2023

Fire Research Group
Department of Mechanical and Mechatronics Engineering
University of Waterloo
Waterloo, ON Canada N2L 3G1

E.Weckman, J. Dabrowski, A. Lakhani and B. Forrest

Residential Fire Risk in Canadian Indigenous Communities

June, 2023

A research report prepared for
National Indigenous Fire Safety Council
under funding Project 40-R-3 (RFP 2022 – 05)

Acknowledgements and Caveats

The National Indigenous Fire Safety Council (NIFSC) is the result of a new Indigenous developed framework designed to support Indigenous communities in the development of their internal capacity to support community safety and resiliency. The NIFSC is Indigenous inspired, designed and led in collaboration with regional and national Indigenous communities, organizations, and leaders.

This report has been developed in response to Research Area #5 (RFP #2022-05 from the 2022-23 NIFSC research agenda) to contribute Research Toward Fire Risk Mitigation in Canadian Indigenous Communities. The broad goals of the work included investigation and documentation of technical household fire risk and hazard scenarios, use of the data to propose risk-reduction strategies or technologies for more resilient fire safety, and to suggest, where possible, risk or tolerability limits as evidence-based benchmarks against which to develop new strategies or assess existing strategies for improvement of fire safety.

The authors would like to acknowledge the National Indigenous Fire Safety Council (NIFSC) for requesting this work and being committed to evidence-based decision-making in such critical areas of community health. In particular, the authors express thanks to the Board of Directors, Nathan Wright, Executive Director, Blaine Wiggins, Senior Director Indigenous Fire Marshals Service, Mandy Desautels Director of Strategic Initiatives, and Len Garis, Director of Research for their vision and guidance as the project unfolded.

The presentation of data within this report cannot be considered as either endorsed by the NIFSC or an expression of their policies or views. Any errors of omission or commission are not the responsibility of the NIFSC.

Further, it must be recognized that there is currently only a very small sample of data to use in analyses of the nature presented here. This, in combination with recognized inconsistencies in some of the databases employed, mean that the results, while deemed to be representative of the larger trends, must be interpreted with care.

Contents

Executive Summary

Preamble

This report draws on a limited sample of state of housing and fire incident data currently available for First Nations Populations on Reserve. There is a goal in moving beyond this current state by, when possible, implementing new forms of data collection, drawing upon different data sources, and framing research questions to include Inuit and Métis populations and communities, as well as First Nations residents on and off reserve.

Analytical Approach

The research reported here includes a review of international literature and existing Canadian housing and fire incident data sources to compile and assess information pertinent to residential fire safety in Canadian Indigenous communities. Relevant fire safety findings from international research were reviewed to provide important background and context. Direct sources of data related to fire incident and housing condition were analysed from: 1) the Canadian Census for First Nations populations, 2) fire incident reports submitted to the National Incident Reporting System (NIRS), and 3) available Home Safety Assessments (HSA) records compiled by the NIFSC. Through examination of the NIRS incident data and observations recorded in the HSA reports, connections between housing condition, technical fire risk parameters, frequency and extent of fire scenarios become clear. The methods used to conduct the literature review as well as the analysis of the aforementioned data sources are explained, followed by a presentation of detailed and pertinent results. The report then concludes with a discussion and an outline of the main conclusions and specific recommendations derived from the study.

Recommendations

Recommendations arising from this research are grouped into two main sections. First are several recommendations related specifically to the data and analysis, followed by a set of recommendations related to risk reduction and intervention strategies.

NIRS Analysis

- Develop a larger, more consistent set of NIRS data to allow improved analysis, cross-comparison of sources and facilitate deeper understanding of community-specific fire risks. This could include development of approaches and education to foster

  a) Broader use of NIRS to report fire incidents and causes through training and community partnerships

  b) Identifying priority fields with mandatory entry

  c) Reviewing, modifying and adding fields to capture key information and aid entry

  d) More consistent reporting of fire incidents and causes

e) Higher accuracy in recording essential fields

f) Minimization of missing and undetermined records

g) Alignment of forms and terminology across reporting entities

h) Further analysis of suspicious residential fires to better define cause and effect toward improved risk reduction

Home Safety Assessments

- Develop a larger, more consistent set of HSA data to allow improved analysis, cross-comparison of sources and facilitate deeper understanding of community-specific fire risks. This could include development of approaches and education to foster

  a) Collection of increased numbers and expanding breadth of the home safety assessment program through training and community partnerships

  b) Extraction of data from other existing sources, such as mould audit or other detailed housing condition reports

  c) Identification of priority fields with mandatory entry

  d) Review and modification of fields or structure of HSA to capture key information and aid entry. For example

     i add other details related to electrical system

     ii add questions related to cooking

     iii add questions related to smokers materials and matches

     iv include field to correlate location with key fire risk indicators

  e) More consistent reporting of observations seen

  f) Alignment of forms and terminology across data sources

Fire Safety and Risk Reduction

- Extend risk-based analysis of key fire safety indicators in high risk communities
- Expand home safety and fire assessment programs into a community-led partnership program to promote engagement, fire safety/maintenance self-education and self-monitoring amongst community members to raise awareness of fire risks. This could include development of approaches and education to foster deeper awareness of

  a) potential home ignition sources

  b) potential home fuel sources

  c) importance of having egress paths

  d) links between maintenance, housekeeping and fire safety

e) improved home and fire safety awareness

- Prioritize dwelling repair or rebuild to shift houses from a state of needing major repair, to needing minor repair, and ideally toward regular maintenance.

Intervention Strategies

- Prioritize the design and implementation of targeted, evidence based strategies (home and life safety education and protection) toward effective measures for reducing risk from key factors
- Implement targeted education on removal of potential ignition sources, identification and improvement of egress pathways to mitigate against preventable fires and their impacts. Priority items include
  a) electrical systems
  b) cooking systems and practices
  c) heating systems
  d) smokers materials
  e) open flames
  f) general home maintenance
  g) good housekeeping
- Target educational outreach to improve fire safety awareness and practices, in particular around links between home maintenance and common sources of ignition
- Target installation of fire detection/prevention systems in areas where they will be most effective
- Develop and implement programs to monitor breadth and effectiveness of adopted measures

Ultimately, these actions will result in expanded home safety and fire incident data from which to better understand technical risk factors. This knowledge can then form the foundation for development of evidence based risk reduction and intervention strategies in First Nations communities. Through strategic community partnerships and engagement, such programs will also promote renewed home and life safety education.

List of Tables

List of Figures

1 Context

Recent summary reports from Statistics Canada have outlined that First Nations people are at a significantly higher risk of casualty in fire than the remainder of the population [1–3]. Analysis of census data has illustrated that Indigenous people are subject to five times higher risk of casualty in fire compared to non-Indigenous people. This rose to astounding levels of 10 times higher for those living on reserve and 17 times higher for Inuit [4, 5]. Given that Indigenous peoples accounted for 5.0% of the Canadian population in 2021, and their population is increasing faster than that of non-Indigenous people[1] [2], this is a critical issue.

Studies have linked the high risk of casualty by fire amongst Indigenous populations to several socio-economic fire risk factors summarized as [6, 7]:

- dwellings in need of major repairs,
- crowded dwellings,
- low-income households,
- prevalence of children under the age of 6 years, and
- households in which one or more family member is unemployed.

In terms of the above fire risk factors, recent studies have further demonstrated clear links between low household income, family structure, poor dwelling conditions and fire risk [8]. In the Canadian First Nations context, on-going issues of poor suitability and condition of housing amongst Indigenous populations is documented in an analysis of 2016 census data [9, 10][2]. Thus, while addressing all fire risk factors faced by First Nations populations is of paramount importance, of particular interest here are technical links relating to fire risk, housing suitability, housing condition and overcrowding. In this context, the present study aims to identify specific technical fire hazard parameters and relate those to 'ignition and fire scenarios' that are reported in the literature and 'ignition and fire incidents' that are known to occur. It is thereafter hoped that these can provide input to the development of evidence-based risk analysis and tolerance criteria for the built environment with regards to, for example, specific building types, functions, fuel loads, ventilation configurations or overall condition of structures. Certain scenarios can be further developed and linked to anticipated fire progression after ignition. Over the longer term, this can then be coupled to response capability and necessary intervention strategies and timelines in representative existing structures.

Utilizing the available fire statistics compiled for First Nations communities in Canada and linking these to the state of housing reports, fire safety considerations in Canadian First Nations communities emerge and are outlined here. As such, this report begins with the objectives of the study, followed by background and methods sections. Through the presentation of evidence-based results and the ensuing discussion, the report ends with proposed solutions and recommendations for strategies to document and decrease fire risk, and thus

[1] between the years of 2016 and 2021

[2] The focus here is Status First Nations people on-reserve; additional reports cover similar information for non-status First Nations people [11], Métis [12] and Inuit populations [13]

increase fire safety in Canadian Indigenous communities.

2 Objectives

The research documented in this report builds upon existing information contained in databases, reports and surveys collected by several organizations in various communities. New analysis of the data is coupled with information obtained through review of the current literature. The overarching aim of the analysis is to compile evidence-based data necessary to forming an understanding of existing household conditions, ignition and fire scenarios, as well as the associated fire safety risks in Canadian Indigenous communities. From this, results can be linked to a timeline for a likely fire scenario to identify and prioritize potential risk reduction and intervention strategies.

Specific objectives are:

a) to investigate hazards and document potential fire scenarios associated with existing household risk factors with the aim of working towards the technical quantification of fire risks,

b) where possible, to use the data to propose risk-reduction strategies or technologies for more resilient fire safety, and

c) to suggest appropriate risk and tolerability limits or criteria that in future could serve as evidence-based regulatory benchmarks for developing and/or verifying strategies for compliance or against which to assess fire safety performance.

3 Background

Use of risk-based analysis methods has gained increasing traction as building regulations transition from prescriptive towards more performance-based approaches. Risk approaches can simultaneously account for multiple performance objectives (i.e. fire safety, serviceability, durability, sustainability, resilience) across a wide range of risk and hazard thresholds of concern [14]. They can also be used to assess fire risk at the community level as demonstrated in recent research on Risk Factors in First Nations in Canada [6, 15]. In these studies, it was found that a broad diversity of conditions and risk factors contribute to the disproportionately higher risk of fire death and injury for Indigenous people in Canada [6, 15]. Consistent with other studies [8, 16–19] , the combinations of age and socio-economic factors, along with household risk factors related to major repairs, high occupancy and crowding were found to contribute to fire risk in varying degrees across Canada, but particularly in Alberta, Manitoba, Quebec, and Saskatchewan [6].

To start the process of documenting and understanding specific fire risk related factors that affect First Nations populations, the 2020 report by Huesken et al. [6], summarized in [15], examined census data from 624 First Nation/Indian Band or Tribal Council areas. They developed a method to quantify relative risk across these communities using nine variables

[3] and concluded that in 2016, over 166,7000 Indigenous people[4] were living at high risk of fire due to prevalence of at least seven of the nine risk factors in their communities. From this basis, it is important to draw a priority ranking list for factors to target risk-based, prevention-focused intervention strategies. To this end, this research undertakes more in-depth documentation and investigation of technical household fire risk and hazard scenarios associated with crowding, occupancy, housing condition and the need for major repairs in First Nations communities. The derived data can then be used to set evidence-based benchmarks against which to propose risk-reduction strategies or technologies to build more resilient fire-safe homes.

4 Methods

A review of literature and existing data sources was conducted to compile and assess information pertinent to residential fire safety. Relevant fire safety findings from the literature were reviewed to provide important background and context. Particular emphasis was placed on investigating known relations between housing condition, maintenance, residential fire risk and home fire safety, as well as strategies for risk mitigation, fire prevention and education. From this, common household fire ignition sources and scenarios were identified and links developed between typical fire risks, preventative measures and the 5E's - Education, Enforcement, Engineering/Environment, Emergency response and Economic incentive - of fire prevention [20].

Direct sources of data on housing condition and fire incidents in Canadian communities included reported information from the 2016 and 2021 censuses, fire incident reports submitted by First Nations communities to the National Incident Reporting System (NIRS), as well as data and comments in Home Safety Assessments (HSA) compiled by the National Indigenous Fire Safety Council (NIFSC). Census data was first used to develop more in depth understanding of the current housing situation in rural and on-reserve First Nations communities. Data from the National Incident Reporting System (NIRS) and available Home Safety Assessments (HSA) were reviewed to evaluate connections between reported technical fire risk factors (such as: ignition source, ventilation and overall condition of structures) and their relation to frequency and extent of 'fire incidents' in First Nations residential environments. The NIRS data was filtered and analyzed to better estimate distributions of fire incidents across communities and to identify commonly occurring ignition sources and locations in the reported incidents. These were compared to common ignition sources reported in other documentation and groupings of similar fire risk factors were combined into broader technical fire risk categories. With the above information, HSA questions were filtered and similarly grouped into broad technical fire risk categories. The data was then analyzed to determine a consistent set of fire risk categories. Although based on a very small subset

[3]Proportion of residents who were (1) aged under 6, (2) aged over 65, (3) frequently moving house, (4) unemployed, (5) lone parent families, (6) living in houses requiring major repairs, (7) living in crowded houses (more people than rooms), (8) living in high occupancy houses (5+ people), and (9) renting housing.

[4]by 2021, this number would grow to over 182,000 people based on the current population growth

of data, the percentages of potential issues within and across communities were estimated both across individual questions in the reports, and within broader categories. In this way, connections were drawn, as appropriate, between information provided through the census, NIRS incident data and observations recorded on household conditions in the HSA reports. Key results from the literature review were very briefly summarized in Section 3; further details of the methods used in the census, NIRS and HSA data analyses are contained in Sections 4.1 through 4.3 below.

4.1 Analysis of Canadian Census data

A general overview of the census data relating to housing distribution and condition for select on-reserve First Nations and other non-Indigenous rural communities was developed from the 2016 and 2021 census profiles. Four groupings of communities were chosen for comparative analysis as follows:

(a) 24 on-reserve First Nations communities from NIRS incident data.[5]

(b) 16 on-reserve First Nations communities from the 14 sets of HSA data[6].

(c) a selection of 13 on-reserve Indigenous communities not in the HSA or incident databases.[7]

(d) a selection of 37 non-Indigenous rural communities[8].

Data were extracted for each community from the 'Housing' census topic in 2016, and the following specific census topics in 2021:

- Population and Dwelling Characteristics
- Household and Dwellings Characteristics, and
- Household Characteristics

. For both years, the following fields were extracted from the truncated census data:

- Total Private Households
- Band Housing
- Housing Suitability
- Occupied Private Dwellings by Period of Construction, and
- Average Number of Rooms per Dwelling

Statistics related to dwelling condition were extracted from separate and later published data tables [21, 22]. In these, the total number of occupied dwellings in a given community were tabulated with the numbers of dwellings that required each of 'general maintenance', 'minor repairs' and 'major repairs', respectively.

[5]Alberta (6), Saskatchewan (4), Manitoba (5), Ontario (4), Quebec (2), New Brunswick (3)

[6]Alberta (9), Saskatchewan (1), Ontario (1), Quebec (3), Nova Scotia (1), New Brunswick (1)

[7]British Columbia (2), Ontario (4), Quebec (3), Nova Scotia (2), New Brunswick (2)

[8]Yukon (2), British Columbia (5), Alberta (5), Saskatchewan (4), Manitoba (2), Ontario (4), Quebec (6), Nova Scotia (3), New Brunswick (3), Prince Edward Island (3)

Once the data was collected, each of the absolute counts for each category of 'Dwelling Condition', for 'Housing Suitability' and for numbers of 'Occupied Private Dwellings by Period of Construction' over each time period were tabulated for each community. Each of the three factors under 'Dwelling Condition', as well as the factor for 'Housing Suitability', were converted into rates of occurrence by normalizing with the reported total number of private households for that community. From that, the minimum, maximum, and average rates of occurrence were also calculated across all communities within a given analysis group: NIRS, HSA, select Indigenous communities and non-Indigenous rural communities, respectively. To verify the validity of the average value, the standard deviation for the rates of occurrence of each field were also calculated to measure the dispersion of the data with respect to the average.

4.2 Analysis of NIRS data

Fire incident data entered into the National Incident Reporting System (NIRS) for 13 years between 2009 and 2022 was evaluated to determine reported causes and locations of fire incidents, injuries and fatalities[9]. The NIRS data used in this analysis consisted of 1270 incidents logged over the 13 year reporting period[10]. It should be noted that the results reported here must be interpreted with care since the information presented comes from a very small and incomplete set of data in combination with any limitations noted in [7].

For the present analysis, the 1270 NIRS entries were filtered to extract those incidents that related to residential fires, as per the focus of the present research. In the initial stage of analysis, approximately 230 incidents apparently related to fires in residential structures were identified using the 'Property Use Type' entries, including all variances and typographical errors in entry[11] In an attempt to maximize the size of the final dataset, six 'Property Use Type' entries that were unclear were retained at this stage of analysis as well[12]. Further examination of the latter entries illustrated that they contained fire incident data for a mix of residential and non-residential properties. Incidents in the latter category (approximately 42 in total) were deleted and only those incidents at confirmed residential properties[13] were retained in the analysis, resulting a set of 188 incident records.

These 188 records were further filtered to ensure they related to fire events. This was done using information in the fields 'Type of Report', 'Additional Remark 2', 'Describe Incident',

[9]The NIRS data is voluntarily reported by local Canadian authorities in the event of a fire so it does not include information from all fires within a community or geographic area.

[10]According to a recent report[7], the majority of incidents (60%) were logged in 2021. Of these, 53% of the fire incidents were in Alberta with one Band accounting for over 50%, and six Bands for over 70%, of the total number fire incidents. In addition, due to specific requests to log information associated with fatal fires, the NIRS data tends to under-represent those fires which did not involve loss of life

[11]The filtered values included Abandoned Home, Abandoned Dwelling, Apartment (all variations), Dwelling (all variations), House/home (all variations), Residential (all variations) and RV (all variations).

[12]Additional data came from 'Property Use Type' listings for 'Elsipogtog', 'Kahnawake', 'Nipissing First Nation', 'Pekuakamuilnuatsh Takuhikan', 'structure', 'Taillon and son farm'.

[13]Confirmed based on examination of listed property values, property square footage, and a search of each incident address.

and 'Person Completing This Report', four fields in which instances of false alarms, medical assistance only and non-fire related events were reported. This resulted in removal of an additional 13 records [14].

The resulting 175 incidents were then used directly or filtered further to better estimate:

(a) the number of residential fire incidents reported on a per community basis of incidents between the years 2021-2022,

(b) the types and prevalence of ignition sources reported across incidents as well as correlations between ignition source, injury and fatality,

(c) the location of fire origin with respect to type of ignition source across incidents as well as correlations between ignition location, injury and fatality, and

(d) the prevalence of suspicious fires.

The specific filtering and methods used for each analysis are described in the sections below.

4.2.1 Number of Residential Fires (Community distributed)

The number of residential fires reported on a per community basis was estimated by:

(a) grouping incidents with respect to community, band number, band name and province, then cross-checking location according to First Nation names and corresponding band number(s) so the populations could be sourced from [23][15],

(b) determining the population from [23] using the 'Registered Pop.' tab under the General Information heading. Here, the sum of the number of 'Registered Males/Females On Other Reserves' and 'Registered Males/Females Off Reserve' from the table were deducted from the Total Registered Population to estimate the population for that Nation [16],

(c) normalizing the number of fire incidents per 1000 people by dividing the population above by 1000[17], and

(d) determining the number of fire incidents per 1000 people/year by dividing the number of fire incidents for a given community by the normalized population value.

[14] These related to incidents described as 'False Smoke Alarm', 'Medical Lift Assist', 'Medical Assist', 'CO_2 False Alarm', 'Cat caught in furnace ducting', 'Ice rescue' and 'Landslide'

[15] Care had to be taken in doing this since entries into the NIRS were a mix of local community names, names of Nations or bands, band numbers from the Government of Canada database [23] and on-reserve numbers.

[16] The number of Registered Males/Females on Crown Land were not deducted since those categories were very small numbers (e.g. many zeroes and many others less than 10 people).

[17] the smallest community in the dataset had a population of 27 people.

4.2.2 Determination of Ignition Sources

To estimate the number of residential fires that were related to a particular type of ignition source, the following analysis was done:

(a) the 175 records were filtered to separate those incidents where the source of ignition was recorded as 'Cooking Equip', 'Electrical', 'Heating Equip', 'Matches', 'Smokers material', 'Wood Stove', 'Other', 'Not Applicable' or 'Undetermined'. This excluded records where the ignition source was listed as 'Grass/Brush', 'Vehicle' or blank leaving 142 records, and

(b) since only those fire incidents with defined sources of ignition were of interest in the final analysis, 66 incidents that listed the ignition source as 'Other', 'Not Applicable' or 'Undetermined' were further examined and 55 of those were removed leaving 87 records used in the final more detailed analysis of ignition source distribution.

4.2.3 Relation of Ignition Source to Location of Fire Origin, Injury and Death

The 87 fire incidents for which the source of ignition was listed were further analyzed to relate the source of ignition to the location of fire origin by:

(a) filtering the incidents based on 'Area of Origin'[18],

(b) tallying the number of occurrences of each igniting object in each area of origin, and

(c) filtering the 87 incidents to determine the number of those fires that led to injury or death by a given ignition source, in a given area of origin respectively.

4.2.4 Suspicious Fires

In addition to the above incidents, 25 residential fire incidents were identified as being suspicious based on the entry of 'Act or Omission' in the NIRS report. These were also analysed to determine the prevalent sources of ignition.

4.3 Analysis of Home Safety Assessments (HSA)

The compiled Home Safety Assessment reports (HSA) from 14 communities were evaluated to assess connections between the logged responses to the HSA questions and information recorded in the NIRS incident data. The areas for which HSA audits were available included 5 from Alberta, 2 from Saskatchewan, 1 from Ontario, 3 from Quebec, and 1 each from Nova Scotia and New Brunswick[19]. Of these communities, 7 had also reported incidents in the NIRS database.

[18] Blank entries were removed so final incidents included those with an area of origin in the single categories of 'Living Room', 'Bedroom', 'Kitchen', 'Undetermined' and 'Not Applicable' and combined categories of 'Basement'/'Electrical Room', 'Bathroom'/'Laundry Room', and 'Garage/Shed/Deck/Exterior'.

[19] It must be noted that the information used in this analysis comes from a very small sample size. As such, the results must be interpreted with care.

The 251 comments written into the HSA files were screened for relevance to fire safety based on information related to overall condition of a structure as well general home maintenance. A list of common observations was compiled based on the results.

Responses to the 33 specific questions included in the full HSA were then evaluated in more detail. It was found that 29 of these questions contained data relevant to understanding housing condition, general home maintenance and use of fire safety systems. These questions could also be grouped into 5 broader technical categories[20] that have known associated fire risks in residential buildings. Two additional categories related to condition of existing fire safety solutions, i.e, CO and smoke detectors and fire extinguishers, and home fire safety plans were also included. To better understand the fire risk profiles associated with each category, the data was evaluated as follows[21]:

1. Each question was examined to determine the response (yes/no/NA) that related to an increased risk of initiating, exacerbating or rendering occupants unable to escape a fire. For all questions, this response was always 'No'.
2. The total number of 'Yes' and the total number of 'No' responses to each question were determined by summing those responses, respectively, for each community.
3. The total number of valid responses to each question for each community was calculated as the sum of the total 'Yes' and total 'No' responses determined in 2.
4. The ratio of the total number of 'Yes' (or the total number of 'No' responses) determined in 2., over the total of "Yes" plus "No" responses determined in 3., was calculated to determine the percent of 'Yes' and 'No' answers, respectively, for each individual question and community.
5. The average percent possibility of there being a 'No' answer for a given question was then determined by averaging the results for that question in 4. across communities.
6. The upper and lower bounds on risk for the 14 communities were taken, respectively, as the highest and lowest percent 'No' answers (from 4.) across communities
7. Finally, the percent possibility of there being a 'No' answer for those questions in each broader risk category was found by taking the average of the average percentages of 'No' answers for that set of questions across all communities.

5 Results

The following sections contain results of the analyses outlined above.

[20] Electrical, Plumbing, Heating, Egress, Housekeeping

[21] It should be noted that 'N/A' answers within a given community were not included in the analysis; similarly when an entire question was answered as 'N/A', or was not answered, by a given community that community were excluded from any cross community averages (Part 6) as well.

5.1 Review of Literature

The literature review identified a wealth of sources containing information relevant to housing condition, residential fire risks, their frequency of occurrence and relation to household maintenance, housing conditions and fire incidents in both Indigenous and non-Indigenous communities [5–9, 24, 25]. Sources also included research results and reports related to residential ignition sources, fire incidents and associated fire prevention measures [16–20, 26]. From these, as set of common ignition sources could be extracted:

- failure/faults in electrical system,
- poorly maintained appliances and systems,
- overloaded equipment,
- combustibles too close to heat,
- heating systems,
- unattended cooking,
- discarded smoking materials, and
- matches, open flames.

Recent studies have also discussed clear links between low household income, family structure and poor dwelling conditions, as they relate to fire risk [8**?**]. In this respect, household condition and maintenance factors can be described in several different fashions. For the present work, definitions for state of repair and suitability of housing are taken from the definitions of 'Dwelling Condition' and 'Housing Suitability' in the Canadian Census dictionary, as [27]:

- 'Regular maintenance needed' category, includes dwellings where only regular maintenance such as painting or furnace cleaning is required.
- 'Minor repairs needed' category, includes dwellings needing only minor repairs such as dwellings with missing or loose floor tiles, bricks or shingles; or defective steps, railing or siding.
- 'Major repairs needed' category, includes dwellings needing major repairs such as dwellings with defective plumbing or electrical wiring; and dwellings needing structural repairs to walls, floors or ceilings.
- 'Housing suitability' refers to whether a private household is suitable for accommodations according to the National Occupancy Standard (NOS); that is, whether the dwelling has enough bedrooms for the size and composition of the household. A household is deemed to be suitable for accommodations if it has enough bedrooms, as calculated using the NOS.

Residential housing condition considers the technical aspects of the building, such as the construction quality, electrical systems, and heating systems [25]. Some common indicators of poor state of repair of a residence include:

- missing or damaged doors and windows,
- defective, faulty or exposed wiring,

- gaps, cracks or penetration through exterior walls
- shifting, cracking of foundations,
- gaps, cracks or penetration of interior wall lining materials,
- defective plumbing,
- clutter, overcrowding with poor egress paths,
- poor ventilation systems, and
- excess ventilation

Links can be made between the ignition sources, state of repair of housing and prevention or intervention measures based on solely technical fire prevention or mitigation solutions or through broader approaches using principles embodied in the 5E's of fire prevention: Education, Enforcement, Engineering/Environment, Emergency Response and Economic Incentives [18, 20, 25, 26, 28].

5.2 Results from Canadian Census Analysis

As mentioned previously in Section 4.1, the housing data is extracted for 16 on-reserve First Nations communities from the 14 sets of HSA data; for 24 on-reserve First Nations communities from the NIRS incident data; for a selection of 24 on-reserve First Nations communities not in the HSA or incident databases; and a selection of 37 non-Indigenous, rural Canadian communities. Of the six major topics extracted[22], those of most concern in this analysis are: housing suitability, condition of dwelling, and the period(s) of construction for the homes in the various communities.

Before considering the dwelling condition or housing suitability across the communities, it is useful to consider the age or period of construction of the dwellings. Figure 1 shows the age of construction of homes in each of the provinces for the on-reserve communities for which NIRS data was available. It is clear from the plot that the majority of homes on reserves in all provinces were built between 1961 and 2000, with significantly less homes built in each 5 year time period following that. Figure 2 illustrates the same trends in the aggregated data for the on-reserve communities for which HSA data was available.

[22]Described in Section 4.1

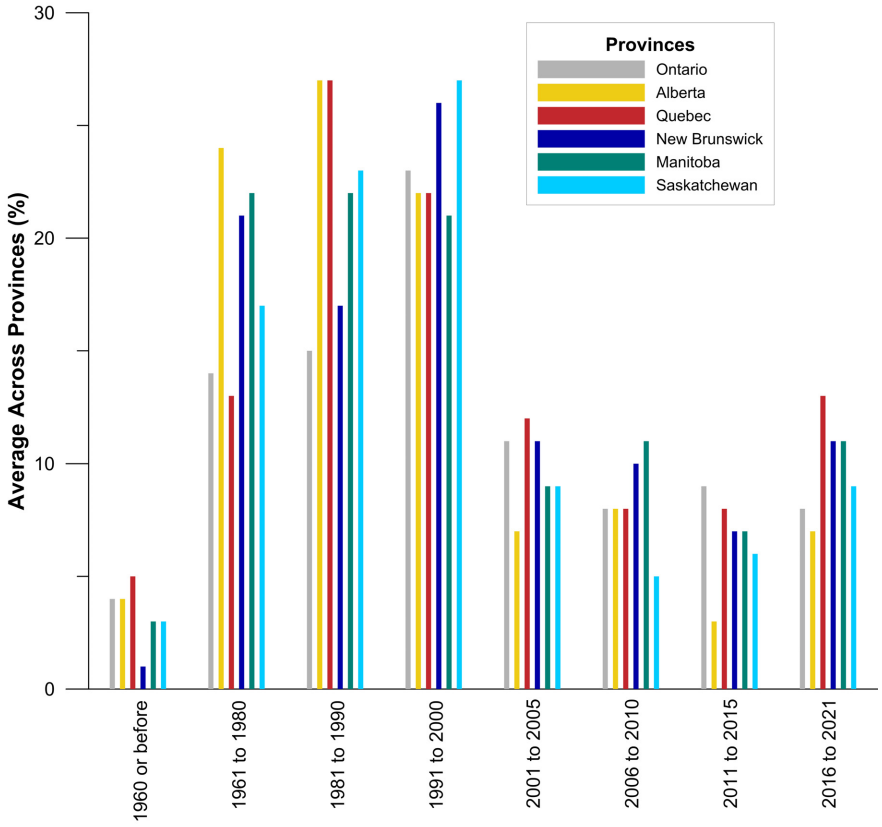


Figure 1: Distribution of homes constructed, by period of construction (NIRS)

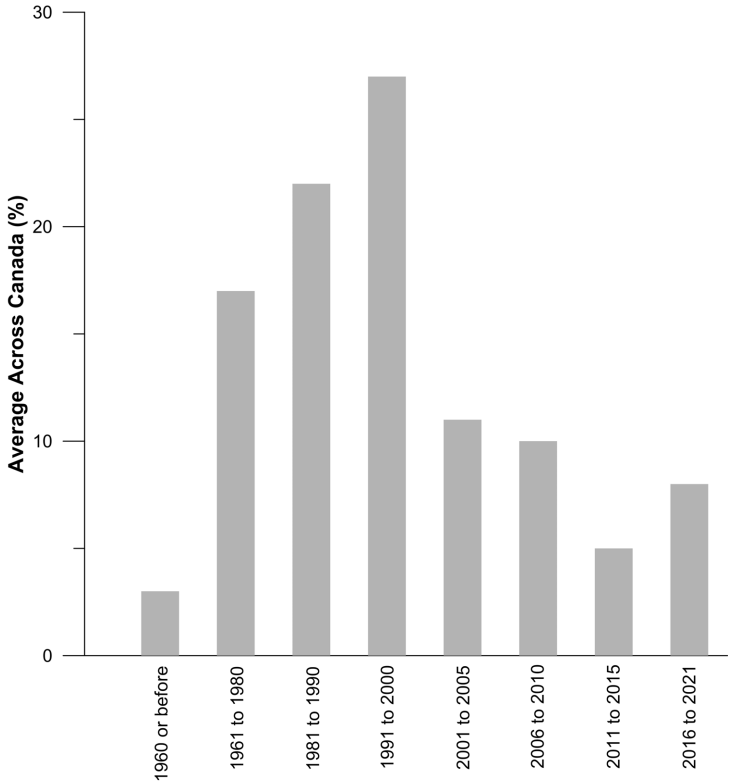


Figure 2: Distribution of homes constructed, by period of construction (HSA)

Figures 3a) through d) show 4 pie charts containing similar information for NIRS, HSA, the randomly selected First Nations and rural non-Indigenous communities, respectively. Results indicate similar distributions of homes by period of construction amongst the the First Nations communities. Figures 3a) through c), with some striking differences for the non-Indigenous rural communities (Figure 3d). As with the NIRS and HSA communities above, dwellings in the the randomly selected First Nations were also predominantly built between 1961 and 2000, with similar percentages, 6-10% new homes being built in each five year increment from 2000-2021. The consistency of housing age across all First Nations suggests that the NIRS and HSA data analyzed here, while only a small set of data, may provide representative examples, in terms of housing age at least, of homes in a large cross-section of on-reserve communities across Canada.

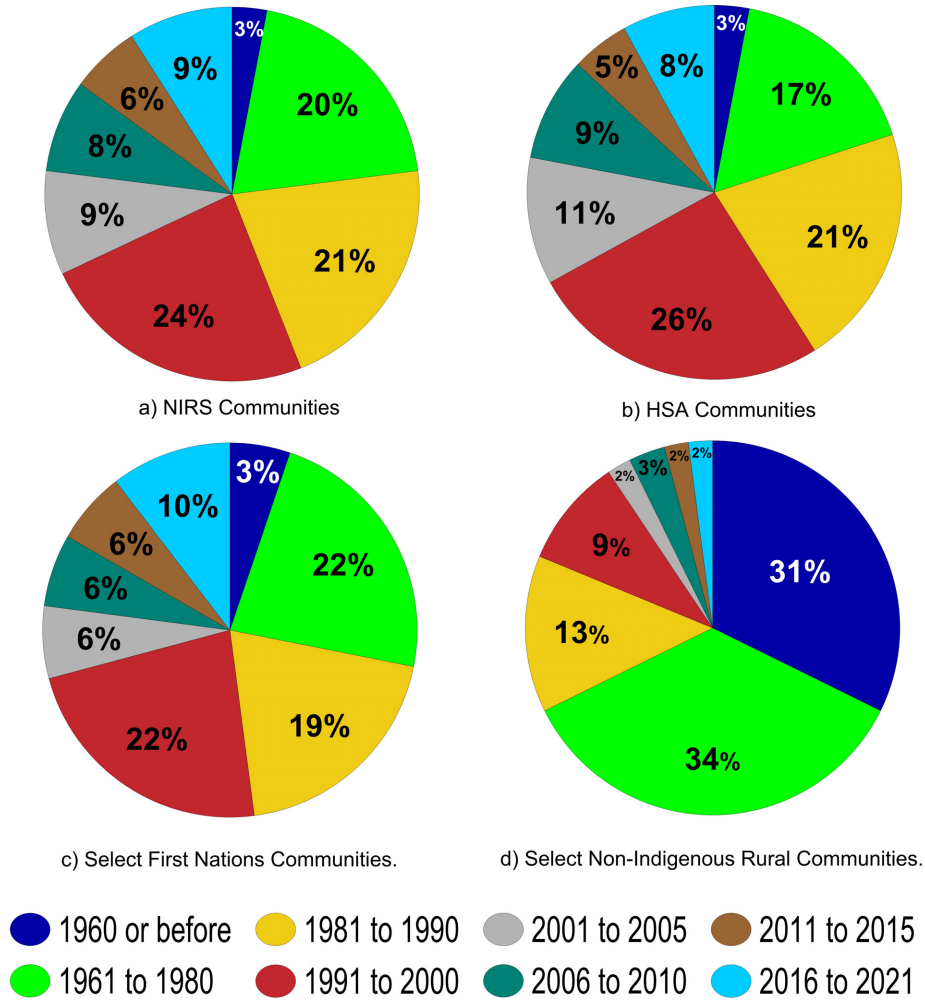


Figure 3: Distribution of homes constructed, by period of construction for: (a) NIRS Communities, (b) HSA Communities, (c) Selected First Nations Communities, and (d) non-Indigenous Rural Communities

Dissimilar from the homes in on-reserve First Nations communities are the 37 non-Indigenous, rural communities also shown in Figure 3d). The dwellings in these communities tend to be older, with 65% of homes built before 1980 and most before 1990, and only a few newer dwellings.

The pie charts in Figure 4 allow comparison of the average of state of repair (dwellings requiring major repairs, minor repairs, or general maintenance) of dwellings for each of the First Nations groups in 2016 and 2021, respectively. Across all sets of communities, the condition of dwellings is the same or possibly marginally better in 2021. In Figure 4, a large percentage, 30-48%, of homes require major repairs with a substantial subset of those dwellings, 11-25%, deemed entirely unsuitable.

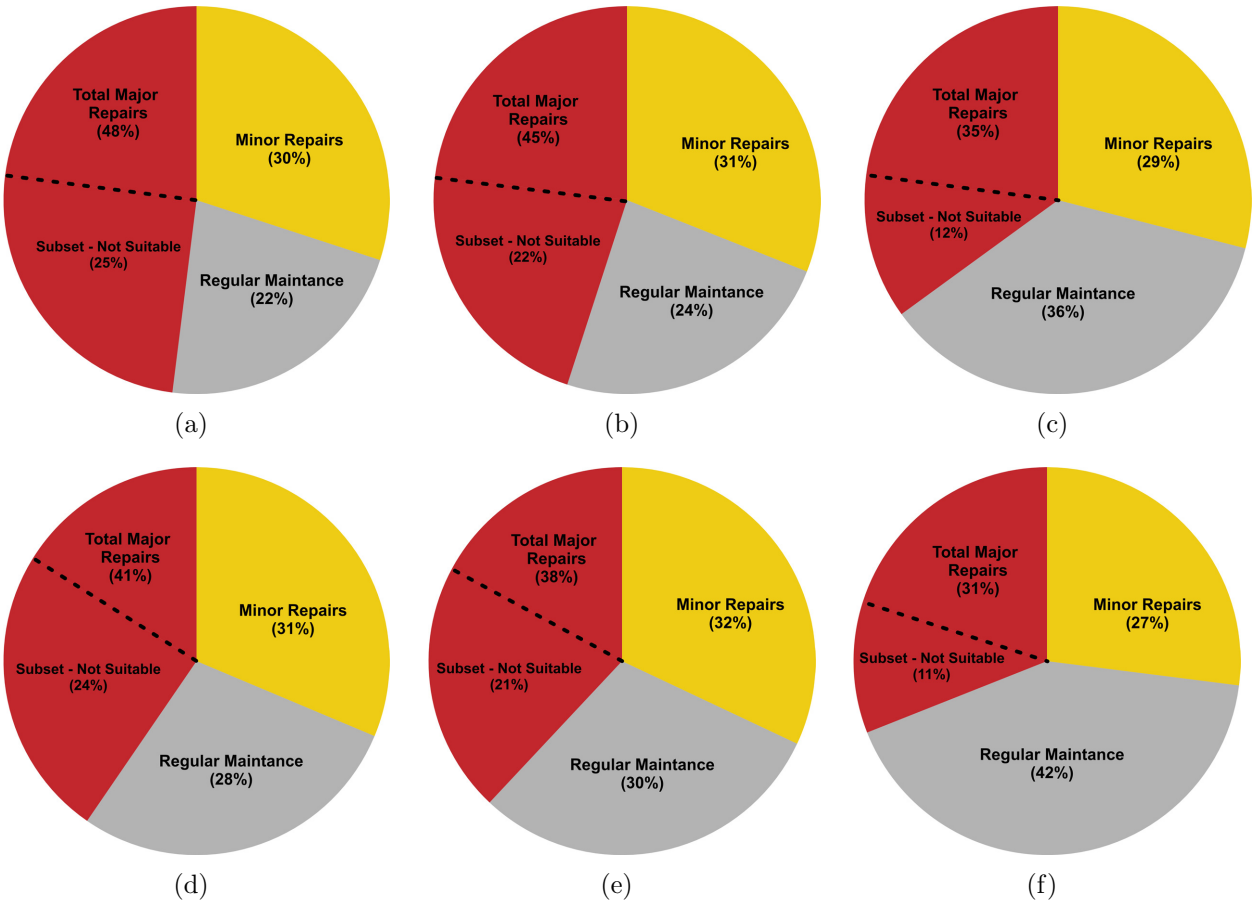


Figure 4: Average state of repair for: (a) NIRS Communities 2016 (b) HSA Communities 2016 (c) Select First Nations Communities 2016, and (d) NIRS Communities 2021 (e) HSA Communities 2021 (f) Select First Nations Communities 2021

Examining the distribution of the state of repair for dwellings in different provinces also provides insight into which communities may be better off than others. The sets of pie charts in Figures 5a) through h) and 6a) through h) illustrate the provincial breakdowns,

in 2016 and 2021 respectively, of dwelling condition for the NIRS communities located in Alberta, Saskatchewan, Manitoba, Ontario, Quebec and New Brunswick and the Selected communities in British Columbia and Nova Scotia, respectively. It is clear that dwellings in communities in Ontario, Quebec and New Brunswick are generally in a much better state of repair than those in Alberta, Saskatchewan and Manitoba. In Ontario, Quebec and New Brunswick the percent of dwellings requiring major repairs is below 32% while in the other provinces it is over 43% and ranges all the way up to 63% in Alberta. Accordingly, Ontario, Quebec and New Brunswick also have the smallest percentage of unsuitable homes, while the fraction of unsuitable dwellings in Alberta, Saskatchewan and Manitoba is considerably higher. Comparison of the data from the different census years, Figures 5a) through h) and 6a) through h), shows little or no improvement in housing condition between 2016 and 2021, with communities in some provinces (notably Saskatchewan and Manitoba) getting worse.

The pie charts in Figures 7a) and b) illustrate the state of repair, in 2016 and 2021 respectively, of dwellings for the non-Indigenous rural communities. Referring to Figures 8 and 9, the homes in the rural non-Indigenous communities, although generally older, are in a much better state of repair, compared to that of First Nations communities.

In 2016 and 2021, across all provinces in non-Indigenous rural communities, 9-10% of houses required major repair, with 2-3% categorized under the subset of not suitable (refer to Figures 8 and 9). These numbers are in stark contrast to the percentages in First Nations communities, as highlighted in Figures 5 and 6) where 30-48% of dwellings required major repairs, and of that, 11-25% were deemed unsuitable. Despite these large differences in percentages of homes requiring major repairs, when considering the provincial breakdowns of the state of housing in both rural non-Indigenous and First Nations communities, a pattern does emerge; generally, it can be seen that provinces that have higher levels of disrepair in First Nations communities also have higher levels of disrepair in non-Indigenous rural communities. For example, non-Indigenous rural communities in Quebec and New Brunswick have lower states of disrepair compared to communities in Alberta and Manitoba. Positively, when comparing the differences between census years, most non-Indigenous rural communities, as well as First Nations communities, show improvements in dwelling conditions from 2016 to 2021, with a few exceptions. Overall, the large discrepancies in the percentage of homes needing major repairs across provinces, between First Nations communities and non-Indigenous rural communities, is quite telling. Recalling the statistics presented in Section 1: Context, that Indigenous peoples were subject to 5 times higher risk of casualty in a fire than non-Indigenous people, paired with the links between the incidence of fire rates, state of repair, and income level that have been established [8, 29], it is expected that as a result of poor housing conditions, First Nations communities would experience a higher rate of fire events. The nature of these relations will be examined further in the following sections.

Figure 5: Average state of repair of dwellings in NIRS communities, 2016: (a) Alberta (b) Saskatchewan (c) Manitoba (d) Ontario (e) Quebec (f) New Brunswick; and average state of repair of dwellings in selected First Nations communities, 2016: (g) British Columbia (h) Nova Scotia

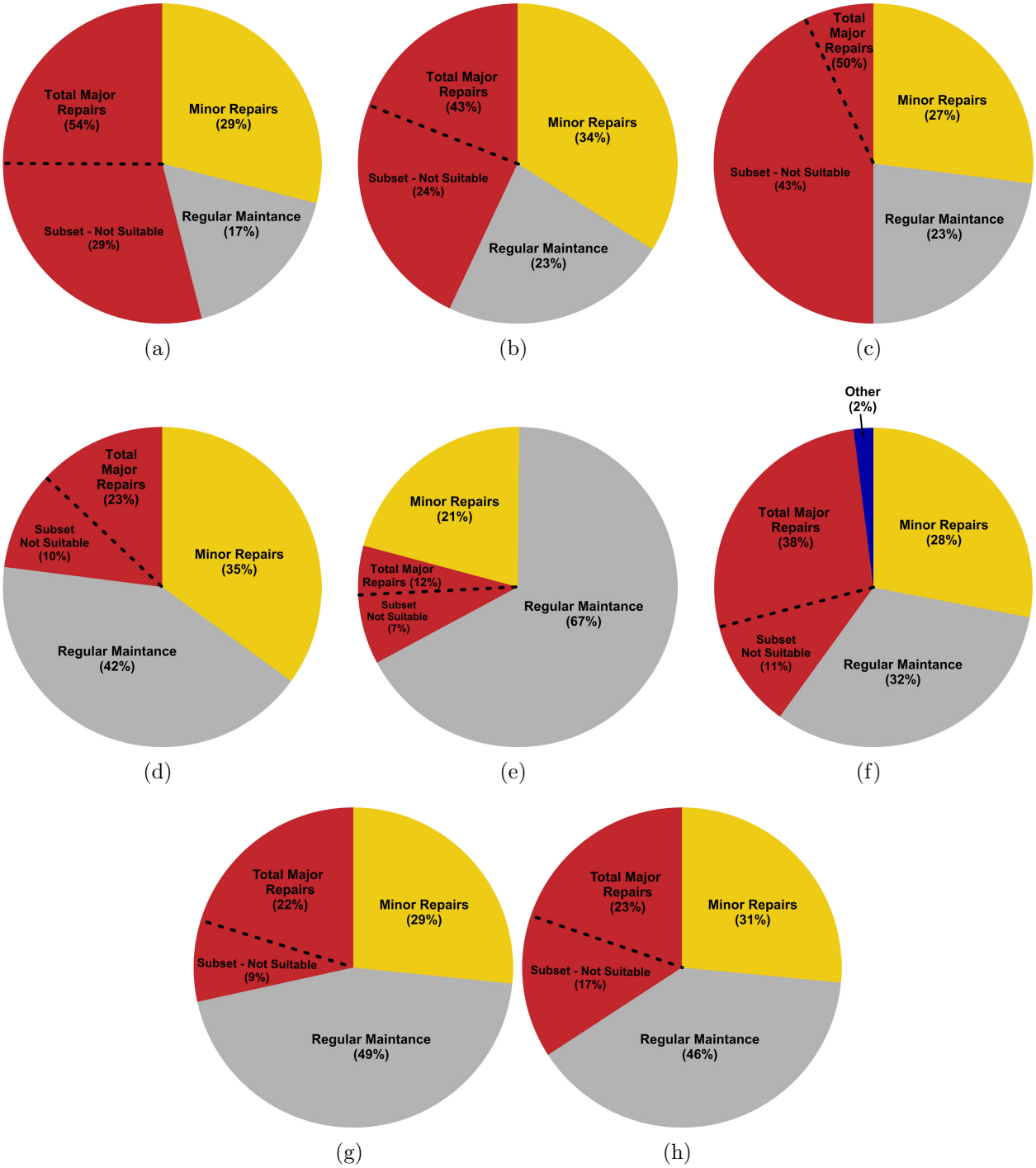
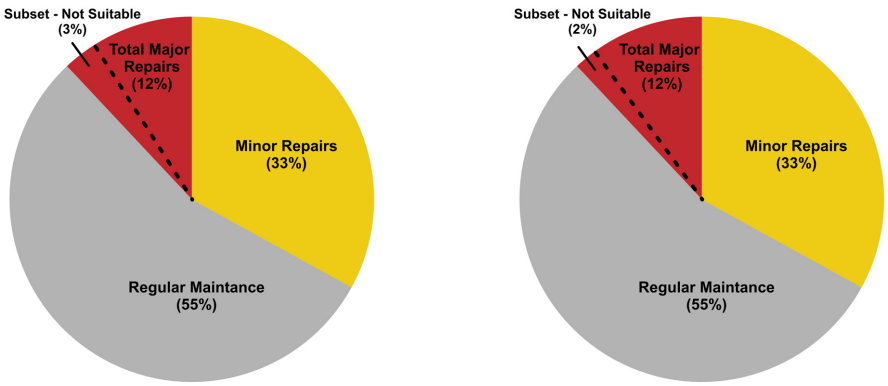


Figure 6: Average state of repair of dwellings in NIRS communities, 2021: (a) Alberta (b) Saskatchewan (c) Manitoba (d) Ontario (e) Quebec (f) New Brunswick; and average state of repair of dwellings in selected First Nations communities, 2021: (g) British Columbia (h) Nova Scotia



(a) (b)

Figure 7: Average state of repair of dwellings in non-Indigenous rural communities (a) 2016 (b) 2021

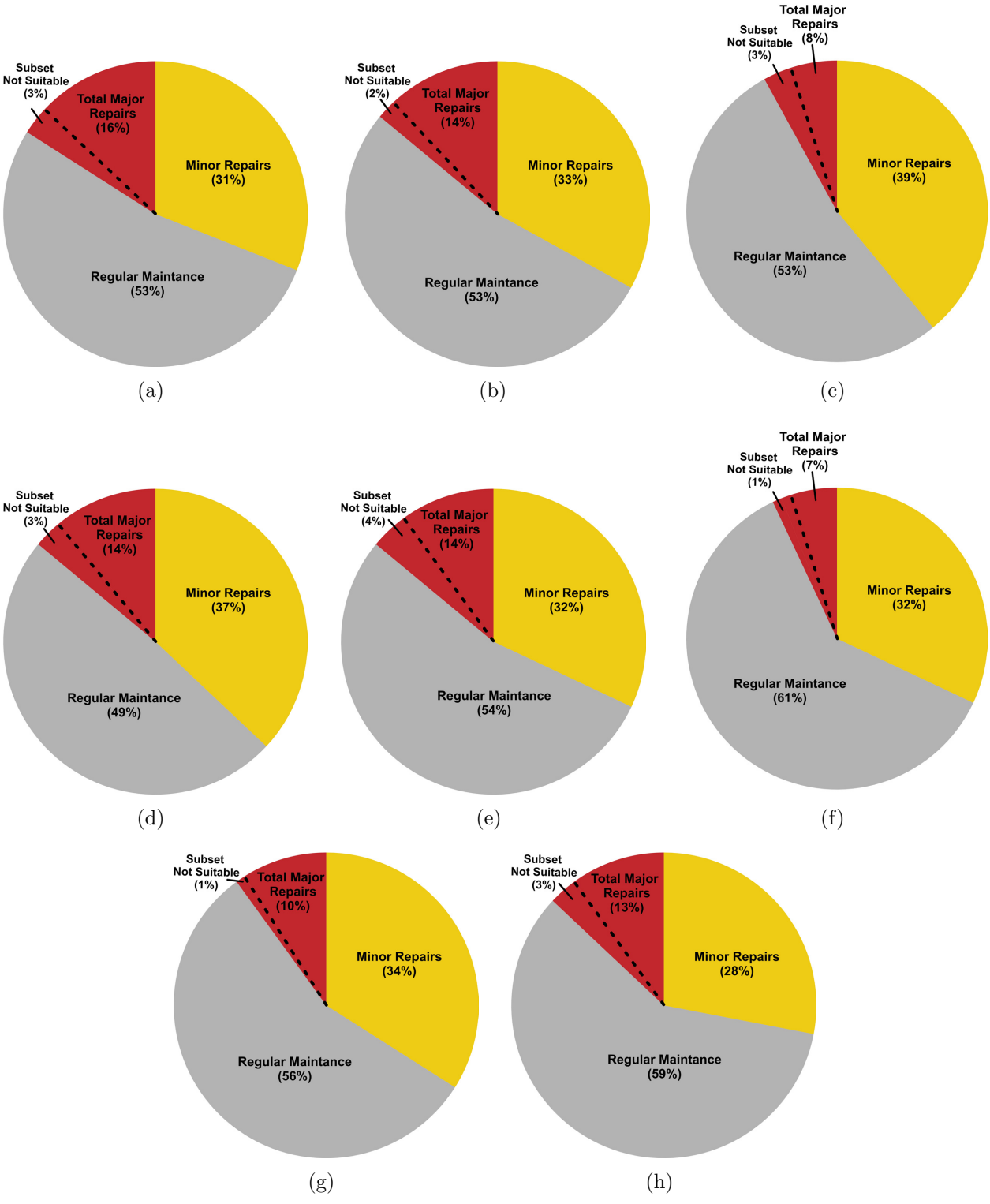


Figure 8: Average of state of repair of dwellings in non-Indigenous rural communities, 2016: (a) British Columbia (b) Alberta (c) Saskatchewan (d) Manitoba (e) Ontario (f) Quebec (g) New Brunswick (h) Nova Scotia

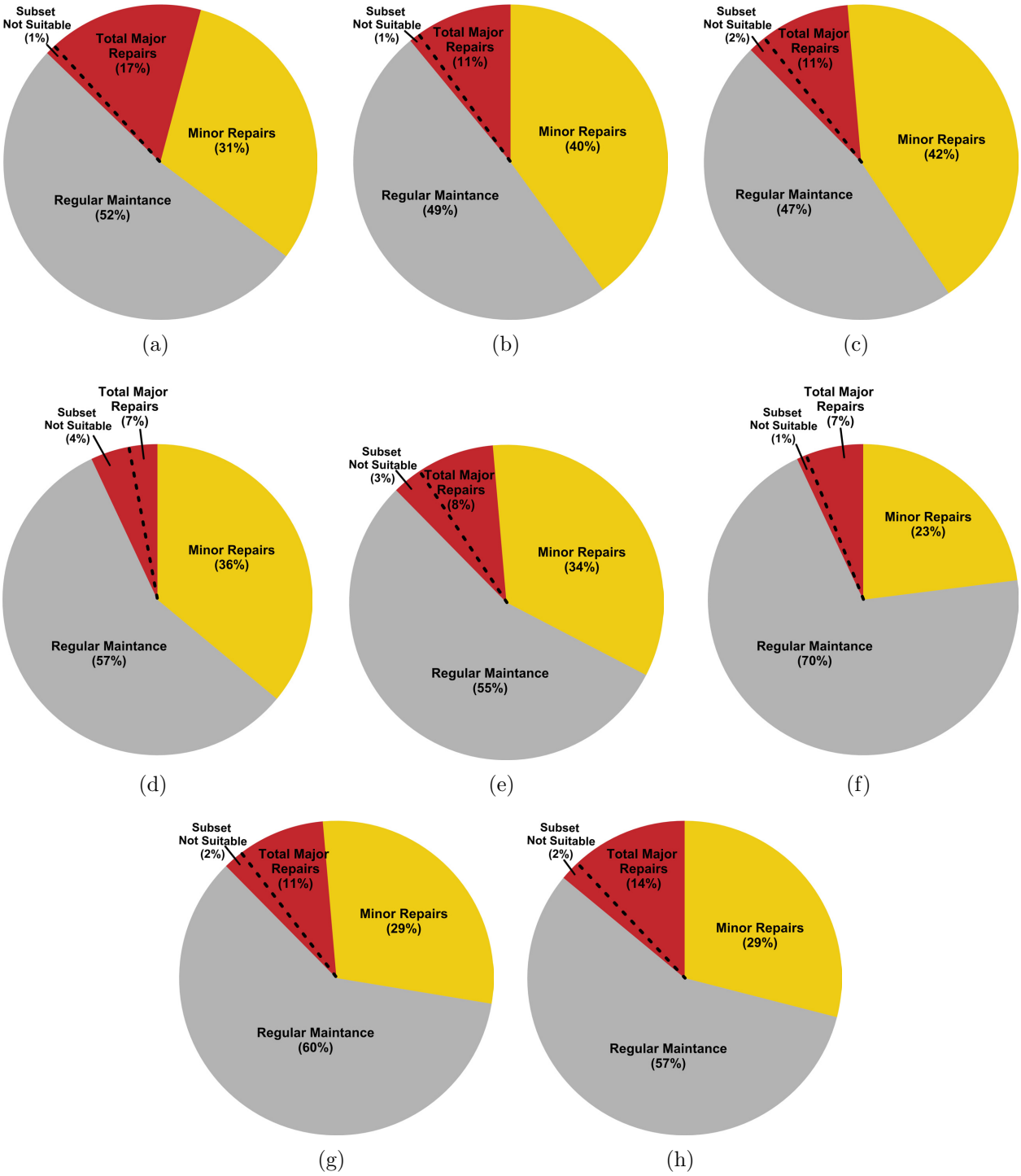


Figure 9: Average of state of repair of non-Indigenous rural communities, 2021: (a) British Columbia (b) Alberta (c) Saskatchewan (d) Manitoba (e) Ontario (f) Quebec (g) New Brunswick (h) Nova Scotia

5.3 Results from NIRS Analysis

After analysis and compilation of the NIRS community fire incident data, there were 52 Nations who reported at least one fire incident in the period between 2021 and 2022. On a population normalized basis, approximately 30% of these communities reported more than one fire per 1000 population, with 3 reporting five or more fires per 1000 population over that time period [23].

Results of the more in-depth analysis of the NIRS data with respect to source of ignition, location of origin, injury and death are shown in Figures 10 through 14 and Tables 1 through 3. The most commonly occurring ignition sources in the reported residential fire incidents fell into the broad categories of 'Undetermined', 'Matches', 'Smokers Materials', 'Electrical' systems, 'Cooking Equipment', 'Heating Equipment', 'Wood Stoves' and 'Other'. The categories of ignition source are consistent with those listed for residential fires in the literature [16, 17, 30, 31] and summaries from fire incidents [32–34].

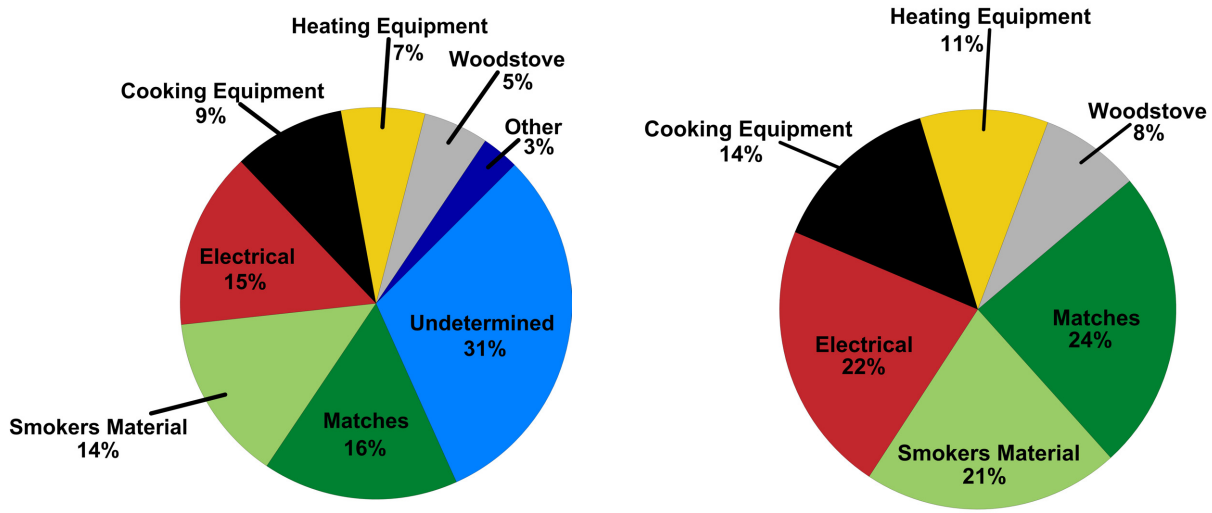
The percentages of fires ignited by sources in each category for the reported incidents are illustrated in the pie charts of Figure 10(a), with 'Undetermined' and 'Other' sources included, and (b), with 'Undetermined' and 'Other' sources excluded, with the latter distribution also tabulated in Table 1. Associated numbers of reported fatalities and injuries are contained in Figure 11. A final comparison is illustrated in Figure 12 where matches and smoking materials have been excluded from consideration to better highlight the distribution of technical ignition sources of most interest in this research.

The largest proportion of fires shown in Figure 10(a) were listed as having unknown sources of ignition (31% 'Undetermined'; 3.1% 'Other'). The overall percentage of unknown ignition sources is lower than the reported value of 55% for fatal fires in First Nations in Ontario [35], comparable to the 31/33% reported across residential fires in Canada (2016/2021 respectively) [36], and higher than values of 15-21% reported for communities in British Columbia and Ontario [34, 37]. This category of ignition often relates to structures that have sustained significant damage during the fire; however, it provides little additional information on the technical fire risk factors related to housing condition so is removed from further consideration here. At the same time, the high percentage of 'Undetermined' sources found in the records does indicate a need to improve the clarity and consistency of reporting information in the NIRS database to minimize the number of instances listed with 'Undetermined' ignition sources. In cases when the ignition source can be determined, it is important that it is entered into the ignition source column of the NIRS incident report[24]. Clear and consistent reporting would greatly minimize the volume of missing information and facilitate automatic data processing during later analysis[25].

[23] It should be noted that all of those reporting over 5 fires have recorded populations less than 400 people, with one having a population less than 100 people.

[24] in the present analysis, there were incidents for which 'Undetermined' was listed in the ignition source column but information on the source of ignition was actually found entered into a different column in the spreadsheet

[25] for further information on this, see also [7].



(a) (b)

Figure 10: Ignition categories in residential fire incidents from NIRS: (a) all categories (b) categories without 'Undetermined' and 'Other' ignition sources

To proceed with the analysis here, the categories of 'Undetermined' and 'Other' sources of ignition are removed and the redistributed distributions of incidents by fire source are shown in Figure 10(b) and summarized in Table 1 to illustrate the relative prevalence of commonly defined sources of ignition across the residential fires reported. The highest proportion, 45%, of fires are ignited by matches (24%) and smokers materials (21%), as seen in Figure 10(b). This proportion is higher than the 20-31% reported for these two ignition categories across fires in recent fire statistics summaries [34, 37–39].

Between matches and smokers materials as sources of ignition, the present data is consistent with other information, in that the number of reported fire incidents initiated by matches was larger than for smokers materials. It is important to note, as well, that fires ignited by matches were linked to more injuries in this subset of incident data, while fires initiated by smokers materials led to higher risk of fatality (Figure 11).

Table 1: Number of fires by ignition source

Ignition Source	Number of Occurrences
Matches	21
Smokers Materials	18
Electrical	19
Cooking Equipment	12
Heating Equipment	9
Wood Stove	7

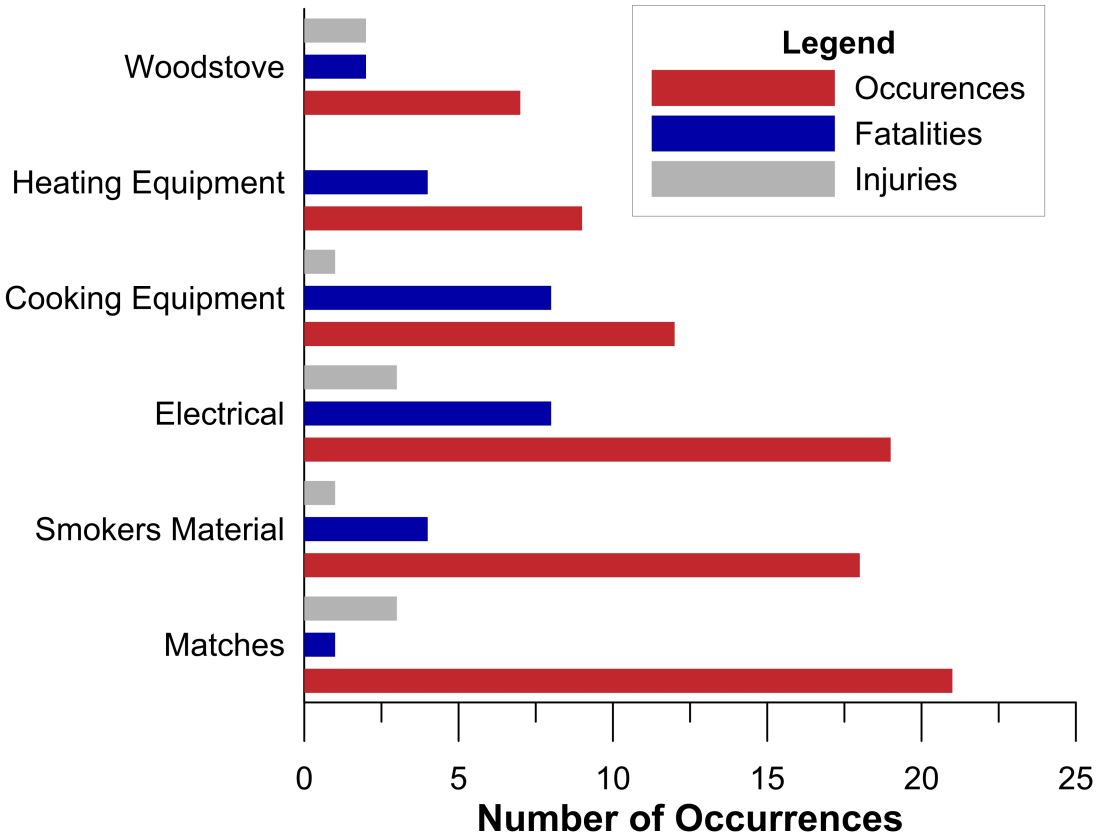


Figure 11: Number of occurrences, fatalities, and injuries across ignition categories

Table 2 summarizes the relation between matches, smokers materials and suspicious fires [26] The primary ignition sources for fires also classified as suspicious was matches (60%) with smokers materials being involved in the other 40% of incidents analyzed. Further and more in depth analysis of these fire categories is also recommended, though outside the scope of the present research.

Table 2: Ignition sources in suspicious fire incidents

Ignition Source	**Number of Incidents**	**Percentage**
Matches	15	60
Smokers Materials	10	40
Total Amount	25	100

Matches and smokers materials are found to be the most common sources of ignition in residential fires amongst the communities studied. Due to the high risk of death and injury in fires associated with these materials, as well as the prevalence of fires ignited by matches and smokers materials, more in depth analysis of the circumstances and fire scenarios associated with these categories of ignition should be undertaken. This would provide important background against which to design intervention programs specifically targeted toward mitigating the impacts of fires initiated by these two types of ignition source. For example, renewed educational campaigns could be carefully designed to specifically target and reduce the number of preventable fires from both matches and smoking materials. Other possible interventions should also be explored and developed in partnership various stakeholders to ensure that they are sustainable and sensitive to the needs of the individual(s) within each community.

Figure 10(b) and Table 1 also illustrate the relative percentages of fires initiated by four other common categories of ignition source. Corresponding numbers of fatalities and injury associated with each of these are in Figure 11. Incidents related to ignition by smoking materials and matches are removed from the analysis and the data re-plotted in Figure 12 to highlight the relative percentage of fires initiated by each of the four key technical fire risk categories most closely associated with housing condition and state of repair. From Figure 12, it can been seen that the majority, 40%, of the fires are initiated by electrical ignition sources, 26% related to cooking equipment, 19% with heating equipment and 15% with wood stoves. This distribution of ignition sources differs significantly from recent statistics published for fatal fires in Canada (2016/2021 respectively) where 30/34% of the fires were due to a combination of electrical distribution, appliances and household equipment, 48/46% of the fires (not including undetermined and smoking materials/matches) were attributed to cooking, and 21/20% to heating equipment [39]; as well as the distribution across all fires in British Columbia (2022) where 32% of the fires were attributed to a combination of electrical

[26] Additional analysis is also present in [7].

distribution, appliances and household equipment, 52% of the fires to cooking, and 16% to heating equipment.

Shown in Figure 11, fires initiated by electrical sources led to the largest number of fatalities in comparison to those ignited by any other source. In addition, these fire scenarios led to levels of injury similar to those attributed to fires ignited by matches. Also striking is that despite the notably lower number of cooking fires reported, similar numbers of fatalities (though less injuries) occurred as for fires initiated by electrical sources. Heating equipment was also associated with ignition in a significant number of fatal fires, with death rates similar in number to those that occurred in fires ignited by smokers materials. Finally, fires associated with wood stoves resulted in a notable number of both injury and death, so this ignition category cannot be dismissed when considering the technical factors that are associated with residential fire risk.

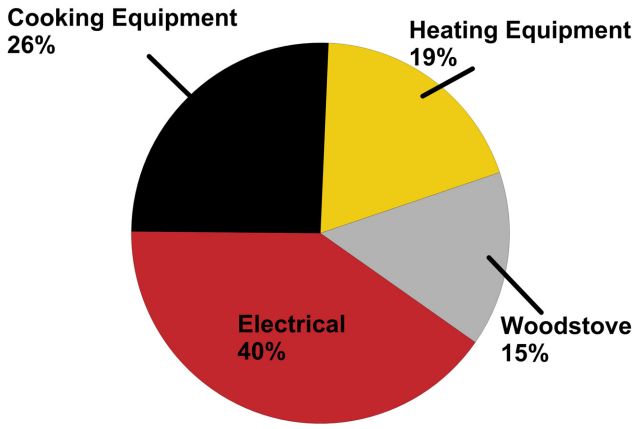


Figure 12: Technical ignition categories in residential fires in NIRS

Correlations between ignition source category and location of fire origin are illustrated in the bar chart shown in Figure 13 with specific numbers listed in Table 3. The location of fire origin was listed as 'Undetermined' for a large number of the fires ignited by matches and smokers materials. Otherwise, however, these ignition categories appeared to be related to fires in most locations inside and exterior to the house. Fires ignited by electrical equipment were most often initiated in the bedroom, kitchen or living room suggesting a high prevalence of electrical ignition sources interior to the structures, while fires ignited by heating equipment occurred largely in the basement or living room. Both of these sources (electrical

and heating equipment) were shown to ignite a lower percentage of fires in other locations throughout the structure as well. As expected, fires ignited by cooking equipment were focused in the kitchen area. Finally, in this data, fires initiated by wood stoves appeared to occur mainly in the living room or exterior areas, suggesting situations wherein wood stoves may have been used for both heating and cooking applications in at least some of the incidents.

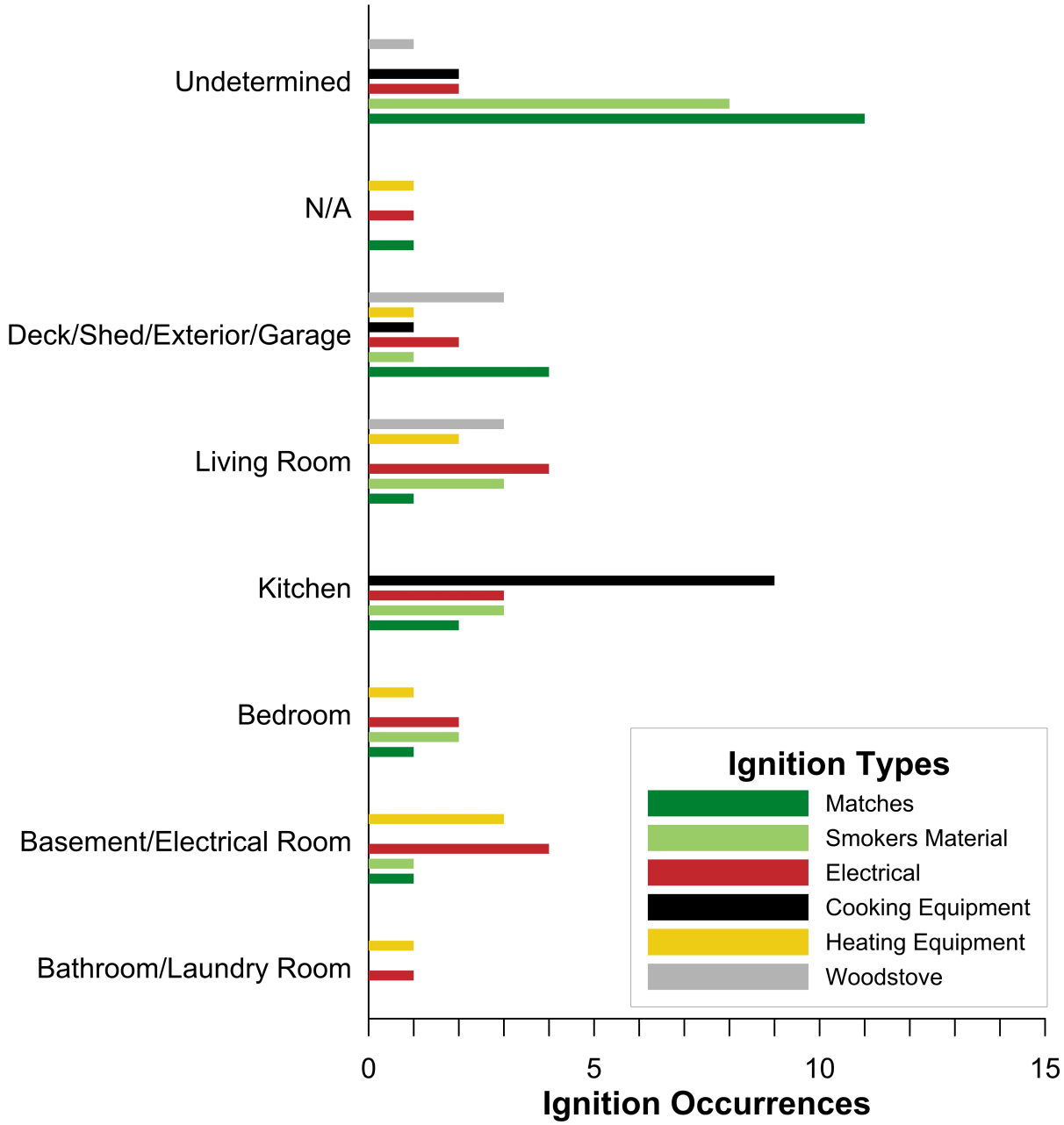


Figure 13: Ignition sources by area of origin

Table 3: Known ignition source occurrences with respect to area of origin

Ignition Source	**Matches**	**Smokers Material**	**Electrical**	**Cooking Equipment**	**Heating Equipment**	**Wood Stove**	**Total**
Living Room	1	3	4	0	2	3	13
Bedroom	1	2	2	0	1	0	6
Kitchen	2	3	3	9	0	0	17
Basement/ Electrical Room	1	1	4	0	3	0	9
Laundry Room/ Bathroom	0	0	1	0	1	0	2
Garage/ Shed/ Exterior/ Deck	4	1	2	1	1	3	12
Undetermined	11	8	2	2	0	1	24
N/A	1	0	1	0	1	0	3
Count:	21	18	19	12	9	7	86

Figure 14 illustrates relations between location of fire origin, injury and death. In line with the association shown in Figure 11 between source of ignition, injury and fatality, the majority of fatal fires started in the living room, followed by the kitchen, bedroom and exterior areas of the house. Aside from apparently higher incidence of exterior fires, these trends appear to be consistent with other sources [34].

While based on data from a very limited set of on-reserve First Nations communities, the NIRS data provides direction for setting potential priority rankings for home maintenance and repair. Technical issues associated each ignition category (electrical, cooking, heating and wood stoves) and their prevalence and location within the home can be directly related to potential fire incidents, as well as the risk of injury or fatality in a fire. The information also provides focus for new educational campaigns, and specifically targeted intervention strategies, that directly address and reduce preventable fires by ignition sources contained within each of the high priority categories and locations with a home.

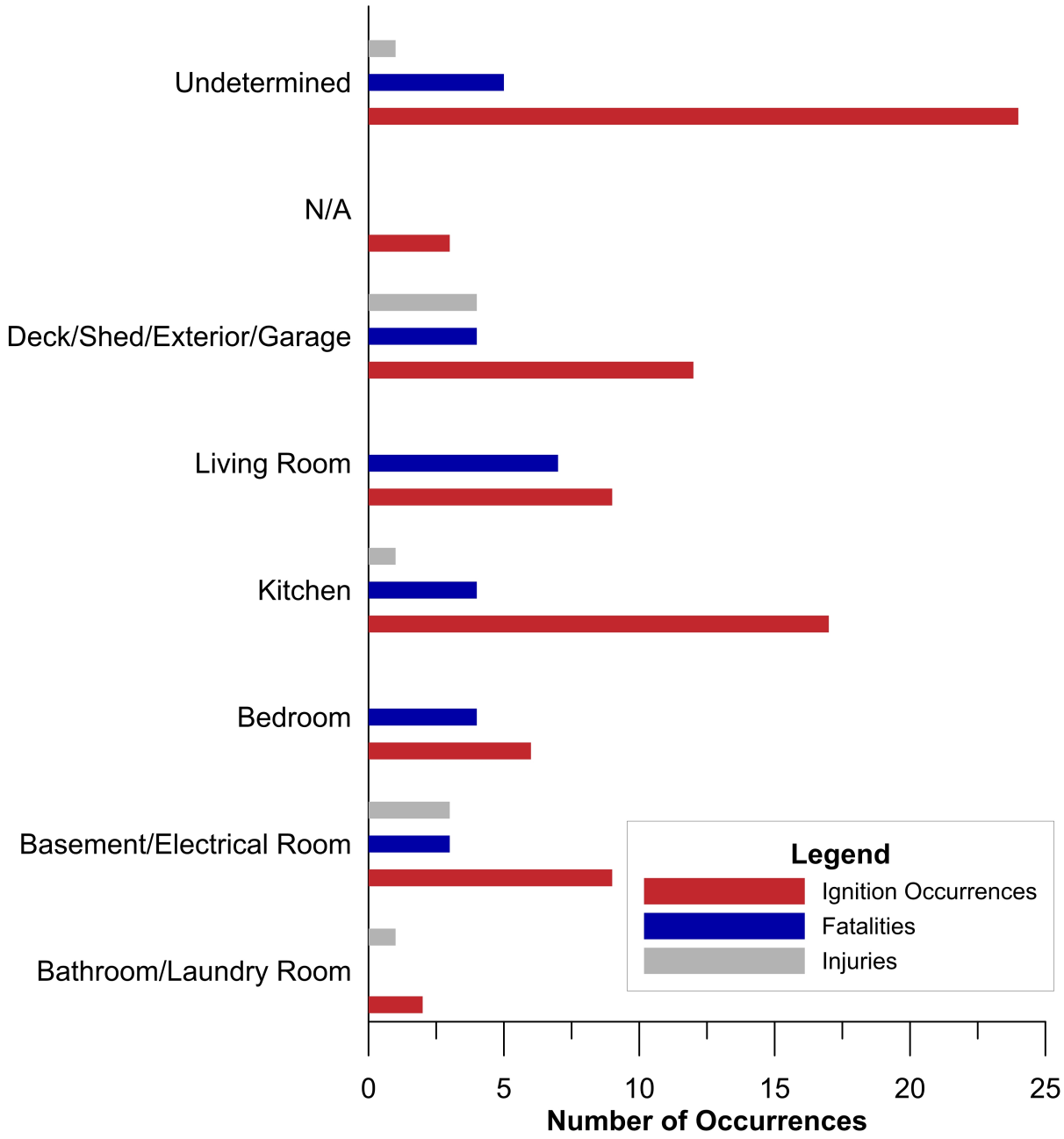


Figure 14: Ignition occurrences, fatalities, and injuries by area of origin

5.4 Results from Home Safety Audit (HSA) Questionnaires

The frequency of occurrence of fire incidents associated with ignition by a given technical ignition source category has been shown in previous studies to be connected to housing condition and maintenance, where housing condition considers aspects of the dwelling such as the construction quality, age and state of repair of the structure, as well as condition, repair and use of electrical and heating systems [24, 25]. It is clear from the census data outlined in

Section 4.1 that a major portion of on-reserve homes are in need of major repair. To capture a better picture of how the necessary repairs relate to fire safety and risk, comments and data reported in Home Safety Assessment's (HSA) taken from 14 communities were filtered and analyzed.

In the first stage of the analysis, the review of 251 written comments entered into the HSA evaluation files pointed to the following important considerations as related to housing condition [24, 40] and risk of fire ignition and/or fire development and spread [17, 26, 30, 41, 42].

- Electrical wiring: bad wiring, air conditioner poorly maintained, fans wired in for ventilation, ageing appliances, poorly installed or inaccessible electrical panels;
- Water Leaks: leaks and lack of moisture isolation around furnaces, electrical panels with water damage and water damage to/around electrical wiring, fans, electrical switches, lamp bulbs, plumbing leaks, rotting wood;
- Air Leaks: cracks in foundations, leaking or broken doors, windows, roof, house envelope, exhaust vent;
- Poor ventilation: mould and direct observation of musty basements, basement door missing.

One community in Quebec had done more specific fire safety audits and reported similar issues including clutter near electrical panels, basement rooms with limited ventilation, missing electrical socket covers, and broken and leaky windows or doors. In addition, they commented on location and state of repair of baseboards and baseboard heating, as well as missing, misplaced or outdated smoke, CO detectors and fire extinguishers, dead batteries in smoke detectors and empty fire extinguishers.

In the second stage, 29 of the 33 questions in the HSA were found to correspond to residential housing condition in relation to fire risk. These were grouped into 5 categories to align with common fire ignition sources and risk categories listed in the literature and seen in the incident reports above. The categories and number of questions in each category were compiled as follows:

(a) Electrical:
overall system (6 questions),
electrical outlets (4 questions from overall system specifically related to outlets);

(b) Heating:
overall system (5 questions),
furnace (4 questions),
baseboard/space heating (3 questions),
wood stove/chimneys (4 questions);

(c) Plumbing (1 question);

(d) Egress pathways (5 questions), and

(e) Housekeeping (3 questions from all categories above).

Additionally, questions on CO/smoke detectors and fire extinguishers, as well as home fire safety plans, included:

(a) Smoke/CO detectors/fire extinguishers (3 questions), and

(b) Home safety plans (3 questions).

Results of the analysis of the HSA data from the 29 questions associated with general maintenance are shown in Tables 4 through 7. Results are specifically summarized for 'Electrical', 'Heating', 'Plumbing', 'Egress Pathways' and 'Housekeeping' fire risk categories. In the second column in each table, the original, numbered questions from the HSA are provided[27][28]. The final columns summarize the upper (highest amongst all communities) and lower (lowest amongst all communities) bound percentages of 'No' answers for a given question[29], as well as the average percentage of 'No' answers across the 14 communities for each individual question, respectively[30]. Although the sample size was sometimes smaller than 14 (as low as 12 communities), this better reflected the lowest percentage determined amongst the communities who answered each question.

Table 4 summarizes results, which are also shown graphically in Figure 15 for those questions in the HSA related to household electrical systems, with answers regrouped to focus specifically on electrical outlets as well. The results illustrate the relatively high potential for issues with electrical systems in the communities studied. Deficiencies with electrical outlets were observed, on average, in 27% of households. As many as 44-99% of households, in at least some communities, reported problems with outlets and switches (Q6,16,17). These included switches and outlets, both inside and outside the dwelling, that were not covered or showed visible discoloration. Since loose or bare wires, as well as uncovered, damaged and overheated outlets are well-known ignition sources in electrical fires, these high numbers of reported deficiencies certainly point to increased risk of electrical fires in the dwellings [26, 43–45].

Table 5 and Figure 16 show results for those questions related to furnaces, baseboard and space heating, and wood stoves, with answers regrouped in Table 6 and shown to the right on Figure 16 to focus specifically on overall condition of the heating system as well. The results illustrate the relatively high potential for issues with heating systems in the communities studied. With respect to maintenance and fire safety, issues with furnaces are most prevalent, upwards of 80% in some communities, followed by baseboard and space heaters for which repair issues were recorded in 40% of the audits in at least some communities. Fire hazards

[27] one question was not assigned a number in the HSA so is listed without a number here.

[28] The full list of questions is also provided in Appendix A1.

[29] recall from Section 4.3 that a 'No' answer correlated with higher risk of fire.

[30] When a community did not answer a question with 'Yes' and 'No' answers, that community response was removed.

Table 4: Maintenance Issues: Electrical

Category	HSA Questions	Lower Bound	Upper Bound	Average
Electrical	3. Are the electrical wires securely attached to the building and free from tree limbs?	0%	17%	5%
	6. Do the exterior outlets have working covers; are they GFCI outlets; is there proper current flow to the outlets; does the outlet breaker work?	0%	55%	21%
	14. Is the electrical panel easily accessed and free from clutter?	0%	27%	10%
	15. Are outlets installed within 6 feet of baths, sinks or any other water source GFCI outlets?	6%	100%	39%
	16. Electrical outlets in all rooms are functioning and there have been no problems with any outlets?	0%	44%	19%
	17. Do all light switches have covers and are they all free from discoloration?	0%	99%	32%
Overall Average		21%		
Electrical Outlets	6. Do the exterior outlets have working covers; are they GFCI outlets; is there proper current flow to the outlets; does the outlet breaker work?	0%	55%	21%
	15. Are outlets installed within 6 feet of baths, sinks or any other water source GFCI outlets?	6%	100%	39%
	16. Electrical outlets in all rooms are functioning and there have been no problems with any outlets?	0%	44%	19%
	17. Do all light switches have covers and are they all free from discoloration?	0%	99%	32%
Overall Average		27%		

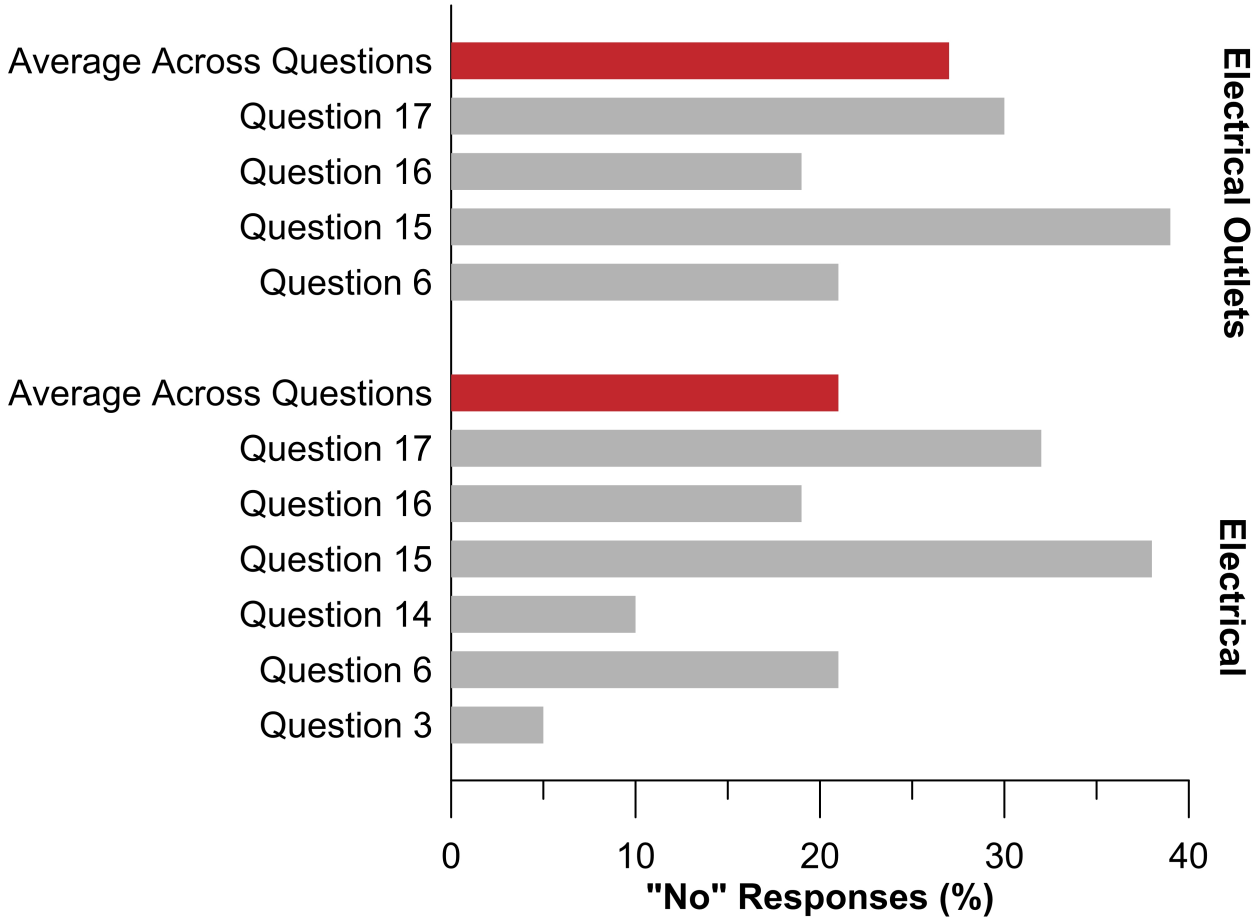


Figure 15: Average percentage of 'No' responses across all communities for each question (gray bars) with average across all questions (red bar) for electrical system and electrical outlet fire risk categories. Refer to Table 4 for list of questions.

related to these categories included obstructions, combustible materials and dust observed near furnaces and heaters, as well as additional issues with thermostats and their regulation of the heat distribution. Wood stoves also present a large potential fire risk, on average 25% across communities. Specifically, poor condition of the units and chimneys was noted to be as high as 58% in some communities, and there was also a general lack of installed and operational fire safety systems such as CO detectors and fire extinguishers (34% and 45%, respectively). All of these factors, summarized in Table 6, are well-known ignition sources in residential fires, so the high percentage of reported deficiencies certainly point to increased risk of fires in the dwellings [8, 30, 31, 34].

Table 7 summarizes results, which are also shown graphically in Figure 17 for those questions in the HSA related to plumbing, means of egress and housekeeping. The average percentage of observed plumbing leaks in key rooms align with average observations of issues with electrical systems, speaking to the overall poor state of repair of many dwellings in the communities studied. General housekeeping, as related to obstruction of electrical and heating systems, has been discussed in the respective sections above. Results in Table 7 point to an extreme concern from a fire safety perspective: this is the high percentages of dwellings, up to 56% in some communities, with obstructed and damaged doors, windows, stairs and handrails, since these provide key egress pathways for residents and thus are directly related to potential for survival in the event of a fire. In addition to hindering egress, broken and damaged doors and windows can provide additional sources of fresh air and ventilation to support combustion and faster growth of the fire, thus contributing to the overall severity of the fire event. This, in turn, can further negatively impact the residents ability to egress.

Two additional important categories of questions related to the observed condition of existing technical fire prevention strategies, i.e, CO and smoke detectors and fire extinguishers, and to home fire safety plans. Results are contained in Table 8 and Figure 18. Overall there are high percentages of homes in which there are no smoke detectors (21% overall and 68% in at least some communities), installed smoke detectors do not work (28% overall and 57% in at least some communities) and/or the home does not have a fire extinguisher (64% overall and 97% in at least some communities). In one community, while smoke detectors were installed in 90% of the residences, approximately 60% of these were determined to be expired and therefore not operational in event of a fire. Again, these results are very concerning given the well-known correlation between working smoke alarms and potential for survival in the event of a fire [16, 17, 19, 20].

Also of note, many homes do not have a complete and effective home fire safety plan. Thirty-three percent of homes had incomplete home fire safety plans in the HSA communities overall, and this number increased to as high as 94% in terms of homes in some communities that did not even have a basic home safety plan. Making a home fire safety plan is extremely important, since fires grow very quickly so there is not time to plan an escape once the fire has ignited. As such, well-practiced home fire safety plans are an important element in escaping from, and thus surviving, a fire [46–48].

Table 5: Maintenance Issues: Heating

Category	HSA Questions	Lower Bound	Upper Bound	Average
Heating System: Furnace	18. Is the furnace clear of obstructions and combustible materials?	0%	80%	16%
	19. Does the furnace appear to be in good condition? Is it clean and free from dust and discoloration on the main body and vent?	0%	80%	16%
	20. Is there a shutoff valve on/near the furnace? Does the furnace turn on as soon as the thermostat is turned up?	0%	80%	11%
	2. Do the Exterior Fuel Tank or Gas Meter have visible shutoff valves?	0%	50%	9%
Overall Average		13%		
Heating System: Baseboard and Space Heaters	21. Are the baseboards and space heaters clear of obstructions?	0%	31%	9%
	22. Are the baseboards and space heaters functioning properly? When you turn up the thermostat do they heat up?	0%	20%	8%
	23. Do the baseboard heaters appear to be in good condition? Are they free from dust and discoloration?	0%	40%	15%
Overall Average		10%		
Heating System: Wood Stove/ Chimney	24. Is the exterior chimney free of cracks, missing bricks, creosote build up, missing chimney cap?	0%	58%	12%
	25. Does the wood stove and interior chimney appear to be in good condition? Is the glass door free from cracks and black discoloration?	0%	52%	10%
	26. Is there a working smoke/CO detector centrally located on the ceiling, but not closer than 20 feet to the wood stove/chimney?	0%	100%	34%
	27. Is there a fire extiguisher within 20 feet of the wood stove or chimney, but not closer than 10 feet?	0%	100%	45%
Overall Average		25%		

Table 6: Maintenance Issues: Heating System Condition

Category	**HSA Questions**	**Lower Bound**	**Upper Bound**	**Average**
Heating System: Condition	19. Does the furnace appear to be in good condition? Is it clean and free from dust and discoloration on the main body and vent?	0%	80%	16%
	22. Are the baseboards and space heaters functioning properly? When you turn up the thermostat do they heat up?	0%	20%	8%
	23. Do the baseboard heaters appear to be in good condition? Are they free from dust and discoloration?	0%	40%	15%
	24. Is the exterior chimney free of cracks, missing bricks, creosote build up, missing chimney cap?	0%	58%	12%
	25. Does the wood stove and interior chimney appear to be in good condition? Is the glass door free from cracks and black discoloration?	0%	52%	10%
Overall Average		12%		

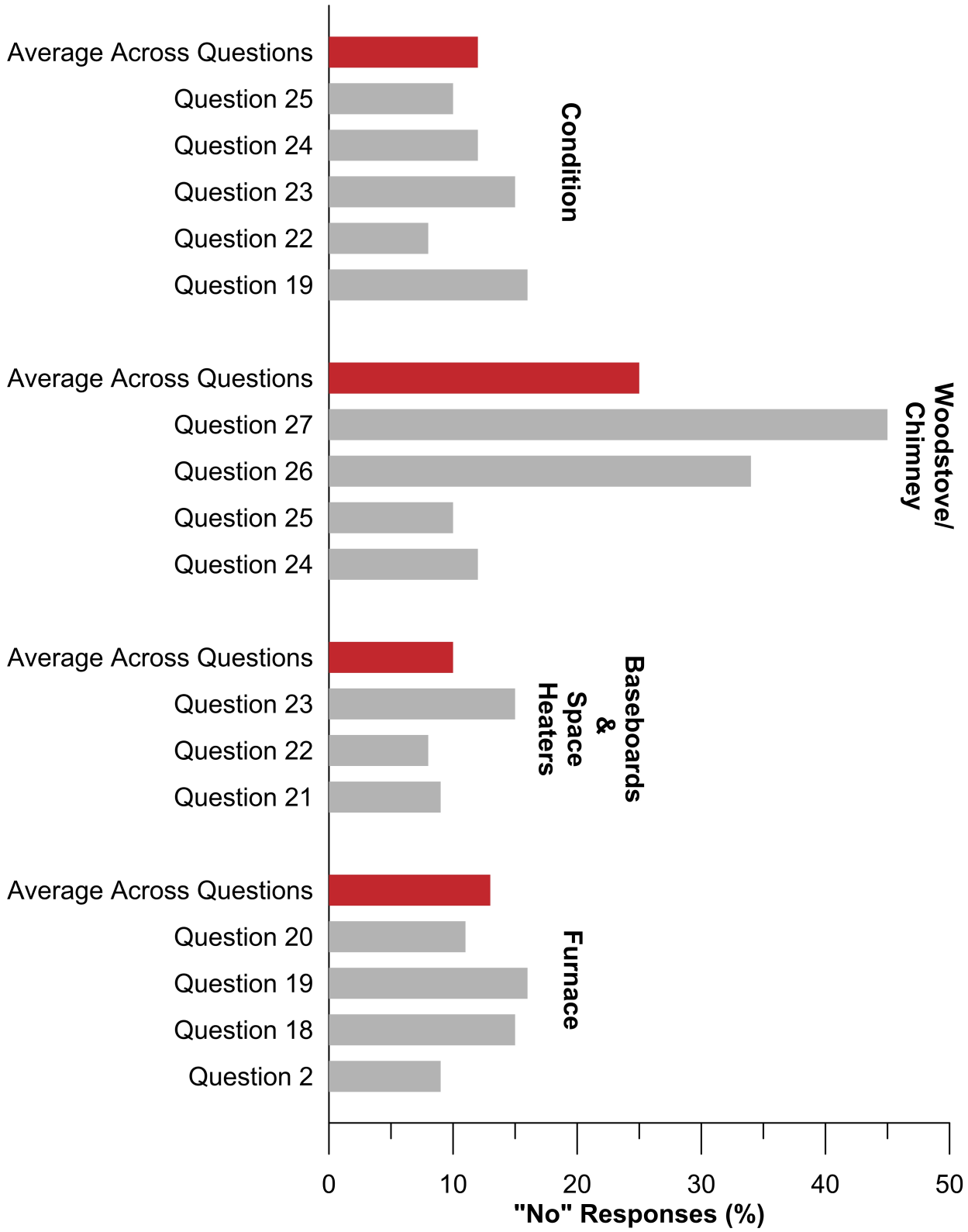


Figure 16: Average percentage of 'No' responses across all communities for each question (gray bars) with average across all questions (red bar) for heating systems and heating system condition fire risk categories. Refer to Table 5 for list of questions.

Table 7: Maintenance Issues: Plumbing, Egress, Housekeeping

Category	HSA Questions	Lower Bound	Upper Bound	Average
Plumbing	13. Are the bathroom, kitchen and/or laundry room free of leaks?	1%	55%	21%
Overall Average		21%		
Means of Egress: Doors, Windows, Steps, Handrails	4. Are the steps and handrails free of rot and cracks? Are the handrails securely attached?	0%	56%	22%
	5. Are the walkway and stairs free from trips and hazards?	0%	21%	7%
	7. Are all exterior doors clear of obstructions and in good working order so they can be used in case of emergency?	0%	54%	16%
	10. Are all doors and windows clear of obstructions and do they open?	0%	46%	19%
	12. Is the staircase free of obstructions and are the handrail and stairs secure?	5%	43%	18%
Overall Average		16%		
Housekeeping	14. Is the electrical panel easily accessed and free from clutter?	0%	27%	10%
	18. Is the furnace clear of obstructions and combustible materials?	0%	80%	18%
	21. Are the baseboards and space heaters clear of obstructions?	0%	31%	8%
Overall Average		12%		

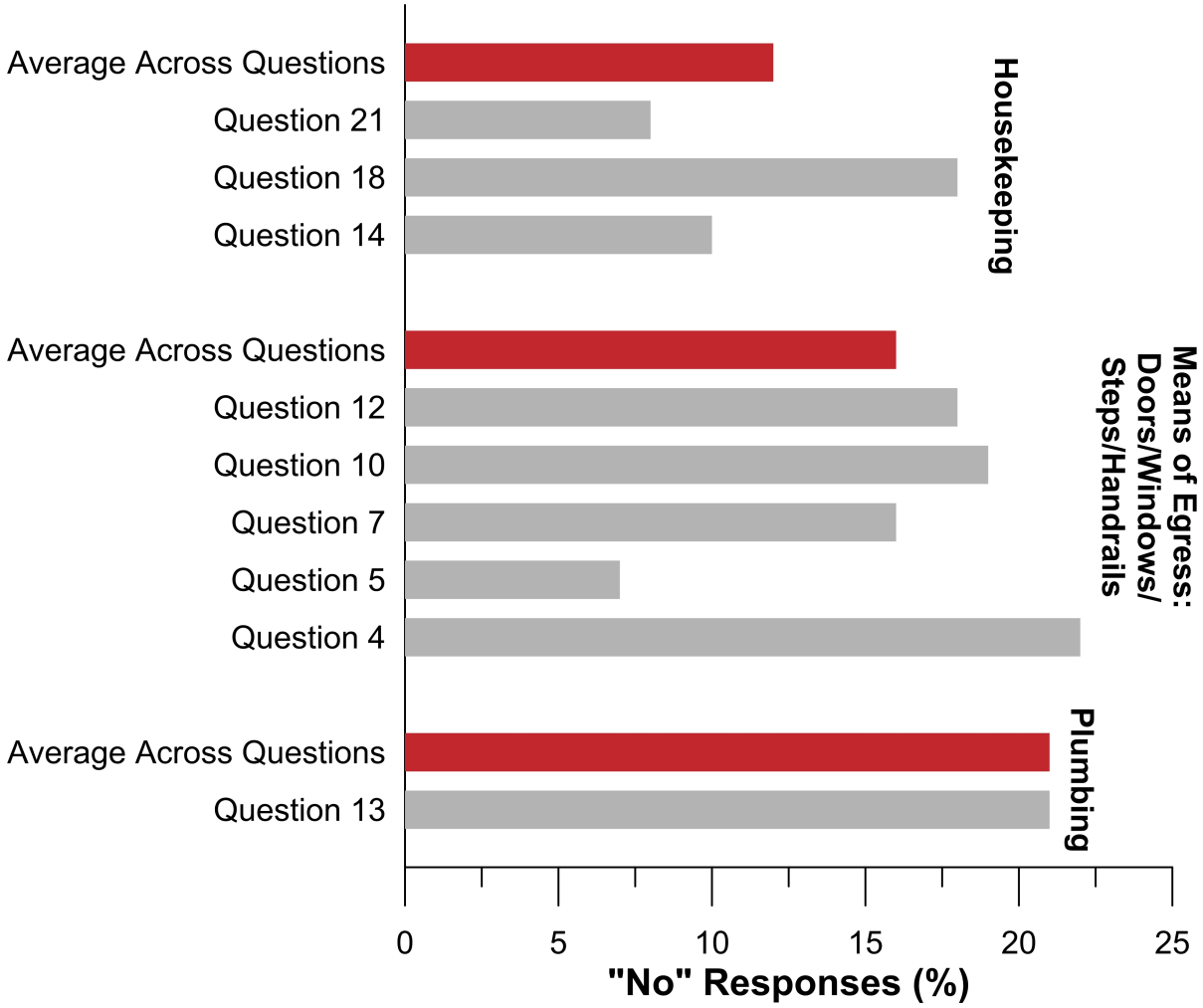


Figure 17: Average percentage of 'No' responses across all communities for each question (gray bars) with average across all questions (red bar) for plumbing, means of egress and housekeeping fire risk categories. Refer to Table 7 for list of questions.

Table 8: Fire Safety Devices and Plans

Category	**HSA Questions**	**Lower Bound**	**Upper Bound**	**Average**
Smoke/CO detectors	8. Are there smoke/CO detectors installed in the home?	0%	68%	21%
	Do they work when tested?	0%	57%	28%
Overall Average		25%		
Fire Extinguishers	9. Is there a minimum of 1 fire extinguisher on each floor?	11%	97%	64%
Overall Average		64%		
Home Safety Plan	28. Does the household have a safety plan and meeting location in place?	0%	94%	49%
	29. Is there a list of emergency numbers and contacts?	0%	82%	36%
	30. Is there a phone that works without power?	0%	65%	12%
Overall Average		33%		

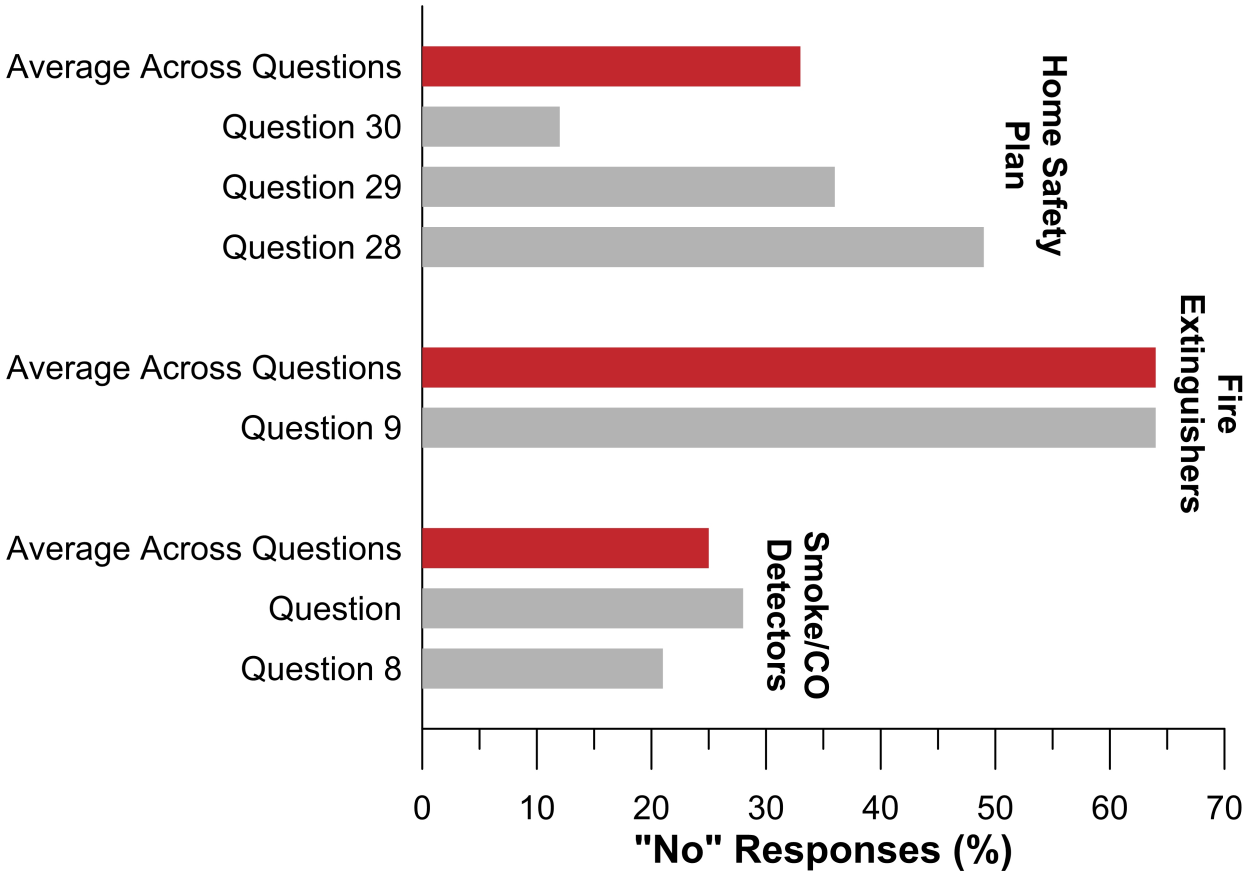


Figure 18: Average percentage of 'No' responses across all communities for each question (gray bars) with average across all questions (red bar) for detectors, extinguishers and home fire safety plan fire risk categories. Refer to Table 8 for list of questions.

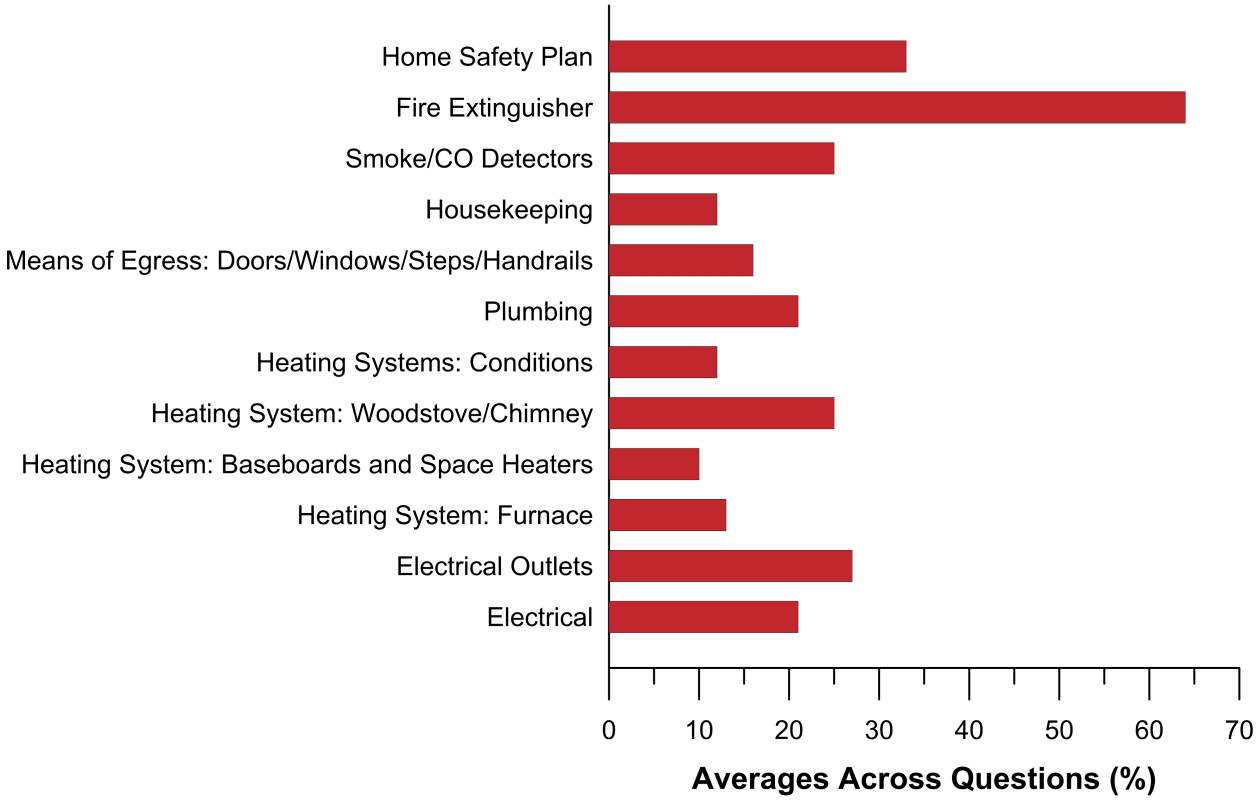


Figure 19: Average percentage of 'No' responses across all communities and all questions (red bar) for each fire risk category.

6 Discussion

Residential housing condition is known to be related to potential ignition sources in fires [8, 29]. The census analysis presented in Section 5.2 highlights the poor state of housing in on-reserve First Nations communities. A recent study documented in detail the condition of structural, mechanical and electrical systems, electrical fixtures, building envelope and plumbing in houses on a First Nations community in Manitoba [25]. Each was rated on a scale from 1 (very poor) to 5 (excellent). For reference, the rating of 'poor' corresponded to elements that were badly enough deteriorated and damaged that there was a very high likelihood of failure. A rating of 'fair', on the other hand, indicated that the element was in need of specialty repair as it could begin to impact surrounding elements. Importantly in the present context, the study concluded that the general state of housing ranked between 'poor' to 'fair', with the issues noted being in large part due to an accumulated backlog of maintenance. These results are confirmed by observations in the HSA files of a wide range of maintenance related issues. Three that would not directly lead to ignition of fires but are still worthy of mention since they might influence the progression of a fire, should one occur are:

- Water Leaks: leaks and lack of moisture isolation around furnaces, plumbing leaks, rotting wood;
- Air Leaks: cracks in foundations, leaking or broken doors, windows, roof, house envelope, exhaust vent;
- Poor ventilation: mould and direct observation of musty basements, basement door missing.

In addition to these observations, the HSA questions and NIRS incident data, when grouped into broader fire risk categories, show good alignment with residential ignition sources listed elsewhere [16–20, 26]. Thus, the percent occurrence of the different ignition sources, as logged in the NIRS incidents, and as gleaned from HSA analyses (Sections 5.3 and 5.4 respectively) are compared in Table 9 to determine commonalities and interconnecting observations and trends in the results.

For the three ignition source categories of 'Electrical', 'Heating' and 'Wood Stove', there is very close correlation between the percentage of fires initiated by each source per the NIRS data and the poor state of repair as recorded in the HSA documentation. The HSA electrical category focuses questions around the general state of repair and functionality of the electrical outlets, switches and overall condition of the electrical system in each residence. The heating system category includes questions that relate to the general state of repair and functionality of the furnace, baseboards and space heaters in each residence. Finally, the wood stove category considers possibles issues with both the state of repair of the chimney and the wood stove itself. In all cases, the questions target factors that are known to increase the risk of fire risk in a given category.

Table 9: Prevalence of ignition sources from HSA data and ignition sources

Ignition Source	**Incident (%)**	HSA (%)
Matches	24	no questions
Smokers Materials	21	no questions
Electrical	22	21
Electrical Outlets		27
Cooking	14	no questions
Furnace, Space Heating	11	12.5
Heating Overall		12
Wood Stove	8	11
Means of Egress	no data	16
Housekeeping	no data	12

Instances of open electrical outlets and switches, substandard or poorly installed/maintained wiring, poorly maintained and aging appliances and poorly installed or inaccessible electrical panels, as well as water damage and water damage to/around electrical wiring, panels, fans, electrical switches and lamp bulbs were observed in 21% of the HSA visits while 22% of fire incidents were attributed to electrical sources of ignition.

Similarly, responses related to the condition of the heating system point to a significant number of potential issues with heating equipment, confirmed by observation of discoloration due to heat, and related to lack of maintenance, obstruction, build up of dust or proximity of flammable materials to the systems. Such concerns were recorded in 12% of HSA visits while 11% of fire incidents were initiated by sources related to heating systems. Specifically for wood stoves, 11% of HSA visits noted issues with stoves and chimneys while less, approximately 8%, of fire incidents were reported to be ignited by a wood stove.

Unfortunately, there are some ignition sources recorded in each set of data that are not covered in the other. For example, there were only a handful of comments entered into the NIRS incident data related to condition of egress paths or housekeeping so no comparison with HSA observations was possible. Alternately, there were no questions on the HSA that directly to related to use of matches or smokers materials in a given household precluding comparison to their 24% and 21% prevalence, respectively, as ignition sources in fire incidents. Similarly, no HSA information was collected, or independent observations made, that related to the state of maintenance and repair of cooking appliances or to housekeeping in the vicinity of cooking areas so, while ignition by cooking related sources did account for 14% of the fires, no comparison could be made with HSA visits for that ignition source category.

In summary, comparisons between the incident and HSA results reveal a high correlation between HSA fire risk categories and ignition sources. Taken together, the combined data from Canadian census, HSA and NIRS sources clearly highlight several key fire risk categories, as well as other factors that could affect the progression of a fire event. In all cases, the factors identified are directly connected to condition and suitability of housing in on-reserve First Nations communities.

In order to improve fire safety moving forward, it is important to assess how this combined information might be used in development of strategies to increase risk awareness and implement risk reduction measures that can directly address and reduce preventable fires by ignition sources contained within each of the high priority categories and locations with a home. One effective method of doing this is to first superimpose the known risk factors over a fire timeline to convey what risks are present and connect those to their direct effects in each phase of a fire [16]. This then provides a framework for assessing the potential impacts of different interventions and risk reduction strategies targeted at each stage of the fire as well. Such an analysis forms the subject of the next section.

7 Looking forward

Development of fire scenarios and timelines are tools that can be used to visualize links between fire risk factors, fire progression and implementation of interventions strategies. Literature has shown that interventions at various stages along a timeline of fire progression will have varying effects in terms of fire risk reduction. For example, Swedish statistics show that well maintained electrical systems can be effective in reducing up-to 14% of fire fatalities [16, 17], and utilizing fire resistant bedding and furnishings can reduce fire fatalities by 46% [16, 18]. These statistics also improve when considering a population with a high rate of smokers [18].

In this context, the overall timeline used here is shown in Figure 20 and is similar to those in the literature [18]. Our generalized fire follows an overall progression timeline of a) initial heat generation to a level that is sufficient to cause b) ignition of a fuel source, followed by c) continued fire growth as more fuel sources become involved in the combustion process to d) the corresponding evacuation of the occupants. Superimposed on the left hand side is a summary of risks, determined in this research, that would be present in each phase of the fire. Down the right had side are the impacts that each individual risk, or group of risks, might have on fire progression in a home or occupants ability to escape. The next stage when analyzing and navigating a standard fire scenario as shown in Figure 20 is to determine intervention strategies designed to reduce risk, or mitigate impact, for each factor listed on the fire timeline. It is also vital that the interventions are effective for different situations and demographics. Populations most at risk of fire fatalities are generally young children, older adults, disabled, or people suffering from substance abuse [17–19, 28, 49], therefore final choice of intervention strategies must consider the demographics within a community as well [17, 28].

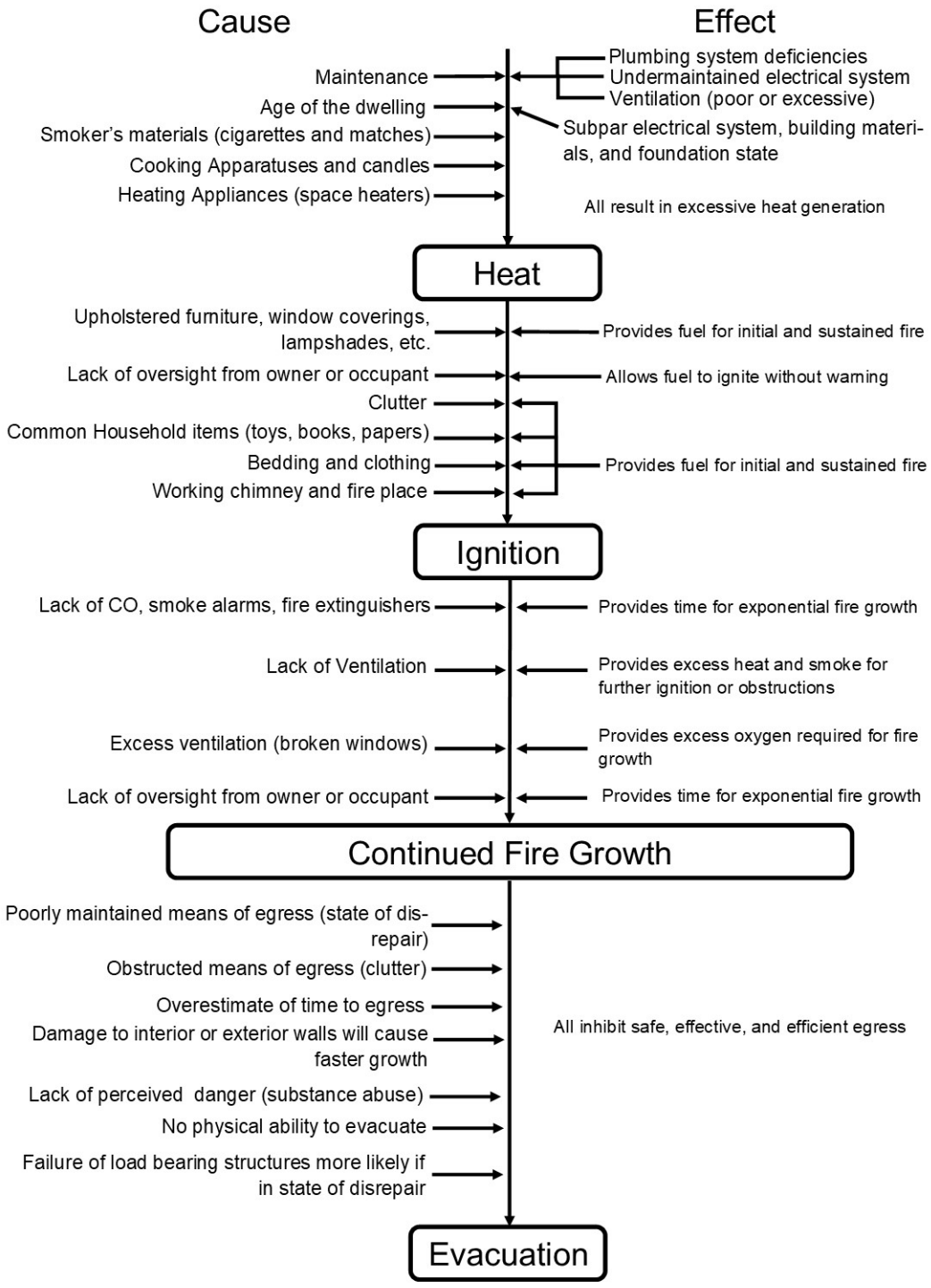


Figure 20: General Fire Progression Timeline

In terms of effectiveness, home fire and safety checks in the UK focused on identifying general safety hazards similar to some those of interest here (flammable liquids, common fuel types, maintenance standards), and coupled those to elementary school fire safety education programs, and smoke alarm installation. Empirical evidence indicated that these combinations of interventions accounted for approximately 57% of the reduction in fire fatalities with 14-30 benefit to cost ratio [16, 50]. Combined education and smoke alarm installation programs aimed towards for high risk populations in Canada resulted in 49% reduction in fires with accompanying decrease in severity as well [28, 51]. A replication of the UK home and fire safety check program in Syd, Sweden found a reduction of 6-8% of fires per year with estimated benefits of 8-11 times the cost of the program [16].

All of the above studies, as well as other similar programs, have clearly indicated that it is important to consider potential effectiveness in implementation of different intervention techniques at a community level. For this, understanding how a given strategy can be categorized into the 5E's of fire protection facilitates better understanding both of the purpose and of the potential effectiveness of approach [5]. Many studies show that installing smoke detectors, fire alarms or suppression systems are an effective method to alert occupants and control a fire once it has formed [7, 16–19, 51], but there are limitations to the effectiveness of these technologies in some situations as well. For example, year round access to a continuous source of water is required for effective use of sprinklers. Similarly, the ability to source and having the economic means to maintain detectors or alarms in working condition is necessary for their continued effectiveness. Alternately, targeted intervention techniques that are aimed at reducing causes and impacts of heat and ignition sources and/or improving quality of egress path(s), can play an equally large role in fire mitigation in some contexts and circumstances [16].

The analysis conducted here indicates that the general state of repair in on-reserve First Nation communities across the country is poor. Targeted funding that can work to alleviate the risks caused by age and poor maintenance of dwellings (subpar electrical systems, leaks in the exterior building envelopes, building materials, poor or excessive ventilation) fall within the category of engineering and environmentally driven interventions listed in the 5E's [20]. As shown in the study [8, 29], poor dwelling condition can result in higher incidences of residential fires, thus funding strategies to improve the overall condition of housing should reduce risk in the present communities as well. Improvements which can reduce, or potentially mitigate, environmental risks across the early heating, ignition and fire growth stage would include improving the overall operational state of electrical, cooking, ventilation and heating systems. Environmental improvements with can reduce, or potentially mitigate, risk during the egress stage relate to minimizing the potential for fire growth, as well as obstruction of the egress pathways. Risk in this area can be mitigated through maintenance of building envelope, including stairs, walls, windows and doors, as well as removal of clutter and general good housekeeping. All of the above measures can form the basis for expanded HSA programs and educational outreach campaigns (education of the 5E's) to allow communities and local leaders to pass on information about the link between maintenance and fire safety, as well as the importance of regular maintenance and housekeeping in keeping the

community safe. Specific educational outreach to reduce the prevalence of fires caused by smokers material, matches and other open flames will allow the risk associated with other common sources of fires to be reduced. These can also be combined with education to raise awareness to other factors influencing risk (i.e. advanced age and substance abuse [17, 49]) and increase the engagement in fire preparedness of the entire community.

Once fire safety measures are implemented and taught, in order to ensure their effectiveness, First Nations communities or organizations should develop and administer individual policies to adopt fire safety measures within their unique cultural and traditional bounds. These should be continually monitored, and modified as necessary, to reduce and mitigate the risk of residential fires, structural damage and fatality [5].

8 Observations Made and Lessons Learned

8.1 Census Data

The majority of the census data that was analyzed suffered from inconsistencies in numbers of dwellings (approximately ± 5) listed in different tables. This resulted in uncertainties in the actual distributions of housing conditions in some of the communities in this study.

Additionally, the census data included references to socioeconomic indicators and their relation to the housing condition. Multiple studies have shown, or inferred from socioeconomic indicators, the correlations between fire risk, housing condition and effectiveness of fire safety implementation strategies. Thus, further analysis into factors such as the primary household maintainer, income level, percentage of income spent on maintenance or other breakdown of money spent relative to condition and suitability of housing may provide further insight into how to prioritize fire risk factors and associated fire safety implementation strategies for the First Nation communities in the present data as well.

8.2 NIRS Data

The major discrepancies with the NIRS data arise from the inconsistencies in entry of the data provided in the reports. These inconsistencies include: (a) many different answers referring to the same element, (b) entries of 'blank' or 'unknown' in key columns, while the pertinent information is instead entered into one of the comment areas, (c) lack of detail in reporting incidents, and (d) lack of alignment of questions across fire reporting entities in Canada or internationally. When the questions and answer keys are not clear, concise and consistent, it becomes very challenging to understand and interpret various outcomes, such as the distribution of fire cause, or risk of fire for various ignition sources and locations. This ultimately complicates both sorting and extracting data which in turn, may lead to large uncertainties and data being lost or excluded from the analysis. Furthermore, since different entities do not use consistent reporting frameworks, it is difficult to analyze and compare across sources, again potentially leading to recommendations that may be misleading or incomplete.

It is critical that reporting of certain aspects of a fire incident be sufficiently detailed that targeted technical solutions can be designed and carried out. For example, under a category such as electrical ignition source, if a more specific cause (electrical outlet, switch, loose wiring, overloading etc.) is detailed in the report, better understanding of specific causes are achieved, cross-comparisons to other databases can be done and, over the longer term, better fire intervention strategies and protection measures can be implemented.

8.3 HSA Data

The HSA reports were extremely useful in linking housing condition to fire risk factors and categories. Cross comparison of the census, NIRS and HSA data indicated several potential areas to improve the HSA as a tool for fire safety data gathering in future. Specifically,

a) the HSA is missing questions related to three of the six key ignition sources. The missing ignition sources are matches (open flames), smokers material, and cooking equipment. Since these three categories together account for 61.8% of known ignition sources, addition of questions related to each category should be considered. These might include:

   - examining the distance from heat producing appliances (heaters, stoves, ovens) and stored combustibles,
   - determining whether unattended cooking takes place,
   - determining whether candles, matches and open flames are regularly used and how lighting materials are stored,
   - determining whether there are extension cords, octopus plugs or substandard wiring in use,
   - determining the state of repair and function of large and smaller heat producing electrical appliances which could include a subset of ovens, microwaves, washing machines, diswashers and clothes and hair dryers, etc.,
   - determining the prevalence of upholstered/plastic materials and their proximity to heat producing devices, and
   - determining smoker practices.

b) The HSA data does not formally document information that could be used to link an observed issue to a room(s) or location(s) within a residential property. While this information was sometimes entered by the assessor, it was not consistently recorded and was difficult to search. This limited the ability to correlate locations and fire risks, which has been shown to be an important factor in reducing fire risk and would also allow better comparison to the data in the NIRS, for example.

c) Many of the fire safety issues identified through the HSA analysis align with those that are investigated as root causes of mold development, also a direct health and safety

risk to the occupant. These include observations related to structural condition, air infiltration and water leakage, damage and condensation, as well as state of repair of plumbing, electrical systems and fixtures. Thus, all relate to provision of healthy and sustainable housing for First Nations communities. As such, all of questions asked, and data collected, from these multiple sources should be integrated into a modified from of HSA tool as the basis for an evidence-based framework through which to prioritize and establish timelines for critical fire safety maintenance and risk reduction interventions.

9 Recommendations

In previous studies, authors have concluded that there are factors that can reduce the fire risk in residential dwellings [5, 7, 20, 29]. Our own findings from the census data, coupled with HSA and NIRS datasets, echo previous findings and lead to recommendations for intervention strategies.

Educational outreach is an extremely effective way to inform communities and individuals of potential fire hazards and their associated risks [16, 28, 52]. Over time, this has been shown to lead to modification of behaviour and improvement of the overall community fire risk profile. Targeted campaigns that focus on fire safety for vulnerable population groups, such as young children, older adults, the disabled, or those suffering from substance abuse can also provide great impact. As one outcome of this research, a series of home maintenance related fire safety vignettes and associated learning materials are being developed as outlined in Appendix A.

Additional intervention strategies for education in fire safety risk and reduction in the adult population should also be considered. One effective methodology for accomplishing this might be through development and use of an engaging and targeted narrative simulation approach [52]. This could be designed in an interactive fashion with stories and discussions tailored to probe participants knowledge of a set of prioritized maintenance-related hazards and how those are connected to fire risk, as well as their understanding of useful risk-reduction measures, safe practices and sound decision-making processes in the event of a fire. Finally, the narrative could be supplemented with support, suggestions and encouragement to make changes toward fire hazard reduction and further training, as needed, on decision making during a stressful fire event. Since narrative simulation is not common in fire safety education, it would be critical to evaluate the effectiveness of such a program and continue to modify the approach accordingly.

In addition to implementation of educational risk reduction measures, targeted interventions aimed towards environmental/engineering changes can be paramount in reducing the negative impacts of fire events on a community. Many studies have focused on adding smoke alarms and sprinklers to dwellings and have shown that these preventative measures are extremely effective in reducing the risk of fire-related fatalities, and damage. Campaigns toward use of these technologies could be extremely effective in reducing risk in some com-

munities in the present context as well. However, it has also been shown that these measures may not be the most effective in all communities, or for all individuals, if the funding, infrastructure and long term support for these systems, are not present [8, 52]. At the same time, the data extracted from the census, HSA datasets, and the NIRS datasets clearly show that the general state of housing is poor in First Nations communities. The links between many of the noted issues with housing condition and fire risk are also extremely clear. Ultimately then, along with educational interventions, targeted funding to improve housing condition in areas such as: (a) electrical systems, (b) ventilation, (c) heating systems and (d) building damage, particularly when aligned and combined with educational interventions and community-specific outreach initiatives, should directly reduce fire risk, and increase fire safety, in these communities.

From the combined analysis of the HSA, NIRS, and census data certain recommendations that tie into environmental/engineering aspects of the 5E's can be outlined. The clear links between ignition sources, fire incidents and thus fire risk from a select number of communities pushes the idea that more information on a broader set of communities should be collected. Further, priority rankings of targeted maintenance interventions should be designed and implemented. While there is a very limited set of data through which to set priorities, it appears that a focus on electrical systems, heating, and cooking appliances could be a first priority to eliminate the risk posed by heat generating systems. Programs targeted toward maintenance of egress pathways, coupled with development of home fire safety plans, should be developed. Subsequent programs could be targeted towards additional aspects of good housekeeping and maintenance of ventilation and plumbing systems.

The lack of fire extinguishers, carbon monoxide detectors, and smoke alarms is, of course, also a significant cause for concern. Extensions of these programs should be balanced against the importance of interventions related to household maintenance which will lead to direct reduction of potential ignition sources and therefore the number of fire incidents. In conclusion, an expanded approach to home safety and fire safety checks will provide reliable and proven method to reduce the fire risk while also promoting education and engagement of the community.

References

[1] Statistics Canada (2022). Census learning centre: collection of data on Indigenous peoples. **url:** www12.statcan.gc.ca/census-recensement/training-formation/videos/Collection-of-data-on-indigenous-peoples.htm, Released: 2022-10-26.

[2] Statistics Canada (2022). Indigenous population continues to grow and is much younger than the non-indigenous population, although the pace of growth has slowed. **url:** www150.statcan.gc.ca/n1/en/daily-quotidien/220921/dq220921a-eng.pdf?st=y5f5JPy7, Released: 2022-09-21.

[3] Statistics Canada (2023). Statistics on indigenous peoples. **url:** www.statcan.gc.ca/en/subjects-start/indigenous_peoples, Released: 2022-03-24.

[4] K. Mohan (2021). Mortality and morbidity related to fire, burns and carbon monoxide poisoning among first nations people, métis and inuit: Findings from the 2011 canadian census health and environment cohort. **url:** https://www150.statcan.gc.ca/n1/daily-quotidien/210325/dq210325g-eng.htm, Released: 2021-03-01.

[5] L. Garis and M Desautels. Fire risk for indigenous people. *FIREFighting in Canada*, Jun 2021. **url:** https://www.firefightingincanada.com/fire-risk-for-indigenous-people. Accessed: 2023-05-4.

[6] S. Huesken, R. Xiao, C. Jennings, and M. Dow. Moving from risk assessment to risk reduction: An analysis of fire-related risk factors in first nation/indian band or tribal council areas across canada. 2020. Report by University of the Fraser Valley for The Aboriginal Firefighters Association of Canada (AFAC) known as the National Indigenous Fire Safety Council (NIFSC).

[7] J. Clare. National Indigenous Fire Safety Data Collection Evaluation: Review of existing practice and recommendations for the future, independent evaluation completed for national indigenous fire safety council. Technical Report, The University of Western Australia, March 2023. 20 p.

[8] D. Antonellis, S. Vaiciulyte, B. Meacham, and C. Jennings. The Invisible US Fire Problem. Kindling publication, Kindling: Fire Safety for All, March 2022, 55p. **url:** https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osInvisibleUSFireProblem.pdf.

[9] Z. Thurston and J. Randle (2022). Housing Experiences in Canada. **url:** www150.statcan.gc.ca/n1/pub/46-28-0001/462800012021001-eng.htm, Released: 2021-11-22.

[10] Z. Thurston and J. Randle (2022). Housing Experiences in Canada: Status First Nations people in 2016. **url:** www150.statcan.gc.ca/n1/pub/46-28-0001/2021001/article/00013-eng.htm, Released: 2022-08-15.

[11] Z. Thurston and J. Randle (2022). Housing Experiences in Canada: Non-status First Nations people in 2016. **url:** www150.statcan.gc.ca/n1/pub/46-28-0001/2021001/article/00012-eng.htm, Released: 2022-08-15.

[12] Z. Thurston and J. Randle (2022). Housing Experiences in Canada: Métis in 2016. **url:** www150.statcan.gc.ca/n1/pub/46-28-0001/2021001/article/00014-eng.htm, Released: 2022-08-15.

[13] Z. Thurston and J. Randle (2022). Housing Experiences in Canada: Inuit in 2016. **url:** www150.statcan.gc.ca/n1/pub/46-28-0001/2021001/article/00015-eng.htm, Released: 2022-08-15.

[14] B. Meacham, I. van Straalen, and B. Ashe. Roadmap for incorporating risk as a basis of performance objectives in building regulation. *Safety Science*, 141:105337, 2021. doi: https://doi.org/10.1016/j.ssci.2021.105337.

[15] L. Garis and M Desautels. Risk assessment and reduction: fire prevention in high-risk communities. *FIREFighting in Canada*, Nov 2021. **url:** https://www.firefightingincanada.com/risk-assesment-and-reduction, Accessed: 2022-01-4.

[16] B. Sund, C. Bonander, N. Jakobsson, and H. Jaldell. Do home fire and safety checks by on-duty firefighters decrease the number of fires? Quasi-experimental evidence from Southern Sweden. *Journal of Safety Research*, 70:39–47, September 2019. doi: https://doi.org/10.1016/j.jsr.2019.04.006.

[17] M. Runefors, N. Johansson, and P. Van Hees. The effectiveness of specific fire prevention measures for different population groups. *Fire Safety Journal*, 91:1044–1050, July 2017. doi: https://doi.org/10.1016/j.firesaf.2017.03.064.

[18] M. Runefors, N. Johansson, and P. van Hees. How could the fire fatalities have been prevented? an analysis of 144 cases during 2011–2014 in sweden: An analysis. *Journal of Fire Sciences*, 34(6):515–527, 2016. doi: https://doi.org/10.1177/0734904116667962.

[19] M. Senthilkumaran, G. Nazari, J. MacDermid, K. Roche, and K. Sopko. Effectiveness of home fire safety interventions. a systematic review and meta-analysis. *PLOS ONE*, 14(5):e0215724, May 2019. doi: https://doi.org/10.1371/journal.pone.0215724.

[20] S. Al-Hajj, E. Desapriya, C. Pawliuk, L. Garis, and I. Pike. Interventions for preventing residential fires in vulnerable neighbourhoods and indigenous communities: A systematic review of the literature. *International Journal of Environmental Research and Public Health*, 19(9), 2022. doi: https://doi.org/10.3390/ijerph19095434.

[21] Statistics Canada (2018). Table 98-400-x2016222: Dwelling condition (4), tenure (4), period of construction (12) and structural type of dwelling (10) for private households of canada, provinces and territories, census divisions and census subdivisions, 2016 census - 25% sample data. [data table]. **url:** www150.statcan.gc.ca/n1/en/catalogue/98-400-X2016222, Released: 2018-03-28.

[22] Statistics Canada (2022). Table 98-10-0233-01: Dwelling condition by tenure: Canada, provinces and territories, census divisions and census subdivisions. [data table]. **url:** www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=9810023301, Released: 2022-09-21.

[23] Indigenous and Northern Affairs Canada (2008). First Nations Profiles. **url:** https://fnp-ppn.aadnc-aandc.gc.ca/FNP/Main/Search/SearchFN.aspx?lang=eng, Accessed = 2023-01-30.

[24] E. Divringi, E. Wallace, K. Wardrip, and E. Nash. Measuring and Understanding Home Repair Costs: A National Typology of Households. Federal Reserve Bank of Philadelphia Report, March 2019, 32p. **url:** https://www.jchs.harvard.edu/improving-americas-housing-2021.

[25] P. Gloux. Good building practice guidelines for healthy and sustainable first nations housing in canada, PhD thesis. University of Manitoba, Winnipeg, Manitoba, 2021. **url:** https://bac-lac.on.worldcat.org/oclc/1341288931.

[26] A. Zheng, F. Rajabali, K. Turcotte, L. Garis, and I. Pike. The Influence of Electrical Fires in Residential Homes: Geospatial Analysis Pointing to Vulnerable Locations and Equipment Failures. Technical Report, BC Injury Research and Prevention Unit, University of the FraserValley: Abbotsford, BC, March 2019, 29p. **url:** https://cjr.ufv.ca/wp-content/uploads/2019/03/The-Influence-of-Electrical-Fires-in-Residential-Homes-March-2019.pdf.

[27] Statistics Canada (2021). Dictionary: Census of Population. **url:**www12.statcan.gc.ca/census-recensement/2021/ref/dict/az/index-eng.cfm?T=7results, Updated: 2022-11-30.

[28] J. Clare, L. Garis, D. Plecas, and C. Jennings. Reduced frequency and severity of residential fires following delivery of fire prevention education by on-duty fire fighters: Cluster randomized controlled study. *Journal of Safety Research*, 43(2):123–128, 2012. doi: https://doi.org/10.1016/j.jsr.2012.03.003.

[29] J. Clare and H. Kelly. Fire and at risk populations in Canada: Analysis of the Canadian National Fire Information Database. Murdoch University and Center for Public Safety and Criminal Justice Research, University of the Fraser Valley, December 2017, 29pp. **url:** https://cjr.ufv.ca/wp-content/uploads/2018/04/Murdoch-University-Fire-and-at-Risk-Populations.pdf.

[30] M. Runefors, R. Andersson, M. Delin, and T. Gell, editors. *Residential Fire Safety: An Interdisciplinary Approach*. The Society of Fire Protection Engineers Series. Springer International Publishing, Cham, 2023. doi: https://doi.org/10.1007/978-3-031-06325-1.

[31] S. Hall. Home structure fires. Technical report, National Fire Protection Association (NFPA), April 2023, 12p. **url:** http://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/oshomes.pdf;
with oshomefirestables.pdf (25pp.).

[32] J. Brown. Most common causes of house fires:and some more unusual, Zurich Municipal. **url:** https://www.acha.co.uk/resources/Common-causes-of-Fire.pdf, Posted: 2016-12-23; Accessed: 2023-06-11.

[33] K. Jackson. 5 Leading Causes of House Fires, Fuse Insurance Ltd. **url:** https://fuseinsurance.ca/5-leading-causes-of-house-fires/, Posted: 2020-10-29, Accessed: 2023-06-11.

[34] Province of British Columbia. BC Office of the Fire Commissioner. Annual report 2022, June 2023, 30p. **url:** http://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/oshomes.pdf.

[35] Government of Ontario. Ontario Chief Coroner's Table on understanding fire deaths in First Nations, May 2023, 35p. **url:** https://www.ontario.ca/document/ontario-chief-coroners-table-understanding-fire-deaths-first-nations/what-review-found.

[36] Statistics Canada (2022). Circumstances surrounding unintentional fire-related deaths, 2011 to 2020. **url:** www150.statcan.gc.ca/n1/daily-quotidien/220616/dq220616b-eng.htm. Released: 2022-06-16.

[37] City of Toronto. Toronto Fire Services. Annual report 2020-2021, December 2022, 56p. **url:** https://www.toronto.ca/wp-content/uploads/2020/12/8d66-TFSAnnualReport-Web-AODA-5-RS1.pdf.

[38] Statistics Canada (2023). Fire incidents increase during the pandemic. **url:**www150.statcan.gc.ca/n1/daily-quotidien/230608/cg-a002-eng.htm. Released: 2023-06-08.

[39] Statistics Canada (2022). Housing Statistics in Canada: A first look at shelter costs for households living on reserve using new data from the 2021 census. **url:** www150.statcan.gc.ca/n1/pub/46-28-0001/2022001/article/00002-eng.htm, Released: 2022-09-21; Accessed: 2023-06-01.

[40] Joint Center for Housing Studies of Harvard University. The State of The Nation's Housing 2022. Harvard Graduate School of Design/HARVARD Kennedy School Report, June 2021, 48p. **url:** https://www.jchs.harvard.edu/state-nations-housing-2022.

[41] Douglas Drysdale. *An Introduction into Fire Dynamics*. John Wiley and Sons, Ltd., 3rd edition edition, 2011.

[42] B. Karlsson and J.G. Quintiere. *Enclosure Fire Dynamics*. CRC Press LLC, 2000.

[43] R. Campbell. Home fires caused by electrical failure or malfunction. Report, National Fire Protection Association (NFPA), November 2021, 10p. **url:** http://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/osHomeFiresCausedbyElectricalFailureMalfunction.pdf.

[44] R. Campbell. Home fire caused by electrical distribution and lighting equipment. Report, National Fire Protection Association (NFPA), February 2022, 6p. **url:** http://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/osElectricalDistLighting.pdf.

[45] Vytenis Babrauskas. Research on electrical fires: The state of the art. *Fire Safety Science*, 9:3–18, 01 2009. doi: https://doi.org/10.3801/IAFSS.FSS.9-3.

[46] Ontario Association of Fire Chiefs (2017). Home Escape Plan.
url: https://www.oafc.on.ca/home-escape-plan, Accessed: 2023-06-12.

[47] U.S. Fire Administration (2023). Home Fire Escape Plans.
url: https://www.usfa.fema.gov/prevention/home-fires/prepare-for-fire/home-fire-escape-plans/, Accessed: 2023-06-10.

[48] National Fire Protection Association (2022). How to make a home fire escape plan.
url: https://www.nfpa.org/Public-Education/Staying-safe/Preparedness/Escape-planning, Accessed: 2023-06-10.

[49] A.P. Harpur, K.E. Boyce, and N.C. McConnell. An investigation into the circumstances surrounding elderly swelling fire fatalities and the barriers to implementing fire safety strategies among this group. *Fire Safety Science - Proceedings of the 11th Int'l Symposium*, 11:1144–1159, 2014. doi: https://DOI: 10.3801/IAFSS.FSS.11-1144.

[50] A. Rogers N. Williams, R. Evans and M. Final evaluation of the home fire risk check grant and fire prevention grant programmes-case studies. Report for Department for Communities and Local Government, Greenstreet Berman Ltd, March 2009. 180 p.

[51] J. Clare, C. Jennings, and L. Garis. Smoke Alarm Response Time: Examining the Relationship Between Working Smoke Alarms, Fire Service Response Times and Fire Outcomes. School of Criminology and Criminal Justice and Center for Public Safety and Criminal Justice Research, University of The Fraser Valley, October 2018, 13pp.

[52] W. Goetz. The Use of a Narrative Simulaton in Rural Residential Fire Prevention: A Preliminary Study of Changes in Behavioral Intention, PhD thesis. University of Kentucky, Lexington, KY, 116p, 2013. **url:** https://uknowledge.uky.edu/edc$_e tds$/5.

Appendix A: Fire Safety Vignettes and Education

Five main fire safety hazard categories were identified from the assessment of the HSA sheets and NIFRS data as the most relevant basis for development of fire safety vignettes and educational materials. These initial educational intervention materials are targeted towards environmental/engineering interventions against fire risk, specifically maintenance, which was the focus of our research. As such, the vignettes will outline fire hazards and risk reductions related to Electrical, Cooking, Heating/Wood Stoves, Egress/Clutter and General Maintenance[31].

Vignettes

The fire safety vignettes will provide a visual experience targeted toward identification of fire safety hazards and their associated dangers. The videos will be appropriate for use in education across a variety of learner groups as each will follow a simple, informative storyline conducive to presentation with and without any accompanying materials. To keep the vignettes short, the focus will be on crisp messaging of hazards/solutions (from a more technical perspective) and where they may occur in a dwelling. This is a relatively common method of dissemination found in fire safety informational/educational videos from other sources. Over a longer time frame, the same messages could be extended across range of different story-based messaging [20, 52].

Captured within each video clip are potential ignition and fuel sources related to a hazard categories common in the home, with emphasis on those found in the analysis outlined in this report. The videos will be aligned with additional documentation that outlines the associated learning objectives and some category-specific story line elements to enable easy connection to the associated learning material. The basic storyline for each vignette is as follows:

1. The targeted hazards are introduced through a 'room' walk through video where all hazards are visible, but not clearly identified (room set up in lab).
2. The fire ignites (ignition and fuel sources vary by category).
3. The initial speed of fire development is presented as clearly as possible; potentially linked to escape time.
4. Safe method(s) to extinguish the fire may also be shown, and cut to different video of what could have happened if the fire had progressed further (smoke-filled room, big fire, from other test videos).

The specific concepts being addressed are listed in Tables A.1, A.2, A.3, A.4, and A.5.

[31] NIFRS data also identified a large number of fire incidents associated with Smoking Materials/Lighters (matches). To target these particular ignition sources, a complementary set of fire safety vignettes and learner-led educational materials are envisioned for a later phase.

A.1: Electrical Hazard(s) Video Components

Potential Ignition Sources	**Potential Fuel Sources**
Exposed socket failure (no cover) Bare wire (short and/or open circuit) Overloaded Circuit	Wiring/cords/plastics around sockets Common household items (plastic toys) Upholstered furniture Curtains
Learning Objectives	
Broken/damaged wiring and extensions cords are a fire hazard Overloaded circuits are a fire hazard Electrical sockets without covers are fire hazards Electrical fires can evolve very quickly	
Safety Solutions	
Plug items into separate sockets Have broken or damaged electrical wiring and extension cords replaced or repaired Replace missing electrical socket covers	

A.2: Cooking Hazard(s) Video Components

Potential Ignition Sources	**Potential Fuel Sources**
Oil/grease fire Clutter on counter near cooking surface Unattended cooking Kitchen appliance failure	Common flammable kitchen items Food
Learning Objectives	
Cooking fires are a major cause of residential fires Always attend food that is cooking 'Minor' chefs should not be alone when cooking Cooking fires can grow very fast Extingquishing oil/grease fires incorrectly can make the fire worse	
Safety Solutions	
Finish cooking and turn off equipment before leaving Don't leave 'minor' chefs unattended Cover oil/grease fire to extinguish, do NOT use water	

A.3: Heating Hazard(s) Video Components

Potential Ignition Sources	**Potential Fuel Sources**
Space heater (tipped, poorly placed Wood stove	Curtains Upholstered furniture Lampshade
Learning Objectives	
Space heaters placed near flammables can lead to fire Flammable objects near wood stoves can lead to fire Poorly maintained chimneys/wood stoves can lead to fire Heating fires can evolve very quickly	
Safety Solutions	
Place space heaters and wood stoves away from flammable materials Be careful with any materials near space heaters and wood stoves Maintain and repair heating appliances when needed	

A.4: Egress/General Maintenance Hazard(s) Video Components

Potential Ignition Sources	**Potential Fuel Sources**
N/A	N/A
Learning Objectives	
Fire triangle (importance of fuel, oxygen and heat) Holes in exterior or interior walls can lead to faster fire growth than sealed walls Household clutter can block possible exit routes which can lead to people trapped inside houses Consider fire exit paths when renovating/building (basement) rooms Knowing your escape plan in case of a fire can increase chances of getting out in time	
Safety Solutions	
Patch exterior/interior walls, ceilings, foundations Think of two exits from your room/home Keep exit paths clear of obstructions	

A.5: Smoking Material/Lighters/Matches Video Components

Potential Ignition Sources	**Potential Fuel Sources**
Matches Smoldering Smoking Materials	Beds, blankets, pillows Upholstered furniture Carpet
Learning Objectives	
All types of smoking materials can pose a fire hazard; should be properly disposed after use Lighters/matches can pose a fire hazard; should be stored properly Children should not be alone with matches	
Safety Solutions	
Encourage people not to smoke inside near furnishings Remove smoking materials from someone falling asleep Store matches/lighters in a safe place Don't play with matches or lighters	

Learner-led Accompanying Material

Modern teaching techniques focus on learner-led education - working with the 'learner' to be more engaging and more effectively 'learned'. Thus, a set of learner-led materials is being developed to complement the videos as well.