ENHANCING FLORIDA'S BUILT ENVIRONMENT RESILIENCE

A RESILIENCE INFERENCE PERFORMANCE LEVEL (RIPL) ANALYSIS OF SINGLE-FAMILY HOME MATERIALITY DESIGN RELIABILITY AND SMART HOME TECHNOLOGY RERPONSIVENESS TO WATER INTRUSION DUE TO HAZARDS

FLORIDA INSTITUTE FOR BUILT ENVIRONMENT RESILIENCE (FIBER)

RIPL

REPORT & RESOURCE GUIDE

FLORIDA OFFICE OF Insurance Regulation

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UNIVERSITY of FLORIDA

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The development of this RIPL report and its associated resources was made possible through the generous support and collaboration of the Florida Office of Insurance Regulation. Their commitment to advancing insurance risk assessment and resilience modeling has been instrumental in enabling this work, providing critical guidance and data that underpin the analyses and findings presented herein. We gratefully acknowledge their partnership and dedication to fostering safer, more resilient communities across Florida.

The development of the RIPL Resource Guide was a collaborative effort involving research faculties, graduate research assistants, and undergraduate scholars from the College of Design, Construction and Planning' Florida Institute for Built Environment Resilience (FIBER) at the University of Florida, including contributors from both the School of Architecture and the Department of Interior Design. Additionally subject matter expertise on insurance industry premium reduction trends was provided by faculty from Florida State University's Department of Risk Management/Insurance, Real Estate and Legal Studies. Their collective expertise and interdisciplinary approach of this team was instrumental in shaping the content and resources presented in this guide.

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List of Acronyms and Initializations

ACSE: The American Society of Civil Engineers
AIA: The American Institutes of Architecture
AMI: American Median Income
AWC: American Wood Council
EPD: Environmental Product Declaration
FEMA: Federal Emergency Management Agency
FIBER: Florida Institute for Built Environment Resilience
HUD: U.S. Department of Housing and Urban Development
IRC: International Residential Code
LBD: Literature Based Discovery
NWS: National Weather Service
OUC: Orlando Utilities Commission
RIPL: Resilience Inference Performance Level
SIPA: Structural Insulated Panel Association
TPM: Technical Performance Measures
UL: Underwriters Laboratories
AHP: Analytical Hierarchical Process
AISI: American Iron and Steel Institute
ANSI: American National Standards Institute
AWPA: American Wood Protection Association
FBC(R): Florida Building Code (Residential)
HEAR: Home Electrification and Appliances Rebate
FLOIR: Florida Office of Insurance Regulation
IBHS: Institute for Business & Home Safety
KPI: Key Performance Indicators
NFIP: National Flood Insurance Program
O.C.: On Center
OSB: Oriented Strand Board
SAMPL: Sustainable Adaptive Material Performance Level
SIR: Susceptible Impacted Recovered
UF: University of Florida
USG: United States Gypsum

Executive Summary

This report provides a preliminary analysis of how building materials and smart home technologies work together to enhance the resilience of single-family homes against hazards that can lead to water intrusion. The smart home technologies specifically examined in this report include systems designed to prevent water intrusion, enable automatic utility shutoffs, and stabilize foundations. The primary objective of this study is to evaluate the potential of these materials their associated assemblies in construction methods and technologies to mitigate risks and reduce insurance losses for residential properties. It is important to recognize that the sensitivity of insurance premiums to changes in risk is influenced by a variety of factors. Thus, efforts to enhance resiliency through the methods described in the previous sections need to be considered in the context of how homeowners insurance premiums are calculated. Resilient design and building practices offer the potential reduces damage to personal property (contents), which is also covered by insurance. In the specific case of risk associated with water intrusion, the extent to which enhanced safety, symbiosis, and sustained adaptability reduce risk must be quantifiable to have a meaningful impact on insurance premiums. The RIPL report model can provide sound accurate value assessments that should not only encourage practical application of resilient efforts, but lower homeowners' insurance premiums.

The analysis presented in this report aims to provide valuable insights for homeowners, builders, and insurers seeking to improve home durability and reduce vulnerability to environmental threats by examining the combination of innovative technology and resilient building practices. This Resilience Inference Performance Level (RIPL) report and its associated design decision support resources can also serve as a complement to other current guides on general building resilience standards for homes and commercial buildings such as those developed by U.S. Department of Housing and Urban Development "Designing for Natural Hazards" volumes and the AIA of Florida "Enhancing the Resilience of Buildings" supplement. The unique strength of the RIPL report and resources lies in their foundation on a validated resilience engineering framework. This framework not only aligns design strategies that reduce risk and enhance resilience with potential insurance savings but also provides the basis for a forward-looking capability. Specifically, it has been designed to support future computational platforms that would enable forecasting and the generation of "what-if" scenarios, making it a powerful tool for proactive planning and decision-making.

The methods used in this study employed a tested resilience engineering logic model to systematically evaluate outcomes and prioritize risk mitigation strategies to design single-family residences. This analysis aimed to identify design and building practices that could significantly reduce potential damage to the home's structure and, as a result, create opportunities for lowering insurance premiums. The study of single-family residence building performance described in this report highlights the importance of combining strategic integration of building materials and smart home technologies to bolster a home's resilience against natural hazards, including hurricanes, floods, fires, and extreme weather events. This approach to proactive home design and building strategies would enhance housing safety and facilitate the development of more sustainable and economically viable residences in hazard-prone areas.

The approach used in this report on enhancing Florida Housing built environment resilience focused on the categories of building materials and smart home technologies. This effort encompassed the following:

1. ***Building Materiality****:* In design and building, the term "materiality" refers to the applied use of various materials or substances in the design and construction of a building. It encompasses not only the selection of building products and finishes but also how these materials are used to create and construct building forms. Prior research suggests that failures of building materials account for approximately 20–25% of home destruction during natural disasters (1). In Florida alone, communities spend tens to hundreds of millions of dollars annually on material cleanup (2).

To address these challenges, our targeted analysis focused on high-performance exterior cladding, interior construction materials, and finishes that are rigorously tested and certified for flame spread resistance and water intrusion prevention. These advanced materials are engineered to minimize long-term deterioration, reduce restoration costs, and significantly enhance a building's resilience to damage and destruction that can occur due to water intrusion.

The foundation of this analysis effort leveraged the Sustainable Adaptive Material Performance Level (SAMPL™) system, which is a comprehensive, computational risk management and design intelligence platform. SAMPL™ enables data-driven selection of building materials, ensuring every choice supports safer, healthier, and more sustainable living environments. The platform offers an interactive dashboard that evaluates material performance based on real-world risk impacts, empowering users to specify materials that improve adaptive responses to environmental hazards and better protect human health and well-being.

Unlike static databases, SAMPL™ is a dynamic, tunable system that adapts to multifactorial, location-specific conditions. It allows users to forecast how materials and finishes will perform under various natural and human-induced hazards, all within a single, testable framework. This innovative capability positions SAMPL™ as a critical tool for advancing resilient, future-ready built environments.

2. *Smart Home Technologies:* Building system monitoring technologies enable early detection and automated response to potential natural hazards. This assessment investigated the response capabilities of intelligent utility shutoff mechanisms that automatically deactivate water, gas, and electrical systems when threats are detected. It also examined foundation monitoring systems that assess structural integrity and soil conditions, as well as integrated sensor networks that provide real-time data on environmental conditions and building performance.

The following sections provide a detailed examination of each technology category, including an explanation of the analytical approaches employed for each category, a presentation of the preliminary results, highlighting both discrete and integrated technical performance measures and an exploration of the interconnections and combined benefits observed when these technologies are implemented together.

The findings of this analysis suggest that a combination of reliable building materials and smart responsive home technologies can significantly enhance a single-family residence's ability to withstand and respond to natural hazards. A bowtie risk model was employed to identify critical failure pathways and mitigation strategies in this analysis. Bowtie models have been increasingly adopted in actuarial science as a risk modeling tool due to their ability to visually map out the relationships between potential threats, critical risk events, and their consequences. The RIPL report's bowtie model that guided this analysis is shown in Figure 1.

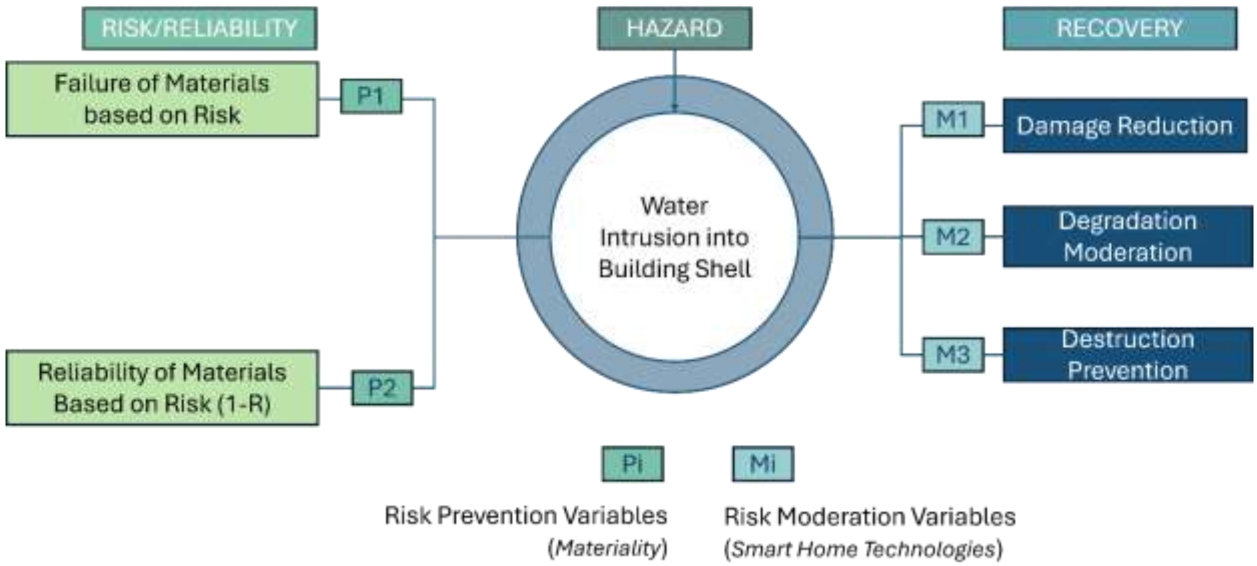


Figure 1. RIPL Bowtie Risk Mitigation Model

This integrated approach has the potential to reduce property damage and lower insurance premiums by mitigating risks associated with environmental threats. This structured analysis offers a holistic view of how these innovative solutions meaningfully contribute to home resilience, providing a foundation for informed decision-making in resilient home design and construction. To encourage more resilience in the built environment, decision makers need to be aware of the benefits and the consequential costs of various options. The RIPL report's model approach presented in the following sections will be valuable for articulating benefits of improved resilience for reducing damages and improving recovery from large loss events, leveraging a comprehensive resilience matrix that can be used to evaluate preventive capabilities of the options. In addition to enhancing education and awareness through visualization tools, other approaches to encouraging investments in resiliency include financial incentives, policy and regulatory support, and community-wide mitigation programs. Further research, performance simulations, and real-world implementation of these interventions are essential to accurately quantify their long-term impact on insurance loss reduction and to advance the development of more resilient housing solutions for the future.

Overview

In recent years, the approach to property insurance premium reduction has shifted from reactive to proactive strategies (3), mirroring trends in other safety-critical industries. This paradigm shift, known as moving from "Safety I" to "Safety II," focuses on leveraging what works well in a system rather than solely analyzing failures (4,5). Insurers play an important role in encouraging loss control. This is evident through their willingness to offer discounts on auto insurance to drivers with better driving histories or premium reductions on workers' compensation policies for companies with specific safety protocols.

The concept of "Adaptive Capacity" has emerged as a key factor in system design, with its outcomes described as "Resilience"(6). Resilience in property insurance contexts could be interpreted as a system's ability to adapt and operate effectively under various expected and unexpected conditions (7). The concept of a built environment engineered for Adaptive Capacity and response Resilience aligns with the principles of Actuarial Science. This connection becomes evident when actuarial science applies probability theory to assess financial risks across various scenarios while identifying and promoting risk-reducing strategies that can lead to lower insurance premiums (8). Both fields focus on risk assessment, mitigation, and adaptive responses to potential threats.

This study explores the underlying principles for identifying systemic links between building resilience and risk reduction, with a particular focus on environmental hazards and disaster events. It presents findings on a range of building products, and assemblies designed to prevent water intrusion, as well as the effectiveness of smart home technologies, automatic utility shutoff systems, and foundation stabilization methods. By evaluating the combined impact of these strategies, the report highlights their potential to reduce the risks associated with environmental hazards and to lower insurance-related losses. Against this backdrop, the Resilience Inference Performance Level (RIPL) report's framework is introduced as a comprehensive approach to assessing and enhancing the resilience of single-family homes.

The FL Office of Insurance Regulation RIPL report and its associated resources serve two primary purposes. First, the report documents the data sources, materials reviewed, assumptions, methodologies, and preliminary findings related to the application of resilient building strategies for single-family homes. This includes an exploration of how resilient construction methods can mitigate risks and potentially reduce insurance premiums by applying resilience frameworks in building practices. Second, the initiative aimed to convene a suite of data-driven resources to support the analysis. This included leveraging existing computational tools such as UF's Sustainable Adaptive Material Performance Level (SAMPL™) platform, to analyze the reliability of common building and finish materials used in residential construction to withstand the risk of water intrusion due to hazards. It also included the development of preliminary predictive models and home design decision support tools that form key components of the study's findings.

Project Approach

Resilience in systems engineering is best viewed as a process rather than a series of specific outcomes, focusing on adaptability to different conditions instead of maintaining stability regardless of circumstances(6,9).

This report introduces a unique application of the SAMPL™ design decision support model as a tool for understanding how building material choices impact housing design resilience. Building on this foundation, the RIPL report leverages the SAMPL™ outcomes to identify key preventative variables-such as material selection-and to assess the moderating effects of Smart Home Technology performance in residential design. Grounded in systems engineering principles for safety-critical systems, this integrated approach offers several distinctive features, including:

1. Insurance-Resilience Synergy: Innovatively aligns risk-reducing and resilience-enhancing design strategies with potential insurance cost savings.
2. Requirements-Driven Methodology: Employs a rigorous, requirements-driven approach to security and business continuity, fundamental to effective resilience engineering.
3. Comprehensive Systems Integration: Adopts a holistic view of operational resilience, considering buildings as dynamic, integrated systems-of-systems encompassing materiality, structural integrity, and smart home technologies.
4. Quantifiable Process Orientation: Defines resilience through a set of definable, manageable, and measurable performance metrics, enabling systematic improvement.
5. Future-Ready Analysis Platform: Serves as a scaffold for developing advanced forecasting capabilities and "what-if" scenario modeling, empowering informed decision-making.

Quantifying the combined performance of complex system elements based on environmental risk using the traits of "Safety, Symbiosis, and Sustainability" can be instrumental in estimating their potential resilience (10). Applying a proactive approach to evaluating the resilience potential of design and construction elements of single-family homes could significantly impact insurance premiums, coverage continuity, and property values for homeowners (11). This comprehensive methodology would offer a more nuanced assessment of a property's resilience and adaptability to environmental stressors. By analyzing the various system components contributing to a home's overall resilience to environmental risks, insurers and homeowners can gain valuable insights into the property's long-term viability and risk profile (12).

In the context of home design resilience, safety reliability refers to a building's ability to withstand and maintain function during climate-related hazards, such as water intrusion from severe weather events. Symbiotic and sustainable responsiveness highlights the importance of homes being able to adapt to regional conditions and recover from both expected and unforeseen environmental challenges, ensuring ongoing resilience as conditions evolve (10,13,14). Residential properties with design features exhibiting high levels of integrated resilience could be significantly less susceptible to catastrophic damage during extreme weather events (15). These robust architectural and engineering solutions would work synergistically to enhance a home's ability to withstand and recover from severe environmental stressors.

Homeowners who implemented resilient design strategies could significantly reduce the risk of extensive property damage, potentially leading to more favorable insurance terms and enhanced long-term property value (16). Homes demonstrating these qualities could qualify for lower insurance premiums, as they present reduced risk to insurers. Additionally, properties incorporating this trait might be better prepared for unexpected environmental challenges, potentially leading to more stable insurance coverage over time (17). This consideration could help homeowners maintain continuity of coverage, even in areas experiencing increasing climate-related risks. Homes with higher resilience scores may qualify for lower premiums, while those with lower scores might face higher costs (18). This approach could incentivize homeowners to invest in resilience features, potentially leading to widespread improvements in housing stock resilience. Furthermore, properties with high resilience scores could see increased market values. Data also suggests that resilient features may make homes more desirable to prospective buyers and increase real estate market value (19). Further, homes with visible hurricane protection features generally sell for higher prices, and professional inspections that verify both visible and hidden features further increase a home's value, likely because buyers feel more confident when these protections are officially confirmed (20).

Demonstration Plan

To better understand and quantify these market and behavioral impacts, it is essential to synthesize existing research on resilience in housing design. A metasynthesis method involves an interpretive review of existing studies to derive new insights and frameworks (21). This approach enables a comprehensive understanding of how resilience principles can be generalized across different contexts, offering theoretical models that integrate safety and performance in building systems (22). This report uses a metasynthesis approach, which synthesizes findings from peer-reviewed and industry-relevant "grey literature" or information produced outside traditional academic publishing channels to evaluate how resilient construction practices can codify risk markers while identifying effective strategies for mitigating potential threats. The research team placed special emphasis on the role of building materials and their assemblies within the structure, particularly in addressing environmental risks such as severe weather events.

The following Vos Viewer map summarizes key themes identified through a systematic Literature-Based Discovery (LBD) approach, focusing on peer-reviewed publications addressing built environment resilience. This review was constrained to studies published in refereed journals between 2014 and 2025, ensuring a comprehensive yet current field analysis. VOS viewer maps visually represent bibliometric networks and scientific landscapes (23). These maps visualize different dimensions of the academic literature, such as keyword co-occurrence, which uncovers relationships between research topics and themes, and thematic clustering, where related documents or keywords are grouped together (24). These maps enable researchers to visualize complex relationships within study data, facilitating a deeper understanding of the structure and evolution of research fields.

The study commenced with an analysis of peer-reviewed literature to ensure scientific rigor in identifying key themes related to building resilience. This approach allowed the research team to focus on themes supported by empirical evidence, replicable methods, and quantifiable results rather than relying on anecdotal information. Figure 2 presents a VOSviewer map illustrating the key themes that emerged as critical to determining built environment resilience. The map utilizes a label view, where labels and circles represent key themes mined from literature deemed relevant through a scoping review. Each circle's size corresponds to the theme's relative importance within the field of study. This visualization technique offers a comprehensive overview of the interconnected concepts and their relative significance in the domain of built environment resilience. By employing this approach, the team was able to discern the most prominent areas of built environment resilience research focus and identify potential gaps or emerging trends in the field.

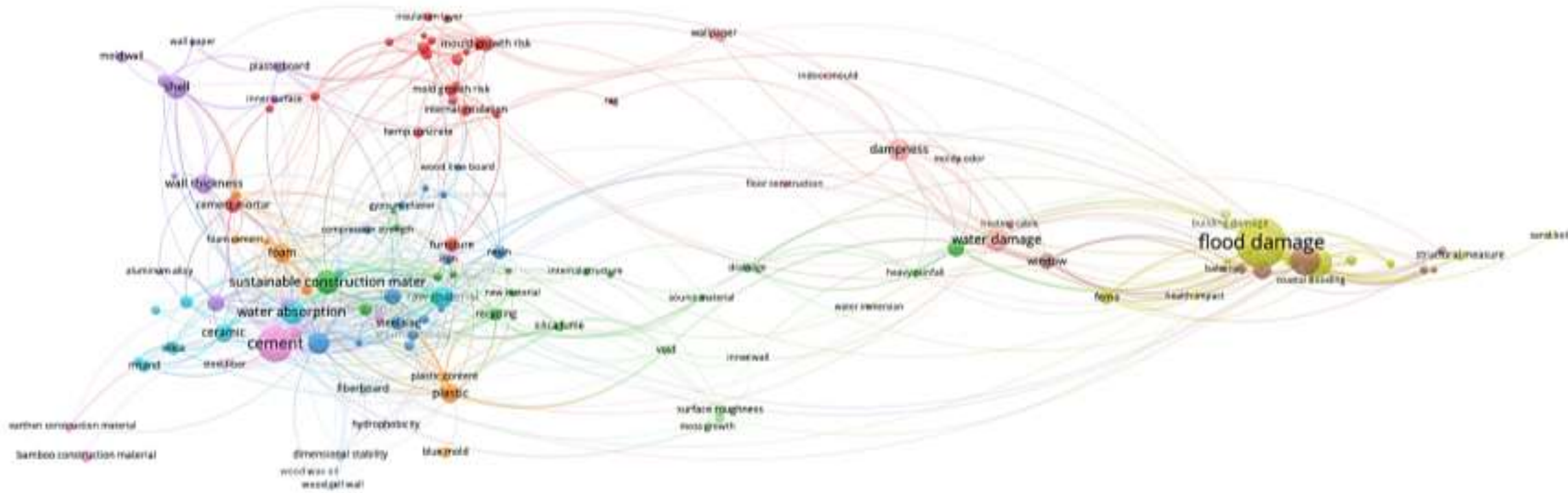


Figure 2. Vos Viewer Map of Built Environment Resilience Literature-Based Discovery.

The preliminary findings from this literature-based discovery underscore the pivotal role of building material selection in enhancing resilience and mitigating environmental hazards, particularly those associated with water intrusion. The results indicate that the choice of materials is crucial in ensuring structural integrity, bolstering a home's resistance to environmental challenges, and minimizing the risks and impacts of water-related damage. Analysis of research literature suggests that thoughtful material selection can significantly improve a home's ability to withstand and recover from water-related incidents. This concept could meaningfully contribute to building resilience and potentially reducing long-term maintenance costs and impacting insurance premiums. By analyzing building materials individually and as components of integrated systems, researchers can better understand their potential to mitigate risks effectively.

The research team also identified notable gaps in the existing peer-reviewed research. Much of the existing research on building materials has not explored the cost-benefit analysis of incorporating resilient building strategies into home design. However, one notable shortcoming, largely outside the purview of the research effort, is the limited quantity of third-party research on Smart Home Technology reliability. This issue is likely due to the rapid evolution of emerging technologies and the challenges associated with studying proprietary systems in a verifiable and transparent manner. Research on the topic of smart home technology that was sourced stressed the importance of increasing policy measures to support the development of the Smart Home Technology market including establishing design and operational standards to ensure quality control and promoting credible third-party research on technology performance (25). Additionally research on homeowner assessment of the utility of Smart Home Technologies emphasized that more extensive research and design that supports Human Factors is needed (26). These gaps underscored an opportunity to broaden the scope of inquiry by including grey literature and accessing reliable data and information repositories containing material testing data, structural assembly evaluations, and a purposeful sample of manufacturers white papers that reference Smart Home Technologies. While these sources do not possess the rigor of peer-reviewed research, this broader approach provides a more comprehensive perspective on Florida's resilient home design standards. It also enables a deeper understanding of both technological advancements and the economic feasibility of resilience-focused construction.

Demonstration Procedure

The findings from this peer-reviewed literature-based discovery, supplemented by a targeted hand search of building construction and insurance industry-specific grey literature in addition to data repositories such as ASTM, ANSI, and Underwriters Laboratories, facilitated the development of a 'Resilience Inference Requirements Analysis' framework. This system integrates research-based taxonomies to systematically evaluate building characteristics, using resilience as a key indicator of system performance and safety. A requirements analysis is a procedure derived from systems engineering that translates stakeholders' needs into detailed technical guidelines for building a system. This process sets clear, measurable goals for how the system should function and perform and any limitations it may have, all while ensuring it supports the project's overall objectives (27). Requirements analysis also contributes to performance modeling and predictive analysis, helping to establish measurable benchmarks and enabling testing to ensure the delivered systems meet their primary objective (28).

The RIPL report and its associated resources demonstrate significant potential as a complementary suite of tools to support the implementation of other resilient construction performance standards, such as the FORTIFIED program created by the Insurance Institute for Business & Home Safety (IBHS) (29), those offered by the US Department of Housing and Urban Development (HUD) (15) and other professional building and design organizations. By integrating research-based methodologies and serving as a scaffold for predictive analysis, RIPL enhances the ability to assess and support resilience in construction practices while aligning with another systems-based approach to strengthening vulnerable building components against extreme weather events.

While many existing guides outline strategies for designing homes resilient to extreme weather events, there remains a critical gap: the lack of standardized frameworks for proactively predicting building resilience. Current methods often rely on checklist-based performance criteria, which are limited in their ability to holistically evaluate adaptive potential and are frequently supported only by retrospective case study data.

Developing resilience metrics grounded in predictive modeling would allow stakeholders to systematically assess the adaptive capacity of specific design elements and approaches. Transitioning from qualitative checklists to quantifiable resilience thresholds enables dynamic risk forecasting and provides actionable insights into how design choices may perform under evolving environmental stressors.

The Key Performance Indicators (KPIs) used to refine the SAMPL™ relational database and dashboards make it possible to assign “degrees of resilience” by calculating material performance membership levels for discrete system elements. Leveraging the SAMPL™ framework supports the development of advanced computational analysis methods, employing a weighted Analytical Hierarchical Process (AHP) to generate a streamlined linear equation framework for robust inference of material resilience performance.

In this study, the RIPL report’s decision support resources utilized the SAMPL™ forecasting model. SAMPL™ evaluates the performance of building materials and finishes by assigning Boolean variables based on the presence or absence of specific Technical Performance Measures (TPM) derived from a representative sample of technical specifications, reports, testing data, and research literature. This approach enhances understanding of core building system performance and provides valuable insights into which materials may offer the greatest return on investment for reducing insurance premiums.

By utilizing this comprehensive evaluation method, we can:

- Systematically assess the resilience of various building material components
- Identify key areas for improvement in building design and materials
- Assess the potential impact of resilient building materials on property risk profiles
- Provide insurers with a more detailed understanding of material-driven property resilience
- Guide homeowners in making informed decisions about selecting and upgrading resilient building materials

This methodology enables a more precise assessment of property risk, potentially leading to more accurate insurance premium calculations and opportunities for homeowners to reduce their insurance costs actively through targeted improvements.

Preliminary Results

The preliminary findings of the analysis of these categories indicate that careful selection of building materials may significantly enhance a home's resilience to environmental hazards. By analyzing these components individually and as part of integrated systems, we can better understand their potential to mitigate risks. Key findings of this analysis include the following:

- Hydrophobic (water-resistant) and moisture-responsive building materials with optimal flame spread ratings can significantly reduce immediate and long-term structural and cosmetic damage caused by fire, flooding, and water intrusion. Materials designed to repel water and adapt to moisture exposure enhance a building's resilience and minimize the need for costly repairs over time.
- Material structural assemblies, including reinforced foundations, moisture-resistant roof ventilation systems, and weather-resistant exterior cladding, are vital in fortifying homes against extreme weather events. The preliminary analysis suggests the performance of these assemblies is highly contingent on the material composition, underscoring the importance of material selection in designing homes capable of withstanding increasingly severe weather events.
- Integrating high-quality building materials with advanced smart home technologies creates a comprehensive approach to resilience, enhancing both risk reduction and early threat detection against natural hazards. This study's preliminary findings indicate that when robust materials are paired with smart home systems, such as fire detection and prevention, flood monitoring and protection, water leak detection, and automated utility management including intelligent emergency utility shutoffs, the overall effectiveness in mitigating environmental risks is increased. Ensuring the quality of materials remains a key consideration, as the long-term performance and reliability of smart systems depend on the foundational strength and durability of the building itself. This integrated strategy supports the inclusion of both advanced materials and smart technologies providing a holistic framework for disaster resilience.

This study highlights the combined benefits of improved safety and cost savings achieved by incorporating the resources compiled in the RIPL report into building design and construction. It also emphasizes the importance of aligning insurance policies with resilience improvements to ensure adequate coverage and maximize the economic advantages of these investments. The following report will outline how these resources were applied to evaluate strategies for enhancing built environment resilience and mitigating environmental hazard risks. Specifically, the analysis examines the combined impact of residential material selection, assemblies, and smart home technologies aimed at mitigating water intrusion risks in Florida homes.

Material Resilience Considerations in Florida Home Design

The performance of building materials can significantly impact insurance rates for homes and other structures (30). Certain materials are associated with lower insurance premiums due to their durability, fire resistance, and ability to withstand severe weather conditions (31). Using more resistant materials can lead to lower repair costs and potentially less extensive claims in the event of water damage (32). Insurers can input many building characteristics into a catastrophe model. One vendor, Verisk, notes that resilience factors are, to some degree, embedded in the building codes and construction practices. Further, information about implemented retrofitting or mitigation measures, like seismic strengthening or flood barriers, can be incorporated to evaluate their effectiveness in reducing damage and enhancing resilience. Model vendors develop vulnerability curves for different structure types, construction materials, occupancy types, and geographic locations. These curves are further adjusted to reflect resiliency measures, including retrofits, improved building codes, flood protection systems, wind-resistant designs, and elevation in flood zones. For a given hazard intensity, resilient structures are assigned lower damage ratios than those without these measures. Additional modifiers to refine building characteristics include the roof shape and material, shutter usage, presence of backup generators, and the type of foundation. As new resilient building materials and resiliency activities, including installation of Smart devices, continue to proliferate, catastrophe modelers can be expected to adjust building vulnerabilities accordingly. This will, in turn, enable insurers to more accurately estimate appropriate premium reductions.

According to the 2023 Florida Building Code, Energy Conservation, Eight Edition, all counties in Florida are designated as warm-humid climate zones (33). Additionally, all 35 coastal counties in Florida are at risk of storm surges due to hurricanes (34). The 8th Edition (2023) Florida Building Code has been updated to incorporate ASCE 7-22: Minimum Design Loads and Associated Criteria for Buildings and Other Structures (35). Consequently, increased wind load provisions in building design within the Florida Building Code (FBC) and the Florida Building Code, Residential (FBCR) have been revised to align with ASCE 7-22 (36). Considering the recent updates to the Florida Building Code and the state's distinct challenges related to extreme weather events and other natural hazards, it is essential to prioritize the resilience of both exterior and interior materials in building design and construction.

Enhanced wind load provisions, in alignment with ASCE 7-22, require more robust exterior materials and construction methods. These materials must meet more stringent wind resistance standards while adhering to enhanced thermal performance criteria. Recent code requirements specify minimum R-values, which measure a material's thermal resistance for core insulation materials used in walls, floors, roofs, and foundations (37). This dual focus on structural resilience and energy efficiency ensures that buildings are robust to climate conditions and regionally environmentally sustainable. Although interior materials are not directly exposed to environmental elements during natural disasters, they are vital to the overall resilience of Florida buildings. This factor is especially true regarding fire resistance, moisture management, and structural integrity (38), which are critical for designing healthy and safe single-family residences.

Given these considerations, it was essential to identify and analyze the risk factors affecting the performance of materials used in residential construction. The structural integrity of a building is inherently linked to the performance of its constituent materials, making this a fundamental aspect of understanding overall structural behavior. Furthermore, as Smart Home Technologies aims to enhance the security and stability of housing structures during adverse weather events and given that structural resilience is mainly dependent on material durability, a comprehensive understanding of material performance became a primary objective of this study. This approach ensured that our research was grounded in a root cause analysis of critical, fundamental factors influencing structural resilience.

Leveraging SAMPL™ as a Material Resilience Requirements Analysis

Resilient design requires a holistic, evidence-driven methodology rooted in solutions-oriented science to ensure adaptive responsiveness to evolving human needs and environmental challenges. Building material systems function as interconnected "systems of systems"—where seamless integration is critical to optimizing structural performance.

The measurable impact of material **strength** (resistance to degradation) and **symbiosis** (adaptive capacity to regional conditions and recovery post-disruption) and **sustainability** in mitigating persistent climate threats, such as water intrusion from extreme weather, highlights

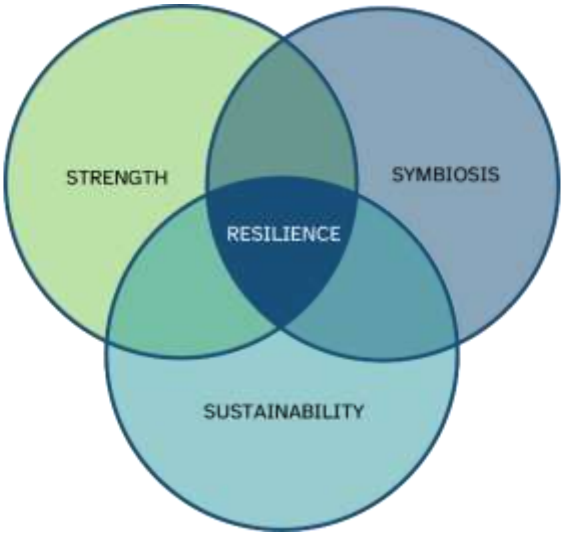


Figure 3. SAMPL Venn Diagram

the urgent need for standardized frameworks to advance designers' understanding of material selection's role in building resilience. Furthermore, water damage may also result from other sources of system disruption not directly related to weather events that may be covered under a Homeowner's policy or a National Flood Insurance Program (NFIP) /private flood policy. Specifically, a significant portion of homeowners water damage claims result from internal plumbing issues rather than external flooding. According to recent statistics approximately 25% of homeowners insurance claims filed from 2018 to 2022 were due to water damage that included internal plumbing failures such as burst pipes, appliance malfunctions, or leaks from toilets and water heaters (39).

To adapt the existing SAMPL™ relational database and computational model to address endemic water intrusion risks in single-family homes in Florida, a metasynthetic analysis of relevant literature and data was conducted to ensure content validity. This meta-synthesis systematically organized sources into thematic clusters, thereby identifying key focus areas that elucidate the relationship between material risk and resilience:

- Material durability under endemic climate stressors
- Adaptive performance in response to environmental conditions
- Identification of systemic interdependencies between material properties and their impact on structural robustness and recovery potential

Figure 4 presents a cluster graph illustrating the three key focus areas of built environment material resilience, highlighting their interconnections and relationships.

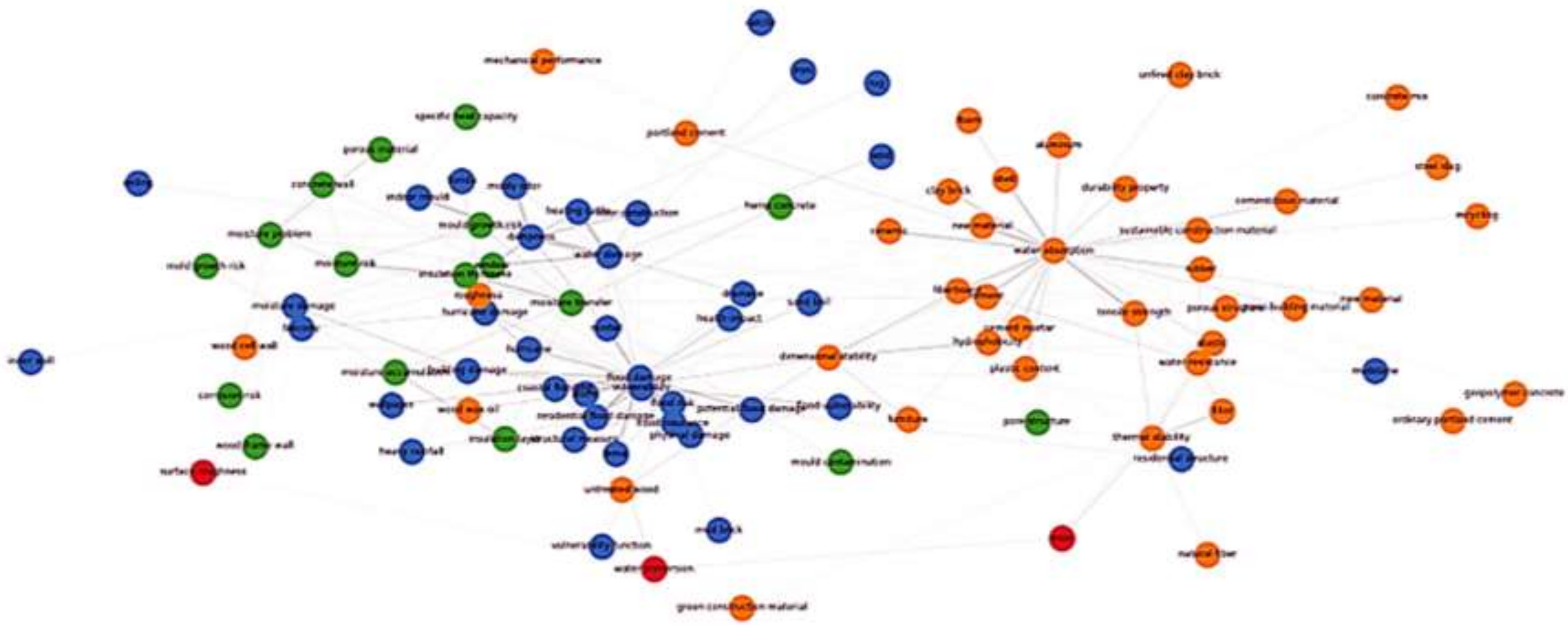


***Figure 4**. Cluster Graph of Material Resilience Metasynthesis Themes*

While wind poses a significant risk to building integrity, its event-specific nature makes probability assessments at a local scale challenging (40,41). Research indicates that water intrusion is critical in ubiquitous and long-term material failure and degradation and can be linked to regional conditions (42). This approach aligns with insurance industry trends, as the Insurance Information Institute noted: 'Water damage claims are among the most common types of property damage claims (43).' By addressing water-related material resilience, property owners may reduce their risk profile and, consequently, their insurance premiums. Given this insight, the team comprehensively analyzed exterior and interior material performance, focusing on immediate water intrusion and long-term degradation resistance.

It is critical to point out that the typical homeowner's policy contains several coverages that are affected by resilience efforts. The policy covers damage to the dwelling (coverage A) and other structures (coverage B) subject to the limits purchased by the homeowner. This coverage extends to damages caused by all perils except those explicitly excluded. While some forms of water damage are covered (e.g., from a broken pipe), water intrusion from an outside source is excluded, which requires homeowners in areas with a risk of flooding to obtain coverage from the NFIP or purchase a standalone flood policy from a private insurer. It is important to note that the potential benefits of resiliency, in the form of reduced insurance premiums, depends on the insurance arrangement.

Table 1 provides an overview of material types, the types of damage caused by water intrusion, and the underlying reasons for these damages.

Table 1. Material Damage Source Assessment

Material Type	**Type of Damage**	**Reason for Damage**
Structural Materials		
Timber	Losses in mechanical strength, High repair costs	Vulnerable to physical degradation from wetting and drying cycles. Wood is considered unacceptable in a low-flood scenario by FEMA. Susceptible to moisture damage and may not be the most sustainable option in flood-prone areas.
Brick	Damage from floodwater	Considered only adequate material, but refurbishment and repair have lower emissions.

Concrete	Damage from floodwater	Acceptable material by FEMA, though GHG emissions and cost after maintenance may make it a less ideal choice.
Steel	Losses in mechanical strength	Considered an unacceptable material in low-flood scenarios.
Metals (Mild Steel)	Corrosion	Susceptible to the corrosive effects of seawater in coastal areas.
Finishes and Wall Materials		
Gypsum Plaster/Board	Softening, potential replacement	Softens when wet. May not maintain integrity or mechanical properties after flooding. Paper-faced gypsum board may not be successfully cleaned after floods to render them free of most harmful pollutants.
Paper, Vinyl, Linoleum	Not resistant to water or moisture damage	Cannot survive wetting and drying associated with floods.

By gaining a deeper understanding of the sources and downstream impacts of damage risks, it becomes possible to analyze material characteristics that may help mitigate the severity of damage and ongoing degradation. Table 2 highlights various material types, their durability against water damage, and their resistance to mold growth.

Table 2. Material Damage Moderation Analysis

Material	Robustness to Water Damage	Resistance to Mold Growth
Structural materials		
Brick (Common Clay)	Acceptable. Adequate material. Refurbishment and repair have lower emissions. Engineering brick and low water absorption brick are suitable.	No specific information on mold resistance.
Concrete/ Concrete Blocks	Acceptable. Acceptable material by FEMA. Can withstand higher pH of 8–10. Precast concrete framing is acceptable by FEMA. Reinforced concrete is flood resistant.	Some fungi can withstand pH 8–10 on concrete.

Steel (Wall Panels, Steel Framework)	Unacceptable in low-flood scenario. Steel frames are among the worst materials to use in a flood zone.	No specific information on mold resistance.
Wood (Solid, Standard Timber)	Unacceptable in a low-flood scenario. Most vulnerable to flood water. Not sustainable in flood zones due to high vulnerability and refurbishment costs. Untreated timber is unsuitable for flooring. Solid wood is flood resistant. Pressure-treated or naturally decay-resistant timber is flood-resistant.	Damp wood is a source of moisture and a medium for mold to live on.
Finishes and Coatings		
Gypsum Plaster and Plasterboard	Softens when wet. Prolonged exposure causes irreversible damage. Water-resistant grades are more flood tolerant. Paper-faced gypsum board may not be successfully cleaned after floods. Lime-based plasters are preferable to gypsum.	Mold can grow on it.
Paints	Cladosporium can grow on latex paint. Water-resistant paints or coatings can be applied to the external face of walls.	Fungal or algal growth can disfigure paint films
Lime-based Materials (Mortar & Render)	Good suitability. Lime-based plasters are preferable to gypsum.	No specific information on mold resistance.
Wallpaper	Some have tiny holes.	No specific information on mold resistance.
Insulation Materials		
Insulation (Fiberglass)	Insulation often comes with Penicillium spores, which are not harmful unless other molds grow on them. Fiberglass batt insulation wicks and retains water, contributing to high moisture levels and extended drying times.	No specific information on mold resistance.

Insulation (Foam/Closed Cell)	Flood resistant. Rigid closed-cell foam insulation materials have low water permeability and are expected to be highly flood-resilient. Closed-cell insulation will not absorb water but may restrict the drying out of a cavity wall. Closed-cell polyurethane insulation performed well, absorbing little moisture and surviving the flood test undamaged.	No specific information on mold resistance.
Flooring Materials		
Carpet	Wool, nylon, polyester, and cotton carpets can support mold growth.	Wool, nylon, polyester, and cotton carpets can support mold growth.
Ceramic Tiles	Water gets underneath; certain fungi can withstand pH 8–10. Clay tiles are a suitable flooring. Glazed ceramic tiles have good suitability.	Certain fungi can withstand pH 8–10.
Concrete Floors	Good suitability.	No specific information on mold resistance.

By analyzing the critical factors contributing to a structure's ability to withstand or recover from water intrusion, the team identified specific TPM that, when evaluated collectively, provide a comprehensive assessment of a building's resilience capabilities. Utilizing Woods's framework for engineering resilient systems as a guide (10), SAMPL™ uses a hierarchical structure of TPM that encompasses three key dimensions: safety, symbiosis, and sustainability. This framework facilitates the quantification and categorization of various levels of material resilience based on distinct typologies, providing a more nuanced understanding of a structure's materiality overall requirements for achieving optimal resilience performance. By using the key dimensions of resilience as a foundation for developing specific material performance criteria related to water intrusion, the team created a comprehensive set of TPM for building resilience. These TPMs address the following critical characteristics:

- STRENGTH: maintainability, tensile strength, flame resistance, smoke resistance, hardness, imperviousness.

- SYMBIOSIS: responsiveness, use life, moisture resistance, durability, self-healing, reclaim/reuse.
- SUSTAINABILITY: embodied carbon, ingredient transparency, ethical supply, recycled content, recyclability potential, low emission, a chain of custody documentation, responsible extraction, regional availability.

The research team compiled this information through a targeted search of technical specifications for materials suitable for residential structures. Data repositories such as the Sweets Product Database (https://sweets.construction.com/), Ecomedes (https://www.ecomedes.com/), and Material Bank (https://www.materialbank.com), along with specific manufacturers' websites, were systematically examined to gather relevant data. This framework enabled Boolean variables to systematically catalog gathered evidence of material performance traits. Specifically, it assessed whether independent testing results or technical specification data substantiated the presence ("1") or absence ("0") of discrete performance capabilities within the material data.

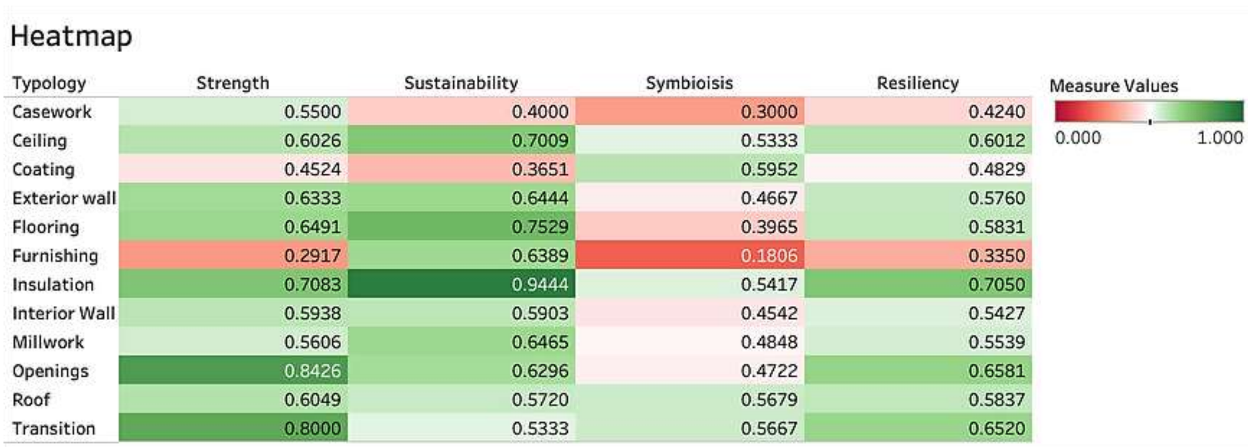
Frameworks such as the one developed as a constituent of this study, which supply TPM foundation data for determining materiality resilience, can be designed to analyze composite criteria governing complex systems operating under nonlinear risk. These frameworks enable future predictive analytics applications through fuzzy inference modeling by providing structured pathways to model uncertainty and interdependent variables. Fuzzy logic accommodates Boolean operations when membership values are restricted to 0 or 1 (44,45). Diagnostic systems based on Boolean consistency ensure logical rigor in medical and technical diagnostics by employing fuzzy rules (46). Boolean relations establish crisp decision boundaries, which are then fuzzified to handle intermediate values. These systems are advantageous in real-world control applications, including nonlinear and complex systems (44).

Using the U.S. Department of Commerce, National Oceanic and Atmospheric Administration National Weather Service Flood Severity Index (47) as a vehicle for weighting the probability risk for water intrusion (48) into buildings. This qualitative scale comprises the following categories, each with its corresponding description: (47)

- Major Flooding: Extensive inundation of structures and roads; significant evacuations and property damage are likely.

- Medium (Moderate) Flooding: Some inundation of structures and roads near streams; some evacuations may be required.
- Minor Flooding: Minimum or no property damage, but possibly some public threat or inconvenience.

Utilizing this scale allowed for the assignment of Subjective Severity Scale weights according to each level, and the implementation of a weighted Analytical Hierarchical Process (AHP) to develop a streamlined linear equation framework. This approach enables robust inference of material resilience performance based on proportional membership levels. AHP has precedent use in to evaluating and compare the performance levels of different system components (49). The resulting computational outputs quantify resilience levels according to the degree to which material-type TPM criteria are satisfied. This approach provides a data-informed an estimation of how effectively each material type meets the established resilience standards within the composite criteria framework for flood risk zones. Figure 5 presents a heatmap diagram illustrating the proportion of resilience composite criteria based on material performance.


Heatmap

Typology	Strength	Sustainability	Symbioisis	Resiliency
Casework	0.5500	0.4000	0.3000	0.4240
Ceiling	0.6026	0.7009	0.5333	0.6012
Coating	0.4524	0.3651	0.5952	0.4829
Exterior wall	0.6333	0.6444	0.4667	0.5760
Flooring	0.6491	0.7529	0.3965	0.5831
Furnishing	0.2917	0.6389	0.1806	0.3350
Insulation	0.7083	0.9444	0.5417	0.7050
Interior Wall	0.5938	0.5903	0.4542	0.5427
Millwork	0.5606	0.6465	0.4848	0.5539
Openings	0.8426	0.6296	0.4722	0.6581
Roof	0.6049	0.5720	0.5679	0.5837
Transition	0.8000	0.5333	0.5667	0.6520

Figure 5. *Proportional Single Family Home Common Materials Resilience Heatmap*

Key aspects of this heatmap visualization include:

1. **Material Types:** Rows represent individual material types assessed in the study, offering a comprehensive overview of their performance characteristics within various building applications.

2. **Resilience Performance Levels:** Columns display the range of resilience performance for each material type, from low to high, according to established flood risk assessment criteria.

3. **Color Gradient Interpretation:** The color intensity of each cell reflects the resilience performance of the corresponding material type, with greener shades indicating higher resilience and redder shades indicating lower resilience. This visual coding enables quick and intuitive evaluation of material performance.

4. **Aggregate Performance Analysis:** The overall pattern reveals insights into the overall performance of different material types relative to resilience standards, supporting a holistic understanding of how material selection impact’s reliability to water intrusion resistance.

Applying this approach allows for a more precise evaluation of a building's resilience, which can directly inform insurance risk assessments and potentially lead to more accurate premium calculations. Preliminary findings from the pilot study indicate that categorizing material data into discrete performance groups enhances the prediction accuracy of interior material safety resilience levels. The predicted results closely correspond with actual observed values, demonstrating the practical effectiveness of this approach to aid in design decision support for enhancing built environment resilience (50). This capability facilitates informed design decisions, ultimately leading to improved resilience in the final product or structure. By demonstrating enhanced resilience through these measurable criteria, property owners may be able to secure more favorable insurance terms, reflecting the reduced risk profile of their assets.

Material Performance Criteria and Installation Methods

Understanding the performance criteria of various material types is crucial in developing effective installation methods for interior and exterior material assemblies. This knowledge enables a comprehensive understanding of how systems of combined installed materials can provide superior moisture control or minimize the impact of moisture intrusion, thereby potentially reducing insurance risks and premiums. It is essential to recognize that no material is entirely impervious to moisture; materials exhibit varying degrees of hydrophobic qualities. This understanding shifts the focus from seeking "waterproof" solutions to implementing systems demonstrating high levels of water resistance reliability and efficient recovery from moisture saturation.

The most effective strategy to mitigate moisture-related problems due to water intrusion requires a systematic approach that involves:

1. Selecting materials that exhibit high levels of moisture resistance and rapid recovery from saturation.
2. Designing installation systems that leverage combinations of materials demonstrating composite resilience traits.
3. Implementing layered defense mechanisms against moisture intrusion.

This approach enhances the structure's resilience to moisture and potentially reduces the risk profile from an insurance perspective, leading to lower premiums.

Flooring: A Case Study in Moisture-Resilient Installation

Flooring systems are particularly vulnerable to moisture-related damage, making them an excellent case study for resilient installation methods. It is essential to always follow the manufacturer's installation instructions when installing any exterior or interior materials to ensure optimal performance and warranty compliance. The following images are provided as general case study examples illustrating installation methods for various material types designed to enhance resistance to degradation caused by water intrusion. These examples are intended for informational purposes only and should not replace the specific guidance provided by material manufacturers.

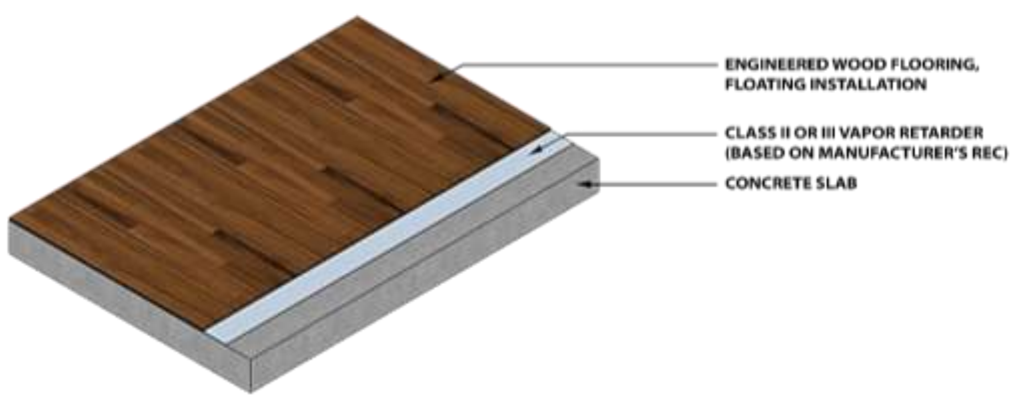


***Figure 6**. Axonometric detail of engineered wood flooring on an existing concrete slab. Floating installation allows flooring to dimensionally adapt to humid conditions.*

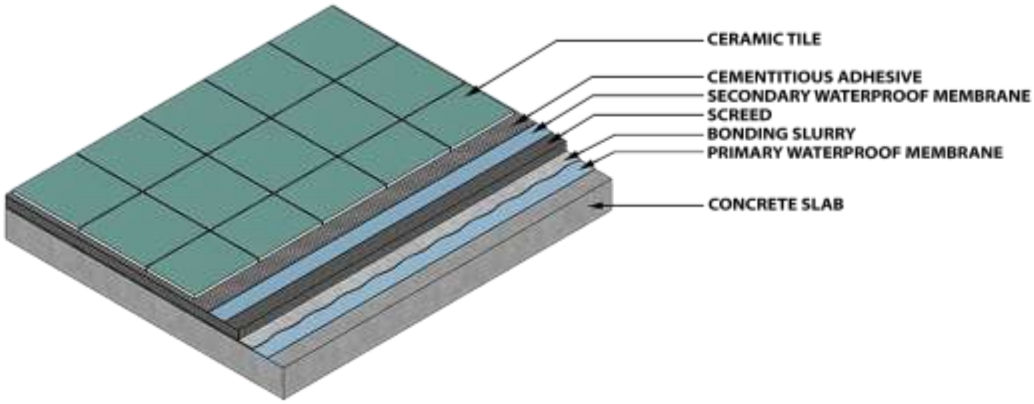


Figure 7. *Axonometric detail of ceramic tile flooring on existing concrete slab. Screeding provides a smooth and level base to prevent ceramic tiles from cracking under stressors.*

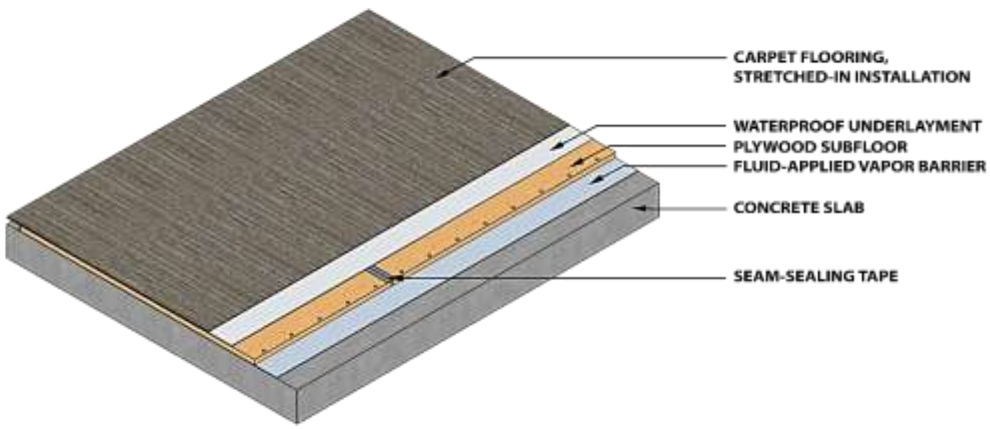


Figure 8. *Axonometric detail of moisture sensitive flooring (ex. carpet) on existing concrete slab. Stretched-in installation for carpet allows this material to be tightened back down in the case of warping from humid conditions.*

These installation methods demonstrate how:

1. Vapor barriers can be effectively incorporated to prevent ground moisture from reaching the flooring material.
2. Proper underlayment selection can enhance the overall moisture resistance of the flooring system.
3. Seam-sealing techniques can prevent moisture intrusion at vulnerable junctions.
4. Elevated installation methods can provide an additional layer of protection against ground-level moisture.

By implementing these moisture-resilient installation techniques, property owners can significantly reduce the risk of water damage, potentially leading to lower insurance premiums due to decreased claim likelihood.

Understanding material performance criteria and leveraging this knowledge in installation design represents a proactive approach to moisture management. This strategy enhances the longevity and performance of building systems and aligns with insurance risk mitigation goals. As the residential construction industry evolves, integrating these moisture-resilient practices may become a standard consideration in insurance premium calculations, offering tangible financial benefits to property owners who adopt these advanced installation methods.

Material Typologies Resilience Summary

Material selection is pivotal in enhancing resilience and mitigating environmental hazards, particularly water intrusion-associated ones. The choice of materials is crucial in ensuring structural integrity, bolstering a home's resistance to environmental challenges, and minimizing the risks and impacts of water-related damage. By understanding material resilience, we gain deeper insights into which structural components and Smart Home technologies yield the best return on investment for adaptive response to water intrusion.

The domain-agnostic SAMPL™ approach has been utilized within the RIPL resources to assess material resilience. This methodology also enables robust inferences regarding how combinations of material properties contribute to overall building structural integrity. By integrating material selection, structural design, and smart technologies, this comprehensive approach provides a holistic understanding of strategies to enhance building resilience.

The following subsection examines how specific material assemblies support structural resilience, building on the previously discussed analysis. It details the application of SAMPL™ for evaluating various material assemblies, their interactions, and their collective impact on a building’s capacity to withstand and recover from water-related challenges. These insights are valuable for optimizing structural design to improve resilience, with the potential to reduce insurance risks and premiums.

Material Assemblies: Key Factors in Supporting Structural Integrity in Florida Home

The team adapted the SAMPL™ method to evaluate how combinations of building materials—referred to as material assemblies—contribute to the structural integrity of residential design elements, particularly in mitigating water intrusion risks. This process involved a detailed analysis of the material assemblies used in key structural components of homes.

In applying SAMPL^{TM}, the team incorporated TPM specifications, which included a thorough review of the testing methodologies used to assess the effectiveness of these assemblies in preventing water infiltration. Compared to the evaluation of individual materials, these testing methodologies were even more critical for assemblies, as the complexity of interactions between materials can significantly influence overall building resilience. By leveraging SAMPL^{TM}, the team gained deeper insights into how well-integrated material assemblies enhance structural integrity and improve a home's capacity to resist and recover from water-related challenges.

This refined approach enabled the following outcomes:

- Identification of key material assemblies within structural elements that are prone to water intrusion
- Assessment of the combined properties and assembly techniques of these material assemblies in relation to their specific applications
- Evaluation of how current testing methods simulate real-world water exposure scenarios and their effectiveness in determining the resilience of material assemblies

By applying this methodology, the team aimed to enhance the understanding of how specific design choices, materials, construction methods, and application contexts of building components can contribute to reducing water-related risks in residential structures, potentially leading to lower insurance premiums for homeowners.

Structural application contexts were established by analyzing water penetration resistance testing data for various building material assemblies. This systematic review aimed to identify building areas most susceptible to water intrusion. The identified vulnerable areas were then used to categorize specific material assemblies within structural components. This categorization enabled a proportional evaluation of resilience levels across different material assemblies, providing a clearer understanding of their contribution to overall structural integrity.

The process involved:

1. Data mining of water penetration resistance test reports
2. Identification of vulnerable building areas
3. Development of a classification system for building elements and materials

4. Establishment of a methodology for proportional resilience level assessment

This approach enables a more granular and quantitative analysis of building resilience against water intrusion, providing a foundation for targeted improvement strategies and risk mitigation measures.

Figure 9 displays a dendrogram that illustrates the hierarchical relationships among building material assemblies. This tree-like diagram visually shows how different material assemblies in a residential building are clustered and interconnected based on their similarities and differences. The branching structure of the dendrogram makes it easy to see how these assemblies are grouped at various levels of similarity, providing insights into the organization and integration of materials within the building. Additionally, a saturation map is included to highlight the extent of relationships among the identified themes, further enhancing the understanding of how material assemblies are structurally related.

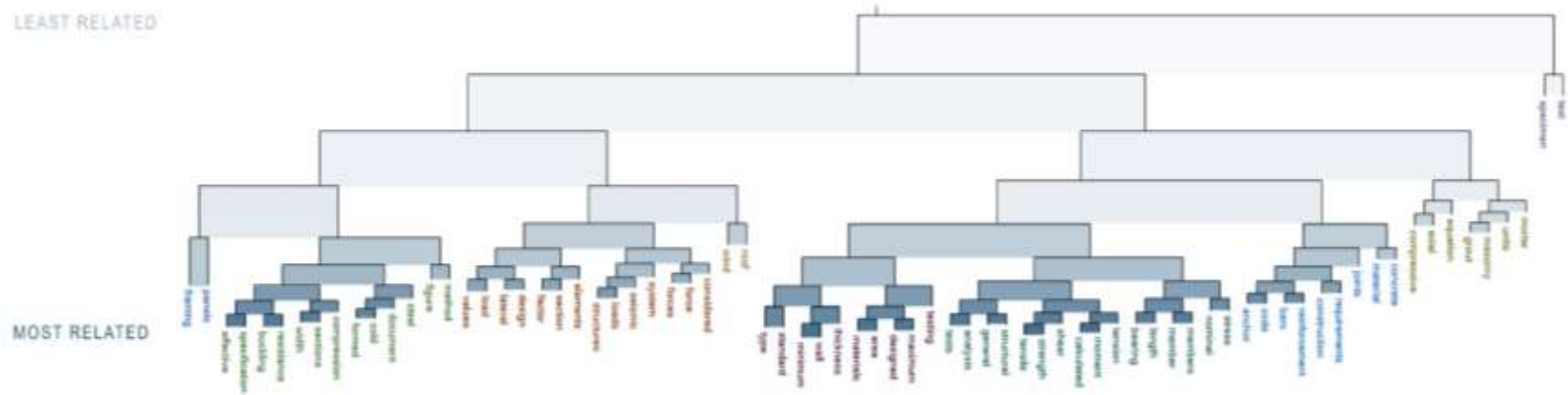


Figure 9. *Dendrogram of Material Assemblies Structural References*

Key Performance Indicators for Assessing Structural Resilience in Buildings

The following table presents a comprehensive breakdown of structural elements, including their contextual applications and corresponding test results. This systematic categorization of structural components, organized by application area, facilitated the cataloging of TPM specifications based on RIPL characteristics.

Specifically, the table encompasses:

1. Detailed delineations of individual structural elements
2. Contextual information on their practical applications
3. Associated testing purpose, outcomes, and associated performance metrics

This structured approach enables a more nuanced understanding of how different material assemblies contribute to structural integrity and overall building resilience, as well as their potential impact on insurance risk assessment. By organizing the data according to material assemblies, we can more effectively analyze the relationship between specific assembly configurations and their role in enhancing a building's resistance to water intrusion.

Table 3. RIPL Relational Database of Building Material Assembly Performance Tests

MATERIAL TYPOLOGY	CONTEXT	SAFETY | SUSTAINABILITY DOCUMENTATION	TESTING FACTORS
WALL CONSTRUCTION			
Wood - CONSTRUCTION/FRAMING			

Interior Load Bearing	construction/frame/ fire blocked to the standard of exterior wall Loss in mechanical strength when inundated, high repair costs.	IRC R602.4 AWC NDS ANSI Literature Review	**IRC 602.4 -** (Flame resistance) AWPA U1 - Usable Wood Species and Preservatives (Responsiveness) **USG SA100 -** (Flame resistance, smoke resistance) **AWC South EPD -** (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **UL 263** - (Fire resistance, Smoke Resistance, Hardness) **ASTM D4933** - Water Resistance **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability
Interior Non-Load Bearing	1. constructed with 2x3" studs, 24" apart oc 2. (not on braced wall line) 2x4" flat stud @ 16" oc. Shall be capped with at least a single top plate + fire-blocked Loss in mechanical strength when inundated, high repair costs.	IRC R602.5 IRC R602.8 AWC NDS ANSI Literature Review	**IRC 602.5 -** (Flame resistance) **AWPA U1** - Usable Wood Species and Preservatives (Responsiveness) **USG SA100** - (Flame resistance, smoke resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **UL 263** - (Fire resistance, Smoke Resistance, Hardness) **ASTM D4933** - Water Resistance **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability
Exterior	Should be fastened following Tables 602.3(1-4), capable of resisting wind loads/pressures, and adjust height dependent on exposure levels Utility studs should not exceed 8' in height. Stud construction should adhere to notching, boring, height, and fastening requirements/schedules outlined by IRC Chapter 6	AWC NDS ANSI IRC 602 Literature Review	**ASTM/UL 263 -** Flame Resistance **AWPA U1** - Usable Wood Species and Preservatives (Responsiveness) **USG SA100** - (Flame resistance, smoke resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **UL 263** - (Fire resistance, Smoke Resistance, Hardness) **ASTM D4933** - Water Resistance **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability
Cripple Wall	The stud should not be smaller than the studding above. It should be shorter than 4' to avoid new story requirements,	IRC R602.9 AWC NDS	Exterior walls should be sheathed for weathering/environmental protection **UL 263** - (Fire resistance, Smoke Resistance, Hardness) **ASTM D4933** - Water Resistance **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability
Wall Bracing (Braced Wall)	Bracing should comply with IRC R602.10.4 PCP/HPS/ABW/PFH/PFG/CS-WSP/CS-G CS-PF/CS-SFB type bracing LIB/DWB/WSP/BV-WSP/SFB/GB/PBS assembly	IRC R602.12 IRC R602.10.4 AWC NDS	**IRC 602.9** - Fire Blocking (Flame Resistance) **IRC 602.10.3-** Length and construction of bracing based upon seismic and wind load on different stories (Load Adaptation) (Multi-Context) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **UL 263** - (Fire resistance, Smoke Resistance, Hardness) **ASTM D4933** - Water Resistance / **ASTM D6513** - Robustness Consistency/Load

			Bearing / **ASTM D6815** - Recovery Reliability
Wood Stud	Minimum No. 3, standard of stud grade lumber Continuous from support as sole plate to support at top plate to resist load perpendicular to wall; support shall be a foundation/floor, ceiling/roof diaphragm/engineering following engineering practices, maximum height + spacing following levels, and environment wood studs 2"x4": 18% load reduction, 0.82 load restriction factor	IRC R602.3(5),(6), IRC 602.3.1 IRC 602.2 BXUV guide - UL263	**IRC Table R602.3(6) -** Bearing wall stud size, height, and spacing for supporting member and windspeed (Load adaptation, Multi-Application, Flame Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential) **UL 263** - (Fire resistance, Smoke Resistance, Hardness) **ASTM D4933** - Water Resistance / **ASTM D6815** - Recovery Reliability
Header	Span should comply with IRC R602.7(1-3) 1. Single Member Headers: framed with single flat 2" nom. member or wall plate not less in width than the wall studs on the top and bottom of the header + face nailed to the top + bottom of the header 2. Rim Board Header: supported at each end by full-height studs (not less than tone plus the number of studs displaced by have of the header span at max spacing) 3. Wood Structural Panel Box header Shall be supported on either side by a jack stud or approved framing anchors Head + sill track No Required in Interior/Exterior Non-bearing walls, no support cripples or blocking required.	IRC R602.7(1-3)	**IRC Table R602.7(2-3)** - Girder and Header Spans for Exterior Walls/Porches (Mult-Application, Multi-Context) Required Fire blocking (Fire Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential) **AWPA U1** - Usable Wood Species and Preservatives (Responsiveness) **ASTM D4933** - Water Resistance **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability, Use-Life
Top Plate	Wood stud walls must be capped with a double top plate, overlapping at corners and intersections with baring partitions. End joints should be offset no less than 24"; thickness <2" + width <studs 1. A single top plate shall be tied at corners, intersecting walls, and at in-line splices in straight walls 2. rafters or joists shall be centered over the studs with a tolerance of not more than 1 inch 3. omission of the top plate is permitted over headers where the headers are adequately tied to adjacent wall sections Shall not be drilled or notched by more than 50% of width and fasted with galvanized metal tie, not less than 16 ga and 1.5: wide, etc.	IRC R602.3.2 IRC R602.6.1	**UL 263** - (Fire resistance, Smoke Resistance, Hardness) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential) **ASTM D4933** - Water Resistance **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability, Use-life

Bottom (Sole) Plate	studs with full beam on 2-by nom. Or a larger plate with width <width of stud	IRC R602.3.4	**UL 263** - (Fire resistance, Smoke Resistance, hardness) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential) **ASTM D4933** - Water Resistance **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815 -** Recovery Reliability, use-life
Wood - COVERINGS			
Fiber Board Sheathing	Where used structurally, it should operate in compliance with the IRC Fiberboard shall be categorized by grade and made with approved materials, tolerances, and physical properties)	IRC R602.1.9 ASTM C208 IRC 602.12.2	**ASTM C208 -** Standard Specification for Cellulosic Fiber Insulating Board (Ingredient transparency, Load Adaption, Responsiveness) **ASTM C209 -** Fire Resistance, Imperviousness, Water Resistance, Hardness **R602.12.2 -** Sheathing material used to construct a bracing unit (multi-context) **EPD –** Multi-context/Multi-application, Chain of Custody, Recycled Content, Ingredient Transparency, Recyclable potential, Responsible extraction
Cement Board		USGA SA100 ESR-2208 ASTM C1325 ANSI A118.9	**USGA SA100 -** Fire Resistance, Smoke Resistance **ASTM C1325 -** Hardness, load adaption **ANSI A118.9 -** Water Resistance, Self-Healing, Load Adaptation **ESR-2208 -** **EPD IES Cement Board -** Imperviousness, Fire Resistance, Ingredient Transparency, Recyclability Potential, Chain of Custody, Water Resistance, Reclaim/Reuse, Responsiveness
Wood Particle Board Sheathing	1. 3/8" thick, 16" spaced studs, siding to stud 2. 1/2" thick, 16" spaced studs, siding to stud 3. 1/2" thick, 16" spaced studs, siding to sheathing	IRC R602.3(3) R602.3(4) ANSI A208.1	**ANSI A208.1** - dimensional tolerances, physical and mechanical properties, and formaldehyde emissions for particleboard (Ingredient transparency/responsiveness) **IRC 602.3** - sheathing applied to exterior face shall we wind resistant according to classification category (Load adaption) **ASTM D4933** - Robustness Consistency / **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability, use-life
Wood Structural Paneling Sheathing	1. Wood structural panel sheathing of thickness 3/8" with 6d common nails @ 12" o.c. in the field, studs spaced 16" apart 2. wood structural panel sheathing of thickness 7/16" with 8d common nails, 12" o.c. in the field, studs spaced 16" apart 3. wood structural panel sheathing of thickness 7/16" with 8d common nails, 12" o.c. in the field, studs spaced 24" apart Should be applied to the exterior side of exterior walls when used as a bracing unit	IRC R602.3(3) IRC 601.12.2	**IRC 602.3 (3)** - sheathing applied to exterior face shall we wind resistant according to classification category (Load Adaptation) **R602.1.8 -** panels should be identified for grade, bond classification, and performance category (Ingredient transparency) **R602.12.2 -** Sheathing material used to construct a bracing unit (multi-context) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential) **ASTM D4933** - Robustness Consistency / **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability, use-life

Wood - FASTENERS			
Toe Nail	1. 4-8d box 2. 3 -8d common 3. 10-d box	ASTM F680-20 TAS 114, Appendix E UL BXUV	**ASTM F680-20 -** Standard Test Methods of Nails (Load Adaption, Responsiveness, Self-Healing, hardness) **TAS 114 Appendix E -** Procedure for Corrosion Resistance (Water Resistance, imperviousness, Responsiveness Use-life) **EPD -** Recycled content, chain of custody, ingredient transparency, ethical supply, responsible extraction
End Nail	1. 2-16d common 2. 3-16d box	ASTM F1667 TAS 114, Appendix E UL BXUV	**ASTM F680-20 -** Standard Test Methods of Nails (Load Adaption, Responsiveness, Self-Healing) **TAS 114 Appendix E -** Procedure for Corrosion Resistance (Water Resistance, Responsiveness, Use-Life)
Face Nail	1. 16d common 2. 4-10d box	ASTM F1667 TAS 114, Appendix E UL BXUV	**ASTM F680-20 -** Standard Test Methods of Nails (Load Adaption, Responsiveness, Self-Healing) **TAS 114 Appendix E - Procedure** for Corrosion Resistance (Water Resistance, Responsiveness, Use-life)
Cold-Formed Steel - CONSTRUCTION/FRAMING			
In-Line Framing	Studs should be located in line with the joist/truss/rafter	AISI S240-20 SB1.2.3	**AISI S240 B1.2.3** In-Line Framing (Load Adaption) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Interior Load Bearing	No more than 60' perp. to joist, no more than 40' parallel to joist, no more than three stories above grade, or AISI S230 wind speed >140 mph + Exposure Cat B or C	IRC R603.1.1 AISI S230 AISI S240 ASTM C955 Literature Review	**AISI S230 Table A1-3** - Types of Steel to Use Per Wind Climate (Imperviousness) **FRC R407.2** - Coating of Rust Resistance & Anti-Corrosive Solutions (Responsiveness/Imperviousness/Water Resistance) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **AISI S100 Section B -** Design Requirements (Load Adaption/Use-Life) **ASTM C955 - Penetration Test -** Procedure for evaluating member's ability to pull the head of a screw below the surface of gypsum panel product (Self-healing) **USG SA100** - (Flame resistance, smoke resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential

Exterior	Considered load bearing wind speed >140 mph + Exposure Cat B or C	IRC R603.1.1 AISI S230 AISI S240 ASTM C955 Literature Review	**AISI S230 Table A1-3** - Types of Steel to Use Per Wind Climate (Imperviousness) **FRC R407.2** - Coating of Rust Resistance & Anti-Corrosive Solutions (Responsiveness/Imperviousness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **AISI S100 Section B -** Design Requirements (Load Adaption/Use-Life) **AISI S240 -** Protective coating/corrosion protection (Water Resistance) **ASTM C955** - Penetration Test - Procedure for evaluating member's ability to pull the head of a screw below the surface of gypsum panel product (Self-healing) **USG SA100** - (Flame resistance, smoke resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody. Recyclable Potential
Wall to Foundation/Floor	Installed according to design standard set in IRC R603.3 - USING 140B WIND SPEED FOR MAX DESIGN 1. Wall bottom track to floor: 2-No.8 screws at 6" o.c 2. Wall bottom track to the foundation: 1/2" min diameter anchor bolt at 4' o.c. 3. wall bottom track to wood sill: steel plate at 3' o.c. with 4-No. 8 screws/4-10d/6-8d common nails	IRC Table R603.3.1 ASTM F1554 ANSI/UL 263/ASTM E119	**IRC Figure R603.3.1(1-3) -** Connection types (Load Adaption, Fire Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Corner Framing	exterior walls where there are corner studs and top tracks	IRC R603.4 Figure R603.9.2.2	**IRC Figure R603.4 -** Connection types (Load Adaption, Fire Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Studs (Structural Exterior)	Stud size dependent on building width and windspeed/exposure cat. according to IRC 6033.3.2 1. secure to top or bottom track with 2 - No. 8 screed at the end, one per flange 2. stud to the structural sheathing, No. 8 Screws, 6" oc from the edge, 12" oc. at support 3. stud to 1/2" gyp with No. 6 screws, 12" oc. - Minimum thickness for load bearing based upon ASTM C955 - 0% load reduction, zero load restricted factor	IRC R603.3.2(1) IRC R603.3.2(2-16) ASTM C955 ANSI/UL 263 CSA S136	**ASTM C955-18e1**: load bearing (transverse and axial) assemblies (Load Adaption) **Penetration Test:** Procedure for evaluating member's ability to pull the head of a screw below the surface of gypsum panel product (Self-healing) **AISI S240 B1.2.2** Wall Studs (Load Adaptation) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Header	Installed upon wall openings in exterior wall + interior load-bearing walls Box beam header/back-to-back headers should be two equal-sized c-shaped members	AISI S230, AISI S240	**AISI S240** - Protective coating/corrosion protection (Water Resistance) **AISI S240 Section B -** Design (Responsiveness, Load Adaption) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable

			Potential
Cold-Formed Steel - COVERINGS			
Plywood/OSB	1. Minimum 7/16" thick OSB (11mm) 2. 15/32" plywood (12mm) Full-height sheathing should extend from the bottom to the top of the wall without opening interruptions. When used for stone/masonry veneer, full height shall comply with IRC	IRC R603.9 IRC R603.9.5 AISI S240-20	**AISI S240** - Tensile Strength, Yield Stress, Bending Rigidity, Shear Strength (Responsiveness, Hardness, Load Adaption) **ASTM/UL 263 -** Fire Resistance **IRC R603.9.5 -** (Multi-context, multi-application) **AWC Plywood EPD -** (Embodied Carbon, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction) **AWC -** Use life, water resistance
Gypsum Board	Typical 1/4" - 5/8"	USGA SA100 ASTM C1396 ASTM C1278 ASTM C473	**USGA SA100 - (**Fire Resistance + Smoke Resistance) **ASTM C1396 -** Standard Spec for GWB (Imperviousness, fire resistance, hardness, self-healing, water resistance, responsiveness) **ASTM C1278 -** Standard Spec for Fiber-Reinforced Gypsum Panel (imperviousness, water resistance) **ASTM C473 -** (Responsiveness, Self-Healing)
Particle Board		ANSI A208.1	**ANSI A208.1 -** (Responsiveness, Reuse, Ingredient Transparency, Load Adaption, Use Life) ANSI A208.1 - dimensional tolerances, physical and mechanical properties, and formaldehyde emissions for particleboard (Ingredient transparency/responsiveness) IRC 602.3 - sheathing applied to exterior face shall we wind resistant according to classification category (Load adaption) ASTM D4933 - Robustness Consistency / ASTM D6513 - Robustness Consistency/Load Bearing / ASTM D6815 - Recovery Reliability, use-life
Cold-Formed Steel - FASTENERS			
Bracing	1. Load-bearing walls with gypsum board/structural sheathing/gyp on one side and sheathing on one side 2. Horizontal steel straps fastened on both sides (mid height), in thirds (9-10' walls) - attached with No. 8 screws, not less than 1.5" in width/33 mm thick 3. Sheathing one side, strapping the other side	IRC R603.3.3(1-2) AISI S240 Section B AISI S100 Section C2.2	**AISI S100 C2.2 -** (Load Adaption, Responsiveness) SIPA EPD - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Anchor Bolts	Not connected more than 12" from the corner/termination of the bottom track; should not exceed 15" in masonry/7" in concrete; can be substituted with anchor straps	IRC R603.3.1 AISI S100 ASTM F1554	**ASTM A641** - Standard Specification for Zinc-Coated Carbon Steel Wire (Load Adaptation) **ASTM A153** - Standard Spec. for Zinc Coating on Iron and Steel Hardware (Chain of Custody) **TMS 402 Ch. 4 -** Prestressed Masonry (Load Adaption, Robustness Consistency) **ASTM F1554** - Standard Specification for Anchor bolts (Ingredient transparency, multi-context, load adaption, hardness, Responsiveness) **AISI S100 Section L** - Serviceability (Use-Life

			/ Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **AISI S100 Section B** - Design Requirements (Load Adaption/Use-Life)
Screws	min. edge distance c.t.c.1/2", ASTM C1513 sheathing: 2- No. 8, 7.4 mm, ASTM C1513 gypsum board: No. 6, ASTM C954/C1513/IRC R702 should have rust-inhibitive coating/not corrosive material	IRC R603.2.5 UL BXUV AISI S100 ASTM C1513	**AISI S904** - Tensile and Shear Strength of Screws (Hardness / Imperviousness) **ASTM C1513** - Standard Spec for Steel Tapping Screws (hardness, load adaption, responsiveness, hardness)
Masonry - CONSTRUCTION/FRAMING			
Concrete Masonry	1. Concrete brick ASTM C55 2. Calcium silicate brick ASTM C73/prefaced masonry using ASTM C744 3. Concrete Masonry unit ASTM 90 4. Concrete facing brick ASTM C1634	ASTM C73, C55, C90, C1634 IRC R606.2.1 TMS 402, 403, 404 Literature Review	**TMS 402/ASCE 5/ACI 530 -** Requirements for Masonry Structures (Load Adaptation, Imperviousness, Responsiveness, Hardness) **ASTM C73 -** Sand lime brick in the presence of water in temperatures below freezing (Responsiveness) **ASTM C55 -** should be free of cracks that impair the strength of the material, high strength, and resistant to water penetration (Imperviousness/Load Adaption) **ASTM C1634** - maximum water absorption and minimum net area compressive strength (Load Adaption/Imperviousness) Interior + Exterior Conditions - Bearing and Non-bearing **PCA EPD -** Ingredient Transparency, **LEED v5 -** Recycled Content
Clay/Shale Masonry	1. Load-bearing structural clay ASTM C34 2. Nonload-bearing structural clay ASTM C56 3. Building brick ASTM C62 4. Solid Masonry ASTM C126 5. Structural Clay facing tile ASTM C212 6. Facing brick ASTM C216 7. Hollow Brick ASTM C652 8. Veneer Brick ASTM C1088 9. Glazed Brick ASTM C1405	ASTM C34, C56, C62, C126, C212, C216, C652, C1088, C1405 Literature Review	**ASTM C34-** water absorption, compressive strength, and heat testing (Imperviousness/Hardness/Fire Resistance) **ASTM C56 -** resistance to damage when freezing while wet (Responsiveness, Water Resistance) **ASTM C56 -** resistance to damage when freezing (Responsiveness, Water Resistance) **EPD Clay Masonry -** Embodied Carbon, ingredient transparency, low emissions, chain of custody, responsible extraction, ethical supply
AAC Masonry	Masonry Unit Thin-bed Mortart, TMS 602, Article 2.2.D.1/2	ASTM C1619, C1693	**ASTM C1619 -** Specification of elastomeric Seals for Joining Concrete Structures (Load Adaption, Hardness, Imperviousness, Responsiveness, Self-Healing) **ASTM C1693 -** Standard Specification for Autoclaved Aerated Concrete (Ingredient Transparency) **EPD Autoclaved Aerated Concrete -** Ingredient transparency, responsible extraction,

Stone Masonry	1. Marble building stone 2. Limestone building stone 3. Granite building stone 4. Sandstone Building stone 5. Slate building stone	ASTM C503, C568M, C615, C616, C629	**ASTM C503 -** Standard Specification for Marble Dimension Stone (Responsiveness, Load Adaption) **ASTM C568 -** Limestone **ASTM C615** - Granite Dimension Stone **ASTM C616** - Quartz-based **ASTM C629** - Slate Dimension Stone
Cast Stone		ASTM C1364	**ASTM C1364 -** Standard for Architectural Cast Stone (Ingredient Transparency, Load Adaptation, Responsiveness, Imperviousness, Hardness, Water Resistance)
Lintel	Masonry over openings shall be supported: 1. steel linter 2. reinforced concrete 3. masonry linter 4. masonry arches	IRC R606.10 TMS 402, 403, 404 ASCE 5 ACI 530	**TMS 402/ASCE 5/ACI 530 -** Requirements for Masonry Structures (Load Adaptation, Imperviousness, Responsiveness, Hardness)
Piers	-height shall not exceed 10x the least dimension - hollow masonry should be filled with Type M or S mortar unless the height is less than 4x the smallest dimension - hollow piers should be capped with 4" of solid masonry concrete/cap block	IRC R606.7 TMS 402, 403, 404	**TMS 402/ASCE 5/ACI 530 -** Requirements for Masonry Structures (Load Adaptation, Imperviousness, Responsiveness, Hardness)
Masonry - COVERINGS			
Stone Masonry Veneer		ASTM C1670	**ASTM C1670 -** Standard Specification for Adhered Manufactured Stone Masonry Veneer Units (Ingredient Transparency)
Masonry Veneer	1. Anchored masonry veneer installed over a backing of wood or cold-formed steel 2. Adhered masonry veneer	IRC R703.8 IRC R606.14.2 IRC R703.12 ASTM C1670	**ASTM C1670 -** Standard Specification for Adhered Manufactured Stone Masonry Veneer Units
Arch Cast Stone		ASTM C1364	**ASTM C1364 -** Standard for Architectural Cast Stone (Ingredient Transparency, Load Adaptation, Responsiveness, Imperviousness, Hardness, use life) **ASTM C119-5 -** Water Resistance/Imperviousness **EPD Architectural Precast -**
Masonry - FASTENERS			
Lateral Support	- masonry wall laterally supported in horizontal or vertical direction 1. cross wall 2. pilaster 3. buttresses 4. structural frame 5. Metal reinforcement 6. Bonding pattern -Bars should be wholly embedded in mortar/grout -Joint reinforcement should not have less than 5/8" mortar coverage from the exposed face -Other reinforcement minimum coverage of one bar diameter over bars, but not less than 3/4" unless exposed to weather/soil. It should be 2"" - interior non-load bearing walls with joint reinforcement/anchored	IRC R606.6.4 TMS 402, 403, 404 ASCE 5 ACI 530	**TMS 402/ASCE 5/ACI 530 -** Requirements for Masonry Structures (Load Adaptation, Imperviousness, Responsiveness, Hardness)

	at vertical intervals of 8" or less (joint reinforcement not less than nine gages)."		
Mortar	Type M, S, or N Mortar used in Category a Seismic Design 1. Surface-bonding Mortar 2. AAC Mortar 3. Adhered Masonry Mortar, Type of S or N 4. Grout, Type M or S Shall meet both proportion and property specifications Hydrated lime, a cubic foot of 40lbs masonry/mortar cement, a cubic foot of weight on a bag Portland cement, a cubic foot of 94 lbs. lime putty, a cubic foot of 80 lbs. sand (damp + loose) cubic foot of 80 lbs. of dry sand	IRC R606.2.8 ASTM C270 ASTM C887 - ASTM C946 TMS 602 ASTM C476 IRC Table R606.3.5.1 ASTM C1093 ASTM C780	**ASTM C476 -** Standard Specification for Grout Masonry (Ingredient Transparency, Hardness) **ASTM C270 -** Standard Specification for Mortar for Unit Masonry **ASTM C780 -** Standard Test Methods for Precons. and Const. Evaluation of Mortars for Plain and Reinforced Concrete (Robustness Consistency, Water Resistance, Hardness) **ASTM C1019 -** Load Adaption, Responsiveness
Wall Ties	1. ends should be embedded in the mortar joints (not less than 5/8" mortar coverage on exposed face) 2. not to be bent after embedded in grout/mortar 3. solid masonry units/solid grouted hollow/hollow units in anchored veneer wall ties embedded not less than 1.5" in mortar 4. hollow masonry unit (not in anchored veneer) should engage outer face shells not less than 1/2"	IRC R606.3.3 IRC R606.3.4.1 ASTM A153, Class B-2 ASTM A641, Class 1 ASTM A167	**ASTM A153 -** Standard Spec. for Zinc Coating on Iron and Steel Hardware (Chain of Custody) **ASTM A641 -** Standard Specification for Zinc-Coated Carbon Steel Wire (Load Adaptation) **ASTM A176 -** Standard Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip (Flame Resistance) **EPD Steel Ties -** Ingredient transparency, multi-context, multi-application,
Anchor Bolts	Anchor to Roof 1. metal strap anchors, 1/2 bolts spaced at least 16" into the masonry. Anchor to Floor 1. metal strap anchors spaced in accordance with manufacturer - 1/2 diameter intervals not exceeding 6' Connection to Masonry Shear Wall Connection to Masonry Column	ASTM A641 Class 3 ASTM A153, Class B-2 IRC R606.6.4.2.1 Florida IRC R606.11 IRC R606.6.4.2.2 TMS 402 Chapter 4	**ASTM A641** - Standard Specification for Zinc-Coated Carbon Steel Wire (Load Adaptation) **ASTM A153** - Standard Spec. for Zinc Coating on Iron and Steel Hardware (Chain of Custody) **TMS 402 Ch. 4 -** Prestressed Masonry (Load Adaption, Robustness Consistency) **ASTM F1554** - Standard Specification for Anchor bolts (Ingredient transparency, multi-context, load adaption, hardness, Responsiveness) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **AISI S100 Section B** - Design Requirements (Load Adaption/Use-Life)
Concrete - CONSTRUCTION/FRAMING			

Exterior Flat	1. 4" max weight 50 psf 2. 6" max weight 75 psf 3. 8" max weight 100 psf 4. 10" max weight 125 psf	PCA 100 ACI 318/332 IRC R608.3 Table ASTM C150/C595/C1157 ASTMC94/C685	**ASTM C150 -** Ingredient Transparency **ASTM C595 -** Standard Spec. for Blended Hydraulic Cement (Responsiveness) **ASTM C1157 -** Standard Spec. for Hydraulic Cement (Responsiveness, Hardness) **ACI 318 -** Building Code Requirements for Structural Concrete (Load Adaptation, Robustness Consistency, Frie Resistance, Responsiveness) **ACI 332 -** Code Requirements for Residential Concrete and Commentary (Imperviousness, Water Resistance, Ingredient Transparency, Load Adaption, Responsiveness) **BES 6001 -** Ethical Supply **LEED v5 -** Recycled Potential/ Florida DEP
Exterior Waffle-Grid	1. 6", max weight 56 psf 2. 8", max weight 76 psf	PCA 100 ACI 318/332 IRC R608.3 Table ASTM C150/C595/C1157	**ASTM C150 -** Ingredient Transparency **ASTM C595 -** Standard Spec. for Blended Hydraulic Cement (Responsiveness) **ASTM C1157 -** Standard Spec. for Hydraulic Cement (Responsiveness, Hardness) **ACI 318 -** Building Code Requirements for Structural Concrete (Load Adaptation, Robustness Consistency, Frie Resistance, Responsiveness) **ACI 332 -** Code Requirements for Residential Concrete and Commentary (Imperviousness, Water Resistance, Ingredient Transparency, Load Adaption, Responsiveness) **BES 6001 -** Ethical Supply **LEED v5 -** Recycled Potential/ Florida DEP
Exterior Screen Grid	1. 6", max weight 53 psf	PCA 100 ACI 318/332 IRC R608.3 Table ASTM C150/C595/C1157	**ASTM C150 -** Ingredient Transparency **ASTM C595 -** Standard Spec. for Blended Hydraulic Cement (Responsiveness) **ASTM C1157 -** Standard Spec. for Hydraulic Cement (Responsiveness, Hardness) **ACI 318 -** Building Code Requirements for Structural Concrete (Load Adaptation, Robustness Consistency, Frie Resistance, Responsiveness) **ACI 332 -** Code Requirements for Residential Concrete and Commentary (Imperviousness, Water Resistance, Ingredient Transparency, Load Adaption, Responsiveness) **BES 6001 -** Ethical Supply **LEED v5 -** Recycled Potential/ Florida DEP
Interior	-both loadbearing and non-loadbearing -light frame construction	PCA 100 ACI 318/332 ACI 318 ASTM C150/C595/C1157	**ASTM C150 -** Ingredient Transparency **ASTM C595 -** Standard Spec. for Blended Hydraulic Cement (Responsiveness) **ASTM C1157 -** Standard Spec. for Hydraulic Cement (Responsiveness, Hardness) **ACI 318 -** Building Code Requirements for Structural Concrete (Load Adaptation, Robustness Consistency, Frie Resistance, Responsiveness) **ACI 332 -** Code Requirements for Residential Concrete and Commentary (Imperviousness, Water Resistance, Ingredient Transparency, Load Adaption, Responsiveness) **BES 6001 -** Ethical Supply **LEED v5 -** Recycled Potential/ Florida DEP
Concrete - COVERINGS			
Interior Covering	1. Rigid foam plastic shall be protected 2. Gypsum board is used to protect foam with mechanical fastening system	IRC R608.4.2 IRC R303.4 IRC R702.3.4	**IRC 602.4 -** (Flame resistance) AWPA U1 - Usable Wood Species and Preservatives (Responsiveness) **USG SA100 -** (Flame resistance, smoke resistance)

	All interior stay-in-place forms should have a covering installed with a mechanical fastening system or an adhesive in addition to mechanical fasteners		EPD - Rigid Foam Board
Exterior Covering	-Rigid foam plastics (constructing stay-in-place forms) should be protected from sunlight and physical damage with exterior wall coverings, i.e., veneer, stucco, etc.	IRC R608.4.3	**IRC 602.4 -** (Flame resistance) AWPA U1 - Usable Wood Species and Preservatives (Responsiveness) **USG SA100 -** (Flame resistance, smoke resistance) EPD - Rigid Foam Board
Concrete - FASTENERS			
Anchor Bolts	- Can be bolted with heads OR double-end threaded rods - bolts and heads must be Great A or Grade 36 - the threaded end of a rod must be embedded into the concrete with a hex or square nut	ASTM A307/F1554/A36 TMS 402 Chapter 4	**ASTM A307 -** Standard specification of carbon Steel Bolts, Studs, and Threaded Bolt (Ingredient transparency, hardness, load adaption, responsiveness) **ASTM F1554-** Standard Specification for Steel Anchor Bolts (hardness, ingredient transparency, Responsiveness, load adaptation) **ASTM A36 -** Standard Specification for Carbon Structural Steel (Hardness, load adaption)
Tension Tie	-Angles and tension tie straps fabricated from sheet steel	ASTM A653/A792/A875 Grade 33	**ASTM A653-** Standard specification for steel sheet, zinc-coated or zinc-iron ally-coated (hardness, load adaption, fire resistance, imperviousness) **ASTM A792 -** Standard Specification for Steel Sheet (imperviousness, heat resistance, load adaption, hardness, **ASTM A875 -** Standard Specification for Steel Sheet Zinc 5% (imperviousness, hardness)
Steel Reinforcement		ASTMA615, ASTM A706, ASTM A996 (Type R)	**ASTM A615 -** Standard Specification for Deformed/Plain Carbon-Steel Bars (ingredient transparency, load adaption, responsiveness) **ASTM A706 -** Standard Specification for Deformed and Plain Low-Alloy Steel Bars (load adaption) **ASTM A996 -** Standard Specification for Rail-Steel and Axle-Steel Deformed Bars (hardness, load adaption) **SIPA EPD -** Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Openings			
Garage Door Glazed Opening	1. Located within 30' of grade shall meet the requirements of large missile test ASTM E1996 2. Located more than 30' above grade shall meet small missile test Cyclic Pressure + Large Missle 1. 9lb window/ 4.5lb skylight 2. 4-8lb window/2 lb skylight	ANSI/DASMA 115 ASTM E1886 ASTM E1996	**DASMA 115 -** Standard Method for Testing section/rolling/flexible doors (load adaption, responsiveness, multi-context) **ASTM E1886 -** Standard Test Method for Performance of Exterior window/curtainwall, door/impact systems (load adaption) **ASTM E1996** - (load adaption) **EPD Opening with Glass**
Plywood/OSB		OIR-B1-1802 Meeting FBC 2007 Table 1609.1.2 AWC NDS	**AISI S240** - Tensile Strength, Yield Stress, Bending Rigidity, Shear Strength (Responsiveness, Hardness, Load Adaption) **ASTM/UL 263 -** Fire Resistance **IRC R603.9.5 -** (Multi-context, Multi-Application) **AWC Plywood EPD -** (Embodied Carbon, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction) **AWC -** Use life, water resistance

Non-Glazed Entry/Garage Door		OIR-B1-1802 ASTM E 330, ANSI/DASMA 108, PA/TAS 202	**ASTM E330 -** Uniform Static Air pressure difference (load adaption) **DASMA 108 -** Uniform Static Air pressure difference (load adaption, hardness, **TAS 202 -** Testing application standard for testing impact and nonimpact-resistant building envelope (load adaptation, water intrusion, responsiveness, robustness consistency, regional availability) **EPD** - Reclaim/Reuse, embodied carbon, chain of custody, use-life, recyclable potential
ROOF CONSTRUCTION			
CONSTRUCTION/FRAMING			
Dimensional Lumber/ Tongue & Groove	1. 2 nails/board 2. 1 nail/board if <6" depth	OIR-B1-1802	**AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential))
Reinforced Concrete	Should be utilized as specific "normal" or "lightweight" due to different insulation capacities	OIR-B1-1802 UL BXUV	**ASTM C150 -** Ingredient Transparency **ASTM C595 -** Standard Spec. for Blended Hydraulic Cement (Responsiveness) **ASTM C1157 -** Standard Spec. for Hydraulic Cement (Responsiveness, Hardness) **ACI 318 -** Building Code Requirements for Structural Concrete (Load Adaptation, Robustness Consistency, Frie Resistance, Responsiveness) **ACI 332 -** Code Requirements for Residential Concrete and Commentary (Imperviousness, Water Resistance, Ingredient Transparency, Load Adaption, Responsiveness) **BES 6001 -** Ethical Supply **LEED v5 -** Recycled Potential/ Florida DEP
Wood Roof Framing	Constitutes: rafters, purlins, joists, bearing walls, and beams/boards. Continuous ties across the structure to prevent roof thrust from being applied to supporting walls.	FBC R802 FBC Section R301.2.1.1 ANSI AWS NDS IRC R606.11(1-3)	**ASTM/UL 263 -** Flame Resistance **ASTM D4761** - Mechanical Properties of Wood-Based Structural Materials (Hardness / Load Adaptation) **ASTM D2555** - Wood Strength Testing (Hardness) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746** - Robustness Consistency
Cold-Form Steel Roof Framing	Constitutes: rafters, bracing, joist, ridge bearing, and bearing walls. All properties should be compliant with FBC R804 Wind uplift strength (for 140mpb Cat B): 1. studs @ 24", roof span 32' = 330 lb connector strength 2. studs @ 24", roof span 36' = 371 lb connector strength 3. studs @ 24", roof span 40', = 411 lb connector strength Steel joists should consider the slab structure to establish the spacing requirements of joints.	FBC R804 ANSI S240 ANSI S230 FBC R603.3.1 UL BXUV	**AISI S230 Table A1-3** - Types of Steel to Use Per Wind Climate (Imperviousness) **FRC R407.2** - Coating of Rust Resistance & Anti-Corrosive Solutions (Responsiveness/Imperviousness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **AISI S100 Section B -** Design Requirements (Load Adaption/Use-Life) **AISI S240 -** Protective coating/corrosion protection (Water Resistance) **ASTM C955** - Penetration Test - Procedure for evaluating member's ability to pull the head of a screw below the surface of gypsum panel product (Self-healing) **SIPA EPD** - Ingredient Transparency, Ethical

			Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Steel Beam	W8x28 Composite/Non-Composite Steel beam 10% load reduction, 0.9 load restricted factor If being used to replace a steel stud or wood stud load-bearing wall, the wall must not have a higher fire rating than the beam, the structural capacity of the beam must be equal or greater than that of the wall, and the level of restraint/strength of the connections must be equal or greater than that of the wall.	BXUV - UL 263	**ASTM/UL 263 -** Flame Resistance **AISI S230** Table A1-3 - Types of Steel To Use Per Wind Climate (Imperviousness) **FRC R407.2** - Coating of Rust Resistance & Anti-Corrosive Solutions (Responsiveness/Imperviousness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100** Section L - Serviceability (Use-Life / Robustness Consistency) **AISI S100** Section M - Design for Fatigue (Responsiveness) **AISI S100** Section B - Design Requirements (Load Adaption/Use-Life) **AISI S240** - Protective coating/corrosion protection (Water Resistance) **ASTM C955** - Penetration Test - Procedure for evaluating member's ability to pull the head of a screw below the surface of gypsum panel product (Self-healing) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Steel Decking	Thickness is determined with a 5% tolerance, allowable load described by the manufacturer, and strength testing completed.	UL BXUV	**SIPA EPD -** Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Batten Decking		OIR-B1-1802 ASTM D6294	**ASTM/UL 263 -** Flame Resistance **ASTM D4761** - Mechanical Properties of Wood-Based Structural Materials (Hardness / Load Adaptation) **ASTM D2555** - Wood Strength Testing (Hardness) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746** - Robustness Consistency
Lumber Sheathing	Thickness and span should be compliant with FBC R803.1	FBC R803.1	**ASTM E661** - Deflection and Damage Resistance Testing (Responsiveness / Load Adaptation) **ASTM D2555** - Wood Strength Testing (Hardness) **ASTM D2718** - Shear Strength of Structural Panels (Hardness / Load Adaptation) **ASTM D3043** - Structural Panels in Flexure (Responsiveness / Load Adaptation) **DOC PS 1 Section 6.1.3.3** - Boiling Test (Water Resistance / Imperviousness) **DOC PS 1 Section 6.1.3.4** - Heat Performance Testing (Flame Resistance) **AWC South EPD** - (Embodied Carbon, Low

			Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential))
Plywood/OSB Roof Sheathing	Attached to the truss/rafter 1. 6d Nails, 6" at edge, 12" in field 2. 7/16" thickness, 8d Nails, 12" in field 3. 7/16" thickness, 8d nailed, 6" in field	OIR-B1-1802	**AISI S240** - Tensile Strength, Yield Stress, Bending Rigidity, Shear Strength (Responsiveness, Hardness, Load Adaption) **ASTM/UL 263 -** Fire Resistance **IRC R603.9.5 -** (multi-context, multi-application) **AWC Plywood EPD -** (Embodied Carbon, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction) **AWC -** Use life, water resistance
Wood Structural Paneling Sheathing	Thickness and span should be compliant with FBC R803.2	FBC R803.1	**IRC 602.3 (3)** - sheathing applied to exterior face shall we wind resistant according to classification category (Load Adaptation) **R602.1.8 -** panels should be identified for grade, bond classification, and performance category (Ingredient transparency) **R602.12.2 -** Sheathing material used to construct a bracing unit (multi-context) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential) **ASTM D4933** - Robustness Consistency / **ASTM D6513** - Robustness Consistency/Load Bearing / **ASTM D6815** - Recovery Reliability, use-life
COVERING			
Wood Shingles	installed following RAS 130, underlayment, tested according to the Cedar Shake and Shingle Bureau, must be attached with stainless steel ring-shank nails	FBC R902.2 FBC Table R907.7.4 AWPA C1 (U1) FBC R905.7	**AWPA U1** - Ingredient Transparency, **ASTM D226** **ASTM D4869** - Responsiveness, Water - Resistance, Hardness, Load adaption, Imperviousness **AWC EPD**
Wood Shakes	installed following RAS 130, underlayment, tested according to the Cedar Shake and Shingle Bureau, must be attached with stainless steel ring-shank nails	FBC R905.8 FBC Table R905.8.5 AWPA Standard U1	**AWPA U1** - Ingredient Transparency, **ASTM D226** **ASTM D4869** - Responsiveness, Water - Resistance, Hardness, Load adaption, Imperviousness **AWC EPD**
Asphalt Shingles	installed with flashing, wind tested to meet Table R905.2.6.1, no less than four fasteners/shingle, fasteners of min. 12-gauge nails complying with ASTM F1667, drip edge, sidewall flashing, valley lining	FBC R905.2 (material) ASTM D3462	**ASTM D3462 -** Water Resistance, Load Adaption, Responsiveness, Fire Resistance, Smoke resistance, Hardness, Imperviousness **Asphalt Shingles EPD -** Ingredient Transparency, Low Emissions, Embodied Carbon, recyclable potential, regional availability, chain of custody,
Clay Roof Tile	installed over solid sheathing, required underlayment, installed with FRSA/TRI installation manual, installed with attachment wire in compliance with ICC R905.3	FBC 905.3.4 (material) ASTM C1167	**ASTM C1167 -** Hardness, Load Adaption, Responsiveness, Water Resistance, Fire Resistance, Smoke Resistance, Imperviousness **Clay Tile EPD -** use life, chain of custody, **BES 6001** - responsible extraction, ingredient transparency, recycled content, regional availability, low emissions, ethical supply, embodied carbon

Concrete Roof Tile	installed over solid sheathing, required underlayment, installed with FRSA/TRI installation manual, installed with attachment wire in compliance with ICC R905.3	FBC R905.3.5 (material) ASTM C1492	**ASTM C1492 -** Ingredient transparency, imperviousness, load adaption, water resistance, smoke resistance, fire resistance **Concrete EPD -** use-life
Metal Roof Shingle	applied to solid/loosely fit deck/underlayment must comply with FBC Table R905.4.4	FBC R905.4 ASTM D3161/UL 580/ UL1897	**UL 580 -** Fire resistance, smoke resistance, responsiveness, load adaption **Steel EPD**
Mineral-Surface Roll Roofing	solid sheathed roof	FBC R905.5 (material) ASTM D3909/ASTM D6380/ CLASS M OR WS	**ASTM D3909 -** Hardness **ASTM D6380 -** Responsiveness, Water Resistance, Imperviousness, Load Adaption, smoke resistance, fire resistance
Slate Shingles	solid sheathed roof, flashing Table R903.2,	FBC R905.6 ASTM D3161 (material) ASTM C406	**ASTM D3161 -** Load adaption, self-healing, responsiveness, fire resistance, smoke resistance, **ASTM C406 -** Imperviousness, Hardness **GSA Specification -** Water Resistance, regional availability, **Slate EPD -** Chain of custody, embodied carbon, ingredient transparency, ethical supply, low emissions
Metal Roof Panel	applied to solid or spaced sheathing	FBC R905.10 FBC Table R905.4.4	**Steel EPD** **IRC 905.10.3**
FASTENERS			
Nails		FBC R904.5.1 ASTM F1667 TAS 114, Appendix E ASTM C1513 UL BXUV	**ASTM F680-20 -** Standard Test Methods of Nails (Load Adaption, Responsiveness, Self-Healing) **TAS 114 Appendix E - Procedure** for Corrosion Resistance (Water Resistance, Responsiveness, Use-life) **ASTM C1513 -** Standard Spec for Steel Tapping Screws (hardness, load adaption, responsiveness, hardness)
Screws	wood screws	FBC R904.2 ANSI/ASMEB 18.6.1 UL BXUV	**AISI S904** - Tensile and Shear Strength of Screws (Hardness / Imperviousness) **ASTM C1513** - Standard Spec for Steel Tapping Screws (hardness, load adaption, responsiveness, hardness)
Underlayment	for asphalt shingles/metal shingles/ mineral wool/slate/wood shakes/wood shingles	FBC R905.1.1.1 Table R905.1.1.1	**USGA SA100 -** (Fire Resistance, Smoke Resistance) **ASTM F2678**
Toe Nails	1. Truss/Rafter anchored to the top of wall plate with nails at an angle 2. Metal connectors 3. Metal connectors secure to truss/rafter with three nail min. 4. Metal connectors attached to the top of wall framing/bond beam with less than 1/2" gap from blocking + blocked no more than 1.5" of truss/rafter + no visible corrosion	OIR-B1-1802 ASTM F680-20 TAS 114, Appendix E UL BXUV	**ASTM F680-20 -** Standard Test Methods of Nails (Load Adaption, Responsiveness, Self-Healing) **TAS 114 Appendix E -** Procedure for Corrosion Resistance (Water Resistance, Responsiveness Use-life)
Single Wrap	1. Metal connector, single strap over truss/rafter, two nails at front min., one nail on opposite side min.	OIR-B1-1802	**SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Double Wrap	1. Metal connector, two straps over truss/rafter attached to one side wall frame/bond beam, two nails at front min., one nail on opposing min. 2. Metal connectors, one strap over truss/rafter, attached both sides of the wall, secured to top plate w/ 3	OIR-B1-1802	**SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential

	nail min. both sides		
Clip Angle	1. Metal connector, no-wrap 2. Metal connector, one strap, three nail min.	OIR-B1-1802 FBC 904.5.3 ASTM A90/A90M, TAS 114 Appendix E	**ASTM A90** - Standard Method for Weight of Coating on Iron and Steel (ingredient transparency) **TAS 114** - Test for Roof Assemblies (responsiveness, imperviousness, water resistance, fire resistance, load adaption) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, *Recyclable Potential*
Anchor Bolts	1. Anchor bolts connected 2. Reinforced concrete roof	ASTM A370 AISI S100 Section M AISI S906 OIR-B1-1802	**AISI S906** - Anchor Structural Tests (Hardness / Imperviousness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section M** - Design for Fatigue (Responsiveness)
FOUNDATION			
Wood - CONSTRUCTION/FRAMING			
Wooden Studs	Must be pressure-preserved treated, dried after. Any cut or drilled ends must be treated with copper naphthenate until the wood cannot absorb more. 2" by 6" members with a spacing of 16" on center with at least 1,250 psi resistance (ANSI AWC NDS). If 12" on center, then wood species must resist 875 psi.	AWPA U1 / IRC R402.1.2 / FBC R402.1.2 / IRC R406.3 / IRC R407.1 (R317)	**AWPA U1** - Usable Wood Species and Preservatives (Responsiveness) **IRC R406.3** - Damp proofing of Wood Foundation Members (Imperviousness / Water Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential))
Wooden Footings	Built-in accordance with Figures R403.1(2) and R403.1(3)	AWC PWF	**AWPA U1** - Usable Wood Species and Preservatives (Responsiveness) **IRC R406.3** - Damp proofing of Wood Foundation Members (Imperviousness / Water Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential))
Wood - FASTENERS			
Fasteners	**Below Grade**: Plywood to the exterior of basements, crawl-space wall studs, or fasteners in knee-wall construction must be Type 304 or 316 stainless steel. **Above Grade**: Plywood to lumber-to-lumber fasteners (non-knee wall construction) must be Type 304 or 316 stainless steel, silicon bronze, copper, hot-dipped galvanized (zinc coated) steel nails, or hot-tumbled galvanized (zinc coated) steel nails.	IRC R402.1.1 / ASTM C1002	**AISI S904** - Tensile and Shear Strength of Screws (Hardness / Imperviousness) **ASTM C1002** - Overall Specification for Steel Screws to Wood Joinery (Hardness / Imperviousness / Load Adaptation) **ASTM F680** - Standard Test Methods for Nails (Responsiveness / Load Adaptation / Self-Healing)
Wood Sole Plate		AWC WFCM	**AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential))
Concrete - CONSTRUCTION/FRAMING			

Concrete	Compressive strength is shown in Table R402.2. Concrete subject to moderate-severe weathering in Table R301.2 must be air-entrained based on Table R402.2. The maximum weight of all elements of concrete mixtures for garage floor slabs/exterior porches, carports, and steps with exposure to deicing chemicals can't exceed percentages of the total weight in Section 19.3.3.4 of ACI 318. Materials in concrete production and testing must be compliant with Chapters 19 and 20 of ACI 318 or ACI 332 and R608.5.1	Table R402.2 / FBC (Residential) 301.2 / ACI 318 19.3.3.4 / ACI 318 19 or 20 / ACI 332 19 or 20 / R608.5.1 / ASCE 32 / R406.1 / R406.2	**IRC Table R402.2** - Minimum Compressive Strength (Load Adaptation/Hardness) **FBC Section 301.2** - Wind Speed Resistance (Load Adaptation-Wind) **ACI 318 19.3** - Strength Testing of Concrete (Hardness/Load Adaptation/Flame Resistance) **ACI 332 R84** - Residential Cast-In-Place Concrete (Hardness/Imperviousness/Responsiveness Reactivity to Weather) ASTM **C33** - Concrete Aggregate Specifications (Ingredient Transparency)
Precast Concrete	Designed following R404.5. All materials must meet the following requirements: **1)** Concrete must have a minimum compressive strength of 5,000 psi at 28 days. Freezing and thawing environments must be air-entrained with a minimum total air content of 5 percent. **2)** Structural reinforcing steel meets ASTM A615, A706M, or A996M. Minimum yield strength shall be 40,000 psi. Steel reinforcement shall be covered by at least 3/4 inch of concrete. **3)** Panel-to-panel connections are Grade II steel fasteners, and **4)** nonstructural fibers conform to ASTM C1116. **5)** Grout used for bedding foundations on concrete footings shall meet ASTM C1107	ASTM A615 / A706M / A996M / ASTM C1116	**ASTM A706M** - Tensile Strength of Rebar (Hardness/Responsiveness) **ASTM C33** - Concrete Aggregate Specifications (Ingredient Transparency)
Concrete Footings	Minimum sizes come from Tables R403.1(1) through R403.1(3) and Figure R403.1(1). Must also resist uplift and overturn of the building based on Table R401.1 and R403.1.2	R403 / ACI 332 / Table R401.4.1 / ASCE 32 / R403.1 / Figure R403.4(2)	**ACI 332 R84** - Residential Cast-In-Place Concrete (Hardness/Imperviousness/Responsiveness Reactivity to Weather) **ASTM C33** - Concrete Aggregate Specifications (Ingredient Transparency)
Crushed Stone Footings	Free from organic, clayey, or silty soils. Angular in nature and must meet ASTM C33 with the maximum stone size being less than 1/2 inch and the minimum stone being bigger than 1/16 inch - Min compressive strength of 1,500 psi	R403.4.1 / Figure 403.4(1) / Table R403.4	**ASTM C33** - Concrete Aggregate Specifications (Ingredient Transparency, Water Resistance, Responsiveness, Imperviousness, Robustness Consistency) **R403.4.1** - Limited by Seismic Requirements (Load Adaption) **Crushed Aggregated EPD** **ASTM D692** - Hardness
Concrete Foundation Walls	Designed with the provisions ACI 318 / ACI 332 / PCA 100 Cross section complies to Table R608.3 or ACI 318		**ASTM C33** - Concrete Aggregate Specifications (Ingredient Transparency)
Concrete - FASTENERS			
Mortar/Grout	Shall be type M or type S mortar	IRC R404.1.2.1(1-2) / ASTM C1107	**ASTM C1107** - Strength of Grout Under Pressure (Hardness/Imperviousness/Responsiveness) **ASTM E119 -** Fire Resistance, Smoke Resistance **Cement Mortar EPD** - Ingredient Transparency, COC,
Steel - CONSTRUCTION/FRAMING			

Cold-formed Steel Framing		AISI S230 / R407.2	**AISI S230 Table A1-3** - Types of Steel To Use Per Wind Climate (Imperviousness) **FRC R407.2** - Coating of Rust Resistance & Anti-Corrosive Solutions (Responsiveness/Imperviousness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ASTM C955** - Penetration Test - Procedure for evaluating member's ability to pull the head of a screw below the surface of gypsum panel product (Self-healing) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Steel - FASTENERS			
Steel Reinforcement (Concrete)	Shall comply with ASTM A615 A706M or A996. A996 bars (rail steel) shall be Type R. Located at the centerline of the wall	ASTM A615/A370 AISI S100 SIPA EPD	**ASTM A615** - Tensile Strength of Rebar (Hardness/Responsiveness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Standard Hook/ Anchor Bolt	Shall comply with Section R608.5.4.5 and Figure R608.5.4	ASTM A370 AISI S100 SIPA EPD	**ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Masonry - CONSTRUCTION/FRAMING			
Masonry Foundation Walls	Designed by TMS 402 / ACI 530/ ASCE 5	R406.1 / R406.2	**ACI 530 -** Ingredient Transparency, Load Adaption, Fire Resistance, Responsiveness, Robustness Consistency **ASCE 5 -** Water Resistance, Recovery Reliability **Masonry EPD -** Sustainability factors
FLOOR-CEILING			
WOOD - Construction/Framing			
Exposed Grid System	Designed by approved engineering practice.	ANSI/UL 263 / IRC Section 304.2.1 USGA SA100 ASTM C635, C645	**ANSI/UL 263** - Flame Resistance Considerations / **IRC Section 304.2.1** - Preservative Treatment **USGA SA100** - (Flame Resistance, Smoke Resistance)

Concealed Grid System	Designed by approved engineering practice.	ANSI/UL 263 / IRC Section 304.2.1 USGA SA100 ASTM C635, C645	**ANSI/UL 263** - Flame Resistance Considerations / **IRC Section 304.2.1** - Preservative Treatment **USGA SA100** - (Flame Resistance, Smoke Resistance)
Dimensional Lumber	Designed by approved engineering practice.	ANSI/UL 263 / IRC Section 304.2.1 USGA SA100	**ANSI/UL 263** - Flame Resistance Considerations / **IRC Section 304.2.1** - Preservative Treatment **USGA SA100** - (Flame Resistance, Smoke Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746** - Robustness Consistency
Metal Furring Channel	(26 gauge) 24" o.c. (18 gauge) 8" steel channel	USGA SA100	**USGA SA100 -** (Fire Resistance, Smoke Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Wooden Joist	Designed by approved engineering practice. 2 x 10, 16" o.c. 2 x 10, 24" o.c.	ANSI/UL 263 / IRC Section 304.2.1 USGA SA100	**ANSI/UL 263** - Flame Resistance Considerations / **IRC Section 304.2.1** - Preservative Treatment **USGA SA100** - (Flame Resistance, Smoke Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746** - Robustness Consistency
Wooden Truss	- Parallel Chord Truss 24" o.c., 11-7/8", 12" - Wood Truss 24" o.c.	ANSI/UL 263 / IRC Section 304.2.1 USGA SA100	**ANSI/UL 263** - Flame Resistance Considerations / **IRC Section 304.2.1** - Preservative Treatment **USGA SA100** - (Flame Resistance, Smoke Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746** - Robustness Consistency
Wooden Girder		ANSI/UL 263 / IRC Section 304.2.1 USGA SA100	**ANSI/UL 263** - Flame Resistance Considerations / **IRC Section 304.2.1** - Preservative Treatment **USGA SA100** - (Flame Resistance, Smoke Resistance) **AWC South EPD** - (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746** - Robustness Consistency
WOOD - Covering			

Subfloor	OSB/Plywood/Wood 1", 1-1/4", 15/32", 19/32", 23/32"	ANSI/UL 263 / IRC Section 304.2.1 USGA SA100	**ANSI/UL 263** - Flame Resistance Considerations / **IRC Section 304.2.1** - Preservative Treatment **USGA SA100** - (Flame Resistance, Smoke Resistance) **AWC Plywood EPD** - (Embodied Carbon, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction) **ASTM D7746** - Robustness Consistency **AISI S240** - Tensile Strength, Yield Stress, Bending Rigidity, Shear Strength (Responsiveness, Hardness, Load Adaption) **IRC R603.9.5** - (multi-context, multi-application) **AWC** - Use life, water resistance."
WOOD - Fasteners			
Underlayment	3/4", 1-1/2"	USGA SA100 ASTM F2873/F2678	**USGA SA100 -** (Fire Resistance, Smoke Resistance) **ASTM F2678 -**
Metal Sheet Fasteners		ANSI / TP1	**ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
CONCRETE - Construction/Framing			
Exposed Grid System	Designed by approved engineering practice.	USGA SA100 ASTM C635, C645, IRC Section 304.1.2	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ATSM A635 -** Load Adaption, responsiveness, multi-context/multi-application **ASTM AC645 -** Self Healing **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA100** - Flame resistance, smoke resistance **Upcodes -**Stainless steel - steel sustainability
Concealed Grid System	Designed by approved engineering practice.	USGA SA100 ASTM C635, C645 IRC Section 304.1.2	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ATSM A635 -** Load Adaption, responsiveness, multi-context/multi-application **ASTM AC645 -** Self Healing **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA100** - Flame resistance, smoke resistance **Upcodes -**Stainless steel - steel sustainability
Precast Concrete	Normal Weight/Lightweight Concrete - 2" precast with 6" deep stems, 48" o.c. - 2" prestressed with 6" deep stems - 8" precast normal weight - 8" min thick precast - 8" min lightweight precast - 2.5" lightweight (J504) Precast Units - 4' or 8' precast units - 6", 8", 10", and 12" precast units	USGA SA100	**USGA SA100 -** (Fire Resistance, Smoke Resistance)
Concrete Slab-On-Ground	Minimum of 3.5" thick Must have contraction joints unless 1) Reinforced with fiber synthetic material that complies with ASTM	ACI 332 / FRC R402.2	**ACI 332 R84** - Residential Cast-In-Place Concrete (Hardness/Imperviousness/Responsiveness Reactivity to Weather)

	C1116 or 2) Reinforced with a weld wire system in the upper third of the slab that complies with ASTM A1064/A1064 M Carbon-Steel Wire and Welded Wire Reinforcement.		
Concrete on Steel Deck	- 2-2.5" concrete on fluted or cellular steel floor - 3-1/4" concrete on 1.5" steel roof deck - 3-1/4" concrete	USGA SA100	**USGA SA100 -** (Fire Resistance, Smoke Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Metal Furring Channel	24" o.c.	USGA SA100	**USGA SA100 -** (Fire Resistance, Smoke Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
CONCRETE - Fasteners			
Underlayment	3/4", 1" Self-leveling, poured gypsum, wood sheathing, subfloor, etc.	USGA SA100 ASTM F2873/F2678	**USGA SA100 -** (Fire Resistance, Smoke Resistance) **ASTM F2678 -**
Contraction Joint		ACI 332 ASTM D545	**ACI 332 R84** - Residential Cast-In-Place Concrete (Hardness/Imperviousness/Responsiveness Reactivity to Weather) **ASTM D545**- Imperviousness, Water Resistance, Responsiveness, Use-life, Recovery Reliability
STEEL - Construction/Framing			
Steel Structural Members	Must comply with AISI S201, must yield 33 ksi	AISI S201/S100 ASCE7 ASTM A370/A924	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA100** - Flame resistance, smoke resistance **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Steel Nonstructural Members	Must comply with AISI S201, must yield 33 ksi	AISI S201	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness)

			ANSI/UL 263 - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Steel Truss	Must comply with AISI S201, must yield 33 ksi	AISI S201 USGA SA100	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Steel C-Joist	Must comply with AISI S201, must yield 33 ksi - Typical 24" o.c.	AISI S201 USGA SA100	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Steel Bar Joist	Typical 24" o.c. - 4' o.c.	AISI S201 USGA SA100	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance)

			AISI S100 Section L - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Concrete Deck		USGA SA100	**USGA SA100 -** (Fire resistance, smoke resistance)
Concrete on Rib-lath Deck	- 2" Concrete, 3-1/4" Concrete	USGA SA100 ASTM A1063	**USGA SA100 -** (Fire resistance, smoke resistance) **ASTM 1063 -** Responsiveness, Water Resistance,
Concrete Corrugated Steel Deck	- 2.5" Concrete	USGA SA100	**USGA SA100 -** (Fire resistance, smoke resistance) **SIPA EPD -** Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Metal Furring Channel	- Typical 24" o.c.	USGA SA100	**USGA SA100 -** (Fire resistance, smoke resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Concealed Grid System	- Light duty, Intermediate Duty, or Heavy Duty	USGA SA100 ASTM C635, C645	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ATSM A635 -** Load Adaption, responsiveness, multi-context/multi-application **ASTM AC645 -** Self Healing **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA100** - Flame resistance, smoke resistance **Upcodes -**Stainless steel - steel sustainability
Exposed Grid System	- Light duty, Intermediate Duty, or Heavy Duty	USGA SA100 ASTM C635, C645	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ATSM A635 -** Load Adaption, responsiveness, multi-context/multi-application **ASTM AC645 -** Self Healing **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA100** - Flame resistance, smoke resistance **Upcodes -**Stainless steel - steel sustainability
STEEL - Covering			
Plywood	- 5/8", 3/4", or 3/4"	USGA SA100	**USGA SA100 -** Fire Resistance, Smoke Resistance **AWC Plywood EPD -** (Embodied Carbon, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction)

Steel Sheet		ATSM A1003 Structural Grade 33 Type H Steel	**ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential **AISI S100 Section M** - Design for Fatigue (Responsiveness)
STEEL - Fasteners			
Metal Sheet Fasteners		ANSI / TP1	**ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ASTM 307** - Carbon Steel Product Strength (Imperviousness / Load and Resistance / Ingredient Transparency) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Anchor Bolts	ANSI 360 Section I8 - Anchor Bolts	ASTM A370 AISI S100 Section M AISI S906	**AISI S906** - Anchor Structural Tests (Hardness / Imperviousness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section M** - Design for Fatigue (Responsiveness)
Metal Screws			**AISI S904** - Tensile and Shear Strength of Screws (Hardness / Imperviousness) **AISI S914** - Joist Connector Strength Testing (Imperviousness) **ASTM A370** - Overall Tensile/Strength Testing for Steel Products (Hardness/Imperviousness) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ASTM 307** - Carbon Steel Product Strength (Imperviousness / Load and Resistance / Ingredient Transparency) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance)
ROOF-CEILING			
Wood - CONSTRUCTION/FRAMING			
Ceiling Joist	- Shall be continuous across the structure or securely joined where they meet over interior partitions - Connected to the top plate - Bearing should not be less than 1.5" on wood/metal or 3" on masonry/concrete	IRC R801.2/3 AWC NDS IRC R802.5	I**RC R801.2 -** Load Adaptation **IRC 801.2 -** Imperviousness **AWC South EPD -** (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746 -** Robustness Consistency

Wood Rafters	- Shall be nailed to the top plate by Table R602.3(1) - Shall be supported by a wall or ridge beam - Designed by accepted engineering practices - Bearing should not be less than 1.5" on wood/metal or 3" on masonry/concrete - Cantilevered portion shall not be less than 3.5" after being notched/ not exceed 24" in the cantilever	IRC R801.2/3 IRC R802.6 AWC NDS	**IRC R801.2 -** Load Adaptation **IRC 801.2 -** Imperviousness **AWC South EPD -** (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746 -** Robustness Consistency
Wood-Ridge	- Used to connect opposing rafter, not less than 1" nom. thickness and not less in-depth than the cut end of the rafter	IRC R801.2/3 AWC NDS IRC R 802.4.1(1)	**IRC R801.2 -** Load Adaptation **IRC 801.2 -** Imperviousness **AWC South EPD -** (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential)) **ASTM D7746 -** Robustness Consistency
Wood Truss	- drawings should be provided with the shipment of the truss to the job site - dead load and live load outlines in drawings - designed by approved engineering practices - max speed 140 mph	USGA SA100 IRC R801.2 IRC R801.3 AWC NDS ANSI/TPI 1 R106.1	**USGA SA100 -** Fire Resistance + Smoke Resistance **IRC R801.2 -** Load Adaptation **IRC 801.2 -** Imperviousness **AWC South EPD -** (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential) **ASTM D7746 -** Robustness Consistency
Wood - COVERINGS			
Lumber Sheathing	- Spaced lumber sheathing for wood shingle and shake roofing shall conform to R905.7/.8	USGA SA100 IRC R803.1 AWC NDS	**USGA SA100 -** Fire Resistance + Smoke Resistance **IRC R801.2** - Load Adaptation **ASTM E661** - Deflection and Damage Resistance Testing (Responsiveness / Load Adaptation) **ASTM D2555** - Wood Strength Testing (Hardness) **ASTM D2718** - Shear Strength of Structural Panels (Hardness / Load Adaptation) **ASTM D3043** - Structural Panels in Flexure (Responsiveness / Load Adaptation) **DOC PS 1 Section 6.1.3.3** - Boiling Test (Water Resistance / Imperviousness) **DOC PS 1 Section 6.1.3.4** - Heat Performance Testing (Flame Resistance) **AWC South EPD -** (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential))
Wood Structural Paneling Sheathing	- Designed to be permanently exposed to outdoor conditions	USGA SA100 IRC R801.2 AWC NDS DOC PS 1, 2 CSA O325, 0437 IRC R803.2.1.1 APA E30	**USGA SA100 -** Fire Resistance + Smoke Resistance **IRC R801.2** - Load Adaptation **IRC R803.2.1.1 -** Responsiveness **APA E30 -** **CSA 0325 -** **CSA 0437** **DOC PS 1, 2** **AWC South EPD -** (Embodied Carbon, Low Emissions, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction, Reclaim/Reuse, Recyclable Potential))

Plywood Sheathing	- 1/2"	USGA SA100 IRC R801.2 AWC NDS	**USGA SA100 -** Fire Resistance + Smoke Resistance **IRC R801.2** - Load Adaptation **IRC 803.2.1.1 -** Fire Resistance **AWC Plywood EPD** - (Embodied Carbon, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction)
Wood - FASTENERS			
Nails		FBC R904.5.1 ASTM F1667 TAS 114, Appendix E ASTM C1513 UL BXUV	**ASTM F680-20 -** Standard Test Methods of Nails (Load Adaption, Responsiveness, Self-Healing, Hardness) **TAS 114 Appendix E - Procedure** for Corrosion Resistance (Water Resistance, Responsiveness, Use-life) **ASTM A653 -** Hardness
Rafter Ties	- Prevent roof thrust from being applied to the supporting wall - Not less than 2" by 4" installed following R802.5.2(1) at a max. of 24" o.c.	IRC R802.5.2.1	**IRC R802.5.2.1 -** Ground/Snow load/ heel joint adjustment (load adaption)
Cold-Form Steel - CONSTRUCTION/FRAMING			
Plywood Deck	23/32"	USGA SA100 IRC R801.2 IRC R801.3	**USGA SA100 -** Fire Resistance + Smoke Resistance **IRC R801.2 -** Load Adaptation **IRC R801.3 -** Imperviousness **AWC Plywood EPD -** (Embodied Carbon, Ingredient Transparency, Ethical Supply, Regional Availability, Responsible Extraction)
Steel Roof Deck	- 7/8: roof deck + 1" noncombustible insulation - 1-1/2" steel roof deck + 3/4" noncombustible insulation - 1-1/2" steel roof deck + 1" noncombustible insulation - 1-1/2" steel roof deck + 1/2" gypsum - 1" fluted steel roof deck - 2" insulated concrete on 9/16" corrugated steel deck - 9/16" deep roof deck - rib type steel roof	AISI S201/S230 USGA SA100 IRC R801.2 IRC R801.3	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance) **AISI S230** Table A1-3 - Types of Steel To Use Per Wind Climate (Imperviousness) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential

Steel Truss	- min. 11-7/8" deep steel roof truss - 48" oc. - Connected to the top track of the load-bearing wall with the required number of No. 10 screws applied through the flange of the truss or using a 54-mil clip angle with the required number of No. 10 screws in each leg	AISI S201/S230 USGA SA100 IRC R801.2 IRC R801.3 IRC R804.3.6 CFSBCSI	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance) **AISI S230** Table A1-3 - Types of Steel To Use Per Wind Climate (Imperviousness) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Steel Rafter	- Size based on the horizontal projection of the roof rafter span - Braced with a member of 45 degrees - Min. connection with No. 10 screws - Max 6" between brace/ceiling joist connection and load-bearing wall	AISI S201/S230 IRC R801.2 IRC R801.3 IRC R804.3.2.1	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance) **AISI S230** Table A1-3 - Types of Steel To Use Per Wind Climate (Imperviousness) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Steel Bar Joist	Typical 24" oc. - 4' o.c. 8" deep steel bar joists - Shall have bearing support length of not less than 1.5" and shall be connected to roof rafters with No. 10 screws - Where continuous joists are framed across interior bearing supports, the interior bearing supports shall be located within 24" of the midspan of the ceiling joist - Shall be laterally braced - Shall be connected to the top track of the load-bearing wall with No. 10 screws applied through the flange of the joist or using a 54 mil clip angle with the required number	AISI S201/S230 USGA SA100 IRC R801.2 IRC R801.3 IRC R804.3.1.1(1-3)	**AISI S240 A4.1.1** - Corrosive Material Coating (Imperviousness) **ASCE7 Section 6.4 or 6.5** - Wind Resistance Testing **ATSM A370** - Elongation Testing (Responsiveness / Imperviousness) **ASTM A924** - Coating Properties (Imperviousness) **AISI S902** - Strength of Cross-Sectional Steel Beam (Load and Resistance) **AISI S100 Section L** - Serviceability (Use-Life / Robustness Consistency) **AISI S100 Section M** - Design for Fatigue (Responsiveness) **ANSI/UL 263** - Flame Resistance Considerations (Flame Resistance) **USGA SA 100 -** (Flame Resistance, Smoke Resistance)

	of No. 10 screws in each leg		**AISI S230** Table A1-3 - Types of Steel to Use Per Wind Climate (Imperviousness) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Recyclable Potential
Cold-Form Steel - COVERING			
Structural Sheathing	- attached with minimum No. 8 self-drill tapping screws - Minimum head diameter of 7.4mm with countersunk heads, installed with min. Edge distance of 3/8"	USGA SA100 AISI S240	**USGA SA100 -** Fire Resistance + Smoke Resistance **AISI S240 -** Tensile Strength, Yield Stress, Bending Rigidity, Shear Strength (Responsiveness, Hardness, Load Adaption)
Gypsum Board	2" Laminated, 1/2" foam board, 2" laminated 1/2" sheathing - Shall be fastened with No. 6 Screws (section R702) - use for ceiling diaphragm	USGA SA100 ASTM C1396 ASTM C1278 ASTM C473	**USGA SA100 - (**Fire Resistance + Smoke Resistance) **ASTM C1396 -** Standard Spec for GWB (Imperviousness, fire resistance, hardness, self-healing, water resistance, responsiveness) **ASTM C1278 -** Standard Spec for Fiber-Reinforced Gypsum Panel (imperviousness, water resistance) **ASTM C473 -** (Responsiveness, Self-Healing)
Cold-Form Steel - FASTENER			
Clip Angle	- Shall have a steel thickness equivalent to or greater than the roof rafter thickness - Shall extend the depth of the roof rafter member to the extent possible	IRC R804.3.2.4 ASTM A90/A90M, TAS 114 Appendix E	**ASTM A90 -** Standard Method for Weight of Coating on Iron and Steel (ingredient transparency) **TAS 114 -** Test for Roof Assemblies (responsiveness, imperviousness, water resistance, fire resistance, load adaption) **SIPA EPD** - Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Steel Straps	- Minimum size of 1.5" by 33 mils - Installed at a max spacing of 4' - Fastened to the bottom flange at each joist with one No. 8 screw, fastened to blocking with 2 No. 8 screws	IRC R804.3.1.2 ASTM E84	**ASTM A653 -** Standard Spec for Steel Sheet, zinc coated (hardness, fire resistance, smoke resistance, load resistance, imperviousness) **ASTM E84 -** (robustness consistency) **SIPA EPD -** Ingredient Transparency, Ethical Supply, Responsible Extraction, Regional Availability, Chain of Custody, Embodied Carbon, Recyclable Potential
Screws	- Shall be installed with a minimum edge distance and center-to-center spacing of 1/2", shall be self-drilling tapping - No. 8, 6, 10	ASTM C1513 ASTM C954	**ASTM C1513 -** Standard Spec for Steel Tapping Screws (hardness, load adaption, responsiveness, hardness) **ASTM C954 -** Hardness, Load Adaption **AISI S904 -** Tensile and Shear Strength of Screws (Hardness / Imperviousness)

This relational database enables the categorization of performance tests for various material assemblies, directly assessing their impact on building structural integrity. By focusing on material assemblies, the database provides a more comprehensive understanding of the requirements needed for a structure to achieve optimal resilience performance. This enhanced understanding informed the development of practical applications that translate resilience research into real-world building practices.

Material assemblies play a pivotal role in safeguarding structural integrity against environmental hazards, especially those related to water intrusion. The thoughtful selection and integration of material assemblies are essential for preserving a building's strength, enhancing its capacity to withstand environmental challenges, and minimizing the risks and consequences of water-related damage. By deepening our understanding of how material assemblies contribute to structural resilience, we can identify which combinations of assemblies and architectural components offer the greatest return on investment for effectively addressing water intrusion.

The team developed structural building sections that incorporate key resilience principles of material assemblies, demonstrating their application in single-family residences. The following details outline how these assemblies are integrated within specific structural components:

1. **Engineering material assemblies for structural components** by combining water-resistant materials with integrated moisture-barrier systems to deliver robust protection for foundations and walls.
2. **Designing cohesive material assemblies** that synergize multiple water-resistant elements, such as precisely overlapped flashing, appropriately sealed windows and doors, and strategically positioned vapor barriers, to enhance overall system performance.
3. **Implementing comprehensive water-resistant assembly strategies** that incorporate extended roof vents and overhangs, high-efficiency guttering, optimized water runoff assemblies, and the application of advanced waterproof coatings to exterior material assemblies.

As previously noted, it is essential to follow all manufacturer instructions and installation guidelines for each material assembly to ensure optimal performance and maintain product warranties. The general building sections and strategies outlined above and section details that follow are intended to serve as reference guides and should be adapted in accordance with specific product requirements and best practices.

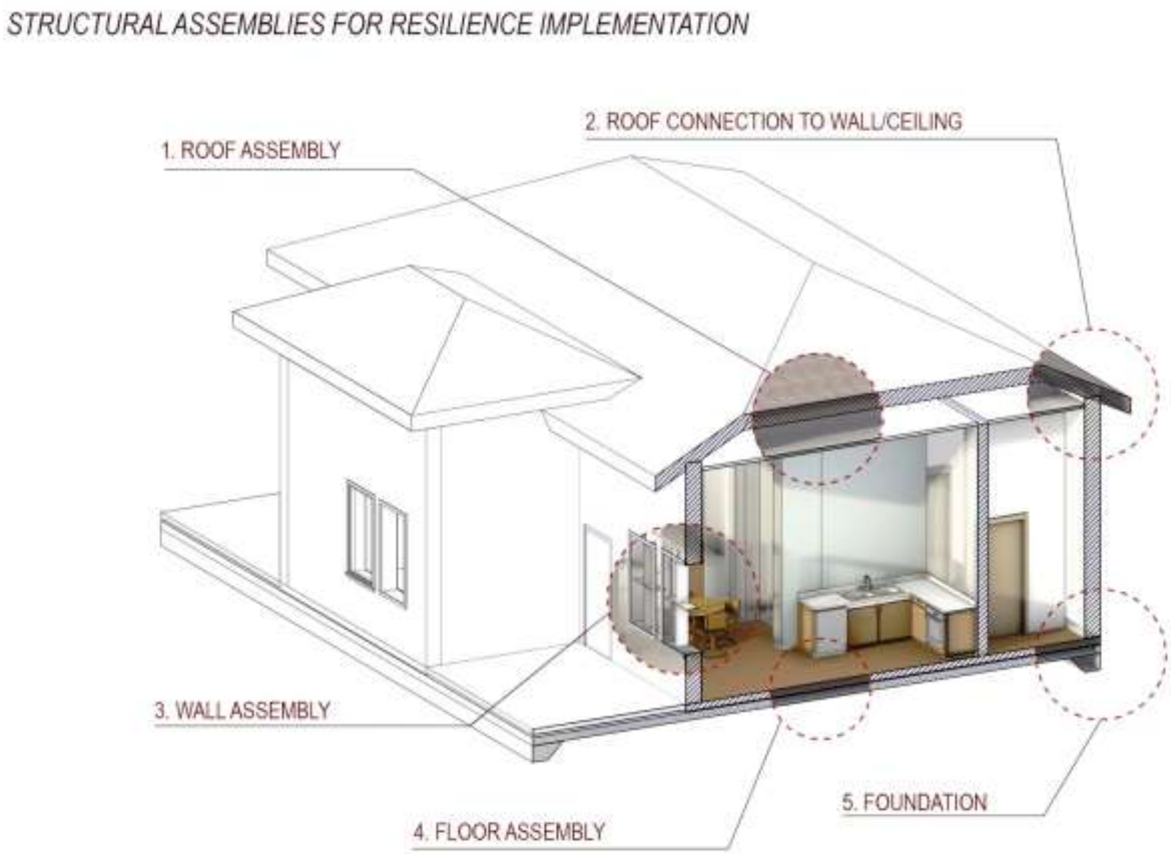


Figure 10. *Isometric Diagram Highlighting Key Structural Locations and Material Assemblies Critical to Resilience*

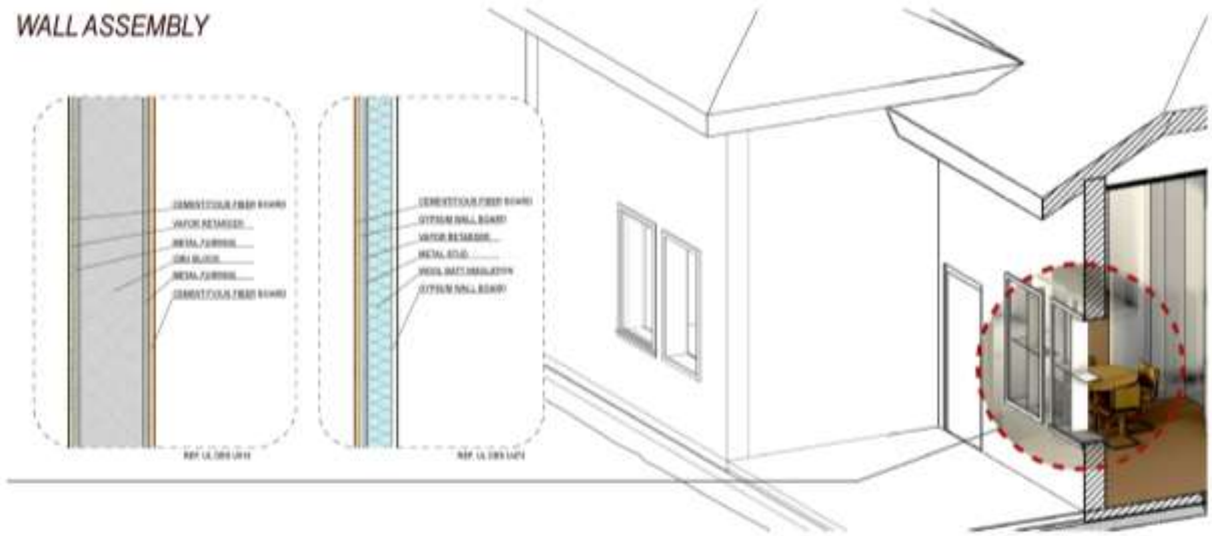


Figure 11. *Blow-up of structural detail for wall material assembly*

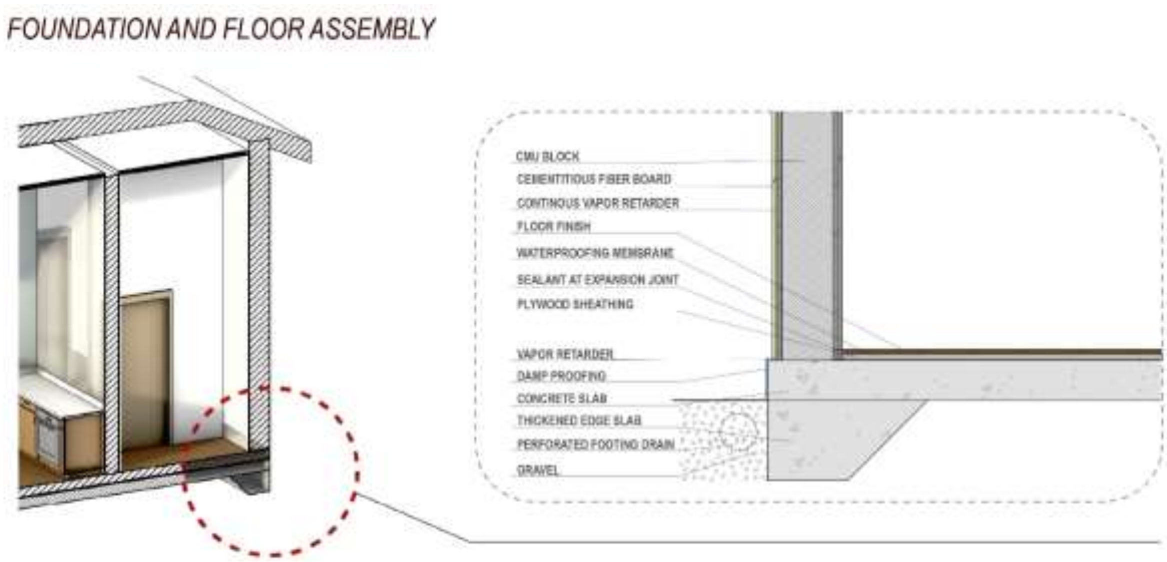


Figure 12. *Detail of moisture resistant floor material assembly*

This section has illustrated how the RIPL approach has been adapted to assess the performance of material assemblies within structural components, focusing on their capacity to withstand environmental stresses. The following section will shift attention to the integration of Smart Home technologies as a complementary strategy for strengthening both material assemblies and overall building resilience. It will examine how the RIPL methodology interfaces with a range of Smart Home technologies, their interactions, and their collective impact on a building's ability to resist and recover from water-related challenges. Through this analysis, the report aims to offer actionable insights for optimizing building material design and technological integration, ultimately enhancing resilience, reducing insurance risks and premiums, and supporting long-term durability.

Framework Development for Smart Home Technology Assessment

The final stage of the RIPL resource guide analysis framework was to evaluate the effectiveness of smart home technologies in mitigating water intrusion risks. Homeowners' insurers have offered discounts to homeowners that installed battery-powered smoke detectors since the 1970s. Studies show that early warning leads to faster evacuation and reduced property damage (51). More recently, insurers have been offering incentives to homeowners to purchase Smart technology products such as smart leak-detection sensors, recognizing that early detection can significantly reduce damage. These efforts by insurers are raising awareness among homeowners about the importance of resiliency more generally.

As a result, there is growing interest in practical solutions that can enhance a home's ability to withstand and recover from water-related incidents. This approach encompassed a comprehensive analysis of the functionality and integration of various devices, such as smart water leak detectors and sensors, within residential systems.

Smart Home Technology Assessment Methodology

1. Technical Specification Evaluation: A representative sample of smart home system technical specifications was assessed and categorized by contextual application:
    - Water monitoring
    - Gas monitoring
    - Electric monitoring
    - Foundation monitoring
2. Qualitative TPM Specifications: Given the context-dependent nature of smart home technology systems, TPM (Technical Performance Measure) specifications were qualitative, featuring capability statements rather than quantitative performance variables.

3. Loss Reduction Capability Assessment: The evaluation of technologies articulated specific loss reduction capabilities in the entire database delivered as an appendix to this report.

This refined methodology enabled several critical outcomes:

1. Identification of key vulnerabilities in water intrusion prevention within smart home systems.
2. Assessment of device effectiveness and integration techniques in specific residential contexts.
3. Evaluation of current testing methods' ability to simulate real-world water exposure scenarios and their impact on overall system resilience.

By applying this approach, the team aimed to enhance understanding of how smart home technologies, device integration, and application contexts contribute to reducing water-related risks. These insights could lead to lower insurance premiums for homeowners adopting such risk-reducing technologies.

Smart Home Technology Comparative Analysis

The following table illustrates a stoplight report delineating a purposeful sample of context-specific smart home technologies and their associated risk capabilities in a feature comparison table. This analysis proves crucial in the context of smart home resilience due to the complexity of interconnected systems compared to standalone devices.

Table 4. RIPL Comparison Table for Single Family Home Smart Home Technologies

(*Detailed specifications of Smart Home Technology performance characteristics can be found in the Appendix section of this report)*

💧 Water Leak Prevention & Shutoff

Product	Auto Shutoff	Leak Detection	Smartphone Control	Good for Homes w/
Ezlo Smart Water Shutoff – Splice Pipe	🟢 Yes	🟢 Optimal	🟢 Full App Control	Ideal for homes with smart home systems
Flo by Moen	🟢 Yes	🟢 Optimal	🟢 Full App Control	Daily water usage, smart speaker integrations
FloLogic	🟢 Yes	🟢 Continuous	🟢 Yes (w/manual override)	Concern about hidden or slow leaks
Guardian by Elexa	🟢 Yes	🟢 Floor + Drip	🟢 Yes	Basement/crawlspace leaks; wide valve coverage
StreamLabs	🟢 Yes	🟢 24/7 Monitoring	🟢 Yes	Frequent travel; remote response needs
Kohler H2Wise+	🟢 Yes	🟢 Fast Response	🟢 Yes	High-end or newer plumbing systems
WaterCop	🟢 Manual reopen	🟡 Basic	🟡 3rd-party alerts only	Budget-conscious retrofits
Flume	🔴 No Shutoff	🟡 Usage Monitoring	🟢 Yes (No shutoff)	Want alerts only; no plumbing modification

🔥 Gas Leak and Safety Shutoff

Product	Auto Shutoff	Gas/Fire Detection	Remote Access
Smartico	🟢 Yes	🟢 Multiple Sensors	🟢 Dispatch-ready

Lorax Systems	🟢 Yes	🟢 Advanced + Optional	🟢 Cloud App
AGS Mini Merlin	🟢 Yes	🟢 Fire/Gas Trigger	🔴 Manual Only
PSP Valve / Firefighter	🟢 Yes	🔴 No	🔴 No

⚡ Smart Electrical Control Panels

Product	Smart Shutoff	Circuit Monitoring	App Control
Span Panel	🟢 Yes	🟢 Detailed per circuit	🟢 Yes
Lumin Smart Panel	🟢 Yes	🟢 Real-time Load Shed	🟢 Yes
Schneider Pulse	🟢 Yes	🟢 With Surge Protection	🟢 Yes
Leviton Smart Breaker	🟢 Yes	🟢 Full Control	🟢 Yes
Simple Touch Outlet	🟢 Timer Only	🔴 No	🔴 No

🧱 Foundation Monitoring

Product	Structural Alerts	Smartphone Access
Slabsure	🟢 Yes	🟢 Yes
Orly by Olshan	🟢 Yes	🟢 Yes

The integration of smart home technology, particularly sensors, is facilitating the growth of parametric insurance, a type of policy that is gaining traction in the market. With parametric insurance, homeowners receive a predetermined payout when specific conditions are met (for example, if a sensor detects floodwater reaching 2 feet inside the home). While the initial underwriting process is more complex, this approach is attracting attention because it eliminates the need for lengthy loss assessments and damage evaluations, as payouts are based on predefined triggers detected by smart home sensors. The Figure 13 presents a saturation diagram that delineates the feature sets and response capability levels for Smart Home Water Leak Prevention, Gas Leak & Safety Shutoff, Smart Electric Control Panels, and Foundation Monitoring. This visualization enables clear comparison of how each feature operates across varying levels of system response and integration. Together, these advancements illustrate how the integration of smart home technologies may streamline insurance processes and enhance homeowners' ability to prevent, detect, and respond to risks, ultimately supporting more resilient and efficiently protected living environments.

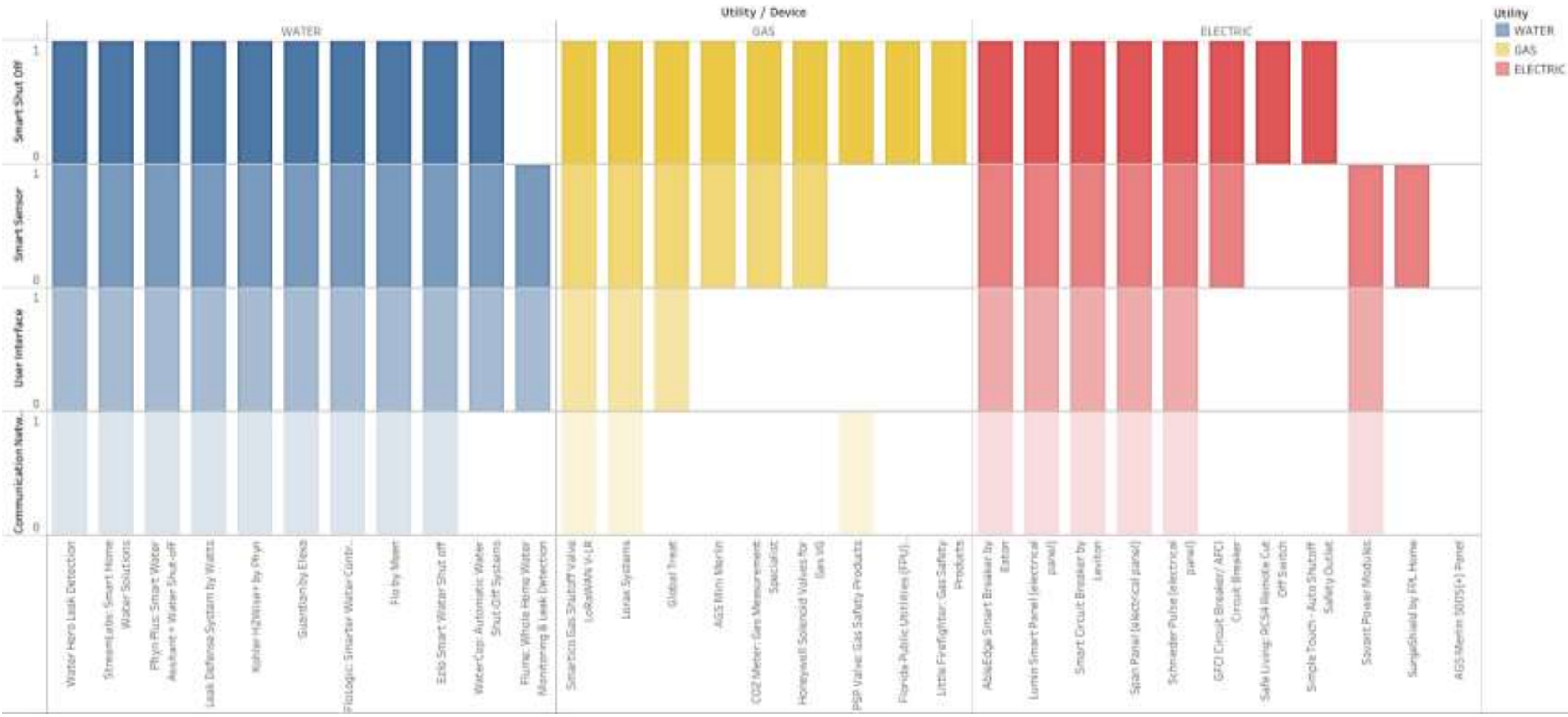


Figure 13. Saturation Analysis of Smart Home Safety Technologies Relevant to Water Intrusion Risks

Return on Investment for Automatic Shutoff Systems

Homeowners who choose to protect their residences with external mitigation devices encourage and improve their homes' lifespan and resiliency. Incorporating automatic shutoff systems for utilities, which, if unmonitored, can cause damage to the house, offers a sense of security to the integrity of single-family residences. Automatic shutoff systems can be utilized by homeowners in the context of water, gas, and electrical utility services within and outside of the home.

Smart home technology such as commercial water mitigation and shutoff systems, gas shutoff systems, and electricity monitoring provide single-family residences with an added incentive to utilize an extra layer of protection through programs offering a return on investment (ROI). The ROI seen by users can typically be observed and received in the form of prevention savings, decreased insurance premiums, and rebates from utility companies with verification of an accurately functioning system.

Resiliency and Catastrophe Modeling

Individual insurers have some experience, gleaned from historical loss events, from which to evaluate how various building characteristics contribute to natural disaster losses, but they generally turn to catastrophe models to perform more robust analysis of potential losses to their exposures. Catastrophe models simulate possible future events using data from 100s of years of historical natural disasters (52). Simulated future events represent a wide spectrum of potential scenarios, including extremely rare but severe events, which are crucial for assessing vulnerabilities and enhancing resilience against unforeseen disasters. Components of simulated event intensity (e.g., wind speed) are translated into structural losses (e.g., roof damage) through engineering models that consider many characteristics of the property (e.g., type of roof). Several characteristics of flood risk make modeling challenging including, for example, the accuracy of resolution: a flood event can have significantly different impact on homes even 50-100 meters apart (53).

Computational modeling of complex system behaviors has proven highly effective for assessing the resilience of built environments to natural hazards, and some of these systems models have gained recognition within actuarial science. While statistical methods are effective for applications such as short-term forecasting, life insurance, and pension analysis, they often struggle to capture the dynamic interactions characteristic of complex systems (54). This limitation stems from a foundational assumption in statistical forecasting that historical patterns can reliably predict future outcomes which may not hold in rapidly evolving or highly interconnected environments (55,56). Traditional regression-based techniques are generally not designed for long-term forecasting or for uncovering complex interdependencies among variables, which can lead to misinterpretations of causality and correlation (55).

The innovative integration of computational modeling and actuarial approaches within the RIPL model enables comprehensive evaluation and comparison of resilience strategies, accounting for the complexity and evolving nature of built environments. By bridging actuarial science with resilience assessment, the RIPL model offers insurance regulators the scaffold for developing integrated tools for risk evaluation and informed policy development.

Preliminary Combined Systems Performance Predictive Models

Precise linear models describing material system behavior at key operational points of SAMPL™ can inform the development of 'IF-THEN' performance inference rules, as referenced in (57), which are utilized within the RIPL Material and Smart Home Technology Fuzzy Inference System predictive model. By accurately characterizing material responses, these models enhance the reliability and specificity of the rule-based inference framework, supporting more robust performance predictions. This human-in-the-loop AI technique offers significant advantages, particularly in system component performance inference. When applied to tabular data, it can surpass other explanation methods regarding interpretability. This superiority stems from its high expressive power and transparency, allowing more precise insights into system behavior and decision-making processes (58).

Fuzzy Inference Models facilitate decision-making by employing rules that emulate human common-sense reasoning, rather than relying solely on precise probabilities—which are often difficult to establish in complex environments. This approach allows computational systems to interpret qualitative performance descriptors in a manner analogous to human assessment. For instance, a rule might state: “If the housing material resists moisture and smart home technologies respond effectively to water entry, then the home is resilient to moisture damage.” Through fuzzy inference, RIPL can more effectively estimate the risk of moisture intrusion and assess a home’s resilience by evaluating the integrated performance of both building materials and smart technologies in mitigating post-hazard impacts. A 3D interactive mesh model demonstrates, like the one pictured in Figure 14 illustrates how the combination of material resilience reliability and Smart Home Technology response dependability influences a home's overall resilience. High-quality, water-resistant materials paired with dependable smart sensors, such as leak detectors and automated shutoff valves, create a layered defense that significantly enhances structural protection against hazards like leaks, floods, and extreme temperatures. This computational modeling approach, exemplified by the RIPL Fuzzy Resilience Inference Model, allows researchers to explore various risk scenarios and better predict how homes will withstand natural hazards. Unlike traditional probabilistic models, which often oversimplify and may not capture the unique responses of individual homes, fuzzy modeling offers a more flexible and realistic assessment. This enables smarter investment decisions in both durable materials and responsive technologies, ultimately supporting the design of safer, more resilient homes prepared for real-world challenges.

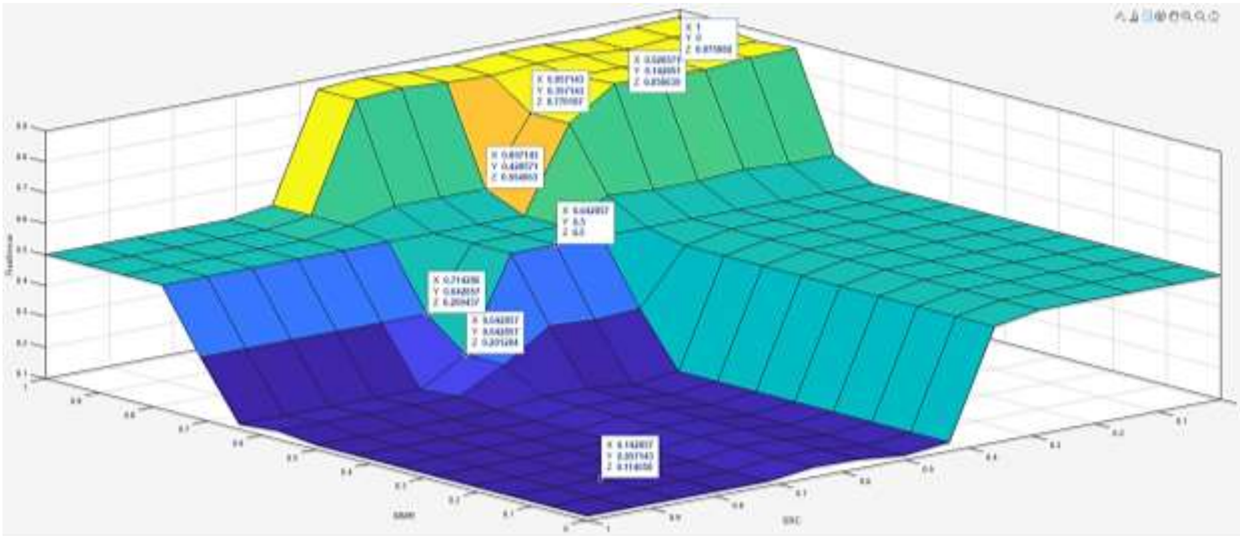


Figure 14. Mesh Model of RIPL Fuzzy Inference System

Preliminary Integrative Systems Performance Predictive Models

One of the greatest challenges in designing resilient homes and built environments is understanding how the various components of a home interact to achieve specific performance goals under complex and dynamic conditions. Research shows that human decision-making, especially when it involves recognizing patterns and predicting outcomes in systems with many interdependent elements, is difficult, even for highly experienced professionals (59). This difficulty arises because cause-and-effect relationships are often obscured in organizationally complex systems, where both internal and external factors interact in unpredictable ways.

System Dynamics Modeling, originally developed from engineering feedback control theory, is a powerful systems engineering technique for analyzing how different design elements and external influences collectively shape a home's resilience over time (60,61). This methodology focuses on the behavior of key variables, such as the flow and accumulation of resources or stresses within a structure, and provides a longitudinal view of how design decisions and environmental factors interact (59,62). By capturing these dynamic feedback loops, System Dynamics Modeling helps reveal how changes to building materials, layout, or smart technologies can influence a home's ability to withstand hazards.

As data science becomes increasingly integral to improving built environment resilience, System Dynamics enables design teams to visualize how homes respond to changing environmental conditions over time, incorporating both internal design variables and external ecological factors. This approach allows stakeholders to address potential vulnerabilities early in the design process, or at least concurrently with design improvements. The process of developing predictive simulation models also supports collaborative, stakeholder-driven design, ensuring that practical needs and feedback are integrated into both the planning and implementation phases (63). By centering the design process on real-world stakeholder input and iterative refinement, this methodology increases the likelihood that specific design features will meet broader resilience objectives, ultimately enhancing the reliability, adaptability, and overall performance of residential structures.

In the RIPL report analysis System Dynamics modeling was employed to create a preliminary model that investigates how specific home features, such as building materials and smart home technologies, may affect the risk of water intrusion during extreme weather events. Drawing on empirical data from major storms in Florida, the model incorporates both weather-related and internal sources of water damage. Utilizing the SIR (Susceptible, Impacted, and Recovered) framework, the animation demonstrates how robust material selection and responsive smart technologies can reduce the number of homes affected by water intrusion and accelerate post-event recovery.

Figure 15 illustrates how the RIPL SIR (Susceptible, Impacted, and Recovered) model predicts the impact of material performance and smart home technology on water intrusion during weather events. The performance values for Material Reliability and Smart Home Technology capabilities used in the SIR model simulations analysis were derived from the RIPL Fuzzy Inference System developed and discussed in the previous section. The model demonstrates that enhancing the quality of building materials and the responsiveness of smart home systems reduces the number of homes affected by water intrusion, while lowering the performance of these features increases vulnerability and the number of impacted homes. This visualization underscores the critical role that both robust materials and advanced technologies play in improving home resilience to extreme weather.

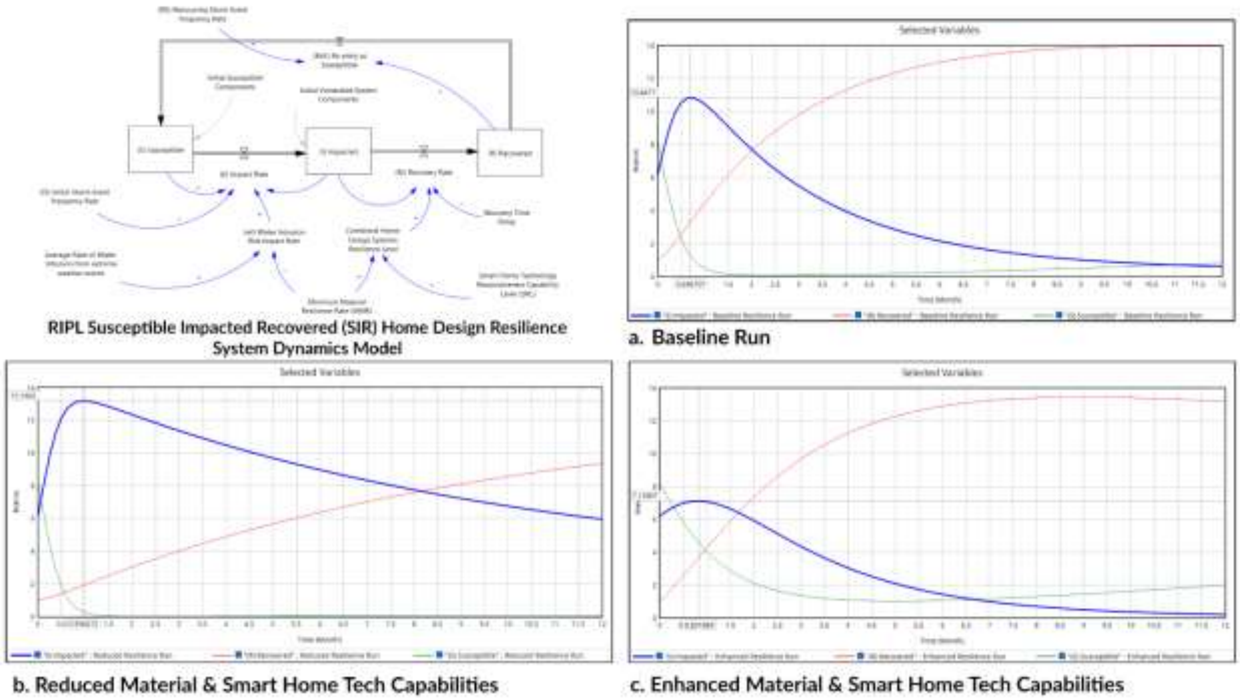


Figure 15. RIPL Florida Housing Resilience SIR Model Outputs a. Baseline, b. Reduced Material & Smart Home Tech Systems Capabilities, c. Enhanced Material & Smart Home Tech

This approach enables a comprehensive evaluation of water intrusion risks and informs home design strategies that can minimize damage, ultimately supporting efforts to lower insurance premiums by enhancing overall resilience

Smart Home Technology Prevention Savings

Water damage is unpredictable, and damage extends beyond the vicinity of the leak. Average water damage, including ceiling damage, to homes can cost an average of $12,500 and upwards (64). Additionally, 60%-70% of homeowners will identify a leak they were unaware of within the first 30 hours of installing smart water mitigation devices (65,66). Incorporating water regulation and smart shutoff systems decreases water damage claims between 80%-96% across various systems (64,67,68).

Return on the incorporation of smart monitoring and detection systems for gas shutoff and regulation reflects in the prevention of life-altering, property-damaging, and potentially fatal gas leaks and fires (69). In the state of Florida, when gas lines pass the residential meter, maintenance becomes the responsibility of the homeowner. Repair bills can reach the hundreds if residents are ignorant of this responsibility and do not continually monitor their gas lines (70).

In Tampa, Florida, gas line inspection for leaks and health can range between $50-$100, basic repairs costing between $150-500, and $1,200 to $3,500 for complete gas line replacements (71). Across the state of Florida, residents report on community platforms gas line repair costs varying from $293 to $935 (72).

Electricity monitoring systems allow homeowners to accurately understand how much energy is being used toward specific devices and functions within the home. Smart shutoff electrical panels such as Span (73), Lumin (74), and Schneider Pulse (75) allow for remote shutoff of breakers when specific aspects of the home are not in use. Building or modifying a home with a specific amperage requires additional infrastructure that can cost upwards of $70,000 (73). Smart electrical panels power a home utilizing the most cost-efficient form of energy to save homeowners infrastructural costs (73,75).Upon integrating smart electric panels, owners have reported energy cost savings of 15% (73).

Expected Losses, Frequency and Severity

Insurers establish premiums for insurance coverage using formulas that include one most fundamental component: expected losses. In the property insurance context, underwriting is the process in which the first objective is to determine the expected loss for a structure. This step is initiated through applications by prospective customers – questionnaires in which details about the property to be covered are collected – and often continues with inspections to confirm the characteristics of the structure which are most important to determining the resilience of the building.

Insurers estimate expected losses not only for determining the premium, but also, more fundamentally, to decide whether to accept the risk of insuring the property at all. For a homeowners (HO) policy, estimating expected loss takes into consideration all potential sources of loss for which the policy would apply. In a typical HO-3 policy, designed for single family homes, coverage includes the dwelling, personal property, and liability.

The higher the expected losses for a property, the less likely the insurer will accept the risk. If the insurer accepts the risk, a higher expected loss requires a higher premium to ensure the solvency of the insurer. While in the business of taking risks several other factors, such as the availability of reinsurance, intervene in this decision.

Expected losses can be broken down into two main components: the expected frequency of loss and the expected severity of loss. Frequency is represented statistically as the probability that a loss will occur and may be further disaggregated into varying levels of loss: e.g., a 10% chance of a total loss to the structure. In the context of natural disasters, the expected losses to properties are tied to the probability of events of different magnitudes. In the underwriting process, insurers consider specific characteristics of the property that affect the probability of a loss. Outside of estimating losses to the dwelling and personal property from natural disasters, this includes such details as whether a homeowner has a dog or runs a business out of the home.

The estimation of potential loss severity begins with assigning values to the dwelling and personal property. If a mortgage is in place, the lender establishes the value of the dwelling to be insured. Homeowners who do not have debt obligations can elect the amount of coverage on the dwelling. In either case, the homeowner also elects the amount of coverage desired for their personal property and liability.

Effect on Premiums of Reduced Expected Losses

Insurers combine estimates of loss severities with probability of losses to establish expected losses. To the extent that the probability of a loss or the potential severity of a loss is reduced, the expected loss is reduced. A lower expected loss implies a lower *pure premium*, the component of the total or *gross premium* that captures only the expected loss. Insurers cannot charge homeowners only the amount of the expected loss because other costs are incurred in the transfer of the risk to the insurer, e.g., the insurer must cover administrative costs, and their objectives also include having sufficient capital for catastrophic losses as well as making a profit.

The typical homeowner's policy contains several coverages that are affected by resilience efforts. The policy covers damage to the dwelling (coverage A) and other structures (coverage B) subject to the limits purchased by the homeowner. This coverage extends to damages caused by all perils except those explicitly excluded. While some forms of water damage are covered (e.g., from a broken pipe), water intrusion from an outside source is excluded, which requires homeowners in areas with a risk of flooding to obtain coverage from the NFIP or purchase a standalone flood policy from a private insurer. It is important to note that the potential benefits of resiliency, in the form of reduced insurance premiums, depends on the insurance arrangement.

When considering the efforts to improve resiliency, including those described in the previous sections, those shown to reduce potential damage should translate to a lower expected loss and, subsequently, lower premiums. As the previous sections show, some resiliency efforts are designed to reduce the probability of a loss while others are more clearly designed to reduce the severity of the loss. Still others enable faster recovery, which allows the homeowner to move back into the home sooner. To the extent that the insurance arrangement includes coverage for loss of use, the expected loss is also reduced via lower temporary living expenses following a covered property loss. Insurers may be reluctant to lower premiums if the reduction in expected losses is not easy to quantify. As certain activities to make a home more resilient are undertaken, data about their effectiveness may prompt insurers to reduce premiums, but some activities may be too new for confidently estimating the amount for which they reduce losses. The RIPL model can improve the ability of insurers to calculate the benefits of resiliency efforts by attaching values to preventive and recovery capabilities.

Insurance Discounts

Smart water shutoff systems, including StreamLabs (64), Flo by Moen (65), Phyn Plus (66), and Flume (68). FloLogic: Smart Water Control (76), and Guardian (77) work with insurance companies to decrease insurance premiums for flood and water damage. Insurance companies such as AIG, American Family Insurance, Amica, bamboo, BerkleyOne, Chubb, Cincinnati Financial Corp., Farmers Insurance, Hoppo, Liberty Mutual Insurance, Nationwide, Progressive, Proper Insurance, Pure Insurance, Selective, SmartInsure, State Farm, Travelers (65,66) all have a working relationship with one or multiple water monitoring and shutoff devices to offer discounted rates with proper verification of a reliable and functioning shutoff and monitoring system. Insurance premium reductions vary between 3%-15% depending on the device and the insurance provider. Devices such as StreamLabs Monitor, Control, and Scout (64) identify premium reductions between 3%-10%, averaging $45-$150 in savings on a $1,500 annual premium (64). If a leak does occur with the installation of an intelligent monitoring and shutoff device, specific manufacturers, such as Flo by Moen, offer added security by promising to meet insurance premium deductibles up to a $5,000 value (65).

Rebates

Apart from personal insurance policies and premiums, homeowners can often receive a rebate from their local water utility company with proper verification and installation of smart water monitoring and shutoff devices. Specific utility companies provide up to a $100 rebate with the installation of devices such as Flo by Moen and Phyn Plus (65,78). Within the state of Florida, current water rebates are offered by Orlando Utilities Commission (OUC) and North Springs Improvement District (Broward County), up to $100 for approved intelligent water monitoring and shutoff devices, including Flo by Moen, Kohler H2Wise/H2Wise (+), Leak Defense System, Phyn Plus, Phyn Water Assistance and StreamLabs Home Water Monitor and Shutoff System (79,80).

With the passing of the Inflation Reduction Act (2022) rebates are available to families in low and middle-income households for the incorporation of energy-efficient appliances valued at a total budget of $9 million (74). Smart electrical panels and breakers such as the Schneider Pulse, Lumin Smart Panel, and Savant Power Modules are all eligible to receive tax reductions from the Energy Efficient Home Improvement Credit (72,73,75). Improvement of electrical breakers and electrical wiring fall under Section 25C of the IRA stating a maximum tax reduction of 30% of improvement costs up to a total value of $600 (74,81,82). If electrical panel upgrades are accompanied by or support clean energy installations, the Residential Clean Energy Credit, Section 25D, states a 20% uncapped tax credit (74). The maximum credit claim under the Energy Efficient Home Improvement credit can reach an annual maximum of $1,200 (81). The Home Electrification and Appliances Rebate (HEAR) Program, section 50122 of the IRA, offers additional incentives (83). Homeowners and renters alike can receive a 100% rebate of improvement cost if the household income is less than 80% of the average median income (AMI) and 50% rebate if the household is between 80%-150% of AMI (83). Maximum rebates for an electrical load service center upgrade are $4,000, and $2,500 for electrical wiring (83).

Caveats of Smart Home Technology Capabilities

Smart home technologies derive their utility from context-dependent interactions between digital systems and the components of physical environment factors such as materiality and structure. Their effectiveness depends on three critical factors:

1. Environmental Resilience of Building Materials

Intelligent systems (e.g., water leak detectors and energy monitors) rely on the integrity of building materials to function optimally. For instance, flood sensors depend on the hydrophobic properties of building materials (84) to prevent false alarms or system failures during water intrusion.

2. System Integration with Building Structure

Smart shutoff systems for gas/water utilities are most effective when paired with structurally sound and damage-resistant building elements. For example, non-waterproof foundations can still foster mold growth even after shutoffs (85).

3. Performance Interdependence on Building and Regional Contexts

A primary factor in smart home systems' success focuses on systems that complement structural strengths (e.g., smart glass in hurricane-prone areas or address material weaknesses (e.g., moisture sensors in homes with hydrophilic material) (86).

Without this holistic focus that includes a comprehensive understanding of materiality and building structural performance capabilities, smart technologies risk becoming isolated solutions instead of integral parts of a resilient ecosystem. Therefore, the context-aware integration of smart technologies, resilient materials, and structural assemblies ensures immediate functionality and long-term adaptability.

The Sankey diagram below illustrates the interconnections between the smart home technology database categories and the RIPL assessment framework's material and building structure capability matrices. This visualization demonstrates how various smart home technologies align with and contribute to different aspects of resilience as defined in the RIPL framework.

SMART HOME TECHNOLOGIES→ BUILDING SYSTEMS→ MATERIALS

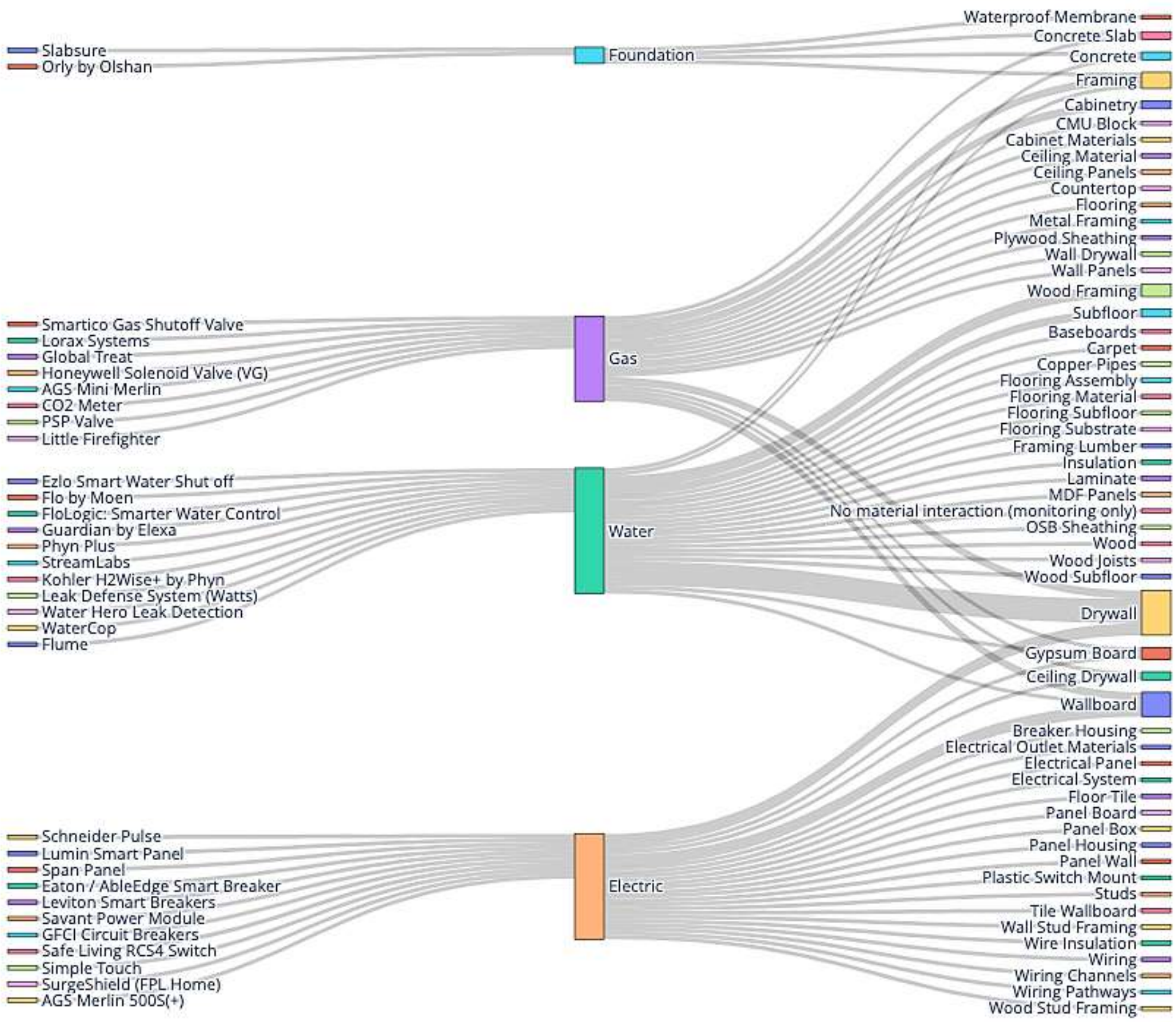


Figure 16. *Sankey Diagram illustrating connectivity between smart home systems, building structural systems, and materiality.*

Guidelines for Smart Home Technology Systems Integration

The following figures illustrate the integration of smart home technologies within the framework of a single-family residence. These visualizations highlight how various systems, such as foundations, gas shutoff devices, water leak detectors, and electrical monitoring sensors, are embedded into the structural and functional elements of the home. By illustrating their placement and interaction with key building components, the figures provide a comprehensive view of how innovative technologies enhance resilience, efficiency, and safety in residential settings.

Figure 17 illustrates automatic water shutoff systems operate by splicing the water line after the residential meter to install a stop valve and remote sensors are placed at fixtures and areas subject to water damage. When a leak is identified through moisture detection or pressure wave analysis, the shutoff valve is activated, and residents receive an alert via app notification. Automatic gas shutoff systems are installed between the street and the residential meter. A solenoid valve will automatically close when energized by an external gas detector. Residents are alerted to gas leaks by alarm systems, smartphone apps, or smart home system integration.

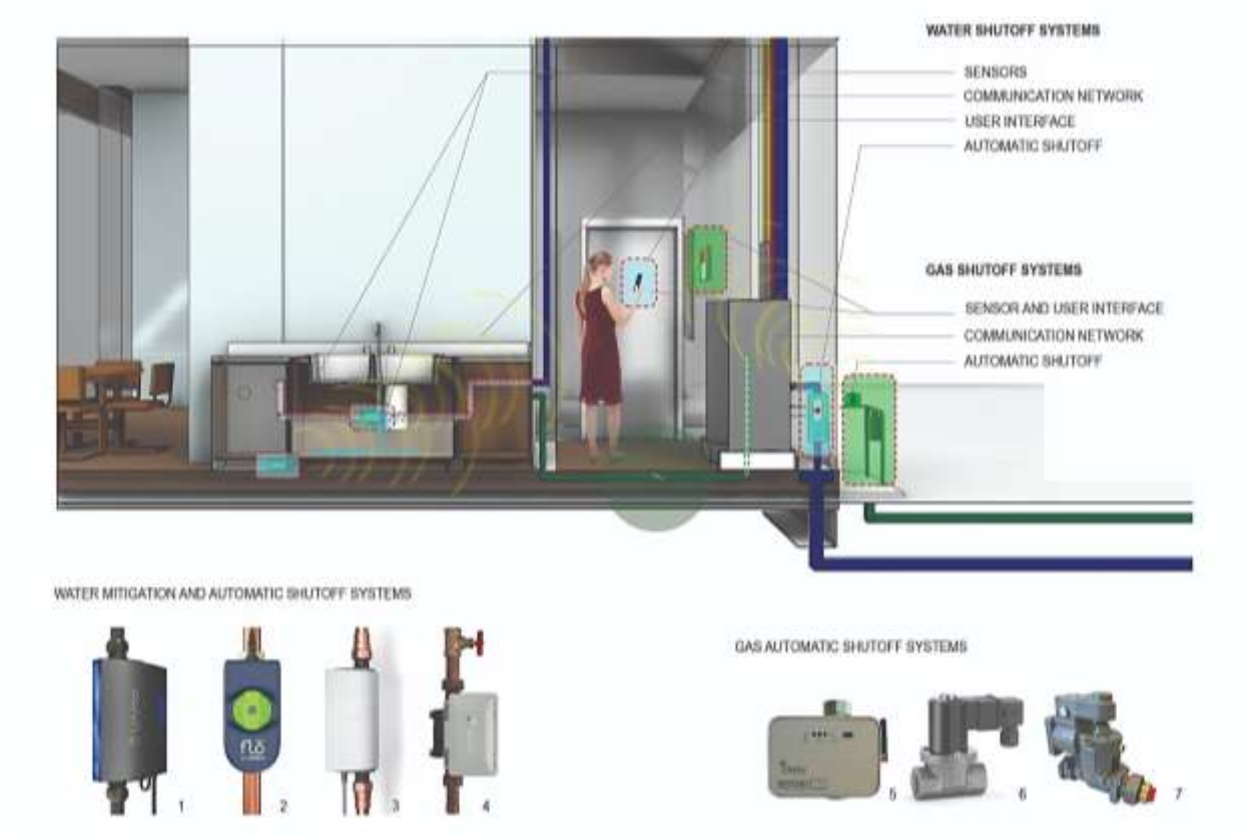


Figure 17. *Diagram of Water & Gas Smart Home Technology Integration and Reference Images*

Image Legend for Figure 17

1. *Phyn Plus Smart Water Assistant + Automatic Shutoff* (66)
2. *Flo by Moen* (65)
3. *Kohler H2Wise+ by Phyn* (87)
4. *Flume: Whole Home Water Monitoring & Leak Detection* (68)
5. *Smartico Gas Shutoff Valve LoRaWAN V-LR* (88)
6. *Honeywell Solenoid Valves for Gas VG* (89)
7. *Lorax Systems* (90)

Figure 18 illustrates smart electric panels operate by monitoring home electric usage through smart phone apps, built in control centers, or smart home systems reporting live usage levels. Certain smart electrical panels automatically turn on and off specific breakers in the event of a power outage or electrical grid interruption and give residents the option for manual remote shutoff. Other devices operate within the electrical panel as exterior circuit breakers can be attached to monitor power usage and automatically shut off breakers in the event of flooding, power outage, or unforeseen circumstances.

Figure 18. *Diagram of Electris Smart Home Technology Integration and Reference Images*

<u>Image Legend for Figure 18</u>

1. *Leviton Smart Circuit Breaker* (91)
2. *Savant Power Module* (92)
3. *Simple Touch - Auto Shutoff Safety Outlet* (93)
4. *GFCI Home line 50 Amp*(91)

Figure 19 illustrates foundation monitoring smart home technologies. Foundation monitoring involves a specific sensor either known as a fiber Bragg grating sensor or a Bragg grating sensor. In essence the sensor utilizes the already existing properties of a fiber optical cable and merely measures for any disruptions in wavelength along the fiber. If the foundation ends up settling or shifting in various spots, a signal is sent from the sensors to a central data collection location. The system then alerts the homeowner before serious damage can occur to the foundation.

Figure 19. *Diagram of Foundation Monitoring Smart Home Technology Integration and Reference Images*

Image Legend for Figure 19

1. *Slabsure* (94)
2. *Orly by Olshan* (95)

Smart Home Technology for Built Environment Resilience Support Summary

Integrating automatic shutoff systems and smart home technologies presents a compelling value proposition for homeowners, insurers, and utility companies. This multi-faceted approach to home resilience offers significant benefits such as:

Financial Advantages

1. Prevention Savings: By dramatically reducing the risk and extent of water damage, these systems can save homeowners thousands of dollars in potential repair costs.

2. Energy Efficiency: Smart electrical panels and monitoring systems enable more efficient energy use, leading to notable reductions in utility bills.
3. Insurance Discounts: Adopting these technologies can result in insurance premium reductions of 3-15%, providing ongoing financial benefits to homeowners.
4. Rebates and Incentives: Various rebate programs from utility companies and government initiatives like the Inflation Reduction Act offer additional financial incentives for adopting these technologies.

Enhanced Home Resilience

1. Early Detection: The ability to identify previously unknown leaks within the first 30 hours of installation significantly improves home maintenance and prevents long-term damage.
2. Comprehensive Protection: These systems offer protection against water, gas, and electrical hazards, providing a holistic approach to home safety.

Long-term Benefits

1. Increased Property Value: Homes equipped with these technologies may see increased property value due to enhanced resilience and efficiency.
2. Environmental Impact: The energy efficiency promoted by these systems aligns with broader sustainability goals, potentially reducing the carbon footprint of residential properties.

As smart home technologies become more accessible to consumers, we may see a shift in insurance models, with more companies offering incentives for smart home technology adoption. Increased integration of these systems in new home constructions as standard features. Further development of interconnected smart home ecosystems that enhance overall home resilience and efficiency. The return on investment for automatic shutoff systems and related smart home technologies extends beyond immediate financial savings. These systems represent a proactive approach to home management, offering long-term benefits in terms of safety, efficiency, and economic security. As the technology continues to evolve and become more accessible, it has the potential to redefine standards of home resilience and insurance risk assessment.

Conclusion

Increasingly insurers have been offering incentives to homeowners to purchase Smart technology products such as smart leak-detection sensors, recognizing that early detection can significantly reduce damage. These efforts by insurers are raising awareness among homeowners about the importance of resiliency more generally.

The NFIP launched Risk Rating 2.0 in 2021 to include property-specific flood risk that considers elevation and proximity to water, foundation type, building replacement cost, and flood frequency and severity. One way that the program encourages resilience is by rewarding mitigation through reduced premiums. Specific resiliency efforts recognized by the program include elevating a structure, installing flood openings, or relocating utilities above the base flood elevation. Discounts for private flood insurance are less common.

Many states have developed programs to encourage resiliency. Notable examples include Florida's My Safe Florida Home Program which provides grants for retrofits (e.g., impact windows, roof straps). Homes that complete specific improvements to mitigate against wind damage qualify for discounts under Florida law.

Programs to promote resilience efforts are making significant progress but there is still work to be done. Challenges from the homeowners' (and contractors') perspective include a lack of understanding of the performance improvements associated with materials and devices that improve resilience, including the beneficial effect on loss control and the costs associated with installation and maintenance. For example, smart devices are only as effective as they are installed, set up and maintained correctly, which may be difficult for individuals unfamiliar with technology. Many devices have advanced features that the average homeowner may never use or understand.

The RIPL report represents a critical milestone in the development of a groundbreaking decision support system based on resilience performance requirement analysis. Unlike existing frameworks, this innovative system integrates advanced methodologies to assess the resilience of single-family homes by combining commonly used residential building materials, structural assemblies, and SMART Home technologies. The findings presented here lay the foundation for creating a robust tool that enables stakeholders like homeowners, builders, and insurers to proactively address natural hazards and optimize home design for enhanced durability. These features provide actionable insights for reducing property damage risks while supporting the development of sustainable and economically viable housing solutions. By aligning resilience strategies with potential insurance savings, this approach holds significant promise for reshaping how insurers evaluate residential properties and calculate premiums.

As a companion to this report a comprehensive single-family home resilience assessment and resource guide, accompanied by responsive GUI dashboards has been created and can be accessed of the Florida Institute for Built Environment Resilience website via the following link **https://dcp.ufl.edu/fiber/resources/**. These ongoing development of these tools and resources will present findings on various technologies, products, and assemblies, including water intrusion mitigation strategies, Smart Home technologies, automatic water and gas shutoff systems, and foundation stabilization solutions. The preliminary predictive models developed can also be further expanded to assess the potential impact of these innovations on risk reduction and their effectiveness in lowering insurance losses.

The ultimate vision for RIPL is to serve as a comprehensive decision support system, equipping insurance organizations with advanced tools for precise forecasting of housing resilience. The innovative resilience engineering framework developed in this study delivers powerful capabilities—including the ability to predict resilience characteristics and generate detailed "what-if" scenarios—that can fundamentally transform risk assessment. By quantifying resilience attributes, RIPL enables insurers to implement targeted risk mitigation strategies and drive down insurance losses. At a minimum, the insights presented in this report empower stakeholders to take proactive measures toward building safer, more resilient communities, while also realizing substantial economic benefits through reduced insurance premiums.

Appendix

Specifications of Smart Home Technology performance characteristics

	TYPE OF CONTROL	SMART SHUTOFF	Y/N	SMART SENSOR	Y/N	USER INTERFACE	Y/N	COMMUNICATION NETWORK	Y/N
WATER									
Ezlo Smart Water Shutoff	Splice Pipe	Instantly stops water flow when leaks are detected, protecting against water damage. IP67-rated for outdoor use and designed for over 20,000 on/off cycles (over 50 years), with automatic weekly self-testing		Features a built-in SmartHub featuring a Z Wave, 700 Series Sensor		From the SmartHub, connection to a smartphone app allows remote control over this and other existing smart home systems for water shutoff.		Operates on a standard 2.4 & 5 GHz WiFi connection.	
Flo by Moen	Splice Pipe	Features an automatic shutoff system when abnormal water usage or a potential leak is identified		Multiple sensors work to detect leaks, learn daily water usage and		The Moen app provides real-time 24/7 alerts and allows remote shutoff from the app. Sensors can be calibrated for		It operates on a 2.4 GHz WiFi connection, allows the defiance to connect to home internet, and	

				water flow through the house system, and identify lead in the system.		sensitivity and connected to various services such as Amazon Alexa, Google Home, Ring, Nice, and Alarm.com.		provides live updates on water usage.	
FloLogic: Smarter Water Control	Splice Pipe	Automatically shuts off water when abnormal flow is detected outside of use patterns.		EverWatch technology is capable of constantly detecting leaks as small as ½ ounce per minute (one tablespoon per minute)		User-controlled app with the ability to shut off water remotely, monitor usage, and a manual override system alert system through the app		The Connect Module uses a secure cloud connection for smartphone devices with app-based controls and alerts, as well as local command and control/standard batteries so that the device does not shut down during internet lulls or power outages.	
Guardian by Elexa	External Pipe Connection	Smart shutoff system that only needs a		A series of three leak		The Guardian app allows the water main		Leak detectors can be placed up to	

		power source to shut off non-exterior waterlines. A manual opening and closing water valve system is also present.		detectors focus on detecting floor leaks, drip leaks, and other unseen leaks, as well as detecting freezes. This feature is accessible through a smartphone app to open or close the water valve.		to be controlled remotely if the user has an internet connection.		1000' from the valve controller.	
Phyn Plus: Smart Water Assitant + Water Shutoff	Splice Pipe	The device learns water habits and then "unlocks" the ability to shut off. The app will alert the owner to allow manual shutoff using		High-definition pressure wave analysis senses leaks by monitoring the flow,		The Phys app dashboard allows for manual shutoff from the app when alerted before automatic shut-off turns on. Leaks are categorized, and		With a connection to WiFi, only the user is alerted to leakages, not any external authorities.	

		a slow-closing stainless steel ball valve.		pressure, and temperature.		alerts are timed based on the severity of the leak.			
StreamLabs: Smart Home Water Solutions	External Pipe Connection or Splice pipes	The StreamLabs Control is a smart automatic water shutoff valve that automatically shuts off water when a leak is detected with Smart Alerts learning leak detection.		Ultrasonic Technology uses sound waves to monitor water during the day and night to provide leak detection.		Customizable alerts and reactions to drip/leak concerns are possible for residents out of their homes. The dashboard can find active leaks and monitor the health of sensors through an easily updated dashboard.		Operates on a WiFi network and sends leak and freeze warning alerts to the smartphone.	
Kohler H2Wise + by Phyn	Splice Pipe	The internal valve can be set up to close automatically, closed remotely via the KOHLER Konnect® app, or manually with a local switch or small screwdriver.		Ultrasonic flow meters and high-definition pressure sensors analyze your home's water usage and		KOHLER Konnect® app sends real-time alerts to your phone if the system detects changes in water pressure that signal potential water leakage or other plumbing problems.		Freeze warnings let you act against frozen pipes to avoid costly damage.	

				measure changes 240 times per second, quickly detecting leaks.					
Leak Defense System by Watts		It features a smart valve with automatic shut-off and a manual shut-off.		Multi-point electronic leak detectors are placed in areas with high risk for plumbing leaks, typically near appliances and fixtures, and will sound an alarm if moisture is detected. Detectors'		From a primary location with clear communication lines, the control panel can easily integrate security systems, BMS systems, and appliances for extra protection.		The mobile app is a monitoring hub for the sensors that send shutoff signals to valves.	

				range can be extended with additional hardware.					
Water Hero Leak Detection	Splice Pipe and External Pipe Connection	Shut-off valves operate based on installed flow sensors.		Flow sensors are integrated into traditional water meters, recording flow information 200 times per second.		Users control the shut-off thresholds of sensors through the website portal or smartphone app or can manually open/close the valve.		Water Hero will send the user a text or email to alert them of automatic shutoff or a risk of freezing.	
WaterCop: Automatic Water Shutoff Systems	Splice Pipe	Once shut off, the ball valve shutoff system must be manually reopened.		If detected, battery-powered moisture sensors in various locations send drip/leak alerts to a shutoff valve.		The third party provides a notification of leak alerts/water shutoff alerts.		A connected power source (inoperable in an outage) allows the system to transmit data between 150-200'.	

Flume: Whole Home Water Monitoring & Leak Detection	External Pipe Connection	No shut-off system is present on the product.		With the device attached to residential water meters, precise water usage can be captured every 5 seconds to provide 24/7 instant leak detection.		From the Flume app, users get notifications if a leak is detected and are given the option to call a Flume technician.		The Flume "Bridge" system captures leak data from up to a thousand feet away, informing the user through the app.	
Gas									
Smartico Gas Shutoff Valve LoRaWAN V-LR	Shut Valve	- remotely shut off the gas supply in the low-pressure gas network - The shutoff valve was made with an autonomous power supply. It has a unique valve		- Magnetic Sensor and Motion Detector		Monitoring and transmission of the following parameters: • battery discharge. • operability of internal sensors. • strikes and changes in position.		- Data is transmission within an unlicensed frequency zone - Can alert/send an alarm to the dispatcher software	

		activation mechanism that allows safe recovery of gas supply				• opening the case. • current valve state			
Lorax Systems	Meter and Shut off Valve	- Automatic and Remote shut off capabilities - Fire is detected at the valve - Overpressure detected (optional) - Water detected (optional) - Methane detected (3rd party)		- Potential to be integrated of LoRa enabled sensors to provide automatic valve shutdown		- Cloud application that provides remote shutoff capabilities		- Cellular or LoRaWAN communication - Central cloud management and control system - Secure shutdown of single or multiple valves - Central registration and lifecycle management - Integration with LoRa-enabled sensors to provide automatic valve shutdown	

Global Treat	Vacuum Regulator with Gas Detection	- Vacuum Regulator. Will shut off when alerted of irregular pressure values		The system will close the gas cylinder valve(s) within seconds of activating a manual panic button, an external alarm signal, or an internal fail-safe alarm signal.		- Remote control by leak detector, panic button, or digital signal such as PLC or computer		- utilized three inputs maximum and four outputs maximum - no notification to the user; the only response from the user	
Honeywell Solenoid Valves for Gas VG	Solenoid Electromagnet	- Uses electromagnetic pulse to sense abnormal flow of gas		- no alert sensor/no external sensor attached provided with		- No Interface		- No alert	

				solenoid valve - must be used in conjunction with a gas monitoring sensor for a smart sensor application					
AGS Mini Merlin	Solenoid Electromagnet with Gas Detection	- 120VAC normally closed gas solenoid valve for safety shut off		- if gas is detected using AGS Gas sensor (14-18AWG 120VAC OUTPUT) - fire alarm is pulled - emergency shutoff button is pushed		- manually controlled, no smart app or interface to monitor		- audible external alarm - no indication of contracting authorities	

CO2 Meter: Gas Measurement Specialist	Solenoid Electromagnet	- Solenoid shut-off valve triggered by an external sensor		- Works in conjunction with external sensor systems (not built into a meter)		external alarm/signal and sensor without digital formatting, digital control		linked to an external alarm system	
PSP Valve: Gas Safety Products	Shut Valve	- Seismic valve		Includes monitoring device to detect if the valve is open or closed - No smart sensor for external monitoring		- can be attached to a home alert system but has no built-in interface for regulation		250 mA, 24-volt rating for computer alarm systems/home alarm systems	
Florida Public Utilities (FPU), Duke Energy, Clearwater Gas, Florida City Gas,	Excess Flow Valve (EFV)								

Little Firefighter: Gas Safety Products	Shut Valve	- Shutoff triggered by earthquake/seismic activity of a 5.4 seismic event or higher		Includes monitoring device to detect if the valve is open or closed - No smart sensor for external monitoring		- can be attached to a home alert system but has no built-in interface for regulation		can be linked to the external alarm system	
Electric									
Schneider Pulse	Electric Panel	200 A Breaker		200 A Breaker + 50k A surge protection built-in - Factory-installed surge protection device - Factory-		Schneider Home app - remote shut off from an app - track consumption on the app		- does not discuss WiFi connection - lug connection to the ground necessary	

				installed backup control switch					
Lumin Smart Panel	Electrical Panel	Smart Power Mode can be configured to shed individual circuits as soon as a grid outage is detected or as soon as the power demanded by circuits in the house exceeds a power limit (this prevents the battery's inverter from tripping) or Once the state of charge of a home's battery decreases (only available with selected battery brands).		- Smart home power mode - single pole and double pole breakers		Lumin App - Lumin measures all of the power being used in an electrical panel. Lumin also directly measures the consumption of the individual circuits under Lumin control		2.4 GHz WiFi network, external WiFi antenna is installed on the Lumin Smart Panel	

		15–20 A (non-GFCI) Breaker							
Span Panel	Electric Panel	100-200 A Breaker is the main over current protection device		Breaker monitors for overflow of electricity, sensors that monitor electricity through each circuit, and all breaker devices.		- SPAN Home App (iOS, Android) - SPAN app allows for remote control of breaker board - outlines the cost of each device plugged into the breaker based on usage		- Primary connectivity: Ethernet, WiFi (2.5, 5 GHz) - secondary connectivity: Cellular (4G/LTE, 3G)	
Eaton, AbleEdge Smart Breaker	Circuit Breaker	- Allows for remote shut off and has a trip breaker the same as a standard electrical breaker trip mechanism		- trip sensor if irregular electrical flow		- app to remotely turn on or off the breaker, ability to receive notification and status of the breaker (open/closed/tripped)		- operates on WiFi, cloud connectivity for internet updating	
Leviton, Smart Circuit Breaker (Thermal,	Circuit Breaker	The circuit breaker will trip the wire when there is an unequal flow from		Regulates electricity flow for overages the same way		INTUITIVE - My Leviton offers single app control of control of the Leviton Smart		SMART - Wi-Fi® or Ethernet connection options for remote monitoring and	

Thermal AF/GF, Thermal GFCI, Thermal GFPE)		the hot wire to the neutral wire.		a typical breaker monitor		Load Center and the Decora Smart™ Wi-Fi® product lines		tripping capabilities, remote firmware updates, and more	
Savant Power Module	Breaker Attachment	- does not control the trip in the breaker but can give options to manage the breaker		- can manually turn on and off breakers - can monitor electricity usage to each breaker		The Savant app notifies users of activity within each breaker it is attached to		not listed, but utilized a WiFi network	
GFCI Circuit Breaker (Easter, GE, Seimens, Square D)	Circuit Breaker	trip in service breaker will turn off all electric flow from that specific breaker		The GFCI monitors the flow on the "hot" wire and the neutral wire in the electric loop to determine if the flow is unbalanced.		A typical circuit breaker does not have a smart interface.		A typical circuit breaker does not have a smart communication network.	

Safe Living Technologies: RCS4 Remote Cut-Off Switch	Key Switch	- remote control button for electrical shutoff - can control up to a total of 4 circuits on one contractor - can purchase up to 4 contractors to control up to 16 circuits		No Sensor		- Remote control is available; do online or digital control through the user interface		- operates using a 9' transmission cable,	
Simple Touch - Auto Shutoff Safety Outlet	Outlet Shut off	- Timer shut-off system closes the flow of electric current from the outlet to the appliance after a set amount of time		- No smart sensor - Receives input from the user on timing choice (1 hr. - 8hr in 2 hr. increments)		- no external interface/cannot be set remotely or notified remotely		- no external communication next work/cannot be set remotely	
SurgeShield by FPL Home	Surge Suppression	- surge protection does not shut off the electric meter to the		- Surge protectors do not have a		- not active user interface for monitoring surge,		- not active communication network for	

		home; it only protects the meter by absorbing excess voltage		sensor system		monitoring of function indicated on equipment		monitoring surge, monitoring of function indicated on equipment	
AGS Merlin 500S(+) Panel	Key Switch	fully compatible with AGS remote Emergency stop terminals, allowing a large number of EPO terminals to be connected in series and wired back to the panel by manual interruption (key or emergency stop button)		can be integrated with a BMS and fire alarm via a low voltage dry contact		- Can be incorporated with an external monitoring system		- no external communication next work/cannot be set remotely	
Foundation									
Slabsure	Fiber Bragg Grating	N/A	N/A	Fiber optic cables are attached to a part of the foundation		cell phone app updates with data collected from the fiber optic system		- many internal data collection center	

				every 10 feet and monitor for irregular movement or data.					
Orly by Olshan	Fiber Bragg Grating	N/A	N/A	Fiber optic cables are attached to the foundation every 10 feet and monitored for irregular movement or data.		cell phone app updates with data collected from the fiber optic system		- one internal data collection center	

Bibliography

1. Ayscue JK. Hurricane damage to residential structures: risk and mitigation. National Hazards Research and Applications Information Center, Institute of …; 1996.

2. FEMA Approves Additional $114 Million for Debris Removal Following Florida's Hurricanes | FEMA.gov [Internet]. 2024 [cited 2025 May 22]. Available from: https://www.fema.gov/press-release/20241203/fema-approves-additional-114-million-debris-removal-following-floridas

3. 4 Ways to Lower Home Insurance Premiums in 2025 | Kiplinger [Internet]. [cited 2025 Mar 21]. Available from: https://www.kiplinger.com/personal-finance/home-insurance/4-ways-to-lower-your-home-insurance-premium-in-2025

4. Hollnagel E, Braithwaite J, Wears RL. Resilient health care. Resilient Health Care. 2018.

5. Hollnagel E, Woods DD, Leveson N. Resilience engineering: Concepts and precepts. Ashgate Publishing, Ltd.; 2006.

6. Sikula NR, Mancillas JW, Linkov I, McDonagh JA. Risk management is not enough: a conceptual model for resilience and adaptation-based vulnerability assessments. Environ Syst Decis. 2015;

7. Glossary [Internet]. InsuResilience Global Partnership. [cited 2025 Mar 21]. Available from: https://www.insuresilience.org/knowledge/glossary/

8. Investopedia [Internet]. [cited 2025 Mar 21]. What Is Actuarial Science? Definition and Examples of Application. Available from: https://www.investopedia.com/terms/a/actuarial-science.asp

9. Norris FH, Stevens SP, Pfefferbaum B, Wyche KF, Pfefferbaum RL. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. Am J Community Psychol. 2008;

10. Woods DD. Four concepts for resilience and the implications for the future of resilience engineering. Reliab Eng Syst Saf. 2015;

11. author/dan-sokolosky. Builder. 2024 [cited 2025 Mar 21]. How Resilient Design Is Shaping the Future of Real Estate. Available from: https://www.builderonline.com/builder-100/building/how-resilient-design-is-shaping-the-future-of-real-estate_o

12. Climate Proof [Internet]. 2024 [cited 2025 Mar 21]. Climate Disasters to Hike Insurance Premiums, UN-backed Funds Earmark Over US$200mn for Adaptation, and More. Available from: https://www.climateproof.news/p/climate-disasters-hike-insurance-premiums-unbacked-funds-earmark-us200mn-adaptation

13. Woods DD. Resilience as Graceful Extensibility to Overcome Brittleness i. Ed Collect Authored Pieces Comp Contrasting Integrating Risk Resil Emphas Ways Meas Resil. 2016;258.

14. Askar R, Bragança L, Gervásio H. Adaptability of Buildings: A Critical Review on the Concept Evolution. Appl Sci. 2021 Jan;11(10):4483.

15. Peavey JB, Shah NB, Moneke C, Kauffman K, Thapa E. Designing for Natural Hazards. Cityscape. 2023;25(1):71–87.

16. Overman O. Building Resilient Homes While Keeping Homeowners Coverage Up to Date [Internet]. 2025 [cited 2025 Mar 21]. Available from: https://www.iamagazine.com/markets/building-resilient-homes-while-keeping-homeowners-coverage-up-to-date

17. Updated Resilient Building Codes Will Benefit Homeowners and Communities | LMG [Internet]. [cited 2025 Mar 21]. Available from: https://www.libertymutualgroup.com/about-lm/corporate-information/sustainability/articles/updated-resilient-building-codes-will-benefit-homeowners-and-communities

18. PricewaterhouseCoopers. PwC. 2023 [cited 2025 Mar 21]. Climate risk and insurance: the case for resilience. Available from: https://www.pwc.com/us/en/industries/financial-services/library/climate-risk-and-insurance.html

19. Stich B. New Report Shows Resilient Construction Offers Strong Return on Investment [Internet]. Insurance Institute for Business & Home Safety. 2022 [cited 2025 Mar 21]. Available from: https://ibhs.org/ibhs-news-releases/new-report-shows-resilient-construction-offers-strong-return-on-investment/

20. Gatzlaff D, McCullough K, Medders L, Nyce CM. The Impact of Hurricane Mitigation Features and Inspection Information on House Prices. J Real Estate Finance Econ. 2018 Nov 1;57(4):566–91.

21. Cooke A, Smith D, Booth A. Beyond PICO: The SPIDER tool for qualitative evidence synthesis. Qual Health Res. 2012;

22. Lachal J, Revah-Levy A, Orri M, Moro MR. Metasynthesis: An original method to synthesize qualitative literature in psychiatry. Front Psychiatry. 2017;

23. VOSviewer [Internet]. [cited 2025 Mar 21]. VOSviewer - Visualizing scientific landscapes. Available from: https://www.vosviewer.com//

24. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84(2):523–38.

25. Wilson C, Hargreaves T, Hauxwell-Baldwin R. Benefits and risks of smart home technologies. Energy Policy. 2017 Apr 1;103:72–83.

26. Dahmen J, Cook DJ, Wang X, Honglei W. Smart Secure Homes: A Survey of Smart Home Technologies that Sense, Assess, and Respond to Security Threats. J Reliab Intell Environ. 2017 Aug;3(2):83–98.

27. Possehl S. Systems Engineering Guidebook. Dep Def Wash DC USA. 2022;

28. Purup PB, Petersen S. Requirement analysis for building performance simulation tools conformed to fit design practice. Autom Constr. 2020 Aug 1;116:103226.

29. FORTIFIED - A Program of IBHS [Internet]. [cited 2025 Mar 22]. Solutions. Available from: https://fortifiedhome.org/solutions/

30. Todoroff N. Bankrate. 2025 [cited 2025 Mar 23]. Factors That Impact Your Cost of Homeowners Insurance. Available from: https://www.bankrate.com/insurance/homeowners-insurance/factors-that-impact-home-insurance-rates/

31. ValuePenguin [Internet]. 2024 [cited 2025 Mar 23]. Can Renovating Your House Lower Your Insurance Costs? Available from: https://www.valuepenguin.com/home-renovation-insurance-savings

32. Wang P, Li Y, Yu P, Zhang Y. The analysis of urban flood risk propagation based on the modified susceptible infected recovered model. J Hydrol. 2021 Dec 1;603:127121.

33. CHAPTER 3 CE GENERAL REQUIREMENTS - 2023 FLORIDA BUILDING CODE, ENERGY CONSERVATION, EIGHTH EDITION [Internet]. [cited 2025 Mar 23]. Available from: https://codes.iccsafe.org/content/FLEC2023P1/chapter-3-ce-general-requirements

34. Disaster Preparedness Maps [Internet]. [cited 2025 Mar 23]. Available from: https://www.floridadisaster.org/planprepare/disaster-preparedness-maps/

35. WIND LOADS – IMPACTS FROM ASCE 7-22 [Internet]. Florida Building Commission; 2024. Available from: http://www.floridabuilding.org/fbc/thecode/2023_Code_Development/2023_Code_Resources/ASCE-7-22_Wind_Loads_Fact_Sheet.pdf

36. Highlights of Significant Changes to the Wind Load Provisions of ASCE 7-22 [Internet]. US Department of Homeland Security: FEMA; 2022. Available from: https://www.fema.gov/sites/default/files/documents/fema_asce-7-22-wind-highlights_fact-sheet_2022.pdf

37. Analysis of Changes for the 8th Edition (2023) Florida Building Code [Internet]. Florida Building Code; Available from: https://www.floridabuilding.org/fbc/thecode/2023_Code_Development/2023_Code_Resources/Analysis-of-Changes-8th-Ed-2023-FBCB-Final.pdf

38. CHAPTER 8 INTERIOR FINISHES AND DECORATIVE MATERIALS - 2023 FLORIDA BUILDING CODE, BUILDING, EIGHTH EDITION [Internet]. [cited 2025 Mar 23]. Available from: https://codes.iccsafe.org/content/FLBC2023P2/chapter-12-interior-environment#FLBC2023P2_Ch12_Sec1204

39. This Old House [Internet]. [cited 2025 May 30]. Water Damage Statistics and Information. Available from: https://www.thisoldhouse.com/foundations/reviews/water-damage-statistics

40. Martinez-García FP, Contreras-de-Villar A, Muñoz-Perez JJ. Review of Wind Models at a Local Scale: Advantages and Disadvantages. J Mar Sci Eng. 2021 Mar;9(3):318.

41. Khajwal AB, Noshadravan A. Probabilistic Hurricane Wind-Induced Loss Model for Risk Assessment on a Regional Scale. ASCE-ASME J Risk Uncertain Eng Syst Part Civ Eng. 2020 Jun 1;6(2):04020020.

42. Norman CR, Kelley KL, Sanner C, Lueck S, Norman J, Norrow C. Water Intrusion: An Analysis of Water Sources, Categories, and the Degradation Science of Building Materials. Water. 2024 Jan;16(11):1576.

43. Facts + Statistics: Homeowners and renters insurance | III [Internet]. [cited 2025 Mar 23]. Available from: https://www.iii.org/fact-statistic/facts-statistics-homeowners-and-renters-insurance

44. Espitia H, Soriano J, Machón I, López H. Compact Fuzzy Systems Based on Boolean Relations. Appl Sci. 2021 Feb 18;11(4):1793.

45. Espitia H, Soriano J, Machón I, López H. Design Methodology for the Implementation of Fuzzy Inference Systems Based on Boolean Relations. Electronics. 2019 Nov;8(11):1243.

46. Dragović I, Turajlić N, Pilčević D, Petrović B, Radojević D. A Boolean Consistent Fuzzy Inference System for Diagnosing Diseases and Its Application for Determining Peritonitis Likelihood. Comput Math Methods Med. 2015;2015:147947.

47. Floods: The Awesome Power [Brochure]. [Internet]. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.; 2010. Available from: Retrieved from https://www.weather.gov/media/twc/FloodsTheAwesomePowerMay2010.pdf

48. Monica Hersher [Internet]. [cited 2025 Mar 24]. Unraveling misconceptions of flood risk. Available from: https://www.monicahersher.com/portfolio/flooding-common-misconceptions

49. Leal JE. AHP-express: A simplified version of the analytical hierarchy process method. MethodsX. 2020 Jan 1;7:100748.

50. Platt LS, Chen X. A Computational Approach to Estimating Healthcare Contact Surface Material Resilience. HERD Health Environ Res Des J. 2023 Apr 1;16(2):268–83.

51. Gilbert SW. Estimating Smoke Alarm Effectiveness in Homes. Fire Technol. 2021 May 1;57(3):1497–516.

52. Grossi P, Kunreuther H, Windeler D. An Introduction to Catastrophe Models and Insurance. In: Grossi P, Kunreuther H, editors. Catastrophe Modeling: A New Approach to Managing Risk [Internet]. Boston, MA: Springer US; 2005 [cited 2025 May 30]. p. 23–42. Available from: https://doi.org/10.1007/0-387-23129-3_2

53. An introduction to flood modeling for catastrophe risk management. [cited 2025 May 30]; Available from: https://wires.onlinelibrary.wiley.com/doi/10.1002/wat2.1568

54. Xie Y. Values and limitations of statistical models. Res Soc Stratif Mobil. 2011 Sep 1;29(3):343–9.

55. System Dynamics Modeling | SOA [Internet]. [cited 2025 May 30]. Available from: https://www.soa.org/news-and-publications/newsletters/innovators-and-entrepreneurs/2018/november/ie-2018-iss65/system-dynamics-modeling/

56. Linstone HA. Complexity science: Implications for forecasting. Technol Forecast Soc Change. 1999 Aug 1;62(1):79–90.

57. Kwak HJ, Kim DW, Park GT. A New Fuzzy Inference Technique for Singleton Type-2 Fuzzy Logic Systems. Int J Adv Robot Syst. 2012 Sep 19;9(3):83.

58. Cao J, Zhou T, Zhi S, Lam S, Ren G, Zhang Y, et al. Fuzzy inference system with interpretable fuzzy rules: Advancing explainable artificial intelligence for disease diagnosis—A comprehensive review. Inf Sci. 2024 Mar 1;662:120212.

59. Cronin MA, Gonzalez C, Sterman JD. Why don't well-educated adults understand accumulation? A challenge to researchers, educators, and citizens. Organ Behav Hum Decis Process. 2009 Jan 1;108(1):116–30.

60. Schieritz N, Größler A. Emergent structures in supply chains - A study integrating agent-based and system dynamics modeling. Proc 36th Annu Hawaii Int Conf Syst Sci HICSS 2003. 2003;

61. Wilensky U, Rand W. An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo. Mit Press; 2015.

62. Liu S, Triantis KP, Zhao L, Wang Y. Capturing multi-stage fuzzy uncertainties in hybrid system dynamics and agent-based models for enhancing policy implementation in health systems research. PLoS ONE. 2018;

63. Scott D, Al-jibouri S, Mawdesley M, Long G. METHODS OF RUNNING A SIMULATION GAME. In: INTED2009 Proceedings. IATED; 2009. p. 2641–50.

64. StreamLabsWater [Internet]. [cited 2025 Mar 28]. Insurance Benefits. Available from: https://streamlabswater.com/pages/insurance-benefits

65. Meet Flo Smart Water Shut Off | Smart Water Monitor | Moen [Internet]. [cited 2025 Mar 28]. Available from: https://shop.moen.com/pages/flo-smart-water-monitor

66. Phyn [Internet]. [cited 2025 Mar 28]. Phyn Plus - protect your home from leaks, save money, conserve water. Available from: https://phyn.com/

67. LexisNexis Risk Solutions [Internet]. [cited 2025 Mar 28]. New Loss Correlation Study From LexisNexis Risk Solutions Reveals Use of In-Line Water Shutoff Reduces Escape-of-Water Home Insurance Claims by 96%. Available from: https://risk.lexisnexis.com/about-us/press-room/press-release/20200505-flo-by-moen

68. Flume For Utilities [Internet]. [cited 2025 Mar 28]. Available from: https://flumewater.com/utilities

69. Commission CE. Smart Shutoff Technology for Commercial and Residential Buildings [Internet]. California Energy Commission; current-date [cited 2025 Mar 29]. Available from: https://www.energy.ca.gov/publications/2024/smart-shutoff-technology-commercial-and-residential-buildings

70. Norris M. Florida Public Utilities. [cited 2025 Mar 29]. Gas Line Coverage. Available from: https://fpuc.com/residential/gas-line-coverage/

71. Cost of Gas Line Replacement in Tampa, FL | Tampa Gas Line Service [Internet]. [cited 2025 Mar 29]. Available from: https://tampagaslineservice.com/cost-of/gas-line-replacement

72. Angi [Internet]. [cited 2025 Mar 29]. Gas Line Repair and Replacement Costs [2025 Data]. Available from: https://www.angi.com/articles/average-gas-line-repair-and-installation-costs.htm

73. Home [Internet]. [cited 2025 Mar 29]. Available from: https://www.span.io/

74. Lumin LSP [Internet]. [cited 2025 Mar 29]. Available from: https://www.luminsmart.com/platform/smart-electrical-panel

75. Schneider Pulse | Schneider Electric USA [Internet]. [cited 2025 Mar 29]. Available from: https://www.se.com/us/en/product-range/243168640-schneider-pulse/

76. Leaks are Detected and Stopped Fast With FloLogic - About [Internet]. FloLogic. [cited 2025 Mar 28]. Available from: https://www.flologic.com/flologic-detects-leaks-fast/

77. Guardian by Elexa [Internet]. [cited 2025 Mar 28]. Leak Prevention Starter Kit+. Available from: https://getguardian.com/products/leak-prevention-starter-kit-plus

78. Phyn [Internet]. [cited 2025 Mar 28]. Insurance Savings and Water Rebates. Available from: https://phyn.com/pages/insurance-savings-and-water-rebates

79. Residential Rebates Information [Internet]. [cited 2025 Mar 28]. Available from: https://www.ouc.com/residential/save-energy-water-money/residential-rebates-information

80. Smart Leak Detector Rebate [Internet]. North Springs Improvement District. [cited 2025 Mar 28]. Available from: https://nsidfl.gov/smart-leak-detector-rebate/

81. Energy Efficient Home Improvement Credit | Internal Revenue Service [Internet]. [cited 2025 Mar 29]. Available from: https://www.irs.gov/credits-deductions/energy-efficient-home-improvement-credit

82. Inflation Reduction Act of 2022 | Internal Revenue Service [Internet]. [cited 2025 Mar 29]. Available from: https://www.irs.gov/inflation-reduction-act-of-2022, https://www.irs.gov/inflation-reduction-act-of-2022

83. Home Electrification and Appliances Rebate Program | ENERGY STAR [Internet]. [cited 2025 Mar 29]. Available from: https://www.energystar.gov/partner-resources/state-and-tribal-rebate-programs/hear-program

84. Benefits of Resilient Building [Internet]. [cited 2025 Mar 28]. Available from: https://www.greenbuildermedia.com/blog/benefits-of-resilient-building

85. Waterproofing OS. Is Finishing a Basement Without Waterproofing an Option? | Ohio State Waterproofing [Internet]. 2024 [cited 2025 Mar 28]. Available from: https://ohiostatewaterproofing.com/is-finishing-a-basement-without-waterproofing-an-option/

86. Next-gen smart buildings will run cheaper and greener [Internet]. [cited 2025 Mar 28]. Available from: https://www.autodesk.com/design-make/articles/smart-building

87. kohler [Internet]. [cited 2025 Mar 29]. H2Wise+ Smart Home Water Monitor | K-33604. Available from: https://www.kohler.com/en/products/smart-home/shop-water-monitoring/h2wise-smart-home-water-monitor-and-automatic-shutoff-valve-33604

88. Gas Valve – smartico.biz [Internet]. [cited 2025 Mar 29]. Available from: https://smartico.biz/en/gas-valve-2/

89. Solenoid valves for gas VG | Honeywell [Internet]. [cited 2025 Mar 29]. Available from: https://process.honeywell.com/us/en/products/thermal-solutions/fuel-and-air-delivery/shutoff-valves/solenoid-valves-for-gas-vg

90. Products | Lorax Systems Inc. [Internet]. [cited 2025 Mar 29]. Available from: https://www.loraxsystems.com/products

91. Leviton [Internet]. [cited 2025 Mar 29]. 60A Smart GFCI 2-Pole Branch Circuit Breaker, LB260-GS. Available from: https://store.leviton.com/products/60a-smart-gfci-2-pole-branch-circuit-breaker-lb260-gs

92. Inflation Reduction Act - Savant [Internet]. [cited 2025 Mar 28]. Available from: https://www.savant.com/power/inflation-reduction-act

93. Simple Touch - Auto Shut-Off Safety Outlet Timer - Single Outlet - 8-6-4-2-1 Hours [Internet]. [cited 2025 Mar 29]. Available from: https://teklectric.com/simple-touch-auto-shut-off-safety-outlet-timer-single-outlet-8-6-4-2-1-hours/?srsltid=AfmBOopw9MGF52bDSrHhv9atg2_6EteFOYlrv9dpCi2M-WZwv1JVR-Tz

94. Slabsure [Internet]. [cited 2025 Mar 29]. Available from: https://www.slabsure.com/

95. Foundation Monitoring System [Internet]. Olshan Foundation Solutions. [cited 2025 Mar 29]. Available from: https://www.olshanfoundation.com/services/foundation-repair/foundation-monitoring-system/