

# Wood Stove Inventory and Behaviour Analysis

Prepared for:  
**BC Ministry of Environment**



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## EXECUTIVE SUMMARY

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This report presents a compilation of data from five different surveys completed in BC over the past 12 years that describe residential wood burning appliances and related behaviour. An ENVOLV™ database was used to store information from the surveys, add weighting factors and generate graphs. The surveys were combined into two datasets that can be compared against each other, representative of the years 2003 (2001, 2002, and 2003 surveys) and 2012 (2010 and 2012 surveys).

Based on the data from the surveys, the use of wood for heating in BC has not changed much between 2003 and 2012 and remains stable at about 31%. Wood use per household has also remained stable (except for MV). On the other hand, a clear trend towards more certified appliances can be observed: 68% of all wood stoves were certified for low emissions in 2012 (44% in 2003), and about half the fireplaces (inserts) were certified in 2012. This trend towards cleaner burning appliances is confirmed by the average age of wood stoves, which appears to have fallen from around 18 years in 2003 to around 17 years in 2012 (not including MV, where appliance age appears to have increased). At the same time, there is a trend away from fireplaces and inserts towards certified wood stoves, pellet stoves, and central heating systems, which are generally cleaner burning appliances. This can be expected to lead to lower air emissions, which is also reflected in the overall improvement of attitudes about wood smoke throughout BC.

These expectations are, however, not reflected in the emission results, which show an increase of residential wood combustion emissions since 2003. The increase can be explained based on the large increase in wood use in Metro Vancouver and the FVRD, which is likely not real but due to a major change in methodology between 2003 and 2012 (we believe the 2010 data are more reliable and the 2002 survey may have underestimated wood use in MV). Yet, a decrease since 2003 would be expected due to the larger number of certified appliances in 2012. It is believed that the discrepancy also stems from great local variation in wood user incidence determined from the 2003 and 2012 datasets. Without corroboration from other sources, such as wood stove sales statistics, it remains unclear whether these variations are real or only statistical artefacts. The results should therefore not be taken as ultimate proof that emissions have not decreased since 2003 but it is more likely that firm conclusions cannot be drawn based on the data at hand.

The statistical uncertainties inherent in the survey results increase with respect to the regional results versus overall provincial results. This means that regional trends cannot be determined with as much certainty, especially since the regional wood user incidence sometimes varies strongly between the two datasets, suggesting reasons due to the sample interviewed that may not reflect real circumstances. The data nevertheless allows for some trends and regional differences to be seen with certainty, such as the very high fireplace incidence in Metro Vancouver versus the rest of BC. Several other issues have been investigated and are reported in the body of this report. Emission results were also be presented by sub-region for the 2012 dataset (there were seven regions and 30 sub-regions). Sub-regional results are subject to even greater statistical uncertainty than the regional results. Their interpretation and especially the assessment of any trends over time should therefore be undertaken with much caution and may need confirmation from other sources in order to validate any trends.

## 1.0 BACKGROUND AND METHODOLOGY

### 1.1 PURPOSE

The purpose of this work was to compile a database that would combine several past surveys into one dataset that describes residential wood burning appliances and related behaviour for all of BC. Previous surveys had been conducted between 2001 and 2003, as well as in 2010 and 2012. These were combined into two datasets that can be compared against each other. To do so, the data were aligned and partially adapted to fit the latest BC survey conducted in 2012. All data were integrated into an ENVOLV™ database, which allows for the creation of data output tables or graphs through a user-friendly button interface. A number of reports can be generated based on a full or partial BC dataset, which allows for the identification of trends between the recent surveys and the earlier ones carried out about a decade ago.

### 1.2 PAST SURVEYS

Since 2001, four telephone surveys and one mail survey have been conducted in BC to gauge the use of wood stoves and attitudes around wood smoke:

- the *Okanagan Indoor Wood Burning Appliance Inventory Survey*, covering the Kelowna region, by the Okanagan Air Quality Technical Steering Committee (2001);
- the *“GVRD Residential Wood Burning Survey”* by Ipsos Reid (2002)
- the 2003 BC survey by McIntyre & Mustel Research Limited, which resulted in two published reports: *“Residential Wood Burning Emissions in British Columbia”* (2005) and *“Residential Wood Burning in British Columbia: Public Behaviour and Opinion”* (2006)
- the *“MV Residential Wood Burning Survey”* by Ipsos Reid (2010)
- and the Mustel Group *“Inventory of Wood Burning Appliance Use in BC”* (2012)

Table 1 provides a quick overview of these surveys. The 2001/2/3 surveys were integrated as one single dataset (cohort) to be compared to the 2010/2012 surveys as a second dataset (cohort). This section provides a summary of the methodologies of these surveys, highlighting key differences and explaining how these differences impacted on the creation of an integrated database. For simplicity, the surveys are referred to **by their year** below. Also, we frequently use the abbreviation **MV** for Metro Vancouver and **FVRD** for the Fraser Valley Regional District.

**Table 1: Overview of Past Surveys**

Dataset	Survey	Year	Sample Size	Regions	Sub-Regions	Data provided
2003	Okanagan	2001	778	1	3	Summary report and cross-tables, PDF
	Metro Vancouver/FVRD	2002	500	2		Summary report, PDF
	BC, excl. Okanagan, MV	2003	3,149	7	19	Raw data, XLS
2012	Metro Vancouver	2010	600	1	4	Raw data, XLS
	BC, excl. MV	2012	2,527	6	26	Raw data, XLS

Table 2 shows the regions used in past surveys. The combination of the first three surveys (2001-2003) and the combination of the 2010/12 surveys were used to describe the situation in 2003 and 2012 in the entire province. The regions, however, are defined slightly differently in the 2003 and 2012 surveys: the 2003 survey had separate regions for Skeena and the Northern Interior, whereas these are combined in the 2012 survey. Also, there was regional overlap between the 2001 and 2003 surveys in the Okanagan area.

**Table 2: Geographical Regions Covered in Past Surveys**

2001	2002	2003	2010	2012
	MV		MV	
	FVRD	Sunshine Coast		South Coast Region
Okanagan		Southern Interior		Thompson/Okanagan Region
		Vancouver Island		West Coast Region
		Kootenay		Kootenay/Boundary Region
		Cariboo		Cariboo Region
		Skeena, Northern Interior		Northern Region (Omineca, Skeena and Northeast)

Due to the fact that only three reports were available as raw data (i.e., the survey responses for each phone call), the possibilities to compare the 2010/12 dataset to the earlier surveys are restricted. Only cross-tabulated data that is available from the PDF reports could be used for those surveys, which was generally only available either for the entire region covered or for some sub-regions. Information on the particulars of each survey, data reconciliation, and methodology can be found in **Appendix 1**. A short description of the ENVOLV™ database is in **Appendix 2**.

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## 2.0 RESULTS

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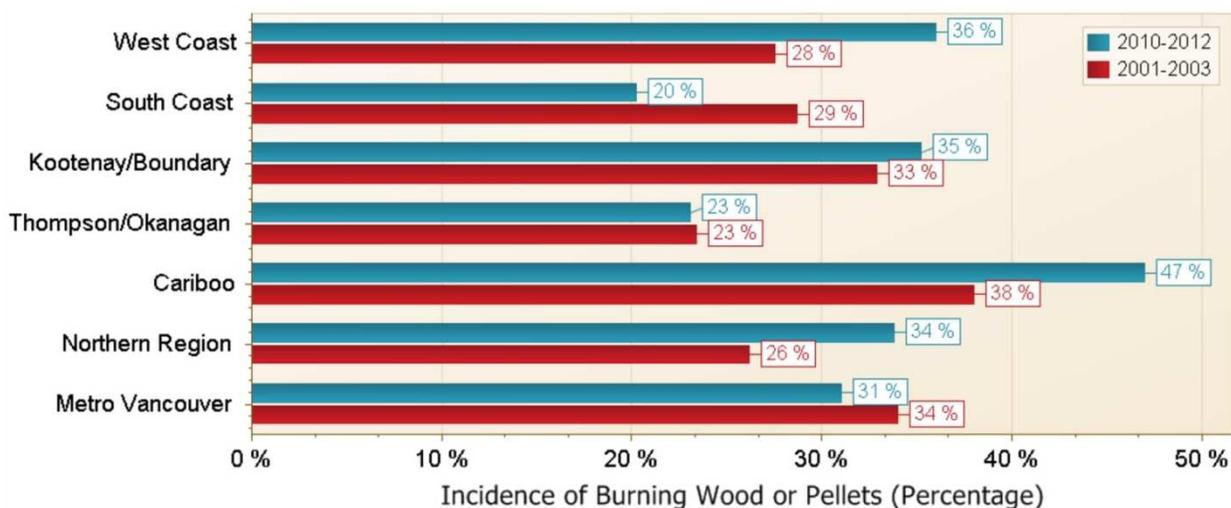
### 2.1 INTRODUCTION

This chapter discusses the results from the combined dataset of the 2010 and 2012 surveys, and the 2001, 2002, and 2003 results, which were combined into a second dataset representative of the situation about a decade ago. We verified that the results generally coincide with those reported in earlier analyses, i.e. the statistical evaluation was performed in the same or a similar way. There may be some differences that stem from differences in methodology (see above). The main advantage of combining these datasets is to have a recent analysis for 2010/12 and also to compare this data to the situation ten years ago in order to detect differences and tendencies with respect to wood burning in BC. The 15 reports from Table 7 in Appendix 1 are discussed below. Note that the 2001 and 2002 reports could only be added integrally, i.e. as percentages from pre-calculated results, since the original raw data was not available. This limits the number of reports and combinations possible for the combined 2003 dataset.

When looking at this data, the confidence intervals need to be kept in mind. Only fairly small samples of the population were interviewed, such that the detailed questions do not always result in very high certainty with respect to the results, and therefore, clear trends between the 2003 and 2012 datasets. For example, the 2003 BC survey had 471 calls to determine users and non-users in the 'Other West Coast' sub-region, which represent 155,000 households. This number of calls resulted in an incidence of 35.1% for wood users for that sub-region. The confidence interval in this case is  $\pm 4.3\%$ , i.e. the actual user incidence may lie between 31 and 39%. With respect to specific questions on wood use (i.e. in relation to 35% of the population), about 100 users were interviewed per region. With the same example, the uncertainty would then be  $\pm 9.4\%$ . Yet, answers to each question were not always available from all users, i.e. they either did not answer some questions or answered with a 'don't know'. In case only half the users would have answered a particular question, the uncertainty then increases to  $\pm 13.5\%$  in the above example, i.e. there would be about a 38% uncertainty with respect to such a datapoint. For the 2012 survey, uncertainty for users and non-users varies between  $\pm 4.7$  and  $7.2\%$ , depending on the region, although overall uncertainty for all of BC is only  $\pm 2.2\%$ . This means that regional results are somewhat less certain and that trends need to be consistent to be regarded as real. These uncertainties may also account for some of the counter-intuitive results that were obtained, such as the increase in emissions from 2003 to 2012, despite only a small increase in wood use and a significant increase in certified appliances.

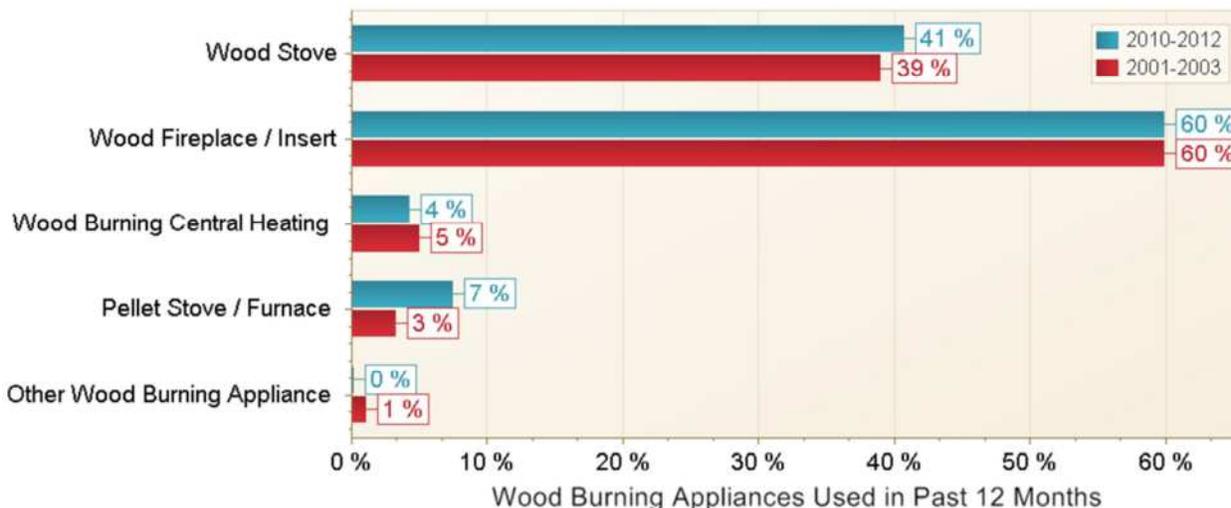
### 2.2 WOOD USERS AND NON-USERS

The incidence of wood users has remained at almost the same level since 2003 in BC, i.e. a BC average of 31% wood users in 2012 and 30% in 2003. Yet, there are regional differences (Figure 1) which should, however, be taken with caution because of the larger confidence interval for the regional results, which can exceed 7%. Wood users are fewer in MV in the 2010 survey, which may be due to new construction which, especially in the MV region, does usually not include wood burning appliances, as well as to fuel switching away from wood fuels. To compare, the 2003 survey by itself determined a wood user incidence of 28.2%, and the 2002 survey resulted in 32% for the Lower Mainland (34% for MV alone), whereas the 2012 survey estimates 30.2%. This would indicate a decrease in MV and a slight increase for the rest of BC, which partially cancel each other out. Apart from MV, the South Coast area, and the Thompson-Okanagan, wood user incidence has increased in BC regions.

**Figure 1 Percentage of Wood Users, by Region (2003 and 2012)**

### 2.3 TYPES OF APPLIANCES

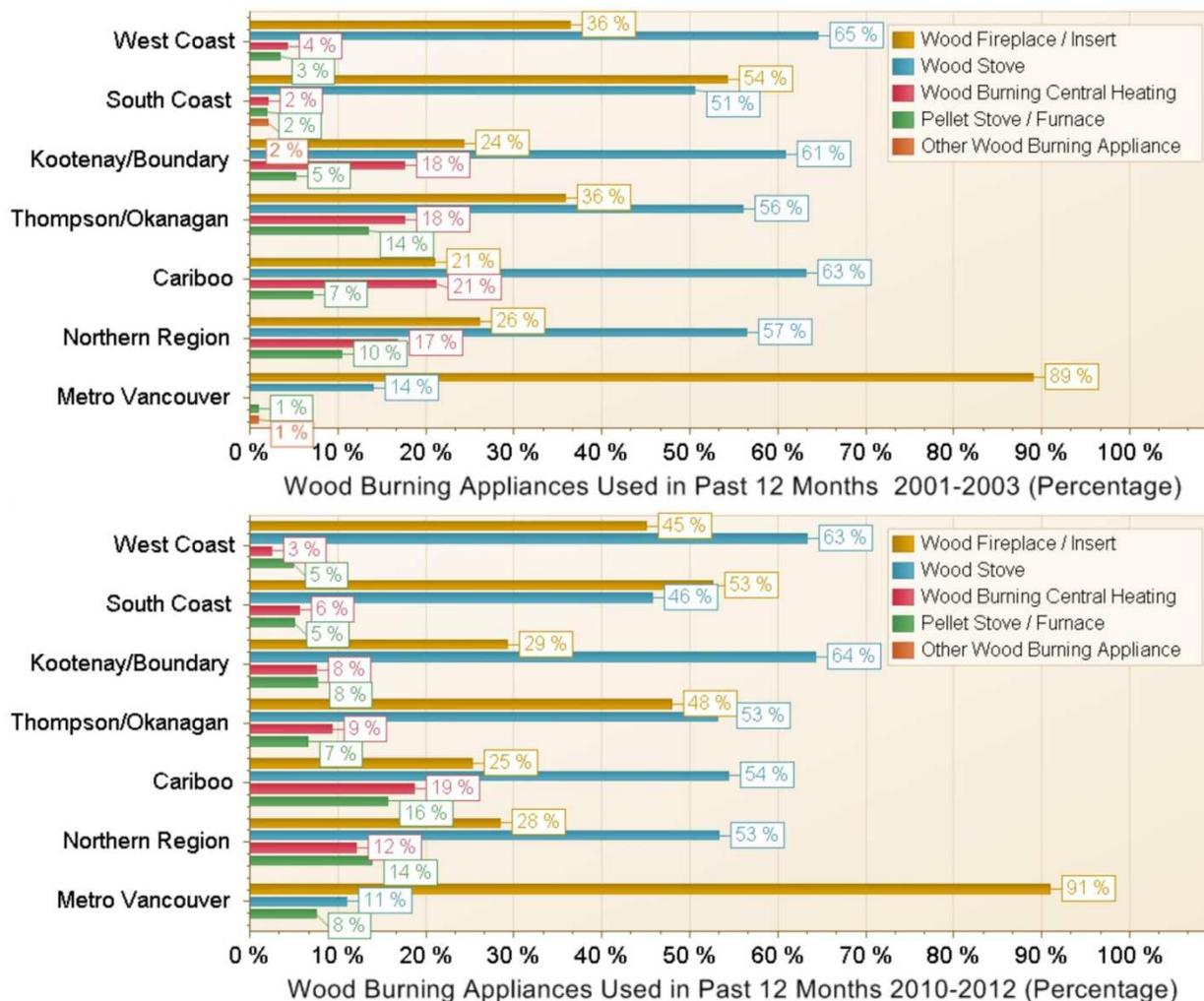
Figure 2 shows there was a transition in the composition of appliances owned by BC residents in the past decade. Note that households surveyed could mention several appliances, i.e. the total does not add up to 100%.

**Figure 2 Wood Burning Appliance Types**

The percentage of fireplaces or inserts remained identical (fireplaces and inserts are not distinguished in the 2012 survey), whereas stoves and pellet stoves increased in number. The latter are generally clean-burning appliances, and the (slight) increase in wood stoves could be due to the purchase of new, certified stoves. Note that the 2010 survey did not ask about central heating systems but only about fireplaces/inserts, stoves, and pellet stoves, i.e. the incidence of central heating systems would be zero in MV data. The 'other' category appears in the 2012 survey (not in 2010) and is not further defined; in the 2003 dataset, it represents masonry heaters in MV and the FVRD only but not appliances in the remainder of BC.

Regionally (Figure 3), the difference between MV and the rest of BC becomes obvious: the incidence of fireplaces is much higher in MV than in the rest of BC. On the other hand, the use of wood stoves has a fairly consistently high level throughout BC, whereas it is low in MV. No major changes have occurred from 2003 to 2012.

**Figure 3 Wood Burning Appliances by Region (2003, above and 2012, below)**



## 2.4 CERTIFIED APPLIANCES

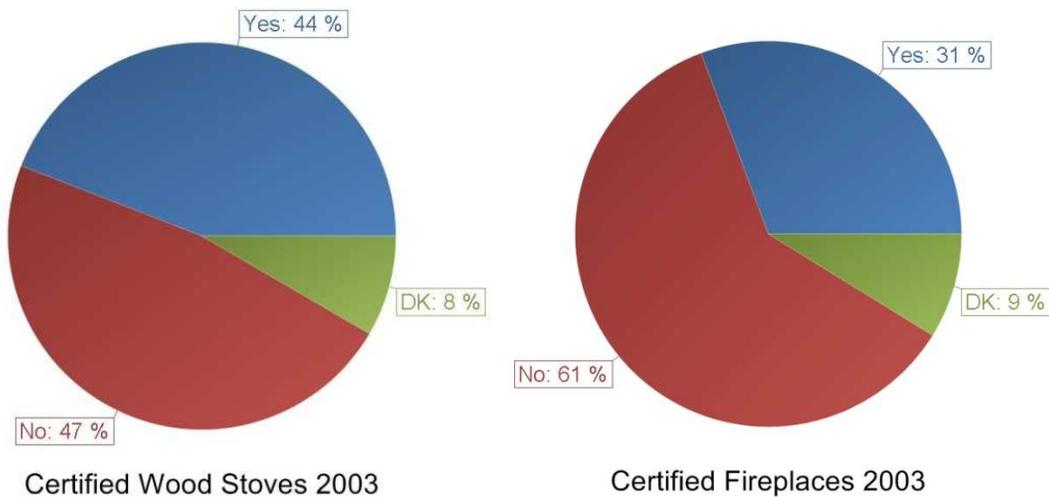
Figure 4 shows the portion of certified woodstoves and fireplace inserts in BC in 2003, followed by graphs illustrating the situation in 2012 (Figure 5). Given there was no information on fireplace insert certification from MV or Kelowna in the earlier surveys, Figure 4 only shows woodstove data from the 2003 survey. The increase in certified stoves in 2012 is apparent. No data is available on pellet stoves or central heating in the early dataset but it is likely that pellet stoves would all be recent and certified installations.

In 2012, almost half the fireplaces (inserts) and more than two-thirds of the wood stoves in BC are certified for low emissions. Taking into account the fairly high portion of households that did not know whether their appliance was certified, the actual percentages could be even higher. That finding may, however, be due to an over-reporting of certification due to either the desire of survey

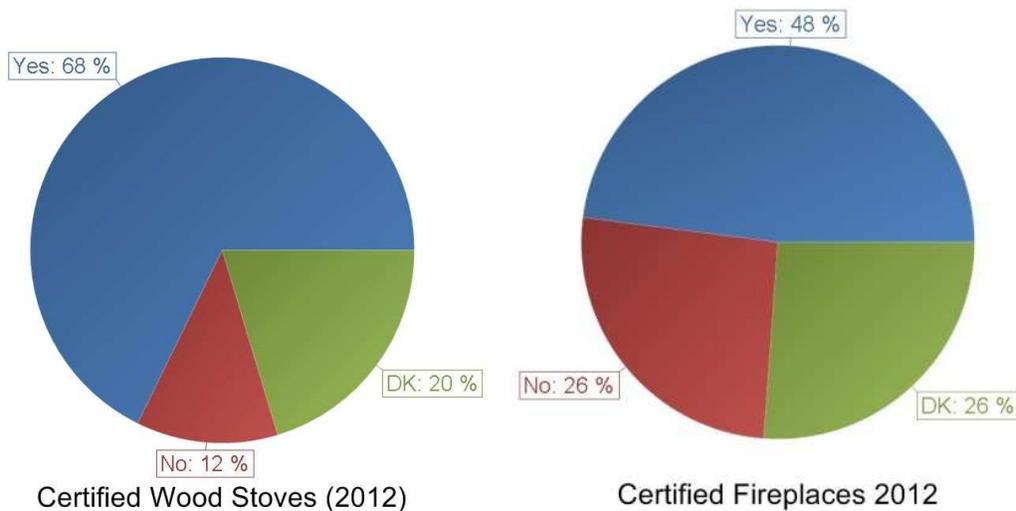
respondents to show they are environmentally responsible or a mixup between CSA safety and environmental certification. For example, 64% of central heating units are reported as low-emission certified whereas certification for this type of appliances has only been available for a few years. This apparent over-reporting of certification may also have occurred for other appliance types.

No data on central heating appliances was available from the 2010 survey; hence, this bar is missing from the regional graph. The regional graphs (Figure 6) show the greatest increase in certified woodstoves is in Metro Vancouver. Pellet stoves are sometimes reported as not certified or 'don't know' but are likely certified in most cases (a number of pellet appliances are uncertified even though they are clean burning, simply because they are exempt from EPA requirements); the low percentage in MV may not reflect reality. The lowest certification rates for fireplaces (inserts) are found in MV and the South Coast – also regions where wood is less used for heating and more for ambiance.

**Figure 4 Certified Wood Stoves (2003)**

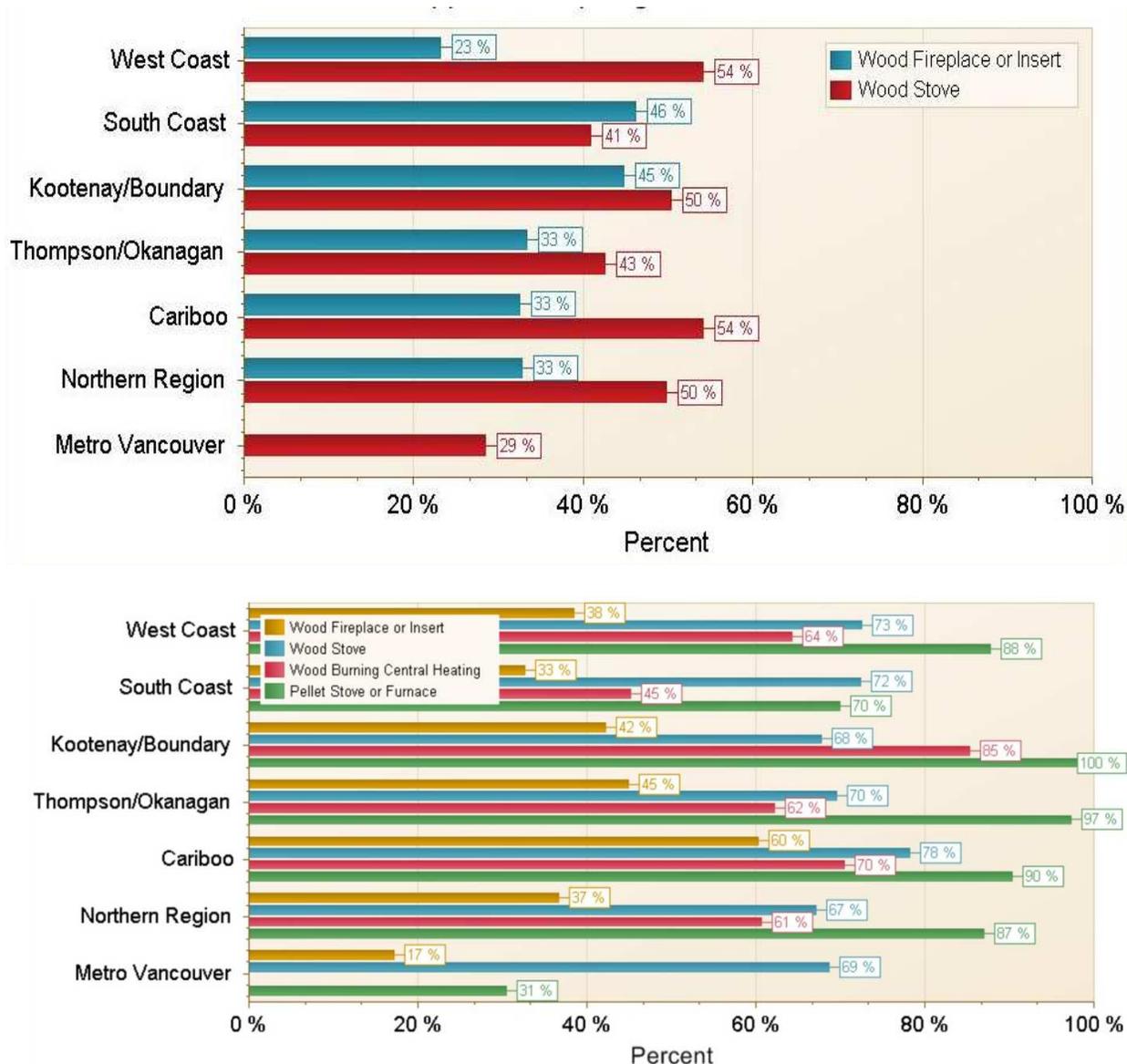


**Figure 5 Certified Appliances (2012)**



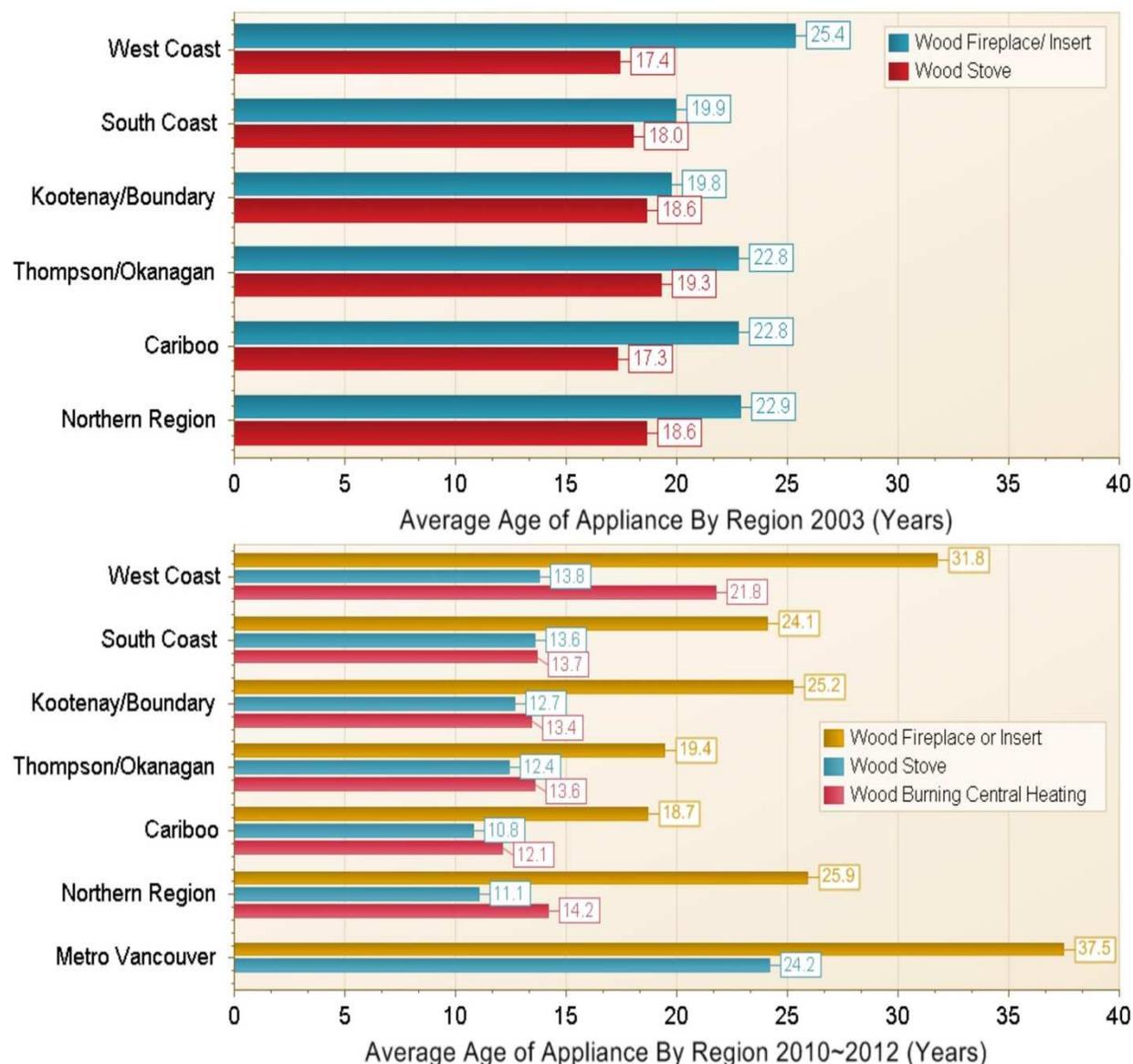
DK: Don't know

**Figure 6 Certified Appliances, by Region (2003, above and 2012, below)**



## 2.5 APPLIANCE AGE

Wood stove age is of great concern as it is an indicator of combustion performance. Wood stoves are also the largest portion of appliances and are used most for heating, whereas fireplaces are more used for ambiance. Indoor central heating systems and pellet stoves are generally cleaner burning and of lesser concern. As such, the stove age is a parameter similar to certification, especially given that since 1994 only certified stoves may be sold in BC.

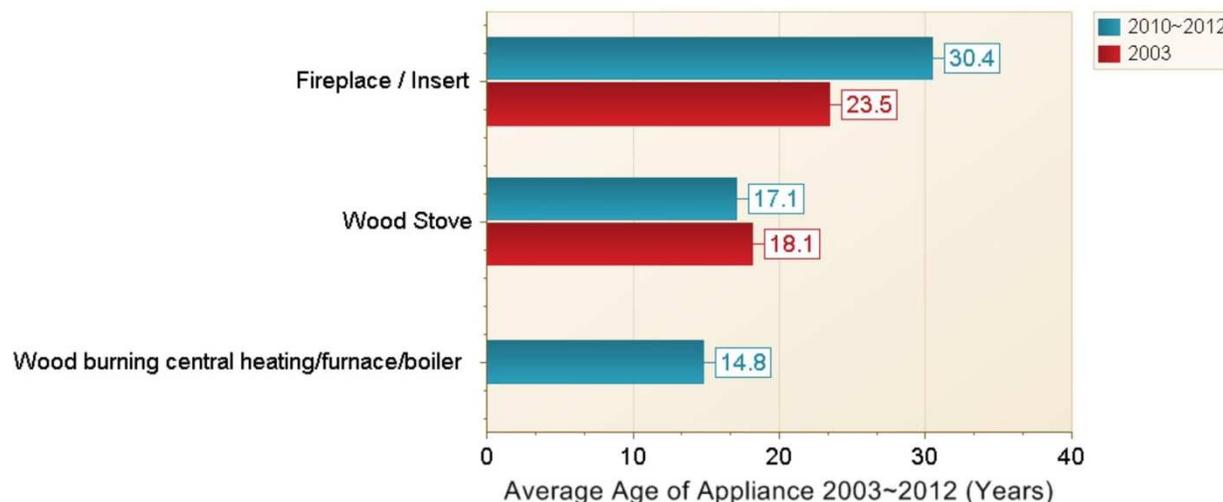
**Figure 7 Wood Stove Age in 2003 (above) and 2012/2010 (below)**

The data is only partially comparable though, since the 2012/10 and 2002 surveys used absolute ages in years whereas the 2003 survey did not ask about appliance age. Instead, it classified equipment as 'advanced/catalytic' or 'conventional', stating that the latter are older than 15 years and the others younger. As mentioned in Appendix 1, we arbitrarily assigned an age of 10 years to the younger stoves and 30 years to the older ones. This is, of course, a very imprecise measure and might account for the somewhat higher ages in the 2003 results. It is therefore not possible to deduce conclusions with certainty from these results. As can be seen from the graphs for recently purchased appliances and planned purchases, an average lower appliance age is, however, plausible for the 2012 dataset. Sadly, the 2002 stove age results were not in the PDF report and could therefore not be integrated here, i.e. we cannot compare results for MV.

The next graph (**Figure 8**) shows appliance age by appliance type for both datasets (note, again, that no data was available from the 2002 MV survey). The increase in fireplace age could simply be

related to the timing of the survey, i.e. eight or nine years later than the earlier ones. Of significance is the wood stove age, which appears to be decreasing, signalling the replacement of older stoves with newer (supposedly certified) ones.

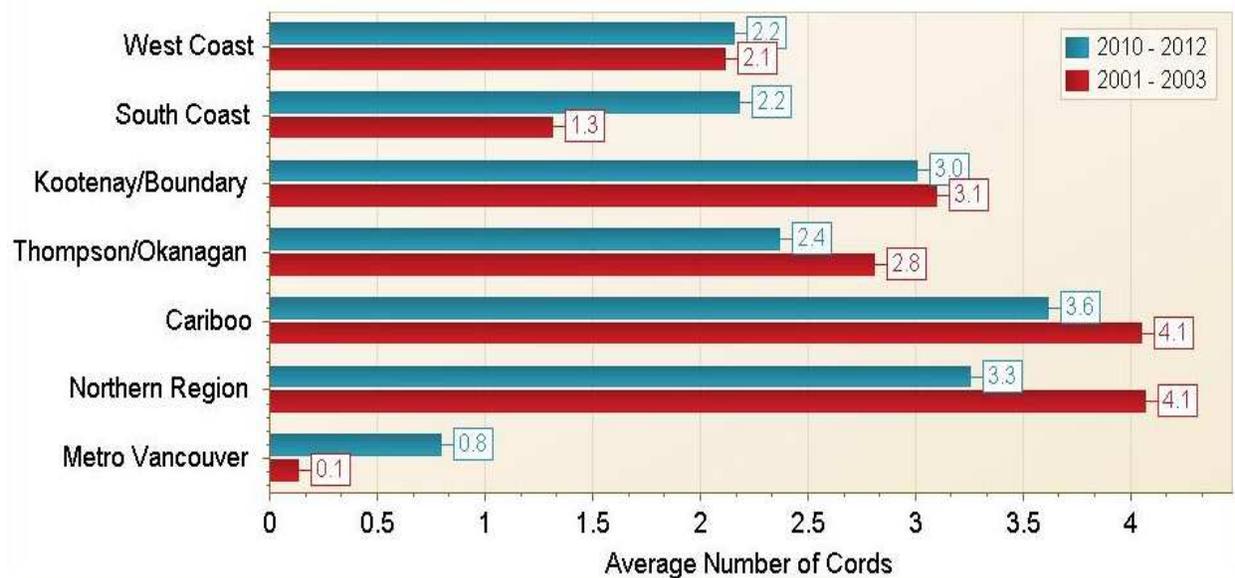
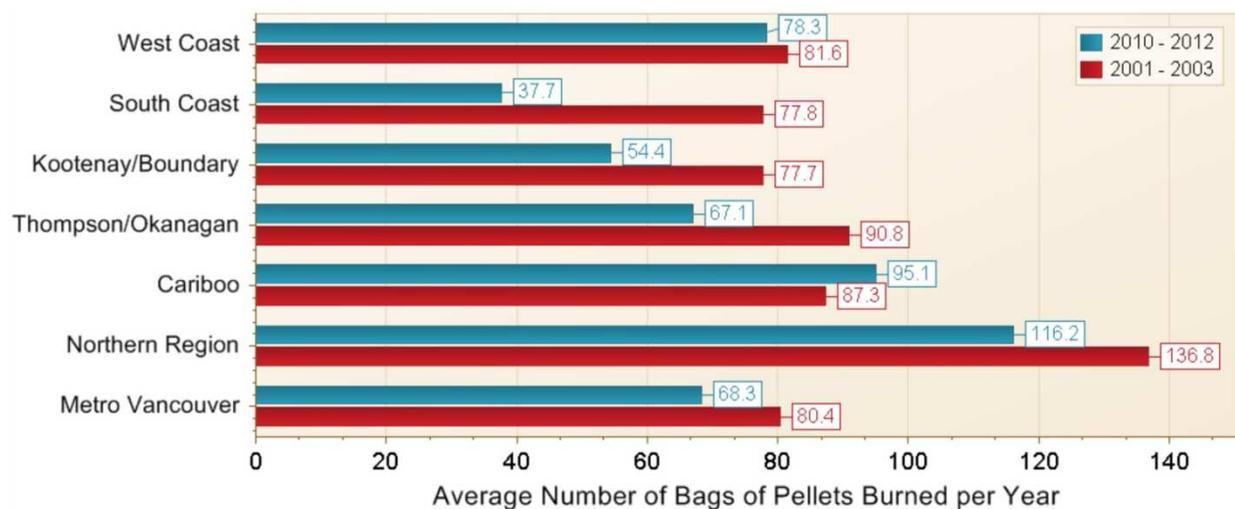
**Figure 8 Appliance Age by Type**



We were not able to reproduce the results contained in the 2012 PDF report for fireplaces and stoves. We obtained lower average ages in both cases, based on a weighted extrapolation.

## 2.6 ANNUAL AMOUNT OF WOOD BURNED

The amount of wood burned per household is a function of climate and to a much lesser degree, the efficiency of wood burning equipment. For many households that use additional fuels for heating, such as electricity, natural gas, or oil, wood use may also vary with the cost of those fuels. In addition, statistical variations can be caused by sample size; this is particularly relevant for the pellet stoves since a much smaller population of such stoves exists in BC than other appliances, making the results statistically less significant (e.g., the large difference for MV for cords, and South Coast for pellets). Generally, the wood amount used per household has apparently not changed significantly since 2003 except in MV, with the Northern Region using most wood – very likely due to the harsher climate. On the other hand, there is lower use of wood in the West Coast, which would indicate use more for ambiance in fireplaces, rather than for space heating. No clear trend upwards or downwards is apparent; possibly, there is less pellet use by those with a pellet stove in 2012 than in 2003.

**Figure 9 Cords of Wood Burned per Year and by Wood-Using Household, by Region****Figure 10 Bags of Pellets Burned per Year (Households with pellet stoves), by Region**

Note: MV and FVRD pellet use data extrapolated from West and South Coast average.

There are several reasons why the data indicate that wood use in MV (and the FVRD) is higher in 2010 than it was in 2003. First, the conversion factor to determine the number of cords from the 2002 report was 712 pieces of split firewood for one cord. On the other hand, the 2010 report suggests that one cord equals 300 pieces of wood. If this number was assumed to have been reported in the 2002 survey as well, the amount would roughly double but would still be considerably lower than the 2010 data, which was collected as cords. Second, the 2002 survey recorded exact amounts, whereas the 2010 survey recorded various ranges. We used the higher limit of each range to estimate the total amount burned, i.e. a 'worst case' approach. This may lead to a higher estimate than using exact number, but even taking this into account would still leave 2010 MV amounts 2-5 times higher than in 2002. Last, the mere fact that the wood amount was determined using two different methodologies (once, asking for pieces of wood burned per day and

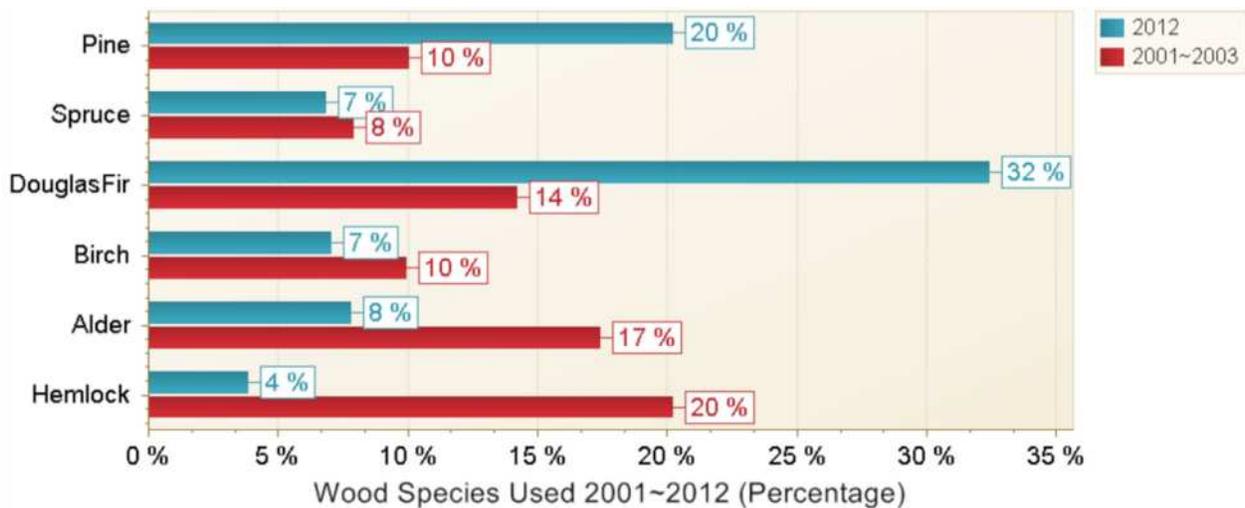
once, asking for cords burned per year) may yield different results in the surveys, i.e. asking about pieces per day may underestimate the total. These possibilities mean that MV results should only be compared with caution between the two datasets.

The MV surveys did not determine the amount of pellets burned; this data was filled in from the 2003 and 2012 surveys, using the average among pellet users from the West and South Coast regions.

## 2.7 TYPE OF WOOD USED

This information was not available from the 2010 survey but it is possible to compare the 2003 and 2012 surveys for the rest of BC. Figure 11 shows how often users report using various species (not absolute distribution of what types is used in BC). A move away from alder and hemlock towards fir and pine becomes obvious.

**Figure 11 Wood Species Used, Incidence of Use Reported**



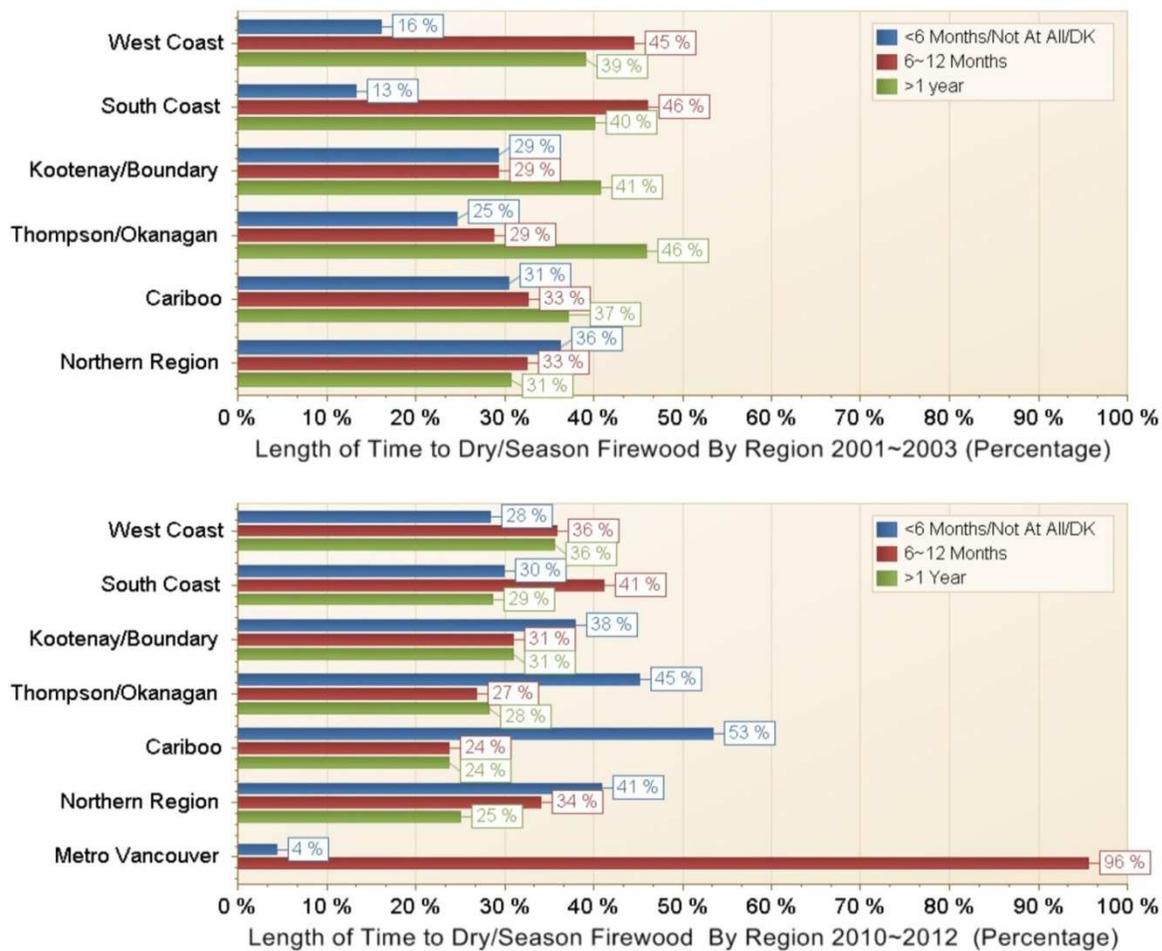
## 2.8 FIREWOOD SEASONING

The 2002 report did not examine the question of seasoning (i.e. MV and also the FVRD are missing from the comparison). Comparing the results for 2003 and 2010/12, it appears that wood is generally well seasoned in the MV area (this is also the area where a considerable proportion of households use firelogs). For the rest of BC, there appears to be a tendency to use wood that is less seasoned. Compared to 2003, where 75 to 85% of households used wood that is seasoned for 6 months or longer, this portion has decreased to between 51 and 75%. Including MV, however, the incidence of seasoned wood use appears to be close to 75% (Figure 12).

**Figure 12 Wood Seasoning, all of BC (2003, left and 2012, right)**



**Figure 13 Wood Seasoning Practices**

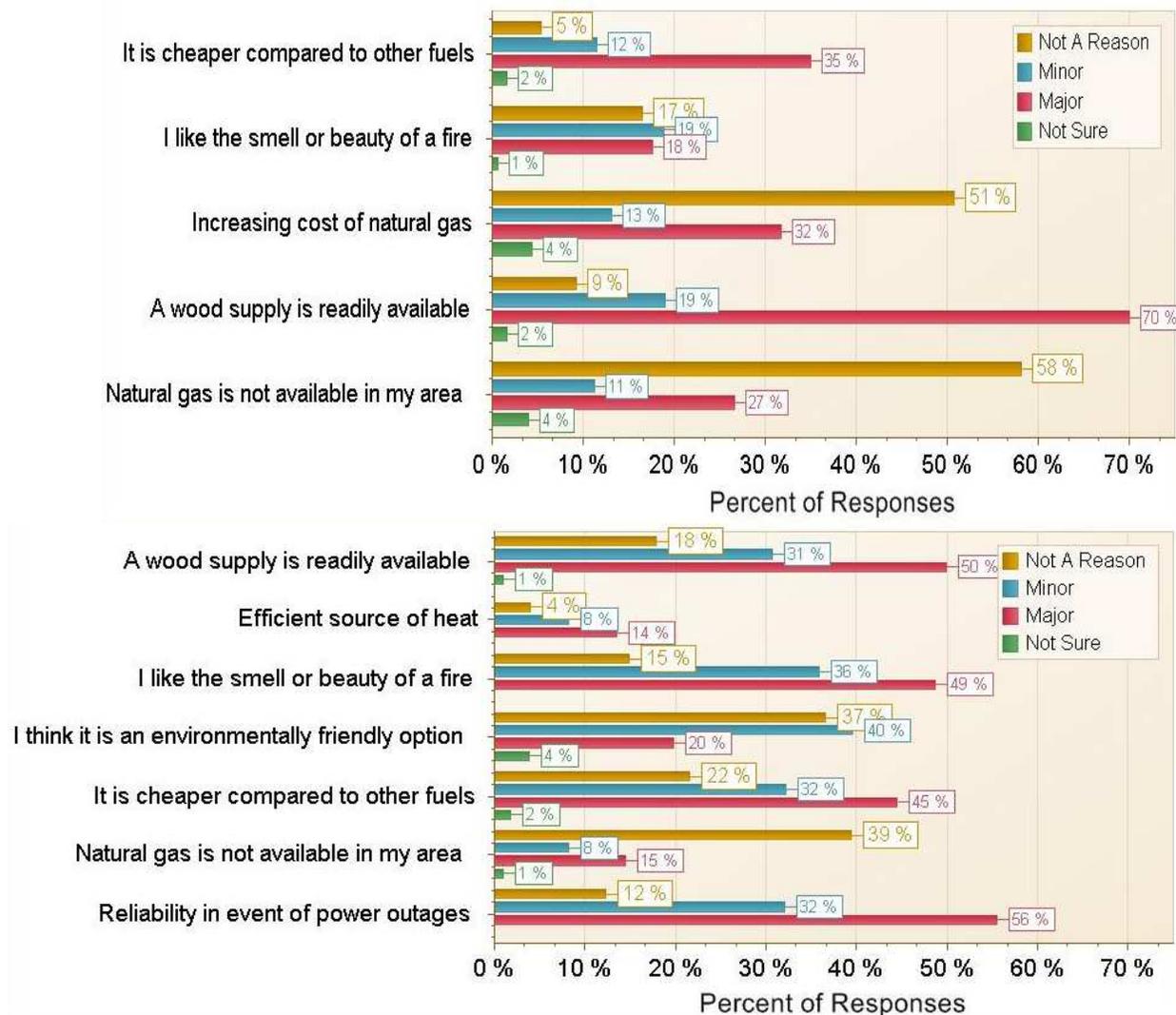


**2.9 REASONS FOR WOOD BURNING**

The surveys used somewhat different questions, such that the results shown here (Figure 14) do not always include all datasets. Specifically,

- For the 2003 dataset, the 2001 and 2002 surveys only asked the first two questions (wood is cheaper, like the smell). The questions about wood availability and increasing cost of natural gas were only contained in the 2003 survey, and none of the early surveys asked about efficiency.
- For the 2012 dataset, four questions as to the reasons for burning wood were identical in the 2010 and 2012 surveys (Wood supply readily available, smell, lower cost, reliability), and combined results are presented. The question about efficiency is only based on the 2010 MV results. The other two questions (natural gas not available and environmentally friendly) only relate to the 2012 survey (MV residents can be presumed to have access to natural gas).

**Figure 14 Reasons for Burning Wood (2003, above and 2012, below)**

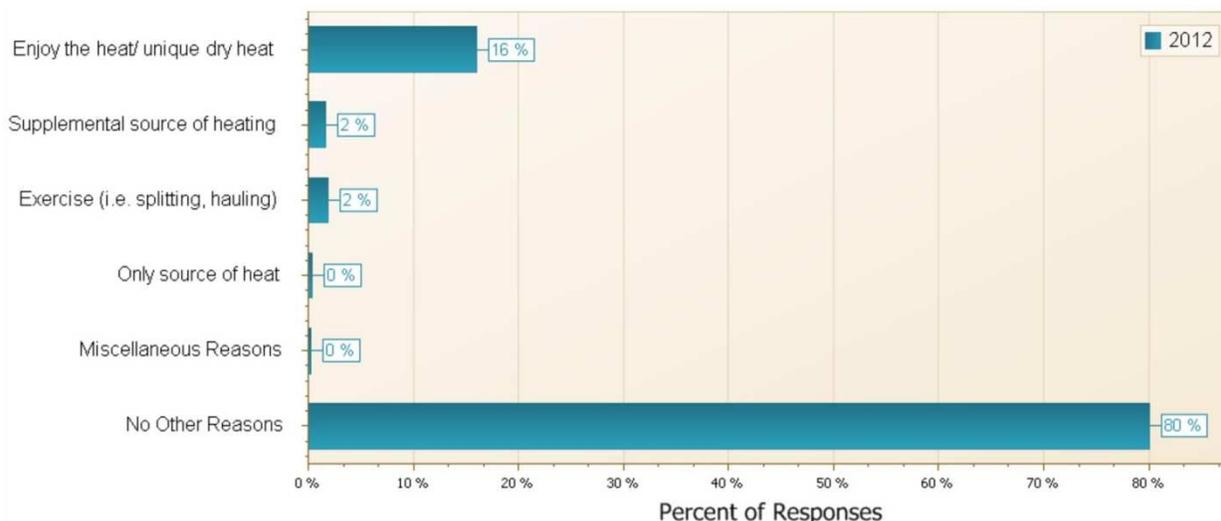


With these restrictions in mind, only the questions about cost and the smell of fire can be compared directly between the two datasets. It appears that energy costs are playing a more significant role in choosing wood for heating. Combining ‘minor and major reasons’, the reason was named by 77% of respondents in 2012 vs only 47% in 2003. There is also a strong increase of participants stating they like the smell of fire. This may indicate a preference for fireplaces used for ambiance (occasional wood burning), rather than for wood stove heating or central heating. The first two

reasons (price and availability) remain the most important reasons for wood burning; the fear of power outages is also an important reason that was not explored in the 2003 dataset.

Figure 15 shows additional reasons for burning wood (only from 2012 data) but these reasons are less significant than the other ones. The first reason (enjoy the unique heat) may be somewhat related to the question “I like the smell and beauty of a fire” and therefore scores fairly high as well.

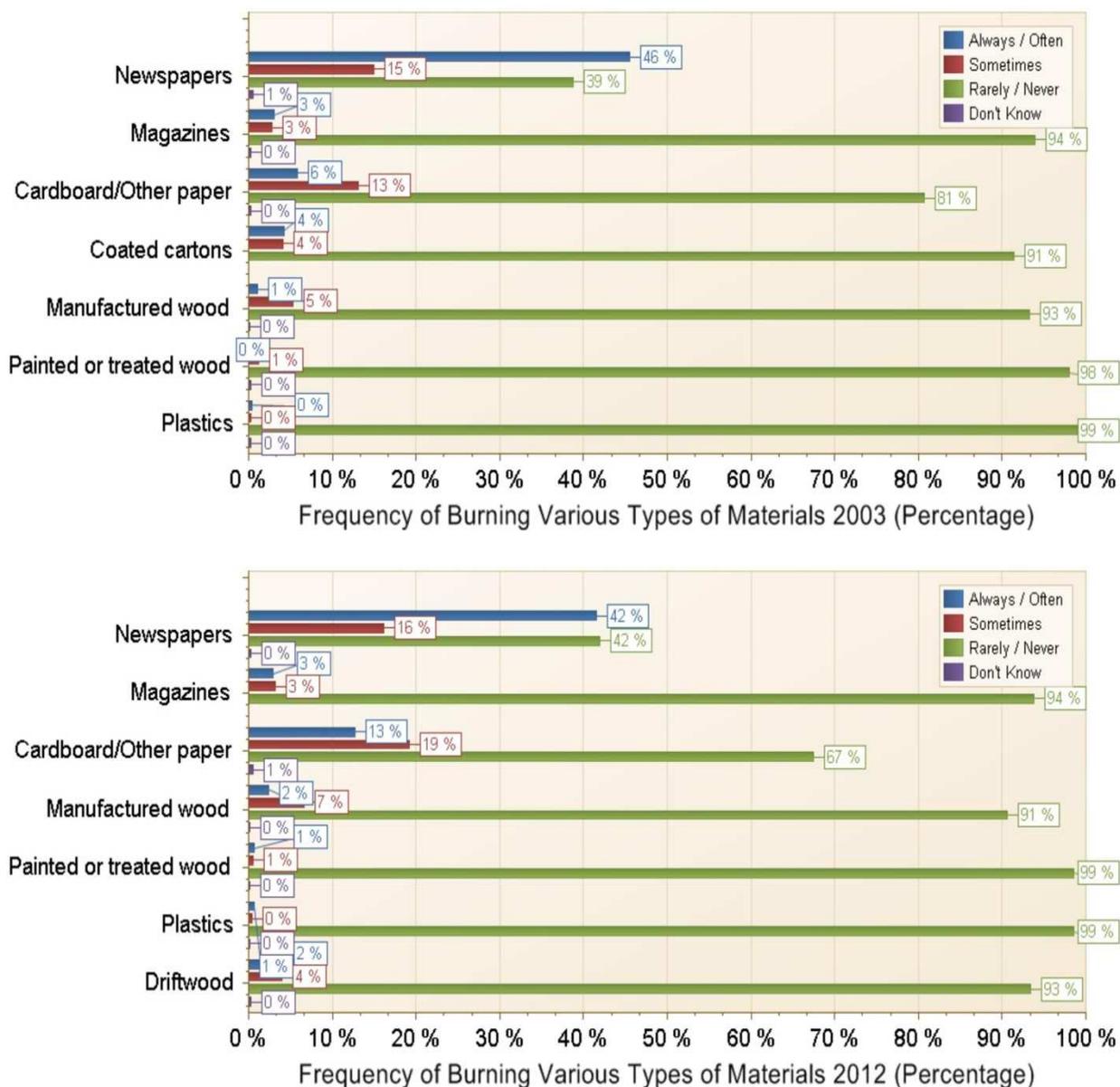
**Figure 15 Additional Reasons for Burning Wood (2012 only)**



## 2.10 OTHER MATERIALS BURNED

In terms of non-wood materials used for heating or kindling (**Figure 16**), the picture has not changed much between 2003 and 2012 (other surveys did not address this matter). Almost 60% use paper to start a fire. Magazines and cardboard are used less, but cardboard somewhat more (up to 32% from 18%) based on the 2012 survey. Problematic material like painted wood or plastics are used very infrequently.

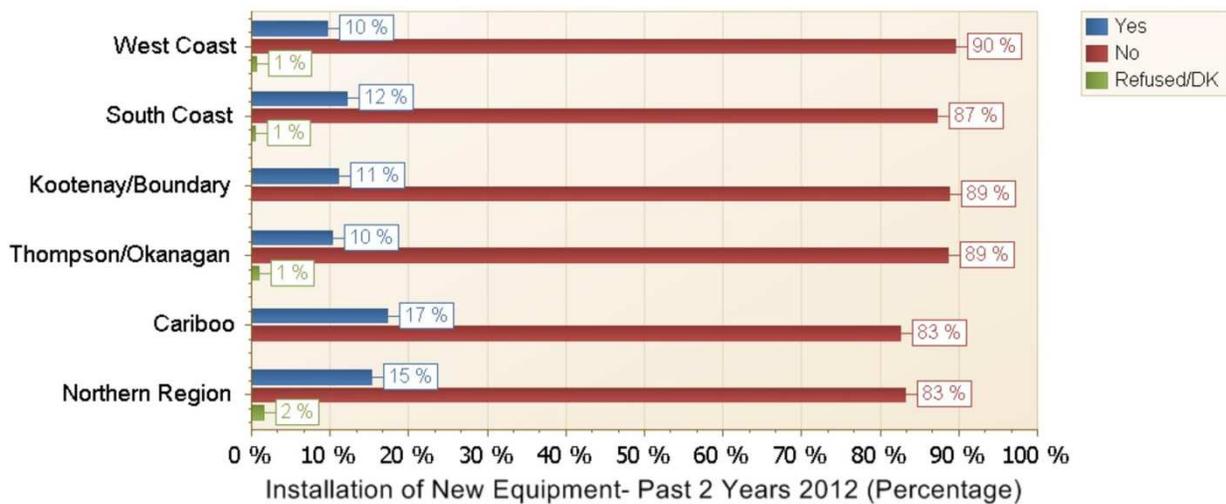
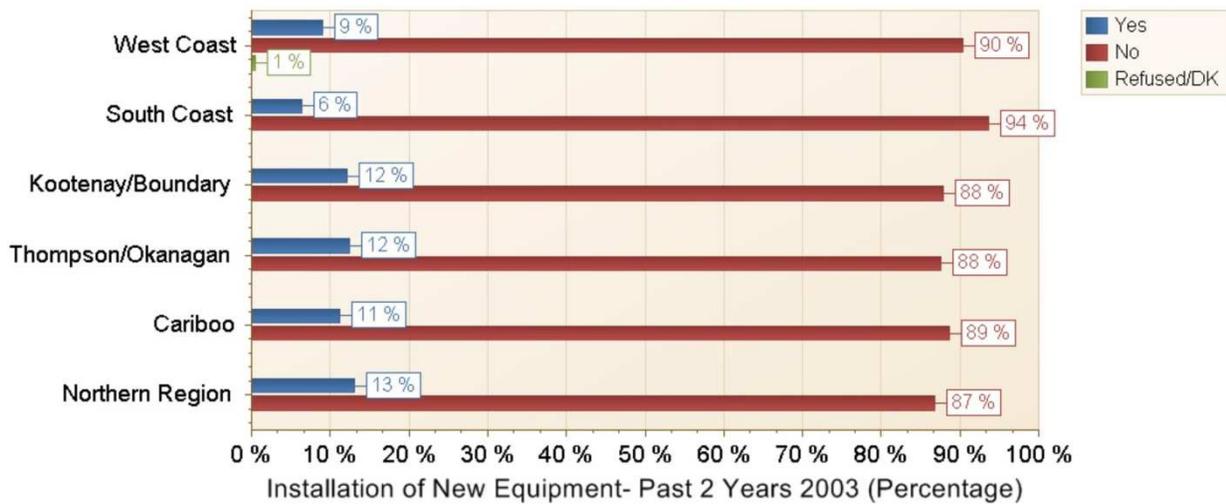
**Figure 16 Other Materials Burned**



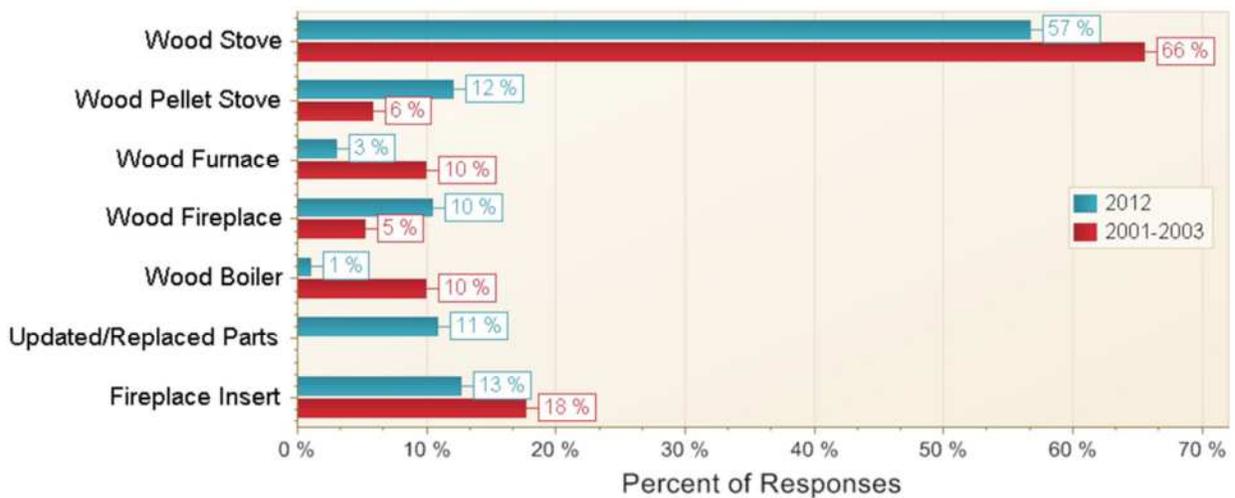
**2.11 EQUIPMENT INSTALLED IN PAST TWO YEARS**

Installations of new wood burning equipment have remained constant between 2003 and 2012 at 11% (this question was only asked in the 2003 and 2012 surveys, i.e. there is no information on MV). When looking at the type of appliances they installed, the majority in each case installed a wood stove. The share of wood stoves has, however, decreased somewhat in 2012. Clearly visible are the trends towards pellet stoves and wood boilers or furnaces. Fireplace inserts were also bought much less than in 2003.

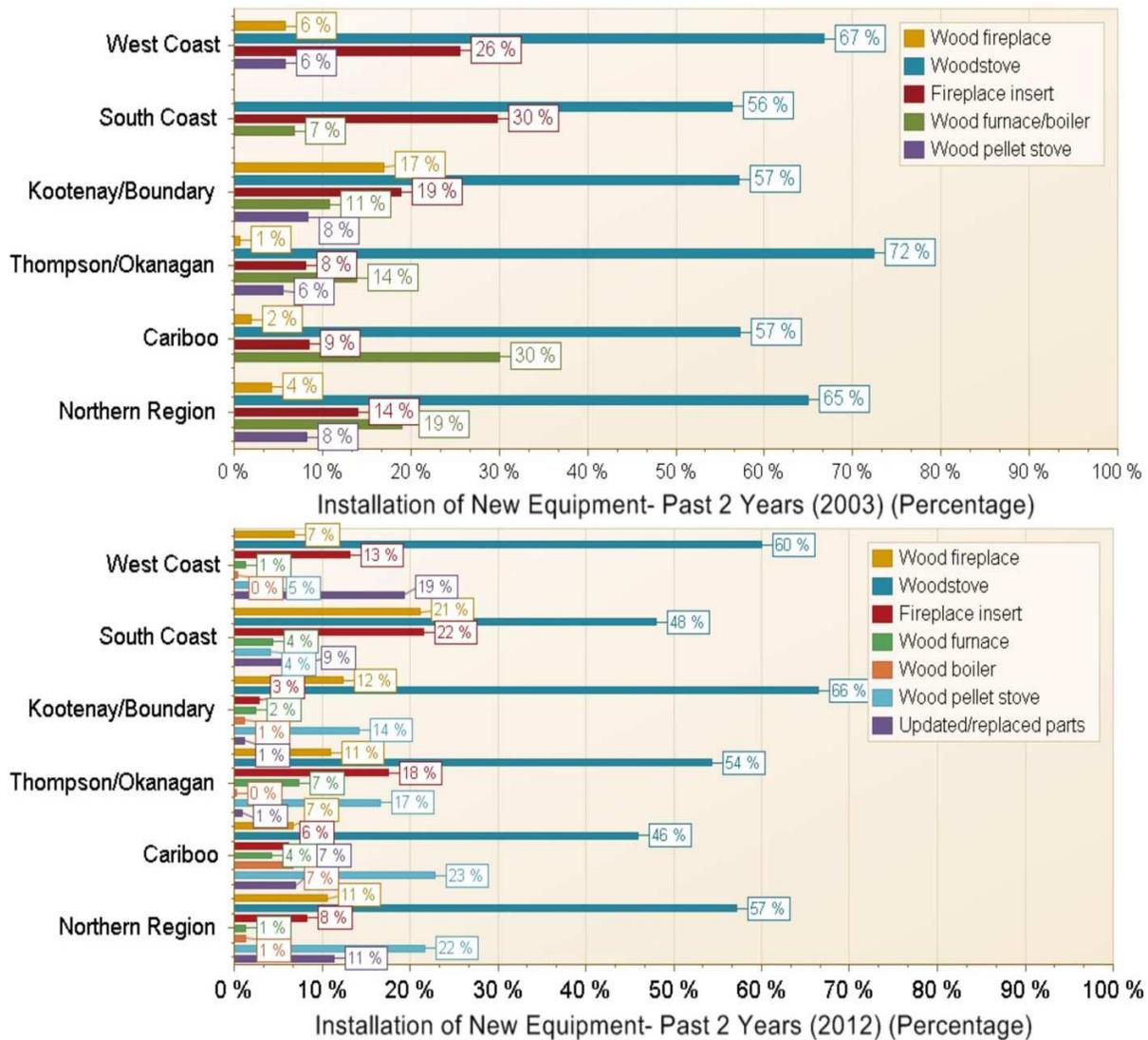
**Figure 17 New Wood Burning Equipment Installed in Past Two Years**



**Figure 18 New Wood Burning Equipment Installed in Past Two Years, by Type**



**Figure 19 Appliance Types Installed in Past Two Years, by Region**



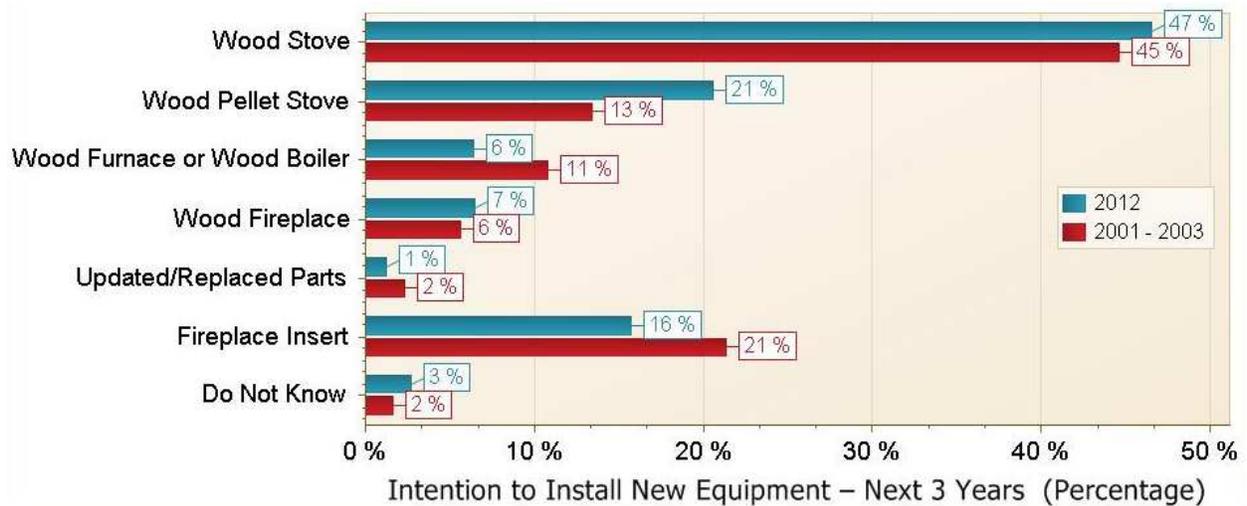
**2.12 INTENTION TO INSTALL IN COMING 2-3 YEARS**

In line with recent installations of wood burning equipment, the 2012 results (2010 MV survey omitted this question) also indicate a larger portion of people that intend to install new equipment in the coming two to three years (26% very or somewhat likely in 2012 vs. 19% in 2003). Looking at the types of intended equipment choices, there is an increase with respect to pellet stoves, though wood stoves remain prominent. Other types are generally less in demand. Note that although the 2002 MV survey asked about future installations, no data on this was included in the PDF report and could therefore not be included here.

**Figure 20 Intention to Install New Equipment**



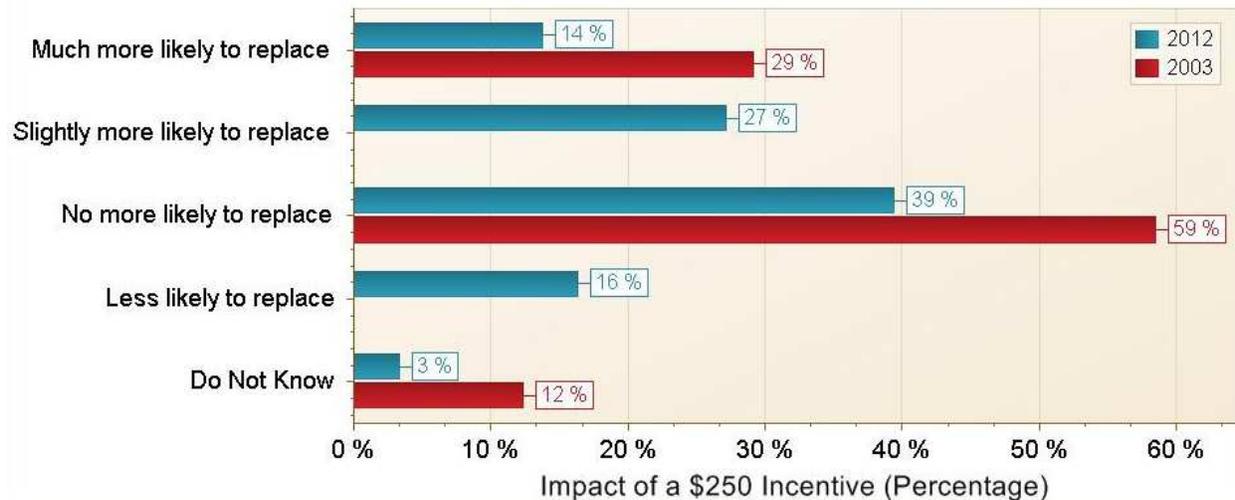
**Figure 21 Intention to Install New Equipment, by Type**



Note: Updated/replacement parts in 2003 actually represent 'miscellaneous' equipment

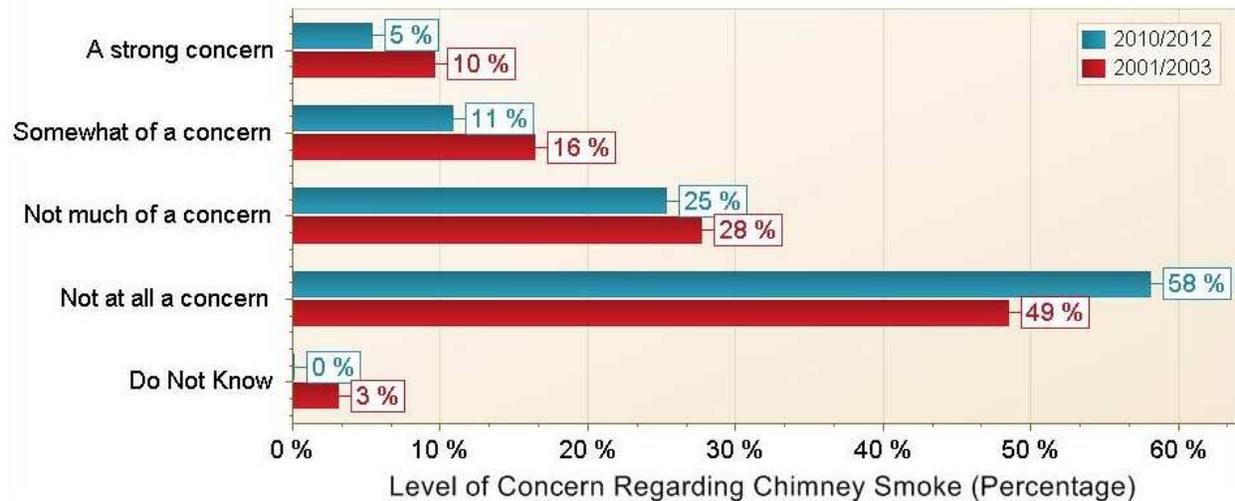
**2.13 RESPONSIVENESS TO A \$250 INCENTIVE FOR WOOD STOVE EXCHANGES**

The 2003 and 2012 surveys asked participants whether they would be more likely to exchange their old stove if an incentive payment was offered them. As **Figure 22** shows, the readiness to replace a stove due to the incentive was 29% in 2003 ('more likely') and was 41% in 2012. This result would indicate that incentive programs still have an impact, possibly even more so than a decade ago. The methodology may, however, have contributed to this result as in 2003, the option 'somewhat more likely' was not given.

**Figure 22 Impact of a \$250 Incentive**

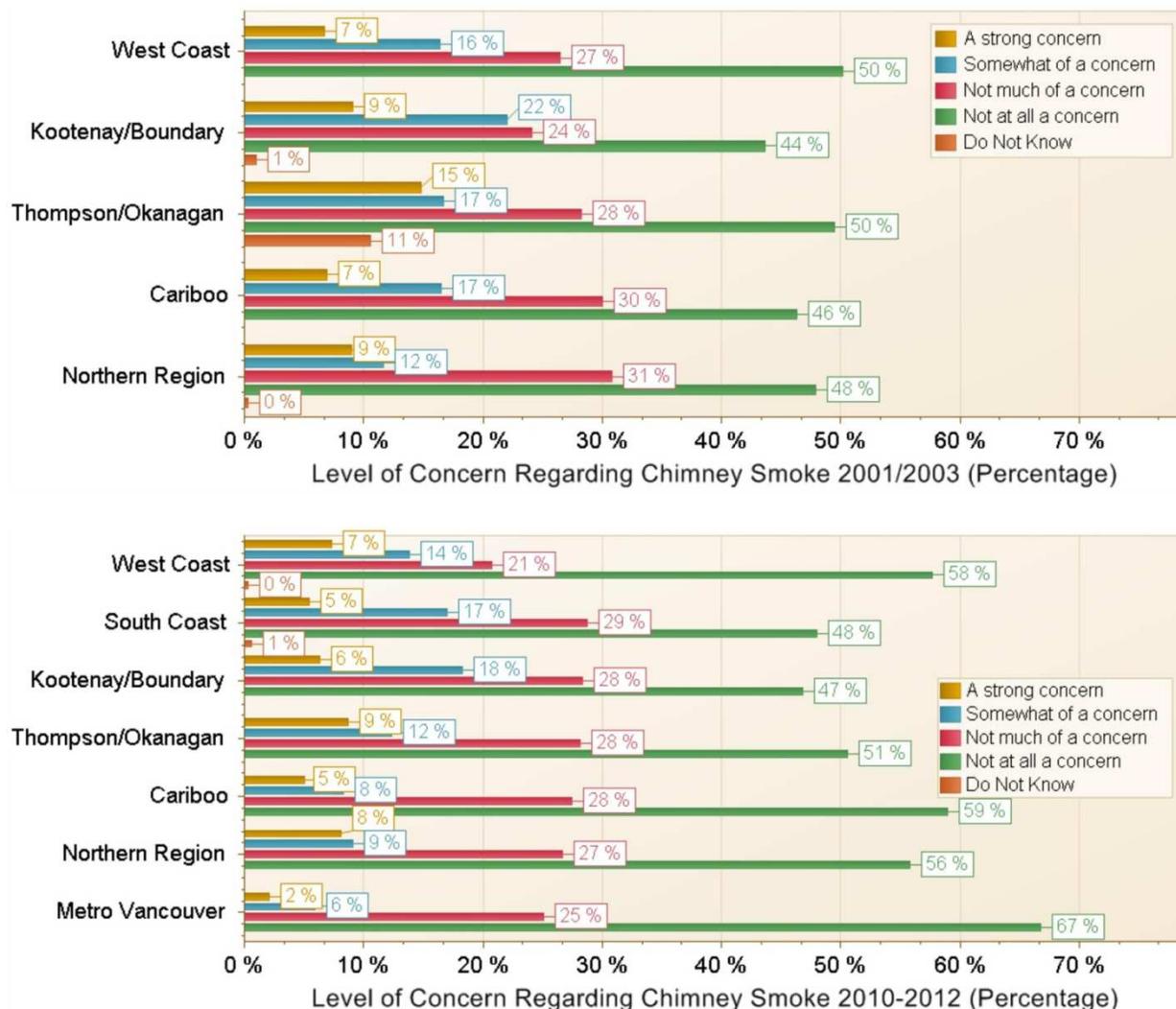
## 2.14 IS CHIMNEY SMOKE A CONCERN FOR YOU?

All surveys with the exception of the 2002 MV survey asked this question about wood smoke concern in their neighbourhood. The majority of BC residents are not concerned about wood smoke. The share of people who are concerned (strong or somewhat) has decreased from 26% in 2003 to 16% in 2012.

**Figure 23 Wood Smoke Concerns**

A comparison by region shows that concerns are lowest in the MV region (only 2010 data available, based on Question 21 in that survey). Concerns were highest in the Thompson/Okanagan region in 2003 but the level of concern has decreased in all regions – especially in the Thompson region.

**Figure 24 Wood Smoke Concerns, by Region**

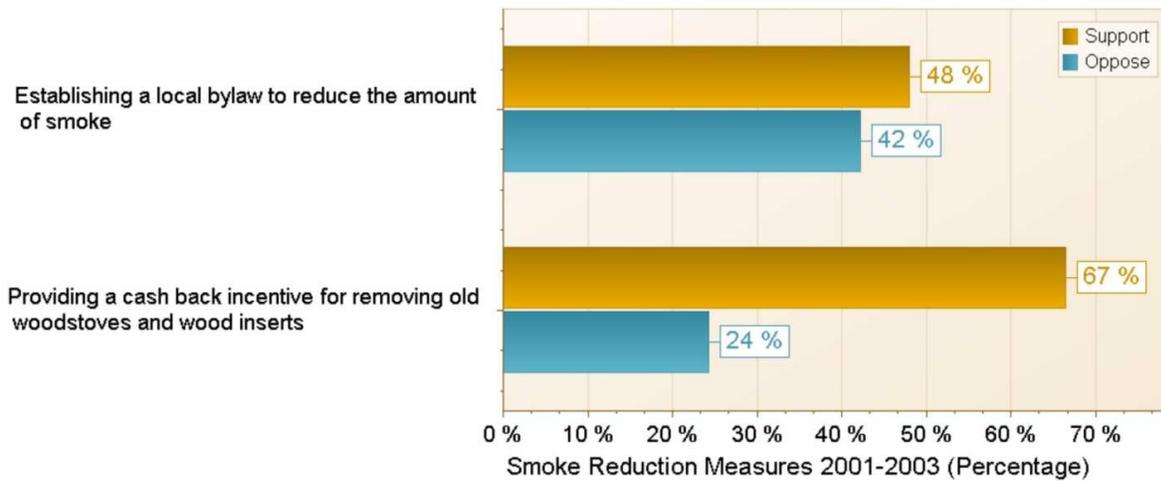


**2.15 WHAT MEASURES TO REDUCE WOOD SMOKE WOULD YOU SUPPORT?**

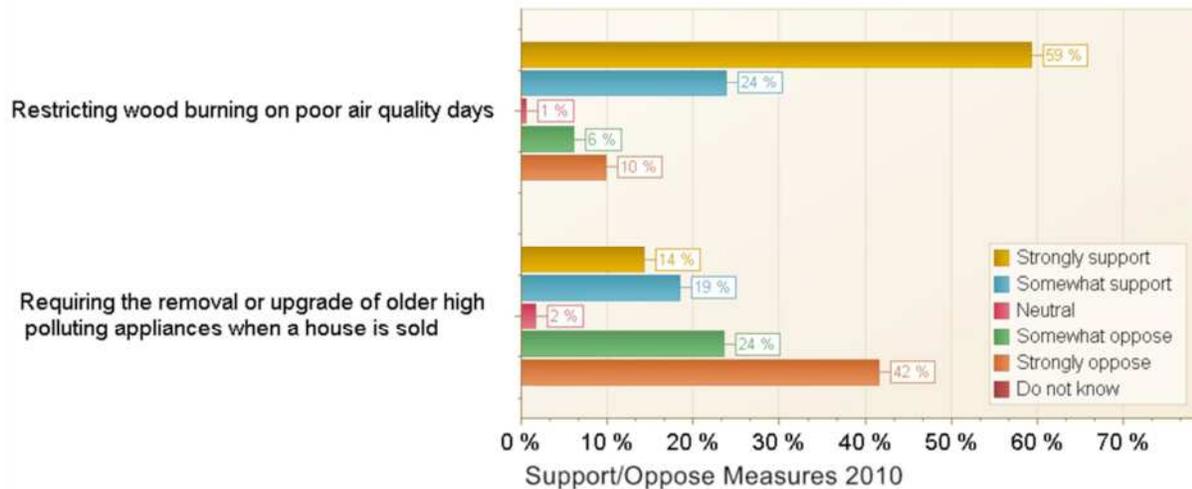
A variety of policy options were presented to participants during the surveys. Only questions comparable to the 2012 survey are presented in the graphs below to allow comparisons between the earlier and later datasets. Also, the 2010 MV data are presented separately since only two questions are identical. For the 2010/12 dataset, it is striking to see that the readiness to restrict wood burning on poor quality days is higher in MV than in the rest of the province. This may be related to the high incidence of fireplaces, i.e. the preference to burn wood for ambiance in MV, whereas people are less tolerant to restricting wood burning in regions where wood is more used to heat the home. Possibly, this also explains the lower incidence of agreement with improvements at the time of sale in MV: if people had the impression they might have to remove or close up their fireplaces before selling their house, they would likely have found this to be a cumbersome measure to take.

Comparing the 2003 and 2012 datasets, support for local bylaws is almost identical, with opposition slightly reduced in the 2012 survey. Support for cash incentives has increased somewhat, from 67 to 71%.

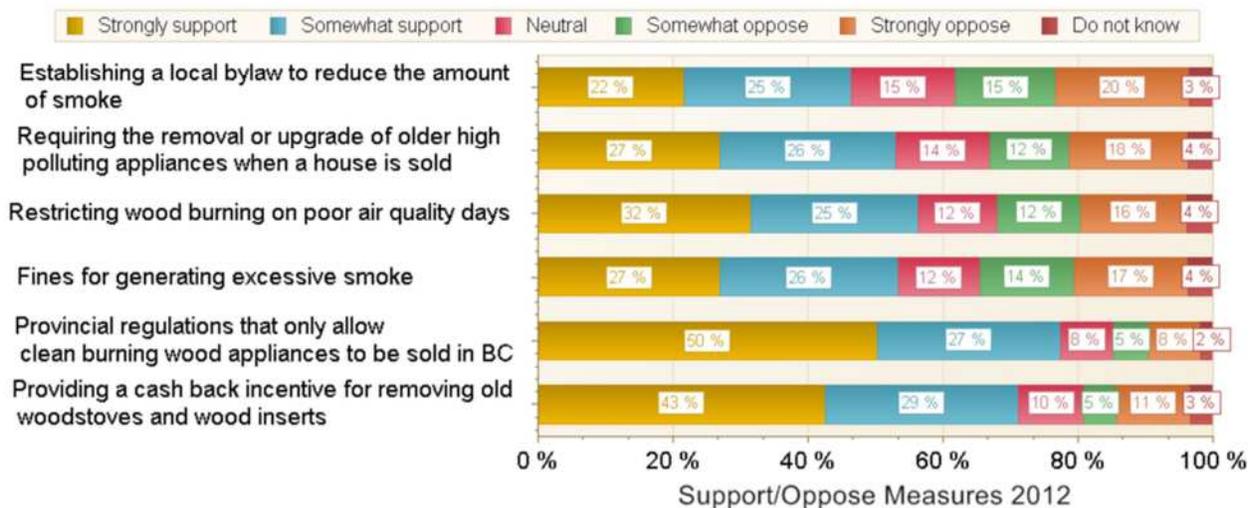
**Figure 25 Opinions on Policy Measures (2003, does not include MV, FVRD)**



**Figure 26 Opinions on Policy Measures (2010 - MV only)**



**Figure 27 Opinions on Policy Measures (2012 only)**



## 2.16 EMISSIONS BY REGION/TYPE OF APPLIANCE

Emissions were calculated according to the methodology outlined in MoE 2005. Essentially, the tonnes of wood burned in each appliance per year was multiplied by specific emission factors for each appliance type (different for certified/uncertified). More detail on the methodology can be found in Appendix 1, Section A.4. The data presented here includes both emissions from stoves and fireplaces and also from pellet stoves, which were reported separately in MoE 2005. The increase in emissions from 2003 to 2005 is a counterintuitive result, given the share of certified appliances has increased and that wood usage per household and wood user incidence have not changed considerably.

A special case are the results for Metro Vancouver, which are much higher in 2010 than in MoE 2005, which refers back to the 2002 PDF report. Although the latter was used to compare results, the version at hand did not contain any emissions calculations and so we are unsure as to the methodology used to compute the earlier results for this region. Also, as mentioned in Section 2.6 above, we are unsure how the fuel amount reported (pieces of wood) was converted to tonnes of wood burned and then, emissions. A different factor used to translate pieces to cords may be partially responsible for the different results – ours are three times larger than the ones reported in MoE 2005. Also, different emission factors have been used (see Table 10 in Appendix 1). These older emission factors have been improved since then, which leads to significant changes for some of the air contaminants. The results presented in Table 3 and Table 4 use the same factors as those used for the rest of BC and apply them to the MV and FVRD regions.

**Table 3: Wood Burning Appliance Emissions in 2003, by Region**

Region	CO	NO <sub>x</sub>	SO <sub>x</sub>	VOC	TPM	PM10	PM2.5
West Coast	17,600	336	48	4,335	3,312	3,131	3,128
South Coast	5,032	94	13	1,157	996	943	942
Kootenay/Boundary	6,654	127	18	1,817	1,307	1,234	1,233
Thompson/Okanagan	13,395	252	36	3,514	2,761	2,612	2,609
Cariboo	3,900	75	11	1,056	758	716	715
Northern Region	9,485	188	27	2,524	1,864	1,761	1,760
Metro Vancouver	2,547	48	7	302	610	583	580
<b>BC Total</b>	<b>58,613</b>	<b>1,120</b>	<b>160</b>	<b>14,705</b>	<b>11,608</b>	<b>10,980</b>	<b>10,967</b>

**Table 4: Wood Burning Appliance Emissions in 2012, by Region and Sub-Region**

Region	CO	NO <sub>x</sub>	SO <sub>x</sub>	VOC	TPM	PM10	PM2.5
Capital Regional District	7,264	138	20	1,616	1,283	1,214	1,213
Nanaimo	1,036	21	3	234	178	168	168
Campbell River	678	14	2	156	113	106	106
Port Alberni	475	9	1	108	82	78	78
Cowichan Valley	2,082	41	6	481	363	343	343
Comox Valley	1,027	20	3	249	175	166	166
Other West Coast Region	9,357	189	27	2,122	1,505	1,421	1,420
<b>West Coast Total</b>	<b>21,919</b>	<b>432</b>	<b>62</b>	<b>4,966</b>	<b>3,699</b>	<b>3,496</b>	<b>3,494</b>
Sea to Sky Corridor	1,809	34	5	460	331	312	312
Fraser Valley Regional District	1,556	31	4	314	301	285	285
Sunshine Coast	2,082	41	6	466	343	324	324
<b>South Coast Total</b>	<b>5,447</b>	<b>106</b>	<b>15</b>	<b>1,240</b>	<b>975</b>	<b>921</b>	<b>921</b>
Grand Forks	361	7	1	86	61	58	58
Cranbrook and Kimberley	785	16	2	180	129	122	122
Golden	637	13	2	166	113	106	106
Other Kootenay/ Boundary Region	5,026	97	14	1,230	892	842	842
<b>Kootenay/Boundary Total</b>	<b>6,809</b>	<b>133</b>	<b>19</b>	<b>1,662</b>	<b>1,195</b>	<b>1,128</b>	<b>1,128</b>
Kelowna	670	13	2	147	136	129	129
Kamloops	425	9	1	86	73	69	69
Shuswap	565	12	2	128	94	88	88
Other Thompson/ Okanagan Region	8,448	167	24	1,942	1,444	1,364	1,363
Princeton	286	6	1	63	44	41	41
<b>Thompson/Okanagan Total</b>	<b>10,394</b>	<b>207</b>	<b>30</b>	<b>2,366</b>	<b>1,791</b>	<b>1,691</b>	<b>1,690</b>
Quesnel	714	15	2	170	125	118	118
Williams Lake	585	12	2	136	98	92	92
Other Cariboo Region	2,319	48	7	580	407	384	384
<b>Cariboo Total</b>	<b>3,618</b>	<b>75</b>	<b>11</b>	<b>886</b>	<b>630</b>	<b>594</b>	<b>594</b>
Prince George	953	19	3	218	161	152	152
Bulkley Valley/ Lakes District	2,106	45	6	520	367	346	346
Other Northern Region	5,668	115	16	1,436	1,032	974	974
<b>Northern Region Total</b>	<b>8,727</b>	<b>179</b>	<b>25</b>	<b>2,174</b>	<b>1,560</b>	<b>1,472</b>	<b>1,472</b>
Central	3,069	59	8	615	668	635	633
Northeast	1,294	25	4	268	273	260	259
South of Fraser	4,135	78	11	874	918	873	870
North Shore	1,121	21	3	235	251	238	238
<b>Metro Vancouver Total</b>	<b>9,619</b>	<b>183</b>	<b>26</b>	<b>1,992</b>	<b>2,110</b>	<b>2,006</b>	<b>2,000</b>
<b>BC Total</b>	<b>66,533</b>	<b>1,315</b>	<b>188</b>	<b>15,286</b>	<b>11,960</b>	<b>11,308</b>	<b>11,299</b>

The factor responsible for the increase in emissions cannot be an increase in the number of households – the data used only indicates a small (<1%) increase from 2003 to 2012, and there is only a small increase of the share of users in 2012. There is, however, a sharp rise in the amount of wood burned per user in MV. The MV change alone is responsible for most of the increase, i.e. 7,000 tonnes in the case of CO. In addition, the FVRD results were also much lower in 2002, and account for the remaining ~1,000 tonnes. Whereas some information on the 2002 results was obtained from Metro Vancouver (MV 2012), we were not able to ascertain how the wood amount per household was determined; the amount of wood burned, however, was determined as 26,000 tonnes by Metro Vancouver, which is not very different from our own numbers. This therefore confirms the low emission results for 2002 in MV and the FVRD and suggests that it is due to the methodological difference in how the wood amount used per year was determined in each survey (2010 asked about cords per year, 2002 asked about pieces of wood used per month). It appears the 2002 methodology underestimates the wood amounts used.

Another strong increase can be observed in Vancouver Island (West Coast Region). This appears to be due to the higher wood user incidence determined for this region in the 2012 survey: it stands at 35% in 2012 versus only 27.5% in 2003. The disproportionate increase could be due to statistical uncertainties (see Section 2.1), i.e. the apparent increase in emissions from wood burning appliances in BC may stem from the variability of the underlying data, rather than presenting the true state of things. It is also possible that these increases are real and due to a move away from natural gas towards wood when pricing was high in recent years – these trends would need corroboration from other sources to be accepted as valid. Table 5 shows a comparison of the regional user incidence in 2003 and 2012 for some strongly diverging cases. Given it is unusual that user incidence has changed this much in only ten years, the regional emission results should be taken with some caution and it may not be possible to deduce trends with much certainty.

**Table 5: Examples of Diverging Results for User Incidence**

Sub-Region	2002/2003	2010/2012
Capital Region	19.7%	32.7%
FVRD	24.0%	10.3%
Golden	42.5%	57.6%
Williams Lake	25.4%	36.8%
Bulkley Valley	39.8%	55.2%
Northeast MV	58.0%	35.8%

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## 3.0 CONCLUSIONS

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At the provincial level, the use of wood for heating has not changed much between the 2003 and 2012 datasets. The data shows a small increase in households who use wood, from 30 to 31%. Wood use per household has remained stable (except in MV which showed a dramatic increase), and given the number of households did not increase much based on the statistical data used, provincial wood combustion activity has remained almost constant. On the other hand, a clear trend towards more certified appliances can be observed: 68% of all wood stoves were certified for low emissions in 2012, versus only 44% in 2003 – actual numbers could be even higher, given that about a quarter of respondents indicated they were not sure about the certification status of their appliance. Also, about half the fireplaces (inserts) were certified in 2012. This agrees with a lower average age of appliances outside the MV region. At the same time, there is a trend away from fireplaces and inserts towards certified wood stoves, pellet stoves, and central heating systems, which are generally cleaner burning appliances. This can be expected to lead to lower air emissions, which is also reflected in the overall improvement of attitudes about wood smoke throughout BC. The data collected on low-emission certification of appliances may, however, also be exaggerated due to intentional over-reporting or confusion between safety and environmental certification of appliances (there is some indication this is at least the case for central heating appliances).

The expectations about lower emissions are, however, not reflected in the calculated results, which show an increase of residential wood combustion emissions since 2003. It is believed that these results stem from the great variation in wood user incidence determined from the 2003 and 2012 datasets, combined with data uncertainties with respect to Metro Vancouver and the FVRD in the 2002 survey. It is believed that the 2002 results for MV and the FVRD may have underestimated the amount of wood used due to the methodology used in the survey to assess these amounts. The results should therefore not be taken as proof that emissions have increased but it is more likely that firm conclusions cannot be drawn based on the data at hand.

Statistical uncertainties inherent in the survey results increase with respect to the regional results versus overall provincial results. This means that regional trends cannot be determined with as much certainty. In some instances, the regional wood user incidence has varied strongly between the two datasets; this can be a statistical artefact due to the larger 95% confidence intervals (possibly, 30% of the value determined or more in some cases). Wood user incidence has varied by around  $\pm 8$  percentage points in the West and South Coast regions, as well as in the Cariboo and the Northern Region. It is possible that such increases are due to rising natural gas priced in the first decade of this century, i.e. especially on Vancouver Island, where natural gas costs are very high, people may have switched to wood over the past decade. The differences are so strong that corroboration from other sources, such as wood stove sales statistics for the regions in question, would be required to confirm the results obtained here. Clear regional results could be obtained on several other issues, though:

- Fireplace use is much more prevalent in MV and the South Coast area than in the rest of BC. This suggests increased use for ambiance and less for actual premise heating.
- Pellet stoves have increased in quantity in most regions.
- Many more appliances are now certified for low emissions – about 70% of woodstoves are certified, and between 33 and 50% of fireplaces (with the exception of Metro Vancouver).
- Appliance age is decreasing fairly uniformly across all regions, apart from MV.
- The annual amount of wood burned per household has remained fairly constant, with a tendency towards less wood use (the changes in MV and the South Coast region are likely due to methodological differences between surveys).

- Pellet use per household is highest in regions with the coldest climate.
- A trend towards less wood seasoning is apparent in most regions, apart from MV.
- Most new installations of wood burning appliances took place in the Cariboo, Northern Region, and the South Coast in the past two years. In the South Coast Region, the incidence of new installations reported in 2012 doubled in comparison to 2003.
- Concerns about wood smoke are highest in the Thompson/Okanagan region but the level of concern has decreased in all regions – especially in the Thompson region. It is lowest in MV and the Cariboo.
- The emission calculations show increases in the West and South Coast, and MV Regions but it is likely that these increases are due to methodological reasons. In other regions, results indicate the same or a slightly lower emission level.

For sub-regional results, the above-mentioned limitations are even more important to consider. Sub-regional results may be used to assess a probability that the local prevalence is above or below the regional average. Since such data has a higher risk of emphasizing spurious differences (statistical artifacts), several strategies should be employed before drawing any conclusions: (1) looking for a consistent or inconsistent pattern of differences, (2) consistency with what we know from other sources of information, and (3) looking at how things have changed since the 2003 survey (i.e., refer to the past survey reports listed in Section 1.2), or (4) commission a local survey with a sample that provides greater certainty.

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## 4.0 RECOMMENDATIONS

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Several points were found to need improvement during our research with respect to future surveys on wood stoves in BC:

- In regions where user incidence increased considerably over the past decade, corroboration of the results should be attempted to confirm the emission increase determined based on the available data; for example, by obtaining sales statistics for wood stoves.
- As in the 2012 survey, behavioural questions should be asked last to avoid any bias; for example, a question about health risks will likely reduce the readiness of participants to later on during the interview disclose they burn plastics in their stoves.
- The interviewer should ask whether the household has a wood fireplace without insert to avoid double-counting with fireplaces that have an insert (following question).
- As in the 2012 survey, the interviewer should ask about certification for each appliance separately (where applicable), rather than as a general question that does not allow allocating this information to specific appliances.
- The question about certification should include a brief explanation that this is not about safety but environmental (emissions) certification, to avoid false positive reporting on this issue. This is especially important for furnaces and other such appliances, for which emissions certification has only been available in recent years.
- The amount of cords of wood burned per year should be investigated using the same size classes that were used in the 2012 survey; interviewers also need to confirm that the participants understands they are asking about a full cord (4x4x8 ft) and not just a face cord (4x8 ft, single stack).
- To properly allocate emissions, a follow-up question should address how much wood is burned in each appliance named by the interviewee.
- A distinction between fireplaces and fireplaces with inserts (as in the 2003 survey but not in 2012) would aid in emission calculations since different emission factors are used for each.
- Questions about the amount of wood fuels used should include pellets, artificial logs, and scrap wood. This should be part of the question about wood species used (i.e. if firewood, specify composition of species used).
- ENVOLV can be updated to import modified data sets with minimal modification to the database structure and data translation scripts. However, in order to streamline the process of importing future survey data it is suggested that any new survey maintains a similar structure to the 2012 British Columbia survey (Excel raw data file).

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## APPENDIX 1 – DETAILS ON PAST SURVEYS

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### A.1 COMPARISON OF SURVEYS

The surveys rely on random samples from the phone book, distributed statistically to represent all regions sampled. The 2012 survey also had 500 surveys completed over the Internet. For all surveys, regions and sub-regions were defined. Note the surveys are simply referred to by the year they were completed in for subsequent tables.

**2012 Survey:** The approach to sampling was to set disproportionate targets for each region and sub-region, with an approximate ratio of two-thirds users (of wood for heating) to one-third non users. In order to establish the actual incidence of users, surveys were conducted at random with both users and non-users and proportions of completed surveys were monitored up until the point that the smaller non-user targets were reached. Once the non-user targets were reached those quota cells closed and surveys were only completed with users (an over-sample). At the data processing stage, results were weighted back into proportion according to known incidence levels of users versus non-users and according to 2006 Statistics Canada (Statcan) data on the number of households in each region and sub-region.

**2010 Survey:** To ensure appropriate representation from key target groups, quotas were set by region and whether or not respondents have a wood burning device (a split of about 50% between wood users and non-users). The final data were weighted by region and the incidence of wood burning devices to ensure that it is reflective of the actual population in Metro Vancouver according to Statcan 2006 Census data. The percentage of homeownership in the survey stands at 81%, which may mean the results are somewhat tilted towards homeowners, since home ownership in the Lower Mainland stands at only approximately 65%.

**2003 Survey:** The survey used disproportionate sampling in selecting the number of wood-burning households. Non-wood fuel users were surveyed as a control group and as such, only half of the number of non-users was surveyed relative to the users. In the end, the complete responses amounted to a minimum of 100 wood users and 50 non-users for each survey region. In effect, wood burning households were over-sampled from a representative population in order to better study variations within this group (for example, geographic variations). In cases where respondents could not identify their wood heating equipment, a worst case scenario was assumed to estimate air emissions. When several wood burning devices existed in the household, wood consumption was distributed equally over all devices. Some fireplace inserts may have been reported as separate devices when there really was only one fireplace with insert.

**2002 Survey:** 200 households were interviewed in the FVRD and 300 in the (then) Greater Vancouver area. Results were then weighted based on year 2000 Statcan population data.

**2001 Survey:** The Okanagan survey was conducted by mail, not telephone. For the mail survey, each geographic area of the Central, North and Okanagan-Similkameen Regions were identified by their Postal Codes (i.e. Central Okanagan: 9 areas - Peachland, Westbank/Lakeview, Kelowna to Winfield) and each were surveyed proportionally.

Table 6 compares how the various surveys classified wood and non-wood heating systems. The 2003 survey had already integrated the Okanagan survey, i.e. these were deemed compatible. The 2012 survey has somewhat more detail than the 2003 survey, i.e. heat pumps and propane are listed as separate items.

The 2001 Okanagan survey further distinguishes advanced wood stoves and advanced fireplace inserts (for new purchases only) and asked for the stove model and whether or not it is CSA/EPA certified for low emissions, whereas the 2003 survey asked about conventional, advanced, and catalytic versions of the two. The 2002 survey did not enquire about non-wood heating sources. It distinguished conventional, non-catalytic, and catalytic wood stoves. Both MV surveys did not ask about central heating systems using wood but identified a small number of masonry heaters. Only the 2010 MV survey identified fireplace inserts as a separate category; it determined whether units were CSA or EPA certified with a separate question, as did the 2012 survey. The 2012 and 2003 surveys also distinguished central wood boilers from forced air heaters, as well as heaters installed indoors and outdoors.

**Table 6: Heating Systems in Past Surveys**

2001	2002	2003	2010	2012
Natural Gas	-	Natural Gas	Natural Gas	Natural Gas
Electricity	-	Electricity	Electricity	Electricity
Electricity/gas	-	% each	-	-
Electricity/oil	-	% each	-	-
Fuel or heating oil	-	Fuel or heating oil	Fuel or heating oil	Fuel or heating oil
-	-	-	-	Heat pump
-	-	-	Propane fireplace	Propane
Other	-	Other	Other	Other
-	-	Planned or recent fuel switch	-	-
Wood	Wood or pellets	Wood	Wood or pellets	Wood or pellets
		Wood pellets		
<i>Wood stove</i>	<i>Wood stove</i>	<i>Wood stove</i>	<i>Wood stove</i>	<i>Wood stove</i>
<i>Masonry fireplace</i>	<i>Fireplace</i>	<i>Wood fireplace</i>	<i>Wood fireplace, incl. masonry</i>	<i>Wood fireplace/insert</i>
-	-	-	<i>Fireplace insert</i>	-
-	<i>Masonry heater</i>	-	-	-
<i>Pellet stove</i>	<i>Pellet stove</i>	<i>Pellet stove</i>	<i>Pellet stove</i>	<i>Pellet stove or furnace</i>
<i>Central furnace</i>	-	<i>Wood furnace or boiler</i>	-	<i>Wood burning central heating system</i>

As Table 8 shows, there is some congruence between surveys (since the design of newer surveys tried to incorporate some of the questions asked before) but also considerable diversity, i.e. the number of options provided to answer a question varied, and some questions were only asked in some of the surveys. Specifically,

- Only the Metro Vancouver surveys (2002/2010) recorded the gender of the person interviewed.
- No consistent information is available on how or when wood fuels are purchased.
- Household size, income, and rural or urban settings were not determined consistently.
- Behavioral and preference questions are only consistent between the BC surveys (2003/2012) but are treated differently in the others.

On the other hand,

- All surveys determined the type of house, albeit they did not always offer the same options.
- All surveys enquired about plans to purchase new wood burning equipment and the reasons why people use wood as a heating fuel.
- Wood species is also always a question, since this information is important to estimate emissions. Whether the wood is seasoned was asked in all but the 2002 surveys.

- A question about the amount of fuel burned in a year was also asked but answers are not always consistently given and require some assumptions to be reconciled (even in the original reports).

Given there is so much variety between the datasets, 15 output reports were generated in ENVOLV (see Table 7). Note that even for these 15, not all data was available from each survey, i.e. in some cases a full comparison between the earlier and later datasets is not always possible.

**Table 7: Output Reports Created from the Combined Dataset**

Theme	ID	Report Topic	Remark
Wood Burning Appliances	1	Wood use for heating (users/non-users)	
	2	Types of wood burning appliances	
	3	Percentage of appliances that are certified	
	4	Wood stove age	NA for 2002,2001
Wood as a Fuel	5	Annual amount of wood burned (cords, bags of pellets)	
	6	Type of wood used (tree species)	NA for 2010
	7	Duration of seasoning	NA for 2002
Wood Burning Behaviour	8	Reasons for wood burning	NA for 2001
	9	Other materials burned	Only 2003/12
Installation of New Appliances	10	Equipment installed in past two years	Only 2003/12
	11	Intention to install in coming 2-3 years	NA for 2010
	12	Responsiveness to a \$250 incentive for wood stove exchanges	Only 2003/12
Attitudes	13	Is chimney smoke a concern for you?	NA 2002
	14	What measures to reduce wood smoke would you support?	NOTE: not all options given in all surveys NA 2002
Emissions	15	Emissions by region/type of appliance	

NA: Not available

**Table 8: Additional Survey Questions**

2001	2002	2003	2010	2012
	Gender	Gender	Gender	
			Age	
Rent or own	Rent or own	Rent or own	Rent or own	Rent or own
			Income bracket	
House type (7)	House type (5)	House type (6)	House type (4)	House type (6)
House age		Year house built	House age	Decade house built
House size (ft <sup>2</sup> )		House size (ft <sup>2</sup> )		House size (ft <sup>2</sup> )
	Household size	Household size		
Additional buildings heated				
		Rural/urban		Rural/urban
Stove age	Stove age	Years wood used	Stove age	Stove age
Is wood smoke a nuisance?		Air quality opinions (5)	Air quality opinions (3)	Air quality opinions (4)
Visible smoke (4)				
% heat from wood; month used	Days stove used per month	Time wood added; Days/hours used per year	Days/hours stove used per year	% heat from wood; times per week; time of day
Fuel amounts (cords per year)	Pieces of firewood per day	Fuel amounts (cords per year) or # of artif. logs/bags	Fuel amounts (cords per year)	# of pellet bags; cords or other explanation
Wood fuel type (5) Other fuels (5)	Wood type (5)	Wood type (5) Other fuels (11)	Wood fuel type (4)	Wood types (13) Other fuels (7)
Duration of seasoning (6)		Duration of seasoning (4)	Seasoned or not	Seasoned or not
			Wood source	Purchased/free
When procured				How/when delivered
		Wood storage (8)		Wood storage (4)
			Wood price	
Reason for burning wood (3)	Reason for burning wood (2)	Reason for burning wood (5)	Reason for burning wood (6)	Reason for burning wood (10)
Impact of natural gas price		Impact of natural gas price		
Future plans (4) and reasons (6)	Future plans (5)	Future plans (10) and reasons (14)	Future plans (3)	Future plans (6) and reasons (13)
		Recent installations & reason		Recent installations & reason
In favour of regulations? (2)		In favour of regulation? (2)	In favour of regulations? (7)	In favour of regulations? (6)
			Respiratory illnesses	
Awareness of wood stove exchange program		In favour of wood stove exchange subsidy?		Awareness of or participation in wood stove exchange program
		Impact of subsidy		Impact of subsidy
		Awareness of regulations		Awareness of regulations
Awareness of good practices		Awareness of good practices		

Note: Numbers in brackets represent number of options to answer each question

## A.2 DATA RECONCILIATION

We used the most recent (2012) survey as a template and adjusted the other surveys to this one, i.e. responses were allocated to the 2012 questions whenever possible. In some cases, where earlier surveys had more detail, additional detail was added to the 2012 template for future perusal.

Specifically, the 2012 survey:

- asked whether people had burned wood in the last year, rather than whether they had a wood burning appliance, as did the other surveys. This difference was deemed immaterial and responses to these questions were compared directly. This survey question (Q9) was taken as the basis to determine the percentage of wood users.
- Uses 2006 Statcan data adjusted with Canada Post data on households, which brings that information close to 2011 census data (MG 2012). 2006 data were used for the MV 2010 survey, however, to remain consistent with that report's methodology.

The 2010 survey

- asked about forced air and hydronic heating in MV, in addition to natural gas and other heat sources. Both these responses were translated to natural gas, which is the most likely heating source for both forced air and hydronic heating in MV.
- For Question 5 (Number of wood burning appliances), participants sometimes responded they had both a conventional fireplace and a fireplace insert, but did not provide ages for these appliances. In such case, it was assumed that the inserts are in the conventional fireplace(s), i.e. they are the same appliance. The number of conventional fireplaces was then corrected to zero.
- Instead of allocating certification or operational status to specific appliances, the 2010 MV survey only asked a general question about certification. We had to convert the answer 'some' (are certified) to 'not specified' since no allocation was possible.
- The question about equipment that was operational was also a general one in the 2010 survey. We converted the answer 'some' (are operational) to a YES to the question whether the household is actually burning wood.
- The reported age of the appliances was increased by two years in order to align with the 2012 survey.
- In terms of seasonal wood burning (hours per week), the 2010 survey only distinguished two seasons. These were split equally into four seasons in order to align with the 2012 survey. Monthly hours were divided by four to obtain weekly hours.
- Some surveys determined the amount of wood used by offering various ranges as an answer. These ranges differed between the 2012 and 2010 surveys for the amount of cords burned per year. A larger (worst case) range was allocated whenever the 2010 survey had less range options. On the other hand, a new size class specific to only this survey was created for users that use less than 10 pieces per year, translated as 0.02 cords. Also, the amount of pellets burned had not been recorded in 2010 and was therefore estimated for this analysis, based on the average in the South and West Coast regions (similar climate) in the 2012 survey, in order to estimate air emissions.
- No allocation between appliances was provided in the data, such that the wood was assumed to be burned in equal portions in each appliance reported for the same household.
- In terms of reasons to burn wood, there was no 'moderate' reason in the 2012 survey; this answer in the 2010 survey was therefore converted to a 'major' reason.
- For house types, the 2010 survey had a category 'other' – this was deemed equivalent to 'trailer/mobile home' in the 2012 survey.
- The 2010 report does not specify the number of households that were the basis of the statistical analysis, but mentions the 2006 census and seems to use 'private dwellings' as the

basis (p.13). To combine the 2010 and 2012 results for all of BC, however, we used the one-family dwellings from the 2006 census to remain consistent with the 2012 survey and other surveys, as this is a lower number and using all households would tilt the results to overemphasize the MV region.

- To determine the split between users and non-users, we relied on the number of users that actually reported wood use in the survey. The question whether appliances were operational was therefore not the final verdict, but only a subset of this group who also reported wood burning (number of cords burned >0) was used to determine the portion of wood users in MV.

The 2003 survey was treated thus:

- The user/non-user split was based on the corresponding column in the 2003 raw data, i.e. the participants were clearly identified as users or non-users and none of the survey questions had to be interpreted to determine percentages.
- The 2003 survey asked about more heating sources than the 2012 survey. If a 50/50 mix of wood and electricity or natural gas was reported, electricity or natural gas was taken as the main heating source. Solar heating was converted to 'miscellaneous'.
- For the age of fireplace inserts and woodstoves, the 2003 survey only determined whether these were younger or older than 15 years. We arbitrarily assigned an age of 10 years to the appliances reported as less than 15 years, and 30 years to the older ones.
- The 2003 survey only identified 'advanced' fireplace inserts as EPA certified (Question 18); no stoves were identified as certified. Given that new stoves sold in BC must be EPA certified since 1994, we took 'advanced' and 'catalytic' stoves bought within 15 years before the survey as equivalent to certified stoves in the 2012 survey.
- The options provided for the range of wood quantities used per year differed between the 2003 and 2012 surveys. The larger (worst case) range was allocated whenever the 2003 survey had less options. Although allocation of the amounts burned between appliances was provided in the data, the wood was assumed to be burned in equal portions in each appliance reported for the same household, to remain consistent with the other surveys.
- Options provided to name wood species used as firewood were less than in the 2012 survey; most participants that used 'other' species named hemlock; these amounts were therefore counted as hemlock in the emission calculations and would be reported as such in output tables but really also contain some indefinite amount of other species.
- The 2003 survey asked about what time wood was burned during the day; the 2012 survey had more detail here as it distinguished the answers for four seasons. The 2003 answers were taken to apply to the winter season only.
- In terms of seasonal wood burning (hours per week), the 2003 survey distinguished twelve months. These were combined into four seasons in order to align with the 2012 survey.
- The 2003 did not, as did the 2012 survey, distinguish wood furnaces and boilers. It was not possible to split the category 'boilers & furnaces' up into two categories in order to correspond to the 2012 survey.
- On some of the questions on opinions, the 2012 report had more options than the 2003 report. We therefore converted yes/no answers from the 2003 survey to "very much in favour" and "against", i.e. the strongest meaning provided in the 2012 survey.
- For population weighting, the 2003 survey used 2003 Canada Post data on the number of households. This was mainly consistent with 2001 Statcan data. No adjustment was made to weight the data, given that extrapolation should be based on contemporary population data, not recent data.

For the 2002 survey covering Metro Vancouver (MV) and the FVRD (no raw data was available, only the PDF summary report was available),

- results were reported for MV and the FVRD or even as a total for both combined. Where data were not distinguished in the PDF report, we used the same average number for all these regions (the report details that 6% of MV residents and 3% of FVRD residents with wood burning devices are not using them but does not allow to allocate these between the appliance types).
- Some parameters, such as appliance age and house type, were not included in the PDF and could therefore not be integrated into the database.
- The survey did not ask whether wood burning appliances were certified. We assumed that non-catalytic and catalytic wood stoves were certified, whereas conventional stoves were not.
- The survey asked both about the intention to buy a new wood burning appliance and about readiness to convert to a cleaner wood-burning technology in light of pollution concerns. The latter question did not specify the timeframe (in the next 2-3 years) as did other surveys and the former question. Given the positive answers as 'intend to buy' were much lower and that the other question also included gas fireplaces, we used Question 12 (intent to buy wood burner over the next few years) as equivalent to the other surveys and ignored Question 11 from this survey.
- The amount of wood burned was not reported as cords per year but as pieces of split firewood per day. We converted this amount to cords using 712 pieces of split firewood per cord [Trees 2012]. Also, the amount of pellets was estimated based on the average in the South and West Coast regions (similar climate) in the 2003 survey in order to estimate air emissions. Days of firewood use per month were multiplied by the average number of logs per day to arrive at the total amount of wood burned.
- The type of wood species burned was reported but not the actual amount or percentages by appliance. We therefore had to normalize the percentages of species reported so the total would become 100% (more than 100% were reported since participants could name several species). This amount was simply divided equally across all wood burning appliances. Also, cedar, scrap lumber, firelogs, and 'don't know' were combined into one generic wood category for emission calculations. This leads to some uncertainty for MV, given more than half of the wood burned belongs to these categories.

The 2001 survey for the Okanagan

- contained data for the three regional districts of the Okanagan, i.e. there was overlap with the 2003 survey, which covered the Okanagan apart from Kelowna. Therefore, the 2001 survey results for the Central Okanagan were applied to 31,582 Kelowna households only (as in MoE 2005), leaving the remainder of the Okanagan represented by 2003 survey results. For some parameters, Kelowna results (Kelowna North Central, Robertson Park, and Hospital Area) were reported for the City and were then taken directly.
- The survey distinguished mixes of heating oil and electricity and gas and electricity as the main heating source. In these cases, electricity was considered an auxiliary source and fossil fuels were taken as the main source.

### A.3 WEIGHTING

The survey raw data represent only a small portion of the population, in different proportions to the number of households in the seven regions and disproportionate in terms of wood users and non-users (more users are interviewed than non-users). To extrapolate the survey results to the region

and province, the results therefore need to be weighted to bring them back into proportion with the actual population numbers and wood user share.

Weighting of raw data was conducted based on the same weighting factors reported in each raw dataset (2010, 2012). The 2003 raw dataset did not include any weighting factors, such that these had to be created. The survey included an additional component to determine the incidence of wood users that included a larger number of participants for a simple yes/no question (the entire set of questions was only put to a smaller subset of participants). Based on the user share thus determined, weighting factors were developed for 2003 in the same manner as was done for the 2012 survey.

As mentioned earlier, the 2012 survey oversampled users and weighted based on known incidence of wood use and population data. The 2010 report interviewed equal numbers of users and non-users and also weighted by population (2006 census data) and known wood use incidence. For any particular question, the percentage of responses given was then calculated as:

$$\text{Response [\%]} = \frac{\sum(\text{specific responses by region} \times \text{weighting factor})}{\sum(\text{all responses by region} \times \text{weighting factor})}$$

For example, the percentage of wood users in any region would be the incidence of weighted positive responses divided by the weighted total number of responses, including non-users.

Note that the weighting we created for the 2003 dataset is necessarily different from the one used in MoE 2005 (Residential Wood-Burning Emissions in BC). Table 9 shows why this is so: based on the 2003 raw data provided for the database integration work, the split between users and non-users interviewed for the survey differ from the ones reported in Table 1 of the 2005 report, "*Residential Wood Burning Emissions in British Columbia*". Since the numbers we determined are based on actual counts from the raw data, we used these numbers instead of those reported in Table 1 of the 2005 report "*Residential Wood Burning Emissions in British Columbia*". This leads to slightly different weighting factors and thus, slightly different output results for the 15 *Envolv* reports generated when compared to the results presented in the 2005 and 2006 reports.

**Table 9: Comparison of 2003 Raw Data and the 2005 Emissions Report**

Region code	Sub-Region	MoE 2005 Data		2003 Raw Data	
		Sample users	Sample non-users	Sample users	Sample non-users
12	Capital Regional District	100	51	100	51
11	Other Vancouver Island	148	57	126	55
21	Sunshine Coast	100	48	125	50
22	Sea-to-Sky Airshed	104	57	101	57
31	Shuswap	106	53	125	68
32	Kamloops	101	50	100	51
33	Other Southern Interior	118	66	100	50
41	Golden Airshed	100	61	135	50
42	Cranbrook Airshed	100	51	100	62
43	Elk Valley Airshed	100	52	100	51
44	Nelson Airshed	101	52	100	51
45	Other Kootenay	134	48	100	50
51	Williams Lake	102	54	125	56
52	Quesnel	111	54	100	53
53	Other Cariboo	112	51	100	50
61	Prince George	123	51	135	80
62	Other Northern	107	78	100	50
71	Bulkley Valley/Lakes Airshed	106	51	127	64
72	Other Skeena	127	64	101	50
	<b>TOTAL</b>	<b>2100</b>	<b>1049</b>	<b>2100</b>	<b>1049</b>

#### A.4 EMISSION CALCULATIONS

The 2005 report “*Residential Wood Burning Emissions in British Columbia*” (MoE 2005) estimates air emissions from residential wood smoke in BC. It regroups the data from the 2001, 2002, and 2003 surveys and applies the following methodology to estimate air emissions:

1. Survey results were weighted according to the number of households in each region of BC.
2. The amount of wood burned given in cords was converted to cubic metres using a factor of 2.27 solid m<sup>3</sup>/cord (stacked).
3. Wood density by species was calculated to 18% moisture content (wet basis) to represent seasoned wood. This was converted from literature numbers for 12% (dry basis) and corrected for volumetric shrinkage. We used the values in the fifth column of Table B.3 of MoE 2005 for each species (averages were used where offered for species groups) as the basis for determining the amounts of wood burned. For fir, the average between coastal and interior Douglas fir was used. The hardwood value (average) was used to represent poplar. For fruit trees, the cherry density was used. For mixed or unknown species, the BC average of 530 kg/m<sup>3</sup> was used.
4. By multiplying the density by the number of cords, the tonnes of wood burned by year (by species, as % of total) in a given appliance were calculated. The ranges reported were applied as the higher end of the range (e.g., 1-1.5 cords was taken as 1.5 cords). Less than ¼ cord was taken as ¼ and more than 4 cords as 6 cords. For pellets, an amount of 40 lbs per bag was assumed, as in the 2012 survey.

5. The amount of wood was converted to air emissions using the *National Emissions Inventory and Projections Task Group Guidebook* emission factors (EF) as defined for various wood burning appliances in kg/tonne of wood, as described in MoE 2005. There is a discrepancy between these factors and those used in the 2002 report (see Table 10 for a comparison), which leads to somewhat different results for Metro Vancouver and the FVRD.
6. The same emission factors were also used to estimate emissions from pellet stoves in kg/tonne of pellets. Whenever respondents were unsure their appliance was certified, we took the appliance not to be certified. Certified and 'advanced' woodstoves have the same emission factors and were grouped together (the 2012 survey no longer distinguishes advanced stoves but only EPA certified). Likewise, advanced fireplaces and inserts are treated alike, not being distinguished in the 2012 survey and also having identical emission factors. When respondents were unsure whether their wood furnace was inside or outside, it was deemed to be inside.

**Table 10: Comparison of Emission Factors (EF) Used in 2002 (left) and MoE 2005 (right)**

Contaminant	Fireplaces		Certified inserts		Masonry fireplaces		Conv. Wood stoves		Certified stoves		Pellet stoves		Central furnaces
CO	126.3	77.7	-	70.4	74.5	115.4	115.4	100	70.4	19.7	8.8	68.5	
NOx	1.4		-	1.4	1.4		1.4		1.4	1.4		1.4	
TPM	13.5	19.3	-	5.1	14.4		15.3	24.6	5.1	1.2		14.1	
PM10	13.0	18.5	-	4.8	13.3	13.6	13.6	23.2	4.8	1.1		13.3	
PM2.5	12.9	18.5	-	4.8	13.3	13.6	13.6	23.2	4.8	1.1		13.3	
SOx	0.2		-	0.2	0.2		0.2		0.2	0.2		0.2	
VOC	21.0	6.5	-	7.0	21.3		35.5		7.0	1.5		21.3	

Note: Emission factors were identical for certified stoves and central furnaces in both reports.

The formula used to estimate emissions from residential wood burning can thus be represented as follows:

$$\text{Emissions (by species burned)} = \# \text{ of cords} \times 2.27 \times \text{density (species specific)} \times \text{EF (appliance specific)}$$

Wherever percentages of wood burned by species were reported, this procedure was repeated for the remaining fractions to combine these into the total emissions for each appliance. Wood species were not reported in the 2010 MV survey. Consequently, to estimate emissions, all wood was considered 'Other' wood, and a generic wood log density was applied to determine the amount burned. Also, the fuels not listed as species (scrap, firelogs and 'Don't know') were treated as generic wood logs to determine the amounts burned per year. Table 11 shows the adjusted amounts of each wood type. Since several types could be mentioned, the total in the 2002 survey added up to more than 100% and was therefore normalized to 100% in the table below. The 2012 survey did not include firelogs and lumber as part of the fuels burned but as part of another question, which could not be integrated with the former.

**Table 11: Adjustments to Account for Wood Species Between Surveys (% Fuel Used in Region)**

Year	Region	Alder	Fir	Maple	Hemlock	Birch	Cedar	Scrap lumber	Art. Firelogs	Don't know
2012	BC	8	33	*	4	7	*	n/a	n/a	*
2002	MV	17.9	14.6	6.5	4.9	4.1	4.1	19.5	13.8	14.6
2002	FVRD	21.1	19.3	16.9	8.4	9.0	3.0	12.7	4.2	5.4
2010	MV	66						9	21	1

\* 20% pine, 7% Spruce and 20% other species

A total of 11 different appliance types were distinguished, including certified and non-certified variations. The same methodology was also applied to the regional results from the 2001 and 2002 surveys to integrate the data for all of BC. Given the AP-42 emission factors for residential wood stoves were not updated since 1996, the same factors as in MoE 2005 were used in the database.

Environment Canada commissioned a study to measure emissions from wood burning appliances in 2008, with the objective to “provide emission factors which represent real world emissions of specific compounds emitted from wood burning appliances, and compare them to factors for the same compounds as defined in the AP-42 published by the US EPA, the Canadian Air Pollutant Emissions Inventories, and other recent studies that address similar interests.” This study compared two different non-catalytic certified stoves and concluded that modern non-catalytic wood stoves are likely to emit somewhat less than the AP-42 emission factors, due to the latter being based on older technology from at least two decades ago. Given the differences are relatively small (see Table 12 below) and that they would likely only apply to the most recent stoves, no change was made to the emissions calculations with references to the earlier methodology. In the future, as older wood stoves are replaced with newer ones, some modification to the emission factors used may be indicated.

**Table 12: Comparison of Emission Factors Used to Field Measurements (certified stoves, in kg/tonne of wood burned)**

Contaminant	Emission Factors used in MoE 2005	Results of Environment Canada Sampling [EC 2009]
CO	70.4	82
NO <sub>x</sub>	1.4	0.9
TPM	5.1	3.7
PM <sub>10</sub>	4.8	No data
PM <sub>2.5</sub>	4.8	2.2
SO <sub>x</sub>	0.2	No data
VOC	7	5.3

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## APPENDIX 2 - ENVOLV™ STRUCTURE

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### DATABASE STRUCTURE

The ENVOLV application uses a Microsoft Access Database to store all the wood stove survey and emission data. Data was retrieved from a number of different sources then translated and saved in the Microsoft Access tables as noted below.

- **Raw2003:** Contains raw 2003 survey data that was imported from the original 2003 data source.
- **Raw2010:** Contains raw 2010 survey data that was imported from the original 2010 data source.
- **Raw2012:** Contains raw 2012 survey data that was imported from the original 2012 data source.
- **Questions:** The Questions Table is used to define equivalencies between the questions in each survey so that data from each individual survey could be combined into one unified dataset. Since the 2012 survey was used as the foundation for our report, all other survey questions map back to 2012.
- **Sources:** The Sources Table is used as a supporting table when survey data is translated and saved to the CombinedData Table.
- **CombinedData:** The process of combining survey data starts by using VB Scripts to translate and combine data from Raw003, Raw2010 and Raw2012 data tables.
- **WeightedData:** The second part of the process involves VB Scripts that sum question results from the CombinedData Table and when needed apply household population counts from the Regions Table. All the Charts that are available in ENVOLV use the WeightedData Table as a data source.
- **Regions:** The Regions Table contains region and sub-region names. It also contains household population information as well as wood user percentage values for each data source.
- **EmissionsByUser:** The EmissionsByUser Table stores calculated emission totals for each wood burning user.
- **EmissionsByApplianceFactor:** The EmissionsByApplianceFactor Table contains emission factor information that is used when emission totals are calculated.
- **TreeSpecies:** The TreeSpecies Table contains tree species density information that is used when emission totals are calculated.