Evaluation of the Construction Research Centre: Climate resilience initiatives and the fire safety unit

May 28, 2026



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Initialisms and abbreviations

AI	Artificial intelligence
CLT	Cross-laminated timber
EMTC	Encapsulated mass timber construction
FNNBOA	First Nations National Building Officers Association
FTE	Full-time equivalent
FWCI	Field-weighted citation impact
FY	Fiscal year
HICC	Housing, Infrastructure and Communities Canada
MOU	Memorandum of understanding
NAS	National Adaptation Strategy
NRCan	Natural Resources Canada
NRC	National Research Council of Canada
NSERC	Natural Sciences and Engineering Research Canada
OAE	Office of Audit and Evaluation
OGD	Other government department
R&D	Research and development
WUI	Wildland-urban interface

Introduction

The evaluation of the National Research Council of Canada's (NRC) Construction Research Centre focused on 2 elements of the research centre:

1. **The climate resilience initiatives**
    - Climate-Resilient Building and Core Public Infrastructure Initiative from fiscal year (FY) 2016–17 to 2020–21
    - Climate Resilient Built Environment Initiative from FY 2021–22 to 2024–25
2. **The fire safety unit** from FY 2019–20 to 2024–25

The evaluation was conducted in FY 2025–26 in accordance with the NRC's Departmental Evaluation Plan and the Treasury Board of Canada's Policy on Results. This was the first evaluation of the climate resilience initiatives and the fire safety unit. The last evaluation of the Construction Research Centre, conducted in FY 2020–21, focused on the NRC's Codes Canada.

This report presents a profile of both elements, followed by findings on relevance, organizational capacity and effectiveness. It concludes with recommendations for improvement.

The report uses icons to highlight specific types of information:



Indicates information that helps readers understand the findings.



Indicates a quote that illustrates or supports the main findings.

Evaluation approach

The NRC's Office of Audit and Evaluation led the evaluation. A mixed methods approach incorporated quantitative and qualitative data from multiple sources, including document and data review, stakeholder surveys, internal and external interviews, and a peer review of the fire safety unit.

The evaluation examined the following evaluation questions:

1. **Relevance**: Are the roles and priorities of the climate resilience initiatives and the fire safety unit clear and appropriate?
2. **Organizational capacity**: Do the climate resilience initiatives and the fire safety unit have the facilities, capabilities and capacity to achieve their objectives?
3. **Effectiveness**: To what extent did the climate resilience initiatives and the fire safety unit achieve their intended outputs, outcomes and impacts, including support for business innovation?



Appendix A details the evaluation methodology and lists peer review committee members. Appendix B outlines the limitations and mitigation strategies.

Profile

The NRC's Construction Research Centre supports the development and deployment of new construction technologies and provides expertise to other sectors, including aerospace, transportation, and information and communications technology. The research centre includes 6 research and development (R&D) units (refer to Figure 1).

The **climate resilience initiatives** are housed within the built environment climate change initiatives R&D resource unit. This unit includes the Canadian Construction Materials Centre, the Canadian National Master Construction Specification and the Construction Research Centre's Business Development team.

The **fire safety unit** was originally a distinct unit within the Construction Research Centre. Following a reorganization in September 2023, this unit merged with the Industrialized and Digitalized Construction team and the Building Technology Optimization team to form the advanced construction practice and fire safety unit.

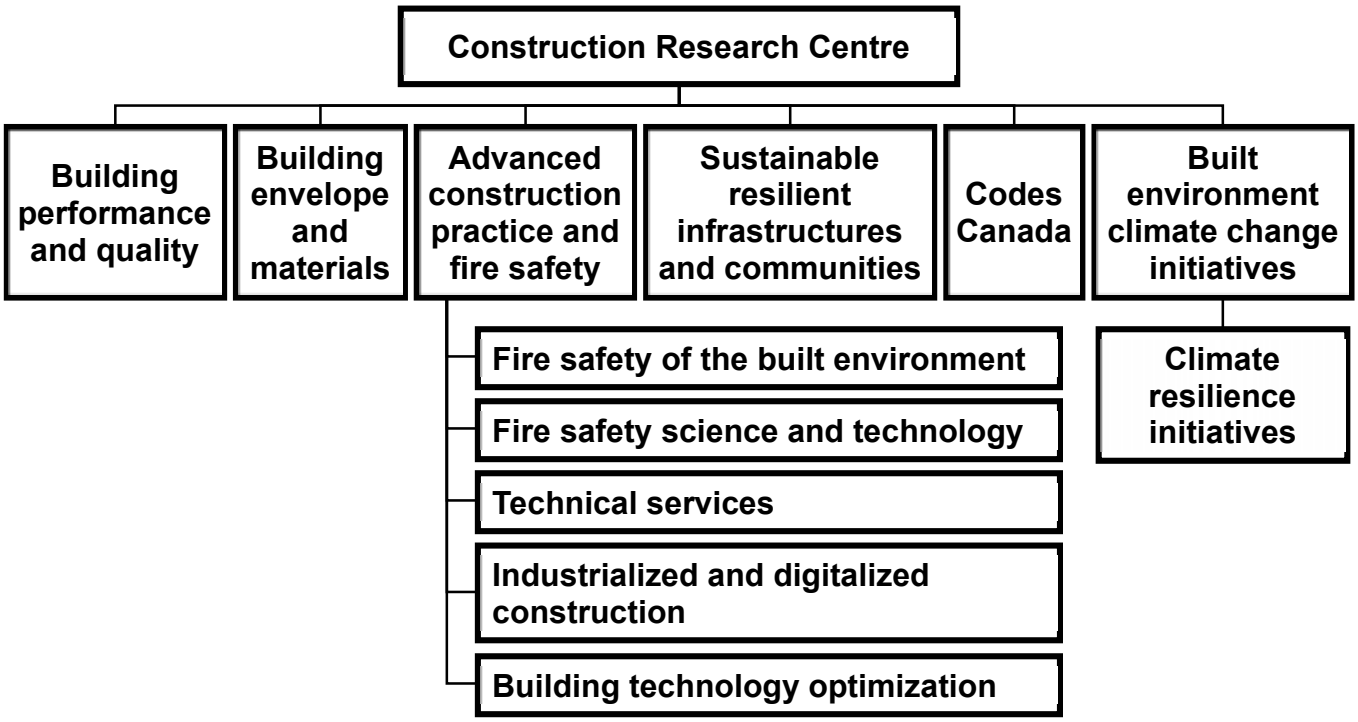


This evaluation focuses on the 3 teams that comprised the fire safety unit prior to the reorganization and that continue to conduct fire safety research and testing:

- Fire safety of the built environment
- Fire safety science and technology
- Technical services

For simplicity, these teams are referred to as the **fire safety unit** throughout this report.

Figure 1. Construction Research Centre organizational structure



Sources: Construction Research Centre Strategic Plan 2024–2029 and Fire Safety Strategic Plan 2024–2029

Canadian regulatory framework

Both the climate resilience initiatives and the fire safety unit support the Canadian regulatory framework, which includes:

Regulations

Regulations are specific rules that are primarily managed at the provincial or territorial level, with the federal government playing an indirect role through the development of National Model Codes that inform provincial and territorial regulations. Together, these regulations establish minimum standards for safety, health, accessibility and environmental performance in new construction, renovations and infrastructure projects. Regulatory mechanisms include instruments such as zoning bylaws, professional certification requirements and the Impact Assessment Act.

National Model Codes

National Model Codes set minimum technical requirements for health, safety, accessibility, protection of buildings from fire or structural damage and environmental protection. They become regulations once adopted by provincial and territorial governments. The current codes include:

- National Building Code of Canada
- National Fire Code of Canada
- National Plumbing Code of Canada
- National Energy Code of Canada for Buildings
- National Farm Building Code of Canada

The NRC plays a central role in their development. An NRC representative serves as a permanent member and co-chair of the Canadian Board for Harmonized Construction Codes (CBHCC), which develops the National Model Codes. NRC researchers also participate on code development committees and task groups, providing scientific and technical expertise to support proposed code changes. Through Codes Canada, the NRC serves as the secretariat for CBHCC, providing technical, policy and administrative support, including publishing the codes.

Standards

Standards provide a uniform method to assess performance or install, use or maintain a material, product or system. They are established through expert consensus and approved by a recognized body. Standards may be voluntary or mandatory when referenced in National Model Codes.

The NRC contributes science-based research and participates as subject matter experts on technical committees to support standards development.

Specifications

Specifications detail requirements for products, materials and services used in construction projects. They can become regulations if formally adopted, referenced or incorporated into law.

The NRC develops, maintains and publishes the Canadian National Master Construction Specification, which provides model design and construction specifications for buildings and infrastructure.

National guides

National guides are voluntary technical documents that offer evidence-based recommendations to inform decision making. The NRC develops and publishes these guides in collaboration with national and international experts.

Climate resilience initiatives

The climate resilience initiatives include the **Climate-Resilient Building and Core Public Infrastructure Initiative** and the subsequent **Climate Resilient Built Environment Initiative**. Led by the Construction Research Centre, these initiatives support the Government of Canada's climate resilience objectives by providing guidance, tools and standards to improve the durability and climate readiness of buildings and infrastructure, including bridges, roads, water and wastewater systems, and transit.

Climate-Resilient Building and Core Public Infrastructure Initiative

Launched under the Government of Canada's 2016 Pan-Canadian Framework on Clean Growth and Climate Change, the Climate-Resilient Building and Core Public Infrastructure Initiative received $42.5 million over 5 years from Infrastructure Canada, renamed Housing, Infrastructure and Communities Canada (HICC) in 2024, to provide knowledge that integrates climate resilience into building and infrastructure design, guides, standards and codes (refer to **Error! Reference source not found.**).

Table 1. Funding for the Climate-Resilient Building and Core Public Infrastructure Initiative, FY 2016–17 to 2020–21 (millions of dollars)

Fiscal year	Funding*
2016–17	$4.0
2017–18	$11.5
2018–19	$9.5
2019–20	$9.0
2020–21	$8.6
Total	**$42.6**

Source: Finance data, memorandum of understanding (2016) and amendment to the memorandum of understanding (2018)

Infrastructure Canada selected the NRC to undertake this initiative based on its mandate under the *National Research Council Act*, its role as secretariat for the National Model Codes, its

* Figures are rounded to the nearest tenth of a million dollars, which may result in minor discrepancies.

management of the Canadian National Master Construction Specification, its operation of the Canadian Construction Materials Centre and its extensive civil engineering and building R&D expertise.

Climate Resilient Built Environment Initiative

The Climate Resilient Built Environment Initiative builds on the research and tools generated through the previous initiative. This 5-year, $35 million initiative funded by HICC (refer to table 2), expands and mobilizes climate resilience knowledge and builds capacity across Canada's construction sector.

Table 2. Funding for the Climate Resilient Built Environment Initiative, FY 2021–22 to 2025–26 (millions of dollars)

Fiscal year	**Funding**Error! Bookmark not defined.
2021–22	$7.0
2022–23	$7.0
2023–24	$7.0
2024–25	$7.0
2025–26	$7.0
Total	**$35.0**

Sources: Finance data, memorandum of understanding (2021)

In December 2023, the initiative received an additional $30.million over 5 years under Canada's National Adaptation Strategy (NAS), bringing total funding to $65.1 million (refer to table 3). This additional funding was intended to accelerate work on climate-informed building and infrastructure codes and technical solutions and to broaden the initiative's scope to include residential retrofits, additional flood data and asset management tools.

Table 3. Funding for the Climate Resilient Built Environment Initiative–National Adaptation Strategy, FY 2023–24 to 2027–28 (millions of dollars)

Fiscal year	**Funding**Error! Bookmark not defined.
2023–24	$6.4
2024–25	$6.4
2025–26	$6.3
2026–27	$5.5
2027–28	$5.5
Total	**$30.1**

Sources: Finance data, memorandum of understanding (2023)

Note: Note: Of the total $30.1 million, $10.2 million was allocated to the NRC's Ocean, Coastal and River Engineering Research Centre, $0.8 million to the Automotive and Surface Transportation Research Centre and $1.3 million to the Aerospace Research Centre.

Fire safety unit

The fire safety unit conducts strategic research and provides scientific and technical services to support the Canadian regulatory framework, enable industry to develop and de-risk products and technologies and enhance fire safety in the Canadian built environment. The unit is composed of 3 teams:

1. **Fire safety of the built environment**: Develops tools and methods that support a shift from prescriptive to performance-based codes,† which emphasize achieving specific building outcomes, such as fire resistance or energy efficiency, rather than following fixed construction methods. The team advances low-carbon, fire-safe materials and solutions and, with funding from the NRC's climate resilience initiatives, assesses fire risks in the wildland–urban interface (WUI) and the effects of climate change on fire behaviour.
2. **Fire safety science and technology**: De-risks new technologies, including low-carbon materials, energy systems and lithium-ion batteries, by developing fire protection technologies, test methods, fire risk assessments and hazard mitigation strategies. The team also integrates building information modelling into fire safety and develops digital tools to assess fire risks in low-carbon buildings and fire protection systems.
3. **Technical services**: Provides specialized technical services, including fire testing, welding and fabrication, instrumentation, programming and calibration, chemistry support, off-site fire testing demonstrations and data and report preparation.

The fire safety unit conducts research across 3 core R&D areas:

1. **Resilience and adaptation to large outdoor and asset fires**: Focuses on reducing loss of life and property and improving community resilience to major outdoor and infrastructure fires, including wildfire, bridge, tunnel, hazardous material and transportation fires.
2. **Fire safety technologies for sustainability and innovation**: Advances sustainable technologies and integrates fire-safe solutions into innovative building materials and systems to enhance the competitiveness of Canada's construction industry.
3. **Application of digital and computational technologies in fire safety**: Leverages digital tools and computational methods to increase efficiency, reduce costs and strengthen fire safety across the Canadian construction sector.

† A performance-based code establishes minimum performance requirements for buildings and building elements, rather than prescribing specific materials or construction methods. Emphasizing outcomes such as energy efficiency, fire safety and structural stability, it supports innovation, flexibility and cost-effective, tailored solutions compared with traditional prescriptive codes. Source: Construction Law Made Easy (2026). What is the performance-based Building Code?

Over the last 6 years, the fire safety unit averaged annual expenditures of $4.6 million (refer to **Table** 4). The unit received an average annual budget of $4.8 million and generated an average of $0.5 million per year in revenues. Expenditures increased significantly in FY 2023–24, when the unit began contributing to the Construction Research Centre's Platform to Decarbonize the Construction Sector at Scale.

Table 4. Fire safety unit financial profile by fiscal year (millions of dollars)‡

Category	2019–20	2020–21	2021–22	2022–23	2023–24	2024–25
Budget	$3.2	$3.4	$3.6	$4.2	$6.0	$8.6
Earned revenue	$0.5	$0.2	$0.6	$0.5	$0.4	$0.5
Expenditures	$3.3	$3.3	$3.5	$3.8	$5.4	$8.4

Sources: Finance data and human resource data from FY 2019–20 to 2024–25

‡ Figures are rounded to the nearest tenth of a million dollars, which may result in minor discrepancies in values.

1 Relevance

Climate resilience initiatives

The climate resilience initiatives align with federal roles and national strategies. The NRC provides national coordination and leadership in climate resilient buildings and infrastructure research. The NRC is recognized nationally and internationally as a leader in this field.

The initiatives' research projects effectively respond to current research needs and advance Canada's broader climate adaptation priorities. Experts and stakeholders identified knowledge mobilization as a key priority moving forward.

1.1 Alignment with federal roles

The climate resilience initiatives align with the federal mandate for climate adaptation in buildings and infrastructure and complement other federal climate adaptation activities. The NRC helps to align efforts across departments and sectors to support a coordinated approach to advancing research on climate resilient buildings and infrastructure.

Federal roles in climate adaptation for buildings and infrastructure

In Canada, climate adaptation for buildings and infrastructure is a shared responsibility among all levels of government. The federal government provides national leadership and support, while provinces and territories adopt and enforce building codes and municipalities regulate and manage local buildings and infrastructure.

The federal government's role in climate adaptation for buildings and infrastructure includes:

1. **National strategies**: Setting national climate strategies such as the Pan-Canadian Framework on Clean Growth and Climate Change and Canada's National Adaptation Strategy to provide national leadership on climate change
2. **National Model Codes**: Contributing to the development of the codes and acting as secretariat to the Canadian Board for Harmonized Construction Codes (CBHCC)
3. **Research and data**: Funding, generating and disseminating climate research and data to inform technical guidance, standards and codes, while enabling industry to meet growing demand for products and services that enhance climate resilience
4. **Federal assets**: Designing, maintaining and managing federal buildings, infrastructure and facilities to withstand climate change

The NRC's climate resilience initiatives align with these federal roles by advancing national strategies, informing the development of the National Model Codes, producing research and data and providing guidance for climate resilient federal buildings and infrastructure. NRC staff and representatives from other government departments (OGDs) consistently noted that these initiatives contribute directly to national strategies and support the federal mandate for buildings and infrastructure, including Housing, Infrastructure and Communities Canada's (HICC) mandate.

Several OGDs contribute to climate resilience in buildings and infrastructure by providing funding, conducting research or performing regulatory activities that complement the NRC's climate resilience initiatives, including:

1. **Defence Research and Development Canada**: Supports climate adaptation in defence infrastructure and bases
2. **Housing, Infrastructure and Communities Canada (HICC)**: Supports climate resilient design through the NRC's climate resilience initiatives and leads the infrastructure component of Canada's National Adaptation Strategy
3. **Indigenous Services Canada**: Funds and supports climate resilient infrastructure in First Nations, Inuit and Métis communities
4. **Natural Resources Canada (NRCan)**: Conducts climate research, funds adaptation projects in the natural resource sectors (forestry, mining and energy) and provides environmental data and analysis
5. **Standards Council of Canada**: Collaborates with the climate resilience initiatives to develop and update climate resilience standards and leads the Standards to Support Resilience in Infrastructure Program
6. **Transport Canada**: Assesses climate risks in transportation and rail infrastructure and funds related adaptation initiatives

Collectively, these contributions demonstrate the breadth of federal climate adaptation efforts and underscore the importance of coordination and leadership to support alignment and avoid duplication. The NRC plays a central coordinating role for research through its climate resilience initiatives, which have established advisory boards for each major research area, including climate data, coastal flood risk and bridges. These boards bring together representatives from government, academia, professional associations and industry to align efforts, exchange knowledge, identify gaps and focus research priorities.



> "Without the NRC's leadership, climate efforts would remain fragmented rather than integrated into a consistent, national framework."
>
> —External stakeholder

The NRC is well positioned to undertake climate resilience initiatives given its role in coordinating, informing and publishing Canada's National Model Codes and its recognized

expertise in building science. Nearly all surveyed stakeholders (98%) and staff agreed that the NRC is the appropriate organization to undertake this work.

1.2 Strategic direction

The climate resilience initiatives addressed knowledge gaps and research needs and established a targeted research program that supports climate adaptation priorities. The NRC is recognized nationally and internationally as a leader in climate resilient buildings and infrastructure. Experts and stakeholders identified knowledge mobilization as a top priority moving forward.

The direction of the climate resilience initiatives was guided by 3 memoranda of understanding (MOUs) with HICC signed in 2016, 2021 and 2023, and by an assessment of knowledge gaps and research needs (PDF) completed during the first 6 months of the Climate-Resilient Building and Core Public Infrastructure Initiative. This approach established a research program focused on climate data, flood adaptation, resilient buildings, bridges, roads, transit, water and wastewater systems, remote communities and environmental life-cycle assessments. The Climate Resilient Built Environment Initiative expanded the scope to address additional gaps and stakeholder needs, including resilient dams, nature-based solutions, residential retrofits and asset management tools. Surveyed stakeholders generally supported this focus and a majority (63%) viewed the initiative's research as highly distinct within the Canadian climate adaptation landscape.

Experts, staff and stakeholders viewed the NRC as a national and international leader in climate resilient buildings and infrastructure. They identified advanced research, regulatory influence, extensive collaborations, international partnerships and active participation in international consortia and standards development as key factors supporting this leadership. The engagement of the NRC in this area is reflected in the NRC's participation in more than 100 national and international conferences, including the 2023 International Conference on Civil, Structural and Transportation Engineering and the 2025 American Meteorological Society Annual Meeting.

Looking ahead, climate experts and stakeholders identified knowledge mobilization as a top priority for the climate-resilience initiatives. They emphasized the need to translate large volumes of technical research and guidance into clear, practical advice and training where appropriate. This information should target specific types of end-users, including professional associations, municipalities, industry sectors and the general public. Experts and stakeholders also advised incorporating evidence on the economic and financial benefits of adopting climate resilience practices to increase adoption.

Experts also identified potential areas for further NRC research, including:

- Assessing climate change impacts on system-level vulnerabilities and interdependencies across critical infrastructure, such as electrical, technology and telecommunications
- Examining compounding and cascading hazards associated with climate change, such as extreme heat triggering wildfires, drought and power outages

1.3 Project selection and planning

The climate-resilience initiatives have undertaken a substantial number of projects across a broad range of topics. Project selection aligns well with the initiatives' strategic direction. Earlier engagement of end-users could further enhance the practical relevance of projects and increase uptake of resulting guidance.

The scope and volume of work undertaken through the climate resilience initiatives have been substantial. Over 5 years, the Climate-Resilient Building and Core Public Infrastructure Initiative completed 43 projects across multiple research areas, with a strong emphasis on contributing to standards, specifications and codes. The Climate Resilient Built Environment Initiative is on track to complete 63 projects, with an additional 18 supported through National Adaptation Strategy (NAS) funding. This initiative includes an increased focus on technical solutions, resilient residential retrofits and flooding (refer to Table 5). The distribution of projects shows an evolution in priorities over time, with growing emphasis on applied research areas such as flooding, nature-based solutions and residential retrofits.

Table 5. Projects counts by thrust across initiatives

Project thrust	Climate-Resilient Building and Core Public Infrastructure	Climate Resilient Built Environment	Climate Resilient Built Environment–NAS	Total	Total %
Standards, specifications and codes	24	12	8	**44**	35%
Tools	10	11	2	**23**	19%
Technical solutions	4	10	1	**15**	12%
Resilient residential retrofit	0	5	6	**11**	9%
Flooding	0	10	1	**11**	9%
Nature-based solutions	2	8	0	**10**	8%
Guidance	3	7	0	**10**	8%
Total	**43**	**63**	**18**	**124**	**100%**

Source: Project data from FY 2016–17 to 2024–25

Projects were selected based on alignment with the initiatives' strategic direction, available expertise and resources, collaboration opportunities and anticipated impacts. All surveyed stakeholders confirmed that the initiatives' direction and project selection align with current research needs and Canada's broader climate adaptation priorities.

Some staff and stakeholders suggested that earlier engagement of end-users in projects, such as design professionals, municipalities and Indigenous communities, could further enhance the practical relevance of the projects, increase adoption of research-based guidance and broaden awareness of the initiatives.

Fire safety unit

The fire safety unit aligns with federal roles and national priorities and is unique in Canada. The unit is recognized as a national leader in fire safety research, with global expertise in fire-safe mass timber and wildland–urban interface (WUI) fires.

Moving forward, the unit could balance its short-term technical services with more strategic, longer-term research. Increased stakeholder input could further enhance project relevance and support both immediate and future fire safety needs.

1.4 Alignment with federal roles

The fire safety unit aligns with federal roles and national priorities and complements fire safety activities undertaken by other federal departments. Its placement within the NRC is well suited to support the unit's role of providing impartial scientific evidence and access to expertise across other research centres.

Federal roles in fire safety for the built environment

In Canada, fire safety in the built environment[1] is mainly the responsibility of provinces, territories and municipalities. Provinces and territories establish the legal framework and regulations for fire safety, while municipalities enforce regulations and provide fire protection services. The federal government plays an essential supportive role in advancing fire safety in the built environment through research and guidance, which informs the National Model Codes.

The fire safety unit aligns with these federal roles by supporting the development of the National Model Codes, advancing research and producing technical guidance to enhance fire safety in the built environment, including guidance applying to infrastructure beyond buildings.

Several federal organizations, including departments, agencies and other entities, fund or conduct fire testing and limited fire safety research in support of their respective mandates. Excluding the NRC, 10 organizations contribute to fire safety in the built environment and 14 engage in wildfire-related research and initiatives.

Key areas of complementarity between the fire safety unit and OGDs include:

- **Wildfire research and resources**: Natural Resources Canada (NRCan) and the fire safety unit both conduct wildfire-related research. NRCan focuses on wildland fire control, while the fire safety unit emphasizes structural resilience in the WUI. Coordination to avoid duplication occurs through technical committees and regular senior-level discussions.
- **Fire safety engineering research**: Natural Sciences and Engineering Research Canada (NSERC) funds academic research on fire safety engineering and engineered wood, including on forest resilience, fire-prediction models and wood-based building systems. The fire safety unit supports select NSERC-funded projects, such as those at Carleton University's Ember Fire Group, by providing expertise and testing facilities.
- **Innovative wood products**: NRCan funds research and commercialization of wood building products through programs such as the Green Construction Through Wood program, with product testing often conducted at NRC's fire safety facilities. The fire safety unit supports these efforts by conducting fire testing and performance research that informs safety standards and advances the development of innovative wood construction materials and methods.

The peer review committee, stakeholders and fire safety staff agreed that the fire safety unit plays a critical national role. It aligns with federal roles and supports federal priorities such as modular construction, fire-safe affordable housing and climate adaptation. The unit's placement within the NRC supports the development of impartial, evidence-based guidance and provides access to complementary expertise across NRC research centres, such as the Automotive and Surface Transportation Research Centre and the Clean Energy Innovation Research Centre.

The majority of surveyed stakeholders (92%) support the NRC's continued involvement, citing its technical expertise and objectivity. In addition, 62% view its research and technical services as highly distinct within Canada, while the remainder consider them somewhat distinct. This distinction reflects the NRC's unique national role, as no OGDs have the technical expertise or capacity to conduct scientific fire safety research that informs the development of the National Model Codes.



"The work of the NRC is critical. We need the guidance and advice from fire protection experts to define guidelines, thresholds for protection, and to work with industry for consensus-based approaches."

—External stakeholder

1.5 Strategic direction

The fire safety unit advances the Construction Research Centre's goals, supports NRC priorities and aligns with current fire safety needs. The unit is recognized as Canada's leader in fire safety research in the built environment and as a global leader in fire-safe mass timber and WUI fires. Stakeholders also identified emerging fire safety needs that the unit could consider for the future.

The fire safety unit's strategic direction is guided by the objectives of the Construction Research Centre, which align with the NRC 2024–2029 Strategic Plan (PDF). The unit advances the research centre's goals of decarbonizing construction, enhancing building resilience and enabling innovation, while supporting the NRC priorities related to climate resilience, sustainability and digital research.

The peer review committee and stakeholders agreed that the unit's strategic direction aligns with current fire safety research priorities. In particular, its focus on fire-safe mass timber supports federal and provincial priorities and could be further expanded to support the federal priority of affordable housing[2] through research and testing of fire-safe mass timber modular construction.

The peer review committee and 90% of surveyed stakeholders consider the unit to be Canada's leader in fire safety research in the built environment and a global authority on fire-safe mass timber and WUI fires. This recognition stems from the unit's expertise, testing capabilities and contributions to standards and codes. The unit also maintains a strong national and international presence at conferences and on committees.

Fire safety unit researchers have presented and published at more than 60 international fire engineering and fire safety conferences and have served as committee chairs, keynote speakers or panelists at more than a dozen prominent annual events, including the World Conference on Timber Engineering in 2014, 2018, 2021 and 2025 and the International Conference on Information Systems for Crisis Response and Management in 2010, 2019 and 2025.

Reflecting emerging national fire safety needs and research gaps, the peer review committee and stakeholders identified several high-priority areas where the fire safety unit could provide leadership to advance fire safety in Canada, including:

- Supporting performance-based code regulation through the development of clear code objectives and safety criteria

- Developing information to facilitate the effective implementation of performance-based codes
- Assessing fire risks associated with alternative energy systems, such as battery energy storage systems and related fire and explosion interactions
- Developing AI-enabled fire detection and analytics
- Integrating digital twin technologies and dynamic virtual replicas of physical assets, systems or environments, to support fire simulations, firefighter training and the optimization of evacuation planning
- Testing the fire behaviour of emerging construction materials such as bio-based products
- Enhancing knowledge translation of existing fire safety research and guidance into clear, practical advice for targeted stakeholder groups

1.6 Project selection and planning

The fire safety unit's project portfolio focuses primarily on short-term, industry-driven technical service projects. This emphasis can limit capacity for longer-term strategic research. The unit could balance these short-term projects with longer-term strategic research and increasing stakeholder input to enhance project relevance.

A substantial portion of the fire safety unit's project portfolio consists of short-term technical services projects of 1 year or less. Industry is the primary client and represents 73% of these projects. However, industry projects generated somewhat less revenue ($6.2 million) than projects funded by OGDs ($6.7 million) over the 13 years examined. This difference may be attributed to the predominance of small-sized enterprises with 1 to 99 employees in Canada's construction sector, and their limited capacity to fund longer-term research.

Although longer-term and strategic R&D projects funded by OGDs are fewer in number, they contribute more to total revenue because of their larger scale, longer duration and greater complexity (refer to Table 6 and Table 7). For example, a strategic R&D project to develop a WUI fire standard for HICC from FY 2020–21 to 2025–26 is expected to generate $1.3 million.



Technical services: Provide clients with short-term, specialized, fee-for-service support, including fire testing, standards compliance, instrumentation, programming, calibration, data analysis and reporting, and chemistry services.

Strategic R&D: Advances foundational knowledge, de-risks innovation and accelerates commercialization. Examples include developing fire safety technologies that promote sustainable innovative building design and conducting research on human behaviour during fires, emergency egress and community evacuation.

Table 6. Number of projects by client and project type, FY 2012–13 to 2024–25

Client	Up to 1 year	1 to 6 years	Strategic R&D	Technical services	Total
Industry	86	21	23	84	**107**
OGD	30	12	14	28	**42**
Academia	6	8	3	11	**14**
Other[§]	7	4	9	2	**11**
Total	**129**	**45**	**49**	**125**	**174**

Table 7. Revenue by client and project type, FY 2012–13 to 2024–25 (millions of dollars)

Client	Up to 1 year	1 to 6 years	Strategic R&D	Technical services	Total
Industry	$3.1	$3.1	$2.6	$3.6	**$6.2**
OGD	$3.1	$3.6	$2.1	$4.6	**$6.7**
Academia	$0.1	$0.3	$0.1	$0.3	**$0.4**
Other[§]	$0.3	$0.6	$0.8	$0.1	**$0.9**
Total	**$6.6**	**$7.6**	**$5.6**	**$8.6**	**$14.2**

Source: Project data from FY 2012–13 to 2024–25

The peer review committee noted that the unit's technical service projects, such as standards compliance, are generally focused on addressing the immediate, short-term needs of individual enterprises. To enable the unit to have a significant volume of research projects that proactively addresses systemic issues applicable to the broader sector, stakeholders suggested establishing more formal engagement mechanisms for stakeholder input. These could include advisory boards modelled on those from the climate resilience initiatives or structured consultations with industry, regulators, provincial authorities and communities. These approaches could enhance the strategic relevance of projects and support alignment with emerging fire safety needs.

The peer review committee also observed that the unit's business approach could benefit from a stronger commercial orientation. This would include the unit developing a stronger understanding of potential revenue opportunities and pursuing new revenue streams such as in commercial testing. In addition, the peer review committee noted that the unit should further pursue potential international research funding opportunities.

[§] Includes associations, international organizations and research institutes.

2 Organizational capacity

Climate resilience initiatives

The climate resilience initiatives effectively leveraged facilities and expertise across NRC research centres to address an expanding research scope. The initiatives could further strengthen its capabilities by building capacity in knowledge translation, cost–benefit analysis and change management to support awareness and adoption of research-based adaptation measures.

2.1 Facilities

The climate resilience initiatives accessed facilities across NRC research centres and used their unique capabilities to support climate resilience projects. These facilities were generally viewed as effective, although the fire safety testing facility was noted as requiring upgrades.

The initiatives involved collaborations with multiple NRC research centres and leveraged a broad range of specialized facilities and expertise to address complex climate risks. Key facilities supporting this work included:

- **Hygrothermal performance of buildings testing facilities, Construction Research Centre**: Includes a dynamic roofing facility, one of the largest dynamic testing tables globally, that simulates wind effects on roofing systems and installations, enabling realistic assessment of building resilience under extreme weather



Dynamic roofing facility at the NRC

- **Fire safety testing facility, Construction Research Centre**: Refer to section 2.3, Fire safety unit – Facilities, for more information on this facility
- **Coastal wave basin research facility, Ocean Coastal and River Engineering Research Centre**: A configurable 3D basin and wide 2D flume for modelling wave and current interactions with structures and shorelines. This facility provides insight into coastal and flood resilience
- **Mining wear and corrosion test facility, Clean Energy Innovation Research Centre**: Equipped for advanced wear, erosion and corrosion–erosion testing to assess the durability of concrete bridge components

- **Wind tunnel research facility, Aerospace Research Centre**: A suite of tunnels used to test structural performance, such as bridge cables, under extreme climate conditions

Staff involved in the initiatives reported mixed views on the NRC facilities used for climate resilience projects. The wind tunnel facility was highly rated and the corrosion facility was noted as a valuable asset that is unique in Canada. The coastal wave basin was considered capable but aging, while the fire safety testing facility was identified as requiring upgrades.

Among surveyed stakeholders, 64% rated the NRC facilities used for climate resilience projects as very effective, 27% as moderately effective and 9% as not effective. Stakeholders who rated facilities as moderately or not effective identified several gaps. These included the need to modernize some facilities to align with international capabilities, reduce environmental impacts and support research on urban microclimates, hail and large-scale fire testing.

Interviewed researchers noted that facility availability, more than suitability, could be a challenge. Some facilities, such as the large wave flume research facility, were booked up to 1 year in advance. External facilities, including university and industry labs, were used to meet some immediate needs. However, these arrangements introduced limitations such as long wait times and differences in testing protocols and technical expertise.

2.2 Capacity and expertise

The climate resilience initiatives demonstrate an ability to mobilize multidisciplinary expertise and strategically scale capacity to meet expanding climate-resilience research needs. The initiatives could further strengthen capabilities by building capacity in knowledge translation, cost–benefit analysis and change management to support awareness and adoption of research-based adaptation measures.

The climate-resilience initiatives drew on specialized expertise from across the NRC. Most research for the Climate-Resilient Building and Core Public Infrastructure Initiative was conducted by the Construction Research Centre. Participation from the Ocean, Coastal and River Engineering Research Centre expanded under the Climate Resilient Built Environment Initiative, reflecting a deliberate shift toward coastal and flood resilience and strong cross-centre collaboration.

Other centres, including the Automotive and Surface Transportation Research Centre, the Design and Fabrication Services Branch, the Aerospace Research Centre and the Clean Energy Innovation Research Centre, also contributed expertise. Expertise drawn from across the NRC included:

- Infrastructure and building science (design, materials, structural performance, durability and resilience)
- Data analytics

- Climate and building modelling
- Hydrodynamics
- Ice mechanics
- Fire dynamics and human behaviour in fire
- Aerodynamics

The Climate-Resilient Building and Core Public Infrastructure Initiative operated with a team of 11 Construction Research Centre staff. The team increased to 14 staff under the subsequent Climate Resilient Built Environment Initiative, reflecting a strategic expansion to meet the initiative's broader scope. New roles, such as theme leads, a technical outreach officer and a policy officer, were introduced to support more complex research activities and strengthen stakeholder outreach and the mobilization of research outputs.

Staff perspectives on capacity and expertise were mixed. Some noted that staff were stretched, while others felt current capacity was sufficient. While most staff recognized that the NRC has the necessary expertise to support the initiatives, some identified gaps in research translation and cost–benefit analysis. Among surveyed stakeholders, 55% agreed that the NRC has strong climate resilience expertise, while 45% moderately agreed. A few stakeholders suggested that expertise could be further strengthened by incorporating change management capabilities to help navigate political and social barriers to implementing climate adaptation measures.

Fire safety unit

Current NRC fire safety facilities meet some immediate fire safety priorities, with the unit relying on international laboratories for any full-scale fire testing. To better address emerging fire safety priorities, the unit would require enhanced facilities and expanded capabilities. The unit possesses strong research and technical expertise. However, much of this expertise is concentrated among a small number of senior researchers and technicians nearing retirement, making succession planning important for sustaining the unit's future role.

2.3 Facilities

The fire safety testing facility (M-59) meets some immediate fire safety needs but lacks the capacity to support research and testing in critical emerging fire safety priorities. The closure of the National Fire Laboratory reduced the number of industry projects. Upgrades are viewed as important to enable research in new priority areas and reduce the fire safety unit's reliance on international laboratories.

M-59 was established in 1958 to conduct fire safety research and fire resistance testing and to develop and evaluate fire protection systems. It includes:

- **Column test furnace**: Tests the fire resistance of full-scale loaded columns and is one of the world's largest column furnaces
- **Wall test furnace**: Tests the fire resistance of wall assemblies and doors and accommodates specimens up to 3 metres x 3 metres with loads up to 2000 kN



Wall test furnace at the NRC

- **Floor and ceiling test furnace**: Measures the fire resistance of 3.9 metres x 4.8 metres specimens with loads up to 2000 kN
- **Intermediate-scale test furnace**: Measures the fire resistance of 1.2 metres x 1.8 metres specimens with loads up to 218 kN for floors and 118 kN for walls
- **Immersive technologies for human behaviour in fire laboratory**: Simulates complex emergency scenarios using immersive virtual and augmented reality
- **Fire chemistry laboratory**: Determines the properties of materials under various fire conditions and includes a cone calorimeter and other analytical instruments

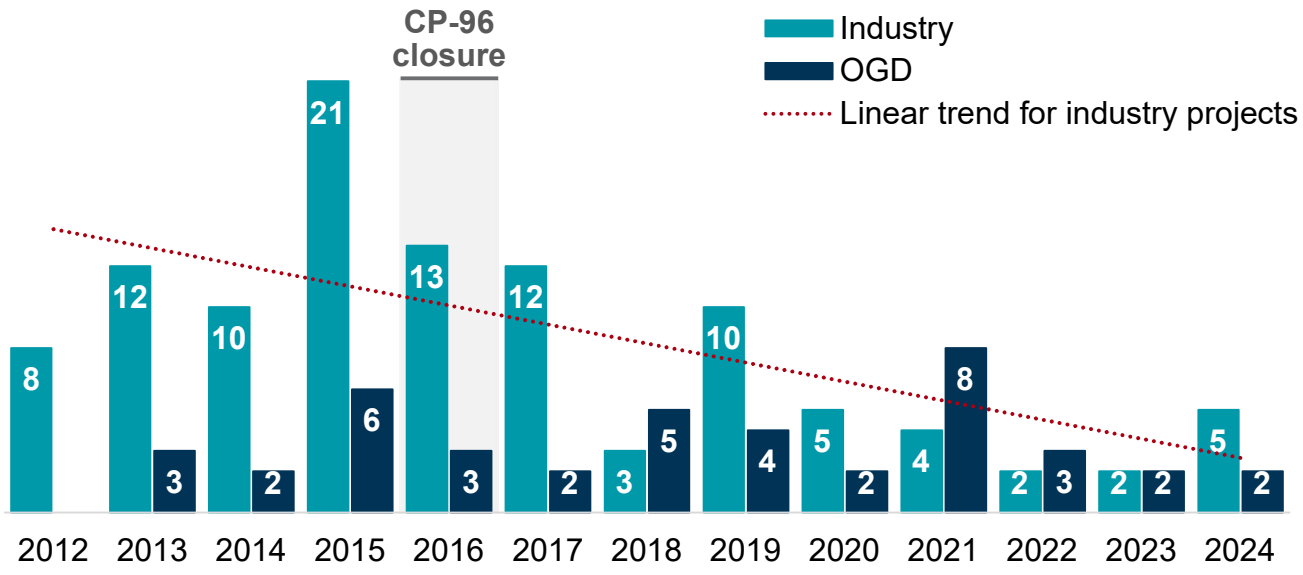
The peer review committee, stakeholders and staff reported that M-59 can support some immediate industry needs and limited testing. Its size and capabilities, however, constrain the scope and frequency of work and limit the fire safety unit's ability to address some existing and emerging needs. These include testing innovative or combustible materials, building façades, smoke management systems, fire behaviour, field-based burns and full-scale mass timber construction.

The peer review committee concluded that the unit has the potential to lead research and testing in critical emerging areas, such as fire implications of alternative energy systems within the built environment. Progress in these areas is constrained by the lack of critical infrastructure, including a smoke abatement system capable of capturing fire test by-products. This limitation prevents the unit from testing construction materials beyond wood and restricts activities to encapsulated mass timber assemblies classified as non-combustible. Consequently, the unit's ability to fully test and evaluate all components of mass timber construction remains limited.

Surveyed stakeholders expressed mixed views on M-59's effectiveness to support the fire safety unit's objectives, with 47% rating it effective, 23% moderately effective and 30% slightly or not effective. Stakeholders noted that M-59 is Canada's only government fire laboratory able to support projects that serve industry, policy and public interests.

Until fall 2016, M-59 was 1 of 2 NRC fire safety facilities. The National Fire Laboratory (CP-96) opened in 1981 as Canada's only full-scale fire laboratory capable of testing buildings larger than 2 storeys and transportation systems larger than a consumer passenger vehicle. It included a 10-storey smoke tower and other large-scale staging and testing areas. Operations at the National Fire Laboratory ceased in fall 2016 due to environmental issues. This closure resulted in a significant reduction in the fire safety unit's research and testing capability. Staff report that M-59 can accommodate only about 25% of the testing volume previously supported by the National Fire Laboratory. Project data show that the number of industry projects declined following the closure (refer to Figure 2).

Figure 2. Industry and other government department projects by fiscal year, FY 2012–13 to 2024–25



The linear trend was calculated using the least squares method.

Source: Project data from FY 2012–13 to 2024–25

Since the closure of the National Fire Laboratory, the unit has relied on international laboratories for full-scale fire testing. These include Sandia National Laboratories and the Southwest Research Institute, which are contract laboratories for the United States government, and the National Fire Research Laboratory at the National Institute of Standards and Technology, a US government laboratory. Fire safety staff and stakeholders reported that this reliance has increased costs, delayed project timelines and introduced risks related to quality control, intellectual property and the loss of institutional knowledge. They also noted that these laboratories have gained NRC technical and operational expertise through observation and training by fire safety staff. This transfer of expertise could reduce the unit's competitive advantage in North America.

The peer review committee, stakeholders and staff emphasized that the closure of the National Fire Laboratory has significantly constrained research on mass timber, combustible and emerging materials, modular construction, human behaviour in fire and performance-based design. It has also stalled progress on the CAN/ULC-S134 exterior wall fire test standard, reduced the generation of new non-combustible and large-scale test data, eliminated full-scale training opportunities for future fire safety engineers and limited the development of NRC fire safety educational materials. The closure has also affected other NRC research centres, including the Automotive and Surface Transportation Research Centre and the Aerospace Research Centre.



> "The fire safety unit's involvement in the education of future practitioners in fire science appears to have diminished. We cannot educate future practitioners without having a facility where they can experience full-scale fire demonstrations."
>
> —External stakeholder

The peer review committee concluded that upgrades to M-59 or another strategy that provides reliable and accessible Canadian capabilities are critical to meeting current and future research needs and recommended timely action on this issue. The committee and other stakeholders emphasized that upgrades to NRC fire testing capabilities would restore important testing capacity, support Canadian regulations and enhance Canada's global position in fire safety research.

At the time of this evaluation, the fire safety unit was examining options to reduce reliance on international laboratories and better support future research and testing priorities.

2.4 Capacity and expertise

The fire safety unit has important research and technical expertise concentrated among a small number of senior staff nearing retirement. This creates a significant risk of specialized knowledge loss. Succession planning is essential to sustain and strengthen the unit's future capacity.

The fire safety unit has expertise in:

- Fire dynamics, including growth, spread and flammability
- Fire detection, suppression and smoke management
- Fire risk management, fire resistance and structural fire safety
- Human behaviour in fire and egress
- Fire modelling and fire testing
- Research computation and AI-based analysis, decision making and tools

- Performance-based design and building codes
- Community fire safety and firefighting training

As of November 2025, the unit had a total of 26 staff, including 12 research officers, 8 technical officers, 4 research associates, 1 technical manager and 1 director.

Since 2016, the unit has contributed to the NRC's climate resilience initiatives through research and testing of wildland–urban interface (WUI) fires and wildfire smoke. Since 2023, it has supported the Platform to Decarbonize the Construction Sector at Scale through research on de-risking low-carbon materials, energy harvesting systems and lithium-ion battery applications. The unit also advanced the development of digital fire risk assessments and fire and evacuation modelling. According to the fire safety unit's 2024–2029 Strategic Plan and staff, the unit's level of involvement in the climate resilience initiatives and technical services is not sustainable. Both the peer review committee and stakeholders noted that the unit has limited capacity to take on any additional research projects given the current workload.

To address immediate workload pressures, additional non-term full-time equivalents (FTEs) were added in FY 2023–24 and 2024–25 to support the Platform to Decarbonize the Construction Sector at Scale. A significant number of students were hired and collaborations with academia and other government departments (OGDs) were expanded (refer to Table 8).

The peer review committee commented that, while students help support research capacity, reliance on them is not effective for reducing workload pressures or supporting knowledge transfer. This approach also places additional demands on staff time and resources for training and coaching.

Table 8. Fire safety full-time equivalents, term and student counts by fiscal year, FY 2019–20 to 2024–25

Staff type	2019–20	2020–21	2021–22	2022–23	2023–24	2024–25
FTE	15.7	17.1	16.6	18.7	22.0	22.0
Term FTE	2.8	2.0	3.6	3.5	2.0	4.0
Student[**]	0.4	2.2	2.9	2.9	4.5	14.9
Total	**18.9**	**21.3**	**23.1**	**25.1**	**28.5**	**40.9**
Salary expenses in millions of dollars (including employee benefits payments)	$2.6	$2.8	$3.0	$3.3	$4.8	$7.3

Sources: Finance data and human resource data from FY 2019–20 to 2024–25

The closure of the National Fire Laboratory reduced the number of technical officers, as only 1 of the 8 officers from that facility were retained (though the officers at M-59 remained) and

[**] Student employment at the NRC is typically for approximately 4 months.

limited the fire safety unit's capabilities in fixed and mobile firefighting, fire and explosion hazards from batteries and tunnel fire safety research. At present, much of the unit's expertise is concentrated among a small number of senior researchers and technicians nearing retirement. According to stakeholders and the peer review committee, this creates a significant risk of knowledge loss and is compounded by the absence of a formal succession plan.

The unit currently has 1 senior expert in human behaviour in fire and single-egress fire safety and 1 in mass timber fire research. Both areas are growing in importance given federal priorities related to housing and low-carbon construction.



> "While there is a strong foundation in technical capabilities, the unit struggles with insufficient personnel to support ongoing and future research initiatives effectively."
>
> —External stakeholder

Among surveyed stakeholders, 55% agreed that the unit currently has the expertise to meet its objectives, while the remainder moderately agreed. Some noted that capacity is limited, with client response times delayed due to the small team and competing demands, including international fire testing and committee work. One stakeholder noted that limited capacity makes collaboration difficult and insufficient resources constrain the unit's ability to address critical mass timber research. Stakeholders also identified a need to strengthen the unit's knowledge of international regulations and its ability to translate research into performance-based codes.

Effectiveness

Climate-resilience initiatives

The climate resilience initiatives have made substantial contributions to advancing climate adaptation in Canada's buildings and infrastructure through published research, the development of future climate data, guidance and tools, and extensive stakeholder collaboration. These efforts have strengthened climate-resilient design practices and informed national standards, specifications and codes.

Adoption of these products is increasing across governments and professional design associations, though it is limited within industry. The initiatives are also fostering business innovation by supporting the development of climate-resilience certification for construction products. To further expand impact, continued knowledge mobilization, targeted outreach and long-term cost–benefit analysis of these adaptation measures will be essential to increasing awareness and broadening adoption across Canada's construction sector.

The effectiveness of the climate-resilience initiatives was evaluated by examining peer-reviewed publications, completion of memorandum of understanding (MOU) deliverables, the extent of collaboration and support for business innovation. The status of the deliverables outlines in successive MOUs with Housing, Infrastructure and Communities Canada (HICC) are presented in Table 9.

Table 9. Status of deliverables outlined in memorandums of understanding with Housing, Infrastructure and Communities Canada, by initiative

Activity	Climate-Resilient Building and Core Public Infrastructure Initiative	Climate Resilient Built Environment Initiative	Climate Resilient Built Environment Initiative–NAS
Guidance for buildings, infrastructure and remote and Indigenous housing	Complete	Not applicable	Not applicable
Guidance for transit, nature-based solutions, flood control, and northern remote and Indigenous communities	Not applicable	On track	Not applicable
Guidance for residential retrofits	Not applicable	Not applicable	On track
Flood-related data	Not applicable	Not applicable	On track
Historical and future climate data	Complete	Not applicable	Not applicable
Asset management tools	Not applicable	On track	On track
Assessment of climate resilient construction materials and systems	Not applicable	On track	On track
Technical solutions (development and de-risk)	Not applicable	On track	On track
Integration of guidance into standards and specifications	Complete	On track	On track
Changes to National Model Codes	Complete	Too early to assess	Too early to assess
Adoption of guidance, standards and codes by industry, provinces, territories and municipalities	Underway	Too early to assess	Too early to assess

3.1 Peer-reviewed publications

The climate-resilience initiatives generated a large volume of peer-reviewed publications on climate adaptation in buildings and infrastructure, ranking third among Canadian organizations by publication volume. The field-weighted citation impact (FWCI) of these publications has remained slightly below the world average, suggesting an opportunity to increase their citation impact.

Between 2016 and 2024, the climate resilience initiatives produced 211 peer-reviewed publications. Publication output rose at the conclusion of the Climate-Resilient Building and Core Public Infrastructure Initiative in 2020 as many research projects were completed. It continued to grow as the scope of research expanded under the subsequent initiative.

Among Canadian organizations, the NRC ranked third in the number of publications on climate adaptation in buildings and infrastructure, following the University of British Columbia and Concordia University (refer to Table 10). This indicates that the climate-resilience initiatives are among Canada's leading contributors to research on climate resilient buildings and infrastructure.

Table 10. Top 10 Canadian organizations publishing on climate adaptation in buildings and infrastructure, 2016 to 2024[††]

Canadian organization	Publications
University of British Columbia	72
Concordia University	67
National Research Council of Canada	**52**
University of Toronto	47
Western University	35
McGill University	33
University of Waterloo	33
Université Laval	30
University of Guelph	30

Source: 2016–2024 bibliometric report by the NRC's intelligence and analytics team

The FWCI of all publications from the NRC's climate resilience initiatives is 0.85, which is below the global average of 1.0. This indicates that the published research has been cited less frequently than comparable work worldwide.

[††] To compare the initiatives' publication volume with peer organizations in Canada, datasets were developed using select keywords relevant to climate adaptation in buildings and infrastructure. See Appendix A for more detail.

According to the Construction Research Centre's strategic plan, the applied and regulatory-focused nature of the research centre's research means that publications may take longer to generate citations than those from other NRC research centres. This aligns with bibliometric evidence indicating that applied and engineering research often experience slower citation growth than fundamental scientific disciplines[3], which may partially explain the initiatives' lower FWCI.

Notably, the 37% of the initiatives' publications that were open access achieved a higher FWCI of 1.01, while non-open access publications had an FWCI of 0.77. Greater accessibility through open access increases visibility, supports faster dissemination and appears to increase research impact.[4]



Open access publications are research articles made freely available online, allowing anyone with internet access to read, download and use the content without subscription or payment.

3.2 Contributions to guidance, data and tools

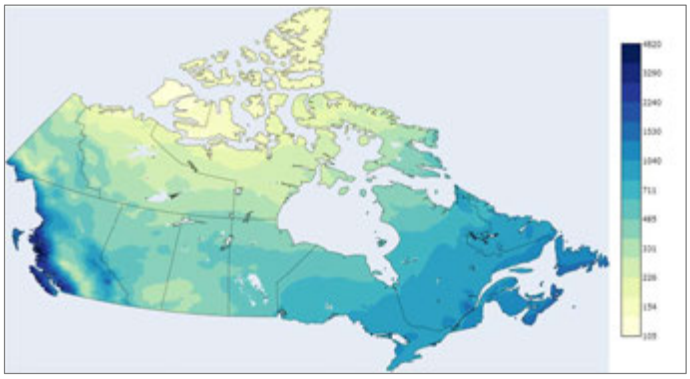
The climate resilience initiatives have significantly advanced climate adaptation for Canada's buildings and infrastructure by developing climate data, science-based guidance and climate resilience tools. Updated national climate data are now integrated into the 2025 National Building Code of Canada and the Canadian Highway Bridge Design Code, making Canada the first country to embed future climate projections directly into national codes. More than 20 guidance documents are informing design and engineering practices, while tools developed through the initiatives support climate-informed decision making across diverse building and infrastructure types.

Climate data

In partnership with Environment and Climate Change Canada, NRC researchers updated the climate design data originally developed in the 1960s and used in Canadian highway bridge design codes and the National Building Code of Canada. The updated historical data were incorporated into subsequent editions of the Canadian Highway Bridge Design Code and the National Building Code of Canada. It also established a baseline for developing future climate datasets through new climate modelling and analytical methods. This approach was later adopted by the International Energy Agency to generate future climate data for 15 cities across 10 climate types, demonstrating the global relevance of this research.

Several design tools incorporate both the historic and future climate data, such as:

- **Climate-RCI**: Uses the data to determine roof performance requirements
- **Hygrothermal database of building materials**: Used the data to develop a repository of 5 hygrothermal properties related to heat and moisture for 34 building materials
- **Design Value Explorer**: Used the data to develop an online tool that shows how climate change may influence design values under different future scenarios



A map of historical values for annual precipitation

Source: Design Value Explorer – Pacific Climate Impacts Consortium - University of Victoria

The integration of future climate data into the 2025 Canadian Highway Bridge Design Code and the 2025 National Building Code of Canada has made Canada the first country in the world to include national requirements for designing buildings and bridges that account for future climate conditions. This represents a major shift in design practice by providing mandatory national guidance that supports the construction of climate resilient infrastructure.

Under the Climate-Resilient Building and Core Public Infrastructure Initiative, the NRC also developed the Canadian Coastal Climate Risk Information System. This system provides numerical simulations of storm surges and waves using historical and future climate data. With funding from the National Adaptation Strategy (NAS), the model has been enhanced to improve climate risk assessments for key infrastructure, including transportation systems and ports. A new cloud platform has also been developed to strengthen the analytical capabilities for storm surge and wave data and improve simulations through detailed environmental and risk assessments. These capabilities are critical to support flood hazard mapping and emergency response planning.

Current work focuses on validating the model, improving the accuracy of forecasting simulations and advancing the cloud platform to strengthen the use of storm surge data in coastal infrastructure design.

Climate resilience guidance

The Climate-Resilient Building and Core Public Infrastructure Initiative produced 14 guidance documents:

- 5 on buildings
- 1 on infrastructure
- 7 on buildings and infrastructure
- 1 on remote and Indigenous housing

Under the Climate Resilient Built Environment Initiative, 7 guidance documents have been produced to date:

- 2 on buildings
- 1 on transit
- 3 on nature-based solutions
- 1 on Indigenous communities

Refer to Appendix C for a detailed list.

These guidance documents address critical knowledge and technical gaps. For example, the Guide for design of flood-resistant buildings (2021) provides technical guidance for planning and designing buildings that can withstand riverine, coastal and urban flooding. This guidance addresses a gap in the 2020 National Building Code of Canada.

Another example is the Nature-based infrastructure for coastal flood and erosion risk management: a Canadian design guide (2024). This publication provides evidence-based methods for selecting, designing, deploying and managing natural or nature-based features to reduce coastal flooding and erosion. Developed with contributions from 50 experts across 25 organizations, the guide has been incorporated into planning documents, such as the Intact Centre on Climate Adaptation's Managing Rising Risks: Climate Resilient Shorelines for Canada (2025). It has also informed applied projects, including the Nature-Based Coastal Climate Adaptation (Living Dikes) Project, which implements nature-based coastal defences.

Additional funding secured under NAS in FY 2023–24 supports the development of guidance for climate resilient residential retrofits. This includes the Multi-Hazard Resilient Retrofit Database developed by Partners for Action at the University of Waterloo to inform contractors and homeowners, and resilience retrofit checklists developed by the Institute for Catastrophic Loss Reduction.

The NRC is also collaborating with the Canada Mortgage and Housing Corporation to assess the costs associated with resilient retrofit measures. This work will inform a cost–benefit analysis of residential retrofits.

Climate resilience tools

The Climate Resilient Built Environment Initiative is developing tools to help designers, engineers and asset managers assess the impacts of climate change on new and existing infrastructure. These tools also support public infrastructure owners and operators in integrating climate risk considerations into decision-making processes. To date, the initiative has contributed to the development of 3 operational tools and technical solutions that support asset management.

Under the Climate-Resilient Building and Core Public Infrastructure Initiative the NRC, in collaboration with Catapult Satellite Applications and Transport Canada, advanced the development of BRIGITAL, a decision-support tool that uses satellite monitoring of bridge displacements to assess bridge performance. BRIGITAL detects subtle ground and structural movements and provides weather-independent displacement data that complement traditional visual inspections. This tool has been expanded through the Climate Resilient Built Environment Initiative to include early warnings of scour risks, which are caused by the erosion of soil around piers and abutments and are a leading cause of highway bridge collapse in North America.

In partnership with the Canadian Construction Materials Centre, the Climate Resilient Built Environment Initiative is developing a certification system for climate resilient construction materials and systems. A resilience assessment pilot is ready to be launched to evaluate the wildfire resistance of roofing, cladding and decking products and systems. The pilot will establish new evaluation criteria for resistance to extreme wind conditions.

The Climate Resilient Built Environment Initiative has also contributed to the development and de-risking of technical solutions that improve the design, construction and management of buildings and infrastructure. A road performance tool developed under the Climate-Resilient Building and Core Public Infrastructure Initiative is being updated and 2 additional tools are under development. All 3 tools integrate the future climate data generated through the Climate-Resilient Building and Core Public Infrastructure Initiative. These tools include:

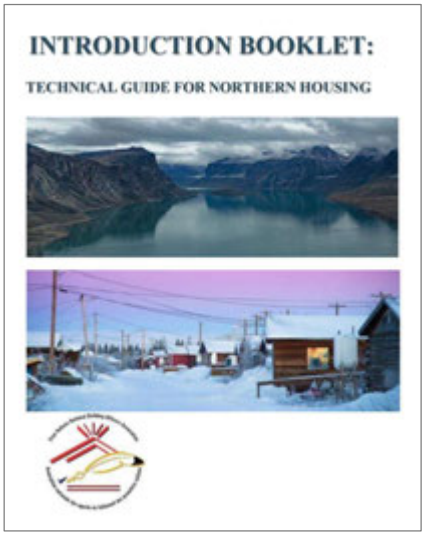
1. **Pavement adaptation support tool**: Analyzes the effects of climate change on pavement performance
2. **Pavement mechanistic-empirical design tool**: Predicts road pavement performance and service life
3. **Climate adaptation and asphalt selection tool**: Helps users select asphalt materials suited to a road's location under future climate conditions

3.1 Stakeholder collaboration

The climate resilience initiatives have collaborated with an extensive network of stakeholders to conduct research and develop science-based guidance for climate resilient buildings and infrastructure.

From their inception, the initiatives have leveraged extensive collaborations to advance their research and outputs. More than 300 collaborators have contributed to these initiatives, representing all levels of government, national and international experts, design professionals such as architects, engineers and urban planners, industry, academia, non-profit organizations and Indigenous communities.

By engaging a diverse range of partners, the initiatives have increased awareness, fostered the exchange of ideas and best practices, and supported coordinated action. These collaborations have supported the development of integrated, science-based solutions to the complex and cross-jurisdictional challenges of climate adaptation. Collaboration has taken many forms, including stakeholder consultations and workshops, participation in standards and codes committees, cross-government meetings, advisory panels and technical committees for each research theme.



Introduction Booklet: Technical Guide for Northern Housing

For example, in partnership with Indigenous organizations, the Climate-Resilient Building and Core Public Infrastructure Initiative supported the development of the Technical Guide for Northern Housing, led by the First Nations National Building Officers Association (FNNBOA). The guide provides user-friendly best practice booklets for housing construction in Northern and remote regions, including the Arctic, the Subarctic and Inuit Nunangat communities.

According to the FNNBOA, approximately 60% of its building officers who received information about the guide through email, newsletters or web links, downloaded it, which demonstrates strong uptake. FNNBOA also integrates the guide into its training on inspections and building codes, demonstrating its practical relevance and value to Indigenous housing professionals. Building on this experience, FNNBOA has since developed the Arctic Energy Modelling project, which provides evidence-based guidance for building energy-efficient housing in northern environments and reflects lessons learned through its collaboration with the NRC.

To further increase the uptake of climate resilience tools and resources, the initiative should continue to collaborate with Indigenous communities and maintain a presence at Indigenous housing conferences to strengthen meaningful knowledge exchange and relationship building.

3.2 Adoption of guidance, data and tools

Guidance, data and tools developed through the climate resilience initiatives are publicly available through online platforms, contributing to stakeholder awareness. Adoption of these resources is increasing as federal programs integrate resilience requirements into funding for buildings and infrastructure. Professional design associations, regional governments and industry are beginning to adopt these resources. However, limited awareness continues to hinder broader adoption.

Availability of guidance, data and tools

The climate resilience initiatives have made their data, guidance and tools publicly available online. Many stakeholder organizations, including the Canada Mortgage and Housing Corporation and the Federation of Canadian Municipalities, reference and link to these resources. Guidance, data and tools produced under these initiatives have been integrated into national online platforms, including the Design Value Explorer, ClimateData.ca and Climate Insight. Federal platforms such as the Canadian Centre for Climate Services also aggregate information and link to these climate data resources.

The landscape of climate resilience guidance for buildings and infrastructure in Canada is crowded. HICC's 2025 Baseline Assessment of Climate Resilient Infrastructure Guidance Implementation in Canada identified 156 publicly available guidance documents for climate resilient infrastructure in Canada. Stakeholder awareness of the NRC's climate resilience initiatives and their resources is strong. More than half of surveyed stakeholders (51%) reported being very aware of the initiatives' activities, with an additional 46% somewhat aware and only 3% unaware. This high level of awareness is likely partly due to the resources being freely accessible online. To further enhance visibility, uptake and impact, the initiatives should continue actively promoting these websites to stakeholders.

Adoption by federal government

The federal government, as a major funder of buildings and infrastructure, plays an important role in advancing the adoption of climate resilient design and construction practices through its funding program requirements. The 2023 NAS set a target that, starting in 2024, all new federal infrastructure funding programs integrate climate resilience into their planning and design. A key objective of the climate resilience initiatives is to develop the data, guidance and tools necessary to support this commitment.

A review undertaken by HICC of 24 federally funded programs for buildings and infrastructure found that 5 include climate resilience requirements informed by NRC climate resilience research or guidance. These programs include multiple departments:

- **Housing, Infrastructure and Communities Canada (HICC)**: Disaster Mitigation and Adaptation Fund, Canada Housing and Infrastructure Fund, Natural Infrastructure Fund and Canada Public Transit Fund
- **Transport Canada**: Transportation Assets Risk Assessment Program
- **Public Safety Canada**: Disaster Financial Assistance Arrangements program

These programs require applicants to assess climate risks and design mitigation measures using the best available climate data, resilience research, guidance and standards. The inclusion of these requirements reflects growing federal adoption of outputs from the climate resilience initiatives. For example, Public Safety Canada's Disaster Risk Reduction incentive under the Disaster Financial Assistance Arrangements program provides financial incentives for provinces and territories to incorporate climate resilience measures into post-disaster reconstruction.

Adoption by professional design associations, regional governments and industry

The stakeholder survey indicates growing adoption of the NRC climate resilience guidance, data and tools across professional design associations, such as architects, engineers and urban planners, regional governments including provincial, territorial and municipal governments, and industry. Among respondents who considered the guides relevant to their organizations, more than half (52%) reported using at least one guide. The Nature-based infrastructure for coastal flood and erosion risk management: A Canadian design guide and the Guide for design of flood-resistant buildings were the most widely used (71% and 65%, respectively).

Most users found the guides very or moderately effective and practical. Stakeholders noted that the guides improved technical knowledge, design rigour and material selection, and supported training, capacity building and client engagement. Some stakeholders noted that the guidance is highly technical, which may limit its use by non-specialists. Among those who had not used the guides, the most frequently cited reason was a lack of awareness.

For NRC climate resilience design guidance, data and tools available through national online platforms, 41% of respondents who considered them relevant to their organizations reported using at least one. Among users, 68% rated them very effective and the remainder moderately effective. These tools and platforms were recognized for providing accurate climate data, supporting code compliance and serving as authoritative references for professional practice. Among respondents who had not used the tools, 94% cited lack of awareness and 6% reported using an alternative tool.

While the effectiveness of the guides and online platforms was rated highly, limited awareness remains the primary barrier to broader adoption. Some stakeholders noted that climate resilience guides and tools would benefit from clearer identification of intended end-users to

support uptake and accessibility. While many NRC climate resilience resources identify target audiences, the level of specificity varies. For instance, the National Guide for Wildland–Urban Interface Fires (2021) states it is intended for any qualified practitioners with wildfire knowledge. In contrast, the Climate resilience buildings: Guideline for management of overheating risk in residential buildings (2021) specifies building developers, architects, modellers and heating, ventilation and air conditioning engineers as its target users.

Building the awareness of the climate resilience guidance, data and tools across governments, industry and design professionals will take time. To meet the NAS' 2030 target that 80% of public and municipal organizations integrate climate adaptation into decision making, the Climate Resilient Built Environment Initiative will need to prioritize knowledge mobilization and targeted outreach.

3.3 Contributions to standards, specifications and codes

Through the climate resilience initiatives, the NRC contributed to advancing climate resilience in Canadian standards, specifications and codes. Adoption of NRC-supported climate resilience standards is increasing. Provincial, territorial and municipal governments are emerging as early users, while uptake within industry remains limited.

Standards

The Climate-Resilient Building and Core Public Infrastructure Initiative supported the updates to 7 standards, ranging from CSA W200, Design of bioretention systems (2018), to CSA A123.26, Performance requirements for climate resilience of low slope membrane roofing systems (2021). Building on this work, the Climate Resilient Built Environment Initiative has supported 6 updates to standards, ranging from CSA S7, Pedestrian, cycling, and multiuse bridge design guideline (2023) to the CSA A440 series on fenestration (2024, updated 2026). Refer to Appendix C for full details on standards.

Adoption of NRC-supported standards

Adoption of NRC-supported climate resilience standards are increasing among stakeholders. Among surveyed stakeholders who considered the standards relevant to their work, 60% reported using at least 1 and 60% rated them very effective, with the remainder rating them moderately effective. Users described the standards as clear, relevant and practical, supporting climate resilient design in both Canada and the United States. They have been applied to bridges, building retrofits and glazing systems and have informed international codes and standards developed by organizations such as the American Society of Civil Engineers and the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Stakeholders reported that the standards support decision making, innovation and product development by providing guidance on life cycle costs and material performance. They

emphasized the need for ongoing updates to maintain relevance. Among respondents who had not used the standards, lack of awareness (83%) and high purchase cost (17%), which can range from $180 to $400 per document, were identified as the main barriers.

At the provincial, territorial and municipal levels, there is emerging evidence that resilience measures are being implemented by asset owners and decision makers, although capacity and approaches vary by jurisdiction. Smaller communities, such as Lytton, British Columbia, are developing community resilience plans. Larger municipalities are integrating resilience into design standards and construction practices, such as the Toronto Green Standard. Several provinces, territories and municipalities have requested NRC advice and expertise to integrate future climate data into their planning, following updates to the 2025 National Building Code of Canada.

Stakeholders noted low uptake of climate resilience standards across the Canadian construction industry. While a few manufacturers have begun applying these standards, most builders continue to construct to minimum code requirements, often prioritizing lower upfront costs over voluntary resilience measures. To encourage broader industry adoption, some stakeholders suggested introducing financial incentives for manufacturers and builders, providing evidence of the long-term financial benefits of applying the standards, integrating climate resilience standards into local regulations and mandating their use for federally owned assets.

Specifications and codes

Through research conducted under the climate resilience initiatives, the NRC contributes science-based knowledge that informs construction specifications and codes. This research supports the Canadian National Master Construction Specification technical team and the technical committees under the Canadian Board for Harmonized Construction Codes, which are responsible for updating building and infrastructure content within national specifications and codes.

NRC climate resilience research informed multiple updates to the Canadian National Master Construction Specification, published in 2018, 2022, 2023, 2024 and 2025. These updates support a consistent framework for creating project-specific construction documents and support quality, accuracy and efficiency in specifying materials, methods and procedures for public and private projects.

Research under the Climate-Resilient Building and Core Public Infrastructure Initiative contributed to updates to National Model Codes, including the:

- 2019 Canadian Highway Bridge Design Code, including updates to improve infrastructure resilience
- 2020 National Building Code of Canada, including updates to wind data, new roof snow load provisions, updated referenced standards, expanded durability guidance and provisions enabling tall wood construction

- 2021 Canadian Electrical Code, introducing new requirements for electrical installations at risk of flooding damage

Research under the Climate Resilient Built Environment Initiative further informed updates to the 2025 Canadian Highway Bridge Design Code, which now includes:

- Integration of future climate data developed under the Climate-Resilient Building and Core Public Infrastructure Initiative, making it the first Canadian infrastructure design standard to embed predictive climate modelling into technical requirements
- Updated hydrologic and hydraulic methods
- New service life design for hazard resilience to extend bridge lifespans, reduce repair costs and minimize disruptions from extreme weather, flooding, scour and wildfires
- New provisions on corrosion

In addition, research under the Climate Resilient Built Environment Initiative contributed to updates to the 2025 National Building Code of Canada and its supporting committees, including:

- Incorporation of NRC future climate data for the next 50 years, marking a global milestone as the first National Model Code worldwide to integrate climate adaptation directly into its requirements
- Informing the establishment of a national model codes committee on Climate Change Adaptation under the Canadian Board for Harmonized Construction Codes tasked with developing requirements for the 2030 edition of the National Building Code that enhance building resilience to extreme heat, flooding, permafrost thaw and extreme wind

3.4 Support for business innovation

Although business innovation is not a primary focus of the climate resilience initiatives, they contribute to innovation by supporting the development of climate resilience certification for construction products.

The primary focus of the climate-resilience initiatives is to conduct research and provide guidance and tools that support climate resilient design and the development of standards and codes. When adaptation measures become regulatory requirements, businesses receive clearer and more predictable signals that encourage innovation, which can stimulate technological advancement by creating incentives for firms to develop new products, processes and services to comply more efficiently or gain competitive advantages.

To support business innovation, the Climate Resilient Built Environment Initiative, in collaboration with the NRC's Canadian Construction Materials Centre, is developing technical

guidance for evaluating climate resilient construction products. In FY 2023–24, the initiative and the centre began developing a climate resilient product assessment pilot project. This pilot establishes testing procedures and certification requirements for climate resilient materials and systems, with the goal of expanding the centre's services to include climate resilience certification. Extreme wind and wildfires are the first hazards for which the pilot will assess claims of resilience for construction products. By providing clear certification criteria, the pilot aims to reduce uncertainty, support innovation, promote code compliance and build market confidence among municipalities and Indigenous communities across Canada.

In addition, the Climate Resilient Built Environment Initiative has connected with the NRC Industrial Research Assistance Program (NRC IRAP). Together, they share climate resilience resources with manufacturers and industry organizations, helping to raise awareness and identify potential partners interested in addressing building or infrastructure adaptation challenges. This coordination connects NRC research outputs with businesses seeking to validate new technologies or integrate climate resilience into their products and services.

Fire safety unit

The fire safety unit's research, testing and technical expertise informed mass timber design, wildland–urban interface (WUI) fire resilience and fire protection practices. Its work has contributed to strengthening community and building resilience to WUI fires, demonstrated the fire resilience and structural stability of mass timber, improved evacuation planning and established the foundation for developing digital fire safety tools for the built environment. These contributions have influenced guidance, standards and codes and supported the adoption of fire-safe, sustainable construction practices. To increase adoption of tools and resources and enhance testing capabilities, the unit should strengthen outreach and expand partnerships.

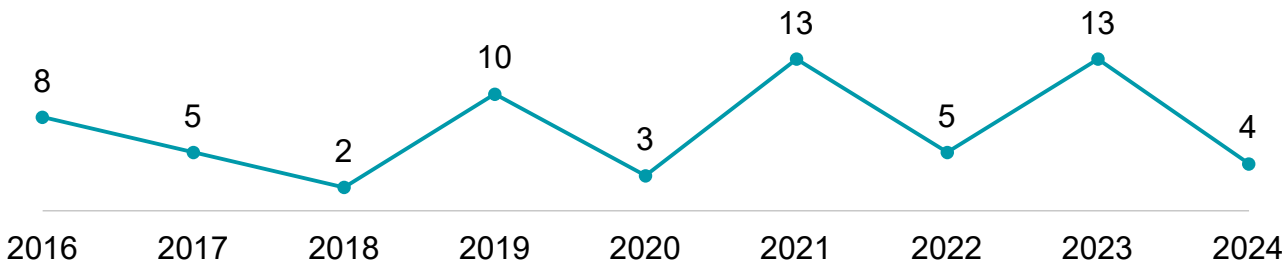
The effectiveness of the fire safety unit was assessed through publications, contributions to guidance, standards and codes, advances in fire safe sustainable materials and digital tools and its partnerships, collaborations and engagement activities.

3.5 Peer-reviewed publications

The fire safety unit has produced a considerable body of peer-reviewed publications in its area of expertise, ranking second among Canadian organizations by volume of fire safety research published. Its FWCI is well above the global average, at 1.61, reflecting the influence of several highly cited publications.

Between 2016 and 2024, the fire safety unit produced 63 peer-reviewed publications. Since 2019, the number of new publications has followed a biannual cycle, reflecting the unit's typical 2-year research-to-publication timeline (refer to Figure 3).

Figure 3. Peer-reviewed publication count, 2016 to 2024



Source: 2016–2024 bibliometric report by the NRC's intelligence and analytics team

Among Canadian organizations, the NRC ranked second in the number of publications on fire safety in the built environment, following the University of Alberta (refer to Table 11). This demonstrates that the fire safety unit is among the Canada's leading contributors to research in this area.

Table 11. Top 10 Canadian organizations publishing on fire safety in the built environment, 2016 to 2024‡‡

Canadian organization	Publications
University of Alberta	49
The NRC's fire safety unit	**40**
York University	33
University of British Columbia	32
Natural Resources Canada	30
Lakehead University	30
Université Laval	30
Carleton University	29
University of Toronto	21
FPInnovations	18

‡‡ To compare the fire safety unit's volume of publications with peer organizations in Canada, data-sets of publications were developed using select keywords deemed most relevant to fire safety in the built environment. Refer to Appendix A for more details.

Source: 2016–2024 bibliometric report by the NRC's intelligence and analytics team

Although the unit's peer-reviewed publications are substantial, its primary focus is supporting industry to develop and de-risk innovative fire protection systems and providing the technical foundation for fire-safe building design. This work typically results in proprietary client reports, international collaborative reports and guidelines rather than peer-reviewed publications.

The unit's publications have an FWCI of 1.61, well above the global average of 1.0. This is driven partly by several publications with very high FWCI scores, with 4 publications ranging from 6.48 to 15.1.

For example, Employing the hydraulic model in assessing emergency movement (2016) had an FWCI of 15.1 (73 citations) at the time of the evaluation. Published as a chapter in the Society of Fire Protection Engineers Handbook of Fire Protection Engineering, it adapted modelling techniques from engineering, safety science and human behaviour, broadening its relevance across multiple research communities. Its focus on emergency evacuations and age-related demographics was particularly relevant given the increase in wildfires and an aging population.

3.6 Contributions to guides

The fire safety unit's research, testing and technical expertise supported the development of 6 national fire safety guides. These guides are widely valued by stakeholders for their practical and technical content. Limited awareness among non-users indicates a need for stronger outreach to increase adoption.

Through its published research, materials and benchmark testing, and guidance through committees and working groups, the fire safety unit contributed to the development of 6 fire safety guides. Key guides address fire-safe mass timber construction and wildfire resilience, including (refer to Appendix D for a full list):

- Canadian CLT Handbook (PDF), 2019
- National Guide for Wildland–Urban Interface Fires (PDF), 2021
- Technical Guide for the Design and Construction of Tall Wood Buildings in Canada (PDF), 2022

Among surveyed stakeholders who considered the guides relevant to their organization, 71% reported using at least one. Usage was highest for the:

- **Canadian CLT Handbook**: 94% of relevant respondents reported using it. Users highlighted its practical guidance on cross-laminated timber (CLT), its broad recognition and adoption across Canada's design, regulatory and construction sectors and its influence on the American CLT Handbook

- **Technical Guide for the Design and Construction of Tall Wood Buildings in Canada**: 90% of relevant respondents reported using it. Users highlighted its value in providing technical direction on mass timber design and construction and its role in supporting engineered wood use in Canadian construction.

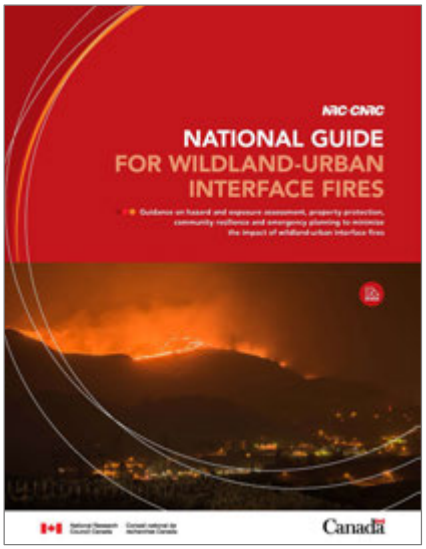
Stakeholders noted that non-use was due primarily to a lack of awareness of the guides, indicating an opportunity to strengthen outreach and dissemination to increase uptake.

Case study: National Guide for Wildland–Urban Interface Fires

The fire safety unit convened an international network of experts to develop the National Guide for Wildland–Urban Interface Fires, which provides recommendations to reduce the severity of WUI fire damage and loss. Although adoption is voluntary, several municipalities have implemented its recommendations. Transitioning the guide into national standards has strong potential to increase use and adoption across Canada.

Development and recognition

In response to growing wildfire risk driven by climate change, 12 fire safety unit researchers commenced work on wildfire resilience in 2016. In 2018, they established an international technical committee of experts from government, academia, industry and emergency services to develop a national guide for WUI fires. This created new cross-sector collaboration on wildfire mitigation among stakeholders who had not previously collaborated.



National guide for wildland–urban interface fires

Published in 2021, the WUI guide is the first of its kind in Canada. Drawing on domestic and international research, codes, standards and guides, it provides detailed recommendations for hazard assessment, vegetation management, fire-resistant construction, emergency planning and community outreach. The guide has been widely promoted through presentations at major conferences and forums, including the Society of Fire Protection Engineers Annual Conference and Natural Resources Canada's (NRCan) Intergovernmental Table on Wildland Fire Risk. As of August 2025, the guide had been downloaded from the NRC website more than 10,000 times.

A 2021 impact analysis by the Institute for Catastrophic Loss Reduction found that applying the guide's recommendations across Canada could prevent up to $500 billion in economic losses, save 2,300 lives and create 19,000 long-term jobs over a decade.

Dr. Noureddine Bénichou, who led the development of the WUI guide, has received national and international recognition, including the 2021 Sjölin Award from the International FORUM of Fire Research Directors and the 2022 Fire Researcher of the Year Award from the Canadian Association of Fire Chiefs. The potential impact of the guide was further recognized when Dr. Bénichou received the 2023 Public Service Awards of Excellence, Excellence in Profession.

Adoption and application

The WUI guide has been referenced by major organizations, including FireSmart Canada, the Canadian Interagency Forest Fire Centre and the Canadian Association of Fire Chiefs. Its recommendations have informed FireSmart's Wildfire-Resilience Best-Practice Checklist for Home Construction, Renovation and Landscaping (PDF) and the Canadian Fire Chief's Guide for Development Design Approval (PDF). Among surveyed industry, government and emergency management stakeholders, 62% were aware of the WUI guide and 61% of those aware reported using it. Users indicated that the guide supports fire risk assessment, community preparedness and reduces the likelihood of building ignition.

While adoption remains voluntary, several communities have integrated WUI principles into their rebuilding and planning efforts:

- **Lytton, British Columbia**: Consulted with fire safety unit researchers on wildfire-resilient building design after a 2021 wildfire. The village amended a bylaw to incorporate WUI recommendations, which later became voluntary following the municipality's decision not to proceed with Building Amendment Bylaw No. 730, 2023. As of early 2025, builders had constructed at least one residential rebuild based on the WUI guide and FireSmart checklists.
- **Kanaka Bar Indian Band (T'eqt'aqtn'mux), British Columbia**: Consulted with fire safety unit researchers on wildfire-resilient building design after the 2023 Kookipi Creek wildfire.
- **Jasper, Alberta**: Following a 2024 wildfire, the town consulted with fire safety unit researchers on a wildfire-resilient community rebuild plan. Jasper and Parks Canada updated their wildfire risk reduction fire restoration projects, rebuilding guide and development policies to include wildfire safety and resilience measures recommended in the WUI guide.

Future directions

Stakeholders viewed the WUI guide as credible and technically sound, noting the NRC's reputation helped elevated wildfire resilience as a national priority. Stakeholders identified

barriers to broader adoption of the guide, including its length and complexity, high material costs, lack of insurance incentives for using fire-safe materials and limited consistency across provincial and municipal codes and bylaws. Stakeholders suggested that the NRC strengthen future adoption by developing simplified tiered guidance, discipline-specific resources, visual aids and assembly diagrams, WUI-compliant material lists and training tools for planners and builders.

To support adoption, the fire safety unit is collaborating with the Standards Council of Canada to develop 2 national standards and a supplementary guidebook based on the WUI guide. This transition from guide to standards is expected to improve consistency, credibility and cost efficiency by harmonizing requirements across jurisdictions.

3.7 Contributions to standards and codes

The fire safety unit has helped shape national and international fire safety standards and codes through research and testing that informed over 30 new or revised standards and 3 editions of Canada's National Model Codes. While adoption among governments and industry is increasing, greater awareness of these standards will be important to support broader stakeholder uptake.

Standards

The fire safety unit's research and testing has informed national and international standards over the evaluation period, including:

- **National Fire Protection Association standards (2024–2026)**: Research and testing informed revisions to 10 fire safety, smoke control and wildland fire protection standards and 1 building construction and safety code
- **International Organization for Standardization (ISO) (2015–2024)**: The unit's fire science data and modelling research influenced 9 standards and 6 technical specifications on fire safety engineering, validation of fire models, life safety and toxic gas analysis
- **American National Standards Institute and APA – The Engineered Wood Association (ANSI/APA) PRG 320-2019: Standard for Performance-Rated Cross-Laminated Timber (2019)**: The unit's research and fire testing on the performance and adhesive for CLT were adopted by all North American CLT standards
- **Canadian Standards Association (CSA) standards (2019–2024)**: The unit provided testing and research on mass timber, fibre-reinforced polymer fire safety and building-integrated photovoltaics that contributed to the development or revision of 4 standards
- **Standards Council of Canada and Underwriters Laboratories of Canada (CAN/ULC) standards**: The unit's testing informed the development of 8 standards and

the full 500 series of standards on fire test methods and fire suppression systems for mass timber

Overall, 65% of surveyed stakeholders who considered the standards relevant to their organizations reported using them. Reported usage was highest for CAN/ULC-S146, Standard Method of Test for the Evaluation of Encapsulation Materials and Assemblies of Materials for the Protection of Structural Timber Element, with 88% of relevant respondents reporting its use. Users indicated that the standard support design and material selection and promote broader use of wood in Canadian construction. Among stakeholders who had not used the remaining standards, lack of awareness was the primary reason for non-use. One respondent noted that because the standards are voluntary, they chose not to use them.

Codes

The peer review committee noted that the fire safety unit's research and testing influenced the development of National Model Codes and that its expertise is highly sought after by domestic and international code committees. The unit contributed to key updates to the National Building Code of Canada and National Fire Code of Canada in 2015, 2020 and 2025. Key contributions include clarifying fire safety provisions for accessibility and single egress, supporting the introduction of encapsulated mass timber construction (EMTC), informing amendments that expand wood construction up to 12 storeys (18 stories is under consideration for the 2030 edition of the National Model Codes) and strengthening firefighter safety through enhanced fire protection measures for hazardous environments.

Among surveyed federal departments, regional governments and industry stakeholders, 62% reported using fire safety updates to the National Building Code of Canada provisions and noted that these updates provided additional clarity. Those who had not used the updates cited primarily lack of awareness as the reason for non-use.

In addition, fire safety unit staff participated in more than 30 national and international standards and code committees, working groups and boards in fire safety, mass timber and wildfire. This demonstrates the unit's significant role in informing standards and codes in Canada and its global leadership in advancing fire-safe mass timber construction and WUI fire research.

3.8 Contributions to fire safe sustainable material: Mass timber

Through its research and testing, the fire safety unit advanced knowledge of the fire resilience and structural stability of mass timber, helping to transform it from an unviable construction material into a trusted, code-compliant option. Opportunities remain to further support wider adoption of fire-safe mass timber.

Mass timber, a sustainable material made of wood layers bonded into solid panels for structural use, offers notable environmental and economic benefits. The material is flammable, susceptible to moisture and has associated with high insurance costs due to limited long-term performance data.

Before 2005, mass timber was not considered a viable construction material in Canada. The 2005 National Model Codes introduced objective-based performance goals, which provide greater flexibility in meeting code requirements, enabling the inclusion of glued-laminated timber and marking the beginning of mass timber's emergence as a potential construction material.

To support the adoption of safer, more sustainable building materials, the fire safety unit conducted research and large-scale fire testing that confirmed the fire resilience of mass timber. This included its structural stability, minimal re-ignition risk from char layers and its greater load-bearing capacity compared to conventional construction materials.



Compared to concrete and steel, mass timber is lighter, generates less waste, is easy to recycle, emits less carbon dioxide (CO_2) during manufacturing, captures and stores CO_2 and enables faster construction with prefabricated products.[5]

The fire safety unit's research and fire testing have made important data-driven contributions to the fire safety of mass timber in construction, including:

- Large-scale compartment mass timber fire tests on tall wood buildings under non-standard conditions, without sprinklers or firefighting intervention, which informed code changes to the 2020 National Building Code of Canada, enabling mass timber structures from 6 storeys to 12
- Fully encapsulated mass timber tests, including CLT, nail-laminated and glued-laminated timber, demonstrated that complete encapsulation leads to fire decay and burnout
- Partially encapsulated tests that identified adhesive performance issues in early CLT products prompting a revision to the ANSI/APA PRG 320 standard
- Nail-laminated timber tests with large exposed surfaces showed fire decay and burnout, with similar fire behaviour in residential non-combustible material tests

Based on this research, Dr. Joseph Su has received national and international recognition, including: the 2019 Fire Protection Research Foundation Medal from the National Fire Protection Association, the 2019 Interflam Best Paper Award at the Interflam Conference and the 2025 King Charles III Coronation Medal from the Governor General of Canada.

The fire safety unit's research and testing also informed major code updates in Canada and abroad:

- 2015 National Building Code of Canada: Permitted EMTC for residential buildings up to 6 storeys
- 2020 National Building Code of Canada: Extended EMTC for residential buildings to 12 storeys
- 2025 National Building Code of Canada and National Fire Code of Canada: Further extended EMTC to 12-storey height (up to 50 metres), enabled use in public and medium industrial buildings, allows greater exposed mass timber, introduces new encapsulation and performance-based fire safety options and strengthens safety for hazardous environments
- 2021 International Building Code, United States: Permitted EMTC up to 18 storeys
- 2024 International Building Code: Allows exposed wood ceilings and beams and varying levels of exposed mass timber in 12-storey buildings
- National Building Code – 2023 Alberta Edition: Permits EMTC up to 12 storeys

Consideration is also being given to changes for the 2030 edition of the codes, including:

- 2024 British Columbia Building Code: Permits EMTC up to 18 storeys
- 2025 Ontario and Quebec building codes: Permit EMTC up to 18 storeys

Adoption and impact

Nearly all surveyed industry respondents (89%) and all government respondents (100%) were aware of the unit's mass timber testing. All mass timber producers agreed this testing influenced their production methods and enhanced competitiveness, noting that it improved building safety and increased public trust and adoption of mass timber.

Among surveyed industry stakeholders who reported using mass timber in construction projects, all agreed that the unit's testing increased confidence in code compliance and enhanced market competitiveness. Furthermore, 71% indicated that the testing had influenced their organization's material choices in favour of mass timber. Similarly, all surveyed government stakeholders who incorporate mass timber in their projects agreed that the testing strengthened confidence in code compliance, deepened understanding of fire safety considerations and supported the acceptance of mass timber as a safe and sustainable construction material.

Stakeholders further noted that the unit's testing enhances Canada's construction industry competitiveness, informs international codes and standards, influences global building design and promotes safer practices for mass timber installation. Staff and stakeholders highlighted the unit's demonstration of mass timber's fire performance as its most significant achievement.



> "Helping determine fire resistance [of mass timber structures]…has been critical to our organization and our Canadian success in the mass timber industry."
>
> —External stakeholder

Market reports indicate that updates to national and provincial building codes, informed by the unit's research and testing, have accelerated the adoption of mass timber in Canada's construction industry. Since 2016, more than 1,500 mid-rise and 400 tall mass timber buildings have been built across the country, including:[6]

- Brock Commons at the University of British Columbia (18 storeys), one of the tallest mass timber buildings in the world[7]
- Academic Wood Tower at the University of Toronto (14 storeys)

While the fire safety unit has made significant progress in advancing mass timber research and fire testing, stakeholders identified several areas for improvement. These include:

- Broadening research and testing to include other sustainable materials (e.g., bio-based materials, aerated concrete, green aluminum and steel), modular construction, firestopping and thermal performance in mass timber connections
- Upgrading the NRC's fire testing facility to include a smoke abatement system to support testing of combustible materials
- Strengthening collaborations with end-users, such as the Canadian fire marshals and fire commissioners, so that resources are practical and effective
- Investing in performance-based mass timber codes to move beyond the current reliance on objective-based approaches

Stakeholders also noted several barriers to wider industry adoption, including high testing costs, overly conservative encapsulation requirements, elevated insurance premiums and limited supplier availability, particularly for prefabricated materials. They suggested that government support for testing, open access building designs co-developed with industry and product labelling for fire-resistance compliance could help reduce these barriers and promote broader adoption of fire-safe mass timber across Canada.

3.9 Contributions to digital fire safety tools and wildfire R&D

The fire safety unit developed digital fire safety tools that enhance Canada's ability to predict, monitor and respond to wildfires, including the WUI–NITY, which has been applied in 3 community evacuation drills. The unit has also created innovative tests, simulations and assessments that strengthen communities' ability to evaluate, mitigate and respond to wildfire risk.

Digital fire safety tools

Global adoption of digital technologies in the built environment, such as the Internet of Things, AI and building information modelling, is accelerating. Canada's construction sector, however, has lagged behind in adopting these innovations. To improve productivity, efficiency and safety, the fire safety unit is developing advanced digital fire safety tools that support the sector's modernization, including:

- **Wildfire hazard mapping tool**: The unit mapped historical and projected extreme weather, wildfire behaviour and hazards in WUI areas across 11 Canadian cities. Results indicate longer wildfire seasons, increasing wildfire-conducive weather, more intense wildfires and greater demand for suppression resources. Data from projected modelling can assist these communities in anticipating future wildfire risks.
- **Mapping tool on community-specific construction guidelines**: The unit created a location-based mapping tool providing construction guidelines that integrate wildfire hazards, exposure and recommended construction classes for over 600 locations referenced in the National Building Code. The tool offers community-specific data on wildfire hazards in Canada under varying degrees of global warming to support builders and decision makers.
- **Machine learning hazard assessment tool**: The unit created a machine learning tool that uses past incident and experimental data to predict hazard levels and ignition probability in WUI areas. It accounts for ember mass, size, construction materials and wind speed and measures combined effects of thermal radiation and ember ignition. Data from over 1,000 experiments are being compiled to form a national ignition probability database.
- **AI and remote sensing applications**: The unit is applying artificial intelligence and remote sensing technologies to develop automated tools for high-resolution fuel mapping, hazard detection and wildfire risk assessment in WUI areas. The resulting data will enhance the WUI guide and support improved wildfire monitoring.
- **WUI–NITY**: A simulation platform for WUI fire evacuation developed with international collaborators in 2018–2019,[8] WUI–NITY, is an online simulation platform for community evacuation during WUI fires. It integrates 2D and 3D visualizations of fire spread, human movement and traffic congestion to support real-time decision making by responders and communities.

WUI–NITY has been used for evacuation and preparedness drills in: Kelowna, British Columbia (2025); Roxborough Park, Colorado (2019, 2024); and Ashland, Oregon (2025). FireSmart is expanding Canadian participation in these NRC-funded drills, which help assess alert systems, human behaviour and emergency planning. Data collected from these drills are shared with communities to improve preparedness and inform the development of a Canadian evacuation modelling framework.

The fire safety unit led the research and contributed to the development and updates, for all 4 versions of WUI–NITY. For WUI–NITY 4, the latest version, the unit analyzed social media data to model evacuation behaviour and developed virtual reality driving simulations. The team received the 2025 Fire Protection Research Foundation Medal from the US-based National Fire Protection Association. Despite this international recognition, 70% of surveyed government and emergency management respondents were unaware of WUI–NITY, and few had used it. Those who had used it found it valuable for education and planning. Limited awareness of the tool may stem from the absence of WUI–NITY in key national wildfire resources, such as the Government of Canada's Wildfires in Canada toolkit.

Wildfire R&D projects

The fire safety unit is leading more than $6 million in wildfire-related R&D projects to develop, refine and standardize tools that support the WUI guide, improve fire-safe construction practices and enhance community wildfire resilience across Canada. Key initiatives include:

- **Standardized risk assessment framework**: Developing a national framework for wildfire risk assessments in collaboration with Public Safety Canada and NRCan
- **Firebrand ember generator**: Building Canada's first ember generator to characterize structure ignition under exposure to flame, embers and heat, supporting realistic ignition scenario development
- **WUI fire simulator**: Creating a simulation tool that models radiation, ember impact, heat release, vegetation burning and heat fluxes between wildfires and urban areas to assess structural vulnerabilities
- **Smoke mitigation research**: Testing residential air filters against simulated wildfire smoke to improve indoor air quality during wildfire events
- **Wildfire and flooding index**: Developing an index with international collaborators to optimize resource allocation when wildfire and flooding occur successively
- **NRC's Low Carbon Built Environment Challenge program**: Integrating wildfire events and resilience measures into life cycle assessments to improve carbon emission estimates, support low-carbon building practices and quantify fire-related environmental impacts

Collectively, these projects advance Canada's capacity to manage wildfire risk, improve fire-safe construction methods and integrate climate resilience into building and planning practices.

3.10 Partnerships, collaborations and stakeholder outreach

Stakeholders reported limited awareness of the fire safety unit's research and tools. Strengthening outreach, improving collaboration and expanding partnerships can provide key opportunities to increase impact and uptake of the unit's work.

The peer review committee and stakeholders emphasized the importance of increasing the visibility of the fire safety unit and its work, particularly as climate resilience, low-carbon construction and community safety become increasingly central to public policy.

Less than half of surveyed stakeholders reported high awareness of the fire safety unit's research (49%) and technical services (44%), while the remainder were somewhat aware. Staff indicated that awareness of the unit is limited due to the absence of a dedicated website and few formal opportunities or mechanisms for technology and knowledge transfer. They suggested enhancing outreach and visibility through the development of a dedicated website, complemented by workshops, technical events, advisory boards and formal consultations to increase the uptake of research and tools.

Staff also identified opportunities to deepen collaboration with:

- Insurance and risk modelling firms: Integrate fire risk data into design and real-world applications
- Indigenous and remote communities: Advance wildfire resilience and culturally appropriate evacuation strategies
- International fire safety organizations: Align global standards and expand collaborative research
- Infrastructure-focused organizations: Extend fire safety research to critical infrastructure
- Canadian construction companies: Understand practical challenges and enhance adoption of fire-resilient materials and construction practices
- Municipalities and firefighting organizations: Support the relevance and practicality of tools for key end-users

Recommendations

Recommendation 1

Enhance knowledge mobilization

Knowledge mobilization was identified by climate experts and stakeholders as the top future priority for the climate resilience initiative, recognizing that effective dissemination and uptake of research outputs are essential to strengthening Canada's adaptation of buildings and infrastructure to improve climate resilience.

Similarly, reflecting emerging national fire safety needs and research gaps, both the peer review committee and stakeholders highlighted the need to enhance knowledge translation of existing fire safety research, guidance and tools. For the fire safety unit, the peer review committee and stakeholders highlighted the importance of increasing the visibility of its expertise, resources and services to better support policy development, industry practices and community safety.

Enhancing visibility and knowledge mobilization is particularly critical as climate resilience, low-carbon construction and community fire safety and emergency preparedness become increasingly central to public policy and infrastructure planning. Stakeholder survey results further reinforced this need, indicating that limited awareness is a primary barrier to the broader use of NRC's guides, tools and standards.

Together, these findings underscore the importance of strengthening knowledge mobilization strategies to ensure that NRC's research and guidance are effectively reaching and benefiting design professionals, industry, communities and the decision makers they are intended to support.

Recommendation

Both the Climate Resilient Built Environment Initiative and the fire safety unit should strengthen knowledge mobilization and outreach to increase awareness and adoption of science-based guidance, tools and standards. This could include:

- Identifying key end-user groups for information and products
- Creating clear, user-friendly guidance documents tailored to those specific end-users, translating technical findings into practical applications

Management response and action plan

Risk level: Moderate

Response: Accepted

Actions:

1. Relaunch NRC Construction Research Centre Innovation newsletter: to share updates, guidance, and technical briefs in accessible language.

   Measure of achievement:

   Construction Innovation newsletter re-launched, enabling delivery of targeted technical content to 50,000 plus subscribers in the architectural and engineering community, building officials and other code users, collaborators and receptors of NRC research.

   Expected date of completion: December 2026

   Proposed person responsible: Director General, Construction

2. Develop a knowledge mobilization plan for the Climate Resilient Built Environment (CRBE) initiative that identifies priority audiences (e.g., professional associations, OGD authorities, and SMEs) and outlines effective dissemination methods.

   Measures of achievement:

   a. Knowledge mobilization plan for CRBE completed and approved by the DG of Construction and provided to the VP of Engineering, including up-front engagement with receptors in third phase of initiative and dissemination of findings from CRBE II
   b. Progress report on engagement and activities reaching milestones established, provided by the DG of Construction to the VP of Engineering

   Expected dates of completion:

   a. December 2026
   b. December 2027

   Proposed person responsible: Director, CRBE Initiative

3. Develop a knowledge mobilization plan for the fire safety unit that identifies priority audiences (e.g., municipal building officials, professional associations, fire marshals, OGD authorities, and SMEs) and outlines effective dissemination methods.

   Measures of achievement:

   a. Knowledge mobilization plan for fire safety unit completed and approved by the DG of Construction and provided to the VP of Engineering, leveraging dissemination

mechanisms such as Construction Innovation and webinars for targeted outreach on key outputs (e.g., mass timber, single egress construction, wildland–urban interface).

b. Report on expanded activities and updated approach including plans for emerging areas, provided by the DG Construction to the VP Engineering.

Expected dates of completion:

a. May 2027

b. Final report May 2028

Proposed person responsible: Director, fire safety unit

Recommendation 2

Clarify the fire safety unit's future focus areas

The peer review committee and stakeholders identified the importance of defining and focusing on areas of greatest impact to guide future project selection. With much of the unit's expertise concentrated among a small number of senior researchers and technicians approaching retirement, knowledge transfer and mentoring were identified as critical to maintaining long-term technical capacity.

In addition, staff and external stakeholders highlighted the need for a nationally coordinated approach to fire safety research and testing, including expanding access to testing facilities and stronger collaboration across sectors to address emerging national fire safety challenges.

Clarifying the fire safety unit's future focus areas will strengthen its ability to address evolving fire safety priorities, optimize the use of its specialized capabilities and ensure sustainable capacity through effective succession planning.

Recommendation

The fire safety unit should clarify and prioritize its future focus areas based on emerging fire safety priorities, capabilities and expertise while establishing a succession plan to sustain long-term retention of knowledge retention and technical capacity. This should include:

- Defining clear research priorities beyond the 2024–2029 strategic plan to maximize impact, informed through engaging fire safety stakeholders to identify emerging needs
- Basing future research priorities on an analysis of short- and medium-term capabilities and identifying future options to address any capability gaps

- Developing a succession plan to preserve the unit's specialized expertise and ensure alignment with its planned research priorities

Management response and action plan

Risk level: Moderate

Response: Accepted

Actions:

1. Develop forward-looking research priorities beyond the 2024–2029 strategic plan

   Measures of achievement:

   a. Consolidation and validation of existing gap analysis report, leveraging international benchmarks and fire safety stakeholders, provided by the DG of Construction to the VP of Engineering

   b. Report on plans and priorities identifying short-, medium-, and long-term priorities and considering organizational capabilities to address identified gaps, leveraging the Construction Research Centre mission areas and Annual Planning and Review process, approved by the DG of Construction and provided to the VP of Engineering

   Expected dates of completion:

   a. October 2026

   b. October 2027

   Proposed person responsible: Director, fire safety unit

2. Develop a succession plan: Update competency mapping to identify expertise gaps, and establish mentoring and documentation protocols to ensure continuity

   Measure of achievement:

   Succession plan approved by DG of Construction and provided to the VP of Engineering, leveraging the annual talent management process

   Expected date of completion: May 2027

   Proposed person responsible: Director, fire safety unit

Appendices

Appendix A: Methodology

The evaluation was conducted by the NRC's Office of Audit and Evaluation (OAE) using a mixed-methods approach that incorporated qualitative and quantitative data from several lines of evidence. The lines of evidence were:

Bibliometric study

The NRC's intelligence and analytics team conducted a bibliometric analysis of publications authored by researchers of the climate resilience initiatives and the fire safety unit between 2016 and 2024. Publication datasets were compiled by searching the Scopus database to identify NRC-affiliated or relevant publications based on metadata and authorship. Both datasets were validated by their respective initiative and unit, with additional relevant publications added as required.

In addition, additional datasets were developed using keyword searches conducted in Scopus in April 2025, which identified publications containing selected keywords in their titles and abstracts. The keywords were validated by the respective directors and the search strategies were developed by the NRC's intelligence and analytics team. These datasets include highly relevant publications within each program's research field and were used to benchmark performance against national and international peers. Publication volumes within each benchmarking dataset were analyzed to identify the top publishing organizations in Canada.

Environmental scan

The NRC's intelligence and analytics team conducted a fire safety environmental scan to identify federal organizations with a role in fire safety in the built environment and to gather data on damage costs and fatalities associated with wildland–urban interface (WUI) fires. The team also carried out a climate resilience environmental scan to identify federal and provincial departments involved in climate adaptation for buildings and infrastructure as well as to map the federal funding landscape supporting climate resilient buildings and infrastructure projects.

Data review

Administrative and performance data for FY 2016–17 to 2024–25 (climate resilience initiatives) and 2012–13 to 2024–25 (fire safety unit) were reviewed to provide information on research, capacity, capability, outputs, outcomes and impacts. These included financial, human resources, project, client, performance and intellectual property data.

Document review

A range of documents were reviewed: strategic and operational plans, facility reviews, annual reports, project documentation as well as conference, committee and task group documents and other relevant documents.

Stakeholder survey

Two stakeholder surveys were conducted, one for fire safety stakeholders and one for climate resilience stakeholders. Survey invitations were sent to stakeholders from academia, government (federal, provincial, territorial and municipal), professional associations, industry and other relevant organizations that had previous interactions with the climate resilience initiatives or the fire safety unit. This included clients, collaborators, advisors, committee members and workshop participants. A total of 63 stakeholders completed the climate resilience survey (a 21% response rate) and 41 stakeholders completed the fire safety survey (a 19% response rate).

Impact case study

The National Guide for Wildland-Urban Interface Fires was chosen as a case study because its research is jointly funded by the climate resilience initiatives and the fire safety unit. The case study provides an in-depth examination of the collaborative, societal, industry, economic and environmental impacts resulting from the adoption of WUI guidance. It was informed by input from NRC experts and collaborators as well as by environmental scans, document reviews and data analyses.

Key informant interviews

Individual and group interviews were conducted with NRC staff and external stakeholders. Interviews gathered insights on their experiences, perspectives and expert knowledge related to the capabilities, research, outputs, outcomes, impacts and collaborations. For the climate-resilience initiatives, interviews were completed with 13 NRC staff, 14 stakeholders and 3 climate experts. For the fire safety unit, interviews were conducted with 11 NRC staff and 12 stakeholders.

Peer review

An international peer review committee was convened to assess the fire safety unit’s relevance and effectiveness. The committee included 7 experts in fire safety and engineering. The committee received preliminary evaluation findings and supporting documents in advance of a 3-day site visit to the NRC’s fire safety facilities in Ottawa (October 21 to 23, 2025). Following the visit, the committee produced a report with recommendations.

Peer review committee members

The peer review committee for the fire safety unit was composed of the following members, listed in alphabetical order:

Dr. Marc Alam

Senior Manager, Canadian Wood Council, Canada

Mary Cianchetti

President of Standards, CSA Group, Canada

Member of the Construction Research Centre Advisory Board

Dr. Eric Guillaume, Committee Chair

General Manager, Efectis, France

Dr. Matthew Hoehler (pre-assessment only)

Chief, Fire Research Division, National Institute of Standards and Technology, United States

John Jessett

Deputy Fire Chief, Department of National Defence, Canada

Dr. Sam Salem

Full professor of structural and fire safety engineering, Department of Civil Engineering, Lakehead University, Canada

Emmanuel Sopeju

Fire protection engineer, Canada

Appendix B: Methodological limitations and mitigations

Although the evaluation encountered minor challenges, methodological limitations were mitigated where possible through the use of multiple lines of evidence and the triangulation of data. Details on the limitations and mitigation strategies of the evaluation team are described below.

Sample bias

The OAE selected interviewees and survey respondents who had previous interactions with climate resilience initiatives or the fire safety unit to ensure participants possessed sufficient knowledge to have informed perspectives. However, this focus may have excluded individuals who were aware of, or had used, the outputs and activities of these groups but had no direct interaction with the climate resilience initiatives or the fire safety unit.

Mitigation

Efforts were made to include a diverse sample and ensure representation across stakeholder groups, geographic locations, organizational sectors and project types.

Survey response bias

When reporting awareness or use of a guide, tool or standard, survey respondents who were unsure or selected “not relevant to my organization” were omitted from the figures. Consequently, reported percentages of awareness and use may be overstated relative to the broader stakeholder population and should not necessarily be seen as representative.

Mitigation

Results were interpreted with caution and clearly contextualized in the analysis. Where possible, qualitative data from interviews and document reviews were used to triangulate findings and provide a broader understanding of awareness and uptake among all stakeholder groups.

Appendix C: Guides, standards, specifications and codes

Climate-Resilient Building and Core Public Infrastructure Initiative

Guides

- Guideline on Basement Flood Protection and Risk Reduction, 2018
- Guide for Design of Flood-Resistant Buildings (PDF), 2021
- Guidelines for Improving Flood-Resistance for Existing Buildings (PDF), 2021
- National Guide for Wildland–Urban Interface Fires (PDF), 2021
- Guideline for Management of Overheating Risk in Residential Buildings (PDF), 2021
- Practical Guidance for Private-Side Drainage Systems to Reduce Basement Flood Risk (PDF), 2021
- Coastal flood risk assessment guidelines for building and infrastructure design: Supporting flood resilience on Canada's coasts (PDF), 2020
- Technical Guide for Northern Housing, 2021

Specifications

- Canadian National Master Construction Specification, sections that include new climate-resilience content, 2018 and 2022

Standards

- CSA W200, Design of bioretention systems, 2018
- CSA W201, Construction of bioretention systems, 2018
- CSA S900.1, Climate change adaptation for wastewater treatment plants, 2018
- CSA S478, Durability in buildings, 2019
- A440.4:19 (R2024), Window, door and skylight installation, 2019
- CSA A123.26, Performance requirements for climate resilience of low slope membrane roofing systems, 2021
- CSA A123.21, Standard test method for the dynamic wind uplift resistance of membrane-roofing systems, 2021

Reports

- Weathering the storm: Developing a Canadian Standard for Flood-Resilient Existing Communities (PDF), 2019
- Climate-Resilient Buildings and Core Public Infrastructure: An Assessment of the Impact of Climate Change on Climatic Design Data in Canada (PDF), 2020
- Estimating the Benefits of Climate Resilient Buildings and Core Public Infrastructure (CRBCPI) (PDF), 2020
- Nature-Based Solutions (NBSs) to Mitigate Urban Heat Island (UHI) Effects in Canadian Cities (PDF), 2020
- Impact Assessment of the National Guide for Wildland–Urban Interface Fires (PDF), 2021

Codes

- CSA S6:19 (R2024), Canadian Highway Bridge Design Code, 2019
- CSA C22.1:21, Canadian Electrical Code, Part 1, 2021 edition
- National Model Codes, 2015, 2020, 2025 editions

Tools

- Design Value Explorer (DVE)
- Building reference year climate datasets for 564 reference locations in Canada
- Climate-RCI for climate resilient design of roofs
- Hygrothermal database of building materials (HygDbM)

Climate Resilient Built Environment Initiative

Guides

- 2022 Global Building Resilience Guidelines (PDF), 2022
- Nature-Based Infrastructure for Coastal Flood and Erosion Risk Management: A Canadian Design Guide (PDF), 2024
- Effects of Climate Change on Life-Cycle Performance of Structures and Infrastructure Systems: Safety, Reliability, and Risk, 2024
- Guide to Bridge Hydraulics, third edition, 2025

- On Floods Caused by River Ice: An Overview of Mitigation Measures (PDF), 2025

Specifications

- Canadian National Master Construction Specification (NMS), sections that include new climate resilience content, 2023, 2024, 2025

Standards

- CSA S7, Pedestrian, cycling, and multiuse bridge design guideline, 2023
- CSA S478, Durability in buildings, 2024
- A440.4:19 (R2024), Window, door and skylight installation, 2019
- CSA S910.1:25, Climate change vulnerability assessment for dams in Canada, 2025
- CSA W224, Coastal flood risk assessment for buildings and infrastructure, 2024
- CSA W212:25, Temporary flood protection barrier performance testing for Canadian climates, 2025

Reports

- Rising seas and shifting sands (PDF), 2021
- Satellite monitoring for early detection of excessive displacements on bridges, 2021
- Sea ice in changing climate and impacts on Inuit communities, 2022
- Evaluation of a basic procedure to assess climate impact on sea ice: Hudson Bay as a test case, 2022
- Delivering climate responsive resilient building codes and standards, 2022
- A decision support system to optimize water distribution systems maintenance and rehabilitation under changing climate: Literature review (PDF), 2022
- Understanding nature based solutions (NBS) on buildings to mitigate urban heat islanding (UHI) (PDF), 2022
- Adaptation of dams to climate change: Gap analysis (PDF), 2023
- A review of flooding and erosion in Canadian rivers: A precursor to guidance for nature-based solutions (PDF), 2023
- State-of-practice, research gaps, and plan for safety and serviceability performance evaluation of residential building balconies in a changing climate (PDF), 2024

Code

- CSA S6:19, Canadian Highway Bridge Design Code (2024)

Tools

- Climate Insight
- ClimateData.ca
- Development of climate adaptation and asphalt selection tool, CAAST (PDF), 2023
- Directory Data Sheet, 2023
- Canadian climate risk information system (CCRIS)
- BRIGITAL software, for satellite-based bridge performance assessment
- Resilience retrofit guidelines for hail, wildfire and hail, 2025

Climate Resilient Built Environment Initiative–National Adaptation Strategy

Reports

- Summary of the scientometric study and stakeholder engagement on resilient residential retrofit theme under National Research Council's Climate Resilient Built Environment Initiative (PDF), 2024

Tool

- Multi-Hazard Resilient Retrofits database, 2025

Fire safety unit

Guides

- Canadian CLT handbook (PDF), 2019
- Water supply for public protection: A guide to recommended practice in Canada (PDF), 2020
- National guide for wildland–urban interface fires (PDF), 2021
- Technical guide for the design and construction of tall wood buildings in Canada (PDF), 2022

- American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE Handbook – HVAC Applications, chapter 54, Fire and smoke control, 2023
- Canadian Construction Material Centre Canadian code compliance evaluation of DC315: intumescent coating as a thermal barrier over spray urethane insulation, CMC14036-R (PDF), modified 2025

Standards and technical specifications

- NFPA 13, Standards for the installation of sprinkler systems, 2025
- NFPA 25, Standard for the inspection, testing, and maintenance of water-based fire protection systems, 2026
- NFPA 72: National fire alarm and signaling code, 2025
- NFPA 80, Standard for fire doors and other opening protectives, 2025
- NFPA 92, Standard for smoke control systems, 2024
- NFPA 96, Standard for ventilation control and fire protection of commercial cooking operations, 2024
- NFPA 101, Life safety code, 2024
- NFPA 105, Standard for smoke Door assemblies and other opening protectives, 2025
- NFPA 502, Standard for road tunnels, bridges, and other limited access highways, 2026
- NFPA 1140, Standard for wildland fire protection, 2022
- NFPA 5000: Building construction and safety code (performance-based standards), 2024
- ISO 834-1:2025, Fire-resistance tests – Elements of building construction, 2025
- ISO 6021:2024, Firebrand generator, 2024
- ISO/TS 12828-3:2024, Validation method for fire gas analysis, Part 3, 2024
- ISO/TS 16733-1:2024, Fire safety engineering – Selection of design fire scenarios and design fires, 2024
- ISO/TS 16733-2:2026, Fire safety engineering – Selection of design fire scenarios and design fires, Part 2 - Design fires, 2026
- ISO/TS 17886:2024, Fire safety engineering: Design of evacuation experiments, 2024
- ISO/TS 19677:2025, Assessing the adverse impact of wildland fires on the environment and to people through environmental exposure, 2025
- ISO 19702:2024: Sampling and analysis of toxic gases and vapours in fire effluents using Fourier transform infrared (FTIR) spectroscopy, 2024

- ISO 20710-1:2022, Fire safety engineering – Active fire protection systems, Part 1, 2022
- ISO 20414:2020, Fire safety engineering – Verification and validation protocol for building fire evacuation models, 2020
- ISO/TS 21602:2022, Fire safety engineering – Estimating the reduction in movement speed based on visibility and irritant species concentration, 2022
- ISO/TS 23782:2024, Requirements for large-scale test methods to represent fire threats to people in different fire scenarios, 2024
- ISO/TS 23782:2024, Requirements for large-scale test methods to represent fire threats to people in different fire scenarios, 2019
- ISO 24678-2:2022, Fire safety engineering – Requirements governing algebraic formulae, Part 2, 2022
- ISO 24678-3:2022, Fire safety engineering – Requirements governing algebraic formulae, Part 3, 2022
- ISO 24678-4:2023, Fire safety engineering – Requirements governing algebraic formulae, Part 4, 2023
- ISO 24678-5: 2023, Fire safety engineering – Requirements governing algebraic formulae, Part 5, 2023
- ISO 24678-7:2019, Fire safety engineering – Requirements governing algebraic formulae, Part 7 ,2019
- ISO 24678-9:2022, Fire safety engineering – Requirements governing algebraic formulae, Part 9, 2022
- ISO 24679-1:2019, Fire safety engineering – Performance of structures in fire, Part 1, 2019
- ISO 24679-5:2023, Fire safety engineering – Performance of structures in fire, Part 5, 2023
- ISO 24679-8: 2022, Fire safety engineering – Performance of structures in fire, Part 8, 2022
- ISO 26367-3:2019, Guidelines for assessing the adverse environmental impact of fire effluents, Part 1, second edition, 2019
- ISO 26367-3:2022, Guidelines for assessing the adverse environmental impact of fire effluents, Part 3, 2022
- ISO 29903-1:2020, Comparison of toxic gas data from different tests, Part 1, reaffirmed 2025
- CSA C22.2 No. 63092-2:24, Photovoltaics in buildings – Part 2: Requirements for building-integrated photovoltaic systems, 2024

- CSA O86:24, Engineered design in wood, 2024
- CSA S504:19, Fire resilient planning for Northern communities, 2019
- CSA S806, Design and construction of building structures with fibre-reinforced polymer, reaffirmed 2021
- CAN/ULC-S115, Standard method of fire tests of firestop systems, reaffirmed 2023
- CAN/ULC-S134, Standard Method of Fire Test of Exterior Wall Assemblies, 2021
- CAN/ULC-S138, Standard Method of Test for Fire Growth of Insulated Building Panels in a Full-Scale Room Configuration, 2021
- CSA S504:19, Fire resilient planning for Northern communities, 2021
- CAN/ULC-S144-13, Standard method of fire test of exterior wall assemblies, 2021
- CAN/ULC-S145, Standard method of test for the evaluation of protective coverings for foamed plastic insulation – Full scale room test, reaffirmed 2023
- CAN/ULC-S146, Standard method of test for the evaluation of encapsulation materials and assemblies of materials for the protection of structural timber elements, reaffirmed 2025
- CAN/ULC S500 series, Fire suppression system components, 2019–2025
- CAN/ULC-S101, Standard method of fire endurance tests of building construction and materials, 2021
- CAN/ULC S1001, Integrated systems testing of fire protection and life safety systems, 2023
- ANSI/APA PRG 320-2018: Standard for performance-rated cross-laminated timber, 2019
- buildingSMART International information delivery specification (IDS) project report, 2023

Codes

- National Building Code of Canada, 2015, 2020, 2025
- National Fire Code of Canada, 2015, 2020, 2025
- USA 2021 International Building Code (IBC), construction types: IV-A, IV-B and IV-C, 2021
- 2024 International Building Code (I-Codes), 2024
- ACI CODE-440.11-22: Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars – Code and Commentary, 2023

[1] The built environment consists of human-made structures and spaces that support living, working and recreational, including the wildland–urban interface.

[2] Office of the Prime Minister, Prime Minister of Canada's Mandate Letter (May 2025).

[3] Moed, H.F. (2005), Citation analysis in research evaluation. In *Information Science and Knowledge Management*, vol. 9. Glänzel, W., Schubert, A. (2003), A new classification scheme of science fields and subfields designed for scientometric evaluation purposes. *Scientometrics*, 56, 357–67. Larivière et al. (2008), Long-term variations in the aging of scientific literature: From exponential growth to steady-state science (1900–2004). *Journal of the American Society for Information Science and Technology*, 59, 288–96.

[4] Lewis (2018), The open access citation advantage: Does it exist and what does it mean for libraries? *ITAL*, 37(3) and Langham-Putrow et al., (2021).

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[7] University of British Columbia (n.d.), Brock Commons residence at UBC.

[8] International partners include the National Fire Protection Association (NFPA) Fire Safety Research Foundation (USA), Lund University (Sweden), Imperial College (UK), Movement Strategies (UK) and Royal Melbourne Institute of Technology, RMIT (Australia).