilience extends beyond the reach of the property and physical structures.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
○	○	○	E O	**3.2.1 - Improvements to Infrastructure** Communicate to local and state representatives, officials, and utility and transportation departments the desire for enhanced infrastructure that can withstand the effects of natural disasters.	*3.2.1* *Communities, cities and states may be more motivated to build for 'beyond code' resilience objectives if incentives such as improved sustainability are strongly emphasized in discussions. Transparent and effective communication with individual and collective members of the public will be needed.* *This engagement also provides critical information on local emergency response plans which can be integrated into the operational resilience of the building (Section 1).* *Improvements to infrastructure will promote safer access to the site during and after the natural disaster (Section 3.1.3) and enhance resilience of utility networks (Section 3.1.4)*
○	○	○	E O	**3.2.2 - Diverse Community Mobility** Facilitate the use and operation of public transit and active transportation in and out of the surrounding area including the site (Section 3.1.3) and enhance the sense of community in response to a natural disaster.	*3.2.2* *Severe windstorms may impede safe aerial transportation of supplies and critical personnel in and out of the affected area for several days. Road networks may also be compromised due to wind-borne debris, dangerous wind conditions, and flooding (Section 0.1.1).* *References:* *USGBC RELi 2.0, CV Credit 2.0*

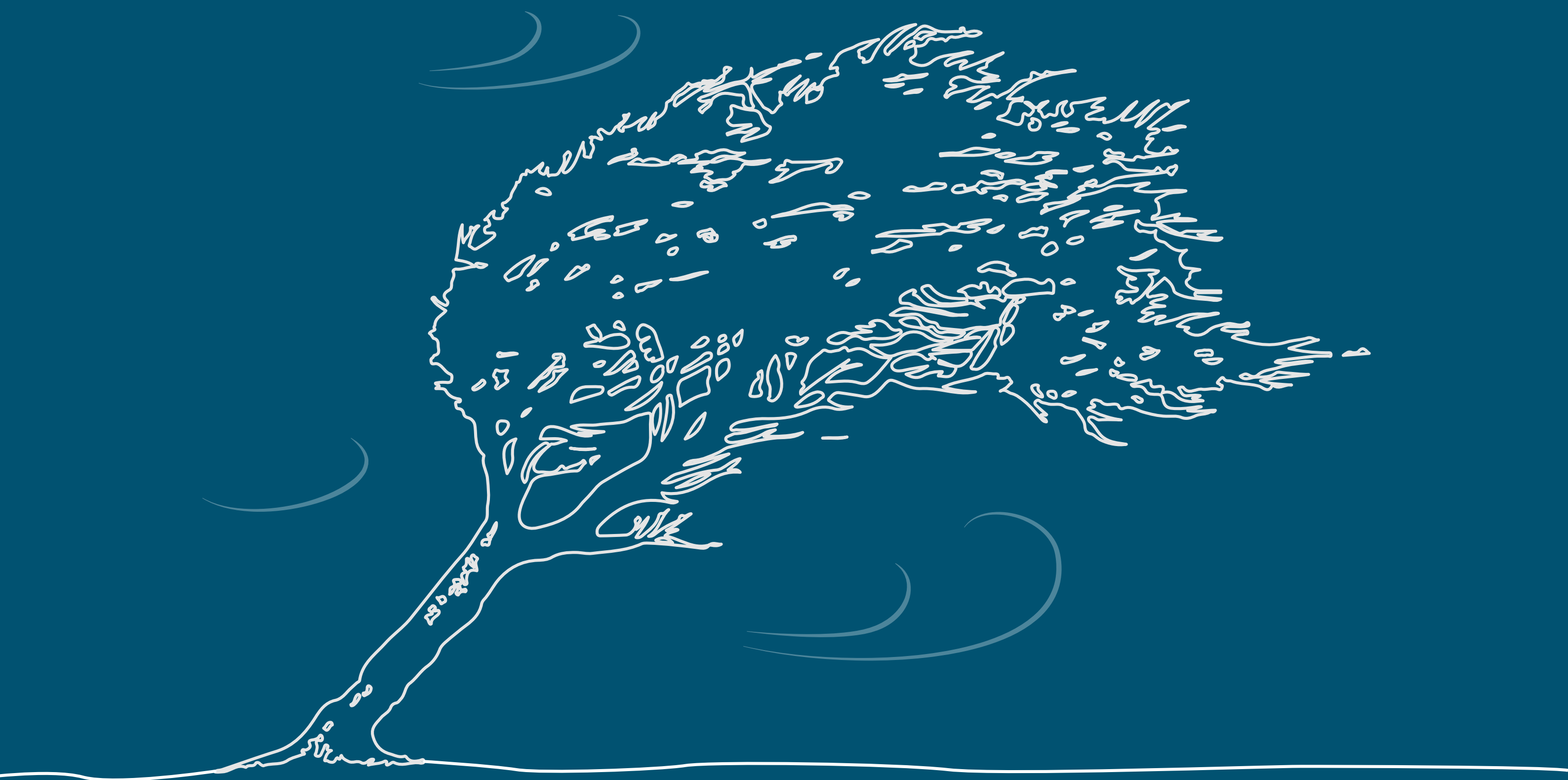
Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
○	○	○	E 0	**3.2.3 - Civic Engagement** Promote active participation within the organization and the community to strengthen social and economic networks.	*3.2.3* *Community members should be encouraged to participate in local disaster recovery programs or organizations to expedite community restoration (e.g. cleanup of wind-borne debris, support of temporary services provided to heavily affected groups). Communication tools via radio stations, websites, online forums, etc. can be used to spread helpful information about severe windstorm effects, mitigation measures that the community can adopt, and recovery actions that need to be taken following disaster.* *References:* *USGBC RELi 2.0 CV Credit 4.0*
○	○	○	E 0	**3.2.4 - Community Education** The site should serve as a resource in the community for resilience-based initiatives and be a known source of wind and natural disaster information. The site leadership can facilitate discussions around resilient-minded development.	*3.2.4* *Members of the community should be cognizant of the wind hazards that threaten their homes, schools, businesses, and establishments and should know the proper response to an impending severe windstorm, capitalizing on any available lead time. Community members should know, for example, the location of safe rooms and shelters, mitigation measures to limit damage from wind-borne debris, and items needed for preparation and storage of food, water, and emergency essentials.*


Hurricane Laura, © NOAA

4

RESILIENCE ASSESSMENT

Evaluate downtime, financial losses, and life safety to understand success of the design and planning measures in meeting the resilience objectives



4.1 Resilience Assessment Guidelines

Intent: Ensure that the Resilience Assessment is performed appropriately to most accurately estimate direct financial loss and downtime.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E	**4.1.1 - General Resilience Assessment Guidelines** Conduct a risk assessment consistent with the resilience objectives for the building. Any method used must quantitatively include multiple hazard scenarios, vulnerability, and consequence. For Silver and Gold ratings, this includes a short qualitative assessment and a building-level loss assessment using HAZUS or a similar assessment technique. For Platinum-rated buildings, carry out a probabilistic, component-level assessment to establish losses, casualties, and downtime.	*4.1.1* *Assessment of resilience is essential to verify that the design approaches successfully achieve the desired resilience objective.* *As resilience assessments can take many forms, this rating system allows for an assessment level consistent with the desired resilience rating. For Silver- and Gold-rated buildings, this is limited to a semi-quantitative assessment.* *For Platinum-rated buildings, it is necessary to conduct a thorough assessment including component-level detail and an evaluation of downtime and casualty. Many occupancies are dependent on off-site factors which will affect continuation of normal operation. These include how quickly employees are expected to return to work and any hindrances to their production or services. “Uncontrollable” externalities such as limited transportation access and damages to surrounding structures and buildings may further add to downtime. While such factors are difficult to extensively evaluate and mitigate, this criterion will help the Owner be aware of all risks.*

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4.1.2 Detailed Resilience Assessment Guidelines

The following components should be included in a robust probabilistic building loss and downtime assessment:

- Site-specific hazard data, including the effects of climate change, is used to establish the magnitude of the REDi™ Level Wind Event (500 year MRI).
- The expected loss results (50% probability of non-exceedance) are used at a minimum.
- Loss calculations are performed using the actual amount and location of damageable structural and non-structural components and contents where possible. This can be accomplished with component-level fragility and consequence functions (similar to those for seismic hazard in FEMA P-58).

Where the default fragility curves and consequence functions are not provided for a particular component or would not provide an adequate representation of the expected damage and consequence, they should be developed based on engineering judgment, empirical analysis, FEMA Restoration Tables, or obtained from peer-reviewed literature.

A complete component-based extreme windstorm risk methodology, adapted from REDi™ Seismic, will be included in an upcoming version of REDi™ Extreme Windstorms.

4.1.2

Performance-based wind design is an emerging area of study. Currently, the readily-available component fragility curves are predominantly for seismic behavior. In absence of better information, seismic fragility curves can be used in the assessments, as long as appropriate consideration has been given by the designer and it is reviewed by the peer review team for low and high cycle fatigue in the wind event.

If using a Monte Carlo simulation approach, sufficient realizations should be used such that the calculated loss does not vary by more than 5% when the number of realizations is increased.

Reference:

- *FEMA P-58: Seismic Performance Assessment of Buildings*

4.2 Life Safety Assessment

Intent: Review design and emergency response planning to ensure that best practice has been followed regarding to life safety.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	●	●	E	**4.2.1 - Life Safety** The best way to maximize life safety during extreme windstorms is to create a robust structural design according to the building code, to implement enhanced design of non-structural components, and to establish thoughtful Emergency Response Plans. An assessment review should be conducted of the Owner's/operator's ERPs to ensure that they include best-practice health and safety approaches.	*4.2.1* *Design codes do not address building contents (e.g. storage systems) which can cause injury or even fatality if they fall on someone. By following the REDi™ Extreme Windstorms guidelines, these building contents should be secured against wind-induced motions (Section 2.3).*

4.3 Direct Financial Loss Assessment

Intent: Evaluate the success of the resulting design in meeting the quantitative financial loss objectives associated with the desired REDi™ Rating.

Platinum	Gold	Silver	Lead	CRITERIA	COMMENTARY
●	○	○	E	**4.3.1 - Direct Financial Loss Assessment** Direct financial loss is derived through an assessment methodology similar to HAZUS, while incorporating component fragilities. The losses are expressed as the repair cost divided by the Total Building Value (see Glossary of Terms). This does not consider indirect financial loss such as business interruption.	*4.3.1* *The consequences for repair costs associated with severe damage (i.e. damage that would require replacement of a particular component) should reflect, at minimum, the original hard costs for that component. The consequence function should be adjusted as necessary.*
●	○	○	E	**4.3.2 - Valuable Building Contents** Include valuable building contents in the loss assessment, such as medical equipment and machine servers, desktop electronics, art installations, and inventory that exceed more than 10% of the Total Replacement Value.	

4.4 Downtime Assessment

Intent: Evaluate the risks and losses in further detail.

Platinum	Gold	Silver	CRITERIA	COMMENTARY
●	○	○	**4.4.1 - Downtime Assessment** Carry out an assessment of downtime for the building, including consideration of the factors below:	*4.4.1* *The benefit from implementing recommendations to minimize the 'impeding factors' (Section 1.4) may be applied in the cost assessment.*
			Impeding Factors Quantify the cost and effect of delays to initiation of post-windstorm repairs caused by 'impeding factors'—inspection, access to financing, engineering review or re-design, contractor mobilization, and permitting.	
			Utility Disruption Account for utility disruption in the downtime associated with functional recovery.	*See Section 1.2*
			Long-Lead Time Items Include the time associated with procuring any 'long-lead time' components in the downtime calculations if they are expected to be damaged.	
			Critical Building Contents Include building contents, which, if damaged, would hinder re-occupancy or functional recovery.	

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