A pilot survey of fire loads in Canadian homes

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A Pilot Survey of Fire Loads in Canadian Homes

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Abstract

This report presents the results of a pilot survey of combustible items in residential living rooms located on the main floor and basement levels. The survey was conducted using a web-based questionnaire. The main objective of the survey was to determine the types of movable fire loads found in living rooms situated on the main floor and basement levels.

The survey attracted 74 respondents. The efficacy of the survey methodology is discussed, and the main combustible furniture is identified. The types of furniture on the main floor and in basement living rooms were found to be similar, but basements contained a greater variety of furniture. The values of fire load densities calculated using estimated weights of furniture were within the range of values found in the literature.

Keywords: fire load, fire load density, fire load survey

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Abbreviations

MJ	Mega joules
Max	Maximum
Min	Minimum
TV	Television set

A Pilot Survey of Fire Loads in Canadian Homes

by
Alex Bwalya, Mohamed Sultan and Noureddine Bénichou

1 Introduction

Fires in residential buildings are often fatal and result in substantial property losses. Canadian fire statistics from the province of Ontario for the period 1995 to 1998 show that fires in residential properties accounted for 66% of the total number of fires and 95% of the total number of deaths[1], and that the most fatal fires originated in a living room area. Fire statistics from 1999, for the whole of Canada, show a similar pattern: the largest number of fires occurred in residential properties (40% of a total of 55,169 fires), with associated deaths and monetary losses of 73% and 42%, respectively [2].

In order to develop solutions to mitigate fire deaths and property losses in residential buildings, better methods of predicting the progression of a fire are needed. These methods should account for the factors that affect the intensity of a fire: the quantity and type of combustible contents, the ignition source and process as well as the growth and spread of the fire from the first to subsequent items ignited. In addition, the effects of building features, such as openings for ventilation (windows and doors), construction materials, and the dimensions of the compartment where the fire originated should also be taken into consideration. The quantity of combustibles in a compartment is commonly expressed as the total heat energy (MJ) that can be released through fully-ventilated combustion, and is known as the fire load. The fire load is often expressed as an energy density (fire load per unit floor area in MJ/m^2) to enable extrapolation to compartments of different sizes. At times, the contribution of the combustible parts of the building structure (the fixed fire load) is included in the total fire load. However, it is often the quantity of the building's combustible contents (the movable fire load) that is needed.

This report presents the results of a pilot survey of combustible household items, which was carried out using a carefully-designed internet-based questionnaire. The need for the survey was established through a literature review [3], which revealed that there was a lack of fire load data for Canadian homes. The main objective of the survey was to determine the types of movable fire loads found in living rooms situated on the main floor and basement levels.

Residential buildings contain a great diversity of combustible household items, ranging from furnishings to electronic audio, visual and computer equipment, all of which

are made from an equally diverse range of materials with different burning characteristics. The major combustible building material used in the construction of Canadian homes is wood. It is used in various forms (dimension lumber or engineered types) for the framing, floor joists, panels used for the sub-floors, and the sheathing of the roof and exterior walls. Whereas the fire resistance of wall and floor assemblies can be prescribed and their material composition known with certainty, this is not the case for combustible household contents, for which the quantity, type and arrangement of the combustibles is different for every home. This presents the greatest difficulty in any attempt to predict fire development in a given room with any confidence.

2 The Survey Method

Many published fire load surveys have been conducted by physically entering a building and listing the contents and their pertinent characteristics. This method is laborious, time consuming and, at times, progress can be hampered by privacy concerns. In addition, the judgement of the characteristics of the combustibles is done largely subjectively because it is impracticable to measure and determine precisely the material composition of every combustible item in the room.

Given the widespread use of Internet communication (electronic mail and the world wide web) in homes and places of work, it was felt that a questionnaire distributed through the Internet was capable of reaching a greater cross-section of the population. However, it was also recognized that using a questionnaire had the following disadvantages: a) much of the information obtained would be qualitative, b) the accuracy of any quantitative information cannot be easily verified, and c) many assumptions have to be made in order to quantify the combustibles. Despite these shortcomings, it was decided to study the feasibility of using this method for collecting the data.

The survey was primarily focused on combustible items found in living rooms, family rooms or recreation rooms located on either the main floor or basement level. In the context of this survey, the term ‘living room’ is used to refer to any of the aforementioned rooms.

2.1 Questionnaire Structure

The questionnaire had 64 questions. The authors’ co-workers at the Institute for Research in Construction (IRC) at the National Research Council of Canada (NRC) were selected for the pilot survey because of the ease of distributing the questionnaire.

Admittedly, a sample selected this way may not be representative of the general population as lower income families are probably under-represented.

The request for participants was sent out by e-mail. A hyperlink to the web page for the questionnaire was included in the e-mail. Respondents followed the hyperlink to complete the questionnaire and upon completion, their anonymous numerical responses were stored on a web server and could be retrieved for analysis at any time.

The questionnaire had a predetermined list of household items, which are commonly found in living rooms. Drop-down boxes were placed beside each item, from which quantities, sizes, materials and other pertinent attributes could be selected. In addition, there were questions about the type and size of the home, the number of exits, and the number of windows in a specified living room. The full questionnaire is given in Appendix A.

2.2 Assumptions

It is generally advisable to use a high value of fire load that can be foreseen during the life span of a building in a fire safety evaluation so as to arrive at what is commonly known as a worst-case fire scenario. Consistent with this approach, the fire loads presented in this report were calculated using the highest values of weight and heat of combustion found for each grouping of furniture. In addition, most of the furniture was assumed to consist of combustible materials (wood and synthetic polymeric products), which would completely burn during a fire. The value of the fire load calculated this way is assumed to be higher than the true average value as in reality some furniture may have non-combustible components; for example, glass-topped tables and steel-framed upholstered furniture, and, in addition, a living room setting is unlikely to consist entirely of heavyweight furniture.

2.3 Weights and Combustion Data for Furniture

Where possible, published data on heat of combustion [4,5,6] were used in the calculation of the fire loads. Electronic equipment, such as television (TV) sets and computers was assumed to consist of a 20 % combustible mass (mainly the plastic casing).

Weights, dimensions and the composition of representative furniture items were obtained from the manufacturers and local shops. From the information collected, low, medium and high values of weight were determined for each furniture item, but only the

high values were used in the calculation of the fire loads to be on the conservative side. The weights and heats of combustion used in the calculation of the fire loads are given in Appendix B.

Carpeting and area rugs were included in the calculation of the fire load. Carpeting (including the padding underneath it) was assumed to cover the entire floor, whereas area rugs were assumed to cover 80 % of the floor area.

3 Results

Seventy-four completed questionnaires were received. A breakdown of the types of homes found in the survey results is shown in Figure 1. The largest proportion of the homes was two-storey single-family detached homes.

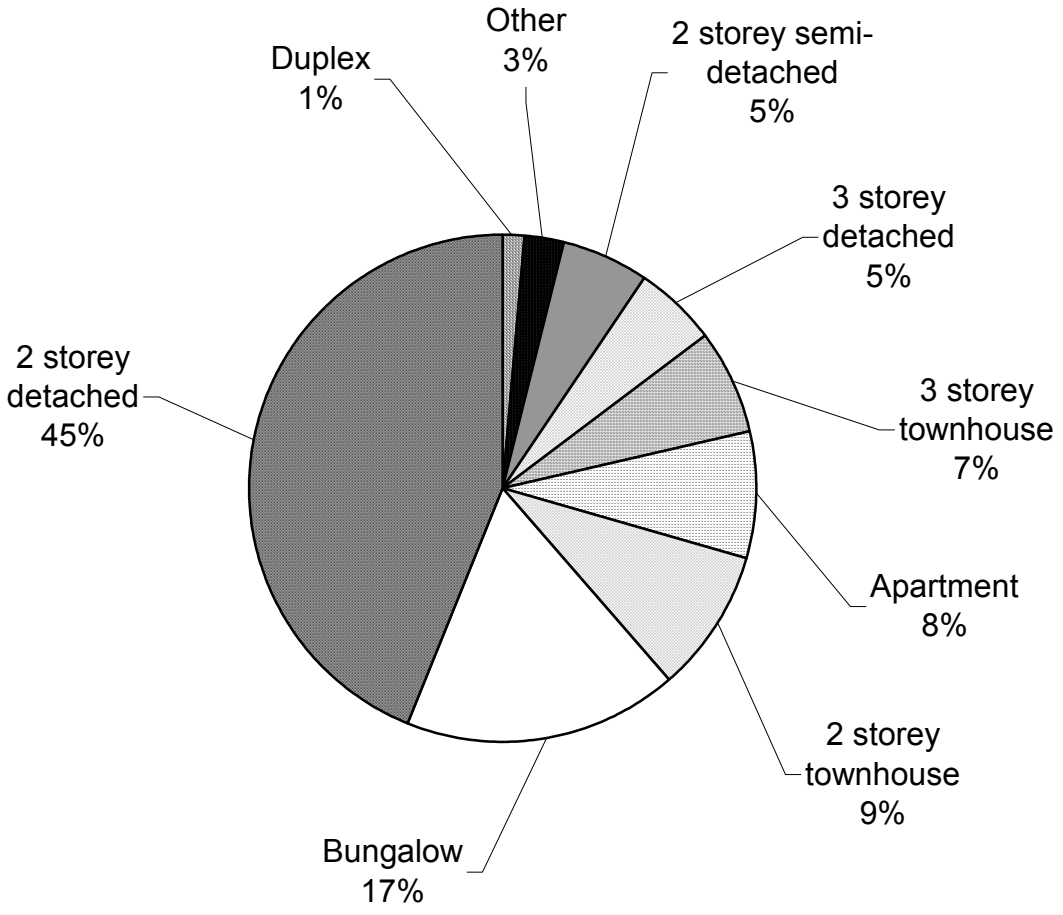

Figure 1. Distribution of homes

3.1 Main Floor Living Rooms

To determine whether the values of floor areas obtained from the survey were reasonable, floor areas for two-storey detached homes were compared with the values obtained from information provided with homes listed for sale on a popular real estate web site[7] within in the Ottawa-Carleton region. The results are shown in Figure 2 (real estate listings) and Figure 3 (survey data). The trends are similar, with most of the homes having living room floor areas between 15 m^2 and 25 m^2, with a mean value of 22 m^2 for the survey, and 20 m^2 for the data from the real estate listings. However, the survey results have a much wider spread and values above 40 m^2 and below 10 m^2 do not appear to be realistic. Figure 4 shows that the distribution of living room floor areas for all the homes in the surveys has a similar pattern: a mean of 22 m^2 and standard deviation of 10 m^2.

Errors in the floor areas obtained from the survey would influence values of fire load density – rooms misjudged to be small and large would have high and low fire load densities, respectively.

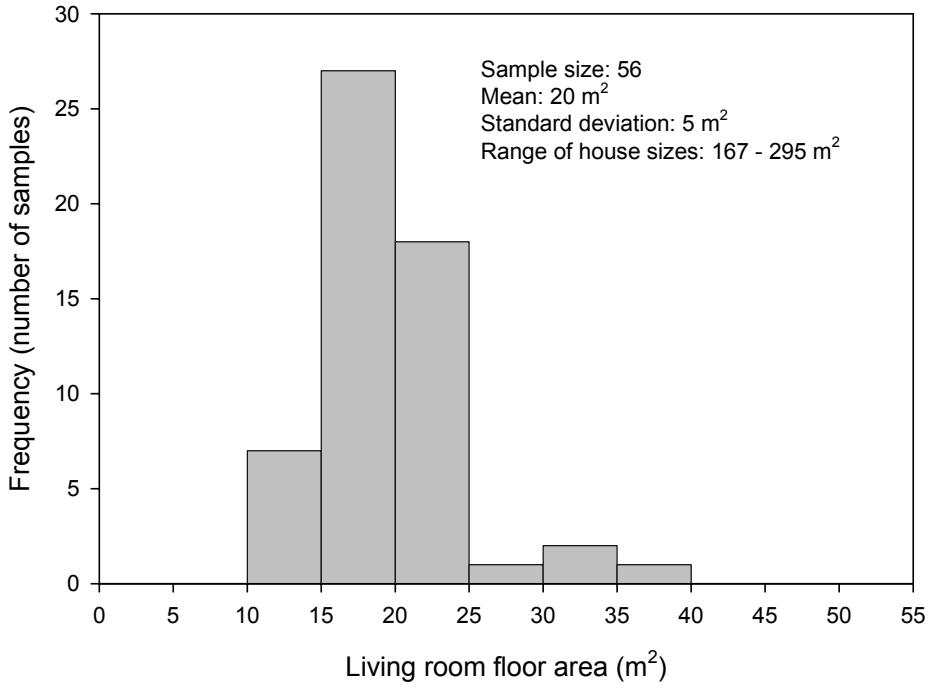

Figure 2. Frequency distribution of living room floor areas for 56 two-storey detached homes listed for sale on a popular real estate web site.

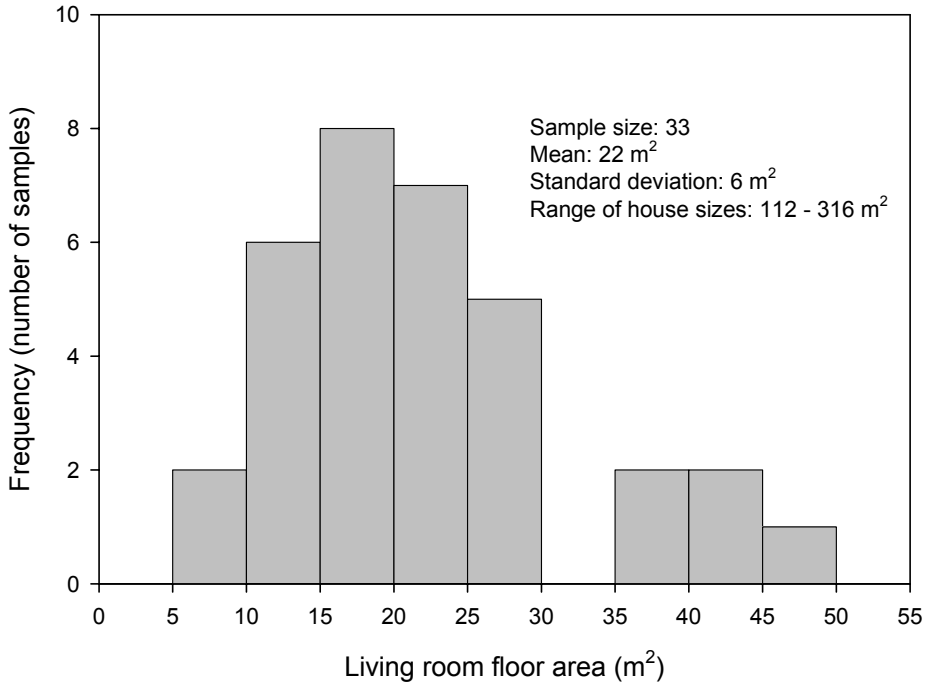

Figure 3. Frequency distribution of living room floor areas for 33 two-storey detached homes obtained from the survey

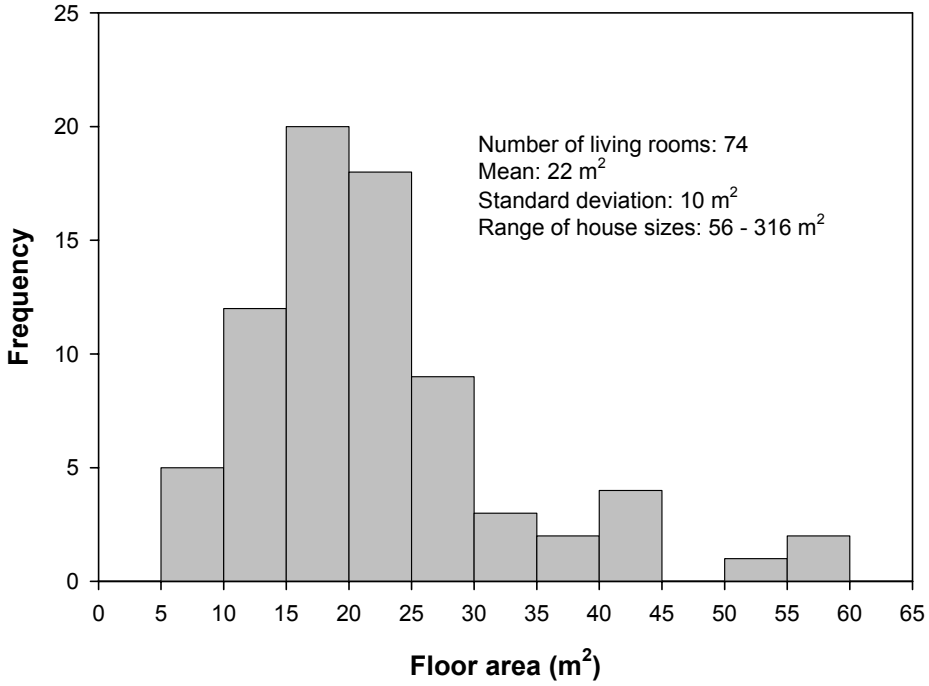

Figure 4. Frequency distribution of living room floor areas for all the homes in the survey.

Table 1 shows the average values of living room floor areas, the number and area of windows for the different types of homes. Most of the homes have at least two windows and the area of the largest windows is typically greater than 2 m^2. These values are not definitive because the size of the sample studied is small and some types of homes are not well represented.

Table 1. Average values of living room floor area, number and area of windows

Home	Living room area (m^2)	Number of windows	Area of largest window (m^2)	Number of samples
Apartment	24	3	3.4	6
3 storey town home	23	2	3.2	5
2 Storey semi-detached	17	1	2.7	4
2 storey detached	22	2	2.5	33
3 storey detached	15	2	1.4	4
2 storey town home	22	2	3.5	6
Bungalow	26	3	2.6	13
Duplex	9	2	2.2	2

3.1.1 Combustible Contents

Figure 5 shows the total quantity of each type of furniture found in the survey in ascending order of the total fire load. As can be expected, upholstered furniture makes a significant contribution. It is capable of bringing about untenable conditions and, possibly, flashover on its own. It is also evident that the contribution of other items is significant. However, due to the slow burning rate of most wood-based furniture, their main effect would be to extend the duration of burning.

Figure 6 shows the frequency distribution of the number of individual unspecified items shown in Figure 5. It can be inferred, from Figure 6, that typical living rooms contain four to eight of the items listed in Figure 5. These items typically include a TV and at least one of the furniture combinations listed in Table C-1 (Appendix C). Therefore, there is

clearly no one typical living room layout. However, the typical contents could be considered to be items found in at least 40 % of the homes, which, going by Figure 5, are items present in quantities greater than 30. These are: a sofa, loveseat, recliner/chair, TV, bookcase, entertainment unit, coffee table and side table.

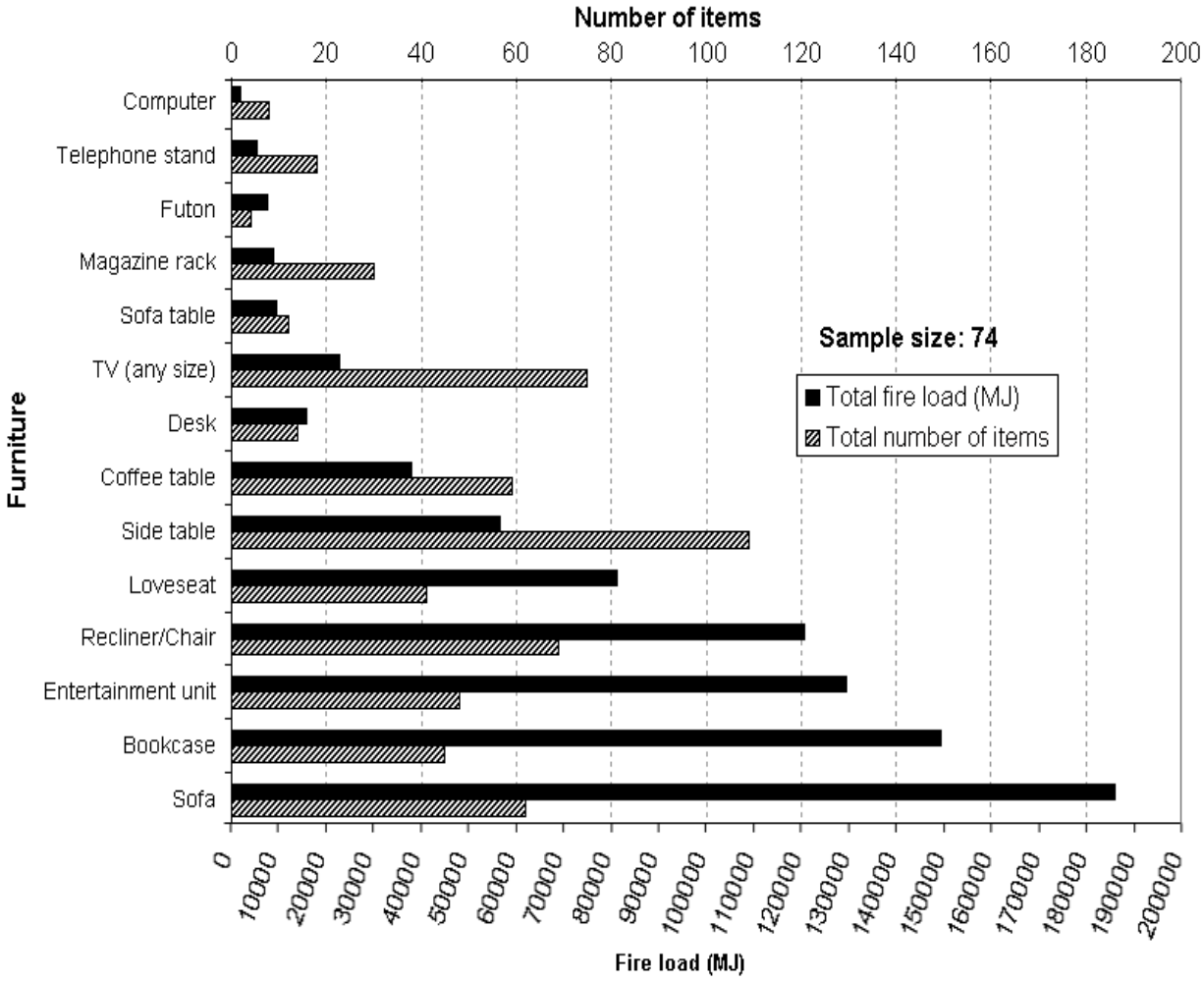

Figure 5. Furniture in main floor living room (in ascending order of total fire load)

Figure 7 shows the frequency distribution of the total fire load for each type of home, which has a normal distribution with a mean of 10000 MJ and a standard deviation of 3000 MJ. The average fire load density for each type of home is given in Table 2, based on the average floor area of 22 m^2 obtained from the survey.

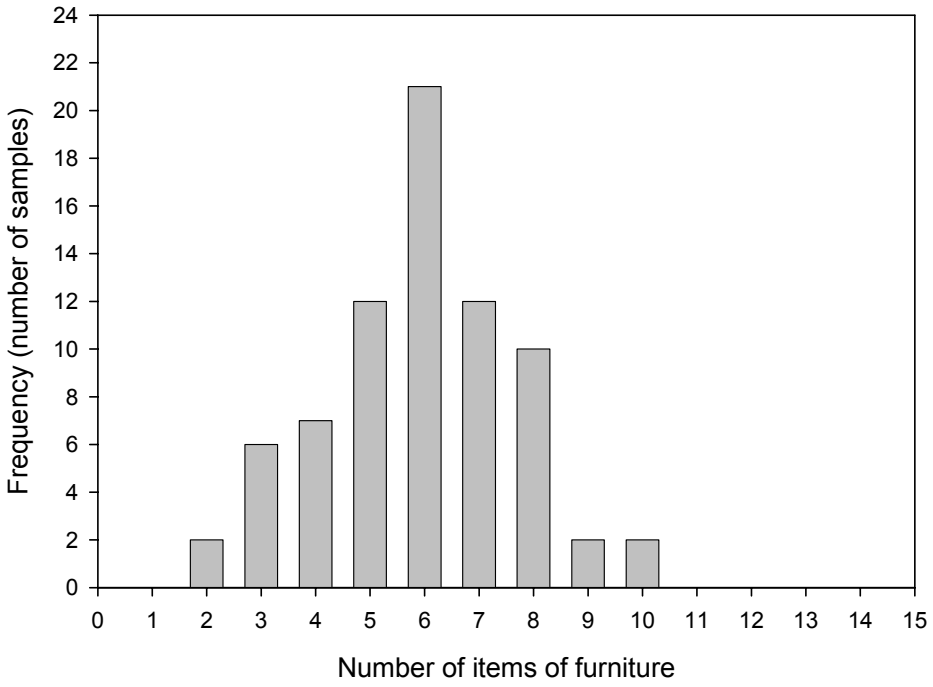

Figure 6. Frequency distribution of total number of furniture items identified in Figure 5, which were found in the homes.

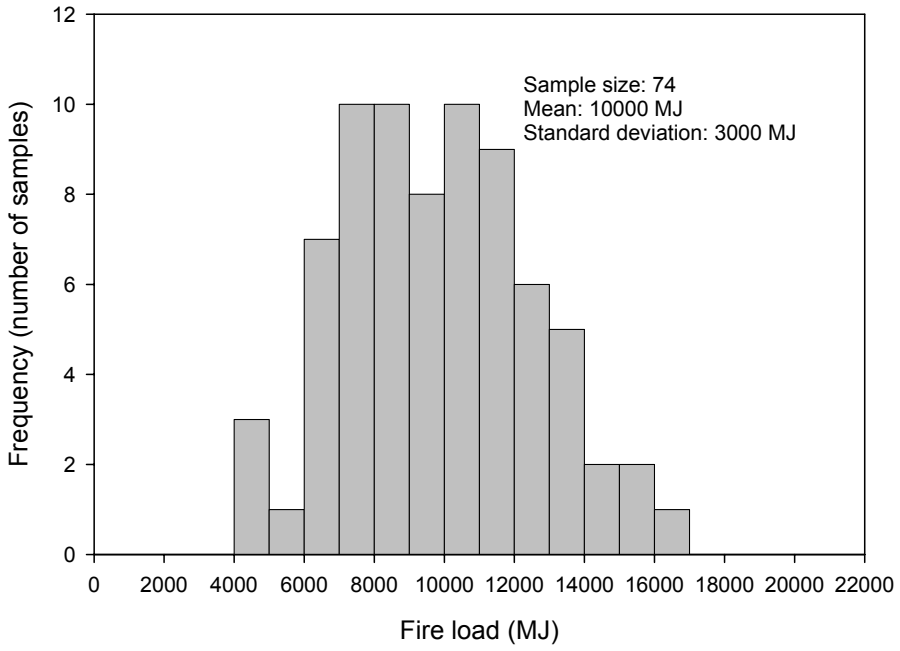

Figure 7. Frequency distribution of total fire load for living rooms

Table 2. Mean values of fire load and fire load density for the various homes

Home type	Mean fire load (MJ)	Mean fire load density based on floor area of 22 m^2 (MJ/m^2)	Number of samples
Apartment	12000	550	6
3 storey town home	11000	500	5
2 storey semi-detached	10000	450	4
2 storey detached	11000	500	33
3 storey detached	11000	500	4
2 storey town home	10000	450	6
Bungalow	10000	450	13
Duplex	7000	300	2

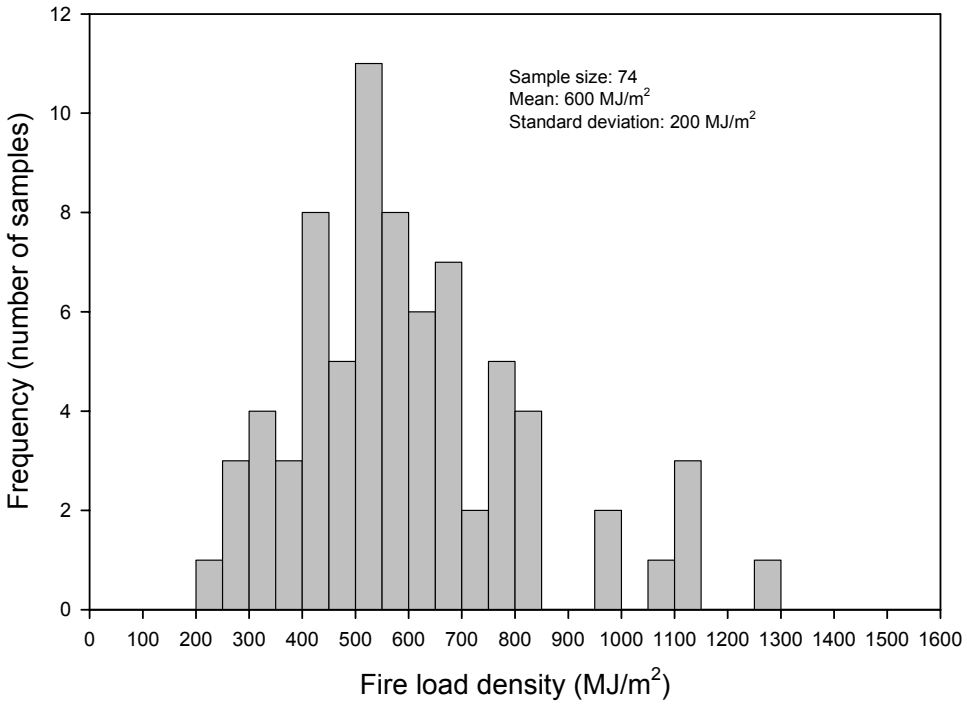

Figure 8. Frequency distribution of fire load density for living rooms.

3.2 Basements

The floor areas of living rooms in basements were found to vary widely, as can be seen in Figure 9. The values below 10 m^2 and above 45 m^2 do not appear to be realistic. If these values were excluded, the average floor area and standard deviation would be 28 m^2 and 9 m^2, respectively. Whereas the average floor area is not significantly different from the value of 30 m^2 obtained using all of the data, the dispersion is reduced considerably. These results could not be compared with ones from real estate listings because information on basement living room sizes was frequently omitted in the listings.

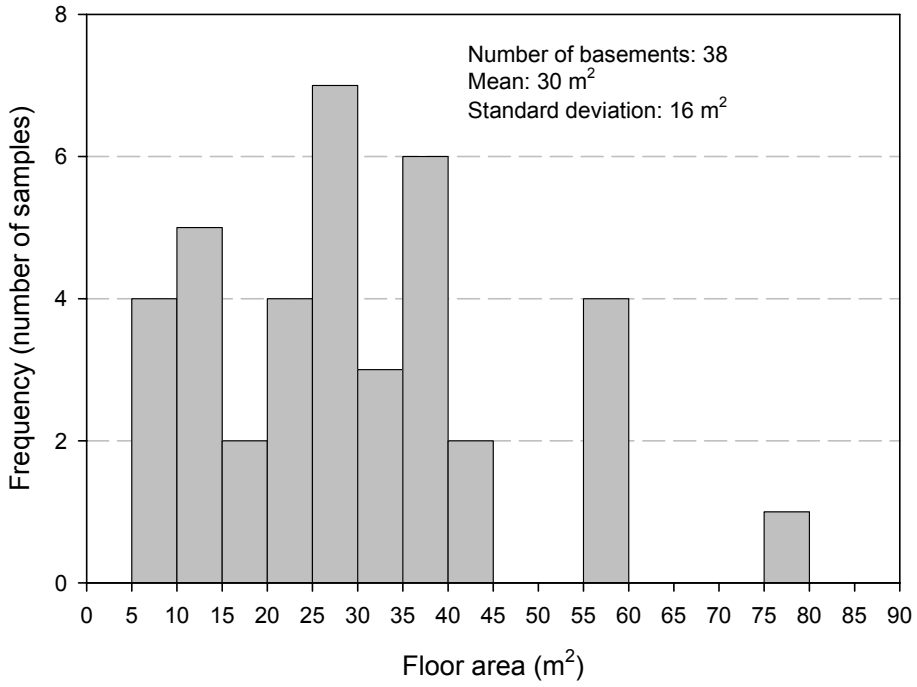

Figure 9. Frequency distribution of floor areas of basement living rooms.

Table 3 shows the average values of the living room floor area, and the number and area of windows for the different types of homes.

Thirty-eight (60 %) of the 63 homes that had basements had a finished portion of the basement being used as a living room. Sixty three percent of the homes with a finished portion of the basement had a door on the main floor leading to the basement. The state of the ceiling in the basements is shown in Figure 10.

Table 3. Average values of basement living room floor area, number and area of windows for each type of home.

Home	Living room area (m^2)	Number of windows	Area of largest window (m^2)	Number of samples
2 Storey semi-detached	24	2	0.6	4
Bungalow	37	4	0.9	11
2 storey detached	33	2	0.5	18
3 storey detached	14	3	0.1	2
2 storey town home	14	2	1.3	6
3 storey town home	32	3	0.3	3
Duplex	7	6	1.4	1

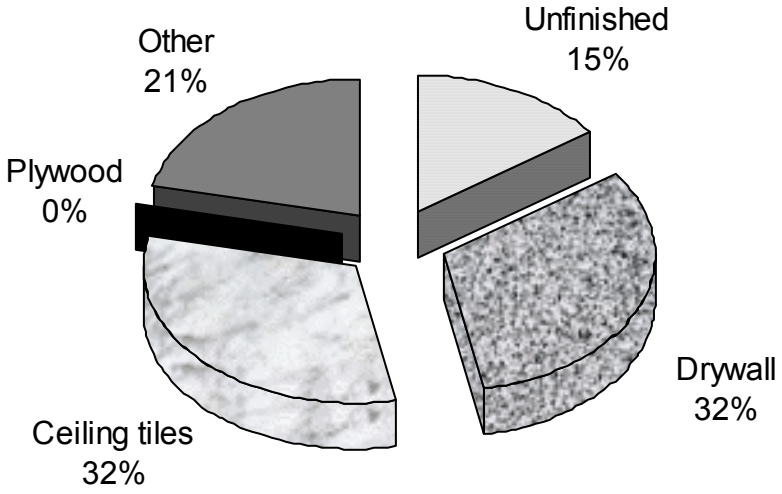

Figure 10. Basement ceiling finish

3.2.1 Combustible Contents

Figure 11 shows the quantities of each type of furniture found in basement living rooms in ascending order of the total potential heat energy that could be released by complete combustion. Most of the furniture was also found in main floor living rooms.

A typical basement would be assumed to contain items found in at least 40 % of the sample, that is, items recording a count greater than 15 in Figure 11. These are: a sofa, bookcase, entertainment unit, recliner/chair, loveseat, drawer chest, desk, coffee table, side table, light chair, TV and computer.

The frequency distribution of the total fire load is shown in Figure 12 and the fire load density distribution is shown in Figure 13. The total fire loads are comparable with the values for main floor living rooms. The mean fire load density is a little less in basements because the average floor area is greater than that for main floor living rooms.

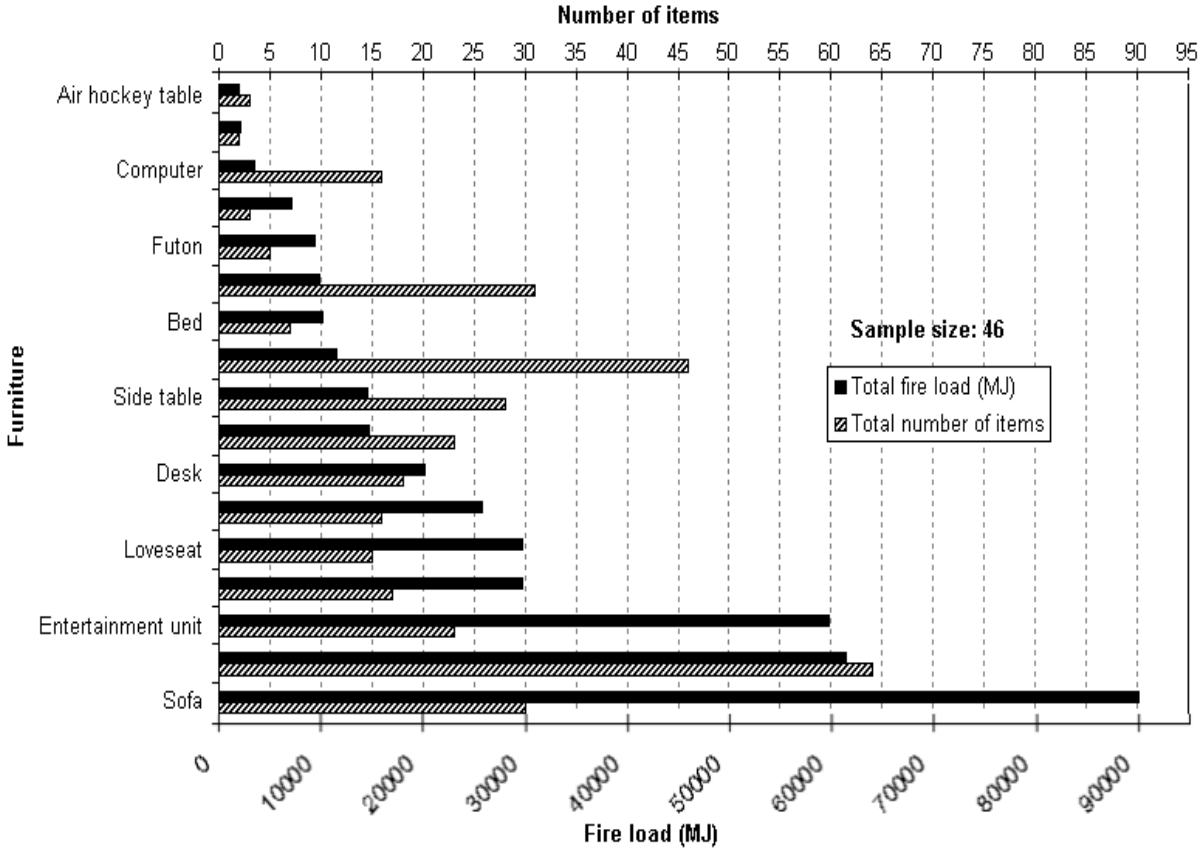

Figure 11. Furniture in basement living rooms (ranked in ascending order of total fire load)

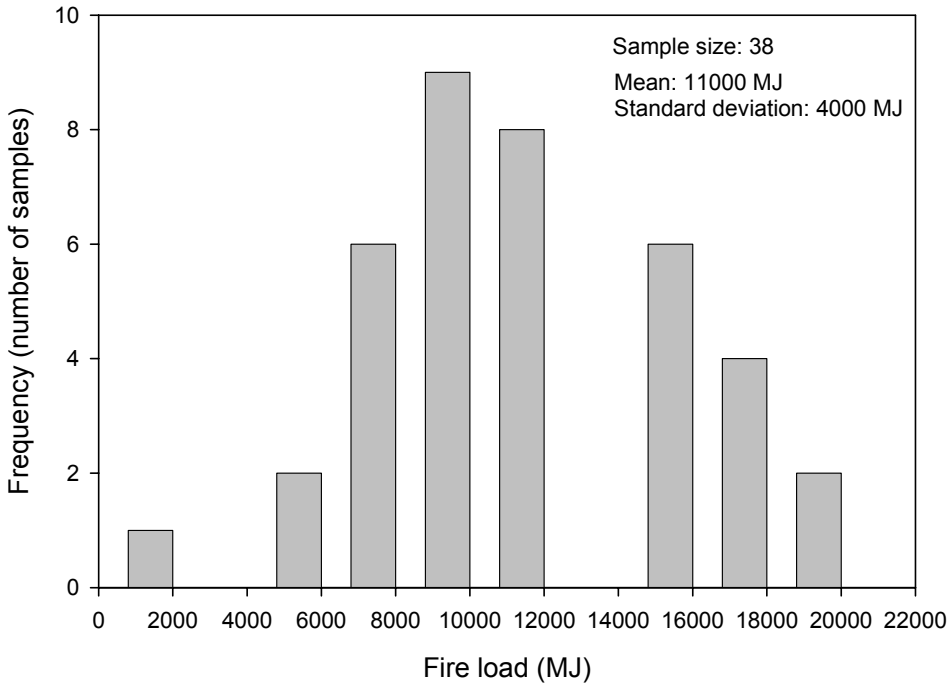

Figure 12. Frequency distribution of fire load for basement living rooms.

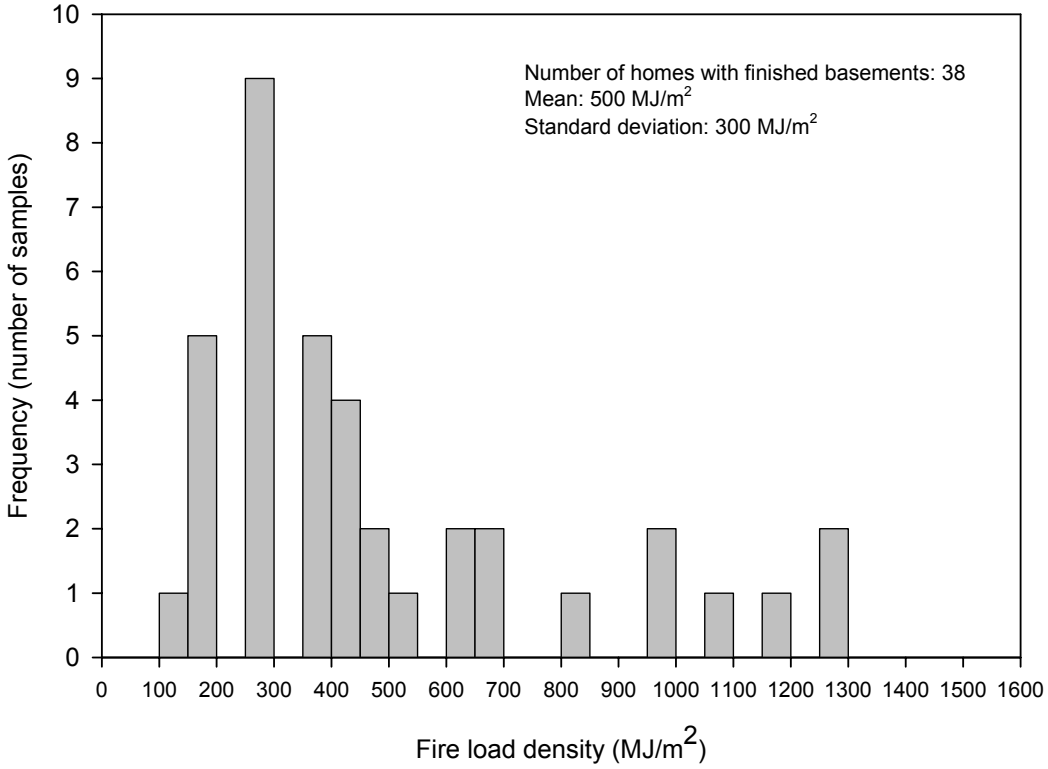

Figure 13. Frequency distribution of fire load density for basement living rooms.

3.3 Discussion of the Results

Many published fire load surveys have shown that fire loads in houses vary greatly, even within the same geographical location. The values obtained in the current survey compare favourably with those reported in the literature (especially for the US), as shown in Table 4.

Table 4. Published fire load densities for residential occupancies

Fire load density (MJ/m^2)	Country	Reference	Notes
450	US	8	Survey of basement recreation rooms in 200 single family detached homes
500	US	8	Survey of 70 residential recreation rooms
400,800,1200	New Zealand	9	Recommended in the New Zealand building code
600	Sweden	11	-
724	New Zealand	12	-
670	Japan	13	Survey of 214 homes
600, 500	Canada	-	This survey (mean values for main floor and basement living rooms in 74 homes)

The values of the total fire load presented in this report are speculative to the extent that the actual weights and material composition of the combustibles are not known. However, these values are reasonable as they are based on realistic weight and heat of combustion values. Arguably, fire load numbers alone are not indicative of how a fire will progress or what its size will be; they merely permit the estimation of some fire effects such as the likelihood of flashover and the duration of burning using empirical formulae.

The main combustibles in main floor and basement living rooms found in this study are listed in Table 5.

Table 5. Combustibles found in main floor and basement living rooms

Living room location	Type of furniture
Main floor Basement	▪ Upholstered furniture (sofa, loveseat, recliner/chair, futon, light-framed chair) ▪ Other furniture (telephone stand, magazine rack, side table, coffee table, desk, bookcase, entertainment unit) ▪ Electronic equipment (TV and computer)
Basement only	▪ Bedroom type furniture (bed, drawer chest) ▪ Other recreational related (pool table, table tennis table, foosball table)

4 Conclusions

The fire load survey reported here identifies the main types of combustibles, which can be found in main floor and basement living rooms. Admittedly, the restrictive nature of the questionnaire precludes the quantification of miscellaneous combustible items that could contribute to the total fire load, such as paper products, toys and other articles strewn all around the room. Nevertheless, this study has identified combustibles, which could be targeted for experimentation to produce information that can be used in the development of design fires.

The fire loads in basement and main floor living rooms appear to be similar. However, basements may contain a greater variety of furniture than main floor living rooms.

A fire load survey conducted using a questionnaire has limitations when it comes to determining accurate room dimensions and weights of combustibles. However, the types of combustibles in a particular room can be identified by this method. This is important in determining realistic fire scenarios.

5 Recommendations

1. Extend the survey to a wider cross-section of the population.

2. Design mock-ups of furniture identified in the pilot survey and conduct an experimental study to determine: a) their combustion characteristics, b) how fires involving these combustibles progress in simulated living rooms.

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Appendix A: Survey Questionnaire

GENERAL:

1. Type of home

--Select--

2. Approximate square footage of home (excluding basement)

--Select--

3. What is the approximate area of the exit corridor from the bedroom area?

--Select--

4. Please specify the number of exits from the main level of your home.

--Select--

5. Where are the stairs to the second floor located? (Answer only if applicable) -

--Select--

MAIN FLOOR LIVING SPACE:

6. Which room (living room/family room) on your **main** floor do you use most often? (For some homes this could be on the second floor.)

--Select--

The next 10 questions are about the room, which you have selected in the previous question.

7. Room dimensions (Length (L), Width (W)):

L: --Select--

W: --Select--

8. Number of windows

--Select--

9. Size of largest window. (Width (W), Length (L))

W: --Select--

H: --Select--

10. Window coverings

--Select--

11. Floor finish

--Select--

12. Wall finish

--Select--

13. Please specify the quantity of the following items in the room of interest:

3 seat sofa(s) 0	Loveseat(s) 0	Recliner(s)/one seat upholstered chair(s) 0
futon(s) 0	Side table(s) 0	Coffee table(s) 0
Computer(s) 0	Non-metallic desks 0	Wooden entertainment unit 0
Sofa Table(s) 0	Magazine table/rack 0	Telephone stand(s) 0

14. Bookshelves

Quantity --Select--	Average size --Select--

15. Size of television

--Select--

16. Type of fireplace

--Select--

BASEMENT:

The remainder of the questions are about your **basement**. (If you do not have a basement please scroll down to the end and click on "Submit Survey")

17. Is there a door on the stairs leading to the basement?

--Select--

18. What percentage of your basement is finished?

--Select--

19. Number of windows

--Select--

20. Size of largest window.

W: --Select--

H: --Select--

21. If you have the following rooms in your basement, please select 'Yes'.

Recreational area Yes No ☐ ◉	Office Yes No ☐ ◉	Bedroom Yes No ☐ ◉

The remainder of the questions will now focus on the **recreational space/family room** in your **basement**. (If you do not have a recreational space/family room in your basement or if your basement is unfinished, then scroll down to the end and click on "Submit Survey")

22. Room dimensions:

L: --Select--

W: --Select--

23. Window coverings

--Select--

24. Floor finish

--Select--

25. Wall finish

--Select--

26. Ceiling finish

--Select--

27. Please specify the quantity of the following items in the recreational space/family room:

3 seat sofa(s) 0	Loveseat(s) 0	Recliner(s)/one seat upholstered chair(s) 0
Futon(s) 0	Side table(s) 0	Coffee table(s) 0
Computer(s) 0	Non-metallic computer tables/desks 0	Wooden entertainment unit 0
Chest of drawers 0	Non-metallic chairs 0	Air hockey table 0
Pool table 0	Foosball table 0	Table tennis table 0

28. Bookshelves

Quantity --Select--	Average size --Select--

29. Type of bed

--Select--

30. Size of television

--Select--

31. Type of fireplace

--Select--

Submit Survey

Appendix B: Weight and Heat of Combustion Values

Table B-1. Weight and heat of combustion values

Item	Description	Weight (kg)			Heat of combustion (MJ/kg)		
		Low	Medium	High	Low	Medium	High
1	Three-seat sofa	46	65	91	15	18	33
2	Loveseat	38	48	60	15	18	33
3	Recliner/chair	27	41	53	15	18	33
4	Futon	44	51	57	15	18	33
5	Side table	6	16	26	16	18	20
6	Coffee table	9	24	32	16	18	20
7	Computer	23	30	40	18	20	22
8	Computer desk	19	43	56	16	18	20
9	Entertainment unit / TV stand	21	67	130	16	18	20
10	Sofa table	32	35	40	16	18	20
11	Magazine table/rack	6	11	15	16	18	20
12	Telephone stand	6	11	15	16	18	20
13	Bookcase	10	30	48	16	18	20
14	TV: <13”	11	12	13	23	25	27
15	TV: 14” – 20"	22	26	31	23	25	27
16	TV: 21” – 26"	41	50	55	23	25	27
17	TV: 27"	41	50	55	23	25	27
18	TV: 28” – 36"	53	67	80	23	25	27
19	TV: >37"	72	95	128	23	25	27
20	Drawer chest	31	53	80	18	18	20
21	Light chair/computer chair	6	12	16	23	25	27
22	Mattress and box-spring (double)	61	68	73	20	22	24
23	Air hockey table	26	30	34	16	18	20
24	Foosball table	26	30	34	16	18	20
25	Table tennis table	47	50	53	16	18	20
26	Night table	14	22	27	16	18	20
27	Pool table	113	115	118	16	18	20

Appendix C: Furniture Arrangements

TableC-1. Some layouts of furniture found in main floor living rooms.

#	Furniture Arrangement	Number of homes	% (of total sample)
1	Sofa/loveseat/chair/coffee table/entertainment unit/bookcase	5	7
2	Sofa/loveseat/chair/coffee table/entertainment unit	11	15
3	Sofa/loveseat/chair/coffee table/side table	5	7
4	Sofa/loveseat/chair	7	9
5	Sofa/loveseat/entertainment unit	14	19
6	Sofa/loveseat/bookcase	7	9
7	Sofa/loveseat	24	32
8	Sofa/chair	30	41
9	Loveseat/chair	15	20
10	Sofas/two chairs	10	14
11	Two sofas/loveseat	1	1
12	Two sofas/chair	2	3