Fire Safety Challenges of Green Buildings

Final Report

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THE
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FIRE RESEARCH

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FOREWORD

Many new commercial facilities are being designed and constructed with an objective of achieving a “green building” certification. There are many sustainable building features and products that singly or together may have an impact on fire safety unless there is a design approach which mitigates those effects. The Foundation commissioned this study to develop a baseline of information on the intersection of “green building” design and fire safety and to identify gaps and specific research needs associated with understanding and addressing fire risk and hazards with green building design.

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KEYWORDS: Sustainability, green building, building design, fire protection

Fire Safety Challenges of Green Buildings

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Executive Summary

A global literature review was undertaken to (a) identify actual incidents of fires in green buildings or involving green building elements, (b) identify issues with green building elements or features which, without mitigating strategies, increase fire risk, decrease safety or decrease building performance in comparison with conventional construction, (c) identify reports, studies and best practice cases which speak to the issue of addressing fire risk introduced by specific green building design elements, and (d) identify research studies in which building safety, life safety and fire safety have been incorporated as an explicit element in green building indices. In addition, consideration was given to how one might express the level of increased risk or hazard, or decreased performance, associated with fire performance of green building features. Steps were also taken to identify gaps and specific research needs associated with understanding and addressing fire risk and hazards with green building design.

Outcomes of this effort include the following:

- There are currently no fire incident reporting systems in the United States or other countries surveyed which specifically collect and track data on fire incidents in green buildings or on items labeled as green building elements or features. Unless changes are made to reporting systems such as NFIRS, it will be difficult to track such fire incident data.

- Web searches and surveys have identified more than two dozen reported fire incidents that are related to green issues. Examples include fires associated with photovoltaic (PV) panels and roof materials, fire and safety hazards attributed to increased energy efficiency aims in residential buildings (primarily insulation related), fire involving insulating materials, fires associated with exterior cladding that contains combustible insulation materials or coatings, and fire performance of timber frame buildings with lightweight engineered lumber (LEL) components.

- Studies related to green building and fire issues produced by BRE, BRANZ, FMGlobal and the NASFM have been identified. Research on specific building elements with green attributes, but not necessarily labeled as green, such as lightweight engineered lumber (LEL), has been identified at UL and NRC Canada.

- From the materials reviewed, a comprehensive list of green building site and design features / elements / attributes has been compiled. The list is titled “Table 4. Green Building / Site Elements and Attributes” and can be found in Section 3.

- From the materials reviewed, a list of fire-related hazards and risk factors, associated with green building elements, has been compiled. The list is titled “Table 5. Hazard, Risk and Performance Attributes” and can be found in Section 4.

- Using Table 4 and Table 5, a set of matrices relating green attributes and potential fire hazards was developed. The matrix concept is illustrated in “Figure 1. Matrix of Green Attributes and Potential Fire Hazards**”** and can be found in Section 5. The complete set of matrices is detailed in Appendix E.

- Using the matrices identified above, an approach for illustrating the relative fire risk or hazard, or decreased fire performance, associated with green building elements, was developed. The relative risk matrix is illustrated in "Figure 2. Relative Fire Risk/Hazard Level of Green Attributes" and can be found in Section 5. A complete matrix, which is based on a qualitative expert judgment approach for illustrating relative risk levels, can be found in Appendix F.

- Potential mitigation strategies for addressing the relative increase in fire risk or hazard associated with the green building elements and features have been identified. These are presented at a basic level (e.g., provide automatic sprinkler protection). In many cases, adherence with existing test standards, codes and related design guidelines associated with conventional construction will help mitigate potential increases in fire risk or hazard associated with green building elements. Approval or certification of products which meet loss prevention criteria, and are indicated as having some type of green attribute which might gain credit in a green certification scheme, have been identified within the FM Approvals system and UL Product Certification system.

- Review of a sample of green rating schemes for which data were readily available, including LEED (residential and retail), BREEAM (new buildings), GREEN MARK (residential and nonresidential), as well as the IgCC, indicates that fire safety objectives are not explicitly considered. However, as noted above, implementation of certain green features could have a negative impact on fire or life safety if not mitigated. A qualitative approach using text and pictograms was used to reflect areas of fire and life safety concern, as illustrated in Figures 4 through 6, and applied to the sample of green building rating schemes reviewed, as illustrated in "Figure 7. Extract from GREEN MARK Assessment for Potential Unintended Fire Consequences", all of which can be found in Section 5. Detailed matrices of the assessment of the green rating schemes for potential unintended fire consequences can be found in Appendix G.

- It was determined that the green building rating scheme of the German Sustainable Building Council (DGNB) includes criteria for fire prevention (http://www.dgnb-system.de/dgnb-system/en/system/criteria/, accessed last on 10/29/12). Detail on the weights of fire prevention attributes relative to the green attributes was not able to be verified; however, it is understood that some credit is given for fire protection features such as smoke extract, automatic sprinklers, and structural fire protection.

- It was determined that BREEAM-in-USE (http://www.breeam.org/page.jsp?id=373, last accessed on 10/29/12), a recent BRE scheme to help building managers reduce the running costs and improve the environmental performance of existing buildings, incorporates fire risk reduction attributes. The fire risk reduction attributes related to such issues as whether a fire risk assessment has been conducted, are emergency plans in place, and so forth. No indication of consideration of fire protection systems was identified.

In order to fill gaps in knowledge to better address fire issues with green building features, further research is suggested in several areas.

- To address the lack of reported fire experience with green buildings and green building elements, especially in buildings which have a green rating or certification, a modification is required to fire incident data reporting systems as NFIRS. This could perhaps be done in collaboration with the USGBC and/or AIA, and parallel organizations in other countries. If this avenue is pursued, there will be challenges associated with how responding fire departments are able to identify LEED, BREEAM, or other such ratings for buildings. In cases where ratings or certifications are posted on buildings (e.g., LEED, Energy Star, BREEAM or other), this information could be readily captured by fire fighters responding to fire incidents in the building. In cases where such ratings or certifications are not posted, inclusion of specific features such as 'double-wall façade' or 'LEL' might be added to the incident reporting system, or additional guidance can be provided to first responders in identifying green attributes of buildings.

- To address the lack of analysis on fire 'risk' associated with green building elements, it is suggested that a more extensive research project is needed to review existing studies and reports on fire performance of green building elements, even if not explicitly identified as such (e.g., LEL). Research is needed to (a) develop a clear set of comparative performance data between green and 'conventional' methods, (b), develop an approach to convert the relative performance data into relative risk or hazard measures, and (c) conduct a risk (or hazard) characterization and ranking exercise, with a representative group of stakeholders, to develop agreed risk/hazard/performance levels.

- To explore the extent to which current standard test methods are appropriate for evaluating both green and fire safety criteria, and result in adequate mitigation of fire risk / hazard concerns, investigation into level of fire performance delivered by current standard test methods and into the *in situ* fire performance of green building elements is recommended.

- To address the lack of published case studies in which increased fire risk or hazards associated with green building elements have been specifically addressed, groups such as SFPE, NFPA, AIA and the USGBC can be encouraged to hold symposia on these topics and encourage publication of case studies in proceedings and associated journals. While such some studies have been published, they mostly reflect 'issues or concerns' with green building features without significant quantification of impacts and formal risk analysis.

- To address the lack of studies which have investigated incorporating building safety, life safety and fire safety as explicit elements in green building indices, joint research efforts between the FPRF and the USGBC and other promulgators of such indices could be explored with the aim to incorporate fire and life safety objectives as fundamental elements in green rating schemes and codes.

- To facilitate better collection of relevant data on fire safety challenges with green buildings in the future, a fire and green building data repository could be established. This might build on an existing effort (e.g., http://www.firemarshals.org/programs/greenbuildingsandfiresafetyprojects.html, last accessed 10/29/2012) or be supported by the FPRF or other organizations.

Table of Contents

1. Background and Introduction

This report has been prepared for the Fire Protection Research Foundation (FPRF) as the deliverable for the project *Safety Challenges of Green Buildings*. Section 1.1 reflects the Problem Statement, Project Objectives and Tasks as specified in the request for proposal. Section 1.2 reflects additional tasks which were explored. Section 1.3 summarizes the direction taken based on research undertaken.

1.1 Problem Statement, Project Objectives and Tasks

1.1.1 Problem Statement

To enhance their market value, and improve the sustainability of operations, many new commercial and industrial facilities are being designed and constructed with the goal of achieving a "green" certification, the most common of which in the U.S. is the LEED certification by the U.S. Green Building Council. The International Code Council and other groups are promulgating "green" building codes. These changes to building design and materials are an opportunity for safety improvements but may also include building performance, fire and safety challenges that have unintended consequences for sustainability from property damage as well as life safety. An assessment of fire performance (among other considerations) of green buildings, and focused research on the primary changes affecting building performance, fire and safety, are required. Furthermore, a systematic method needs to be developed for implementation in the certification process that integrates the consideration of fire as well as other hazard risk factors as part of design performance metrics.

1.1.2 Project Objectives

In addressing the problem as identified above, two objectives were provided:

(a) Systematically document a set of green building design elements that increase safety hazards, and
(b) Share best practices for hazard risk mitigation.

1.1.3 Tasks

To indicate progress on meeting the above objective, the following task was identified:

1. Conduct a global literature search to:
    - Identify documented fire incidents in the built inventory of green buildings,
    - Define a specific set of elements in green building design, including configuration and materials, which, without mitigating strategies, increase fire risk, decrease safety or decrease building performance in comparison with conventional construction,
    - Identify and summarize existing best practice case studies in which the risk introduced by specific green building design elements has been explicitly addressed, and
    - Compile research studies related to incorporating building safety, life safety and fire safety as an explicit element in green building indices, identifying gaps and specific needed research areas.

1.2 Additional Tasks

While the principal task was to conduct a global literature search in order to identify attributes as reflected in the specified task above, it was observed that it might be beneficial to consider approaches for presenting relative hazard or risk associated with green building elements and features, especially if such information was not identified as part of the literature search. As such, the project team proposed to pursue several additional activities as outlined below:

- Develop a list of fire and life safety attributes of concern against which to compare or assess the relative safety performance of green building elements (e.g., toxicity, flame spread, smoke spread, impact of fire-fighting operations, etc.).
- Review LEED and other such systems to understand implication of fire and safety performance objectives on green ratings or compliance requirements.
- Develop set of green and 'safety' performance objectives (metrics if possible). This is needed to assess combined performance.
- In addition to the literature search, survey various building regulatory agencies and fire research institutions around the world to obtain their experiences with fire and green buildings.
- Compile from the information search and survey existing research studies related to incorporating building safety, life safety and fire safety as an explicit element in green building indices, identifying gaps and specific needed research areas identified in those reports.
- Develop a first-order risk matrix / risk ranking approach that couples green building elements, products, systems and features with identified fire or life safety impacts of concern, benchmarking initially against 'conventional' construction and experience, using a relative 'greater than,' 'equivalent to,' or 'less than' approach, based in the first instance on expert judgment.
- Present a 'first-order' risk and performance assessment tool (matrix, perhaps) which incorporates green and safety performance indicators, and allows for future systematic assessment and documentation of green building design elements that may increase fire safety hazards.

1.3 Research Direction and Observations

Research was conducted as outlined above, beginning with a literature search, followed up by surveys, and including steps towards development of a hazard or risk ranking matrix. Research included green building site issues in addition to green building elements, since fire safety can be impacted by fire fighter access the site and building. Since few incidents of fires in documented green buildings were identified, there is currently insufficient data for quantified risk assessment. Also, since only limited data were found on actual fire performance tests of green building elements, and no data were found on comparative hazard analysis, a qualitative risk/hazard ranking approach was ultimately pursued. As presented, the relative rankings are based on expert judgment, and a much more formal process is recommended for obtaining stakeholder input on the hazard / risk factors and establishing rankings should future work be undertaken on this project. In addition, since this effort did not consider the green or sustainability benefits of fire protection measures, it is recommended that this aspect be included in future research associated with this FPRF project.

2. Information Search

Various searches and inquiries have been undertaken by the project team with the aim to identify fire incident reports, news reports, fire investigation reports, and research reports related to fires in green buildings and fires involving green building elements. These include web-based searches using generic search platforms (e.g., Google), targeted searches supported by WPI library staff (e.g., LEXIS/NEXIS), and searches of research and academic institution holdings (e.g., NIST, NRCC, BRANZ, WPI, etc.). The searches by the project team were supplemented by searches conducted by NFPA Research staff, inquires sent to the Technical Panel for this project, and inquires sent to the FPRF Property Insurance Research Group which sponsored this project. In addition, targeted inquiries were made via the IRCC (a group of 14 building regulatory agencies in 12 countries, www.irccbuildingregulations.org) and the Fire FORUM (an international group of fire research laboratory directors, http://www.fireforum.org/). Representative findings are provided below, with additional information in the appendices.

2.1 Representative Fire Incidents

In order to identify as many fire incidents involving green buildings and building elements as practicable, the project team reached out to several entities in the USA and internationally, including building regulatory agencies, fire service entities, insurance companies and research entities. The first stage involved web-based searches and requests via NFPA for fire incident data base searches. As a result of these searches a few dozen incidents were identified. A representative selection of incidents is presented in Table 1. While relatively small in number when compared to all fires, these incidents reflect a diverse set of fire and green building / element related issues, and helped form the basis of attributes identified and considered in Table 4 (Section 3) and Table 5 (Section 4).

Table 1. Representative Fire Incidents

Commercial Photovoltaic Panel Fire	
383 kW roof PV system fire, Target Store, Bakersfield, CA, April 2009	http://nfpa.typepad.com/files/target-fire-report-09apr29.pdf (last accessed 10/21/12)
PV roof fire, France warehouse, January 2010	http://www.aria.developpement-durable.gouv.fr/ressources/fd_37736_valdereuil_jfm_en.pdf (last accessed 10/21/12)
Roof PV system in Goch, Germany, April 2012.	http://www.feuerwehr-goch.de/index.php?id=22&tx_ttnews%5Btt_news%5D=596&cHash=982afcd5c431b7299f67de4af397cc43 (last accessed 10/21/12)
1,208kW roof PV system, Mt. Holly, NC, April 2011	http://www.solarabcs.org/about/publications/meeting_presentations_minutes/2011/12/pdfs/Duke-Webinar-Dec2011.pdf (last accessed 10/21/12)
PV roof fire, Trenton, NJ, March 2012	http://blog.nj.com/centraljersey_impact/print.html?entry=/2012/03/trenton_firefighters_battle_ro.html (last accessed 10/21/12)
	http://www.nj.com/mercer/index.ssf/2012/03/solar_panels_source_of_fire_at.html (last accessed 10/21/12)
Residential Photovoltaic Panel Fire	
PV Fire: Experience and Studies, UL, 2009	http://www.solarabcs.org/about/publications/meeting_presentations_minutes/2011/02/pdfs/Arc-PV_Fire_sm.pdf (last accessed 10/21/12)
PV fires, FPRF report, 2010	http://www.nfpa.org/assets/files/pdf/research/fftacticssolarpower.pdf (last accessed 10/21/12)
PV fire, San Diego, CA, April 2010	http://www.nctimes.com/article_8a32fb03-9e3f-58ca-b860-9c7fe1e28c7e.html (last accessed 10/21/12)
PV fire, Stittingbourne, UK, March 2012	http://www.kentonline.co.uk/kentonline/news/2012/march/30/solar_panels.aspx (last accessed 10/21/12)

Table 1. Representative Fire Incidents	
Battery Storage and UPS Fire	
Battery fire, Data Center, Taiwan, February 2009	http://indico.cern.ch/getFile.py/access?sessionId=8&resId=1&materialId=0&confId=45473 (last accessed 10/21/12)
Residential Spray Foam Insulation Fire	
Foam insulation home fire, North Falmouth, MA, May 2008	http://www.capecodonline.com/apps/pbcs.dll/article?AID=/20080520/NEWS/805200318/-1/rss01 (last accessed 10/21/12)
	http://www.greenbuildingadvisor.com/blogs/dept/green-building-news/three-massachusetts-home-fires-linked-spray-foam-installation (last accessed 10/21/12)
Foam insulation, Woods Hole, MA, February 2011	http://www.capecodonline.com/apps/pbcs.dll/article?AID=/20110211/NEWS/102110323 (last accessed 10/21/12)
Foam insulation fire, Quebec, May 2010	http://www.greenbuildingadvisor.com/blogs/dept/green-building-news/nze-project-tragic-fire-and-will-rebuild (last accessed 10/21/12)
Residential Foil Insulation, Fire / Shock Hazards	
Home Insulation Program (Australia)	http://www.climatechange.gov.au/government/initiatives/hisp/key-statistics.aspx (last accessed 10/21/12)
	http://www.productsafety.gov.au/content/index.phtml/itemId/974027/ (last accessed 10/21/12)
	http://www.wsws.org/articles/2010/feb2010/insu-f22.shtml (last accessed 10/21/12)
	http://www.theaustralian.com.au/news/garretts-roofing-fire-admission/story-e6frg6n6-1225829880090 (last accessed 10/21/12)
Exterior Finish and Insulation Systems Fire	
The Monte Carlo Exterior Façade Fire (2008)	http://usatoday30.usatoday.com/news/nation/2008-01-25-vegas-fire_N.htm (last accessed 10/21/12) http://magazine.sfpe.org/fire-investigation/monte-carlo-exterior-facade-fire (last accessed 10/21/12)
Sandwich Panels / Structural Integrated Panel (SIP) with Combustible Foam Insulation or Coating	
Borgata Casino, Atlantic City, NJ, Façade Fire (2007)	http://www.fireengineering.com/articles/2010/05/modern-building-materials-are-factors-in-atlantic-city-fires.html (last accessed 10/21/12)
Apartment Façade Fire, Busan, Korea	http://koreabridge.net/post/haeundae-highrise-fire-busan-marine-city-burns (last accessed 10/21/12)
	http://view.koreaherald.com/kh/view.php?ud=20101001000621&cpv=0 (last accessed 10/21/12)
Apartment Façade and Scaffold Fire, Shaghai, China	http://www.boston.com/bigpicture/2010/11/shanghai_apartment_fire.html (last accessed 10/21/12)
	http://www.bbc.co.uk/news/world-asia-pacific-11760467 (last accessed 10/21/12)
High-Rise Façade Fires, UAE	http://gulfnews.com/news/gulf/uae/emergencies/fire-breaks-out-at-sharjah-tower-1.1014750 (last accessed 10/21/12)
	http://www.emirates247.com/news/emirates/dh50-000-fine-for-fire-safety-violation-in-high-rises-2012-05-07-1.457534 (last accessed 10/21/12)
	http://article.wn.com/view/2012/05/02/Municipality_moves_to_ban_flammable_tiles/ (last accessed 10/21/12)
	http://article.wn.com/view/2012/05/02/Tower_cladding_in_UAE_fuels_fire/ (last accessed 10/21/12)
	http://article.wn.com/view/2012/05/01/Experts_shed_light_on_how_fires_spread_in_towers/ (last accessed 10/21/12)
Façade Fire, Beijing, China	http://www.nytimes.com/2009/02/10/world/asia/10beijing.html?_r=1 (last accessed 10/21/12)

2.2 Selected Resources Related to Fire and green Building Concerns

In addition to identifying fire incidents, the project team was also interested in identifying fire-related concerns with green buildings and building elements. The starting point for this search was also web-based searches, considering general media, trade publications, peer review articles, and research reports. Much like the incident data, the number of publications / resources identified is somewhat low.

This is in part due to challenges associated with web searches, limited responses to inquiries (see survey section), and general lack of efforts on fire and green building issues *defined as such*. This latter point is important, as some of the research identified by the project team has been attributed by the team as being related to green building issues, but might not have been by entities which conducted research that is cited (e.g., UL investigation into LEL and structural stability concerns, which was more closely identified as a fire fighter safety issue). This type of confounding representation likely means more research is available, but requires more effort to identify. Nonetheless, Table 2 contains a representation of the types of articles, reports and studies related to fire and green building concerns.

Table 2. Fire Safety Concerns in Green Buildings: Selected Resources	
Overall Concerns	
BRANZ - Building Sustainability and Fire-Safety Design Interactions (2012)	http://www.branz.co.nz/cms_show_download.php?id=716733515027fe4626188881f674635d51e3cfb0 (last accessed 10/21/12)
BRE – Impact of Fire on the Environment and Building Sustainability (2010)	http://www.communities.gov.uk/documents/planningandbuilding/pdf/1795639.pdf (last accessed 10/21/12)
Green Fire Initiatives - Links to Related Studies, National Association of State Fire Marshals (2010)	http://www.firemarshals.org/greenbuilding/greenfireinitiatives.html#greenroofs (last accessed 10/21/12)
Bridging the Gap: Fire Safety and Green Buildings, NASFM 2010	http://firemarshals.org/greenbuilding/bridgingthegap.html (last accessed 10/21/12)
Fire Safety Green Buildings, an IQP project by Joyce, Miller, Wamakima (WPI 2008)	http://www.wpi.edu/Pubs/E-project/Available/E-project-121908-111921/unrestricted/Final_IQP_Report.pdf (last accessed 10/21/12)
Photovoltaic / Energy systems	
Fire Operations for Photovoltaic Emergencies, CAL Fire-office State Fire Marshal, 2010	http://osfm.fire.ca.gov/fromthechief/pdf/sfmreportnov10.pdf (last accessed 10/21/12)
Fire Fighter Safety and Emergency Response for Solar Power Systems	http://www.nfpa.org/assets/files/pdf/research/fftacticssolarpower.pdf (last accessed 10/21/12)
Firefighter Safety and Photovoltaic Installations Research Project, UL 2011	http://www.ul.com/global/documents/offerings/industries/buildingmaterials/fireservice/PV-FF_SafetyFinalReport.pdf (last accessed 10/21/12)
The Ground-fault Protection Blind Spot: A Safety Concern for Larger Photovoltaic Systems	http://www.solarabcs.org/about/publications/reports/blindspot/pdfs/BlindSpot.pdf (last accessed 10/21/12)
Lightweight Wood Structures	
Lightweight structure fire, NFPA	http://www.nfpa.org/publicJournalDetail.asp?categoryID=1857&itemID=43878&src=NFPAJournal&cookie%5Ftest=1 (last accessed 10/21/12)
Structural collapse under fire conditions, Toomey 2008	http://www.fireengineering.com/articles/print/volume-161/issue-5/departments/training-notebook/structural-collapse-under-fire-conditions.html (last accessed 10/21/12)
Improving Fire Safety by Understanding the Fire Performance of Engineered Floor Systems and Providing the Fire Service with Information for Tactical Decision Making, UL 2012	http://www.ul.com/global/documents/offerings/industries/buildingmaterials/fireservice/basementfires/2009 NIST ARRA Compilation Report.pdf (last accessed 10/21/12)
Structural Collapse: The Hidden Dangers of residential fires (Dalton)	http://www.fireengineering.com/articles/print/volume-162/issue-10/features/structural-collapse.html (last accessed 10/21/12)
Architectural	
Fire Safety concern on well-sealed green buildings with low OTTVs (Chow 2010)	http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1000&context=ihpbc (last accessed 10/21/12)
A short note on fire safety for new architectural features (Chow 2004)	http://www.bse.polyu.edu.hk/researchCentre/Fire_Engineering/summary_of_output/journal/IJAS/V5/p.1-4.pdf (last accessed 10/21/12)

Table 2. Fire Safety Concerns in Green Buildings: Selected Resources	
Architectural	
Performance of double-skin façade	http://www.bse.polyu.edu.hk/researchCentre/Fire_Engineering/summary_of_output/journal/IJEPBFC/V6/p.155-167.pdf (last accessed 10/21/12)
Window reflecting melting vinyl siding	http://www.greenbuildingadvisor.com/blogs/dept/musings/window-reflections-can-melt-vinyl-siding (last accessed 10/21/12)
Fire Hazards of Foam Insulation	
Exterior walls, foam insulating materials, and property risk considerations (2007)	http://www.risklogic.com/articles/may2007.html (last accessed 10/21/12)
Panelized Construction problems	http://www.njeifs.com/lawyer-attorney-1513025.html (last accessed 10/21/12)
Toxicity of Flame Retardants in Foam Insulation and Other Products	
Brominated flame retardants and health concerns	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241790/ (last accessed 10/21/12)
PBDE flame retardants / potential adverse health effects	http://www.actabiomedica.it/data/2008/3_2008/costa.pdf (last accessed 10/21/12)
Toxicity of flame retardants and impact on fire fighters	http://www.nist.gov/el/fire_research/upload/4-Purser.pdf (last accessed 10/21/12)
Industrialized Roof Farming	
Rooftops take urban farming to the skies	http://today.msnbc.msn.com/id/32643514/ns/today-green/t/rooftops-take-urban-farming-skies (last accessed 10/21/12)
Wind Farm	
Dark side of Green Wind Turbine accidents	http://eastcountymagazine.org/print/9238 (last accessed 10/21/12)

While details can be found via the links provided, selected incidents, test programs and mitigation approaches are summarized in Appendix B. In addition, the following resources provide significant discussion relative to the project focus, and are highly recommended as key sources of information on the topic of green buildings and fire:

- The BRANZ study, *Building Sustainability and Fire-Safety Design Interactions,* http://www.branz.co.nz/cms_show_download.php?id=716733515027fe4626188881f674635d51e3cfb0 (last accessed 10/21/12)
- The BRE study, *Impact of Fire on the Environment and Building Sustainability*, http://www.communities.gov.uk/documents/planningandbuilding/pdf/1795639.pdf (last accessed 10/21/12)
- The NASFM Green Buildings and Fire Safety Project (report and web links), http://www.firemarshals.org/programs/greenbuildingsandfiresafetyprojects.html (last accessed 10/21/12)

In addition, it is worth noting that two of the above studies, those by BRE and BRANZ, also address the contribution of fire protection measures to sustainability. While this effort did not consider this topic, it is an area that should be considered in the overall assessment of building fire safety and sustainability. In this regard, studies undertaken by FMGlobal contribute significantly in this area as well:

- *The Influence of Risk Factors on Sustainable Development* – http://www.fmglobal.com/assets/pdf/P09104a.pdf (last accessed 10/21/12)

- *Environmental Impact of Fire Sprinklers* – http://www.fmglobal.com/assets/pdf/P10062.pdf (last accessed on 10/21/12 - registration may be necessary)

It is recommended that future research into the interactions of fire protection and building sustainability include consideration of the potential benefits of fire protection to sustainability as well as the potential detriments of green construction to fire and life safety.

2.3 International Survey and Responses

In addition to the web-based searches, a number of targeted inquiries were sent out, including requests for information sent to the NFPA Research Division, the FPRF panel members and their organizations, member countries of the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) and associated organizations in their countries (i.e., fire service, research or insurance entities to which they forwarded requests and/or provided contact information), and members of the International FORUM of Fire Research Directors (the FORUM). Response was reasonable (e.g., NFPA, several FPRF panel members and 8 of 14 IRCC members responded); however, data were limited, since in all cases it was reported that data specific to fire in green buildings is not being tracked, as this criterion is not including in existing fire incident reporting systems (including NFIRS in the USA). That challenge aside, some data on fires involving green building elements was provided, such as by the New South Wales Fire Brigade (Australia) as reflected in Table 3 below (see Appendix C for complete survey responses).

Table 3. Survey Responses from New South Wales Fire Brigade

Country / Entity	Fire Incident Experience/Tracking in green Buildings	Fire Incident Experience/Tracking Involving green Building Elements	Risk-Based Assessment of green Building Elements
Australia			
New South Wales Fire Brigade	The structures that subscribe to the National Built Environment Rating System (NABERS) are usually commercial or government buildings. In most cases they are relatively new and range from modern high rise premises in the city (e.g., No. 1 Bligh St.) to restored and renovated federation style buildings (e.g., 39 Hunter St.) The building codes also provide for prescribed or engineered fire safety solutions. There are no specific AIRS codes for "Green" buildings therefore it is very difficult to determine if there have been any fires or dominant fire causes in these buildings.	Ceiling Insulation: FIRU have experienced major concerns with this issue particularly in residential, nursing homes and aged care facilities. Cellulose fibre insulation in close proximity to downlights and insulation batts including non-compliance with electrical wiring rules have been the dominant concerns. AIRS analysis for insulation fires 29/02/2008 to 22/06/2011. Data provided by SIS: The data includes 102 incidents that occurred in metropolitan, regional and country areas. Of these incidents 75 were directly related to downlights and their associated transformers in close proximity to ceiling insulation. Some of the fires resulted in substantial property damage. Insulated Sandwich Panels: No specific AIRS codes for Insulated Sandwich Panels. FIRU have reports of residential structures constructed of insulated sandwich panels in locations ranging from Broken Hill to Thredbo. Laminated Timber I-Beams: No specific AIRS codes for Laminated Timber I-Beams. A combination of open plan living and modern furnishings (e.g. polyurethane foam settees, etc.) can create fuel packages that will reach temperatures of 1000-1200 degrees Celsius that can rapidly weaken structural elements. Photovoltaic Solar Installations: No specific AIRS codes for PV solar installations. It is estimated that NSW has about 150,000 PV solar installations. Predominant causes include faulty components and incorrect installation. (2010 to August 2012 = nine reported incidents) FIRU research indicates major problems with PV solar installations. No remote solar isolation switching, no DC rest device for Firefighters and no 24/7 availability of qualified PV solar electricians. This has been reflected in reports from around Australia, Germany and the US. From FIRU research it appears that major fire services throughout Australasia, United Kingdom, Germany and the United States have experienced concerns with "Green" building elements. When attending fire calls operational Firefighters are unable to readily determine if it is a "Green" building or one with "Green" building elements.	FRNSW has a Risk Based Approach for all incidents, including all types of structures. This is supported by a broad range of Standard Operational Guidelines (SOGs), Safety Bulletins and Operations Bulletins. No specific effort related to green buildings.

2.4 Review of Representative Green Building Rating Schemes for Fire Considerations

The problem statement for this project noted the proliferation of rating schemes for green buildings and the development of green building and construction codes which promote the use of green materials and systems, but which perhaps do not consider fire safety concerns, and that "a systematic method needs to be developed for implementation in the certification process that integrates the consideration of fire as well as other hazard risk factors as part of design performance metrics." In order to make progress on this, not only is it required to understand what constitutes green buildings and elements, and what fire hazards or risks they might pose, it is important to understand in which areas the existing rating schemes and codes might be imposing unintended fire safety consequences.

The information search revealed that globally there more than two dozen green building rating schemes available (e.g., see http://www.gsa.gov/graphics/ogp/sustainable_bldg_rating_systems.pdf, last accessed on 10/29/12). In addition, several systems have multiple schemes by building use, such as retail, school, residential, office, etc., and some include separate schemes for new and existing buildings. Likewise, there are a number of green building codes world-wide, including the IgCC, the Code for Sustainable Homes in England (http://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf, last accessed on 10/29/12) and others.

Only a small subset of the available green rating systems was able to be reviewed within the bounds and scope of this project. The sample of green rating schemes selected for this project was determined based on freely available information. The sample ultimately included LEED (residential and retail), BREEAM (new buildings), GREEN MARK (residential and nonresidential), and the IgCC. More discussion on the review and findings relative to these schemes can be found in Section 5 and Appendix G.

Review of this sample of green building rating schemes and the IgCC indicated that fire safety objectives are not explicitly considered in these systems. This is not unexpected, however, since the focus is principally on resource efficiency (e.g., energy, water, materials) and not on safety. In the case of BREEAM, a study by BRE (BRE BD2709, 2010, p45) notes that "fire safety and fire protection are not included in most BREEAM schemes since most BREEAM schemes assess new buildings and the BREEAM assessment takes for granted that the building will satisfy the Building Regulations; the BREEAM assessment relates to additional sustainability features."

Although no specific references regarding fire safety objectives were identified in LEED and GREEN MARK documentation, it is hypothesized that similar rationale applies as with BREEAM. With a voluntary system, which aims to encourage sustainable practices, it is anticipated that basic building code requirements, including fire safety, are met via code compliance. This is also the case with the IgCC, which is intended to work along with the International Building Code (IBC) and relevant codes and standards. If one then assumed that the risks or hazards associated with green building elements and features are addressed adequately by building codes and standards, one could assume that no additional risk or hazards exist. However, it can be that current fire tests, which have been determined as adequate for conventional construction, may not yet be fully vetted for innovative and green construction with respect to performance in use (e.g., LEL). Further study is recommended in this area.

Although none of the green building rating schemes that were reviewed during this project included fire safety objectives, it was found that the scheme of the German Sustainable Building Council (DGNB) includes criteria for fire prevention (http://www.dgnb-system.de/dgnb-system/en/system/criteria/, accessed last on 10/29/12). Although detail on the weights of fire prevention attributes relative to the green attributes was not able to be verified it is understood that some credit is given for fire protection features such as smoke extract, automatic sprinklers, and structural fire protection.

Likewise, it was determined that BREEAM-in-USE (http://www.breeam.org/page.jsp?id=373, last accessed on 10/29/12), a recent BRE scheme to help building managers reduce the running costs and improve the environmental performance of existing buildings, incorporates fire risk reduction attributes (BRE, 2010). The fire risk reduction attributes related to such issues as whether a fire risk assessment has been conducted, are emergency plans in place, and so forth. No indication of consideration of fire protection systems was identified.

3. Green Building / Site Elements & Attributes

Given the focus of the study, a necessary step was to identify green building features to consider. The following table reflects green building elements and attributes that were selected for this effort based on the literature review and survey responses (see Appendices A, B and C). While this list is extensive, it may not be exhaustive, and it is recommended that the list be updated by future studies as knowledge of other green materials, features, elements and attributes is identified.

Table 4. Green Building / Site Elements and Attributes

Structural Materials and Systems	Interior Materials and Finishes	Alternative Energy Systems
- Lightweight engineered lumber	- FRP walls / finishes	- PV roof panels
- Lightweight concrete	- Bio-polymer wall / finishes	- Oil-filled PV panels
- Fiber reinforced polymer (FRP) elements	- Bamboo walls / finishes	- Wind turbines
- Plastic lumber	- Wood panel walls / finishes	- Hydrogen fuel cells
- Bio-polymer lumber	- Bio-filtration walls	- Battery storage systems
- Bamboo	- Glass walls	- Cogeneration systems
- Phase-change materials	- FRP flooring	- Wood pellet systems
- Nano materials	- Bio-polymer flooring	- Electric vehicle charging station
- Extended solar roof panels	- Bamboo flooring	- Tankless water heaters
Exterior Materials and Systems	**Interior Space Attributes**	**Site Issues**
- Structural integrated panel (SIP)	- Tighter construction	- Permeable concrete systems
- Exterior insulation & finish (EFIS)	- Higher insulation values	- Permeable asphalt paving
- Rigid foam insulation	- More enclosed spaces	- Use of pavers
- Spray-applied foam insulation	- More open space (horizontal)	- Extent (area) of lawn
- Foil insulation systems	- More open space (vertical)	- Water catchment / features
- High-performance glazing	- Interior vegetation	- Vegetation for shading
- Low-emissivity & reflective coating	- Skylights	- Building orientation
- Double-skin façade / cavity walls	- Solar tubes	- Increased building density
- Bamboo, other cellulosic	- Increased acoustic insulation	- Localized energy production
- Bio-polymers, FRPs	**Building Systems & Issues**	- Localized water treatment
- Vegetative roof systems	- Natural ventilation	- Localized waste treatment
- PVC rainwater catchment	- High volume low speed fans	- Reduced water supply
- Exterior cable / cable trays	- Refrigerant materials	- Hydrogen infrastructure
Façade Attributes	- Grey-water for suppression	- Community charging stations
- Area of glazing	- Rain-water for suppression	
- Area of combustible material	- On-site water treatment	
- Awnings	- On-site waste treatment	
- Exterior vegetative covering	- On-site cogeneration	
	- High reliance on natural lighting	
	- PV exit lighting	
	- Reduced water suppression systems	

4. Attributes of Green Building or Site Which Could Impact Fire, Life Safety, Building or Fire Service Performance

In order to assess relative increases in fire hazard or risk or decreases in safety or performance of green building elements or attributes as compared with conventional construction, a list of risk, hazard or performance attributes of concern was required. The list in Table 5 was compiled from a combination of fire and life safety performance objectives typically addressed by building and fire codes and from issues identified during the literature review. This list reflects a focus on occupant and emergency responder safety issues and building performance issues. The list does not explicitly consider building contents protection, business continuity, or related market issues, which may also be of concern. While the list of attributes might be expanded or refined in the future, it provides a reasonable starting point and basis for comparative analysis.

Table 5. Hazard, Risk and Performance Attributes

Poses potential ignition hazard
Poses potential shock hazard
Poses potential explosion hazard
Poses potential toxicity hazard
Readily ignitable
Burns readily once ignited
Contributes more fuel / increased heat release rate (HRR)
Material affects burning characteristics
Fast(er) fire growth rate
Significant smoke production/hazard
Potential for shorter time to failure
Failure affects burning characteristics
Failure presents smoke spread concern
Failure presents flame spread concern
Material presents flame spread concern
May impact smoke/heat venting
May impact occupant evacuation
May impact fire-fighter (FF) water availability
May impact suppression effectiveness
May impact fire apparatus access
May impact fire-fighter (FF) access and operations
May impact containment of runoff

The lists in Tables 4 and 5 were used in the development of matrices which could potentially be used as a checklist to help review a building plan, a building and/or a building site for potential risks or hazards, as well as a mechanism to reflect relative risk level associated with the green building element. These matrices / tools are discussed in Section 5.2 and 5.3 respectively and detailed in Appendix D and Appendix E. The information in Tables 4 and 5 also formed the basis of the relative hazard and mitigation matrix discussed in Section 5.4.

5. Hazard / Risk Assessment and Ranking

There are various approaches to fire hazard and risk assessment and ranking, from qualitative to quantitative. Detailed discussion of these can be found in many sources, including the *SFPE Handbook of Fire Protection Engineering* (NFPA, 2008), *SFPE Engineering Guide on Fire Risk Assessment* (SFPE, 2006), NFPA 551, *Guide for the Evaluation of Fire Risk Assessments* (NFPA, 2012), textbooks (e.g., Ramachandran and Charters, 2011), and in the literature (e.g., Meacham, 2004; Meacham et al., 2012).

Given the scope, data, time and resources for this effort, the approach taken was qualitative, both for hazard / risk identification and level of severity (concern, importance). A principal driver for qualitative risk assessment is the lack of data on fires in green buildings and elements. Based on surveys and searches, needed data are not being collected systematically, and the number of incidents identified is small in number. Likewise, for the hazard assessment, while there are detailed assessments of specific building systems and elements, such as UL and NRC Canada research on lightweight engineered lumber (LEL) performance under fire conditions (e.g., see http://www.nrc-cnrc.gc.ca/eng/ci/v16n2/1.html, http://www.ul.com/global/eng/pages/offerings/industries/buildingmaterials/fire/fireservice/lightweight/), the data and the applications are limited with respect to the population of buildings which might be impacted. While generalizations can be extracted, such as certain floor systems using unprotected LEL joists between the basement level and first floor level of a single family dwelling failed more quickly than typical sawn lumber wood construction (i.e. 2x4 construction) for the scenarios and fires tested, it is difficult to quantify the actual difference in hazard or risk in comparison to the conventional wood construction without significantly more analysis. However, if such detailed analysis is undertaken, that will be a large step towards quantitative hazard assessment. Such an activity is recommended for the future.

The above discussion relative to fire performance of LEL floor systems as compared with 'conventional' construction is indicative of another challenge: assessing the relative increase in fire hazard or risk, or decrease in safety performance, associated with green building elements, even if they comply with current code requirements and associated test requirements. On the one hand, it is easy to say that any product, whether it green or conventional, achieves the same level of required performance as dictated by current regulatory requirements. However, as is being indicated by the LEL floor system research, while individual elements and products might achieve minimum test and code compliance, there can still be a difference in safety performance in relation to the product in use as part of a larger building system. This is not to say that forcing all green products to comply with current building code requirements and fire test requirements is in any way bad: quite the contrary, it is a very good first step and is a solid mitigation strategy. However, because of the intrinsic properties of some green elements, such as less material (e.g., LEL, or lighter weight high-strength concrete), or modified properties relative to energy performance which could increase fire or safety hazards beyond typical conventional system installations (e.g., more insulation, if combustible, adds the potential for additional fire load, even if a fire barrier is required; therefore, the magnitude of fire hazard would be larger than conventional systems if the thermal barrier fails), there are identifiable areas of concern that are currently not quantified. In-use configuration and fire scenarios are clear areas for further research and development.

Even when taking a qualitative approach to hazard / risk ranking, as done in this report, there are several ways in which the information can be presented and different depths at which the hazard or risk factors can be addressed relative to the green building issues identified. In the following sections three representations are provided: a detailed matrix with green element and attributes and potential hazard / risk factors; a tabular approach with fewer attributes but more discussion; and a qualitative pictorial indication of potential fire hazards within green rating schemes. Each of these approaches reflects a different area of focus. The detailed matrix is provided as the basis for a potential hazard / risk ranking tool. The user might see an input screen, where she indicates specific green elements or site features associated with a project, and the outcome would identify specific areas of concern and relative level of increased risk or hazard or decreased safety performance. This would then require mitigation options to be explored and implemented as desired. The tabular format presents the risk / hazard concerns in narrative form, provides a subjective ranking of relative importance level, and presents general mitigation strategies (e.g., use approved products, provide thermal barrier, provide sprinkler protection, etc.). This could be used for policy-level decisions or to guide selection of mitigation strategies. The pictorial approach might serve as the basis for some type of quick overview guide or energy and fire performance ranking for a building. All of these approaches are currently subjective and based on the views of the project team, and should be taken as illustrative only.

Building on the issue of limited input for the rankings as presented in this report, another complication at this stage is the lack of broad stakeholder participation to reach agreed upon risk / hazard attributes and relative risk / hazard rankings that would be required for implementable tools. The need for broad stakeholder participation in achieving consensus is widely understood, since whether or not increased hazard (or risk) is present, and if so, to whom or what, will depend on the stakeholder position (e.g., see Meacham, 2004; AS/NZS4630, 2004; ISO 31000, 2009; Meacham et al., 2008; Watts, 2008). In the above discussion, for example, manufacturers of LEL systems would likely have a much different perspective than the fire service. To get a balanced and agreed upon set of risk / hazard rankings, broad stakeholder participation, developed within a structured risk / hazard ranking exercise / environment, would be needed. Various approaches for conducting such as process are described in the literature (e.g., NAP, 1996; Meacham, 2000; Watts, 2008; Ramachandran and Charters, 2011). This is a recommended are for future development. Since such a broad stakeholder exercise was not undertaken as part of this effort, the hazard / risk / performance rankings as expressed within this report should be taken as illustrative only.

5.1 Detailed Matrices of Green Building Elements/Features and Hazard/Risk Factors

As noted in Section 4, a list of potential fire hazards / risks associated with the green building elements and attributes identified in Section 3 was developed. These can be combined into matrices which can be used as an assessment tool and as a hazard or risk presentation tool. An example of the combined attribute – fire hazard matrix for *Exterior Materials and Systems* is shown in Figure 1 below. A complete set of matrices by building / site area can be found in Appendix D.

Figure 1. Matrix of Green Attributes and Potential Fire Hazards

It is suggested that a blank matrix, as illustrated in Figure 1, could serve as a checklist for engineers, designers, insurers, authorities or others when reviewing site plans, building designs, renovation designs or buildings to guide inspection of green attributes which could result in a fire hazard or building fire performance concern. It does not, however, give any indication of the relative magnitude of the increased hazard or decreased performance. However, the matrix has the potential to be developed into a hazard / performance ranking tool, where the user identifies the green element or attribute in the design or building, and the tool provides an indication as to whether any increased fire risk or decrease performance might be expected. A potential approach to presenting relative risk/hazard information that could be generated by such a tool is illustrated in Figure 2 below.

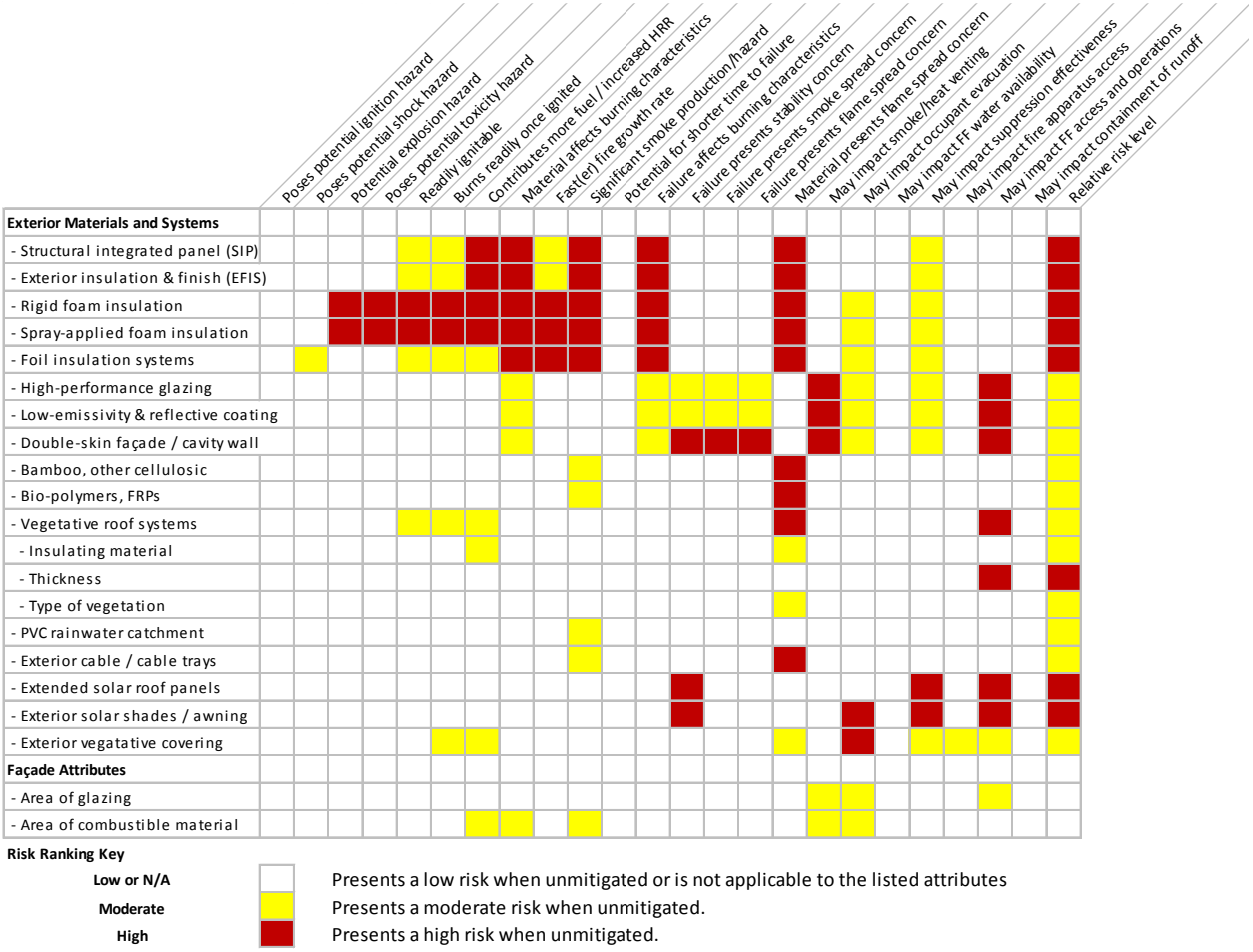


Figure 2. Relative Fire Risk/Hazard Level of green Attributes

In this figure, a relative level of fire risk or hazard is illustrated, wherein the blank boxes reflect low (or not applicable) risk or hazard, yellow boxes reflect moderate risk or hazard, and red reflects high risk or hazard, *in comparison to conventional element, systems and features*, and where no mitigation measure has been implemented. (As discussed earlier in the report, some level of mitigation is provided by compliance with existing building regulations and test standards; however, more research is needed to explore the degree of mitigation as compared with conventional construction in the context of the design and fire scenario.) Note that as discussed before, the assigned levels are all based on limited expert judgment at this time and should be taken as illustrative only. It is conceivable that a tool like this can be developed for engineers, designers, insurers, authorities or others when reviewing site plans, building designs, renovation designs or buildings to assist in hazard or risk analysis, and for developing mitigation strategies. Depending on what mechanism is used to create the underlying estimation of relative risk[1], this format lends itself to development into a spreadsheet tool. A complete set of exemplar matrices by building / site area can be found in Appendix E.

[1] For example, a semi-qualitative approach could be used where 'low,' 'moderate' and 'high' risk are assigned numerical values, and the 'relative risk level' is estimated as a weighted function of the importance or influence of hazard impact on the various 'green' elements.

5.2 Tabular Representation of Potential Fire Hazards with green Building Elements

While the presentation of information as reflect in the matrices in section 5.1 have the benefit of details associated with green elements and features, it has the shortcomings of lack of description of how the hazard or risk manifests and what potential mitigation strategies might be. In order to combine all of this information, we chose to develop a tabular representation of the green element, fire hazard (or risk), level of concern, and potential mitigation strategies. This is illustrated in Figure 3 below for the same *Exterior Materials and Systems* building areas used in the previous section. Although this is subjective at this point, the techniques overviewed before can be applied to result in a more quantitatively-based representation. A complete table for all building/site areas can be found in Appendix F.

Material / System / Attribute	Hazard	Concern Level	Potential Mitigation Stratgies
Exterior Materials and Systems			
- Structural integrated panel (SIP)	If fail, insulation can contribute to flame spread, smoke production and fuel load.	High	Approved / listed materials. Assure proper sealing of panels. Take care during installation, including retrofits, relative to potential sources of ignition.
- Exterior insulation & finish (EFIS)	If fail, insulation can contribute to flame spread, smoke production and fuel load.	High	Approved / listed materials. Assure proper sealing of panels. Take care during installation, including retrofits, relative to potential sources of ignition.
- Rigid foam insulation	Can contribute to flame spread, smoke and toxic product development and fuel load.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Flame retardants. Sprinklers.
- Spray-applied foam insulation	Can contribute to flame spread, smoke and toxic product development and fuel load.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Flame retardants. Sprinklers.
- Foil insulation systems	Can contribute to shock hazard for installers. Can contribute to flame spread and fuel load.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Sprinklers.
- High-performance glazing	Can change thermal characteristics of compartment for burning. Can impact FF access.	Moderate	Sprinklers. Assure adequate FD access. Assure mechanism for FD smoke/heat venting. Approved / listed materials.
- Low-emissivity & reflective coating	Can change thermal characteristics of compartment for burning. Can impact FF access.	Moderate	Sprinklers. Assure adequate FD access. Assure mechanism for FD smoke/heat venting. Approved / listed materials.
- Double-skin façade	Can change thermal characteristics of compartment for burning. Can impact FF access. Can present 'chimney' for vertical smoke and flame spread if not properly fire stopped.	Moderate	Appropriate fire stop between floors. Sprinklers may have some benefit (sprinklered building). Assure mechanism for FD smoke/heat venting. Approved / listed materials.
- Bamboo, other cellulosic	Can contribute to flame spread, smoke development and fuel load.	Moderate	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Bio-polymers, FRPs	Can contribute to flame spread, smoke development and fuel load.	Low	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Vegetative roof systems	Can contribute to fire load, spread of fire, impact FF operations, impact smoke and heat venting, contribute to stability issues.	Moderate	Manage fire risk of vegetation. Assure use of fire tested components. Provide adequate area for FD acces, smoke/heat venting, and other operations.Approved / listed materials.
- PVC rainwater catchment	Can contribute additional fuel load.	Low	Limit volume.
- Exterior cable / cable trays	Can contribute additional fuel load.	Low	Limit volume.Approved / listed materials.
Façade Attributes			
- Area of glazing	Can present more opportunity for breakage and subsequent fire spread and/or barrier to FF access depending on type.	Moderate	
- Area of combustible material	Larger area (volume) provides increased fuel load.	High	Limit volume.
- Awnings	Impacts FF access.	Low	
- Exterior vegetative covering	Can impact FF access and present WUI issue.	Low	Limit volume.

Figure 3. Tabular Representation of green Element, Hazard, Concern Level and Mitigation

5.3 Fire Hazards Associated with Green Rating Schemes and Codes

This aspect of the project involved review of various green building rating schemes, as well as the International Green Construction Code (IgCC), to determine (a) if and how fire and life safety objectives are included, and (b) if and how green attributes considered by the scheme may affect fire and life safety performance. Globally there more than two dozen green building rating schemes available for use (e.g., see http://www.gsa.gov/graphics/ogp/sustainable_bldg_rating_systems.pdf, last accessed on 10/29/12). In addition, several systems have multiple schemes by building use, such as retail, school, residential, office, etc., and some include separate schemes for new and existing buildings. Unfortunately, only a small subset of these systems was able to be reviewed within the bounds and scope of this project. Likewise, there are a number of green building codes world-wide, including the International Green Construction Code (IgCC), the Code for Sustainable Homes in England (http://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf, last accessed on 10/29/12) and others.

The sample of green building rating schemes selected for this project was determined based on freely available information. The sample ultimately included LEED (residential and retail), BREEAM (new buildings), GREEN MARK (residential and nonresidential), and the IgCC. Review of this sample of green building rating schemes and the IgCC indicated that fire safety objectives are not explicitly considered in these systems. This is understandable since the focus is sustainability. However, it means that the potential exists for competing objectives with fire and life safety concerns.

While the sample of green building rating schemes did not include any schemes that included fire safety objectives, it was determined during the research effort that the green building rating scheme of the German Sustainable Building Council (DGNB) includes criteria for fire prevention (http://www.dgnb-system.de/dgnb-system/en/system/criteria/, accessed last on 10/29/12). However, detail on the weights of fire prevention attributes relative to the green attributes was not able to be verified. Nonetheless, it is understood that some credit is given for fire protection features such as smoke extract, automatic sprinklers, and structural fire protection. Likewise, it was determined that BREEAM-in-USE (http://www.breeam.org/page.jsp?id=373, last accessed on 10/29/12), a recent BRE scheme to help building managers reduce the running costs and improve the environmental performance of existing buildings, incorporates fire risk reduction attributes (BRE, 2010). The fire risk reduction attributes related to such issues as whether a fire risk assessment has been conducted, are emergency plans in place, and so forth. No indication of consideration of fire protection systems was identified as part of BREEAM-in-USE.

Given the nature of the green building rating schemes that were reviewed, and the use of these systems by architects and others for which imagery is as illustrative as test, the approach taken for the review and presentation of these systems was to identify and pictorially classify a set of potential fire risk/hazard considerations and potential fire impacts, and to identify in each rating scheme reviewed where such risks might be introduced. The list of hazard/risk considerations, fire impacts, and consolidated representation of fire hazard and impact are illustrated in Figures 4-6 below.

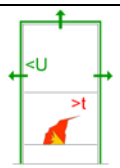
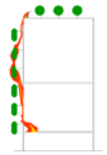
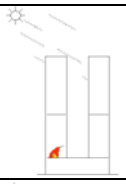
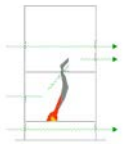
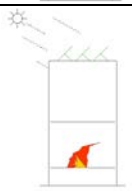
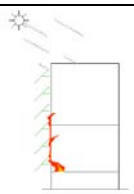
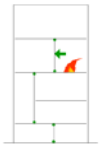
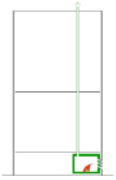
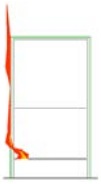
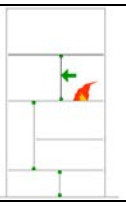
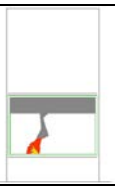
	Schematic Depiction of Interaction	Hazard Description		Schematic Depiction of Interaction	Hazard Description
1		Insulation increases interior temperature	8		The use of greenery systems on the envelope invades the surface with combustible material (dry and local species required)
2		Natural lighting and ventilation requires a non-compact building form	9		Natural ventilation requires connecting the exterior with the interior building parts
3		Renewable energy systems require invading part of the building envelope	10		Water consumption reduction influences the election of fire suppression systems
4		Daylight control devices require invading part of the building envelope	11		Noise reduction strategies require the use of non-rigid (elastic) joints
5		Disposal of rooms for waste or recyclable materials increases fire loads	12		Vegetation protection and use of greenery to reduce heat island effect influence the building surroundings conditions (may affect fire conditions)
6		Specific facade materials and systems reduce the election for optimal performance and may affect fire conditions	13		Structural materials prone to quicker failure.
7		Specific interior materials and systems reduce the election for optimal performance and may affect fire conditions	14		Adds additional fuel load to building

Figure 4. Schematic Representation of Fire Hazard

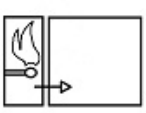
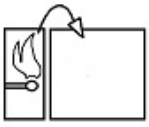
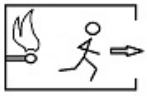
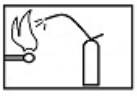
Interior Spread	Exterior Spread	Evacuation	FP Systems	Fire Service	Structure
					

Figure 5. Schematic Representation of Fire Impact

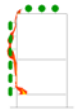
	Schematic Depiction of Interaction	Hazard Description	Primary Issues Associated with Fire Interaction with Green Elements					
			Interior Spread	Exterior Spread	Evacuation	FP Systems	Fire Service	Structure
1		Insulation increases interior temperature						
2		Natural lighting and ventilation requires a non-compact building form						
3		Renewable energy systems require invading part of the building envelope						
4		Daylight control devices require invading part of the building envelope						
5		Disposal of rooms for waste or recyclable materials increases fire loads						
6		Specific facade materials and systems reduce the election for optimal performance and may affect fire conditions						
7		Specific interior materials and systems reduce the election for optimal performance and may affect fire conditions						
8		The use of greenery systems on the envelope invades the surface with combustible material (dry and local species required)						
9		Natural ventilation requires connecting the exterior with the interior building parts						
10		Water consumption reduction influences the election of fire suppression systems						
11		Noise reduction strategies require the use of non rigid (elastic) joints						
12		Vegetation protection and use of greenery to reduce heat island effect influence the building surroundings conditions (may affect fire conditions)						
13		Structural materials prone to quicker failure.						
14		Adds additional fuel load to building						

Figure 6. Schematic Representation of Fire Impacts Associated with Green Building Features

Using the above system, the sample group of green building rating schemes and the IgCC were then reviewed, and the illustrative schematics for fire hazard impacts associated with green building features were applied. An illustration of the resulting comparison matrix is shown in Figure 7.

for the review, each rating system / code that was reviewed was converted into the format below, identifying Category/Chapter in the document, Section/Assessment issue being addressed, Aims of the scheme (where stated), Credits/Scores (where provided / used in the scheme), specific Requirements/Criteria required to be achieved, Procedures to be followed in achieving the targeted performance, Primary or Secondary fire hazards that were identified as part of the review, and a Summary of the potential fire impact represented by the schematic illustration (Figure 4).

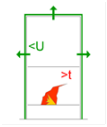
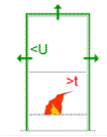
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Energy Efficiency (116 p. max.)	NRB 1-1 Thermal performance of Building Envelope- ETTV Enhance the overall thermal performance of the building envelope to minimize heat gain thus reducing the overall cooling load requirement		12	Maximum ETTV = 50 W/m2	Increase envelope insulation	(P) Increasing insulation (diminishing ETTV value) will increase interior temperature under fire (S) Can affect compartmentalization, the structure time resistance or evacuation	
				Use sun control devices		(P) May influence fire exterior spread (S) May disturb fire brigade intervention	
	NRB 1-2 Air-Conditioning System Encourage the use of better energy efficient air-conditioned equipment to minimize energy consumption		30	(a) Water-Cooled Chilled-Water Plant (b) Air Cooled Chilled-Water Plant/Unitary Air-Conditioners			
	NRB 1-3 Building Envelope-Design/Thermal Parameter Enhance the overall thermal performance of building envelope to minimize heat gain		35	(a) Minimum direct west facing façade through building design orientation (b) (i) Minimum west facing window openings (ii) Effective sunshading provision for windows on the west façade with minimum shading of 30% (c) Better thermal transmittance (U-value) of external west facing walls (≤ 2 W/m2K) (d) Better thermal transmittance (U-value) of roof	Increase envelope insulation	(P) Increasing insulation (diminishing ETTV value) will increase interior temperature under fire (S) Can affect compartmentalization, the structure time resistance or evacuation	

Figure 7. Extract from GREEN MARK Assessment for Potential Unintended Fire Consequences

It should be noted that the conversion of the various green rating schemes and the IgCC into a common format required some interpretation on the part of the project team, since different terminology is used in each system. However, the intent is to be illustrative of the potential fire hazards for similar elements across the systems, so the need to exactly reproduce each rating system was not seen as imperative. Full schematic comparisons are provided in Appendix G.

6. Summary and Conclusions

A global literature review was undertaken to (a) identify actual incidents of fires in green buildings or involving green building elements, (b) identify issues with green building elements or features which, without mitigating strategies, increase fire risk, decrease safety or decrease building performance in comparison with conventional construction, (c) identify reports, studies and best practice cases which speak to the issue of addressing fire risk introduced by specific green building design elements, and (d) identify research studies in which building safety, life safety and fire safety have been incorporated as an explicit element in green building indices. In addition, consideration was given to how one might express the level of increased risk or hazard, or decreased performance, associated with fire performance of green building features. Steps were also taken to identify gaps and specific research needs associated with understanding and addressing fire risk and hazards with green building design.

Outcomes of this effort include the following:

- There are currently no fire incident reporting systems in the United States or other countries surveyed which specifically collect and track data on fire incidents in green buildings or on items labeled as green building elements or features. Unless changes are made to reporting systems such as NFIRS, it will be difficult to track such fire incident data.

- Web searches and surveys have identified more than two dozen reported fire incidents that are related to green issues. Examples include fires associated with photovoltaic (PV) panels and roof materials, fire and safety hazards attributed to increased energy efficiency aims in residential buildings (primarily insulation related), fire involving insulating materials, fires associated with exterior cladding that contains combustible insulation materials or coatings, and fire performance of timber frame buildings with lightweight engineered lumber (LEL) components.

- Studies related to green building and fire issues produced by BRE, BRANZ, FMGlobal and the NASFM have been identified. Research on specific building elements with green attributes, but not necessarily labeled as green, such as lightweight engineered lumber (LEL), has been identified at UL and NRC Canada.

- From the materials reviewed, a comprehensive list of green building site and design features / elements / attributes has been compiled. The list is titled “Table 4. Green Building / Site Elements and Attributes” and can be found in Section 3.

- From the materials reviewed, a list of fire-related hazards and risk factors, associated with green building elements, has been compiled. The list is titled “Table 5. Hazard, Risk and Performance Attributes” and can be found in Section 4.

- Using Table 4 and Table 5, a set of matrices relating green attributes and potential fire hazards was developed. The matrix concept is illustrated in “Figure 1. Matrix of Green Attributes and Potential Fire Hazards**”** and can be found in Section 5. The complete set of matrices is detailed in Appendix E.

- Using the matrices identified above, an approach for illustrating the relative fire risk or hazard, or decreased fire performance, associated with green building elements, was developed. The relative risk matrix is illustrated in "Figure 2. Relative Fire Risk/Hazard Level of Green Attributes" and can be found in Section 5. A complete matrix, which is based on a qualitative expert judgment approach for illustrating relative risk levels, can be found in Appendix F.

- Potential mitigation strategies for addressing the relative increase in fire risk or hazard associated with the green building elements and features have been identified. These are presented at a basic level (e.g., provide automatic sprinkler protection). In many cases, adherence with existing test standards, codes and related design guidelines associated with conventional construction will help mitigate potential increases in fire risk or hazard associated with green building elements. Approval or certification of products which meet loss prevention criteria, and are indicated as having some type of green attribute which might gain credit in a green certification scheme, have been identified within the FM Approvals system and UL Product Certification system.

- Review of a sample of green rating schemes for which data were readily available, including LEED (residential and retail), BREEAM (new buildings), GREEN MARK (residential and nonresidential), as well as the IgCC, indicates that fire safety objectives are not explicitly considered. However, as noted above, implementation of certain green features could have a negative impact on fire or life safety if not mitigated. A qualitative approach using text and pictograms was used to reflect areas of fire and life safety concern, as illustrated in Figures 4 through 6, and applied to the sample of green building rating schemes reviewed, as illustrated in "Figure 7. Extract from GREEN MARK Assessment for Potential Unintended Fire Consequences", all of which can be found in Section 5. Detailed matrices of the assessment of the green rating schemes for potential unintended fire consequences can be found in Appendix G.

- It was determined that the green building rating scheme of the German Sustainable Building Council (DGNB) includes criteria for fire prevention (http://www.dgnb-system.de/dgnb-system/en/system/criteria/, accessed last on 10/29/12). Detail on the weights of fire prevention attributes relative to the green attributes was not able to be verified; however, it is understood that some credit is given for fire protection features such as smoke extract, automatic sprinklers, and structural fire protection.

- It was determined that BREEAM-in-USE (http://www.breeam.org/page.jsp?id=373, last accessed on 10/29/12), a recent BRE scheme to help building managers reduce the running costs and improve the environmental performance of existing buildings, incorporates fire risk reduction attributes. The fire risk reduction attributes related to such issues as whether a fire risk assessment has been conducted, are emergency plans in place, and so forth. No indication of consideration of fire protection systems was identified.

In order to fill gaps in knowledge to better address fire issues with green building features, further research is suggested in several areas.

- To address the lack of reported fire experience with green buildings and green building elements, especially in buildings which have a green rating or certification, a modification is required to fire incident data reporting systems as NFIRS. This could perhaps be done in collaboration with the USGBC and/or AIA, and parallel organizations in other countries. If this avenue is pursued, there will be challenges associated with how responding fire departments are able to identify LEED, BREEAM, or other such ratings for buildings. In cases where ratings or certifications are posted on buildings (e.g., LEED, Energy Star, BREEAM or other), this information could be readily captured by fire fighters responding to fire incidents in the building. In cases where such ratings or certifications are not posted, inclusion of specific features such as 'double-wall façade' or 'LEL' might be added to the incident reporting system, or additional guidance can be provided to first responders in identifying green attributes of buildings.

- To address the lack of analysis on fire 'risk' associated with green building elements, it is suggested that a more extensive research project is needed to review existing studies and reports on fire performance of green building elements, even if not explicitly identified as such (e.g., LEL). Research is needed to (a) develop a clear set of comparative performance data between green and 'conventional' methods, (b), develop an approach to convert the relative performance data into relative risk or hazard measures, and (c) conduct a risk (or hazard) characterization and ranking exercise, with a representative group of stakeholders, to develop agreed risk/hazard/performance levels.

- To explore the extent to which current standard test methods are appropriate for evaluating both green and fire safety criteria, and result in adequate mitigation of fire risk / hazard concerns, investigation into level of fire performance delivered by current standard test methods and into the *in situ* fire performance of green building elements is recommended.

- To address the lack of published case studies in which increased fire risk or hazards associated with green building elements have been specifically addressed, groups such as SFPE, NFPA, AIA and the USGBC can be encouraged to hold symposia on these topics and encourage publication of case studies in proceedings and associated journals. While such some studies have been published, they mostly reflect 'issues or concerns' with green building features without significant quantification of impacts and formal risk analysis.

- To address the lack of studies which have investigated incorporating building safety, life safety and fire safety as explicit elements in green building indices, joint research efforts between the FPRF and the USGBC and other promulgators of such indices could be explored with the aim to incorporate fire and life safety objectives as fundamental elements in green rating schemes and codes.

- To facilitate better collection of relevant data on fire safety challenges with green buildings in the future, a fire and green building data repository could be established. This might build on an existing effort (e.g., http://www.firemarshals.org/programs/greenbuildingsandfiresafetyprojects.html, last accessed 10/29/2012), or be supported by the FPRF or other organizations.

7. References

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BRE 2709 (2010). *Impact of fire on the environment and building sustainability BD 2709*. Department for Communities and Local Government, UK. Available at http://www.communities.gov.uk/documents/planningandbuilding/pdf/1795639.pdf Last accessed 10/21/2012.

ISO 31000, 2009. *Risk management-Principles and guidelines*, ISO, Geneva, Switzerland.

Meacham, B.J., 2000. "Application of a Decision-Support Tool for Comparing and Ranking Risk Factors for Incorporation into Performance-Based Building Regulations," in *Proceedings of the Third International Conference on Performance-Based Codes and Fire Safety Design Methods,* SFPE, Bethesda, MD.

Meacham, B.J. 2004. "Understanding Risk: Quantification, Perceptions and Characterization," *Journal of Fire Protection Engineering*, 14, 3, pp. 199–227.

Meacham, B.J., Johnson, P.J., Charters, D. and Salisbury, M., 2008. "Building Fire Risk Analysis," Section 5, Chapter 12, *SFPE Handbook of Fire Protection Engineering*, 4th Edition, NFPA and SFPE, Quincy, MA, USA.

Meacham, B.J., Dembsey, N.A., Johann, M., Schebel, K. and Tubbs, J., "Use of Small-Scale Test Data to Enhance Fire-Related Threat, Vulnerability, Consequence and Risk Assessment for Passenger Rail Vehicles," *Journal of Homeland Security and Emergency Management*, Vol. 9, Issue 1, January 2012.

NFPA 551, *Guide for the Evaluation of Fire Risk Assessments*, NFPA, Quincy, MA.

NAP, 1996. *Understanding Risk: Informing Decisions in a Democratic Society,* National Academy Press, Washington, DC

Ramachandran G. and Charters, D. 2011. *Quantitative Risk Assessment in Fire Safety*, Spon Press, London, England

SFPE (2008). *SFPE Handbook of Fire Protection Engineering.* NFPA, Quincy, MA.

SFPE (2006). *SFPE Engineering Guide on Fire Risk Assessment*, SFPE, Bethesda, MD.

Watts, J. 2008. "Fire Risk Indexing," Section 5, Chapter 10, *SFPE Handbook of Fire Protection Engineering*, 4th Edition, NFPA and SFPE, Quincy, MA, USA.

Appendix A. Informational Resources

This section provides a listing of resources identified during the search for information on fire incidents in green buildings, reports on fire studies of green building elements, and related information. While not all items were referenced or were ultimately of value to the project, they are included for completeness. Specific resources listed and discussed in Section 4 and other sections of this report are not necessarily repeated here.

It is worth highlighting that the following resources provide significant discussion relative to the project focus and are highly recommended as key sources of information on the topic of green buildings and fire:

- The BRANZ study, *Building Sustainability and Fire-Safety Design Interactions,* http://www.branz.co.nz/cms_show_download.php?id=716733515027fe4626188881f674635d51e3cfb0 (last accessed 10/21/12)
- The BRE study, *Impact of Fire on the Environment and Building Sustainability*, http://www.communities.gov.uk/documents/planningandbuilding/pdf/1795639.pdf (last accessed 10/21/12)
- The NASFM Green Buildings and Fire Safety Project (report and web links), http://www.firemarshals.org/programs/greenbuildingsandfiresafetyprojects.html (last accessed 10/21/12)

Conference, Trade Magazine, Journal Articles and Government Reports

Barber, D. (2012). "Can Building Sustainability be Enhanced through Fire Engineering of Structures?," *Proceedings, 9th International Conference on Performance-Based Codes and Fire Safety Design*, SFPE, Bethesda, MA. Discussion of fire and sustainability concepts, including what makes a material 'sustainable'.

Bill, R.G., Jr., Meredith, K., Krishnamoorthy, N., Dorofeev, S., and Gritzo, L.A. (2010), "The Relationship of Sustainability to Flammability of Construction Material," 12th International Fire Science & Engineering Conference, *Interflam 2010,* Interscience Communications, Ltd. Discusses flammability of construction materials which have been identified as having a green or sustainable attribute.

BRE 2709 (2010). *Impact of fire on the environment and building sustainability BD 2709*. Department for Communities and Local Government, UK. Last accessed 10/21/2012. Available at http://www.communities.gov.uk/documents/planningandbuilding/pdf/1795639.pdf

Carter, M., Lee, N., Oliver, E. & Post, M. 2011. *Promoting the Design of Buildings that are Fire Safe and Sustainable, A Review for Fire Protection Association Australia.* An Interactive Qualifying Project Report submitted in Partial Fulfillment of the Bachelor of Science, Worcester Polytechnic Institute, Worcester, MA

Charters, D.A. and Fraser-Mitchell, J. (2007). "The Potential Role and Contributions of Fire Safety to Sustainable Buildings," *Interflam 2007*, Interscience Communications Ltd., pp, 1231-1242. Discusses contribution of fire protection systems and features to building sustainability.

Chow, C.L., Chow, W.K. (2003). "Assessing Fire Safety Provisions for Satisfying Green or Sustainable Building Design Criteria: Preliminary Suggestions," *International Journal on Architectural Science*, 4(3):141,142-146. Academic study on assessment of fire safety provisions for satisfying green or sustainable building design criteria and preliminary suggestions. Recommends creation of assessment scheme for inspecting fire safety in green or sustainable buildings.

Chow, W. K. & Hung, W. Y. (2006). Effect of cavity depth on smoke spreading of double-skin facade. *Building and Environment,* 41**,** 970-979. Discusses testing relative to smoke propagation within cavity of double-skin façade. Shows relationship based on depth, with 1 m allowing for smoke spread in the testing that was conducted.

Chow, W.K. and Chow, C.L. (2005). "Evacuation with Smoke Control for Atria in Green and Sustainable Buildings," *Building and Environment*, 40, pp. 195-200. Discusses competing objectives of building, fire and green codes and attributes, focusing on how atria – which meet green criteria but not all prescriptive fire codes in Hong Kong – can aid evacuation during fire.

Chow, W.K., Hung, W.Y., Gao, Y., Zou, G. and Dong, H. (2007). "Experimental Study on Smoke Movement Leading to Glass Damages in Double-Skinned Façade," *Construction and Building Materials*, 21, pp. 556-566. Discusses testing conducted relative to breaking glass on double-skin façade due to fire. Testing showed cavity depth of 1m resulted in glass breakage and smoke spread concerns.

DECC (2010). The green deal: A summary of the Government's proposals. Department of Energy and Climate Change, England. Report number 10D/996. Available at http://www.decc.gov.uk/assets/decc/legislation/energybill/1010-green-deal-summary-proposals.pdf Accessed 6/26/2012. UK's proposal of the Green Deal: what it is and why it's needed.

Dent, S. (2010). "Fire protection engineering and sustainable design why performance-based design will become increasingly important in the future," *Fire Protection Engineering*, Penton. Available from: http://magazine.sfpe.org/fire-protection-design/fire-protection-engineering-and-sustainable-design. Accessed 6/26/2012. Discusses that performance-based design will become increasingly important in the future due to issues associated with the challenges a fire protection engineer faces with sustainable/green building design and increased number of people inside a building. Also provides two case studies of how fire protection design worked with a green sustainable building.

Ding, W., Hasemi, Y. & Yamada, T. (2005). Natural ventilation performance of a double-skin facade with a solar chimney. *Energy and Buildings,* 37**,** 411-418. Discusses non-fire ventilation performance of double-skin façade.

Emberley, R.L., Pearson, T.M., Andrews, A.S. (2012) Green Buildings and Fire Performance, Research report submitted as part of Course FP571, Performance-Based Design, Worcester Polytechnic Institute, Worcester, MA. Summarizes areas of potential concern based on review of literature.

Grant, C.C. (2010). *Fire fighter safety and emergency response for solar power systems*. A report of the Fire Protection Research Foundation, Quincy, MA. Accessible from the internet at http://www.nfpa.org/assets/files/pdf/research/fftacticssolarpower.pdf. Accessed 6/26/2012. Investigation of fire fighter safety and emergency response for solar power systems. Report focuses on the fact of growing demand for alternative energy and the number of areas of concern with hazard mitigation and emergency response. Includes several case studies of fire incidents, review of fire fighter tactics, and recommendations for further research.

Green Building Challenges for the Fire Service, Fire Engineering (web article), c2011 Available from: http://www.fireengineering.com/articles/2011/01/green-building-challenges-for-the-fire-service.html. Accessed 8/1/2012. This website contains the report of Green Building Challenges for the Fire Service. Discusses several issues that face the fire service and provide justification of why it is a problem.: Site and Landscape Issues, Building Envelope, Vegetative roof systems, high performance glazing, building design attributes, water conservation, alternative power systems, wind turbine systems, hydrogen fuel cell power systems, battery storage systems.

Gritzo, L. A., Doerr, W., Bill, R., Ali, H., Nong, S. & Kranser, L. (2009). *The Influence of Risk Factors on Sustainable Development*. Norwood, MA, USA: FM Global, Research Division. Available at http://www.fmglobal.com/assets/pdf/P09104a.pdf. Last accessed 10/21/2012.

Hirschler, M.M. (2008). "Polyurethane foam and fire safety," *Polym. Adv. Technol.*; 19: 521–529. Includes discussion of toxic impacts of flame retardants.

Hofmeister, C. E. (2010). "Prescriptive to Performance-Based Design in Green Buildings," *Fire Protection Engineering*, Penton Press. http://fpemag.com/archives/article.asp?issue_id=54&i=452 Accessed 3/24/2012

Jarrett, R., Lin, X.G., and Westcott, M. (2011) *CSIRO risk profile analysis - guidance for the home insulation safety program*. CSIRO Report No. EP112079. Australia. The 2011 report for the Home Insulation Safety Program that set out to give advice on the Home Insulation Program and identify and rank dwellings with insulation according to risk indicators. Report provides information of Fire Risk, Safety Risk, Inspection Results, and Risk Profiling Tool.

Kasmauskas, D. G. (2010). "Green Construction and Fire Protection: Will LEED eventually recognize the environmental benefits of fire sprinklers?," *Fire Protection Engineering*, Penton Press. http://magazine.sfpe.org/fire-protection-design/green-construction-and-fire-protection Accessed 3/24/2012.

Kortt, M.A. and Dollery, B. (2012). "The home insulation program: An example of Australian government failure," *The Australian Journal of Public Administration*; Vol. 71, No. 1, pp. 65–75 doi:10.1111/j.1467-8500.2012.00754.x. Report on the failure of the Home Insulation Program. Offers start to finish information of program including analysis and lessons for the future.

McVay, P., Jackson, K., Christian, M., Fitzgerald, W., Jognson. M, Hall, M. and Cass, B. (2010). *Home Insulation Program,* ANAO Audit Report No.12 2010–11. Australia: Australian National Audit Office. Audit report on the Home Insulation Program that details why the program went into place, the failing of the Home Insulation Program, creation of the Home Insulation Safety Program, and key milestones of the program as well (what phase the program was in and money used to that point.)

Miller, L., Joyce, S., and Wamakima, D. (2008). *Fire Safety in Green Buildings.* Interactive Qualifying Project, Worcester Polytechnic Institute, Worcester, MA.

Modern Green-Building Fire Protection [Internet]: HPAC Engineering; c2009 [cited 2012 August 1]. Available from: http://hpac.com/fastrack/Modern-Green-Building-Fire-Protection/. Encourages the use of fire safety and fire protection practices through use of awareness, codes and standards, LEED certification, fire detection technology, and fire suppression technology.

Murphy, J. J. and Tidwell, J. (2010). *Bridging the Gap: Fire Safety and the Green Building,* National Association of State Fire Marshals.http://www.firemarshals.org/greenbuilding/bridgingthegap.html Last accessed 8/12/2012.

Ohlemiller, T.J. and Shields, J.R. (2008) Aspects of the Fire Behavior of Thermoplastic Materials, NIST Technical Note 1493, Gaithersburg, MD.

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Shields, T. J., Silcock, G. W. H. & Hassani, S. K. S. (1997). The behavior of double glazing in an enclosure fire. *Journal of Applied Fire Science,* 7**,** 267-286.

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Stec, W. J. & Van Paassen, A. H. C. (2002). Validation of the simulation models of the double skin facade. *Advances in Building Technology,* 2**,** 1181-1188.

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Informational Articles / Resources about Fire and Green Elements / Systems

Summary of Wind Turbine Accident data to 30 June 2012 Caithness Windfarm Information Forum [Internet]: Caithness Windfarm; c2012 [cited 2012 August 1]. Available from: http://www.caithnesswindfarms.co.uk/accidents.pdf. This is a document by Caithness Windfarm of Wind Turbine Accidents to 30 June 2012. The document has a long list of the different types of accidents that can happen when using a Wind Turbine. It lists fire as the second most common accident and the difficulty in extinguishing them.

Do HVLS Fans Risk Fire Safety? [Internet]: Klausbruckner and Associates; c2011 [cited 2012 August 1]. Available from: http://www.klausbruckner.com/blog/do-hvls-fans-risk-fire-safety/. This article contains information about a recent study of HVLS fans. The study focused on: Do HVLS fans obstruct sprinkler operation in case of fire and does their additional air flow produced while in operation increase fire spread or negatively impact overall fire dynamics?

Fire & Flammability [Internet]: Solar America Board for Codes and Standards; c2011 [cited 2012 August 1]. Available from: http://www.solarabcs.org/current-issues/fire.html. This website contains a list of Codes and Standards identified fire and flammability safety areas. It has links to articles of : "The Ground-Fault Protection: 'Blind Spot' A Safety Concern for Larger PV Systems in the U.S.", "Prevention of PV Modules as the Cause of a Fire", "Fire Class Rating of PV Systems" and "Fire Fighter Safety in Buildings with PV Modules."

Fire-Resistant Insulation and Systems [Internet]Webpage: This Old House [cited 2012 6/29]. Available from: http://www.thisoldhouse.com/toh/photos/0,,20156142_20362077,00.html. Popular Home improvement magazine that lists Fire safety items to install in homes. Includes some factoids on wool insulation fire safety rating.

Fire Code Requirements for Spf Applications [Internet]: Sprayfoam.com [cited 2012 August 1]. Available from: http://www.sprayfoam.com/leps/letitem.cfm?letid=38. Industry website that contains information of fire code requirements (NFPA, International Residential Code, ASTM, ICC) for spray foam applications. Specific data includes Fire Test Requirements, Surface Burning Characteristics, Special Approvals, Exceptions to the Thermal Barrier Rule, Ignition Barriers, Steiner Tunnel Test and procedure for it, Foam Plastics and the FTC Consent Decree, Room Corner Fire Tests, Thermal barrier test and Hourly Fire Ratings, Hourly Fire Ratings, Thermal Barrier Test, Attic and Crawl Space Test, Standard Fire Test for Evaluation of Fire Propagation Characteristics of Exterior Non-Load Bearing Wall Assemblies Containing Combustible Components, Evaluations Services and Reports, and Acceptance Criteria for Spray Polyurethane Foam.

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Underwood J. Fire-resistant details studying the houses that survived the 1993 Laguna beach fire storm yields lessons in building to withstand the heat. Fine Homebuilding.

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ANSI/SPRI VF-1 External Fire Design Standard for Vegetative Roofs. ANSI, Green Roofs for Healthy Cities,; 2010 January 29, 2010:http://www.spri.org/pdf/ansi_spri_vf-1_external_fire_design_standard_for_vegetative_roofs_jan_2010.pdf. Codes and Standards listed by the Approved American National Standard and made for Green Roofs for Healthy Cities. Contains requirements for Vegetative Roofs including definitions, system requirements & general design considerations, vegetative roof design options and maintenance.

Approval Standard for Vegetative Roof Systems [Internet]: FM Approvals; c2010 [cited 2012 August 1]. Available from: http://www.fmglobal.com/assets/pdf/fmapprovals/4477.pdf. Standard for Vegetative Roof System that are used within an FM Approved roof assembly. Contains General information, general requirements, performance requirements, and operations requirements.

ANSI/SPRI VF-1 External Fire Design Standard for Vegetative Roofs [Internet]: Green Roofs for Healthy Cities; c2010 [cited 2012 August 1]. Available from: http://www.greenroofs.org/resources/ANSI_SPRI_VF_1_Extrernal_Fire_Design_Standard_for_Vegetative_Roofs_Jan_2010.pdf. Codes and Standards listed by the Approved American National Standard and made for Green Roofs for Healthy Cities. Contains requirements for Vegetative Roofs including definitions, system requirements & general design considerations, vegetative roof design options and maintenance.

ICC-700 2008. National Green Building Standard. Washington, DC: International Codes Council.

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GREEN MARK, BCA, Singapore, http://www.bca.gov.sg/greenmark/green_mark_buildings.html

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LEED 2009 For Retail: New Construction and Major Renovations. USGBC; 2009 March 2010. Codes and Standards listed by the USGBC. Contains requirements for LEED certification For Retail: New Construction and Major Renovations. Specifies 7 different categories in which a retail structure can earn points towards LEED certification for having certain green elements.

LEED for homes rating system. USGBC; 2008 January 2008. Codes and Standards listed by the USGBC. Contains requirements for LEED certification For Homes. Specifies 7 different categories in which a home can earn points towards LEED certification for having certain green elements.

Articles / Websites Related to Fire Associated with Australian Home Insulation Plan

Australian government's home insulation safety plan. Australian Government News. May 18. 2012. This is an article published on the Newswire by the Australian Government News. The article details general information about the Australian Government's Home Insulation Safety Plan including its set completion date and how many homes that have been inspected by the plan.

Foiled: Garret bans 'dangerous' roof insulation [Internet]Brisbane Times.com.au: Brisbane Times; cFebruary 9, 2010 [cited 2012 5/29]. Available from: http://www.brisbanetimes.com.au/queensland/foiled-garrett-bans-dangerous-roof-insulation-20100209-nojb.html. This is an article published by Brisbane Times in Australia. The article details about the Federal Environment Minister Peter Garrett ban on the use of foil insulation. The article continues offering details of why foil insulation was banned citing electrical problems and deaths during insulation.

Metal foil insulation banned from Federal Government's roof insulation program after four deaths [Internet]The Daily Telegraph AAP: The Daily Telegraph; cFebruary 10, 2010 [cited 2012 5/29]. Available from: http://www.dailytelegraph.com.au/property/metal-foil-insulation-banned-from-federal-governments-roof-insulation-program-after-four-deaths/story-e6frezt0-1225828479206. This is an article published by the Telegraph in Australia. The article details about Federal Environment Minister Peter Garrett ban on the use of foil insulation. The article continues offering details of affected houses, industry, and critics opinions on the subject.

Foil insulation banned amid electrocution fears [Internet]ABC News Online. AU: ABC News; cFebruary 09, 2010 12:57 [cited 2012 5/29]. Available from: http://www.abc.net.au/news/2010-02-09/foil-insulation-banned-amid-electrocution-fears/324984. This is an article published by ABC News. The article details about Federal Environment Minister Peter Garrett ban on the use of foil insulation. The article contains quotes from Peter Garret's statement to the press.

3 out of 4 products do not meet flammability standards [Internet]Kingspan Insulation- Australia: Kingspan; c6/04/2010 [cited 2012 5/29]. Available from: http://www.kingspaninsulation.com.au/News/2010/3-out-of-4-products-do-not-meet-flammability-stand.aspx. Kingspan Insulation is an Australia based company that prides itself in innovative thermal insulation products. In one of their news releases, they detail a study that 3 out of 4 products (foil insulation products) do not meet a flammability index specified by the Building Code of Australia.

Key Statistics [Internet]: Australian Government; c2012 [cited 2012 August 1]. Available from: http://www.climatechange.gov.au/government/initiatives/hisp/key-statistics.aspx. This government website contains key statistics on the Home Insulation Safety Plan. Specifically, it offers the total number of inspections done by the Plan (foil, non-foil), fire incidents linked to the HIP, and calls to the safety hotline.

Study reveals shortfall in insulation standard [Internet]: Kingspan; c2008 [cited 2012 August 1]. Available from: http://www.kingspaninsulation.asia/News/2008/Study-reveals-shortfall-in-insulation-standard.aspx. Trade website newsletter, Kingspan Australia, details a recent study by University of

South Australia discovered the R value of foil-backed glass wool building blanket in-situ was up to 60% less than the certified R-value.

A foil to the insulation debate [Internet]ABC News Blog: ABC News; c11 Feb 2010 [cited 2012 5/29]. Available from: http://www.abc.net.au/environment/articles/2010/02/11/2816444.htm. Blog article from ABC Australia summarizing the what has gone wrong with the Home Insulation Program. Article sides on poor insulation for the majority of the problems that have occurred by the HIP.

Reflective Insulation [Internet]Australian Government Insulation Rebates: Australian Government [cited 2012 5/29]. Available from: http://australian-government-insulation-rebates.com/Products/reflective-insulation.html. Australian Government Insulation Rebate website with details on the HIP.

CSIRO report- FACT SHEET. Australia: CSIRO. Condensed version of the CSIRO Report. Contains information on how many homes were installed under HIP, and expected fire incident rate for households with insulation before, after, and without insulation.

Bita N. Unsafe batts cost $273m to redress. AUS May 18, 2012(1- All-round Country Edition). News article that talks about the amount of tax payer money used to correct the Home Insulation Programs failure. Quotes politicians calling the insulation scheme " one of the most disastrous government programs in living history."

Belukso M, Bruno F. Installation survey and thermal testing of continuous roll form foil Backed fiberglass building blanket insulation. Australia: Institute for Sustainable Systems and Technologies; 2008 22 August 2008. Report nr AFIA 12082008 v2. University Study that was cited by Kingspan that studies installation and thermal testing of continuous roll form foil backed fiberglass building blanket insulation. Report found that the R value can be up to 41% to 60% lower than the certified R value.

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Energy Saving Products [Internet]Website: British Gas; c2012 [cited 2012 June 26]. Available from: http://www.britishgas.co.uk/products-and-services/energy-saving.html. This website details information about British Gas and its options in The Green Deal UK. There are several tabs of information detailing the effectiveness of insulation and energy saving products.

Only one in five consumers will use Green Deal, survey finds [Internet]Website: GreenWise; c2012 [cited 2012 June 26]. Available from: http://www.greenwisebusiness.co.uk/news/only-one-in-five-consumers-will-use-green-deal-survey-finds-3405.aspx. This article contains information about the Green Deal and a recent survey published by the BSI. The survey interviewed people on their knowledge about the Green Deal and other green products. One factoid shows that ~90% of the 1,200 respondents felt like they did not know enough about the Green Deal.

Mason R. Coalition's green deal plans to insulate 14 million homes 'spiralling out of control'. The Telegraph (http://www.telegraph.co.uk/journalists/rowena-mason/9320404/Coalitions-Green-Deal-plans-to-insulate-14-million-homes-spiralling-out-of-control.html) .Accessed 8/24/2012. News article that contains information of how UK's Green Deal is not going as planned. Sources that companies that did sponsor the Green Deal are now holding off development further.

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Ray SD. Energy saving potential of various roof technologies. Massachusetts Institute of Technology: Massachusetts Institute of Technology; 2009 May 05 2010.

Shonnard DR, Kicherer A, Saling P. Industrial applications using BASF eco-efficiency analysis: perspectives on green engineering principles. Environ Sci Technol 2003;37(23):5340,5341-5348.

Mass Save [Internet]; c2012 [cited 2012 August 1]. Available from: http://www.masssave.com/about-mass-save. This government website contains information about the Mass Save plan. Specifically it details specific information for "Your Home", "Your Business" and "For Industry Professionals" to get involved in the green movement.

Home Weatherization [Internet]: Energy.gov; c2012 [cited 2012 August 1]. Available from: http://energy.gov/public-services/homes/home-weatherization. This government website contains information on how to Weatherize your home. It details about the different types of insulation available, how insulation works, among other facts.

BSI-052: Seeing Red Over Green Roofs [Internet]: Building Science; c2011 [cited 2012 August 1]. Available from: http://www.buildingscience.com/documents/insights/bsi-052-seeing-red-over-green-roofs/. This is an opinionated article against the use of Green Roofs. The author provides facts of the dangers of green roofs in a detailed manner of how they work. He also points out the current absurdity of using green technology is woefully energy inefficient compared to the other options out there.

Insulation: are there cracks in the batts story? [Internet]: Habitech Systems; c2011 [cited 2012 August 1]. Available from: http://www.habitechsystems.com.au/news/2011/5/9/insulation-are-there-cracks-

in-the-batts-story.html. This is an industry website detailing information about Insulation. Specifically the website points out the difficulty in installing insulation and the effectiveness of insulation batts.

Cellulose insulation vs. foam insulation [Internet]: Tascon Industries, Inc.; c2011 [cited 2012 August 1]. Available from: http://www.tasconindustries.com/CelluloseVsFoam.html#homefires. This is an industry website detailing information about cellulose insulation vs. foam insulation. The website provides a quick comparison table of the different characteristics between types of insulation. It also contains an article about home fires linked to spray-foam installation.

Therma Fiber Commercial Insulation [Internet] [cited 2012 August 1]. Available from: http://www.thermafiber.com/InsulationProducts/CommercialInsulation. Trade website, Thermafiber, that offers information on different types of commercial insulation. Thermafiber products also contribute 33 LEED credits across 4 categories if installed.

Heating, Ventilation and Air-Conditioning (HVAC) Systems [Internet]: EPA [cited 2012 August 1]. Available from: http://www.epa.gov/iaq/schooldesign/hvac.html. Government website, EPA, that offers information on Heating, Ventilation and Air-Conditioning Systems through codes and standards, definitions, and minimum requirements.

Vital Signs [Internet]: Berkeley [cited 2012 August 1]. Available from: http://arch.ced.berkeley.edu/vitalsigns/res/downloads/rp/glazing/glaz3-bg.pdf. University Project at Berkeley that investigates High Performance Glazing through the codes and standards by state and area. Includes table where each states ability to Save Energy on Residential Energy Building Codes is graded on a report card.

Reducing Urban Heat Islands: Compendium of Strategies [Internet]: EPA [cited 2012 August 1]. Available from: http://www.epa.gov/hiri/resources/pdf/GreenRoofsCompendium.pdf. Government report on Reducing Urban Heat Island: Compendium of Strategies. Includes information on what are green roofs, how they work, the different types of green roofs, benefits and costs, other factors to consider, green roof initiatives, and last resources one could use.

MOHURD Codes and Standards- Wood [Internet] [cited 2012 August 1]. Available from: http://cn.europeanwood.org/fileadmin/ewi/media/building-with-wood-c7.pdf. Industry Document for Codes and Standards of the wood construction code system. Has list of codes and standards that are commonly used in China.

Wood-Frame Housing- A North American Marvel [Internet]: CWA [cited 2012 August 1]. Available from: http://www.cwc.ca/documents/durability/BP4_WoodFrameHousing.pdf . Industry document that contains information about the challenges and effectiveness of using wood construction. Cites information that wood can keep energy bills down, resistant to earthquakes, resistant to storms, stands up to time, and that wood returns structural integrity during a fire.

Wood-frame Construction, Fire Resistance and Sound Transmission [Internet]: Forintek Canada Corp., Société d'habitation du Québec and Canada Mortgage and Housing Corporation. [cited 2012 August 1]. Available from: http://www.forintek.ca/public/pdf/Public_Information/fact%20sheets/Fire-

Sound_ENGLISH%20FINAL.pdf. Industry document that expands upon the usefulness of wood. Includes information of how wood based products provide fire resistance and sound transmission along with pictures of how items are installed.

Details for Conventional Wood Frame Construction [Internet]: American Wood Council [cited 2012 August 1]. Available from: http://www.awc.org/pdf/WCD1-300.pdf. Industry document that details conventional wood frame construction. Contains information on how a wood frame is constructed from what wood is used to flooring. On Page 8, contains details of Firestopping.

Windows and Glazing [Internet]: WBDG; c2010 [cited 2012 August 1]. Available from: http://www.wbdg.org/resources/windows.php. Industry website that contains information about Windows and Glazing from Whole Building design Guide. Gives detailed information of how windows work, how to specify windows and glazing, representative glass specifications, other attributes, and opportunities and cautions. Also includes several case studies and links to standards and codes.

FAQ – Frequently Asked Questions about fire-rated glass & framing [Internet]: Fireglass; c2012 [cited 2012 6/29]. Available from: http://www.fireglass.com/faq/. This industry website (TGP Fire Rated) provides a FAQ about fire-rated glass and framing. The questions and answers detail information about different types of fire rated glass. Specific questions include: What are my primary options in fire-rated glass? And Why is the “fire hose stream” (thermal shock) test so important?

Appendix B. Representative Fire Issues and Mitigation Approaches

This appendix highlights a selection of potential fire concerns with green building elements and potential, but not exhaustive, mitigation strategies. This section is not intended to be a comprehensive treatment; rather, and illustration of challenges and potential mitigation opportunities. Information was obtained during the information search from the sources as indicated.

Spray-on Foam Insulation

Issue

As reflected in the literature review, a number of fires have been reported associated with spray on foam insulation. For example:

Fire investigators suspect that a fire that destroyed a $5 million home in Woods Hole, Mass., was ignited when excess heat was generated by the exothermic reaction that occurs during the installation of spray polyurethane foam [Photo credit: Dave Curran] - http://www.greenbuildingadvisor.com/blogs/dept/green-building-news/three-massachusetts-home-fires-linked-spray-foam-installation (accessed 6/26/2012)

Representative Response

In response to a series of at least three fires of this type in Massachusetts, Massachusetts State Fire Marshal Stephen Coan issued a memo with the text indicated below on 1 July 2011 (http://www.mass.gov/eopss/docs/dfs/osfm/advisories/2011/20110701-spray-foam-insulation-fires.pdf):

"Recently, the Department of Fire Services, Division of Fire Safety, has become aware of a number of fires involving commercially available spray-on foam insulation. At least 3 fires, one being a fatal fire, are believed to have been started during the application of spray foam insulation, and currently remain under investigation. These foam insulation products are being increasingly utilized as part of the "green" building movement. The insulation is a two-part spray foam product and come in several types, either in a "closed" cell foam design (rigid type, solid) and "open" cell foam design (sponge like, not rigid). Information gathered by the Division of Fire Safety from different manufacturers indicate that there are several possible scenarios that could lead to a heat build-up, and a possible fire scenario. These are: improper application techniques (excessive thickness, or spraying new material into the already applied rising foam) and/or improper mixtures of the chemicals at the application nozzle."

Potential Mitigation Strategies

In this case, fire hazards appear to be concentrated during installation / application of the foam. Mitigation strategies include control of ignition sources during application, adherence to installation procedures and guidelines, and implementation of fire watch during application.

Photovoltaic Panels

Issue

As reflected in the literature review and the international survey, a number of fires have been reported associated with photovoltaic panels used of local energy and heating. The material below reflects industry perspectives on the hazards and steps taken towards mitigation.

https://solarjuice.com/blog/buildings-and-pv/solar-panels-and-fire/

Representative Response / Potential Mitigation Strategies

The following material is reprinted from Solar America Board for Codes and Standards, downloaded from http://www.solarabcs.org/current-issues/fire.html (accessed 7/24/2012).

Fire Class Rating of PV Systems

Solar ABCs research investigates whether and how the presence of stand-off mounted PV arrays may affect the fire class rating of common roof covering materials. In particular, these tests were initiated in response to questions from stakeholders about the language in the UL Guide Card that stated that PV modules may or may not reduce the fire class rating of roof coverings when modules of a lower rating are installed above a roof covering with a higher rating. All tests were conducted by UL in Northbrook, IL, with assistance from representatives of Solar ABCs.

In April 2010, Solar ABCs published an interim report, Flammability Testing of Standard Roofing Products in the Presence of Stand-off Mounted PV Modules.

In December 2010, the Standard Technical Panel for UL Standard 1703 appointed a task group to develop a new system fire classification test. This system test will replace the current module fire classification test and will provide a better test for the impact of the photovoltaic system on the fire classification rating of the roof assembly. This task group has developed several drafts of new standard language and is working with stakeholders to obtain broad input into the proposal.

Testing

Since 2009, Underwrites Laboratories, with the support of Solar ABCs, has conducted research testing on issues related to the fire classification rating of PV modules and systems. The following reports detail the tests and results.

Effect of Roof-Mounted Photovoltaic Modules on the Flammability of Roofing Assemblies, September 30, 2009, Revised March 5, 2010

This initial study measured the surface temperature and incident heat flux of a noncombustible roof with a noncombustible PV module surrogate installed at 10, 5, and 2.5 inches above the roof. In addition, limited burning brand and spread of flame tests were conducted using actual PV modules. These tests were designed to (1) develop baseline data on the fire exposure during standard tests for roof with no PV module according to UL 170, (2) determine the effect of varying selected PV installation parameters, and (3) document the impact of lesser fire rated PV modules on common roofing assemblies.

Effect of Rack Mounted Photovoltaic Modules on the Flammability of Roofing Assemblies – Demonstration of Mitigation Concepts, September 30, 2009, Revised February 10, 2010

In a continuation of the first study, several simple design concepts were devised to assess their effectiveness in improving the fire classification rating of the roof with a rack mounted photovoltaic module. The mitigation measures studied includes (1) use of flashing at the leading edge of the roof with control of separation between the roof and flashing, and (2) use of non-combustible back sheet.

Effect of Rack Mounted Photovoltaic Modules on the Fire Classification Rating of Roofing Assemblies, January 30, 2012

The second project further investigated rack mounted PV modules on roof decks to determine (1) the effect of PV modules mounted at angles (positive and negative) to steep and low sloped roof, (2) the impact of PV modules mounted at zero clearance to the roof surface and with the ignition source directed in the plane of the roof or the plane of the PV surface, and (3) the heat release rate and transfer to roof surface of Class A, B, C brands and common materials such as leaf debris and excelsior (wood wool).

Characterization of Photovoltaic Materials – Critical Flux for Ignition/Propagation, January 16, 2012

The third project investigated the critical flux for ignition of roofing and PV products. While the individual values varied, most were within the range of the flux values measured on the roof in the original experiments with the PV module in place.

Determination of Effectiveness of Minimum Gap and Flashing for Rack Mounted Photovoltaic Modules, March 29, 2012

The fourth project was undertaken to validate the performance of two approaches thought to mitigate the effect of roof mounted PV modules on the fire ratings of roofs - a minimum separation gap and a sheet metal flashing to block the passage of flames between the PV module and the roof assembly.

Considerations of Module Position on Roof Deck During Spread of Flame Tests, July 24, 2012

The fifth project included a series of experiments to investigate a modification of the current UL 1703 spread of flame test to (1) expose a PV module to flames originating from the UL 790 (ASTM E108) ignition source, (2) allow those flames to generate on a representative roof section, and (3) observe the

propagation of the flames underneath the candidate PV module being tested. The repositioning of the PV module was conducted to investigate an application of the first item (roof) / second item (module) ignition sequence. This concept was investigated to refine the understanding of the effect of a rack mounted PV array on the fire rating of a Class A roof.

Building Integrated Photovoltaics

The work described above does not apply to Building Integrated Photovoltaic (BIPV) installations. Since BIPV become the roof, they must comply with the fire classification requirements for roof assemblies as described in UL Standard 790.

International Building Code

The 2012 International Building Code includes the following requirement: "1509.6.2 Fire Classification. Rooftop mounted photovoltaic systems shall have the same fire classification as the roof assembly as defined required by Section 1505."

A Solar ABCs White Paper, Impacts on Photovoltaic Installations of Changes to the 2012 International Codes, discusses the fire classification change and other code changes affective photovoltaic installations. The development of the 2015 Edition of the model codes developed by the International Code Council is underway. Code proposals were accepted to change the language in the 2015 International Building Code. There is also an opportunity to submit Public Comments on the actions taken at the Code Development Hearings by the Code Development Committees, and those Public Comments will be heard at the Final Action Hearings on October 24-28, 2012 in Portland, Oregon.

Representative Response / Potential Mitigation Strategies

The following material is reprinted from Solar Panel Fires and Electrical Hazards - InterNACHI http://www.nachi.org/solar-panel-fire-electrical-hazards.htm#ixzz27InjsOlR (accessed 7/24/2012)

Installed properly, PV solar panels do not cause fires. Most PV modules are tested by Underwriters Laboratories (UL), which subjects them to the rigors of everyday use before they are certified. In the rare cases where PV modules have been implicated in house fires, the cause has been electrical arcing due to improper installation, faulty wiring or insufficient insulation.

http://www.nachi.org/solar-panel-fire-electrical-hazards.htm

PV Systems and House Fires

PV systems may be a hazard in the case of a house fire, particularly if firefighters are not aware that a system is installed. Some of these hazards are as follows:

- The conduit leading from PV panels to an inverter may remain live with direct current even after the main service panel has been shut off. Firefighters who unknowingly sever live lines are vulnerable to electrical shock. Some firefighters carry a "hot stick" that aids them in finding live wires, but it does not detect direct current.
- Solar panels and batteries contain toxic chemicals that may be released in a fire and are dangerous if inhaled.
- PV modules may become slippery and pose a slip-and-fall risk to inspectors, technicians and firefighters.
- Solar panels may block key points and pathways that inspectors, technicians and firefighters would otherwise use to mount, navigate and dismount from a roof.
- PV modules may inhibit ventilation of a fire in prime roof locations.
- The added weight of a solar panel array may lead to roof collapse if the integrity of the structure is already compromised by fire.

InterNACHI inspectors may want to check for the following design elements that will prevent PV modules from exacerbating the dangers of a house fire:

- Photovoltaic systems should be installed and subsequently inspected regularly by a qualified professional.
- PV systems should be labeled in a clear and systematic manner to ensure that technicians and firefighters can quickly and easily identify key elements of the system. The main service disconnect panel should be clearly labeled on the outside cover, if it is operable from the outside without opening. Both interior and exterior portions of live conduit should be labeled every 10 feet. Batteries should also be clearly labeled.
- A rooftop shutoff valve should be present. This switch could be utilized to disable the direct current running from the solar panels through the conduit.
- The roof should have sufficient pathways and perimeter space around the PV modules so that inspectors and firefighters can traverse the roof safely.
- There should be a section of the roof left vacant so that it may be ventilated, if necessary.
- Check for damage from rodents and other pests, which could compromise wiring or insulation.
- There should be an integrated arc-fault detection device present in the solar panels, which shuts down individual panels in the case of a malfunction, such as arcing.
- During the permitting process when the PV system is installed, the local fire department should be given a set of the plans to refer to in case of emergency.

Lightweight Engineered Lumber

Issue

Concerns with lightweight engineered lumber (LEL) include decreased thermal resistance to fire and contribution to fuel load. Studies, including those at UL and NRC Canada have highlighted these issues.

UL Test Program

The study, *Structural Stability of Engineered Lumber in Fire Conditions*, involved numerous tests, and a number of project reports and a summary video for firefighters are available on the UL website http://www.ul.com/global/eng/pages/offerings/industries/buildingmaterials/fire/fireservice/lightweight/ (accessed 6/29/2012). The video includes the following summary points from the tests:

- Lightweight assemblies, whether protection or non-protected, fail significantly faster than legacy assemblies.
- Legacy assemblies tend to fail locally while lightweight assemblies tend to fail globally.
- Preheating of wood structural members cause weakening of the structure prior to direct fire involvement.
    - This preheating has a greater impact on the performance of light weight assemblies because of their reduced mass, use of composite materials, and reliance on multiple connectors.

The tests have also been reported on by NFPA, which notes, "Methodologically, the (UL) study aimed to provide 'apples to apples' comparisons among assemblies and to show how different construction materials, including traditional lumber, fared in different types of fires… The experiments documented striking differences between traditional and engineered systems. For example, a traditionally constructed floor system, without a drywall ceiling to protect its underside, withstood the test fire for 18 minutes. By comparison, a similar system using engineered wooden I-beams survived for about six minutes."
http://www.nfpa.org/publicJournalDetail.asp?categoryID=1857&itemID=43878&src=NFPAJournal&cookie%5Ftest=1 (accessed 6/29/2012)

NRC Canada

The National Research Council (NRC) Canada also has been studying this issue. The following summary is also taken from the NFPA website http://www.nfpa.org/publicJournalDetail.asp?categoryID=1857&itemID=43878&src=NFPAJournal&cookie%5Ftest=1. (accessed 6/29/2012)

The NRC study, *Fire Performance of Houses: Phase I Study of Unprotected Floor Assemblies in Basement Fire Scenarios*, was also released last December and sought to establish the "typical sequence of events such as the smoke alarm activation, onset of untenable conditions, and structural failure of test assemblies" in a simulated two-story, single-family house with a basement. "With the relatively severe fire scenarios used in the experiments, the times to reach structural failure for the wood I-joist, steel C-joist, metal plate, and metal web wood truss assemblies were 35 to 60 percent shorter than that for the [traditional] solid wood joist assembly," the study reported. In every instance, the floors failed, "characterized by a sharp increase in floor deflection and usually accompanied by heavy flame penetration through the test assemblies, as well as by a sharp increase in compartment temperature above the test floor assemblies."

The report can be found directly at http://www.isfsi.org/uploads/Part5.pdf. A full set of NRC publications related to fire and building performance can be found at http://www.nrc-cnrc.gc.ca/eng/publications/index.html

Double Skinned Façade / Cavity Walls

Issue

Using poor thermally insulated materials would give higher heat lost, hence increasing the cooling or heating load of the heating, ventilation and air-conditioning system. New architectural features such as double-skin façade might give a lower heat lost rate. However, it is much easier to onset flashover for buildings with a thermally insulated façade. Heat generated in a fire would be trapped to give rapid rise of room air temperature. It appears that poor thermally insulated materials like glass with higher heat lost might be safer in a fire. (Chow, C. L. and Chow, W. K., "Fire Safety Concern on Well-Sealed Green Buildings with Low OTTVs" (2010). *International High Performance Buildings Conference.* Paper 1. http://docs.lib.purdue.edu/ihpbc/1 (accessed 7/24/2012))

Representative Response / Potential Mitigation Strategies

Experimental study on smoke movement leading to glass damages in double-skinned façade (Chow et al., 2007)

The fire hazard of the new architectural feature – double-skinned façade was examined experimentally. Full-scale burning tests on part of the design feature were carried out in a facility developed in a remote area in Northeast China. A total of eight tests were performed to demonstrate how the depth of cavity of a double-skinned façade affects the smoke movement. Surface temperature and heat flux received on the test panels are presented. Cracking patterns found on the glass panels are also observed. The measured results would give the possible smoke movement pattern inside the air cavity. By examining the results for cavity depth of 0.5, 1.0 and 1.5 m, it is found that a deeper cavity might give better safety under the scenario studied. The outer glass panel would be broken rapidly for the cavity of 0.5 m deep. Double-skinned façade with a cavity of 1.0 m deep appeared to be very risky as glass panels above broke most among the different cavity depths. The inner glass panel might be broken before the outer panel. This would give an undesirable outcome. Other separation distances of the two skins should be further examined to give optimum design of cavity depth. Other factors affecting flame and smoke movement should be further investigated.

Ding, W., Hasemi, Y. and Yamada, T., 2005. Smoke Control Using A Double-skin Facade. *Fire Safety Science* 8: 1327-1337. doi:10.3801/IAFSS.FSS.8-1327

Usually for a building with a multistory double-skin façade, smoke of a fire room escaping through the inner façade into the intermediate space between the two skins may accumulate and spread horizontally and/or vertically to other rooms that have openings connected to the intermediate space for the purpose of natural ventilation. However if smoke pressure in the intermediate space can be kept lower than that of the room, smoke spread through the openings will be prevented. Considering similarity of smoke movement and stack natural ventilation, in this paper a double-skin façade used for natural ventilation is also considered for smoke control. As a result, it is proved that smoke spread can be prevented with suitable opening arrangements. Therefore natural ventilation and smoke control can be realized through one system.

Structural Insulated Panels (SIP)

Issue

A structural insulated panel (SIP) consists of two layers of facing material bonded to a low density insulating material in the middle. The face materials can be metal, cement, gypsum board, wood or oriented strand board (OSB). While some studies have been conducted of SIPs usedin residential installations, such as the UK test program listed below, several fires have occurred recently in high-rise buildings with metal clad structural insulating panels.

The performance in fire of structural insulated panels (BD2710) - http://www.communities.gov.uk/documents/planningandbuilding/pdf/1798045.pdf (accessed 7/24/12)

"A structural insulated panel (SIP) consists of two high density face layers bonded both sides to a low density, cellular core substrate. The structural bond between the layers is essential in providing the required load bearing capacity of the panel. The face layers may be cement or gypsum based boards or wood based boards such as oriented strand board (OSB). The materials used for the core substrate range from synthetic rigid foam cores such as extruded or expanded polystyrene, polyurethane, polyisocyanurate to inorganic mineral fibers. The project has identified collapse of the floor as the predominant mode of failure of the building systems tested as part of this work program based on fire penetration into the floor/ceiling void and combustion of the oriented strand board webs of the engineered floor joists leading to loss of load bearing capacity and runaway deflection."

Recently, fires in the UAE, Shanghai and South Korea have raised concerns with façade of metal SIP with potentially non-fire rated insulation. For example:

Hundreds of skyscrapers across the UAE are wrapped in dangerous non fire-rated aluminium cladding panels that may put lives in danger in the event of a fire, Gulf News has learnt. A top executive …, who spoke on condition of anonymity, (stated) "At least 500 towers in the country have non fire-rated panels installed over the last 25 years"

http://gulfnews.com/news/gulf/uae/housing-property/tower-cladding-in-uae-fuels-fire-1.1016836 (accessed 7/24/12)

While some of this may be a result of general construction practice, these systems are used in building retrofit, including energy retrofit. In Busan, South Korea, while the cladding did play a role, the insulating material seems unclear, with some indications that the exterior finish (paint) was to blame. "It took just 20 minutes for the blaze that started at a trash collection site on the fourth floor to travel up to the 38th floor. The building's concrete body was covered with aluminum panels for aesthetic effect, filled with glass fiber for insulation and coated with flammable paint causing the flames to spread upward quickly." (http://english.chosun.com/site/data/html_dir/2010/10/04/2010100401225.html (last

accessed 7/24/2012)) “Experts said yesterday’s fire was their worst nightmare come true. They said high-rises around the nation are particularly vulnerable to fire because they are built with flammable exterior materials. “The sprinkler system worked,” said Lee Gap-jin, a senior official at Busan Fire Department’s Geumgang branch. But building codes didn’t require sprinklers on the janitors’ room floor. “And the flames on the exterior walls were too strong, so the sprinklers weren’t much help,” he said. (http://koreabridge.net/post/haeundae-highrise-fire-busan-marine-city-burns, last accessed 7/24/12).

In Shanghai, the fire was reported as welders igniting combustible scaffolding, which then ignited non-fire rated insulation. "The rigid polyurethane foam pasted on the surface of the other two buildings, which some experts suspect turned the fire into a disaster, will be replaced by fire-resistant materials," Zhang Renliang, head of the Jing'an district government, said at a press conference held regarding the 2012 fire which cost 58 lives (http://www.china.org.cn/china/2010-11/24/content_21407451.htm, last accessed 7/24/12).

http://www.koreaherald.com/national/Detail.jsp?newsMLId=20101001000621 last accessed 7/24/12

http://www.bbc.co.uk/news/world-asia-pacific-11760467 last accessed 7/24/12

Representative Response / Potential Mitigation Strategies

A first response is to use only approved / listed product. However, since it is not clear that these systems are performing as expected, further investigation into fire performance and testing may be warranted.

Vegetative Roof Systems

Issue

Issues with vegetative roof systems include flammability of materials, flammability of vegetation (fire spread), and firefighter access issues (see NASFM, 2010). From the flammability of material side, however, steps have been taken to produce test standards to help offset this issue:

Representative Response / Potential Mitigation Strategies

Approval Standard for Vegetative Roof Systems - FM Approvals - contains general information, general requirements, performance requirements, and operations requirements – available from: http://www.fmglobal.com/assets/pdf/fmapprovals/4477.pdf, last accessed 7/24/12.

ANSI/SPRI VF-1 External Fire Design Standard for Vegetative Roofs, available from: http://www.greenroofs.org/resources/ANSI_SPRI_VF_1_Extrernal_Fire_Design_Standard_for_Vegetative_Roofs_Jan_2010.pdf, last accessed 7/24/12.

Flammability and Toxicity of Foam Insulations

Issue

Several issues with the increasing use of insulating materials for increased energy efficiency were identified. These include hazards associated with do-it-yourself installation of foil and other insulation systems, leading to shock hazards and ignition hazards (e.g., see Australia Home Insulation Program issues), concerns that additional insulation might lead to higher compartment fire temperatures, and that additional insulation adds more fuel load. There have also been issues raised with respect to flame retardants in foam insulations causing health hazards (e.g., see http://media.apps.chicagotribune.com/flames/index.html, last accessed 9/24/2012).

Representative Response / Potential Mitigation Strategies

Potential mitigation options for flammability issues exist with respect to thermal barrier requirements in the US, at least (IBC and IRC). In fact, some argue that the presence of the thermal barrier means flame retardants can be removed. However, other resources note that flame retardants are still needed given the overall flammability and burning characteristics of the foam insulation (e.g., see Hirschler, 2008, *Polymers for Advanced Technologies* and Ohlemiller and Shields, 2008, *NIST Technical Note 1493*). In the end, the efficacy of the thermal barrier only exists if the thermal barrier is in place and functioning properly when needed, and if not, hazards remain. This area seems to warrant further study.

Hirschler, M.M., “Polyurethane foam and fire safety,” *Polym. Adv. Technol*. 2008; 19: 521–529 (2008).

Ohlemiller, T.J. and Shields, J.R., Aspects of the Fire Behavior of Thermoplastic Materials, NIST Technical Note 1493, Gaithersburg, MD (2008).

Appendix C. International Survey and Responses

Country / Entity	Fire Incident Experience/Tracking in green Buildings	Fire Incident Experience/Tracking Involving green Building Elements	Risk-Based Assessment of green Building Elements
Australia			
New South Wales Fire Brigade	The structures that subscribe to the National Built Environment Rating System (NABERS) are usually commercial or government buildings. In most cases they are relatively new and range from modern high rise premises in the city (eg. No. 1 Bligh St.) to restored and renovated federation style buildings (eg. 39 Hunter St.) The building codes also provide for prescribed or engineered fire safety solutions. There are no specific AIRS codes for "Green" buildings therefore it is very difficult to determine if there have been any fires or dominant fire causes in these buildings.	Ceiling Insulation: FIRU have experienced major concerns with this issue particularly in residential, nursing homes and aged care facilities. Cellulose fibre insulation in close proximity to downlights and insulation batts including non-compliance with electrical wiring rules have been the dominant concerns. AIRS analysis for insulation fires 29/02/2008 to 22/06/2011. Data provided by SIS: The data includes 102 incidents that occurred in metropolitan, regional and country areas. Of these incidents 75 were directly related to downlights and their associated transformers in close proximity to ceiling insulation. Some of the fires resulted in substantial property damage. Insulated Sandwich Panels: No specific AIRS codes for Insulated Sandwich Panels. FIRU have reports of residential structures constructed of insulated sandwich panels in locations ranging from Broken Hill to Thredbo. Laminated Timber I-Beams: No specific AIRS codes for Laminated Timber I-Beams. A combination of open plan living and modern furnishings (eg. polyurethane foam settees, etc.) can create fuel packages that will reach temperatures of 1000-1200 degrees Celsius that can rapidly weaken structural elements. Photovoltaic Solar Installations: No specific AIRS codes for PV solar installations. It is estimated that NSW has about 150,000 PV solar installations. Predominant causes include faulty components and incorrect installation. (2010 to August 2012 = nine reported incidents) FIRU research indicates major problems with PV solar installations. No remote solar isolation switching, no DC rest device for Firefighters and no 24/7 availability of qualified PV solar electricians. This has been reflected in reports from around Australia, Germany and the US. From FIRU research it appears that major fire services throughout Australasia, United Kingdom, Germany and the United States have experienced concerns with "Green" building elements. When attending fire calls operational Firefighters are unable to readily determine if it is a "Green" building or one with "Green" building elements.	FRNSW has a Risk Based Approach for all incidents, including all types of structures. This is supported by a broad range of Standard Operational Guidelines (SOGs), Safety Bulletins and Operations Bulletins. No specific effort related to green buildings.
Japan			
National Institute of Land and Infrastructure Management	I do not have any information. Fire department and fire and disaster management agency may have fire data, but they will not supply data by the duty to protect privileged information.	The Japan Association for Fire Science and Engineering annual symposium was held on May 21-22, 2012. There were two paper related to green building elements as attached files. (1)Hiroyuki Tamura (National Research Institute of fire and disaster) et.al., Electricity generation characteristic of a photovoltaic module in a fire. (2)Sanae Matsushima (National Research Institute of fire and disaster) et.al., Electricity generation characteristic of fire-damaged photovoltaic module. (in Japanese)	See papers (only known activity).
Netherlands			
TNO (Technical Research Organization Netherlands)	No information is available within the Netherlands about examples of fire incidents in case of green buildings, because this information is not taken into account within the existing databases.	No information is available within the Netherlands about examples of fire incidents in case of green buildings, because this information is not taken into account within the existing databases.	I also see that no research has been started on this topic within the Netherlands up till now.
New Zealand			
Department of Building and Housing	We're not aware of any fires in 'green buildings' in New Zealand.	However, there have certainly been instances of fires involving building materials that are designed to provide energy efficiency. There have been instances of insulation overheating due to contact with downlights etc. I don't have any specific instances but New Zealand Fire Service may be able to provide statistics if you'd like us to follow up.' We have also had cases of stapling through electrical wiring when retrofitting sub floor insulation – not starting fires but obviously electrocution is an issue.	Not aware of any activities.
BRANZ	No specific data. The New Zealand Fire Service might have some.	Scoping study related to building sustainability and fire safety design interactions might be helpful - http://www.branz.co.nz/cms_show_download.php?id=716733515027fe4626188881f674635d51e3cfb0	

Country / Entity	Fire Incident Experience/Tracking in green Buildings	Fire Incident Experience/Tracking Involving green Building Elements	Risk-Based Assessment of green Building Elements
Norway			
Norwegian Building Authority	I have no information on this subject, but I have forwarded your questions to The Norwegian Insurance Approval Board (responsible of fire statistics collected by the insurance companies) and The Norwegian Fire Protection Association. (BJM note: no response from either.)	I have no information on this subject, but I have forwarded your questions to The Norwegian Insurance Approval Board (responsible of fire statistics collected by the insurance companies) and The Norwegian Fire Protection Association. (BJM note: no response from either.)	
Scotland			
Scottish Government: Building Standards Division	It might also be worth pointing out to Brian that the National fire statistics do not identify fires in buildings with green credentials and / or green certification. However, BRE due carry out fire investigations on behalf of CLG and may well have identified green issues as being a contributory factor to the fire development and subsequent damage. Contact Martin Shipp from BRE at ShippM@bre.co.uk. Martin should also be able to provide contact details of other fire investigators from other research institutions / laboratories, the insurance industry and fire and rescue services who will all have experience in these issues.	The only research we have sponsored through CLG was in relation to the revision of BR 187 'External fire spread: building separation and boundary distances'. BRE intend to publish this document in the Autumn but many questions remain unanswered for highly insulated buildings and BRE have suggested 'further' research in this field. Having said that, BRE have published a very good scoping study on the type of issues (http://www.communities.gov.uk/documents/planningandbuilding/pdf/1795639.pdf). Feel free to forward this to Brian as it is in the public domain anyway.	Finally, BSD have been involved with a UK wide steering group looking at developing a codified methodology to hazard classification of buildings. The intention is to improve fire-fighter safety when carrying out fire-fighting and rescue operations. This could feed into the risk based approach that Brian touches on in his email Contact Dave Berry at dave.berry@farmss.co.uk
Spain			
Eduardo Torroja Institute for Construction Science	No such incident data collected.	No such incident data collected.	No research activities in this area.
Sweden			
Boverket (National Board for Building and Housing)	Boverket haven't got any information on fires in green buildings. The number of buildings built with some sort of certification (LEED etc.) is rather small in Sweden and the statistics from fire incidents does not take into account if it is a green building or not. Responsible for the statistics is the Swedish Civil Contingencies Agency (MSB). You can contact them if you want Swedish fire statistics in general, www.msb.se. Our contact in MSB, Malin, can help you find the right person malin.pettersson@msb.se.	One area that I know has been highlighted is risk to the environment and fire risks in connection with recycling. Growing risk areas are fires in recycling stations close to a building or in buildings (mainly dwellings) but also risk of leakage of contaminated water after putting out a fire in recycling sites.	I don´t know of any special research project regarding green buildings and fire risk in Sweden. The Swedish Fire Research Board (Brandforsk) might know of some on-going projects. http://www.brandforsk.se/eng. You could also contact the research institutes directly. As you might know Lund University (www.brand.lth.se) and SP (Technical Research Institute of Sweden, www.sp.se) are the two main fire research institutes in Sweden.
USA			
National Fire Protection Association	No such incident data collected.	No such incident data collected.	No specific research activities in this area, other than FPRF effort, identified.

Appendix D. Detailed Matrices of Green Elements and Potential Fire Hazards

B.1 Structural Materials and Systems

Structural Materials and Systems	Poses potential ignition hazard	Poses potential shock hazard	Potential explosion hazard	Poses potential toxicity hazard	Readily ignitable	Burns readily once ignited	Contributes more fuel / increased HRR	Material affects burning characteristics	Fast(er) fire growth rate	Significant smoke production/hazard	Potential for shorter time to failure	Failure affects burning characteristics	Failure presents stability concern	Failure presents smoke spread concern	Failure presents flame spread concern	Material presents flame spread concern	May impact smoke/heat venting	May impact occupant evacuation	May impact FF water availability	May impact suppression effectiveness	May impact fire apparatus access	May impact FF access and operations	May impact containment of runoff
- Lightweight engineered lumber																							
- Structural elements																							
- Connections																							
- Lightweight concrete																							
- Structural elements																							
- Connections																							
- FRP elements																							
- Structural elements																							
- Connections																							
- Plastic lumber																							
- Structural elements																							
- Connections																							
- Bio-polymer lumber																							
- Structural elements																							
- Connections																							
- Bamboo																							
- Structural elements																							
- Connections																							
- Phase-change materials																							
- Structural elements																							
- Connections																							
- Nano materials																							
- Structural elements																							
- Connections																							
- Extended solar roof panels																							
- Structural elements																							

B.2 Exterior Materials and Systems

	Poses potential ignition hazard	Poses potential shock hazard	Potential explosion hazard	Poses potential toxicity hazard	Readily ignitable	Burns readily once ignited	Contributes more fuel / increased HRR	Material affects burning characteristics	Fast(er) fire growth rate	Significant smoke production/hazard	Potential for shorter time to failure	Failure affects burning characteristics	Failure presents stability concern	Failure presents smoke spread concern	Failure presents flame spread concern	Material presents flame spread concern	May impact smoke/heat venting	May impact occupant evacuation	May impact FF water availability	May impact suppression effectiveness	May impact fire apparatus access	May impact FF access and operations	May impact containment of runoff
Exterior Materials and Systems																							
- Structural integrated panel (SIP)																							
- Exterior insulation & finish (EFIS)																							
- Rigid foam insulation																							
- Spray-applied foam insulation																							
- Foil insulation systems																							
- High-performance glazing																							
- Low-emissivity & reflective coating																							
- Double-skin façade / cavity wall																							
- Bamboo, other cellulosic																							
- Bio-polymers, FRPs																							
- Vegetative roof systems																							
- Insulating material																							
- Thickness																							
- Type of vegetation																							
- PVC rainwater catchment																							
- Exterior cable / cable trays																							
- Extended solar roof panels																							
- Awnings / exterior solar shades																							
- Exterior vegetative covering																							
Façade Attributes																							
- Area of glazing																							
- Area of combustible material																							

B.3 Interior Materials and Finishes

	Poses potential ignition hazard	Poses potential shock hazard	Potential explosion hazard	Poses potential toxicity hazard	Readily ignitable	Burns readily once ignited	Contributes more fuel / increased HRR	Material affects burning characteristics	Fast(er) fire growth rate	Significant smoke production/hazard	Potential for shorter time to failure	Failure affects burning characteristics	Failure presents stability concern	Failure presents smoke spread concern	Failure presents flame spread concern	Material presents flame spread concern	May impact smoke/heat venting	May impact occupant evacuation	May impact FF water availability	May impact suppression effectiveness	May impact fire apparatus access	May impact FF access and operations	May impact containment of runoff
Interior Materials and Finishes																							
- FRP walls / finishes																							
- Bio-polymer wall / finishes																							
- Bamboo walls / finishes																							
- Bio-filtration walls																							
- Wood panel walls / finishes																							
- Glass walls																							
- FRP flooring																							
- Bio-polymer flooring																							
- Bamboo flooring																							
- Interior vegetation																							
- Skylights																							
- Solar tubes																							
- Increased acoustic insulation																							
- Interior daylight reflecting panel																							
Interior Space Attributes																							
- Tighter construction																							
- Higher insulation values																							
- More enclosed spaces																							
- More open space (horizontal)																							
- More open space (vertical)																							

B.4 Building Systems and Issues

Building Systems & Issues	Poses potential ignition hazard	Poses potential shock hazard	Potential explosion hazard	Poses potential toxicity hazard	Readily ignitable	Burns readily once ignited	Contributes more fuel / increased HRR	Material affects burning characteristics	Fast(er) fire growth rate	Significant smoke production/hazard	Potential for shorter time to failure	Failure affects burning characteristics	Failure presents stability concern	Failure presents smoke spread concern	Failure presents flame spread concern	Material presents flame spread concern	May impact smoke/heat venting	May impact occupant evacuation	May impact FF water availability	May impact suppression effectiveness	May impact fire apparatus access	May impact FF access and operations	May impact containment of runoff
- Natural ventilation																							
- Operable windows																							
- Open floor plan																							
- Natural smoke venting																							
- Dedicated smoke management																							
- High volume low speed fans																							
- Refrigerant materials																							
- Ammonia																							
- Other																							
- Grey-water for suppression																							
- Rain-water for suppression																							
- On-site water treatment																							
- On-site waste treatment																							
- On-site cogeneration																							
- High reliance on natural lighting																							
- PV exit lighting																							
- Reduced water supp. systems																							

B.5 Alternative Energy Systems

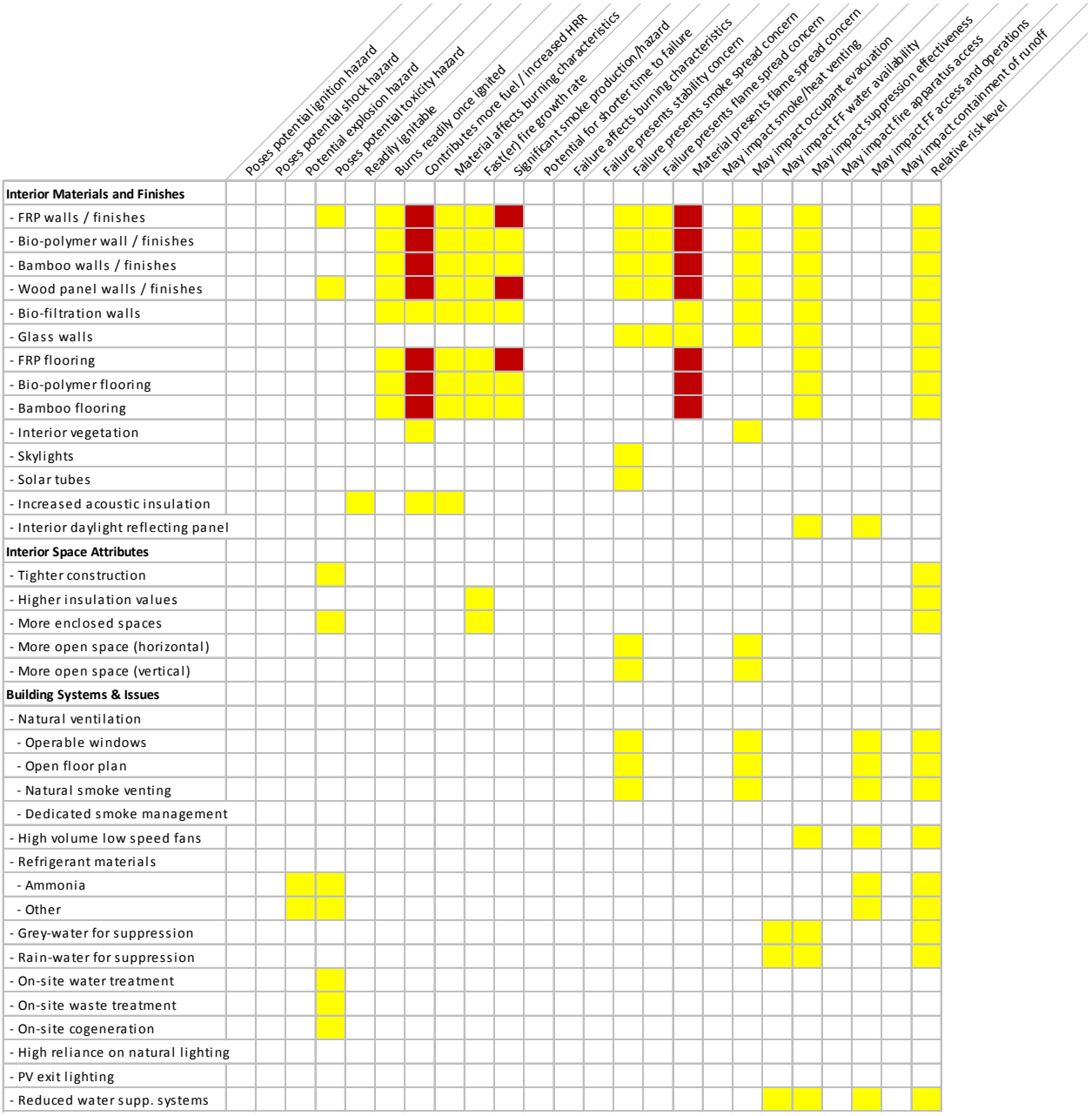
	Poses potential ignition hazard	Poses potential shock hazard	Potential explosion hazard	Poses potential toxicity hazard	Readily ignitable	Burns readily once ignited	Contributes more fuel / increased HRR	Material affects burning characteristics	Fast(er) fire growth rate	Significant smoke production/hazard	Potential for shorter time to failure	Failure affects burning characteristics	Failure presents stability concern	Failure presents smoke spread concern	Failure presents flame spread concern	Material presents flame spread concern	May impact smoke/heat venting	May impact occupant evacuation	May impact FF water availability	May impact suppression effectiveness	May impact fire apparatus access	May impact FF access and operations	May impact containment of runoff
Alternative Energy Systems																							
- PV roof panels																							
- Oil-filled PV panels																							
- Wind turbines																							
- Hydrogen fuel cells																							
- Battery storage systems																							
- Cogeneration systems																							
- Wood pellet systems																							
- Electric vehicle charging station																							
- Tankless water heaters																							

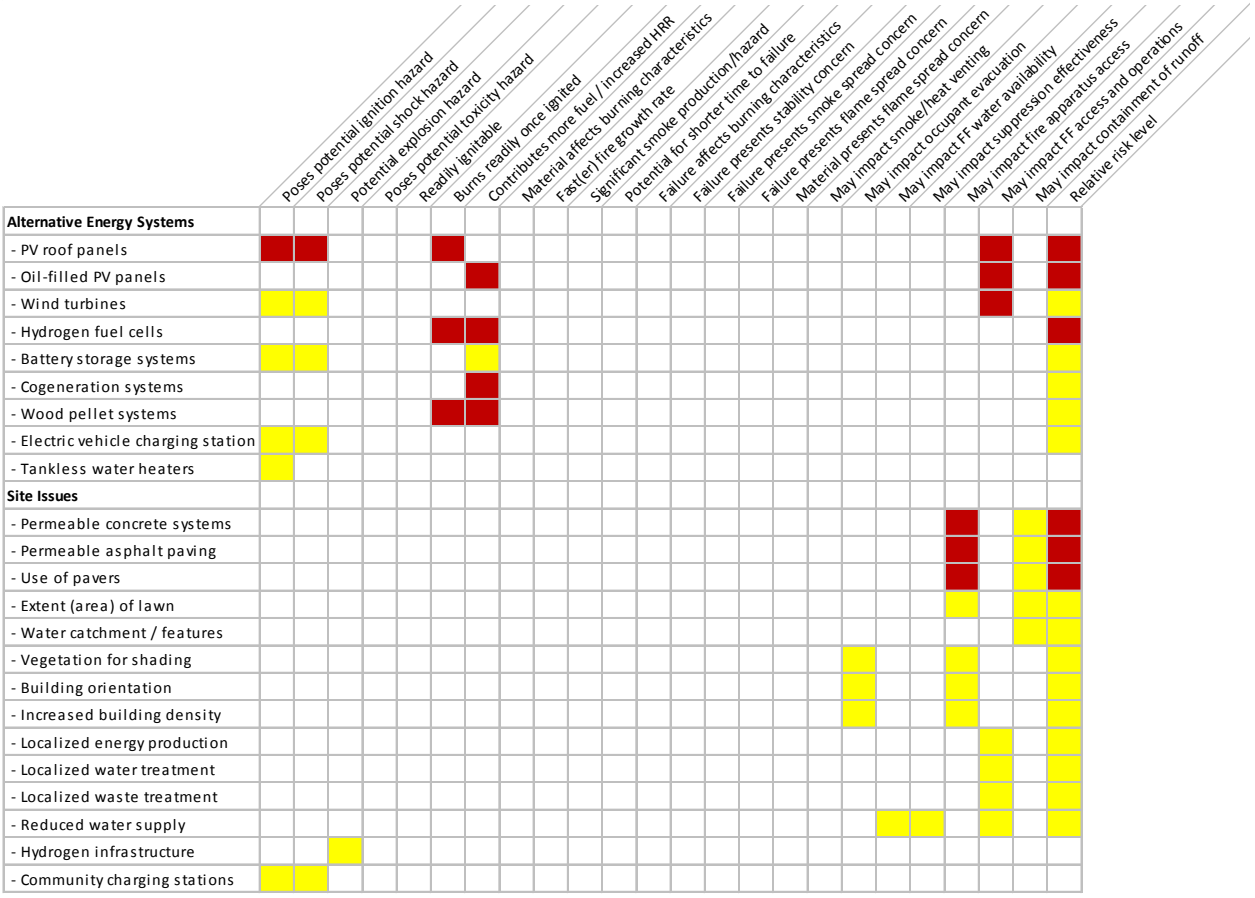
B.6 Site Issues

Site Issues	Poses potential ignition hazard	Poses potential shock hazard	Potential explosion hazard	Poses potential toxicity hazard	Readily ignitable	Burns readily once ignited	Contributes more fuel / increased HRR	Material affects burning characteristics	Fast(er) fire growth rate	Significant smoke production/hazard	Potential for shorter time to failure	Failure affects burning characteristics	Failure presents stability concern	Failure presents smoke spread concern	Failure presents flame spread concern	Material presents flame spread concern	May impact smoke/heat venting	May impact occupant evacuation	May impact FF water availability	May impact suppression effectiveness	May impact fire apparatus access	May impact FF access and operations	May impact containment of runoff
- Permeable concrete systems																							
- Permeables asphalt paving																							
- Use of pavers																							
- Extent (area) of lawn																							
- Water catchment / features																							
- Vegetation for shading																							
- Building orientation																							
- Increased building density																							
- Localized energy production																							
- Localized water treatment																							
- Localized waste treatment																							
- Reduced water supply																							
- Hydrogen infrastructure																							
- Community charging stations																							

Appendix E. Illustration of Relative Hazard Ranking with Detailed Matrix


Poses potential ignition hazard
Poses potential shock hazard
Potential explosion hazard
Poses potential toxicity hazard
Readily ignitable
Burns readily once ignited
Contributes more fuel / increased HRR
Material affects burning characteristics
Fast(er) fire growth rate
Significant smoke production/hazard
Potential for shorter time to failure
Failure affects burning characteristics
Failure presents stability concern
Failure presents smoke spread concern
Failure presents flame spread concern
Material presents flame spread concern
May impact smoke/heat venting
May impact occupant evacuation
May impact FF water availability
May impact suppression effectiveness
May impact fire apparatus access
May impact FF access and operations
May impact containment of runoff
Relative risk level
Structural Materials and Systems
- Lightweight engineered lumber
- Structural elements
- Connections
- Lightweight concrete
- Structural elements
- Connections
- FRP elements
- Structural elements
- Connections
- Plastic lumber
- Structural elements
- Connections
- Bio-polymer lumber
- Structural elements
- Connections
- Bamboo
- Structural elements
- Connections
- Phase-change materials
- Structural elements
- Connections
- Nano materials
- Structural elements
- Connections
- Extended solar roof panels
- Structural elements
Exterior Materials and Systems
- Structural integrated panel (SIP)
- Exterior insulation & finish (EFIS)
- Rigid foam insulation
- Spray-applied foam insulation
- Foil insulation systems
- High-performance glazing
- Low-emissivity & reflective coating
- Double-skin façade / cavity wall
- Bamboo, other cellulosic
- Bio-polymers, FRPs
- Vegetative roof systems
- Insulating material
- Thickness
- Type of vegetation
- PVC rainwater catchment
- Exterior cable / cable trays
- Extended solar roof panels
- Exterior solar shades / awning
- Exterior vegatative covering
Façade Attributes
- Area of glazing
- Area of combustible material


Poses potential ignition hazard
Poses potential shock hazard
Potential explosion hazard
Poses potential toxicity hazard
Readily ignitable
Burns readily once ignited
Contributes more fuel / increased HRR
Material affects burning characteristics
Fast(er) fire growth rate
Significant smoke production/hazard
Potential for shorter time to failure
Failure affects burning characteristics
Failure presents stability concern
Failure presents smoke spread concern
Failure presents flame spread concern
Material presents flame spread concern
May impact smoke/heat venting
May impact occupant evacuation
May impact FF water availability
May impact suppression effectiveness
May impact fire apparatus access
May impact FF access and operations
May impact containment of runoff
Relative risk level
Interior Materials and Finishes
- FRP walls / finishes
- Bio-polymer wall / finishes
- Bamboo walls / finishes
- Wood panel walls / finishes
- Bio-filtration walls
- Glass walls
- FRP flooring
- Bio-polymer flooring
- Bamboo flooring
- Interior vegetation
- Skylights
- Solar tubes
- Increased acoustic insulation
- Interior daylight reflecting panel
Interior Space Attributes
- Tighter construction
- Higher insulation values
- More enclosed spaces
- More open space (horizontal)
- More open space (vertical)
Building Systems & Issues
- Natural ventilation
- Operable windows
- Open floor plan
- Natural smoke venting
- Dedicated smoke management
- High volume low speed fans
- Refrigerant materials
- Ammonia
- Other
- Grey-water for suppression
- Rain-water for suppression
- On-site water treatment
- On-site waste treatment
- On-site cogeneration
- High reliance on natural lighting
- PV exit lighting
- Reduced water supp. systems



Risk Ranking Key

Low or N/A	Presents a low risk when unmitigated or is not applicable to the listed attributes
Moderate	Presents a moderate risk when unmitigated.
High	Presents a high risk when unmitigated.

Appendix F. Tabular Representation of Fire Hazards with Green Building Elements

Material / System / Attribute	Hazard	Concern Level	Potential Mitigation Stratgies
Structural Materials and Systems			
- Lightweight engineered lumber	Can fail more quickly. Contributes to fuel load. Impact for egress and FF. Stability issues.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Sprinklers.
- Lightweight concrete	Can spall more explosively if not treated with fiber. Can fail more quickly. FF and stability issues.	Moderate	Require fibers for strength. Approved / listed materials.
- FRP elements	Can fail more quickly. Contributes to fuel load. Impact for egress and FF. Stability issues.	High	Require formulations with high ignition temperatures, low flame spread and low smoke production; cover with thermal barrier or intumescing cover. Approved / listed materials.
- Plastic lumber	Can fail more quickly. Contributes to fuel load. Impact for egress and FF. Stability issues.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Sprinklers.
- Bio-polymer lumber	Can fail more quickly. Contributes to fuel load. Impact for egress and FF. Stability issues.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Sprinklers.
- Bamboo	Can fail more quickly. Contributes to fuel load. Impact for egress and FF. Stability issues.	Moderate	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Sprinklers.
- Phase-change materials	Unknown	Unknown	Research and testing. Approved / listed materials.
- Nano materials	Unknown	Unknown	Research and testing. Approved / listed materials.
- Extended solar roof panels	Can create hazard to FF if fails. Impacts FF access.	Moderate	Provide fire proofing. Assure options for FF access. Approved / listed materials.
Exterior Materials and Systems			
- Structural integrated panel (SIP)	If fail, insulation can contribute to flame spread, smoke production and fuel load.	High	Approved / listed materials. Assure proper sealing of panels. Take care during installation, including retrofits, relative to potential sources of ignition.
- Exterior insulation & finish (EFIS)	If fail, insulation can contribute to flame spread, smoke production and fuel load.	High	Approved / listed materials. Assure proper sealing of panels. Take care during installation, including retrofits, relative to potential sources of ignition.
- Rigid foam insulation	Can contribute to flame spread, smoke and toxic product development and fuel load.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Flame retardants. Sprinklers.
- Spray-applied foam insulation	Can contribute to flame spread, smoke and toxic product development and fuel load.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Flame retardants. Sprinklers.
- Foil insulation systems	Can contribute to shock hazard for installers. Can contribute to flame spread and fuel load.	High	Fire resistive barrier (e.g., fire rated gypsum). Approved / listed materials. Sprinklers.
- High-performance glazing	Can change thermal characteristics of compartment for burning. Can impact FF access.	Moderate	Sprinklers. Assure adequate FD access. Assure mechanism for FD smoke/heat venting. Approved / listed materials.
- Low-emissivity & reflective coating	Can change thermal characteristics of compartment for burning. Can impact FF access.	Moderate	Sprinklers. Assure adequate FD access. Assure mechanism for FD smoke/heat venting. Approved / listed materials.
- Double-skin façade	Can change thermal characteristics of compartment for burning. Can impact FF access. Can present 'chimney' for vertical smoke and flame spread if not properly fire stopped.	Moderate	Appropriate fire stop between floors. Sprinklers may have some benefit (sprinklered building). Assure mechanism for FD smoke/heat venting. Approved / listed materials.
- Bamboo, other cellulosic	Can contribute to flame spread, smoke development and fuel load.	Moderate	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Bio-polymers, FRPs	Can contribute to flame spread, smoke development and fuel load.	Low	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Vegetative roof systems	Can contribute to fire load, spread of fire, impact FF operations, impact smoke and heat venting, contribute to stability issues.	Moderate	Manage fire risk of vegetation. Assure use of fire tested components. Provide adequate area for FD acces, smoke/heat venting, and other operations.Approved / listed materials.
- PVC rainwater catchment	Can contribute additional fuel load.	Low	Limit volume.
- Exterior cable / cable trays	Can contribute additional fuel load.	Low	Limit volume.Approved / listed materials.
Façade Attributes			
- Area of glazing	Can present more opportunity for breakage and subsequent fire spread and/or barrier to FF access depending on type.	Moderate	
- Area of combustible material	Larger area (volume) provides increased fuel load.	High	Limit volume.
- Awnings	Impacts FF access.	Low	
- Exterior vegetative covering	Can impact FF access and present WUI issue.	Low	Limit volume.

Material / System / Attribute	Hazard	Concern Level	Potential Mitigation Stratgies
Interior Materials and Finishes			
- FRP walls / finishes	Can contribute to flame spread, smoke development and fuel load.	Moderate	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Bio-polymer wall / finishes	Can contribute to flame spread, smoke development and fuel load.	Moderate	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Bamboo walls / finishes	Can contribute to flame spread, smoke development and fuel load.	Moderate	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Wood panel walls / finishes	Can contribute to flame spread, smoke development and fuel load.	Moderate	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Bio-filtration walls	Can contribute to flame spread, smoke spread and fuel load.	Low	Approved / listed materials.
- Glass walls	May not provide adequate fire barrier alone.	Moderate	Approved / listed materials. Sprinklers
- FRP flooring	Can contribute to flame spread, smoke development and fuel load.	Low	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Bio-polymer flooring	Can contribute to flame spread, smoke development and fuel load.	Low	Approved / listed materials. Flame retardant treatments. Sprinklers.
- Bamboo flooring	Can contribute to flame spread, smoke development and fuel load.	Low	Approved / listed materials. Flame retardant treatments. Sprinklers.
Interior Space Attributes			
- Tighter construction	Can change burning characteristics of compartments. Can result in negative health effects, moisture and related issues.	Moderate	Assure adequate air changes and filtering. Approved / listed materials.
- Higher insulation values	Can change compartment burning characteristics, result in additional fuel load and laed to impacts to FF access.	Moderate	Approved / listed materials. Sprinklers.
- More enclosed spaces	Can result in challenges in finding fire source.	Low	Sprinklers.
- More open space (horizontal)	Can contribute to fire and smoke spread.	Moderate	Sprinklers.
- More open space (vertical)	Can contribute to fire and smoke spread.	Moderate	Sprinklers.
- Interior vegetation	Can contribut fuel load. Can impact FF operations.	Low	Sprinklers.
- Skylights	Can contribute to fire and smoke spread.	Low	Approved / listed materials. Sprinklers.
- Solar tubes	Can contribute to fire and smoke spread.	Low	Approved / listed materials. Sprinklers.
- Increased acoustic insulation	Can change compartment burning characteristics, result in additional fuel load and laed to impacts to FF access.	Moderate	Approved / listed materials. Sprinklers.
Building Systems & Issues			
- Natural ventilation	Can impact ability to control smoke. Can influence smoke movement depending on environmental conditions.	Moderate	Dedicated smoke management system. Sprinklers. Dedicated FF smoke venting.
- High volume low speed fans	Can influence sprinkler and detector performance.	Moderate	Additional sprinkler protection beyond code requirements.
- Refrigerant materials	Can provide different burning, toxicity, and HazMat concerns.	Moderate	Approved / listed materials. Treat and protect appropriate to material hazards.
- Grey-water for suppression	Can have impact of water availability for suppresion. Could have impact on MIC issues with sprinkler and hydrant systes.	Low	Assure water is propertly treated for use in sprinkler and standpipe system.
- Rain-water for suppression	Can have impact of water availability for suppresion. Could have impact on MIC issues with sprinkler and hydrant systes.	Low	Assure water is propertly treated for use in sprinkler and standpipe system.
- On-site water treatment	Can have impact of water availability for suppresion. Could have impact on MIC issues with sprinkler and hydrant systes.	Low	Locate in fire rated construction or separate building. Sprinkler.
- On-site waste treatment	Can create HazMat and containment issues.	Low	Locate in fire rated construction or separate building. Sprinkler.
- On-site cogeneration	Can present new fire hazards.	Low	Locate in fire rated construction or separate building. Sprinkler.
- High reliance on natural lighting	Can result in larger area of high-performance glazing.	Moderate	Consider including of battery powered emergency lighting.
- PV exit lighting	Require permanent full lighting to charge material - if used with increased natural lighting may not be effective.	Moderate	Consider including of battery powered emergency lighting.
- Reduced water supp. systems	Local restrictions or conditions (e.g., drought) may limit water available for suppression.	High	Include water storage within building / on-site to meet minimum FP needs.

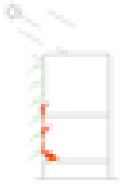
Material / System / Attribute	Hazard	Concern Level	Potential Mitigation Stratgies
Alternative Energy Systems			
- PV roof panels	Presents ignition hazard and contributes to fuel load. Prevents shock hazard to FF. Presents glass breakage hazard.	High	Provide thermal barriers between PV cells and combustible roof material. Use noncombustible roof materials. Design roof space for FF access, heat and smoke venting. Have emergency power interruption. Clearly mark. Approved / listed materials.
- Oil-filled PV panels	Presents ignition hazard and contributes to fuel load.	High	Provide thermal barriers between PV cells and combustible roof material. Use noncombustible roof materials. Design roof space for FF access, heat and smoke venting. Have emergency power interruption. Clearly mark. Approved / listed materials.
- Wind turbines	Potential ignition hazard.	Low	Automatic and manual power interruption.
- Hydrogen fuel cells	Presents explosion hazard and contributes to fuel load.	Moderate	Install in explosion vented or resistant enclosure. Leak detection and automatic shutoff. Clearly mark
- Battery storage systems	Presents ignition hazard and contributes to fuel load. Source of potential shock hazard. My release corrosive or toxic materials if damaged.	Low	Provide adequate compartmentation and special suppression. Clearly mark. Approved / listed materials.
- Cogeneration systems	Additional fuel load.	Low	Provide adequate compartmentation and special suppression. Clearly mark.
- Wood pellet systems	Additional fuel load.	Low	Sprinklers.
- Electric vehicle charging station	Presents ignition hazard.	Low	Adequate shutoffs, shock protection. Clearly mark.
- Tankless water heaters	May present ignition hazard.	Low	Smoke and CO alarms. Approved / listed materials.
Site Issues			
- Permeable concrete systems	May affect pooling of fllamable liquid and resulting pool fire, containment, runoff containment issues.	Moderate	Appropriate emergency response planning, including spill containment and suppression, and vehicle access.
- Permeable asphalt paving	May affect pooling of fllamable liquid and resulting pool fire, containment, runoff containment issues.	Moderate	Appropriate emergency response planning, including spill containment and suppression, and vehicle access.
- Use of pavers	May affect pooling of fllamable liquid and resulting pool fire, containment, runoff containment issues. May also have load-carrying issues wrt fire apparatus.	Moderate	Appropriate emergency response planning, including spill containment and suppression, and vehicle access.
- Extent (area) of lawn	May present fire apparatus access challenges.	Low	Appropriate emergency response planning, including vehicle access.
- Water catchment / features	May present fire apparatus access challenges.	Low	Appropriate emergency response planning, including vehicle access.
- Vegetation for shading	May present fire apparatus access challenges.	Low	Appropriate emergency response planning, including vehicle access.
- Building orientation	May present fire apparatus access challenges.	Low	Appropriate emergency response planning, including vehicle access.
- Increased building density	May present fire apparatus access challenges. May increase fire spread potential.	Moderate	Appropriate emergency response planning, including vehicle access.
- Localized energy production	May present more challenging fires for FD. May present access issues.	Low	Appropriate emergency response planning, including vehicle access.
- Localized water treatment	May present more challenging fires for FD. May present access issues. May impact runoff issues (may overload system with runoff).	Low	Appropriate emergency response planning, including vehicle access.
- Localized waste treatment	May present more challenging fires for FD. May present access issues. May impact runoff issues.	Low	Appropriate emergency response planning, including vehicle access.
- Reduced water supply	Local restrictions or conditions (e.g., drought) may limit water available for suppression.	High	Appropriate emergency response planning, including vehicle access. Consider local water supply (site or facility).
- Hydrogen infrastructure	May present new and challenging fire and explosion hazards, putting several properties at risk depending on density.	Moderate	Appropriate emergency response planning. Appropriate shock protection. Suppression system.
- Community charging stations	May present shock hazards for multiple users.	Low	Appropriate emergency response planning. Suppression system. Explosion venting/protection.

Appendix G. Assessment of LEED, BREEAM, GREENMARK and the IgCC for Fire Safety Objectives

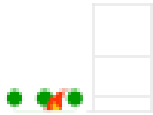
LEED (Homes)

LEED Homes 2008

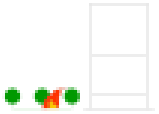
To achieve LEED Homes certification:
1: Prerequisite Requirement- All relevant prerequisites for specific LEED Homes Rating are to be complied with
2: Earn at least 45-59 points for Certification, 60-74 points for Silver, 75-89 points for Gold and 90-136 points for Platinum

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Innovation and Design (ID)	ID Credit 1: Integrated Project Planning (4 Max. Points)	Maximize opportunities for integrated, cost-effective adoption of green design and construction strategies.	Required	Prerequisite 1.1: Preliminary Rating	Hold to meeting for goals of the home		
			1	Credit 1.2: Integrated Project Team	Assemble team with certain skill sets, and have them actively involved in at least 3 of the phases of home design and construction process	(P) Fire protection engineer or background skillset not listed.	
			1	Credit 1.3: Professional Credentialed with Respect to LEED for Homes	Individual who is credentialed with Respect to LEED for Homes		
			1	Credit 1.4: Design Charrette:	Meet with group for full day of design		
			1	Credit 1.5: Building Orientation for Solar Design	50% more glazing on North and south facing walls on building, East-West axis of building is within 15 degrees of due East-West, Roof has minimum of 450 square feet of south facing area for solar applications, 90% of glazing on south-facing wall is completely shaded	(P) May present difficulties under a fire event (i.e. solar electric continues operating) (S) Fire Services movement around the building should be compatible (i.e. access to systems)	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	ID Credit 2: Durability Management Process (3 Max. Points)	Promote durability and high performance of the building enclosure and its components and systems through appropriate design, materials selection, and construction practices.	Required	Prerequisite 2.1: Durability Planning	Complete Durability Risk Evaluation Form and measures to respond, identify/incorporate all applicable indoor moisture control measures, document all measures used, and list durability measures and indicate their locations in project documents for checklist		
			Required	Prerequisite 2.2: Durability Management	Builder must use quality management process to ensure installations of durability measures.		
			3	Credit 2.3: Third-Party Durability Management Verifications	Have Green Rater inspect and verify each measure listed in durability inspection checklist		
	ID Credit 3: Innovative or Regional Design (4 Max. Points)	Minimize the environmental impact of the home by incorporating additional green design and construction measures that have tangible and demonstrable benefits beyond those in the LEED for Homes Rating System.	1	Credit 3.1: Innovation 1	Submit written Innovative Design Request to USGBC explaining merits		
			3	Credit 3.2-3.4 Innovations 2-4	Additional credits can be awarded		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Location & Linkages (LL)	LL Credit 1: LEED for Neighborhood Development (10 Max. Points)	Minimize the environmental impact of land development practices by building homes in LEED for Neighborhood Development certified developments	10	Credit 1: LEED for Neighborhood Development	Complete requirements of LEED for Neighborhood Development certification program		
	LL Credit 2: Site Selection (2 Max. Points)	Avoid development on environmentally sensitive sites	2	Credit 2: Site Selection	Do not develop on the following: Prime farmland, prime soils, soils of state significance, Undeveloped land (elevation lower than 5 ft. above 100-year flood), Threatened or Endangered species habitats, Land within 100 ft. of wetlands, Undeveloped land with 50ft of water body, Land that was previously public parkland* (Unless trade was in equal or greater value)	(P) Wildfires	
	LL Credit 3: Preferred Locations (3 Max. Points)	Encourage the building of LEED homes near or within existing communities.	1	Credit 3.1: Edge Development-	Lot has at least 25% of perimeter is previously developed land.		
			1	Credit 3.2: Infill-	Lot has at least 75% of perimeter is previously developed land		
			1	Credit 3.3- Previously Developed-	Build on previously developed lot		
	LL Credit 4: Infrastructure (1 Max. Point)	Encourage the building of LEED homes in development that are served by or are near existing infrastructure (I.e., sewers and water supply).	1	Credit 4: Existing Infrastructure-	Lot lies within water service lines and sewer lines.		

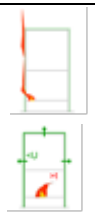
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	LL Credit 5: Community Resources/Transit (3 Max. Points)	Encourage the building of LEED homes in development patterns that allow for walking, biking, or public transit (thereby minimizing dependency on personal automobiles and their associated environmental impacts).	1	Credit 5.1: Basic Community Resources/Transit-	Located by basic community resources listed in LEED Homes 2008 and transit services		
			2	Credit 5.2: Extensive Community Resources/Transit-	Located by more basic community resources than 5.1 requires.		
			3	Credit 5.3: Outstanding Community Resources/Transit-	Located by even more basic community resources than both 5.1 and 5.2		
	LL Credit 6: Access to Open Space (1 Max. Point)	Provide open spaces to encourage walking, physical activity, and time spent outdoors.	1	Credit 6: Access to Open Space-	Location is within half mile of publicly accessible or community based open space that is 3/4 of acre in size.		
Sustainable Sites (SS)	SS Credit 1: Site Stewardship (1 Max. Point)	Minimize long-term environmental damage to the building lot during the construction process	Required	Prerequisites 1.1: Erosion Controls During Construction -	Design/plan measures for erosion control. Implement measures. Erosion control measures listed in LEED Homes SS 1	(P) Debris and Runoff water after a Fire event should be considered	
			1	Credit 1.2: Minimize Disturbed Area of Site-	Develop tree or plant preservation plan with no disturbance zone and leave undisturbed at least 40% of buildable lot area OR build on site with a lot area of less than 1/7 acre/ housing density for project equal to or greater than 7 unit acre.		
	SS Credit 2: Landscaping (7 Max. Point)	Design landscape features to avoid invasive species and minimize demand for water and synthetic	Required	Prerequisites 2.1: No Invasive Plants-	Do not introduce invasive plants		
			2	Credit 2.2: Basic Landscape Design-	Meet all requirements listed in LEED Homes SS 2.2		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
		chemicals.	3	Credit 2.3 Limit Conventional Turf-	Limit use of conventional turf in designed landscape softscapes		
			2	Credit 2.4: Drought-Tolerant Plants-	Install drought-tolerant plants		
			6	Credit 2.5: Reduce Overall Irrigation Demand by at least 20%-	Landscape and irrigation system reduces overall irrigation water usage. Estimates must be precalculated and prepared by professional.		
	SS Credit 3: Local Heat Island Effects (1 Max. Point)	Design landscape features to reduce local heat island effects	1	Credit 3: Reduce Local Heat Island Effects:	Locate trees or other planting that provide shade to at least 50% of sidewalks, patios and driveways 50 feet of the home or Install light colored, high-albedo materials/vegetation that completes the same task as listed above.	(P) Proximity of vegetation	
	SS Credit 4: Surface Water Management (7 Max. Point)	Design site features to minimize erosion and runoff from the home site.	4	Credit 4.1: Permeable Lot-	Design lot so that at least 70% is permeable or designed to capture water runoff	(P) Runoff from Fire event not considered	
			1	Credit 4.2: Permanent Erosion Controls-	If lot has steep slope, reduce long term run off effects. Otherwise, plant one tree, four 5 gallon shrubs, or 50 sq. ft. of native ground cover per 500 square feet of disturbed lot area.		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			2	Credit 4.3: Management of Runoff from Roof-	Install permanent storm water controls and vegetated roof that covers 50% of roof or vegetated roof to cover 100% of roof and designed that all water runoff from home is managed through on site element.	(P) Runoff from Fire event not considered	
	SS Credit 5: Nontoxic Pest Control (2 Max. Point)	Design home features to minimize the need for poisons for control of insects, rodents, and other pests.	2	Credit 5: Pest Control Alternatives-	Implement one or more measures listed in LEED Home SS 5.		
	SS Credit 6: Compact Development (4 Max. Point)	Make use of compact development patterns to conserve land and promote community livability, transportation efficiency, and walkability.	2	Credit 6.1 Moderate Density-	Build homes with average housing density of 7 or more dwelling units per acre of buildable land		
			3	Credit 6.2 High Density-	Build homes with an average housing density of 10 or more dwelling units per acre of buildable land.		
			4	Credit 6.3: Very High Density-	Build homes with an average housing density of 20 or more dwelling units per acre of buildable land.		
Water Efficiency (WE)	WE Credit 1: Water Reuse (5 Max. Point)	Use of municipal recycled water, or offset central water supply through the capture and controlled reuse of rainwater and/or graywater.	4	Credit 1.1: Rainwater Harvesting System-	Installation of rainwater harvesting and storage system for landscaping irrigation use or indoor water use.		
			1	Credit 1.2 Graywater Reuse System-	Install graywater reuse system for landscape irrigation or indoor water use.		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			3	Credit 1.3: Use of Municipal Recycled Water System-	Design plumbing such that irrigation system water demand is supplied by municipal recycled water		
	WE Credit 2: Irrigation System (4 Max. Point)	Minimize outdoor demand for water through water-efficient irrigation.	3	Credit 2.1: High Efficiency Irrigation System-	Install high-efficiency irrigation system that meets any of the following in LEED Home		
			1	Credit 2.2: Third- Party Inspection-	Perform third-party inspection on irrigation system so that the following are met in LEED Home		
			4	Credit 2.3: Reduce Overall Irrigation Demand by at least 45%-	Design landscape and irrigation system to reduce overall irrigation water demand water budget.		
	WE Credit 3: Indoor Water Use (6 Max. Point)	Minimize indoor demand for water through water-efficient fixtures and fittings	3	Credit 3.1: High-Efficiency Fixtures and Fittings-	Meet requirements of LEED Home WE 3.1		
			6	Credit 3.2 Very High Efficiency Fixtures and Fittings-	Meet requirements of LEED Home and exceed requirements WE 3.1		
Energy & Atmosphere (EA)	EA Credit 1: Optimize Energy Performance (34 Max. Point)	Improve the overall energy performance of a home by meeting or exceeding the performance of an ENERGY STAR labeled home.	Required	Prerequisites 1.1: Performance of ENERGY STAR for Homes-	Meet performance requirements of ENERGY STAR for Homes		
			34	Credit 1.2: Exceptional Energy Performance-	Exceed performance of Energy Star for Homes		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	EA Credit 2: Insulation (2 Max. Point)	Design and install insulation to minimize heat transfer and thermal bridging	Required	Prerequisites 2.1: Basic Insulation-	Insulation meets or exceeds R-value requirements listed in Chapter 4 of 2004 International Energy Conservation Code and Grade II specifications set by National Home Energy Rating Standards.		
			2	Credits 2.2: Enhanced Insulation-	Exceed requirements for EA 2.1		
	EA Credit 3: Infiltration (3 Max. Point)	Minimize energy consumption caused by uncontrolled air leakage into and out of conditioned spaces.	Required	Prerequisites 3.1: Reduced Envelope Leakage-	Meet air leakage requirements in EA 3.1 LEED Homes		
			2	Credit 3.2: Greatly Reduced Envelope Leakage-	Meet air leakage requirements in EA 3.2 LEED Homes		
			3	Credits 3.3: Minimal Envelope Leakage-	Meet air leakage requirements in EA 3.3 LEED Homes		
	EA Credit 4: Windows (3 Max. Point)	Maximize the energy performance of windows	Required	Prerequisites 4.1: Good Windows-	Meet all of the requirements and codes listed in EA 4.1 LEED Homes, NFRC ratings, ENERGY STAR		
			2	Credits 4.2: Enhanced Windows-	Meet all requirements of LEED Home and exceed requirements of EA 4.1		
			3	Credit 4.3: Exceptional Windows-	Meet all requirements of LEED Home and exceed requirements of EA 4.1 and 4.2		

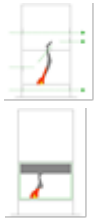
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	EA Credit 5: Heating and Cooling Distribution System (3 Max. Point)	Minimize energy consumption due to thermal bridges and/or leaks in the heating and cooling distribution system	Required	Prerequisites 5.1: Reduced Distribution Losses for Forced-Air Systems-	Limit air leakage rate to outside, no installation of ducts in exterior walls unless extra 5-6 or better insulation is added to maintain overall UA for exterior wall w/o ducts	(P) May affect fire spread and fire reaction	
			2	Credits 5.2: Greatly Reduced Distribution Losses for Forced-Air Systems-	Limit duct air leakage to a greater amount than required for EA 5.1		
			3	Credits 5.3: Minimal Distribution Losses for Forced-Air Systems-	Limit duct air leakage to ≤ 1.0 cfm at 25 Pascals per 100 square feet of conditioned floor area, meet EA 3.3 requirements, or locate air-handler unit and all ductwork visibly within conditioned space		
			Required	Prerequisites 5.1: Reduced Distribution Losses for Nonducted HVAC Systems-	Use at least R-3 insulations around distribution pipes in unconditioned spacing	(P) May affect fire spread and fire reaction	
			2	Credits 5.2: Greatly Reduced Distribution Losses for Nonducted HVAC Systems-	Keep system including boiler and distribution pipes entirely within conditioned envelope		
			3	Credits 5.3: Minimal Distribution Losses for Nonducted HVAC Systems-	Install outdoor reset control		

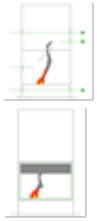
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	EA Credit 6: Space Heating and Cooling Equipment (4 Max. Point)	Reduce energy consumption associated with the heating and cooling systems	Required	Prerequisites 6.1: Good HVAC Design and Installation-	Meet all requirements and codes listed in EA 4.6 LEED Homes, ACCA Manual J, ASHRAE 2001 Handbook of Fundamentals, and/or ENERGY STAR for Homes.		
			2	Credits 6.2: High-Efficiency HVAC-	Install HVAC system that is better than equipment required by ENERGY STAR building option Package		
			4	Credit 6.3: Very High Efficiency HVAC-	Install HVAC system that is substantially better than equipment required by ENERGY STAR building option Package. Any piping that carries water above/below a thermostatic temp must have R-4 insulation or greater		
	EA Credit 7: Water Heating (6 Max. Point)	Reduce energy consumption associated with the domestic hot water system, including improving the efficiency of both the hot water system design and the layout of the fixtures in the home.	2	Credit 7.1:: Efficient Hot Water Distribution -	Design and install hot water distribution system that is energy-efficient and meets the codes and standards listed in EA 7.1 LEED Homes		
			1	Credit 7.2: Pipe Insulation-	All domestic hot water piping has R-4 insulation		
			3	Credit 7.3: Efficient Domestic Hot Water Equipment-	Design and install energy-efficient water heating equipment from Table 20 in EA 7.3 LEED Homes		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	EA Credit 8: Lighting (3 Max. Point)	Reduce energy consumption associated with interior and exterior lighting.	Required	Prerequisites 8.1: ENERGY STAR Lights-	Install at least four ENERGY STAR labeled light fixtures or labeled compact fluorescent light bulbs in high use rooms		
			1.5	Credit 8.2: Improved Lighting-	Install 3 additional ENERGY STAR labeled light fixtures or labeled compact fluorescent bulbs for Indoor lighting and exterior lighting must have either motion sensor controls or integrated photovoltaic cells.(Emergency lighting not included in standard)	(P) Fire safety rating on ENERGY STAR items	
			3	Credit 8.3: Advanced Lighting Package-	Install ENERGY STAR advanced lighting package or install ENERGY STAR labeled lamps in 80% of fixtures throughout home. All ceiling fans must be ENERGY STAR labeled.		
	EA Credit 9: Appliances (3 Max. Point)	Reduce appliance energy consumptions	2	Credit 9.1: High-Efficiency Appliances-	Install appliances that are ENERGY STAR rated		
			1	Credit 9.2: Water-Efficiency Clothes Washer-	Install clothes washer with modified energy factor ≥ 2.0 and water factor < 5.5.		
	EA Credit 10: Renewable Energy (10 Max. Point)	Reduce consumption of nonrenewable energy sources by encouraging the installation and operation of renewable electric generation systems.	10	Credit 10: Renewable Energy System-	Design and install a renewable electricity generation system. More points are awarded by 3% of annual reference electrical load met by system.		
	EA Credit 11: Residential	Select and test air-conditioning refrigerant to	Required	Prerequisites 11.1: Refrigerant Charge Test-	Proof of proper refrigerant charge of air-conditioning system		

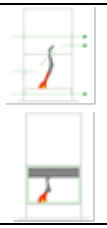
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	Refrigerant Management (1 Max. Point)	ensure performance and minimize contributions to ozone depletion and global warming	1	Credit 11.2: Appropriate HVAC Refrigerants-	Do not use refrigerants, install HVAC system with-non HCFC refrigerant, Install HVAC system with a refrigerant that complies with equation listed in EA 11 for LEED Homes		
Materials and Resources (MR)	MR Credit 1: Material-Efficient Framing (5 Max. Point)	Optimize the use of framing materials	Required	Prerequisites 1.1: Framing Order Waste Factor Limit:	Limit the overall estimated waste factor to 10% or Less		
			1	Credit 1.2: Detailed Framing Documents-	Before construction create detailed framing plans or scopes of work and accompanying architectural details for use on job site.		
			1	Credit 1.3: Detailed Cut List and Lumber Order-	Meet MR 1.2 and include detailed cut list and lumber order that corresponds directly to framing plans and/or scopes of work		
			3	Credit 1.4: Framing Efficiencies-	Implement measures from Table 23 in LEED Homes MR 1.4		
			4	Credit 1.5: Off-Site Fabrication-	Use either panelized or modular, prefabricated construction.		
	MR Credit 2: Environmentally Preferable Products (8 Max. Point)	Increase demand for environmentally preferable products and products or buildings components that are extracted, processed, and manufactured within the region.	Required	Prerequisites 2.1: FSC Certified Tropical Wood-	Provide all wood products with notice containing statement that builder's preference is to purchase products containing tropical wood only if it is FSC-certified, a request from the country of manufacture of each product supplied and request for a list of FSC-certified tropical wood products the vendor can supply. If tropical wood is intentionally used, use only FSC-certified tropical wood products.		

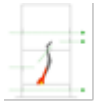
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			8	Credit 2.2: Environmentally Preferable Products-	Meet prescriptive requirements listed in MR 2 in LEED HOMES		
	MR Credit 3: Waste Management (3 Max. Point)	Reduce waste generation to a level below the industry norm.	Required	Prerequisites 3.1: Construction Waste Management Planning-	Investigate and document local options for diversion of all anticipated major constituents of the project waste stream and document diversion rate for construction waste. Also record diversion rate for land clearing/demolition.		
			3	Credit 3.2: Construction Waste Reduction-	Reduce or divert waste generated from new construction activities from landfills and incinerators to level below industry norm by reduced construction waste and increased waste diversion.		
Indoor Environmental Quality (EQ)	EQ Credit 1: ENERGY STAR with Indoor Air Package (13 Max. Point)	Improve the overall quality of a home's indoor environment by installing an approved bundle of air quality measures	13	Credit 1: ENERGY STAR with Indoor Air Packages -	Follow prescriptive codes of US Environmental Protection Agency's ENERGY STAR with Indoor Air Package		
	EQ Credit 2: Combustion Venting (2 Max. Point)	Minimize the leakage of combustion gases into the occupied space of the home	Required	Prerequisites 2.1: Basic Combustion Venting Measures-	No unvented combustion appliances, a CO monitor must be installed on each floor, fireplaces and woodstoves must have doors, space and water heating equipment must be designed and installed with closed combustion, with power-vented exhaust or located in detached utility building or open-air facility.		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			2	Credit 2.2: Enhanced Combustion Venting Measures-	Install no fireplace or woodstove or install one that meets requirements of Table 29 in EQ 2 LEED Homes. Also conduct a Back-Draft Potential Test.		
	EQ Credit 3: Moisture Control (1 Max. Point)	Control indoor moisture levels to provide comfort, reduce risk of mold, and increase the durability of the home	1	Credit 3: Moisture Load Control-	Install dehumidification equipment with sufficient latent capacity to maintain relative humidity at or below 60%.		
	EQ Credit 4: Outdoor Air Ventilation (3 Max. Point)	Reduce occupant exposure to indoor pollutants by ventilating with outdoor air.	Required	Prerequisites 4.1: Basic Outdoor Air Ventilation-	Install a whole building ventilation system that complies with ASHRAE Standard 62.2-2007. Meet continuous ventilation, intermittent ventilation and passive ventilation requirements. Mild Climate exemption if home has fewer than 4,500 infiltration degree-days.		
			2	Credit 4.2: Enhanced Outdoor Air Ventilation-	For Mild climates install whole building active ventilation system that complies with ASHRAE Standard 62.2-2007 or install system that provides heat transfer between incoming outdoor air stream and the exhaust air stream.	(P) May affect fire spread, toxicity, and smoke spread	
			1	Credit 4.3: Third-Party Performance Testing-	Have third-party test flow rate of air brought into home to verify requirements set by ASHRAE.		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	EQ Credit 5: Local Exhaust (2 Max. Point)	Reduce moisture and exposure to indoor pollutants in kitchen and bathrooms	Required	Prerequisite 5.1: Basic Local Exhaust-	Design and install local exhaust system in all bathrooms and kitchens that meet prescriptive codes and exhaust air to outdoors. Use ENERGY STAR labeled bathroom exhaust fans.		
			1	Credit 5.2: Enhanced Local Exhaust Fan-	Have occupancy sensor, automatic humidistat controller, automatic timer to operate fan for time interval after occupant leaves room, continuously operating exhaust fan.		
			1	Credit 5.3: Third-Party Performance Testing-	Perform a third-party test of each exhaust air flow rate for compliance		
	EQ Credit 6: Distribution of Space Heating and Cooling (3 Max. Point)	Provide appropriate distribution of space heating and cooling in the home to improve thermal comfort and energy performance	Required	Prerequisites 6.1: Room-by-Room Load Calculations for Forced-Air-System -	Install ducts accordingly by design calculations from ACCA Manuals J and D, ASHRAE Handbook of Fundamentals, or equivalent computation procedure		
			1	Credit 6.2: Return Air Flow-	Ensure every room has adequate return air flow through multiple returns, transfer grilles or jump ducts. Size of opening to 1 square inch per cfm of supply or demonstrate that pressure differential between closed room and adjacent space with return is no greater than 2.5 PA is required.	(P) May affect fire spread, toxicity, and smoke spread	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			2	Credit 6.3: Third-Party Performance Test-	Have total supply air flow rates in each room tested using flow hood with doors closed or other acceptable methods cited by ACCA Quality Installation Specifications.		
			Required	Prerequisite 6.1: Room-By-Room Load Calculations for Nonducted HVAC Systems-	Install accordingly by design calculations using ACCA Manual J and D, ASHRAE Handbook of Fundamentals or equivalent computation procedure.		
			1	Credit 6.2: Room-by-Room Controls for Nonducted HVAC Systems-	Design HVAC system with flow controls on every radiator		
			2	Credit 6.3: Multiple Zones for Nonducted HVAC Systems-	Install nonducted HVAC system with at least two distinct zones with independent thermostat controls		
	EQ Credit 7: Air Filtering (2 Max. Point)	Reduce Particulate matter from air supply system	Required	Prerequisites 7.1: Good Filters for Forced-Air Systems-	Install air filters with a minimum efficiency reporting value ≥ 8 an ensure air handlers can maintain adequate pressure and air flow. Must be airtight to prevent bypass or leakage		
			1	Credit 7.2: Better filters for Forced-Air Systems:	Install air filters with a minimum efficiency reporting value of ≥ 10 and ensure air handlers can maintain adequate pressure and air flow. Must be airtight to prevent bypass or leakage	(P) May affect fire spread, toxicity, and smoke spread	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			2	Credit 7.3: Best Filters for Forced-Air Systems:	Install air filters with a minimum efficiency reporting value of ≥ 13 and ensure air handlers can maintain adequate pressure and air flow. Must be airtight to prevent bypass or leakage.		
			Required	Prerequisites 7.1: Good Filters for Nonducted HVAC System-	Install air filters with a minimum efficiency reporting value of ≥ 8 and maintain adequate pressure and air flow.		
			1	Credit 7.2: Better Filters for Nonducted HVAC System-	Install air filters with a minimum efficiency reporting value of ≥ 10 and maintain adequate pressure and air flow.	(P) May affect fire spread, toxicity, and smoke spread	
			2	Credit 7.3: Best Filters for Nonducted HVAC System-	Install air filters with a minimum efficiency reporting value of ≥ 13 and maintain adequate pressure and air flow.		
	EQ Credit 8: Contaminant Control (4 Max. Point)	Reduce occupants' and construction workers' exposure to indoor airborne contaminants through source control and removal.	1	Credit 8.1: Indoor Contaminant Control during Construction-	Upon installation, seal all permanent ducts and vents to minimize contamination during construction. Remove any seals after all phases on construction are complete.		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			2	Credit 8.2: Indoor Contaminant Control:	Design and install permanent walk-off mats at each entry, show removal and storage space near primary entryway, separated from living areas, or install a central vacuum system with exhaust to outdoors.	(P) May present difficulties under a fire event	
			1	Credit 8.3: Preoccupancy Flush:	Flush home with fresh air proper to occupancy but after all phases of construction are completed, flush entire home keeping all interior doors open, flush for 48 hours total (nonconsecutive if needed), keep all windows open and run a fan continuously, use additional fans to circulate air within home, replace/clean HVAC air filter afterwards.		
	EQ Credit 9: Radon Protection (1 Max. Point)	Reduce occupant exposure to radon gas and other soil gas contaminants	Required	Prerequisites 9.1: Radon-Resistant Construction in High-Risk Areas-	Design and build home with radon-resistant construction techniques as prescribed by EPA, International Residential Code, Washington State Ventilation and Indoor Air Quality Code, or equivalent Code/standard		
			1	Credit 9.2: Radon-Resistant Construction in Moderate-Risk Area-	If home is outside EPA Radon Zone 1, still design and build home to meet requirements of Prerequisite 9.1 EQ LEED Homes.		
	EQ 10: Garage Pollutant Protection (3 Max. Point)	Reduce occupant exposure to indoor pollutants originating from an adjacent garage.	Required	Prerequisites 10.1: No HVAC in Garage-	Place all air-handling equipment and ductwork outside fire-rated envelope of garage.		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			2	Credit 10.2: Minimize Pollutants from Garage-	Tightly seal shared surfaces between garage and conditioned air space as well as: In conditioned spaces above garage- seal all penetrations, connecting floors and ceiling joist bays, and paint walls and ceiling. and In conditioned spaces next to garage- weather-strip all doors, place carbon monoxide detector in adjacent rooms that share a door with garage, seal all penetrations, and seal all cracks at base of wall		
			1	Credit 10.3: Exhaust Fan in Garage-	Install an exhaust fan in garage that is rated for continuous operation and designed with automatic timer control linked to an occupant sensor, light switch, garage door opening-closing mechanism, carbon monoxide sensor, or equivalent. Timer must provide at least three air changes each time fan is turned on		
			3	Credit 10.4: Detached Garage or No Garage.			
Awareness & Education (AE)	AE Credit 1: Education of the Homeowner or Tenant (2 Max. Point)	Maintain the performance of the home by educating the occupants (I.e., the homeowner or tenant) about the operations and maintenance of the home's LEED features and equipment.	Required	Prerequisites 1.1: Basic Operations Training-	Include operations and maintenance manual, a minimum one-hour walkthrough of the home with occupants that identify installed equipment, instructions in how to use measures and operate equipment, and how to maintain them as well.		

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			1	Credit 1.2: Enhanced Training-	Provide 2 hours of additional training. Examples listed in AE 1.2 LEED Homes		
			1	Credit 1.3: Public Awareness-	Promote general public awareness about LEED for Homes by conducting activities. Activates are described in AE 1.3 LEED for Homes.		
	AE Credit 2: Education of Building Manager (1 Max. Point)	Maintain the performance of the home by educating the building manager about the operations and maintenance of the home's LEED features and equipment.	1	Credit 2: Education of Building Manager-	For multifamily buildings, provide building manager with a building owner's manual or binder and a minimum of a one-hour walkthrough of building before occupancy showing installed equipment, how to use the measures and operate the equipment in each unit along with maintenance.		

LEED (Retail)

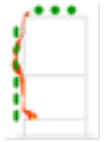
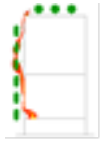
LEED For Retail: New Construction and Major Renovations 2009 Updated November 2011
To achieve LEED Certification:
1: Prerequisite Requirement- All relevant prerequisites for specific LEED Retail: New Construction and Major Renovation Rating are to be complied with
2: Earn at least 40-49 points for Certification, 50-59 points for Silver, 60-79 points for Gold and 80+ points for Platinum

Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Sustainable Sites (SS)	SS Prerequisite 1: Construction Activity Pollution Prevention	To reduce pollution from construction activities by controlling soil erosion, waterway sedimentation, and airborne dust generation.	Required		Have erosion and sedimentation control plan that conforms to 2003 EPA Construction General Permit or local standards (whichever are more stringent)	(P) Debris and Runoff water after Fire event should be considered	
	SS Credit 1: Site Selection (1 Max. Point)	To avoid the development of inappropriate sites and reduce the environmental impact from the location of a building on a site.	1		Do not develop on the following: Prime farmland, Undeveloped land (elevation lower than 5 ft. above 100-year flood), Threatened or Endangered species habitats, Land within 100 ft. of wetlands, Undeveloped land with 50ft of water body, Land that was previously public parkland* (Unless trade was in equal or greater value)		
	SS Credit 2: Development Density and Community Connectivity (5 Max. Point)	To channel development to urban areas with existing infrastructure, protect greenfields, and preserve habitat and natural resources.	5	Option 1: Development Density	Must develop on previously developed site and in a community with min. density of 60,000 square feet per acre net	(P) Proximity of Fire Station is not taken into consideration	

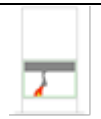
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
				Option 2: Community Connectivity-	Develop on previously developed site, within 10 basic services, within residential area, and have pedestrian access	(P) Fire Station is recommended as a basic service but not a requirement to be within 1/2 mile.	
	SS Credit 3: Brownfield Redevelopment (1 Max. Point)	To rehabilitate damaged sites where development is complicated by environmental contamination, to reduce pressure on undeveloped land.	1	Option 1	Develop on contaminated site by definition of ASTM E1903-97 Phase II Environmental Site Assessment/Local voluntary cleanup program		
				Option 2	Develop on site documented as brownfield by government agency	(P) Types of contamination in soil	
	SS Credit 4: Alternative Transportation (10 Max. Point)	To reduce pollution and land development impacts from automobile use.	6	Option 1: Public Transportation Access-	Close proximity for Rail or Bus Stop proximity		
			1	Option 2: Bicycle Commuting	Provide bicycle racks		
			1	Option 3: Low-Emitting and Fuel-Efficient Vehicles -	Provide full-time equivalent occupants with vehicles, vehicle sharing program, alternative-fuel refueling stations, or preferred parking with low-emitting and fuel-efficient vehicles	(P) Evacuation routes with vehicles (P) Alternative-fuel refueling stations proximity to structures	

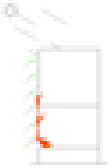
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			3	Option 4: Parking Capacity	Have parking garage that meets but not exceed minimum local zoning requirements, preferred parking for carpools	(P) Limited parking space causes concerns for evacuation routes and access for emergency services	
			1	Option 5: Delivery Service-	Provide delivery service to transport goods		
			1	Option 6: Incentives	Provide incentive program for employees who carpool.		
			1	Option 7: Alternative Transportation Education -	Board or computer display of information on carpool programs, transit trip planning assistance, transit maps	(P) Unless taken into consideration with a Fire Protection Engineer, the education center will cause an unnatural flow to people traffic	
	SS Credit 5.1: Site Development —Protect or Restore Habitat (1 Max. Point)	To conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.	1	Case 1: Greenfield Sites -	Limit proximity between building perimeter and: parking garages, surface walkways, patios, surface parking, utilities, roadway curbs, and constructed areas with permeable surfaces		
				Case 2: Previously Developed Areas or Graded Sites -	Restore or protect site area with native or adapted vegetation's or donate land equivalent	(P) Proximity to vegetation	

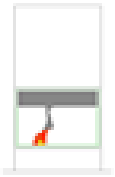
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	SS Credit 5.2: Site Development —Maximize Open Space (1 Max. Point)	To promote biodiversity, by providing a high ratio of open space to development footprint.	1		Provide a vegetated open space in accordance to local zoning open space requirements	(P) Proximity to vegetation	
	SS Credit 6.1: Stormwater Design— Quantity Control (1 Max. Point)	To limit disruption of natural water hydrology by reducing impervious cover, increasing onsite infiltration, reducing or eliminating pollution from storm water runoff, and eliminating contaminants.	1	Case 1: Sites with existing imperviousness 50% or less -	Implement storm water management plan that either: prevents exceeding the peak discharge rate and quantity for the 1- and 2-year 24-hour design storms or protects receiving stream channel from excessive erosion		
				Case 2: Sites with existing Imperviousness greater than 50% -	Implement storm water management plan that has a 35% decrease in volume of storm water runoff from 2-year 24-hour design storm		
	SS Credit 6.2: Stormwater Design— Quality Control (1 Max. Point)	To limit disruption and pollution of natural water flows by managing storm water runoff.	1		Stormwater management plan must reduce impervious cover, promotes infiltration, and captures/treats storm water runoff from 90% of annual rainfall using best management practices.	(P) Does not take into account for fire event runoff	
	SS Credit 7.1: Heat Island Effect— Nonroof (2 Max. Point)	To reduce heat islands1 to minimize impacts on microclimates and human and wildlife habitats.	1	Option 1:	Provide shade for 25% or 50% of site hardscape, use hardscape materials with SRI of at least 29, use open-grid pavement system	(P) Proximity of items used for shade (I.E. Trees) to building	

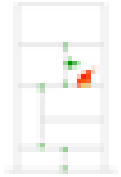
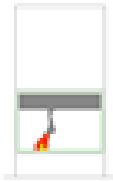
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
			2	Option 2:	Have 25% or 50% of parking spaces are under cover	(P) Suggestions are vegetated green roof and solar panels that may lead to increased fire risk	
	SS Credit 7.2: Heat Island Effect—Roof (1 Max Point)	To reduce heat islands1 to minimize impacts on microclimates and human and wildlife habitats.	1	Option 1:	Use of roofing materials with a solar reflectance index equal to or greater than calculated values for a minimum of 75% of roof surface		
			1	Option 2:	Install vegetated roof that covers 50% of roof	(P) Fuel loads, fire spread (S) May difficult fire services operations	
			1	Option 3:	Install high-albedo and vegetated roof surface that meet calculated values	(P) Fuel loads, fire spread (S) May difficult fire services operations	
	SS Credit 8: Light Pollution Reduction (2 Max. Point)	To minimize light trespass from the building and site, reduce sky glow to increase night sky access, improve nighttime visibility through glare reduction, and reduce development impact on nocturnal environments.	2	Option 1:	Reduce input power to interior luminaries (excluding emergency lights) with direct line of sight to any opening by 50% from 11 pm to 5 am.	(P) Poor external lighting levels may influence Fire Services intervention at night	

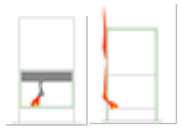
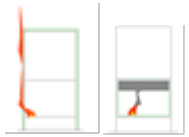
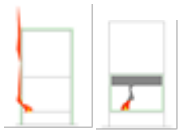
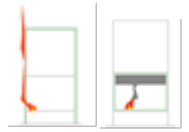
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
				Option 2:	All openings in envelope with direct line of sight to any nonemergency luminaires must have shielding for resultant of transmittance of less than 10% between 11pm and 5 am.	(P) Poor external lighting levels may influence Fire Services intervention at night	
					For exterior lighting, light areas shall not exceed those in ANSI/ASHRAE/IESNA Standard 90.1-2007 with Addenda 1 for documented light zones as well as following IESNA RP-33 for other light zones.	(P) Poor external lighting levels may influence Fire Services intervention at night	
Water Efficiency (WE)	WE Prerequisite 1: Water Use Reduction	To increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.	Required		Has strategy that uses 20% less water than water use baseline calculated for building excluding irrigation	(P) The general Water Consumption Problem may influence its use for Fire Suppression (i.e. the systems efficiency should include the water storage and consumption and the consequences of its use)	
	WE Credit 1: Water-Efficient Landscaping (4 Max. Points)	To limit or eliminate the use of potable water, or other natural surface or subsurface water resources available on or near the project site, for landscape irrigation.	2	Option 1: Reduce by 50%	Reduce potable water consumption for irrigation by 50% from calculated midsummer baseline		
			4	Option 2: Not potable water use or irrigation-	Use only captured/recycled water or use landscaping that does not need permanent irrigation systems		

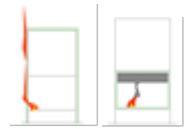
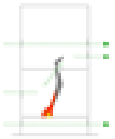
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	WE Credit 2: Innovative Wastewater Technologies (2 Max. Points	To reduce generation of wastewater and potable water demand while increasing the local aquifer recharge.	2	Option 1:	Reduce potable water use for building sewage conveyance by 50% through water-conserving fixtures or nonpotable water		
				Option 2:	Treat 50% of wastewater on-site to tertiary standards	(P) Toxicity	
	WE Credit 3: Water Use Reduction (4 Max. Points)	To further increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.	4		Use a strategy that further reduces water usage than baseline calculated for the building.		
Energy and Atmosphere (EA)	EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems	To verify that the project's energy-related systems are installed and calibrated to perform according to the owner's project requirements, basis of design, and construction documents.	Required		Complete all commissioning activities presented in EA section of LEED Retail: New Construction and Renovation	(P) Activity does not mention any fire protection practice or systems	
	EA Prerequisite 2: Minimum Energy Performance	To establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use.	Required		Whole building energy modeling or compliance with prescriptive code		

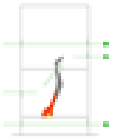
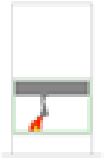
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	EA Prerequisite 3: Fundamental Refrigerant Management	To reduce stratospheric ozone depletion.	Required		No use of chlorofluorocarbon based refrigerants		
	EA Credit 1: Optimize Energy Performance (19 Max. Points)	To achieve levels of energy performance beyond those in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.	19		Whole building energy modeling or compliance with prescriptive code		
	EA Credit 2: On-Site Renewable Energy (7 Max. Points)	To encourage and recognize increasing levels of on-site renewable energy self-supply to reduce environmental and economic impacts associated with fossil fuel energy use.	7		On-site renewable energy systems offset building energy cost	(P) May present difficulties under a fire	
	EA Credit 3: Enhanced Commissioning (2 Max. Points)	To begin commissioning early, in the design process and execute additional activities after systems performance verification is completed.	2		Have plans to further complete additional commissioning process activities that can be found in LEED Reference Guide for Green Building Design and Construction, 2009 Edition	(P) Activity does not mention any fire protection practice or systems	

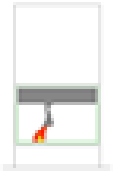
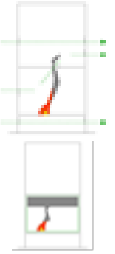
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	EA Credit 4: Enhanced Refrigerant Management (2 Max. Points)	Reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to global climate change.	2		Do not use refrigerants or use refrigerants that minimize or eliminate emissions that are harmful to ozone depletion and climate change	(P) Toxicity	
	EA Credit 5: Measurement and Verification (3 Max. Points)	To provide for the ongoing accountability of building energy consumption over time.	3		Develop and implement measurement and verification plan consistent with prescriptive code		
	EA Credit 6: Green Power (2 Max. Points)	To encourage the development and use of grid-source, renewable energy technologies on a net zero pollution basis.	2		Use renewable energy sources for 35% of buildings electricity in 2 year contract with renewable energy suppliers		
Materials and Resources (MR)	MR Prerequisite 1: Storage and Collection of Recyclables	To facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills.	Required		Conduct waste stream study and provide collection/storage space for top 3	(P) Fuel loads, fire spread	

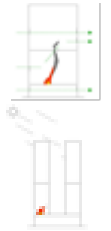
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	MR Credit 1.1: Building Reuse—Maintain Existing Walls, Floors, and Roof (3 Max. Points)	To extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste, and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.	3		Maintain existing building structure and envelope.	(P) Hazardous materials are excluded yet not defined	
	MR Credit 1.2: Building Reuse—Maintain Interior Nonstructural Elements (1 Max. Points)	To extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste, and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.	1		Use existing interior nonstructural elements in at least 50% of completed building	(P) Fire reaction and toxicity	
	MR Credit 2: Construction Waste Management (2 Max. Points)	To divert construction and demolition debris from disposal in landfills and incineration facilities. Redirect recyclable recovered resources to the manufacturing process and reusable materials to appropriate sites.	2		Recycle and/or salvage nonhazardous construction and demolition debris.	(P) Fire reaction and toxicity	

Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	MR Credit 3: Materials Reuse (2 Max. Points)	To reuse building materials and products to reduce demand for virgin materials and to reduce waste, thereby lessening impacts associated with the extraction and processing of virgin resources.	2		Use salvaged, refurbished, or reused materials	(P) Fire reaction and toxicity	
	MR Credit 4: Recycled Content (2 Max. Points)	To increase demand for building products that incorporate recycled content materials, thereby reducing impacts resulting from extraction and processing of virgin materials.	2		Use materials with recycled content	(P) Fire reaction and toxicity	
	MR Credit 5: Regional Materials (2 Max. Points)	To increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation.	2		Use of material within 500 miles of project site	(P) Fire reaction and toxicity	
	MR Credit 6: Rapidly Renewable Materials (1 Max. Points)	To reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials.	1		Use of rapidly renewable building materials and products	(P) Fire reaction and toxicity	

Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	MR Credit 7: Certified Wood (2 Max. Points)	To encourage environmentally responsible forest management.	1		Use of minimum of 50% (on cost) of wood-based materials that are certified by Forest Stewardship Council principles and wood building components	(P) It may be impleaded with criteria for wood building components, but lack of evidence to suggest wood is treated to be fire retardant	
Indoor Environmental Quality (IEQ)	IE Q Prerequisite 1: Minimum Indoor Air Quality Performance	To establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants.	Required		Compliance with prescriptive code and have either Mechanically or Naturally Ventilated Spaces	(P) Air movement within the building may increase O2 and facilitate Smoke Spread	
	IE Q Prerequisite 2: Environmental Tobacco Smoke (ET S) Control	To prevent or minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to environmental tobacco smoke (ETS).	Required		Either no smoking in or within 25 feet of building OR smoking in designated smoking areas.		
	IE Q Credit 1: Outdoor Air Delivery Monitoring (1 Max. Points)	To provide capacity for ventilation system monitoring to help promote occupants' comfort and well-being.	1		Install permanent monitoring systems for ventilation systems. Must generate alarm when airflow values or CO2 levels vary before than 10% on design	(P) May interfere with fire protection systems compatibility	

Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	IE Q Credit 2: Increased Ventilation (1 Max. Points)	To provide additional outdoor air ventilation to improve indoor air quality (IAQ) for improved occupant comfort, well-being, and productivity.	1		Increase airflow from outside by 30%	(P) Air movement within the building may increase O2 and facilitate Smoke Spread	
	IE Q Credit 3.1: Construction Indoor Air Quality Management Plan—During Construction (1 Max. Points)	To reduce indoor air quality (IAQ) problems resulting from the construction or renovation and promote the comfort and well-being of construction workers and building occupants.	1		Have a IAQ management plan during construction and preoccupancy phases that meet prescriptive codes	(P) Lack of information if fire event would occur	
	IE Q Credit 3.2: Construction Indoor Air Quality Management Plan—Before Occupancy (1 Max. Points)	To reduce indoor air quality (IAQ) problems resulting from the construction or renovation to promote the comfort and well-being of construction workers and building occupants.	1		IAQ plan to clean out building once completed by Flush Out or conducting Air testing	(P) Filter materials	
	IE Q Credit 4: Low-Emitting Materials (5 Max. Points)	To reduce the quantity of indoor air contaminants that is odorous, irritating, and/or harmful to the comfort and wellbeing of installers and occupants.	5		Choices between following Adhesive and Sealants, Paints and Coatings, Flooring, Composite Wood and Agrifiber Products, Furniture and Furnishings prescriptive code	(P) Fire reaction and toxicity	

Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	IE Q Credit 5: Indoor Chemical and Pollutant Source Control (1 Max. Points)	To minimize building occupants' exposure to potentially hazardous particulates and chemical pollutants.	1		Have safety measures to keep out pollutants from entering building, exhaust in hazardous areas, new filtration media changes before occupancy, and containment of hazardous materials	(P) Fuel loads, toxicity	
	IE Q Credit 6: Controllability of Systems—Lighting and Thermal Comfort (1 Max. Points)	To provide a high level of lighting system and thermal comfort control1 for individual workstations to promote the productivity, comfort, and well-being of building occupants.	1		Have light controls for 90% of occupants and thermal comfort controls for 50%	(P) May influence Fire Initiation, Internal and Exterior Spread, Smoke movement, Temperatures, Flashovers, Backdrafts, etc.	
	IE Q Credit 7.1: Thermal Comfort—Design (1 Max. Points)	To provide a comfortable thermal environment that promotes occupant productivity and well-being.	1		Follow ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy		
	IE Q Credit 7.2: Thermal Comfort—Employee Verification (1 Max. Points)	To provide for the assessment of building occupants' thermal comfort over time.	1		Achieve IEQ 7.1 and have monitoring systems to ensure building performance meets desired comfort criteria		

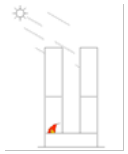
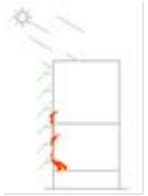
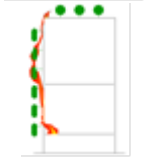
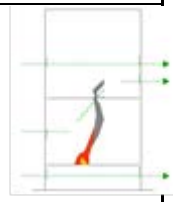
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	IE Q Credit 8.1: Daylight and Views—Daylight (1 Max. Points)	To provide for the building occupants with a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas1 of the building.	1		Follow prescriptive codes for certain illumination levels,	(P) Fire and smoke spread	
	IE Q Credit 8.2: Daylight and Views—Views (1 Max. Points)	To provide for the building occupants a connection to the outdoors through the introduction of daylight and views into the regularly occupied areas1 of the building.	1		Achieve a direct line of sight to the outdoor environment via vision glazing between 30 inches and 90 inches above the finish floor for building occupants in 90% of all regularly occupied areas by stationary retail staff and/or customers.		
Innovation in Design (ID)	ID Credit 1: Innovation in Design (5 Max. Points)	To provide design teams and projects the opportunity to achieve exceptional performance above the requirements set by the LEED Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED Green Building Rating System.	5		Achieve significant and measureable environmental performance using strategy not addressed in LEED	(P) May present challenges	

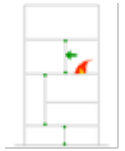
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	ID Credit 2: LEE D Accredited Professional (1 Max. Points)	To support and encourage the design integration required by LEED to streamline the application and certification process.	1		One person is LEED Accredited Professional (AP)		
Regional Priority	Regional Priority (4 Max. Points)	To provide an incentive for the achievement of credits that address geographically-specific environmental priorities.	4		Earn credits identified by USGBC regions that have environmental importance to region	(P) May present challenges based on region	

BREEAM

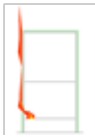
BREEAM New Construction (Building Research Establishment's Environmental Assessment Method) , 2011

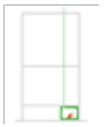
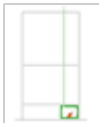
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Management (Man)	Man 01- Sustainable procurement	To ensure delivery of a functional and sustainable asset designed and built in accordance with performance expectations	8			(P) Fire protection is not considered	
	Man 02- Responsible construction practices	To recognise and encourage construction sites which are managed in an environmentally and socially considerate, responsible and accountable manner	2				
	Man 03- Construction site impacts	To recognise and encourage construction sites managed in an environmentally sound manner in terms of resource use, energy consumption and pollution	5			(P) No consideration is done on environmental consequences of a fire event during construction	
	Man 04- Stakeholder participation	To design, plan and deliver accessible functional and inclusive buildings in consultation with current and future building users and other stakeholders	4				
	Man 05- Life cycle cost and service life planning	To recognise and encourage life cycle costing and service life planning in order to improve design, specification and through-life maintenance and operation	3			(P) Life and maintenance of Fire Protection Systems could affect the election (S) Water consumption	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Health and Wellbeing (Hea)	Hea 01- Visual comfort	To ensure daylight, artificial lighting and occupant controls are considered at the design stage to ensure best practice visual performance and comfort for building occupants	BTD		Daylighting design needs a less compact Building Geometry	(P) May influence fire and smoke exterior spread. More transparent surfaces on facades could influence O2 presence (S) May affect evacuation routes and fire services intervention	
					View out and glare requirements	(P) Glare control systems may influence exterior spread and fire services intervention. In the case of green elements, combustible material added	 
	Haa 02- Indoor air quality	To recognise and encourage a healthy internal environment through the specification and installation of appropriate ventilation, equipment and finish	BTD		Minimising sources of indoor air pollution	(P) Air conditions may influence O2 presence and spread	
					Potential for natural ventilation	(P) Air movement within the building may affect fire and smoke spread	

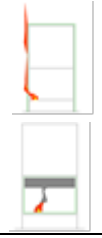
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	Hae 03- Thermal comfort	To ensure that appropriate thermal comfort levels are achieved through design, and controls are selected to maintain thermally comfortable environment for occupants within the building	2				
	Hea 04- Water quality	To minimise the risk of water contamination in buildings services and ensure the provision of clean, fresh sources of water for building users	1				
	Hea 05- Acoustic performance	To ensure the buildings' acoustic performance including sound insulation meet the appropriate standards for its purpose	BTD		Acoustic performance is increased with the use of mass and elastic joints	(P) May influence compartmentalization	
	Hea 06- Safety and security	To recognise and encourage the effective design measures that promote low risk, safe and secure access to and use of the building	2		Safe access and security of site and building. Fire not considered.	(P) Some safety and security aspects considered could affect fire safety	

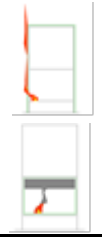
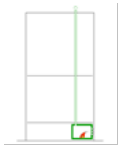
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Energy (Ene)	Ene 01- Reduction of CO2 emissions	To recognise and encourage buildings designed to minimise operational energy demand, consumption and CO2 emissions	15		Energy Demand can be minimised with: • Insulation • Renewal energies • Facade systems or elements • Sustainable and recycled materials	P) The use of better insulation may increase interior temperature in a fire event (P) The use of renewal energies may affect fire and smoke spread (P) The use of façade systems or elements to regulate thermal conditions and sun radiation may influence fire and smoke spread (P) Encouraging the use of sustainable and recycled materials may be contradictory with diminishing combustion and/or toxicity (S) May influence evacuation or fire services intervention	
	Ene 02- Energy monitoring	To recognise and encourage the installation of energy sub-metering that facilitates the monitoring of operational energy consumption	BTD		Use a Building Energy Management System (BEMS) or separate accessible energy submeters	(P) Increasing the systems complexity may affect their response	
	Ene 03- External lighting	To recognise and encourage the specification of energy-efficient light fittings for external areas of the development	1			(P) May affect fire services intervention at night	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	Ene 04- Low and zero carbon technologies	To reduce carbon emissions and atmospheric pollution by encouraging local energy generation from renewable sources to supply a significant proportion of the energy demand	5				
	Ene 05- Energy efficient cold storage	To recognise and encourage the installation of energy efficient refrigeration systems, therefore reducing operational greenhouse gas emissions resulting from the system's energy use	2				
	Ene 06- Energy efficient transportation systems	To recognise and encourage the specification of energy-efficient transportation systems	2				
	Ene 07- Energy efficient laboratory systems	To recognise and encourage laboratory areas that are designed to minimise the CO2 emissions associated with their operational energy consumption	BTD				
	Ene 08- Energy efficient equipment	To recognise and encourage procurement of energy-efficient equipment to ensure optimum performance and energy savings in operation	2				
	Ene 09- Drying space	To provide a reduced energy means of drying clothes	1		Drying lines	(P) May influence fire and smoke spread	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
					Adequate internal heated space with adequate controlled ventilation	(P) Fire loads (S) Fire and smoke spread	
Transportation (Tra)	Tra 01- Public transport accessibility	To recognise and encourage development in proximity of good public transport networks, thereby helping to reduce transport-related pollution and congestion	BTD				
	Tra 02- Proximity to amenities	To encourage and reward a building that is located in close proximity to local amenities, thereby reducing the need for extended travel or multiple trips	BTD		Concentration of different uses and services	(P) May influence human behaviour under fire events (i.e. parents may try to look for their children in an emergency)	
	Tra 03- Cyclist facilities	To encourage building users to cycle by ensuring adequate provision of cyclist facilities	BTD		Storage space, showers, wardrobes and lockers, drying space	(P) May increase fire loads	
	Tra 04- Maximum car parking capacity	To encourage the use of alternative means of transport to the building other than the private car, thereby helping to reduce transport related emissions and traffic congestion associated with the building's operation	BTD				

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	Tra 05- Travel Plan	To recognise the consideration given to accommodating a range of travel options for building users, thereby encouraging the reduction of user reliance on forms of travel that have the highest environmental impact	1				
Water (Wat)	Wat 01- Water consumption	To reduce the consumption of potable water for sanitary use in new buildings from all sources through the use of water efficient components and water recycling systems	5			(P) Water consumption may affect fire systems election	
	Wat 02- Water monitoring	To ensure water consumption can be monitored and managed and therefore encourage reductions in water consumption	1			(P) Monitoring may increase complexity	
	Wat 03- Water leak detection and prevention	To reduce the impact of water leaks that may otherwise go undetected	2				
	Wat 04- Water efficient equipment	To reduce unregulated water consumption by encouraging specification of water efficient equipment	1				

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Materials (Mat)	Mat 01- Life cycle impacts	To recognise and encourage the use of construction materials with low environmental impact (included embodied carbon) over the full life cycle of the building	BTD			(P) Environmental friendly materials may influence fire initiation and spread	
	Mat 02- Hard landscaping and boundary protection	To recognise and encourage the specification of materials for boundary protection and external hard surfaces that have a low environmental impact, taking account of the full life cycle of materials used	1		Use of natural elements	(P) May influence fire spread to buildings	
	Mat 03- Responsible sourcing of materials	To recognise and encourage the specification of responsibly sourced materials for key building elements	3			(P) Environmental friendly materials may influence fire initiation and spread	
	Mat 04- Insulation	To recognise the use of thermal insulation which has a low embodied environmental impact relative to its thermal properties and has been responsibly sourced	2		Use of low embodied impact insulation	(P) Environmental friendly insulation may influence fire initiation and spread	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	Mat 05- Designing for robustness	To recognise and encourage adequate protection of exposed elements of the building and landscape, therefore minimising the frequency of replacement and maximising materials optimisation	1		Use of durable materials Providing protection to sensible building parts	(P) Use of durable materials may influence fire initiation and spread	
Waste (Wst)	Wst 01- Construction waste management	To promote resource efficiency via the effective management and reduction of construction waste	4				
	Wst 02- Recycled aggregates	To recognise and encourage the use of recycled and secondary aggregates, thereby reducing the demand for virgin material and optimising material efficiency in construction	1				
	Wst 03- Operational waste	To recognise and encourage the provision of dedicated storage facilities for a building's operational-related recyclable waste streams, so that this waste is diverted from landfill or incineration	1		Disposal of baskets and storage space with important fire loads probably close to common spaces and egress routes	(P) Fire initiation and spread (S) Ventilation provided may influence fire and smoke spread	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	Wst 04- Speculative floor and ceiling finishes	To encourage the specification and fitting of floor and ceiling finishes selected by the building occupant and therefore avoid unnecessary waste of materials	1				
Land Use and Ecology (LE)	LE 01- Site selection	To encourage the use of previously developed and/or contaminated land and avoid land which has not been previously disturbed	2				
	LE 02- Ecological value of site and protection of ecological features	To encourage development on land that already has limited value to wildfire and to protect existing ecological features from substantial damage during site preparation and completion of construction works	1				
	LE 03- Mitigating ecological impact	To minimise the impact of a building development on existing site ecology	2				
	LE 04- Enhancing site ecology	To recognise and encourage actions taken to maintain and enhance the ecological value of the site as a result of development	BTD			(P) Important fire events could influence site ecology	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	LE 05- Long term impact on biodiversity	To minimise the long term impact of the development on the site and the surroundings area's biodiversity	BTD		Fire not considered	(P) Important fire events could influence impact on biodiversity	
Pollution (Pol)	Pol 01- Impact of refrigerants	To reduce the level of greenhouse gas emissions arising from the leakage of refrigerants from building systems	3				
	Pol 02- NOX emissions	To encourage the supply of heat and/or coolth from a system that minimises NOx emissions, and therefore reduces pollution of the local environment	BTD				
	Pol 03- Surface water run off	To avoid, reduce and delay the discharge of rainfall to public sewers and watercourses, therefore minimising the risk of localised flooding on and off site, watercourse pollution and other environmental damage	5		Fire not considered	(P) Water run off from a fire could influence pollution	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	Pol 04- Reduction of night time light pollution	To ensure that external lighting is concentrated in the appropriate areas and that upward lighting is minimised, reducing unnecessary light pollution, energy consumption and nuisance to neighbouring properties	1			(P) Could influence fire services intervention	
	Pol 05- Noise attenuation	To reduce the likelihood of noise from the new development affecting nearby noise-sensitive buildings	1				
Innovation							
(*) BTD: Building Type Dependent							

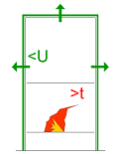
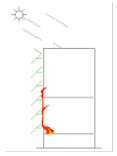
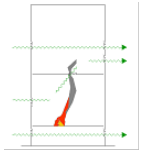
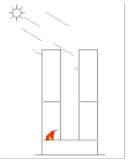
Conclusions:

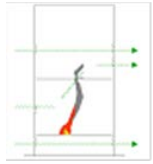
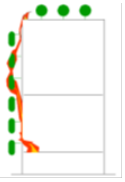
- Fire, by itself, is not considered a requirement for sustainability by BREEAM evaluation system.
- BREEAM evaluation system is mostly Performance-based, especially when facing Energy Efficiency quantification, not forcing many prescriptive architectural features. Nevertheless some aspects like natural lighting or the convenience of exterior views may influence the buildings final shape.
- Some aspects, like waste recycling need, the use of land, water and other resources or transportation requirements is prescriptive and influences buildings overall design.
- Fire should be seen as an indirect threat for many of the BREEAM requirements, including Waste, Contamination, and Water Use.
- Some BREEAM requirements should be studied in parallel to the Fire problem, including the ways to face Energy Efficiency, the use of Materials, Transportation or Health.

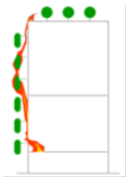
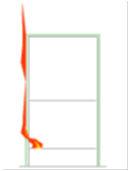
GREEN MARK (Residential)

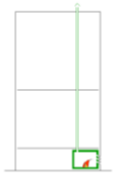
BCA Green Mark for New Residential Buildings, Version RB/4.0 , 2010

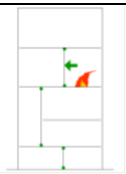
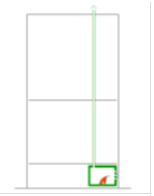
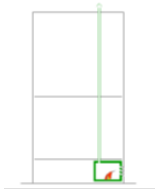
Categories/ Chapter	Section/ Assessment Issues	Aims	Credits/ Scores	Requirements/ Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Prerequisite Requirements		(1) Building envelope design with Residential Envelope Transmittance value (RETV) computed based on the methodology stipulated in the Code		Green Mark Gold: 22 W/m2 Green Mark Platinum: 20 W/m2			
		(2) To be elected for Green Mark Platinum, ventilation simulation modeling		A minimum 80% of dwelling units, wind velocity of 0.6 m/s			
		(3) Prescribed system efficiency of air-conditioning system		Green Mark Gold, Green Mark Platinum, air-conditioning systems with 4-ticks certified under The Singapore Energy Labeling Scheme (COP)			
		(4) Minimum points to be scored under RB 3-1		Green Mark Gold ≥ 3 points Green Mark Platinum ≥ 5 points			

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Energy Efficiency (87 p. max.)	RB 1-1 Thermal performance of Building Envelope Enhance the overall thermal performance of the building envelope to minimize heat gain		15	Maximum RETV = 25 W/m2	Increase envelope insulation	(P) Increasing insulation (diminishing RETV value) will increase interior temperature under fire (S) Can affect compartmentalization, the structure time resistance or evacuation	
					Use sun control devices	(P) May influence fire exterior spread (S) May disturb fire brigade intervention	
	RB 1-2 Naturally Ventilated design and Air-Conditioning System Enhance indoor comfort through good natural ventilation and energy efficient air-conditioners		22	(a) Dwelling Unit Indoor Comfort, using; 1. Ventilation simulation 2. ventilation design (no simulation) and efficient use of Air-Conditioning System (b) Natural Ventilation in common areas	Natural Ventilation Energy efficient air-conditioners	(P) Fresh air may maintain combustion (S) Openings or ducts may affect compartmentalization and smoke spread	
	RB 1-3 Daylighting Encourage design that encourages effective the use of effective daylighting		6	(a) Use of daylight and glare simulation effective daylighting (b) Daylighting in Lift lobbies and corridors, Staircases and Car parks	Optimize the building form for daylighting asks for less compactness	(P) Increasing the perimeter may influence fire exterior spread (S) Less compact form may increase evacuation distances	
	RB 1-4 Artificial Lighting Encourage the use of energy efficient lighting in common areas		10				

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	RB 1-5 Ventilation Carparks Encourage the use of energy efficient design and control of ventilation systems in car parks		6	(a) Car parks designed with natural ventilation (b) CO sensors to control mechanical ventilation		(P) The use of natural ventilation in car parks may influence fire exterior spread	
	RB 1-6 Lifts Encourage the use of lifts with energy efficient features		1				
	RB 1-7 Energy Efficient Features Encourage the use of energy efficient features		7	Examples: · Lifts with gearless drive · Re-generative lifts · Heat recovery devices · Cool paints · Gas water heaters · Calculation of EEI · Provision of vertical greenery system that helps to reduce heat gain	Adding vertical greenery systems	(P) The use of greenery systems may influence fire initiation and fire exterior spread (S) May disturb fire brigade intervention	
	RB 1-8 Renewable Energy Encourage the application of renewable energy sources such as solar energy in build ons		20		· Use of solar photovoltaic systems · Use of solar water heating equipment · Use of wind energy systems	(P) The use of these systems may influence exterior spread (S) May disturb fire brigade intervention (i.e. access to the building or smoke venting)	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Water Efficiency (14 p. max.)	RB 2-1 Water Efficiency Fittings Encourage the use of water efficient fittings		10	(a) Basin taps and mixers (b) Flushing cistern (c) Shower taps, mixers or showerheads (d) Sink/Bib taps and mixers (e) All other water fittings		(P) May affect the election of fire protection systems according to water use	
	RB 2-2 Water Usage Monitoring Provide private meters to monitor water usage		1			(P) Extending Monitoring may influence water systems complexity and increase the possibility of failure	
	RB 2-3 Irrigation system and Landscaping Provision of suitable systems that utilize rainwater or recycled water for some uses		3	(a) use of non potable water for irrigation (b) Use of automatic water efficient irrigation system (c) Use of drought tolerant plants to require minimal irrigation		(P) The use of drought tolerant plants may influence fire initiation and fire spread	
Environmental Protection (41 p. max.)	RB 3.1 Sustainable Construction Encourage recycling and the adoption of building designs, construction practices and materials that are environmentally friendly		10	(a) Use of Sustainable and Recycled Materials (b) Concrete Usage Index (CUI)		(P) Sustainable materials may influence combustion, fire and smoke spread and toxicity	
	RB 3-2 Sustainable Products Promote the use of environmental friendly products that are certified		8			P) Sustainable products may influence combustion, fire and smoke spread and toxicity	

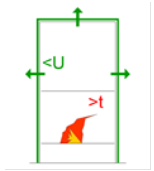
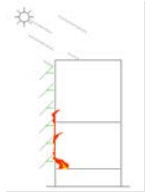
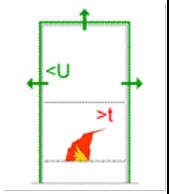
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	RB 3-3 Greenery Provision Encourage greater use of greenery, restoration of trees to reduce heat island effect		8	(a) Green Plot Ratio (b) Restoration of trees (c) Use of compost recycled from horticulture waste		P) Greenery may influence wildfires and affect buildings close to trees concentrations	
	RB 3-4 Environmental Management Practice Encourage the adoption of environmental friendly practices during construction and building operations		8	(a) Implement environmental management (b) Main builder has good track records in the adoption of good environmental practices (c) Building quality under System (CONQUAS) (d) Developer, main builder, M&E consultant and architect under ISO 14000 (e) Project team comprises GMM, GMFM and GMP (f) Building user's guide with details (g) Provision of facilities of recycling bins at each block for collection and storage	Disposal of baskets, places and rooms for collection and storage of recyclable waste such as paper, glass, plastic, etc. Need for ventilation	(P) May influence fire initiation, fire and smoke spread and toxicity (S) The need for ventilation may influence compartmentalization	
	RB 3-5 Green Transport Promote environmental friendly transport		4	(a) good access to MRT/LRT or bus stops (b) covered walkway to public transport (c) electric vehicle charging points (d) covered/sheltered bike parks			
	RB 3-6 Stormwater Management Encourage the treatment of stormwater run-off before discharge to public drains		3	Provision of infiltration features			

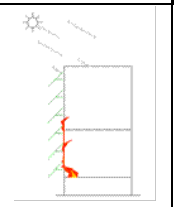
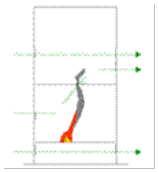
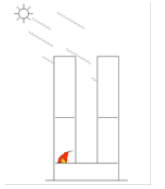
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Indoor Environmental Quality (6p. max.)	RB 4-1 Noise Level Building design to achieve ambient internal noise acceptable		1	55 db (6am-10pm) LeqA 45 db (10pm-6am) LeqA	Elastic joints are needed to connect walls and floors	(P) May influence compartmentalization fire and smoke spread	
	RB 4-2 Indoor Air Pollutants Minimize airborne contaminants to provide indoor environment		2	(a) Use of low volatile organic compounds (VOC) paints (b) Use of environmental friendly adhesives		(P) May influence toxicity	
	RB 4-3 Waste Disposal Minimize airborne contaminants from waste by locating refuse chutes or waste disposal area at open ventilation areas		1		Disposal of baskets, places and rooms for collection and storage of waste. Need for ventilation	(P) May influence fire initiation, fire and smoke spread and toxicity (S) The need for ventilation may influence compartmentalization	
	RB 4-4 Indoor Air Quality in Wet Areas Provision of adequate natural ventilation and daylighting in wet areas such as kitchens, bathrooms and toilets		2				
Other Green Features (7p. max.)	RB 5-1 Green Features and innovations Encourage the use of other green features which are innovative		7	Examples: · Pneumatic waste collection system · Carbon footprint development · Dual chute system · Self cleaning façade system · Conservation of existing building structure · Water efficient washing machines	Disposal of specific places for storage	(P) May influence fire initiation, fire and smoke spread and toxicity (S) The need for ventilation may influence compartmentalization	

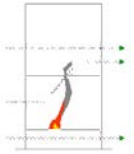
GREEN MARK (Non-Residential)

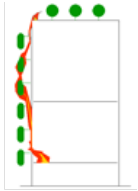
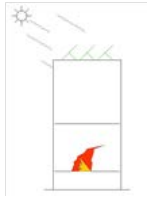
BCA Green Mark for New Non-Residential Buildings, Version RB/4.0 , 2010

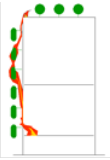
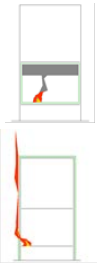
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Prerequisite Requirements	Air-Conditioned Buildings	(1) Building envelope design with Envelope Thermal Transmittance value (ETTV) computed based on the methodology stipulated in the Code		Green Mark Gold: 42 W/m2 Green Mark Platinum: 40 W/m2			
		(2) To demonstrate the stipulated energy savings over its reference model using an energy modeling framework set out		Green Mark Gold: 25% energy savings Green Mark Platinum: 30% energy savings			
		(3) Prescribed system efficiency of air-conditioning system		Prescribed system efficiency of air-conditioning system: i) For buildings using Water Cooled Chilled-Water Plant ii) For buildings using Air Cooled Chilled-Water Plant or Unitary Air-Conditioners			
		(4) Instrumentation for monitoring the water cooled chilled-water plant efficiency is to be provided					
		(5) Minimum points to be scored under NRB 3-1		Green Mark Gold ≥ 3 points Green Mark Platinum ≥ 5 points			
	Non Air-Conditioned Buildings	(1) To be eligible for Green Mark Platinum, ventilation simulation modeling					
		(2) Minimum points to be scored under NRB 3-1		Green Mark Gold ≥ 3 points Green Mark Platinum ≥ 5 points			

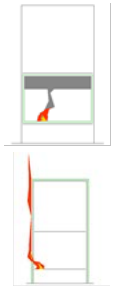
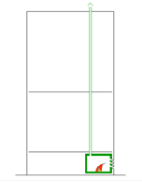
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
Energy Efficiency (116 p. max.)	NRB 1-1 Thermal performance of Building Envelope- ETTV Enhance the overall thermal performance of the building envelope to minimize heat gain thus reducing the overall cooling load requirement		12	Maximum ETTV = 50 W/m2	Increase envelope insulation	(P) Increasing insulation (diminishing ETTV value) will increase interior temperature under fire (S) Can affect compartmentalization, the structure time resistance or evacuation	
				Use sun control devices		(P) May influence fire exterior spread (S) May disturb fire brigade intervention	
	NRB 1-2 Air-Conditioning System Encourage the use of better energy efficient air-conditioned equipment to minimize energy consumption		30	(a) Water-Cooled Chilled-Water Plant (b) Air Cooled Chilled-Water Plant/Unitary Air-Conditioners			
	NRB 1-3 Building Envelope-Design/Thermal Parameter Enhance the overall thermal performance of building envelope to minimize heat gain		35	(a) Minimum direct west facing façade through building design orientation (b) (i) Minimum west facing window openings (ii) Effective sunshading provision for windows on the west façade with minimum shading of 30% (c) Better thermal transmittance (U-value) of external west facing walls (≤ 2 W/m2K) (d) Better thermal transmittance (U-value) of roof	Increase envelope insulation	(P) Increasing insulation (diminishing ETTV value) will increase interior temperature under fire (S) Can affect compartmentalization, the structure time resistance or evacuation	

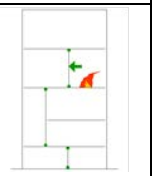
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
					Use sun control devices	(P) May influence fire exterior spread (S) May disturb fire brigade intervention	
	NRB 1-4 Natural Ventilation/Mechanical Ventilation Encourage building design that facilitates good natural ventilation Encourage energy efficient mechanical ventilation		20	(a) Natural Ventilation. (i) Proper design of building layout that utilizes prevailing wind conditions to achieve cross ventilation (ii) Use of ventilation simulation modeling and analysis or wind tunnel testing	Use of openings connecting the exterior with the interior spaces	(P) The use of natural ventilation may influence fire and smoke exterior and interior spread	
				(b) Mechanical Ventilation			
	NRB 1-5 Daylighting Encourage design that encourages effective the use of effective daylighting		6	(a) Use of daylight and glare simulation effective daylighting (b) Daylighting for the following common areas: (i) Toilets (ii) Staircases (iii) Corridors (iv) Lift Lobbies (v) Atriums (vi) Carparks	Optimize the building form for daylighting asks for less compactness	(P) Increasing the perimeter may influence fire exterior spread (S) Less compact form may increase evacuation distances	

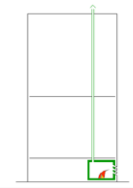
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	NRB 1-6 Artificial Lighting Encourage the use of energy efficient lighting to minimize energy consumption		12				
	NRB 1-7 Ventilation Carparks Encourage the use of energy efficient design and control of ventilation systems in car parks		4	(a) Car parks designed with natural ventilation (b) CO sensors to control mechanical ventilation		(P) The use of natural ventilation in car parks may influence fire exterior spread	
	NRB 1-8 Ventilation in Common Areas Encourage the use of energy efficient design and control of ventilation systems in the following common areas:		5	(a) Toilets (b) Staircases (c) Corridors (d) Lift lobbies (e) Atrium			
	(a) Toilets (b) Staircases (c) Corridors (d) Lift lobbies (e) Atrium		2	Lift and/or escalators with AC variable voltage and variable frequency (VVVF) motor drive and sleep mode features			

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	NRB 1-10 Energy Efficient Practices & Features Encourage the use of energy efficient practices and features which are innovative and/or have positive environmental impact		12	(a) Computation of energy consumption based on design load in the form of energy efficiency index (IEE) (b) Use of vertical greenery system on east and west façade to reduce heat gain (c) Use of energy efficient features Examples: · Heat recovery system · Sun pipes · Lifts with gearless drive · Re-generative lift · Light shelves · Photocell sensors to maximize the use of daylighting · Heat pumps etc.	Adding vertical greenery systems	(P) The use of greenery systems may influence fire initiation and fire exterior spread (S) May disturb fire brigade intervention	
	NRB 1-11 Renewable Energy Encourage the application of renewable energy sources in buildings		20		· Use of solar photovoltaic systems · Use of solar water heating equipment · Use of wind energy systems	(P) The use of these systems may influence exterior spread (S) May disturb fire brigade intervention (i.e. access to the building or smoke venting)	
Water Efficiency (17 p. max.)	NRB 2-1 Water Efficiency Fittings Encourage the use of water efficient fittings covered under the Water Efficiency Labeling Scheme (WELS)		10	(a) Basin taps and mixers (b) Flushing cistern (c) Shower taps, mixers or showerheads (d) Sink/Bib taps and mixers (e) Urinals and urinal flush valve		(P) May affect the election of fire protection systems according to water use	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	NRB 2-2 Water Usage and Leak Detection Promote the use of sub-metering and leak detection system for better control and monitoring		2	(a) Provision of private meters to monitor the major water usage such as irrigation, cooling tower and tenant's usage (b) Linking all private meters to the Building Management System (BMS) for leak detection		(P) Extending Monitoring may influence water systems complexity and increase the possibility of failure	
	NRB 2-3 Irrigation system and Landscaping Provision of suitable systems that utilize rainwater or recycled water and use of plants that require minimal irrigation to reduce potable water consumption		3	(a) Use of non potable water for irrigation (b) Use of automatic water efficient irrigation system (c) Use of drought tolerant plants to require minimal irrigation		(P) The use of drought tolerant plants may influence fire initiation and fire spread	
	NRB 2-4 Water Consumption of Cooling Towers Reduce potable water use for cooling purpose		2	(a) Use of cooling tower water treatment which can achieve 7 or better cycles of concentration at acceptable water quality (b) Use of NEWater or on-site recycled water from approved sources			
Environmental Protection (42 p. max.)	NRB 3.1 Sustainable Construction Encourage recycling and the adoption of building designs, construction practices and materials that are environmentally friendly and sustainable		10	(a) Use of Sustainable and Recycled Materials (i) Green Cements (ii) Recycled Concrete Aggregates (b) Concrete Usage Index (CUI)		(P) Environmentally friendly designs, construction practices and materials may influence combustion, fire and smoke spread and toxicity	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	NRB 3-2 Sustainable Products Promote the use of environmental friendly products that are certified and approved by local certification body and are applicable to non-structural and architectural related building components		8			(P) Environmental friendly products may influence combustion, fire and smoke spread and toxicity	
	NRB 3-3 Greenery Provision Encourage greater use of greenery, restoration of trees to reduce heat island effect		8	(a) Green Plot Ratio (b) Restoration of trees (c) Use of compost recycled from horticulture waste		(P) Greenery may influence wildfires and affect buildings close to trees concentrations	
	NRB 3-4 Environmental Management Practice Encourage the adoption of environmental friendly practices during construction and building operations		7	(a) Implement environmental management (b) Main builder has good track records in the adoption of good environmental practices (c) Building quality under System (CONQUAS) (d) Developer, main builder, M&E consultant and architect under ISO 14000 (e) Project team comprises GMM, GMFM and GMP (f) Building user's guide with details (g) Provision of facilities of recycling bins for collection and storage of different recyclable waste such as paper, glass, plastic food waste etc.	Disposal of baskets, places and rooms for collection and storage of recyclable waste such as paper, glass, plastic, etc. Need for ventilation	(P) May influence fire initiation, fire and smoke spread and toxicity (S) The need for ventilation may influence compartmentalization	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	NRB 3-5 Green Transport Promote environmental friendly transport options and facilities		4	(a) good access to MRT/LRT or bus stops (b) covered walkway to public transport (c) electric vehicle charging points (d) covered/sheltered bike parks			
	NRB 3-6 Refrigerants Reduce the potential damage to the ozone layer and the increase of global warming		2	(a) Refrigerants with ozone depletion potential (b) Use of refrigerant leak detection system			
	NRB 3-7 Stormwater Management Encourage the treatment of stormwater run-off before discharge to public drains		3	Provision of infiltration features			
Indoor Environmental Quality (8p. max.)	NRB 4-1 Thermal Comfort Air-conditioning system is designed to allow for cooling load variation due to fluctuations in ambient air		1	Indoor operative temperature between 24ºC to 26ºC Relative Humidity < 65%			
	NRB 4-2 Noise Level Occupied spaces in the buildings are designed with good ambient sound levels as recommended in SS 553, Table 8		1		Elastic joints are needed to connect walls and floors	(P) May influence compartmentalization fire and smoke spread	
	NRB 4-3 Indoor Air Pollutants Minimize airborne contaminants to provide indoor environment		2	(a) Use of low volatile organic compounds (VOC) paints (b) Use of environmental friendly adhesives		(P) May influence toxicity	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	NRB 4-4 Indoor Air Quality (IAQ) Management Ensure that the building ventilation systems are designed and installed to provide acceptable IAQ under normal operation conditions		2	(a) Provisions of filtration media and differential pressure monitoring equipment in Air Handling Units in accordance with SS 554 (b) Implement effective IAQ management plan to ensure that building ventilation systems are clean and free from residuals left over the construction activities			
	NRB 4-5 High Frequency Ballasts Improve workplace lighting quality by avoiding low frequency flicker associated with fluorescent lighting with the use of high frequency ballasts		2				
	NRB 5-1 Green Features and innovations Encourage the use of other green features which are innovative		7	Examples: · Pneumatic waste collection system · Carbon footprint development · Dual chute system · Self cleaning façade system · Conservation of existing building structure · Etc.	Disposal of specific places for storage	(P) May influence fire initiation, fire and smoke spread and toxicity (S) The need for ventilation may influence compartmentalization	

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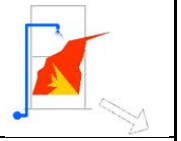
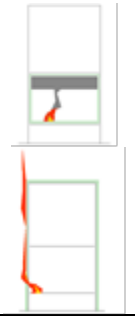
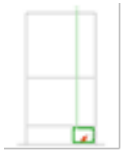
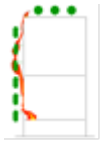
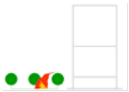
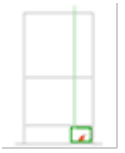
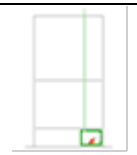
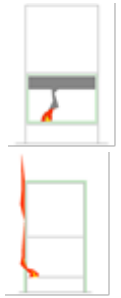
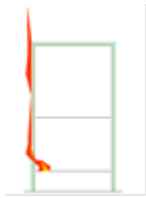
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
1-2 Administration and definitions							
3 Jurisdictional requirements and life cycle assessment	302 Jurisdictional Requirements						
	303 Whole building life cycle assessment			303.1 Whole building life cycle assessment The building project achieves not less than 20% improvement for global warming potential and at least two of the impact measures			
4 Site development and land use	401 General						
	401.2 Predesign site inventory and assessment			Inventory and assessment of the natural resources and baseline conditions of the building site	Identify areas, soils, hydrological conditions, native and invasive plants	(P) Wildfires	
	402 Preservation of Natural Resources						
	402.3 Surface water protection			Buildings and building site improvements shall not be located over around or adjacent to oceans, lakes, rivers, streams and other bodies of water that support fish, recreation or industrial use		(P) Effect of Wildfires, runoff from other locations	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	403 Stormwater Management						
	403.1 Stormwater management			403.1.1 Increased runoff Manage rainfall, retain not less than the volume of a single storm, maintain and restore natural runoff hydrology		P) Runoff after fire event not considered	
	404 Landscape Irrigation and Outdoor Fountains						
	404.1 Landscape irrigation systems			404.1.1 Water for outdoor landscape irrigation Reduce potable water use by 50%		(P) General limitations in water supply could affect its use in fire event	
	405 Management of Vegetation, Soils and Erosion Controls						
	405.1 Soil and water quality protection						
	405.2 Vegetation and soil protection			Vegetation and soil protection plan to identify protection areas and methods to proceed during the construction process	Identification, fencing	(P) Vegetation distance to buildings	
	405.3 Native plant landscaping			Not less than 75% of newly landscape area with native plant species		(P) Some native plant species may not be adequate for fire spread	
	406 Building Site Waste Management						

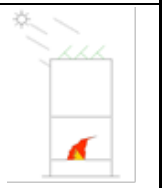
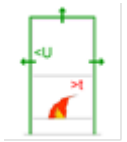
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	406.1 Building site waste management plan			To divert no less than 75% of the land-clearing debris and excavated soils	Materials can be recycled or reused for building purpose	(P) Combustible materials and toxicity	
	407 Transportation Impact						
	407.1 Walkways and bicycle paths			Independent, paved walkway or bicycle path connecting a street to a building entrance		(P) May affect evacuation	
	407.2 Changing and shower facilities			Buildings over 929 m2 and required to be provided with long-term bicycle parking and storage provided with changing room and shower facilities	New rooms and spaces	(P) Fuel Loads in changing rooms (S) Needed ventilation may affect spread	
	407.3 Bicycle parking and storage			Long-term and short-term bicycle parkings		(P) May affect evacuation	
	407.4 Preferred vehicle parking			Those in the parking facility that are located on the shortest route of travel to a building entrance			
				407.4.1 High-occupancy vehicle parking 5% of the employee parking spaces for high occupancy vehicles		(P) Fuel loads may increase	

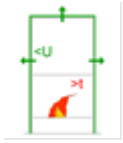
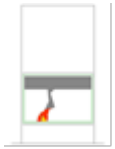
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	408 Heat Island Mitigation						
	408.2 Site Hardscape			In climate zones 1 through 6, IECC, no less than 50% of the site hardscape provided with materials with adequate solar reflectance value, shading by structures, shading by trees or pervious and permeable pavement* (*) Permitted where the use does not interfere with fire and emergency apparatus or vehicle or personnel access and egress		(P) Could affect fire spread	
	408.3 Roof Surfaces			Not less tan 75% of the roof surfaces (zones 1 through 3, *IECC*) covered with a vegetative roof		(P) Fuel loads, fire spread (S) May difficult fire services operations	
				408.3.2 Vegetative roofs Plantings selected based on their hardiness zone classifications Nonvegetated clearances in accordance with the IFC			
	409 Site Lighting						
	409.1 Light pollution control			When applicable, uplight, light trespass and glare shall be limited for exterior lighting		(P) Fire Services intervention at night could be affected	
5 Material Resource conservation and efficiency	501 General						
	502 Construction Material Management						

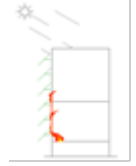
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	502.1 Construction material management			Materials stored and handled during construction shall comply with manufacturer's printed instructions, controlling moisture of porous and fibrous materials		(P) Storage and handling according to manufacturer's instructions may be contradictory with fire initiation and spread (i.e. vertical storage, covered…)	
	503 Construction Waste Management						
	503.1 Construction material and waste management plan			Not less than 50% of nonhazardous construction waste shall be diverted			
	504 Waste Management and Recycling						
	504.1 Recycling areas for waste generated post certificate of occupancy			Waste recycling areas shall be provided in accordance with jurisdiction's regulations, or to accommodate recyclable materials based on the availability of recycling services, or in accordance with an approved design	Specific rooms or closed areas	(P) Important and diverse fuel loads (S) Needed ventilation may affect spread	
	504.2 Storage of lamps, batteries and electronics			Storage space	Specific rooms, perhaps sharing space with or close to recycling areas	(P) Fuel loads, toxicity	
	505 Material Selection						

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	505.1 Material selection and properties			Building materials shall conform to section 505.2 (with some exceptions). Not if a life whole cycle assessment is performed			
	505.2 Material selection			No less than 55% shall comply with: 505.2.1 Used materials and components 505.2.2 Recycled content building materials 505.2.3 Recyclable building materials and building components 505.2.4 Bio-based materials 505.2.5 Indigenous materials		(P) Fire reaction and toxicity	
	506 Lamps						
	507 Building Envelope Moisture Control						
	507.1 Moisture control preventive measures			Moisture preventive measures, including Foundation drainage ,waterproofing and dampproofing, under slab water vapour protection, exterior wall coverings and roof coverings, drainage and flashings		(P) Dryer materials (i.e.insulations) air chambers (i.e. double facades) and spaces help fire spread.	
6 Energy Conservation, efficiency and CO2 emission reduction	601 General						
	601.3.1 Performance-based compliance						
	601.3.2 Prescriptive-based compliance						

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	602 Modeled Performance Pathway Requirements						
	602.1 Performance-based compliance			Source energy (kBtu/sf-y), CO2e 602.1.1 zEPI zEPI≤51 zEPI = 57 x (EUIp/EUI)			
	602. 2 Annual direct and indirect CO2*e* emissions			CO2epd ≥ (zEPI x CO2e srbd) / 57 602.2.1 Onsite electricity 602.2.2 Onsite renewal energy 602.2.3 Annual direct and indirect CO2e emissions associated with onsite use of fossil fuels and purchased district energy			
	603 Energy Metering, Monitoring and Reporting			Energy distribution systems designed such that each primary circuit, panel, feeder, piping system or supply mechanism supplies only one energy use type 603.2.1 HVAC system total energy use 603.2.2 Lighting system total energy use 603.2.3 Plug loads 603.2.4 Process loads 603.2.5 Energy used for building operations loads and other miscellaneous loads	Systems diversification	(P) Could affect safety (i.e. systems compatibility)	

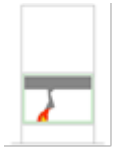
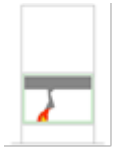
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	604 Automated Demand-response (Auto-DR)			603.3.7 Renewable and waste energy Capable of being metered	Systems diversification	(P) May present difficulties under a fire event (i.e. solar electric continues operating)	
	604.1 Establishing an open and interoperative automated demand-response (AUTO-DR)			Where indicated, buildings that contain heating, ventilating, air-conditioning (HVAC) or lighting systems, an energy management and control system (EMCS) shall be provided and integrated	Systems complexity	(P) May present difficulties	
	605 Building Envelope Systems						
	605.1 Prescriptive compliance			605.1.1 Insulation and fenestration criteria Exceed the International Energy Conservation Code by no less than 10%	Decrease U (W/m2ºK)	(P) Interior temperature increases if compared to previous insulation requirements as low transmittance doesn't allow heat dissipation	
				605.1.1.1 Permanent shading devices for fenestration Vertical fenestration within 45 degrees of the nearest west, south, and east cardinal ordinate shall be shaded by permanent horizontal exterior projections	Permanent elements on the façade	(P) Exterior spread (S) May affects Fire Services intervention	

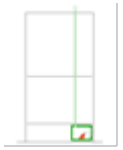
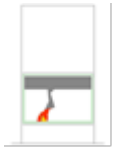
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
				605.1.2 Air leakage The building thermal envelope shall be durably sealed to limit air leakage	Sealing	(P) Interior temperature, less O2	
	605.2 Roof replacement			605.2 Roof replacement Above-deck insulation in accordance with 1003.2.7	Decrease U (W/m2ºK)	(P) Interior temperature	
	606 Building Mechanical Systems						
	606.1 Prescriptive compliance			Building mechanical systems shall comply with IECC and the provisions of the section			
	606.3 Duct and plenum insulation, sealing and testing			Supply and return shall be insulated and sealed		(P) May condition fires in concealed spaces, temperatures, O2 presence	
	606.4 Heating, ventilating and air-conditioning (HVAC) piping insulation			Piping shall be thermally insulated		(P) Insulation materials	
	606.5 Economizers						
	607 Building Service Water Heating Systems						
	608 Building Electrical Power and Lighting Systems						

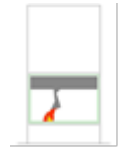
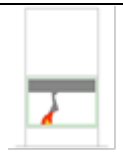
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	608.4 Exterior lighting control			608.4.1 Exterior light reduction Total exterior lighting power is automatically reduced by no less than 30% within 2 hours after facility operations conclude		(P) May influence Fire Services operations at night	
	609 Specific Appliances and Equipment						
	609.2 Permanent appliances and equipment			609.2.1 Elevators 609.2.1.4 Standby mode When the elevator is stopped, not occupied, and with doors closed, lighting, ventilation, and cab displays shall be capable of being de-energized within 5 minutes of stopping, and re-energized prior to opening the doors			
	610 Building Renewable Energy Systems						
	610.2 Solar photovoltaic systems			To provide not less than 2 % of the total estimated annual electric energy consumption	Installed on roofs or integrated on facades and other architectural elements	(P) May influence exterior spread	
	610.3 Wind energy systems			To provide not less than 2% of the total estimated annual electric energy consumption			
	610.4 Solar water heating equipment			To provide not less than 10% of the building's annual estimated hot water energy usage	Installed on roofs or integrated on facades and other architectural elements	(P) May influence exterior spread	

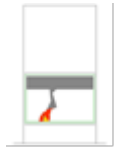
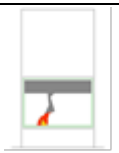
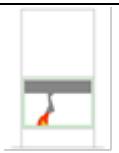
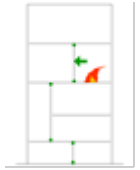
Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	611 Energy Systems Commissioning and Completion						
7 Water Resource conservation, quality and efficiency	701 General			701.1 Scope Establish the means of conserving water, protecting water quality and providing for safe water consumption		(P) No requirement is established for water use in a fire event	
	702 Fixtures, Fittings, Equipments and Appliances						
	703 HVAC Systems and Equipment						
	704 Water Treatment Devices and Equipment						
	705 Metering						
	705.1 Meterning			Water consumed from any source associated with the building or building site shall be metered	Water for Fire suppression purposes not considered in Table 705.1.1		
	706 Nonpotable Water Requirements						

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	706.3 Water Quality			Nonpotable water for each end use application shall meet the minimum water quality requirements as established for the application by the laws	Water for Fire suppression purposes not considered		
	707 Rainwater Collection and Distribution Systems						
	707.5 Rainwater collected for landscape irrigation			Shall not be limited regarding the method of application			
	705.15 Potable water application			When it is to be used for potable water applications, all materials contacting the water shall comply with NSF 61			
	708 Gray Water Systems						
	709 Reclaimed Water Systems						
	710 Alternative Onsite Nonpotable Water Sources						
8 Indoor environmental quality and comfort	801 General						
	801.2 Indoor air quality management plan required			An indoor air quality management plan shall be developed			

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	802 Building Construction Features, Operation and Maintenance Facilitation						
	802.2 Air-handling system access			System components shall allow access for cleaning and repair. Access ports shall be installed in the air-handling system to permit such cleaning and repair	Access Ports	(P) Fire and Smoke spread	
	802.3 Air-handling system filters			Filter racks shall be designed. Access doors and panels provided for filter replacement shall be fitted with flexible seals		(P) Fire and Smoke spread	
	803 HVAC Systems						
	803.1 Construction phase requirements						
	803.1.1 Duct openings			Duct and other openings shall be covered with tape, plastic, sheet metal or shall be closed by an approved method		(P) Fire and Smoke spread	
	803.2 Thermal environmental conditions for human occupancy			Buildings designed in compliance with ASHRAE 55			

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	803.3 Environmental tobacco smoke control			Smoking shall not be allowed inside buildings. Exterior smoking areas located not less than 25 ft (7.5 m) away from building entrances, outdoor intakes and operable windows	Independent rooms	(P) May influence Interior Spread	
	803.4 Isolation of pollutant sources			803.4.1 Printer, copier and janitorial rooms Enclosed rooms over 100 sf (9.3 m2) where the use or storage of chemicals occurs, the enclosing walls shall extend from the floor surface to the underside of the floor, constructed as required for 1-hour fire resistance-rated construction assemblies, doors shall be self-closing and an HVAC system shall be provided			
	804 Specific Indoor Air Quality and Pollutant Control Measures						
	804.1 Fireplaces and appliances			Shall comply with 804.1.1 Venting and combustion air Shall be vented to the outdoors and shall be provided with combustion air provided from the outdoors 804.1.2 Wood-fired appliances Labeled in accordance with EPA 804.1.3 Biomass appliances Labeled in accordance with ASTM		(P) May influence combustion, Fire and Smoke Spread	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	804.2 Post-construction, preoccupancy baseline IAQ testing			The building tested for indoor quality			
	805 Prohibited Materials						
	805.1 Scope			Asbestos-containing materials and Urea-formaldehyde foam insulation shall be prohibited			
	806 Material Emissions and Pollutant Control						
	806.1 Emissions from composite wood products			Composite wood products used interior to approved weather covering of the building shall comply with emission limits or be manufactured in accordance with the standards		(P) Toxicity needs to be checked	
	806.2 Adhesives and sealants			A minimum of 85% by weight or volume, of specific categories of site-applied adhesives and sealants used on the interior side of the building envelope shall comply with the VOC content limits		(P) Toxicity	
	806.3 Architectural paints and coatings					(P) Toxicity	

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	806.4 Flooring					(P) Toxicity	
	806.5 Acoustical ceiling tiles and systems					(P) Toxicity	
	806.6 Insulation					(P) Toxicity	
	807 Acoustics						
	807.1 Sound transmission and sound levels			Where required, buildings and tenant spaces shall comply with the minimum sound transmission class and maximum sound level requirements			
	807.4 Structure-borne sounds			Floor and ceiling assemblies between dwelling rooms or dwelling units and between dwelling rooms or dwelling units and public or service areas within the structure in some occupancies shall have an impact insulation classification (IIC)		(P) May influence Interior Spread	
	808 Daylighting						

Categories / Chapter	Section / Assessment Issues	Aims	Credits / Scores	Requirements / Criteria	Procedures	Fire Hazard Primary (P) & Secondary (S)	Summary
	808.1 General			Fenestration shall be provided in building roofs and walls		(P) May influence Exterior Spread, O2	
	808.2 Applicability						
	808.3 Daylit area of building spaces			In buildings not greater than two stories above grade, not less than 50% of the net floor area shall be located within a daylit area. In buildings, thre or more stories above grade, not less than 25% of the net floor area shall be located within daylit area. 808.3.1 Daylit prescriptive requirements- The total daylight area shall be the sum of the area of all sidelighting daylight zones and the area of all toplighting zones	Influences the building shape	(P) May influence Exterior Spread	
9 Commissioning, operation and maintenance	901 General						
	902 Approved Agency						
	903 Commissioning						
	904 Building Operations and Maintenance						
10 Existing Buildings							
11 Existing building site development							
12 Referenced standards							

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11Existing building site development							
12 Referenced standards							