MARYLAND RESIDENTIAL FIREWOOD/WOOD PELLET UTILIZATION ANALYSIS: A SURVEY TO DETERMINE LOCAL INTEREST AND ASSESS CURRENT AND FUTURE MARKET POTENTIAL

Cuiyin Wu
And
Dr. Bob Tjaden

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Abstract

In order to help the forest industry to revitalize from the 2008 economic recession, this research studied the market potential of firewood and wood pellets as a home heating source. Questionnaires were mailed to 7,000 single family homeowners in rural and suburban Maryland, and 1,184 responses were received (19% response rate). It is estimated that 256,419 cords of firewood and 81,863 tons of wood pellets were burned statewide in the heating season of 2015-2016. The aesthetic value of wood heating is the major motivation; work and mess is the principal barrier. The average volume of wood consumed annually per household is 1.8 cords of firewood or 1.9 tons of wood pellets. The average prices of wood consumed are $192 per cord for firewood and $266 per ton for wood pellets. The threshold prices of electricity, natural gas, oil, and propane for homeowners to switch to wood heating are estimated. Few homeowners know about Maryland Energy Administration's Clean Burning Wood Stove Grant Program.

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"To poke a wood fire is more solid enjoyment than almost anything else in the world."

--Charles Dudley Warner

Introduction

Current Status of Maryland's Forest Industry

Maryland benefits from its abundant forest resources. According to the United States Department of Agriculture Forest Service, there are 2.461 million acres of forest land in Maryland and 72% of these, or 1.773 million acres, are privately owned (Oswalt et al. 2014). The forest industry has long been a main driver of the state economy. In 1914, they represented as the second largest industry (Jonathan Kays; Rider 2005). Tjaden et al. in 2015 reported that the forest industry supported 40,000 employees and had a total economic benefit of $4 billion (U.S Census Bureau 2008). In 2008, the sale of goods and services of the forests' products created tax revenue of $26 million and supported 1,300 related manufacturing facilities (Tjaden et al. 2015; U.S. Bureau of Economic Analysis 2010).

The dynamics of the forest industry have changed significantly as a result of recession over the past 8 years. Maryland's forest industry is still suffering major setbacks as a result of the 2008 economic recession. Numerous primary and secondary forest industry businesses have consolidated or closed their operations, since 2000 many Maryland sawmills have closed. The primary forest industry includes logging and sawmills for processing raw materials, such as lumber, poles and chips processing while secondary forest industry manufactures finished products such as furniture, toys, and other goods (Stoddard and Stoddard 1987).

The issue of fragmentation in forests has aggravated the situation. According to the USDA Forest Service National Woodland Owner Survey in 2006, 86% of the Maryland's private landowners own woodlots less than 10 acres (T. W. Lister et al. 2011). These landowners' objectives have shifted from gaining profits from timber resources to enjoying the aesthetic benefits of the forests (Sampson and DeCoster 2000). Therefore, with less timber resources to supply the local market, businesses associated with the forest industry shrank due to decreasing confidence for future economic success (Bowen, Tassone, and Baird 2016).

In order to help the forest industry to revitalize and foster private landowners' interest in sustainable land stewardship, the intent of this study is to examine the market potential of firewood and wood pellets in Maryland. Specifically, this study seeks to identify the price at which Maryland residents would switch to wood fiber for home heating.

Benefits of Wood Heating

Wood heating has economic, social and environmental advantages. First of all, a sustainable wood industry produces locally-sourced products, supports local economy, and attracts investment by creating jobs and tax revenue which will in turn benefit the local community (Nybakk and Panwar 2015). Galik and Abt found that the increasing demand for wood pellets in European countries does not decrease forest coverage but increases forest areas by providing incentives for private landowners to maintain forest lands. Secondly, the social value provided by wood heating resides in the invaluable interactions among family members and friends in front of a warm fireplace, which fills up the holes of loneliness due to isolation.

Last but not least, compared to fossil fuels, burning wood with high efficiency stoves emits no net release of carbon dioxide to the environment. The carbon benefits of wood pellets have been studied in several previous studies (Dwivedi et al. 2014; Wang et al. 2015; Galik and Abt 2016; Jonker, Junginger, and Faaij 2014; Buchholz et al. 2016). In order to study the reduction of the greenhouse gas emissions from the wood pellet fuel, a team of scientists were commissioned by the Northern Forests Center to conduct a life-cycle analysis of wood pellets. The result shows that the greenhouse gas emissions generated by wood pellets were 54% lower compared to oil and 59% to natural gas (Buchholz and Gunn 2016). Therefore, the carbon benefits provided by wood heating should not be overlooked.

Current Space Heating Condition in the Residential Sector

Currently in Maryland, the residential fuel heating market is dominated by natural gas, which offers a large potential market to convert to heating powered by firewood or wood pellets. According to the Energy Information Administration (EIA), a U.S. Federal Statistical System, among 113.6 million households in U.S., 55.6 million used natural gas as space heating fuel in 2009 (Energy Information Administration 2013). In Maryland, there are 2,165,438 occupied housing units, 53.3% of these units use natural gas as their heating source (48.5% use utility gas and 4.8% use bottled, tank, or LP gas), 37.4% use electricity, 5.3% use fuel oil or kerosene, 2.1% use wood, and 0.1% use solar (U.S. Census Bureau 2015). Homeowners would like to decrease their home heating bills but also are actively seeking sustainable and green energy. Alternative heating sources such as firewood or wood pellets are relatively inexpensive and readily available in Maryland. This study aims to determine whether it is possible for the Maryland's firewood and wood

pellets market to expand as home heating fuels and what market conditions would support or restrict its growth.

Justification

There is minimal literature documenting Maryland's current wood usage as a home heating fuel. The Maryland Forest Service was the last to evaluate Maryland's residential fuelwood usage. It was done by telephone survey as part of a cooperative program among twenty states in the northeastern U.S. (Rowan 1982). Out of 2,700 telephone calls, 2,372 of respondents were located in Maryland, Virginia and Washington, D.C. The assessment estimated that 396,806 households (27% of the total households in Maryland) burned 755,867 cords during 1980-1981 heating season. The assessment also summarized the major four barriers for nonusers to use wood, in order of frequency: 1) home design not suitable to install wood stoves, 2) renters unable to renovate, 3) installation cost, and 4) workload associated with wood heating. This study established a baseline for the volume of wood usage 35 years ago but is not comparable for current analysis since it includes respondents in Washington, D.C. and Virginia. It is imperative to acquire data to study the latest status of wood heating market in Maryland.

In addition to this survey, U.S. Census Bureau is another source to understand Maryland's wood heating usage in the residential sector. The U.S. Census Bureau provides information regarding residential housing characteristics by performing an annual American Community Survey. The Survey estimates that 1.4% occupied housing units heat with wood in Maryland using the survey data collected from 2011 to 2015 (U.S Census Bureau 2015). This estimation is based on all types of housing properties (single-unit

detached, single-unit attached, multi-unit housing, boat, RV, and mobile home) statewide and is not restricted to homeowners.

The Energy Information Administration (EIA) performed estimations on the volume of wood consumed by the residential sector annually (Figure 1) based on this information provided by the Census and the 2009 Residential Energy Consumption Survey (U.S. Energy Information Administration 2013). There is an inconsistency between the estimation performed by the Maryland Forest Service in the heating season of 1980-1981 and the estimation by EIA. According to EIA, 1,021,000 cords of wood were burned while the Rowan estimated that 755,867 were burned. The volume of wood pellets consumed was not taken into account in these previous studies.

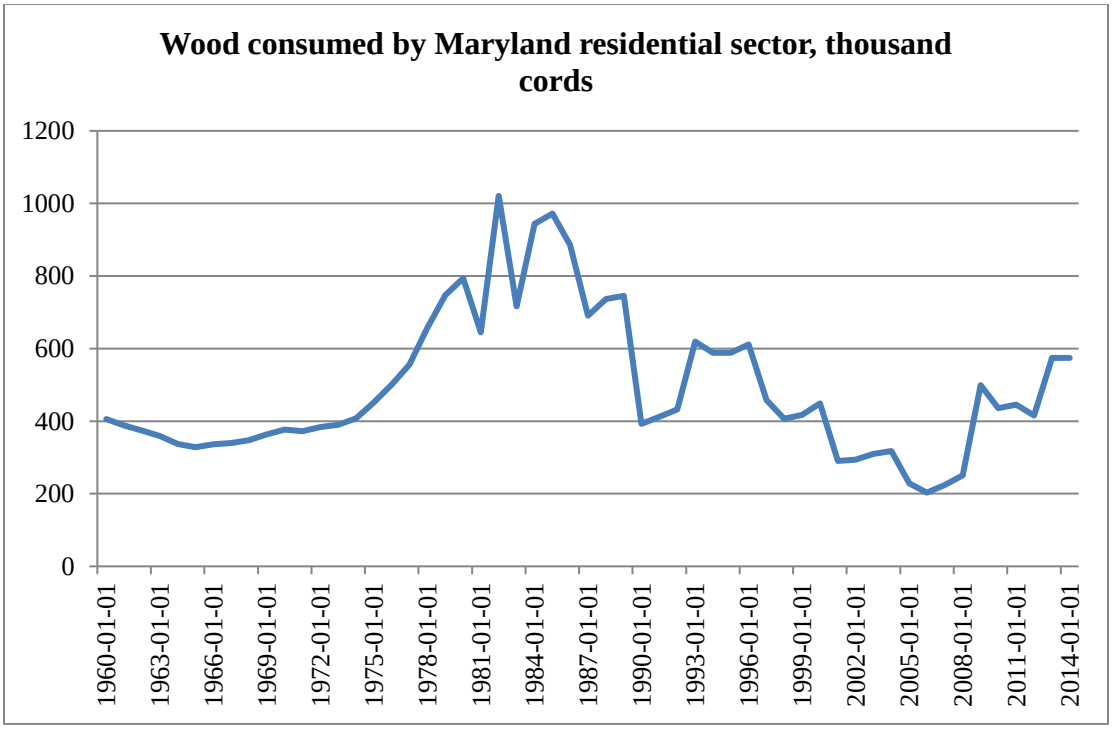


Figure 1. The total volume of wood consumed by Maryland residential sector (U.S. Energy Information Administration 2013)

Understanding the trend in the use of wood as a space heating fuel relies on monitoring wood usage on a regular basis. The State of Vermont, for example, has been

evaluating the residential wood fuels demand every three to five years through telephone surveys since 1981 (Frederick and Jaramillo 2016). The Vermont Department of Forests, Parks & Recreation is able to assess firewood and wood pellets usage statewide by utilizing consistent survey instruments and survey design. Results show that both the number of wood users and the total volume of firewood and wood pellets consumed increased in 2014-2015 heating season compared with the 2007-2008 heating season. Such practice provides informed insight and thorough information for forest industry and government agencies.

Similarly, the Minnesota Department of Natural Resources conducts surveys every few years to monitor the wood heat market and the wood combustion practices in the residential sector through mail surveys (Imbertson, Dillon, and Anton 2016). The survey performed in 2015 has an 18% response rate and the result shows that the volume of wood consumed statewide is increasing. However, the inconsistent survey design compared to previous surveys has reduced the comparability of the survey results and especially the wood usage trend. Consistent survey instruments and survey designs implemented by state agencies every few years could provide reliable time series data. Establishing these data series can help assess the current and future market potential of forest products.

Identifying the limitations of firewood and wood pellets market through regular research studies is critical for the industry to cooperate with the governmental and nongovernmental agencies. For the wood pellets market, securing enough supply for the winter season is a major problem for most consumers. Frederick and Jaramillo noted that 28% of the wood pellet users in Vermont have experienced the situation where regular dealers run out of pellets and 27% have encountered wood pellets rationing. For the

firewood markets, on the other hand, the quantity of the products in the market is not the major concern. However, the quality of the firewood is of vital importance to the wood consumers since they can acquire higher energy efficiency by burning seasoned firewood. Compared to unseasoned firewood, seasoned firewood generates more heat and less smoke. However, consumers sometimes have unpleasant experiences of purchasing unseasoned products but were told the firewood is seasoned. Unethical firewood dealers can jeopardize the market by selling consumers a face cord of firewood at the cost of a full cord of firewood.

The sale of wood stoves can positively impact the firewood and wood pellets market. Increasing purchases of either firewood stoves or wood pellets stoves will boost the firewood and wood pellets market. Lack of innovation for the wood stove technology and interactions among wood stoves businesses are the main constraints inhibiting the wood stove industry from thriving and the forest products industry from prosperity (Nybakk et al. 2013). Wood stove businesses are relatively small in size and do not have funding set aside for research and development activities, leaving wood stoves innovation lacking. Communications among these businesses are also critical in delivering the next generation technology in wood stoves.

High-efficiency automated wood stoves the latest technological revolution in the wood stove industry, would effectively spur conversion to wood heating. Unlike a traditional wood stove, automated wood stoves use sensors and computer chips to monitor the stoves, which allow the users to “load and leave”. Additionally, this stove has exceeded the EPA’s stringent air rules for residential wood heaters, which most wood stoves in the market have difficulties in compliance.

The demand for firewood and wood pellets is closely related to the profitability of forest industry. If more households choose firewood and pellets as their home heating source, the industry would be more profitable, and vice versa. In 2014, a survey questionnaire was performed to assess the forest industry loggers and forest landowners' confidence in the future success and profitability of Maryland's forest industry. On a scale of 1 (not very confident) to 5 (extremely confident), the overall confidence was not very high with an overall confidence of 2.37 for primary and secondary forest industry owners, 2.99 for forest land owners and 3.26 for loggers. This shows that under current changing dynamics, the forest landowners, loggers, and primary and secondary forest industry owners are not highly confident in the sustainability and profitability of the industry over the next five years (Tjaden et al. 2015). Additionally, Tjaden et al. recommend that building up industry future market confidence is critical. In order to have a healthy, vibrant and profitable forest industry, encouraging the state to develop potential biomass markets, such as firewood and wood pellets, and to establish state incentives to stimulate new markets are necessary (Tjaden et al. 2015). Thus, evaluating the market potential of firewood and wood pellets can establish confidence for a sustainable and profitable forest industry.

The policy makers in Maryland need to understand the current wood usage trend to better formulate policies and programs to help the forest industry. Maryland Energy Administration (MEA) has been administering the Clean Burning Wood Stove Program since September 7, 2012. Qualified Maryland homeowners can receive a flat award: $500 per installation for a stick burning stove and $700 for a pellet burning stove. The cost to buy and install a wood or pellet stove can range in price from $2000 to $4,500 depending on the quality of the stove and existing home conditions. The incentives provided by MEA

are about 10% to 25% of installation costs of wood or pellet stoves. However, studies have not been performed on this incentive program and homeowners' attitudes on firewood and wood pellets as a household heating source. If the demand for firewood and wood pellets increases, it will significantly impact the local economy, and potentially the forest industry and forest resources of Maryland.

European countries are the pioneers in studying the motivational factors and barriers for homeowners to switch to wood heating. In Norway, the government managed to decrease the national dependency on electricity generated by fossil fuels and nuclear power by supporting renewable and sustainable heating appliances such as wood pellet stoves (Sopha et al. 2010; Bjørnstad 2012). Many studies have been done in Norway to determine the motivations and barriers for households to adopt these new technologies (Sopha, Klöckner, and Hertwich 2011).

Sopha et al. concluded that there are 4 factors that can potentially influence the adoption process of the alternative heating systems based on a questionnaire survey of Norwegian households. They are socio-demographic factors, communication among households, heating system attributes, and the applied decision strategy. There are four types of applied decision strategies, which are "habitually repeating the product they consume previously, consuming products with highest need satisfaction, consuming products as most of their social network consumes, and social comparison, which is a combination of the three previous strategies". However, Sopha et al. did not take into account the replacement cost or installation cost of the new heating appliances, which also influence the households' adoption behavior.

In order to help influence homeowners to adopt alternative heating systems, the Norwegian government established an incentives program. The Household Subsidy Programme (HSP), whose goal is to reduce the household installation cost of new technologies including wood pellet stoves, was initiated in 2003 and was administered by governmental energy agency Enova SF (Bjørnstad 2012). Each household can receive rebates on three household technologies: (i) air to air heat pumps, (ii) control systems for electric heaters and (iii) wood pellet stoves. Rebates are up to 20% of the investment cost and maximum €650 for heat pumps and pellet stoves, which is $709 if using exchange rate of €1 equals to $1.09 (Bjørnstad 2012).

The result of a mail survey done in 2008 encouraged HSP to establish incentives for Norwegian homeowners. This survey, done by Sopha, Klöckner, and Hertwich, shows that the main barrier for households to switch to wood pellets heating is the initial investment costs which include the cost to purchase and install the stove. Additionally, the result of the survey indicates that an average of 64% of the installation cost, rather than HSP 20% subsidy would be the minimum incentive that is required for nonusers to switch to wood pellet heating. However, this program was considered successful since it helped households to understand other available heating options (Iea-Retd 2012).

The aim of this research is to use survey methodology to examine the market potential of firewood and wood pellets as a home heating source in Maryland. It is critical to understand the motivations and barriers for homeowners to utilize wood as a spatial heating source. The survey implementation process followed Dillman's Total Design Method by sending an introductory letter, a questionnaire package (including cover letter and survey instrument), and two return postcards within a certain timeframe. Employed by

several other research studies, this method was demonstrated to be effective in increasing the survey response rate (Brown and Harris 2000; Fischer 2011; Winter, Vogt, and McCaffrey 2004; Egan, Gibson, and Whipkey 2001; Hartsfield and Ostermeier 2003; Song et al. 2012).

Objectives

The goal of this research is to determine Maryland single family household firewood and wood pellets usage and to evaluate what the motivations and barriers are for homeowners to use wood. Additionally, this research will assess the future market potential of wood fiber as an alternative home heating energy source for Maryland homeowners. This information can help the forest industry to make management and financial decisions as well as expanding markets, and help industry be sustainable.

The specific research objectives of this study are to:

1) Estimate total volume of wood used annually statewide, total volume and percent of wood users by county;
2) Determine the motivations and barriers for homeowners to use firewood and wood pellets;
3) Determine the threshold prices of natural gas, electricity and oil for homeowners to increase wood usage or convert to wood heating;
4) Provide recommendations and action items for the State's policy makers, forest landowners and managers to make informed decisions.

Methods

Following Dillman's Total Design Method, the research was conducted by mail survey with option to complete electronically. The survey instruments were edited and pretested. In February 2016, a package containing two sets of surveys (one for current wood users and one for nonusers) were mailed to 7,000 randomly selected Maryland single family homeowners located in rural and suburban areas. The number of surveys sent to each County is stratified by the percentage of single family household by County for a total of 7,000 households. Respondents were instructed to complete Survey A for wood users if they heat with wood or Survey B for nonusers. All survey information was not traceable to individual respondents. Surveys were coded to keep respondent information confidential.

Survey Respondents Criteria

Only single family homeowners who are over 18 years old are selected as respondents. Renters were excluded because they may not be able to make decisions on major modifications to homes such as adding chimneys and new heating devices. While some would argue that renters consume more wood than homeowners because they have lower income levels (Christiansen et al. 1993), this research followed the methodology used by the previous similar study performed in Norway, which is solely researching the behaviors of single family homeowners (Sopha, Klöckner, and Hertwich 2011). Respondents' housing unit type was defined as a one unit detached home excluding commercial properties, condos, estates, apartments, and multifamily units. Households located in rural and suburban areas were selected. This is because these households are assumed to be more likely to use firewood and wood pellets as home heating sources than households located in urban areas since zoning regulations may prevent homeowners from adding a chimney to existing property. Similarly, homeowners living in Baltimore City were excluded. The

classifications of the residential zoning categories (Table 1) provided by Maryland Department of Planning (MDP) are adopted to define the rural, suburban, and urban areas in this study. Rural areas are defined as areas in the category of "Very Low Density". Suburban areas are defined as areas in the category of "Low Density". Urban areas are defined as areas in the categories of "Moderate Density" and "High Density". Respondents will only be selected from "Very Low Density" and "Low Density".

Table 1. MDP Generalized Zoning Text. Residential Zoning Categories

Very Low Density	max density > 0.2 du/acre and <1.0 du/acre
Low Density	max density > 1and < 3.5 du/acre
Moderate Density	max density > 3.5 du/acre < 10du/acre
High Density	max density > 10du/acre

Note: du is short for dwelling unit(s)

Stratification Strategy

In December 2015, the respondents' mailing list was obtained from the MDP property tax database of all 776,240 Maryland single family homeowners in rural and suburban areas. This list did not contain federal, state, municipal, or corporate ownership. This list was filtered for duplicate names and invalid addresses, leaving the total number of population for this study 443,798. The addresses of 7,000 single family households were randomly selected from this population in the MDP database. The list was randomly stratified and sorted by County. For all the single housing units located in very low and low density zoning areas in Maryland, the percentage for each County was calculated. The number of respondents selected in each County is proportional to the calculated percentage (Table 2).

Table 2. Stratification Summary: Number of Survey Sent to Each County

County	Filtered Single Family Residences	Percentage	# of Surveys Deployed
Allegany County	4,967	1%	78
Anne Arundel County	44,805	10%	707
Baltimore County	37,131	8%	586
Calvert County	17,477	4%	276
Caroline County	3,506	1%	55
Carroll County	24,289	5%	383
Cecil County	11,955	3%	189
Charles County	18,721	4%	295
Dorchester County	3,563	1%	56
Frederick County	23,408	5%	369
Garrett County	2,418	1%	38
Harford County	21,821	5%	344
Howard County	45,738	10%	721
Kent County	2,600	1%	41
Montgomery County	66,148	15%	1,043
Prince George's County	56,219	13%	887
Queen Anne's County	10,239	2%	161
Somerset County	1,025	0%	16
St. Mary's County	19,274	4%	304
Talbot County	7,218	2%	114
Washington County	8,495	2%	134
Wicomico County	5,889	1%	93
Worcester County	6,892	2%	109
Total	**443,798**	**100%**	**7,000**

$$Note: \#\ of\ Surveys\ Deployed = 7000 \times \frac{Filtered\ single\ family\ residence}{443{,}798}$$

Survey Development

Based on whether the survey respondents utilize wood as their heating sources or not, respondents were separated into two groups, wood users and nonusers. Two sets surveys were developed (Appendix A: Firewood/Wood Pellet Users Survey Instrument and Appendix B: Firewood/Wood Pellet Nonusers Survey Instrument). Respondents were instructed to complete Survey A for wood users if they heat with wood or Survey B for nonusers.

For wood users, the questionnaire captured the following information: their annual firewood and/or wood pellets usage from March 2015 to March 2016, primary/secondary heating sources, types of wood heating appliances, problems encountered when purchasing wood, and where they acquire their wood. The primary heating source is defined as the source used 50% or more of the time and secondary source is the source used less than 50% of the time. Additionally, wood users were asked to report what motivated them to use wood and whether they have participated in the Clean Burning Wood Stove Program administered by MEA.

Similar to the wood users' survey, types of the primary heating sources of the nonusers were asked. Nonusers were instructed to choose from several statements which are the challenges for them to heat with wood. Regarding the Clean Burning Wood Stove Program, nonusers were asked whether the incentives provided were adequate to motivate them to convert to wood. Furthermore, the threshold prices of the natural gas, propane, oil, and electricity for homeowners were assessed. Threshold prices are prices at which homeowners will convert to wood heating.

The survey instrument was reviewed by experts in this area. Then, a pretest was administered to five homeowners who also provided their personal insight on the survey as a whole. The Institutional Review Board (IRB)'s protocol was followed. All information was confidential and cannot be traceable to individual respondents.

Survey Implementation Process

The Mason-Dixon Polling and Research group in Washington D.C. was contracted to administer the survey, collect survey data and enter it into an Excel database. The survey implementation process followed Dillman's Total Design Method (1978). On February 19,

2016, the initial notification letters (Appendix E) introducing the participants to the survey team were mailed out (Bob Tjaden and Cuiyin Wu) to inform the participants of the objective of the research. One week later, on February 26, a survey package including an instruction letter (Appendix F) with self-addressed envelope, a branching-out postcard (Appendix H) and two sets of questionnaires (Appendix A and B) were mailed first class. If the respondents wanted to receive a free Firewood Calculation Keycard magnet (Appendix I) and more information about the University of Maryland's Extension Program, they could fill out the branching-out postcard. A total of 7000 survey packages were sent out. Respondents had two options to complete survey, either through the paper version or the web site. One week later, follow-up post cards (Appendix G) were mailed to all recipients as a thank you note for those who completed the survey and a reminder to other possible respondents to complete the survey. Two weeks after the initial survey mail out, another follow up postcard was mailed. All surveys were completed by March 15 2016.

Results

Part I. Data Summary

Out of 7,000 questionnaires sent out, a total of 675 were returned by mail because of either an incorrect address, or a deceased recipient, leaving the survey population at 6,325. There were 495 respondents who completed Survey A and 689 respondents who completed Survey B. Four respondents were deleted because they identified themselves as renters. Survey A refers to questionnaires completed by firewood and pellet users and Survey B refers to questionnaires completed by nonusers. This is a response rate of 19% (1,184/6,325). Out of the 1,184 responses, 1,004 (85%) were completed by mail and 180 (15%) completed online.

1. Regional Distribution of the respondents

Table 3 shows that the more respondents are from Montgomery County (15%), Anne Arundel County (11%), and Howard County (10%). Compared with County stratification percentage, the percentage of Prince George's County respondents is lower by 5%, which is the largest difference followed by Harford and Carroll Counties. All other responses closely reflect original county stratification. Based on the county population stratification percentage, we believe that the responses reasonably represent the opinions of Maryland's single family homeowners.

Table 3. Comparisons of Response Rate and Stratification among Counties

County	Region	Survey A Users	Survey B Nonusers	Total	%	Stratification %
Allegany	Western	1	14	15	1%	1%
Anne Arundel	Southern	58	70	128	11%	10%
Baltimore	Northern	64	43	107	9%	8%
Calvert	Southern	17	24	41	3%	4%
Caroline	Eastern	6	8	14	1%	1%
Carroll	Northern	47	34	81	7%	5%
Cecil	Northern	14	20	34	3%	3%
Charles	Southern	16	26	42	4%	4%
Dorchester	Eastern	3	0	3	0%	1%
Frederick	Western	29	44	73	6%	5%
Garrett	Western	6	3	9	1%	1%
Harford	Northern	43	28	71	6%	5%
Howard	Northern	47	75	122	10%	10%
Kent	Eastern	7	4	11	1%	1%
Montgomery	Northern	53	128	181	15%	15%
Prince George's	Southern	34	55	89	8%	13%
Queen Anne's	Eastern	6	19	25	2%	2%
Somerset	Eastern	1	1	2	0%	0%
St. Mary's	Southern	15	33	48	4%	4%
Talbot	Eastern	8	17	25	2%	2%
Washington	Western	7	11	18	2%	2%
Wicomico	Eastern	4	16	20	2%	1%
Worcester	Eastern	5	12	17	1%	2%
(blank)		4	4	8	1%	0%
Total		495	689	1,184	100%	**100%**

2. Demographics

Figures 2 to 5 show the distribution of respondents' age, education background, house size, and annual household income. Table 4 compares the demographic information between wood users and nonusers. Both of these groups of respondents are affluent, well-educated and own sizable home properties. However, there are some discrepancies between these them. The proportion of male respondents of Survey A is 7% higher than the proportion of Survey B. The percentage of respondents with a 4-year college degree and beyond of Survey A is 6% lower than the percentage of Survey B.

The percentage of respondent with a house size greater than 2,500 square feet of Survey A is 10% lower than the percentage of Survey B.

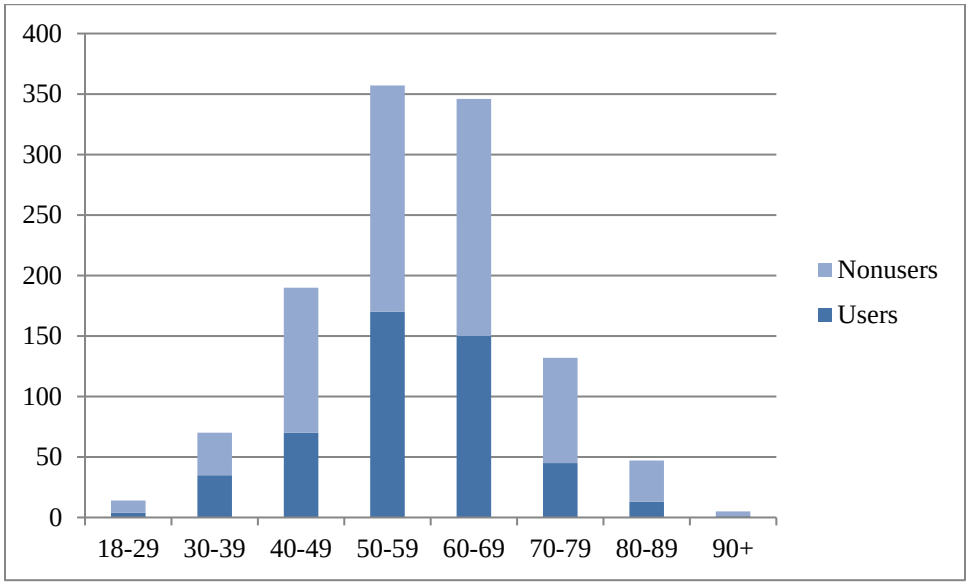


Figure 2. Age (by the number of respondents)

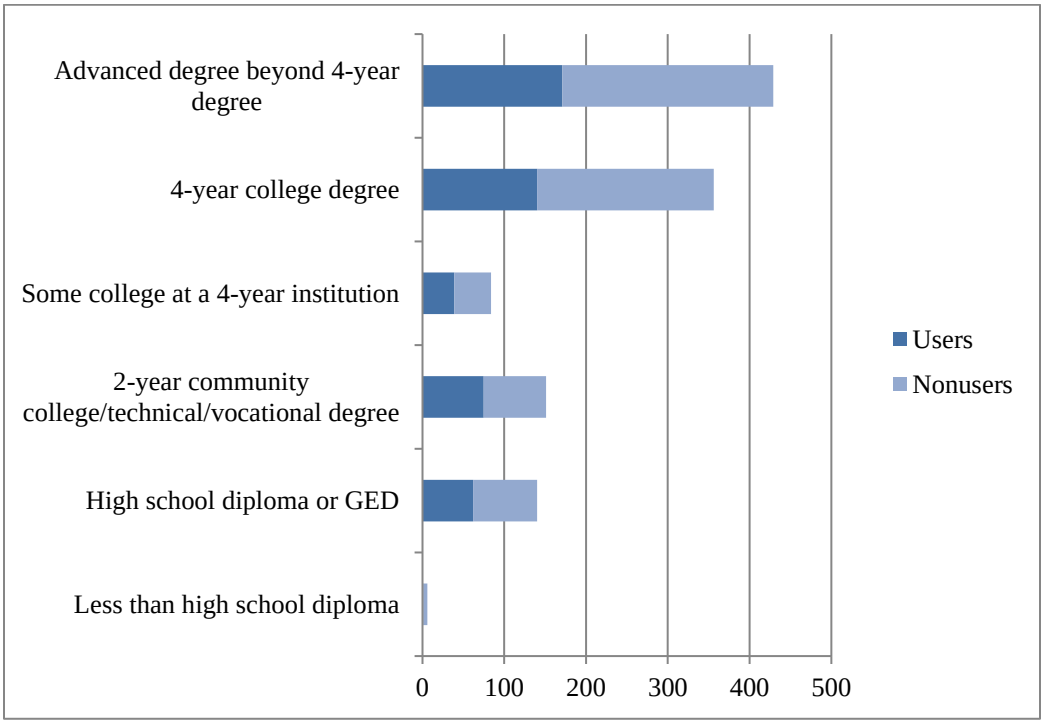


Figure 3. Education Background (by the number of respondents)

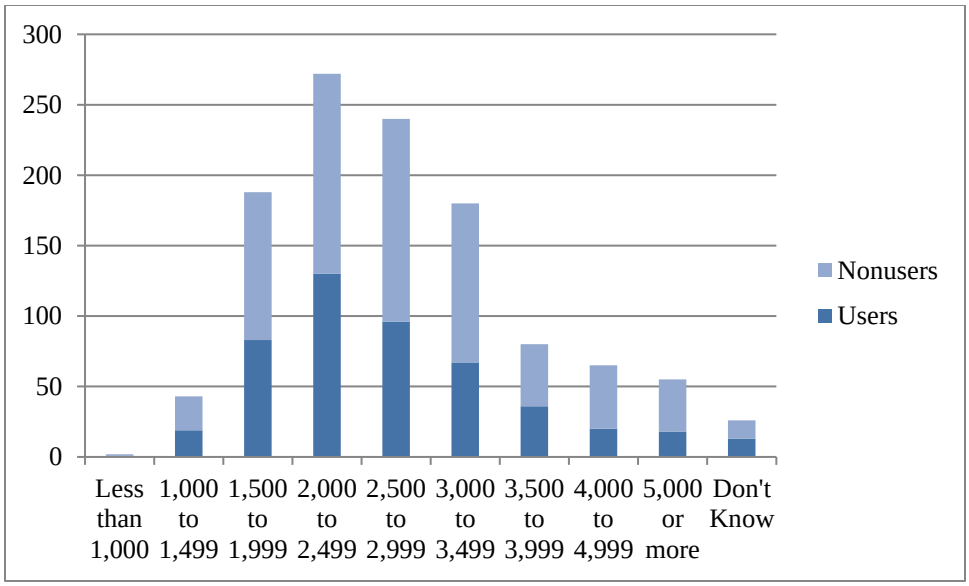


Figure 4. House Size (by the number of respondents)

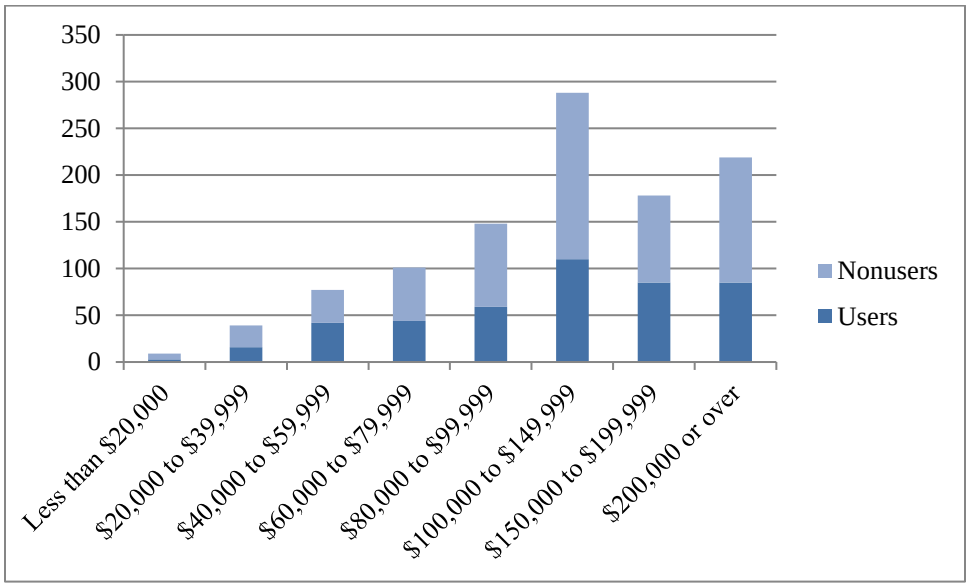


Figure 5. Annual Household Income (by the number of respondents)

Table 4. Summary Demographic Information

	Gender	Median Age	Education	House Size	Annual Household Income
Survey A Users	73% Male	58	64% College +	49% > 2,500 ft^2	63% > $100K
Survey B Nonusers	66% Male	59	70% College +	59% > 2,500 ft^2	66% > $100K

3. Primary heating sources

Home heating options adopted by Maryland homeowners are asked in both sets of survey questionnaires. Out of 1,184 respondents, 42% of them completed Survey A indicating that they use either firewood or wood pellets to heat their houses either as a primary or secondary source. However, 4% of the total respondents use firewood as their primary home heating source and 2% use wood pellets. Natural gas and heat pumps are the two most preferred primary home heating sources for Maryland homeowners (Figure 6).

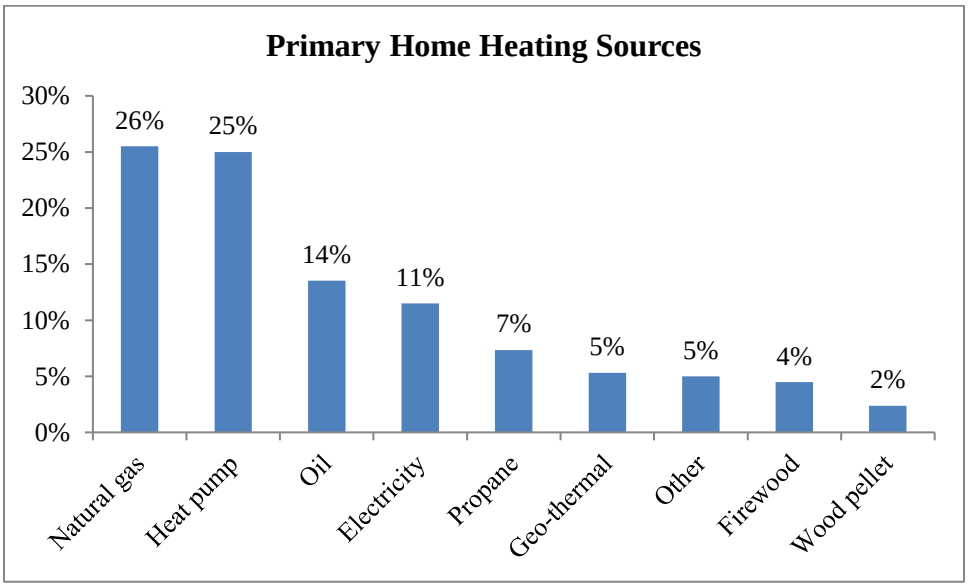


Figure 6. Primary Home Heating Sources of All Survey Participants

For wood users, heat pumps (29%) are the most preferred primary home heating fuel by wood users, followed by oil (18%) and natural gas (16%) (Figure 7). Wood biomass is a popular secondary home heating fuel. Figure 8 indicates that 50% of the respondents use firewood and 15% use wood pellet as a secondary home heating source. When asked about the age of the primary heating system, 42% of the wood users' systems are more than ten years old. For the secondary heating system, 59% reported that the age of secondary heating system is more than ten years old.

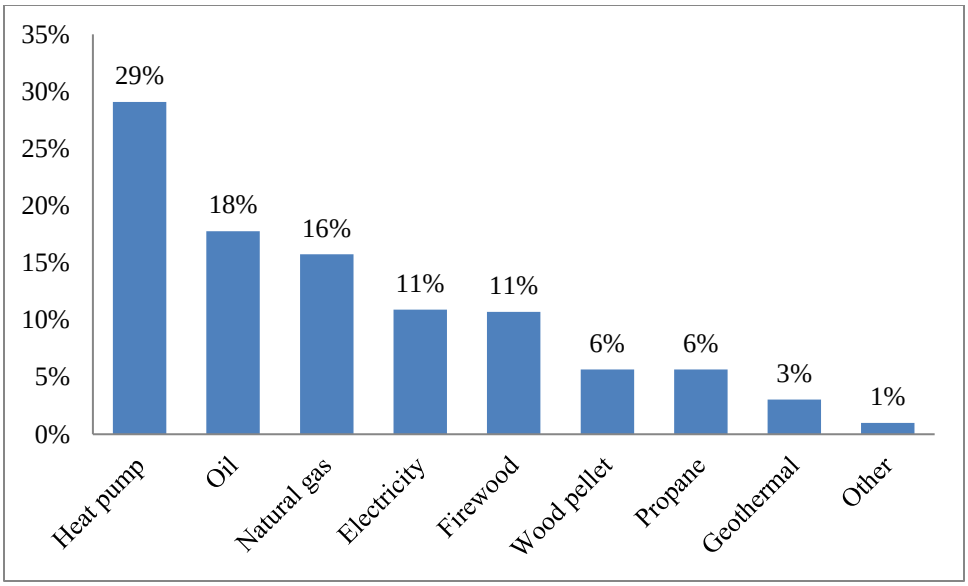


Figure 7. Wood Users' Primary Heating Sources
(by percentage of Survey A respondents)

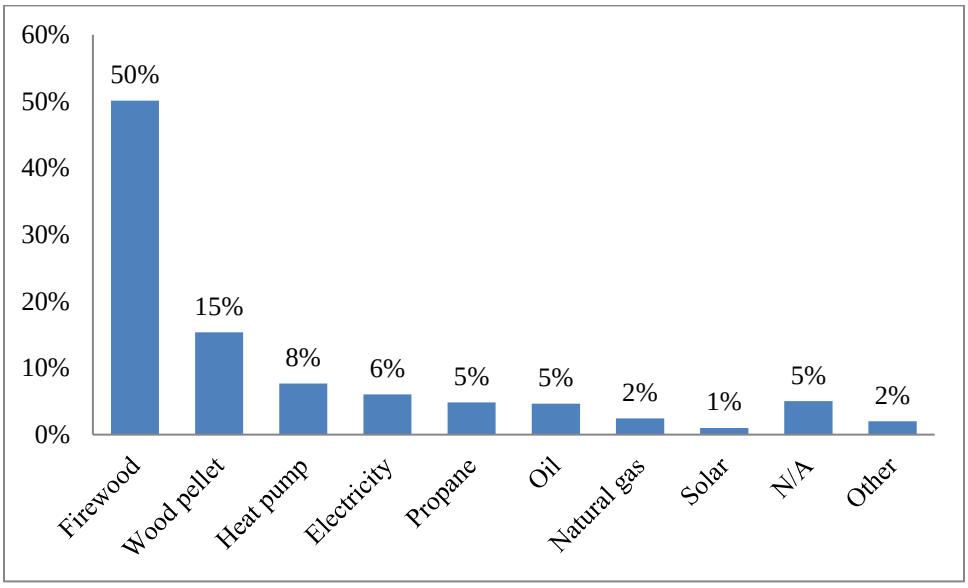


Figure 8. Wood Users' Secondary Heating Sources
(by percentage of Survey A respondents)

For nonusers, the majority of respondents use natural gas (36%) and heat pumps (24%) as their primary heating sources (Figure 9). Similar to the wood users' responses, the majority of the nonusers (42%) own primary heating systems that are over ten years old.

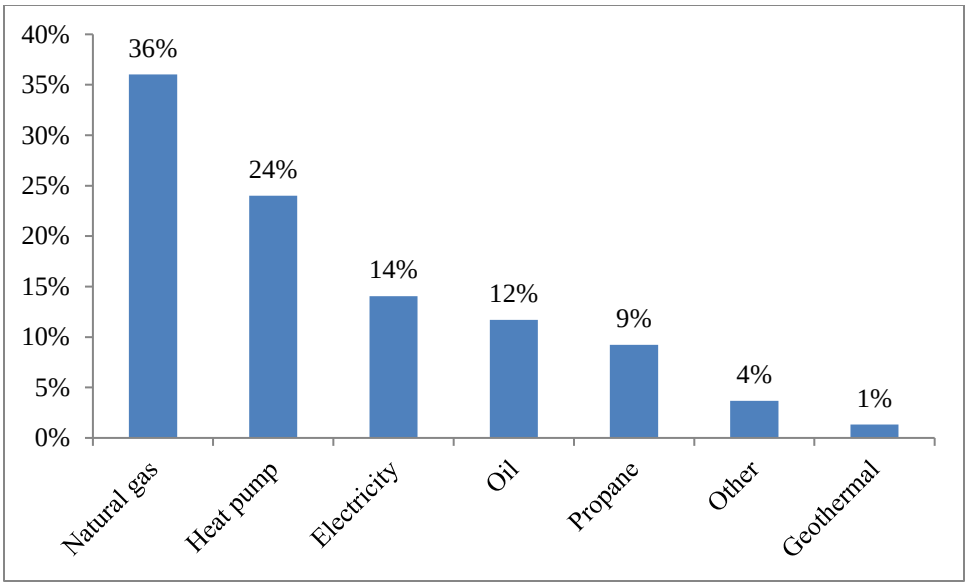


Figure 9. Nonusers' Primary Heating Sources
(by the percentage of Survey B respondents)

4. Wood heating appliances

The specific type of wood heating devices that homeowners use was inquired in Survey A. Out of 495 wood users, 87% of them indicated that they have only one wood heating device. A fireplace is the most prevailing wood heating device utilized by wood users, followed by fireplace inserts, wood stoves and wood pellet stoves (Figure 10). Wood-burning boilers, not commonly used by Maryland homeowners, were only reported installed by 6 respondents.

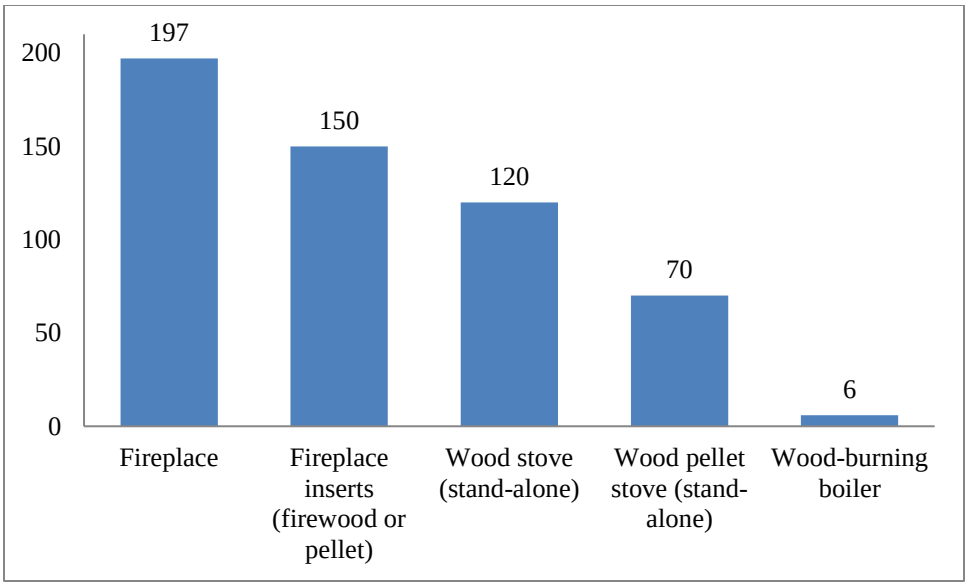


Figure 10. Wood heating device (by the number of respondents)

5. Motivation and Barrier to Wood Heating

Respondents were instructed to choose the listed statements in the surveys that either stimulate or prevent wood use. For wood users, 280 respondents (57%) enjoyed the aesthetical value of wood heating, 266 (54%) responded that they liked the way wood heat feels, and 202 (41%) indicated they had free access to wood (Figure 11).

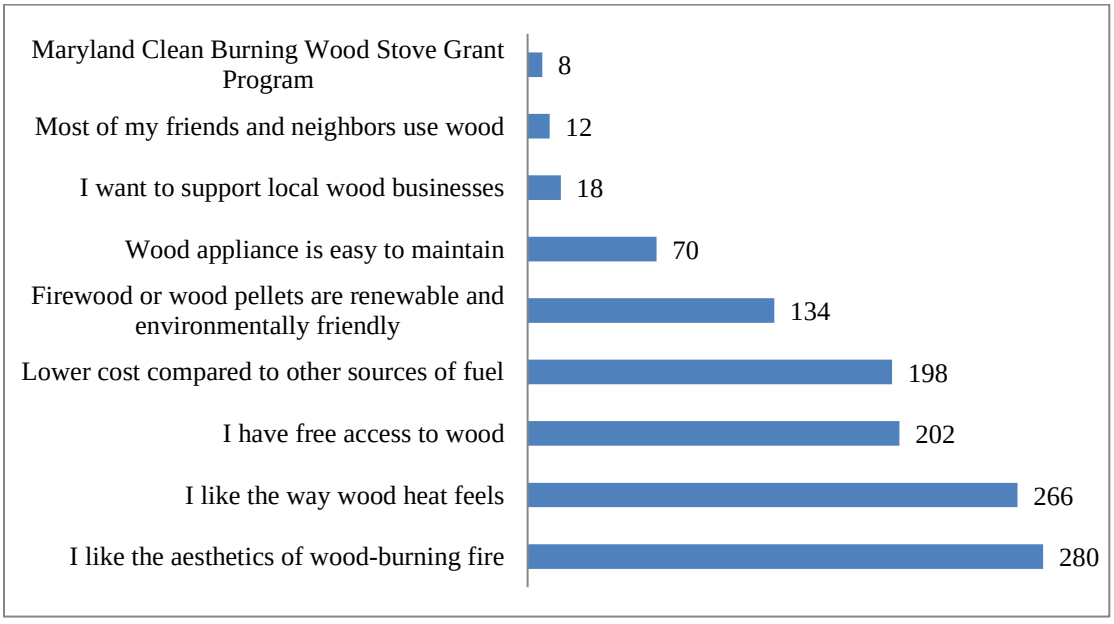


Figure 11. Motivations to use wood (by the number of Survey A respondents)

Figure 12 shows wood heating barriers chosen by nonusers. Out of 689 nonusers, 339 (49%) respondents responded that the work and mess associated with wood heating was the principal barrier prohibiting them from using wood. The second most prevalent reason revealed by 216 (31%) respondents is the lack of a fireplace at home. 133 (19%) respondents were concerned with the capital cost associated with the stoves, and 118 (17%) expressed their concerns of the stoves' incompatibility with their houses.

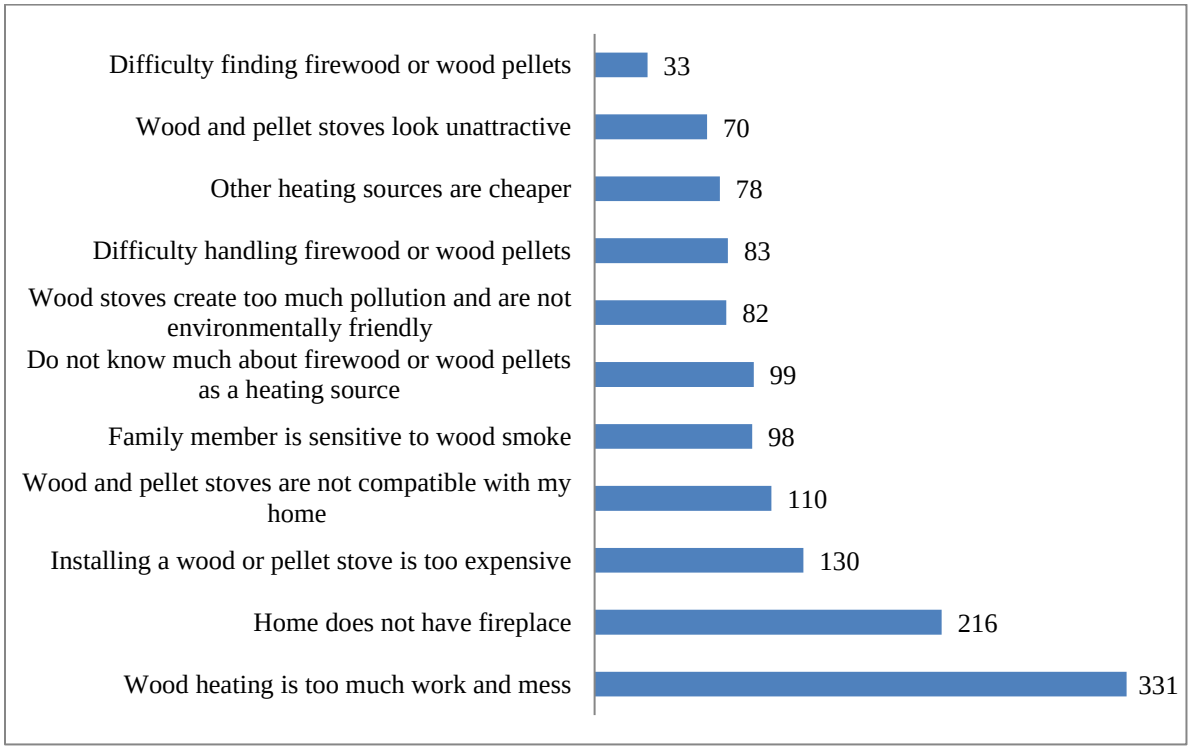


Figure 12. Barriers to Use Wood (by number of Survey B respondents)

6. Quantity and Price of Firewood and Wood Pellets

Respondents were asked to provide the quantity of firewood and wood pellets by volume they burned during the past 12 months using the firewood calculation key that was included in survey. The average quantity of firewood consumed between March 2015 and March 2016 reported by 367 firewood users is 1.8 cords (SD=1.89). The

average quantity of wood pellets consumed during the same period reported by 367 wood pellets users is 1.9 tons (SD=1.73).

Prices of firewood and wood pellets that respondents are purchasing are recorded in Survey A. Firewood prices are provided by cords and by bundles which are very different because the unit price of a bundle amount of firewood sale is much higher than a cord amount of firewood sale. As a result, firewood prices are reported separately. The average price of firewood reported by 160 respondents is $192 per cord (SD=65.45). For 20 other wood users who purchase firewood by bundle, the average price of firewood is $6 per bundle (SD=1.29), with maximum and minimum prices of $10 and $3.99 per bundle respectively. The price of wood pellets is provided by tons and by bags (40 lbs. per bag) which is converted to report through dollars per ton. The mean price of wood pellets reported by 105 respondents is $266 per ton (SD=52.76).

Notably, 409 respondents reported that a portion or all of the wood they use was obtained at no cost. Respondents were asked to estimate the percentage of wood they had free access to out of the total wood they used. The mean percentage of free wood out of the total wood usage amount is 56% (SD=45.72). Particularly, 192 respondents indicated all of the wood they used was obtained at no cost.

7. Maryland's Clean-Burning Wood Stove Grant Program

Questions 19 and 20 in Survey A are intended to determine whether the incentives provided by Maryland's Clean-Burning Wood Grant Program were the motivation for respondents to use wood. Out of 495 wood users, 25 (5%) of them have participated in this program. Table 5 shows the County distribution of these participants. Out of these 25 respondents, 8 (32%) of them were motivated by this program to purchase a stove.

Table 5. County Distribution of the MEA Program Participants

County of Residence	# of Respondents	%
Baltimore	6	24%
Anne Arundel	5	20%
Howard	3	12%
Montgomery	2	8%
Talbot	2	8%
Frederick	2	8%
Carroll	1	4%
St. Mary's	1	4%
Cecil	1	4%
Worcester	1	4%
Harford	1	4%
Total	***25***	***100%***

Survey B respondents were inquired of their knowledge of the Program. Out of 689 respondents, there were 16 (2%) who indicated that they were aware of the program. Additionally, the survey was interested in how respondents would react if this program were to increase its flat rate from $500 to $700 for a wood stove and from $700 to $900 for a pellet stove. Although majority of respondents responded "No" or "Not interested under any circumstances", 43% of responses were positive (Figure 13).

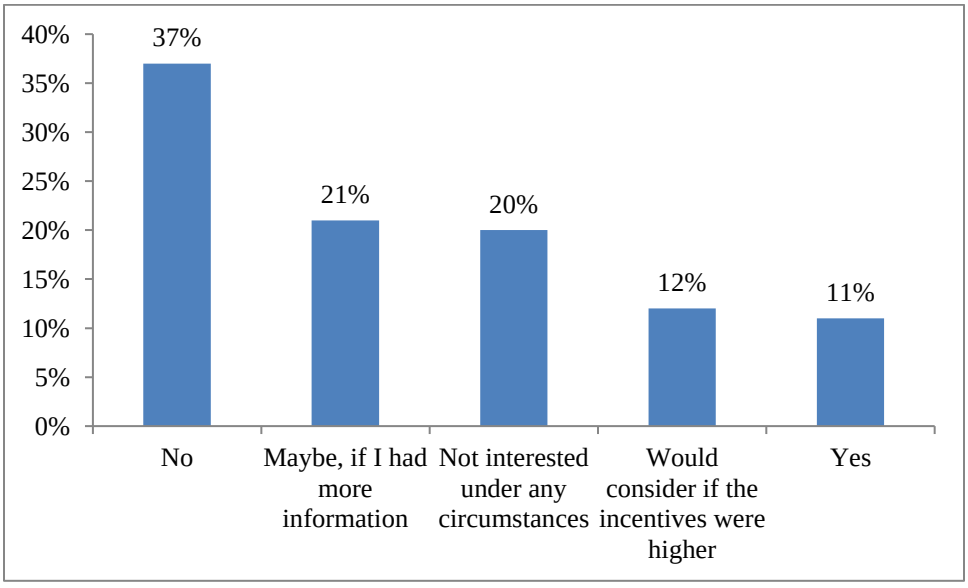


Figure 13. Responses to Hypothetical Incentive Increase of MEA Program

Part II. Statistical Analysis

1. Proportion of wood users in four regions of Maryland

Regional distribution of Maryland Counties (Figure 14) was provided by a previous study done in Maryland (Tjaden et al. 2015) and used by Maryland Department of Natural Resources is applied in Table 6. The response rates in four regions indicate that the proportion of the wood users in each region represent a reasonable approximation of the true population proportion of wood users in the rural and suburban areas of Maryland.

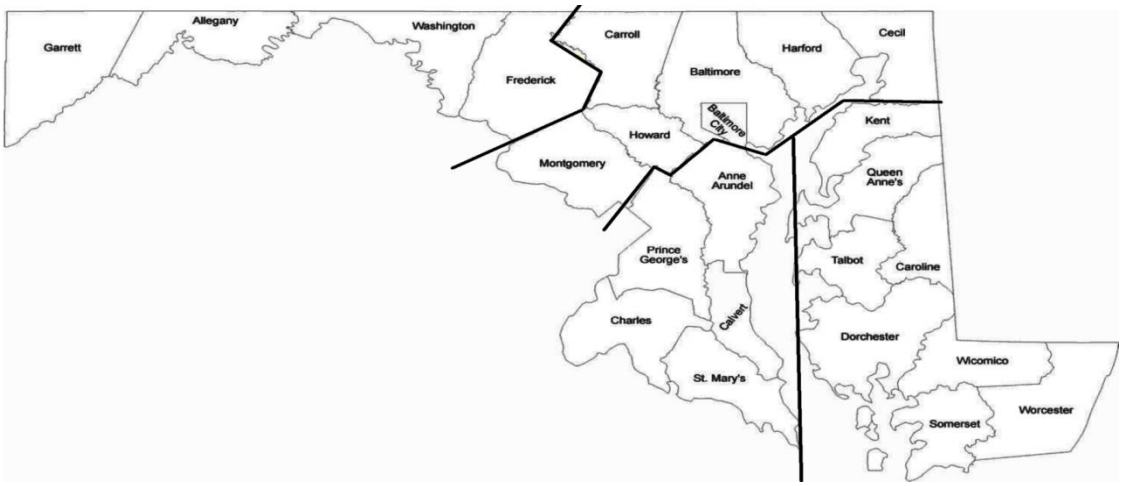


Figure 14. Regional Distribution of Maryland Counties (Tjaden et al. 2015)

Table 6. Comparisons of Overall Response Rate and Proportions of Wood Users among Four Regions in Maryland

Region	Number of Survey Deployed	Number of Participants	Number of Wood Users	Response Rate*	Proportions of Wood Users**
Eastern	646	117	40	18%	34%
Northern	3266	596	268	18%	45%
Southern	2468	348	140	14%	40%
Western	620	115	43	19%	37%
Total	7000	1176	491	17%***	42%

Note:
**Response rate = Number of Participants/Number of Survey Deployed × 100%*
***Proportions of Wood Users = Number of Wood Users/Number of Participants × 100%*

****The response rate 17%=1176/7000. The 675 returned questionnaires were unable to determine the regions they were from, thus were not discounted from the calculation here.*

Notably, the proportion of the wood users from highest to lowest is Northern, Southern, Western and Eastern Maryland. A Chi-square test of goodness of fit was performed to examine the variation of the proportion of wood users among the four regions. The variation among the four regions are not significant, $\chi^2(3, N = 1176) = 6.5154$, $p > 0.05$. The proportion of wood users is the same in four regions.

2. Comparisons of demographical compositions between wood users and nonusers

The demographical compositions for the two groups of respondents are comparative. Chi-square tests of homogeneity are performed to test the statistical differences of the demographical background. Results are shown in Table 7.

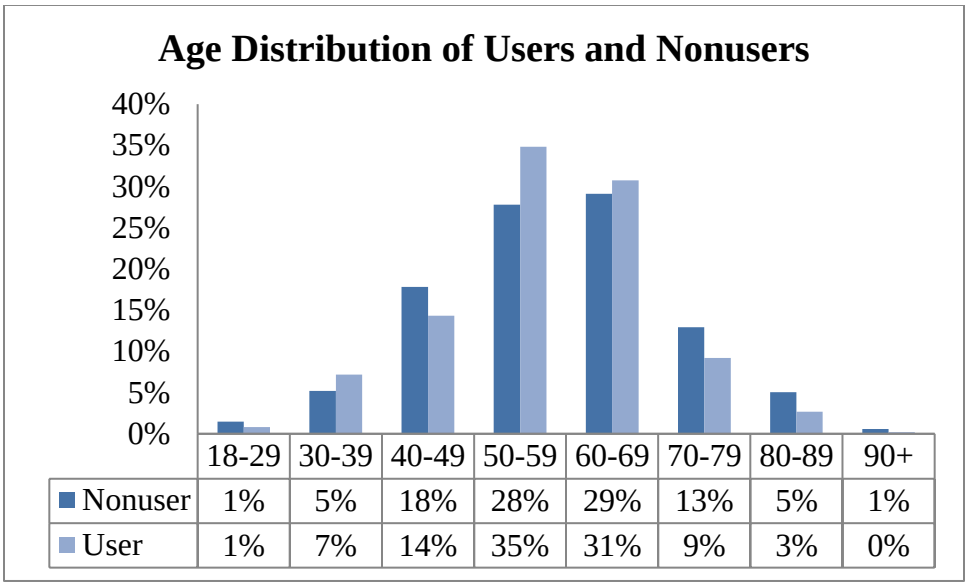
Table 7. Results of Chi-Square Tests between Users and Nonusers against Gender, Age, Education, House Size and Annual Household Income Level

	DF	Chi-square Value	P Value
Gender	1	6.0619	0.0138**
Age	7	18.1839	0.0112**
Education*	1	4.9296	0.0264**
House Size	9	12.6106	0.1810
Annual Household Income	7	10.6926	0.1526

Note:
**Categories for Education are consolidated into 2 groups: "Below College Level" and "Above College Level"*
***Statistically significant at 5% significance level*

Table 7 indicates that there is no significant statistical difference of the house size and annual household income level distribution between wood users and nonusers, considering that both of the P values are greater than 0.05. Additionally, there is significant statistical difference between these two populations in gender ratio, age distribution and education level with P values less than 0.05. The proportion of male participants of the wood users is 6% higher than the nonusers group. Comparing the age

distribution of these two groups, there are 8% more middle aged (50-69) participants of wood users than nonusers. However, the percentage of the participants that are over 70 years old in the nonusers group is 6% higher than that in the users group (Figure 15). Data indicates participants with the 4-year college degree and above are 6% more in the nonusers group than the users group.



	18-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
Nonuser	1%	5%	18%	28%	29%	13%	5%	1%
User	1%	7%	14%	35%	31%	9%	3%	0%

Figure 15. Age Distribution of Survey A and Survey B

3. Comparisons of demographical compositions between online respondents and mail respondents

Chi-square tests of homogeneity are performed to test the statistical differences of the demographic background between mail respondents and online respondents. Results in Table 8 indicate that both age and annual household income are statistically different at 5% significance level. Seventy-three percent of the online respondents are below 60 years old whereas for mail respondents, the proportion is fifty-one percent. Figure 16 shows that the proportion of respondents whose annual household income level is between $80,000 and $150,000 is higher among online respondents than mail respondents. However, for the level below $80,000, the proportion is higher among mail respondents.

Table 8. Results of Chi-square Tests between Online Respondents and Mail Respondents against Gender, Age, Education, House Size, and Annual Household Income Level

	DF	Chi-square Value	P Value
Gender	1	2.17	0.1407
Age*	3	32.8808	<0.0001**
Education*	1	0.3179	0.5729
House Size*	2	5.2586	0.0721
Annual Household Income*	3	9.6169	0.0221**

Note:
**Categories are consolidated into smaller groups for these variables*
***Statistically significant at 5% significance level*

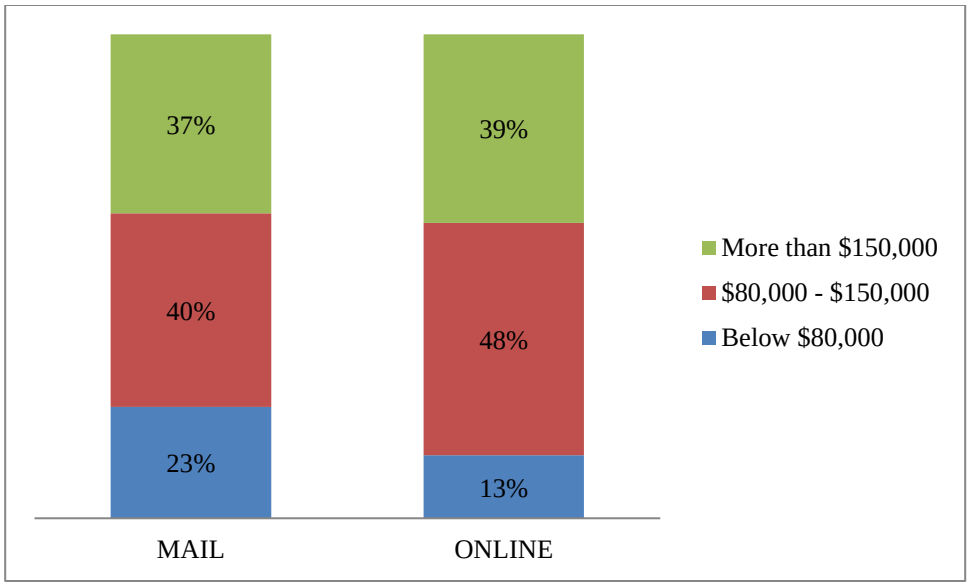


Figure 16. Annual Income Distribution of Mail Respondents and Online Respondents

4. Primary heating sources

A series of statistical tests is performed to determine the possible factors that would impact homeowners' choice of primary home heating sources. The primary home heating sources are consolidated into 5 groups: wood (firewood/wood pellets), electricity/heat pumps, natural gas, oil, and propane. Chi-square tests of homogeneity are applied to study the differences of the demographic compositions among these five groups of homeowners. Table 9 shows that the statistical differences are significant at 5% level for these variables: age, education, house size, annual house income, and region.

Table 9. Results of Chi-square Tests of Gender, Age, Education, House Size, Annual Household Income Level, and Region of 5 Groups of Homeowners

	DF	Chi-square Value	P Value
Gender	4	6.4837	0.1658
Age*	8	16.13	0.0406**
Education*	4	20.4199	0.0004**
House Size*	8	20.5159	0.0086**
Annual Household Income*	8	20.8608	0.0075**
Region	12	95.2728	<0.0001**

Note:
**Categories are consolidated into smaller groups for these variables*
***Statistically significant at 5% significance level*

Figure 17 shows heating preferences for three different age groups: less than 50 years old, 50 to 70 years, and more than 70 years old. The variations of wood, propane, and natural gas usage among these three age groups are relatively small, compared to oil and electricity/heat pumps usage. Comparing with other two age groups, the proportion of oil users is the highest for the age group over 70 years old and the proportion of electricity/heat pumps users is the lowest.

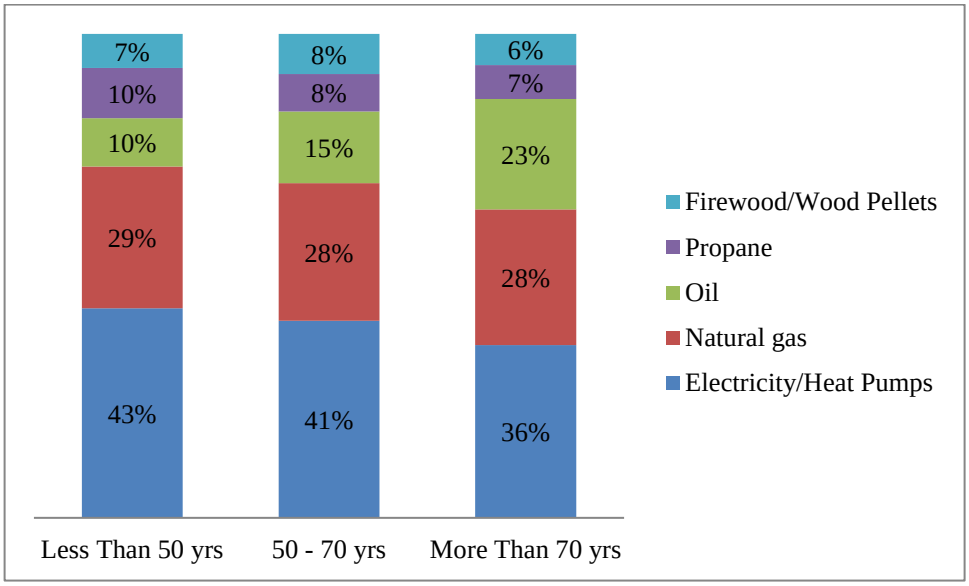


Figure 17. Primary Heating Source and Age Distribution

Figure 18 shows heating preferences between homeowners with educational background below 4-year college degree and homeowners with 4-year college degree and beyond. For the homeowners with 4-year college degree and beyond, the proportion of natural gas users is 13% higher and the electricity/heat pumps users is 7% lower.

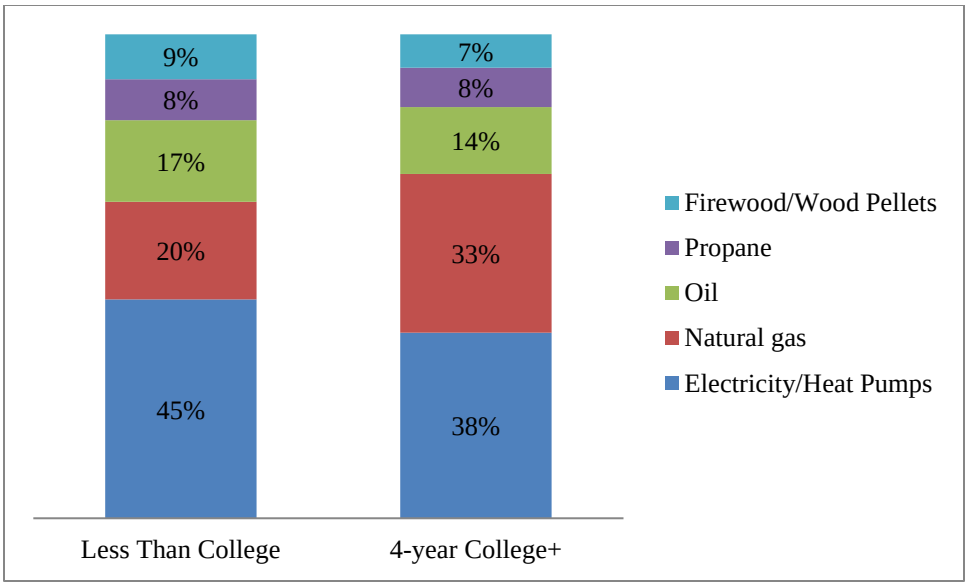


Figure 18. Primary Heating Source and Education

Figure 19 shows heating preferences for three different house size groups: less than 2,000 ft^2, 2,000 to 3,500 ft^2, and more than 3,500 ft^2. For the houses that are greater than 3,500 ft^2, natural gas is the most preferred primary home heating sources. Whereas for houses that are smaller 3,500 ft^2, electricity/heat pumps is the most popular heating sources.

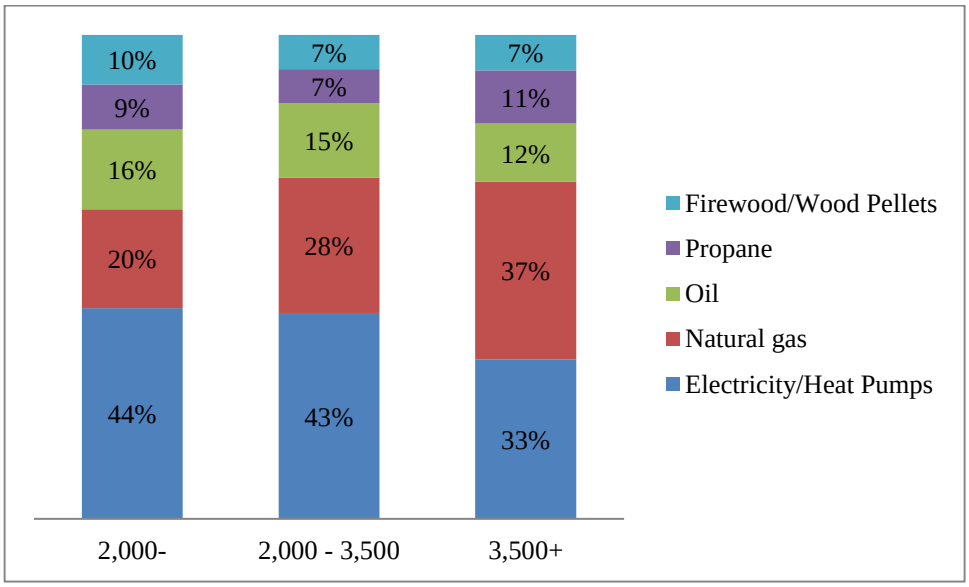


Figure 19. Primary Heating Source and House Size

Figure 20 shows heating preferences for three groups of household income levels: less than $80,000, between $80,000 and $150,000, and more than $150,000. The proportion of natural gas users increases as the annual household income level increases.

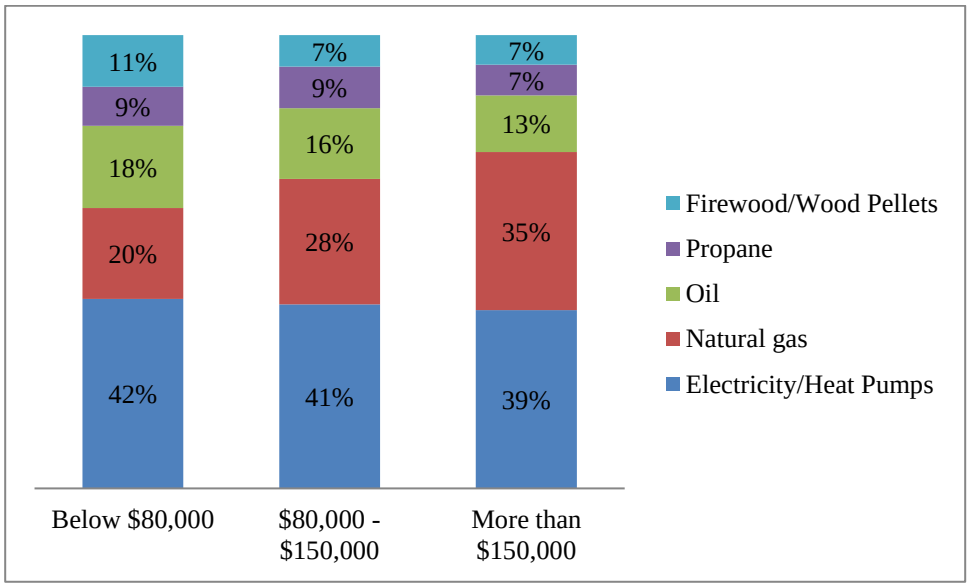


Figure 20. Primary Heating Source and Annual Household Income

Figure 21shows heating preferences among four regions of Maryland. Other than oil, the variations of fuel usage are very different among these four regions. The proportion of wood users is the same for all the regions except Eastern Maryland. The fuel usages are quite distinct between Eastern and Northern Maryland. The difference in the proportion of natural gas users between Northern Maryland and Eastern Maryland is 33%.

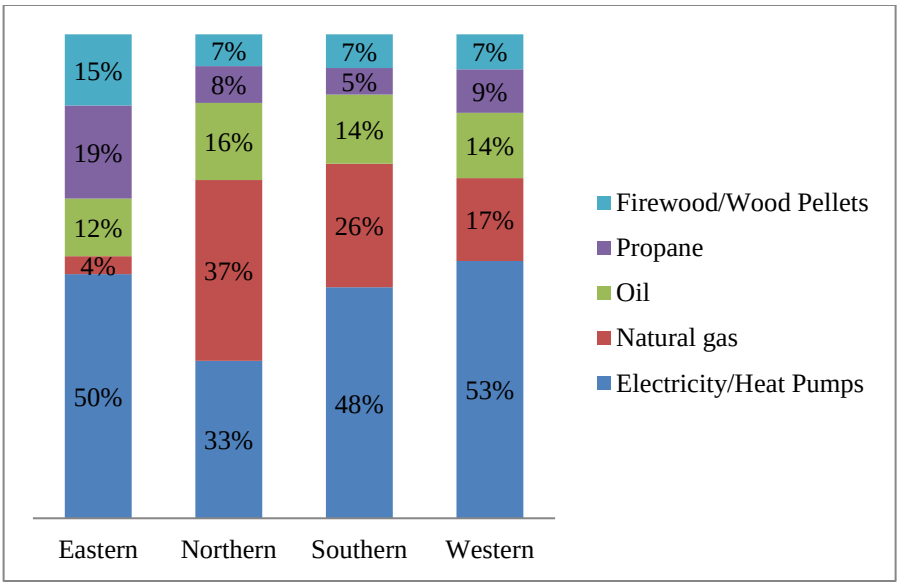


Figure 21. Primary Heating Source and Region

5. Price of Alternative Fuels

Question 14 in Survey A and Question 8 in Survey B were used to assess the effect of price fluctuation of alternative fuels on wood usage. To determine the entry point price of natural gas, electricity and oil for homeowners to switch to use wood or current wood users to increase their current wood usage, the percentage increment of these fuel prices was asked in these two questions.

Survey A: Wood users
14. Please select your response below from the following statement: "If the price of my primary heating source were to increase by _____, I would **increase my current usage** of firewood or wood pellets." *(Please choose only one.)*

❑10%

❑25%

❑50%

❑75%

❑100%

❑Would not change under any circumstance

❑Don't know

Survey B: Nonusers

8. Please select your response below from the following statement: "If the price of my primary heating source were to increase by _____, I would **consider using** firewood or wood pellets." *(Please choose only one.)*

❑10%

❑25%

❑50%

❑75%

❑100%

❑Would not change under any circumstance

❑Don't know

As indicated in Figure 22 and Table 10, responses varied between these two groups of respondents. A Chi-square analysis was performed to determine whether there is statistical difference between wood users and nonusers in response to price fluctuation. The response variations between these two groups are highly significant, $\chi 2(3, N = 1521) = 24.7508$, $p < .0001$. This means that wood users and nonusers respond differently to the price fluctuation of the fuels such as natural gas, electricity, oil, and propane. If the prices of the alternative fuels increase by 50%, 39% of the wood users would increase the percentage of heat from wood. Comparatively, at the same price level, 26% of the nonusers would adjust their heating behavior by converting to wood heating.

Table 10. Descriptive Statistics of Question 14 from Survey A and Question 8 from Survey B

Statement	Survey A Respondents		Survey B Respondents	
	Response	%	Response	%
10%	36	7%	19	3%
25%	84	17%	71	11%
50%	72	15%	82	12%
75%	15	3%	21	3%
100%	12	2%	45	7%
Would not change under any circumstance	172	36%	286	42%
Don't Know	93	19%	149	22%

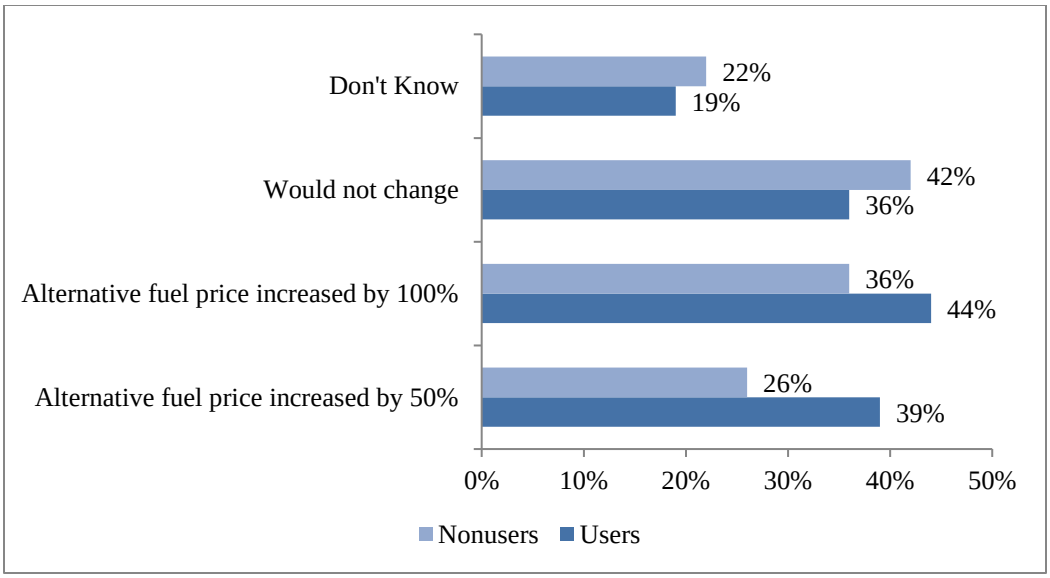


Figure 22. Conditions of Users to Increase Wood Usage and Nonusers to Switch to Wood Heating

Note: "Alternative fuel price increased by 50%" combines categories of fuels prices increased by 10%, 25%, and 50%; "Alternative fuel price increased by 100%" combines categories of fuel prices increased by 10%, 25%, 50%, 75%, and 100%.

6. Firewood and Wood Pellet Users

The majority of the wood users (67%) have used firewood or wood pellets to heat their houses for more than 10 years. When respondents were asked to estimate the percentage of the heat that comes from firewood or wood pellets, 469 wood users reported with an average of 29% (SD=29.27). Out of 495 wood users, 104 participants listed wood pellets as either primary or secondary home heating source, and 299 of them listed firewood. In order to study the comparison between firewood and wood pellet users, 110 participants are classified as wood pellets users, and 385 are firewood users based on their survey responses on Question 4, 5 and 11 of Survey A. Five respondents who used both firewood and wood pellets were grouped into either firewood users or wood pellets users based on the quantity of their wood usage.

The Chi-square results of the analysis of the demographic variations (Gender, Age, Square Footage of Home Property, Education and Household Income Level)

between firewood users and wood pellets users are not significant. However, the Chi-square analysis of the response variation to Question 14 in Survey A between these two groups is significant, $\chi^2(3, N = 822) = 113.4861$, $p < .0001$. Compared to firewood users, wood pellets users are less inclined to be affected by the price fluctuation of the alternative heating fuels, with 44% of pellets users indicating that they would not change their wood usage under any circumstances (Figure 23).

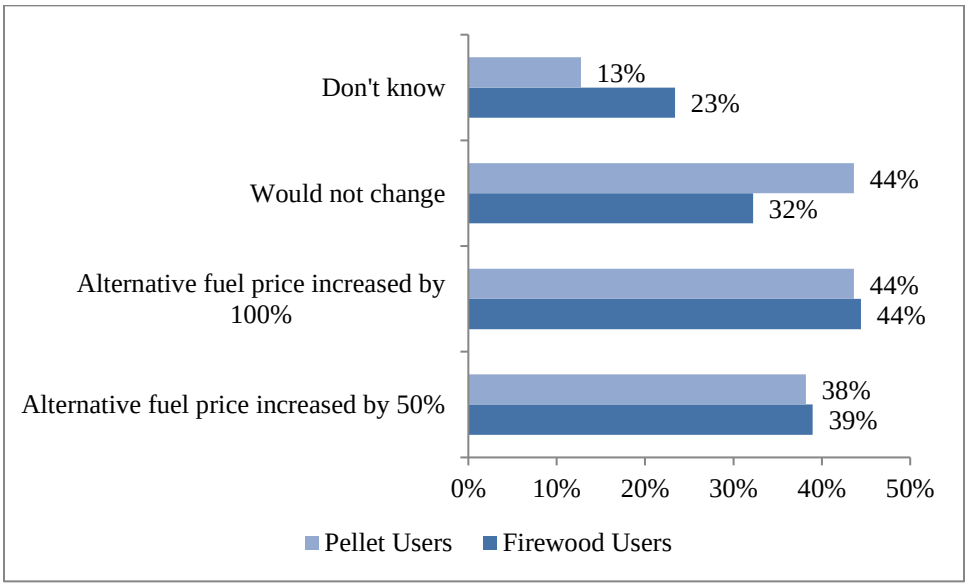


Figure 23. Response Comparison of Firewood Users and Wood Pellets Users of the Condition to Use More Wood (Question 14)

Note: "Alternative fuel price increased by 50%" combines categories of fuels prices increased by 10%, 25%, and 50%; "Alternative fuel price increased by 100%" combines categories of fuel prices increased by 10%, 25%, 50%, 75%, and 100%.

7. Major and supplemental wood users

A total of 81 wood users identified themselves as primary users indicating that their household's primary heating source is firewood or wood pellets. The remaining 410 wood users use heating fuels other than wood as primary heating sources are considered as supplemental users. Statewide, the major wood users burned 34% of all firewood and 47% of all wood pellets, with an average of 4.2 cords of firewood and 3.2 tons per

households. Average supplementary wood users burned 1.4 cords of firewood and 1.4 tons of wood pellets.

A Chi-square analysis was performed to assess whether there is statistical variation among the regional distributions of major wood users and supplemental wood users. The variations among these four regions of Maryland are highly significant, $\chi^2(3, N = 491) = 22.2987$, $p < .0001$. Figure 24 shows the regional comparison of the percentages of these two types of wood users. The proportion of major wood users in Eastern Maryland is 42% which is significantly higher than other three regions. 87% of the wood users in Northern Maryland are supplemental wood users.

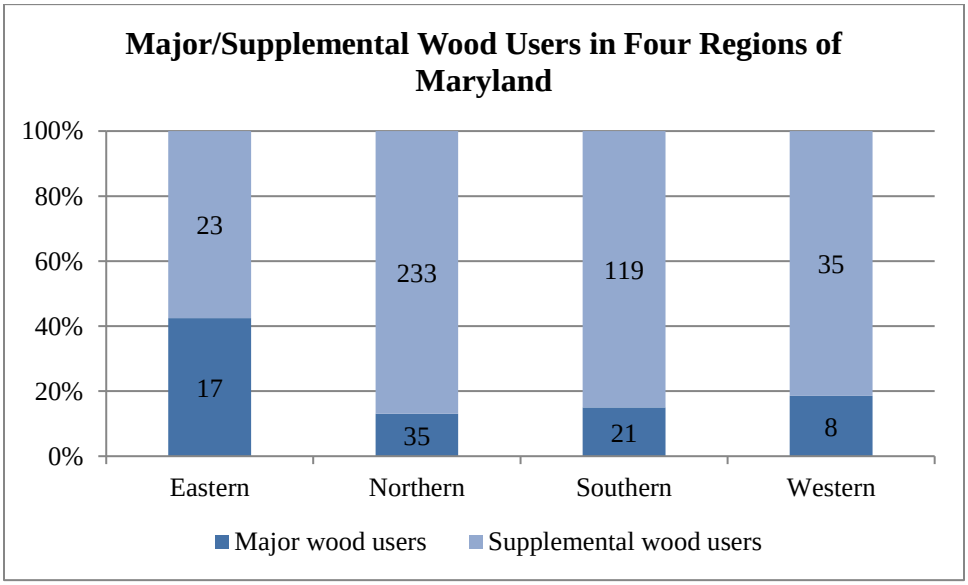


Figure 24. Regional Distribution of Major/Supplemental Wood Users

8. Maryland Energy Administration Clean-Burning Wood Stove Grant Program

Out of the 689 nonusers, 16 of them were aware of the program but failed to participate. These respondents shared a similar attitude towards this program. None of them were interested in this program even with increased incentives. Ten respondents were not interested under any circumstances. The installation cost is not a barrier that prevents them from heating with wood. The cost to install the wood stoves plus the cost

to purchase are referred as the installation cost. Cross-referencing their responses to Question 8 reveals that the cost of their primary heating fuels is not a barrier either. Question 8 assesses the price level of the alternative heating fuels at which nonusers would convert to wood heating. The majority of these respondents (13 of these 16) would not convert under any circumstances.

When respondents were asked whether they would consider participating in the program if the incentives provided increase by $200, 383 of them responded “No” or “Not interested under any circumstances”, and 75 of them responded “Yes”. Chi-square tests of homogeneity are performed to test the statistical differences of the demographic background and fuel usages between these two groups of respondents. Table 11 shows that the statistical differences in age, education, house size, and primary heating sources are significant at 5% significance level.

Table 11. Results of Chi-square Tests between Respondents who Responded “Yes” and Respondents who Responded “No” or “Not interested under any circumstances”

	DF	Chi-square Value	P Value
Gender	1	2.7555	0.0969
Age*	2	32.3684	<0.0001**
Education*	1	4.1441	0.0418**
House Size*	2	8.4426	0.0147**
Annual Household Income*	3	5.9292	0.1151
Primary Heating Sources*	4	14.837	0.0051**

Note:
**Categories are consolidated into smaller groups for these variables*
***Statistically significant at 5% significance level*

Figure 25 to 27 show the differences in distribution of age, education, and house size among these two groups. Figure 25 reveals that for the group of respondents who are willing to participate in the program with the incentive increase, the proportion of younger generation (less than 50 years old) is 28% higher and the older generation (greater than 70 years old) is 20% lower. Figure 26 indicates that the percentage of

respondents with higher education is 12% higher for the group that is unwilling to participate in the program. Figure 27 shows that the percentage of house size that is greater less than 2,000 ft^2 is 14% higher among the group of respondents that are willing to participate in the program.

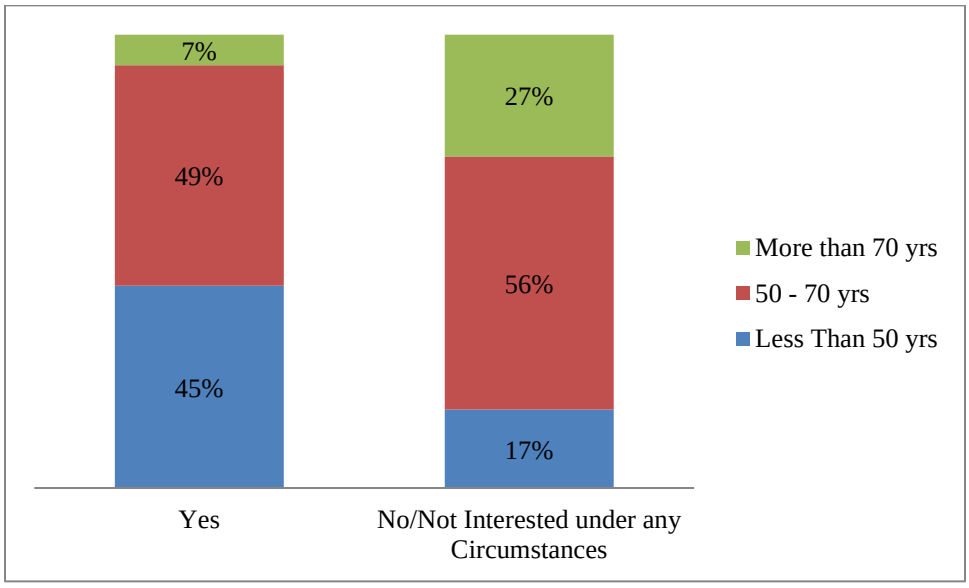


Figure 25. Age Distribution and Responses to Hypothetical Incentive Increase

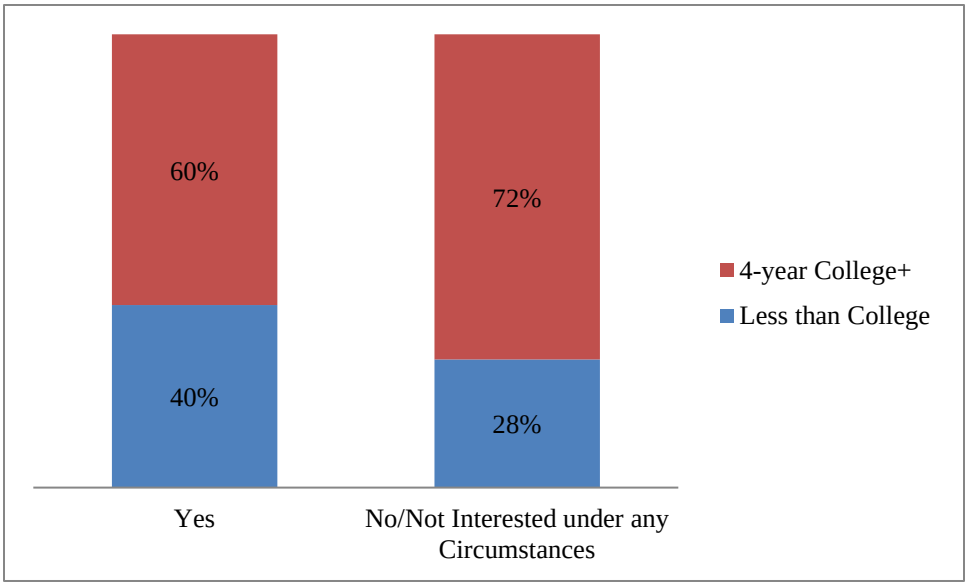


Figure 26. Education and Responses to Hypothetical Incentive Increase

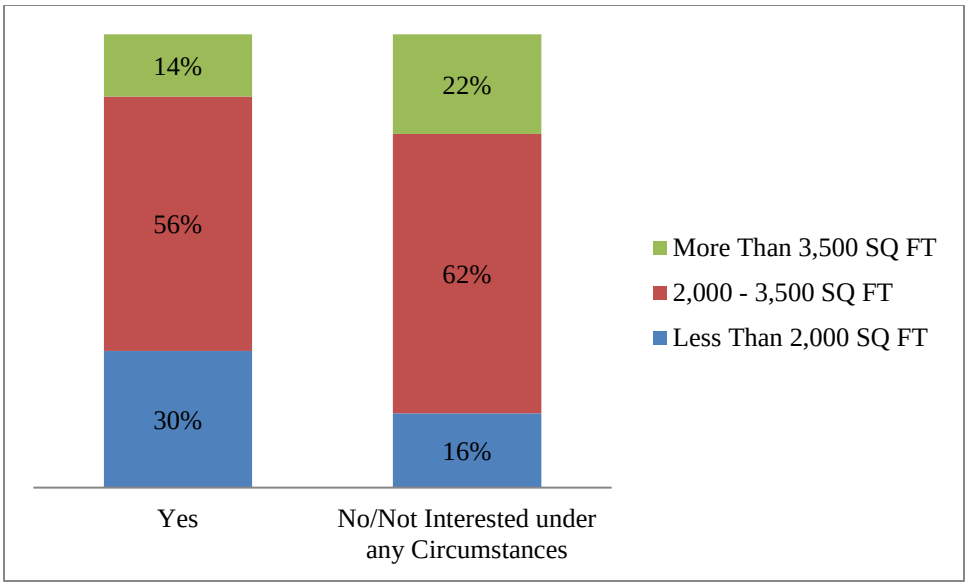


Figure 27. House Size and Responses to Hypothetical Incentive Increase

Table 11 suggests that the choices of primary home heating fuels varied between these two groups. Figure 28 shows that 19% of the respondents who responded "Yes" to the incentive increase use propane, whereas 9% of the respondents who responded "No" or "Not interested under any circumstances" use propane. Additionally, 21% of the respondents that are willing to participate use natural gas, whereas 42% of the respondents of the other group use natural gas.

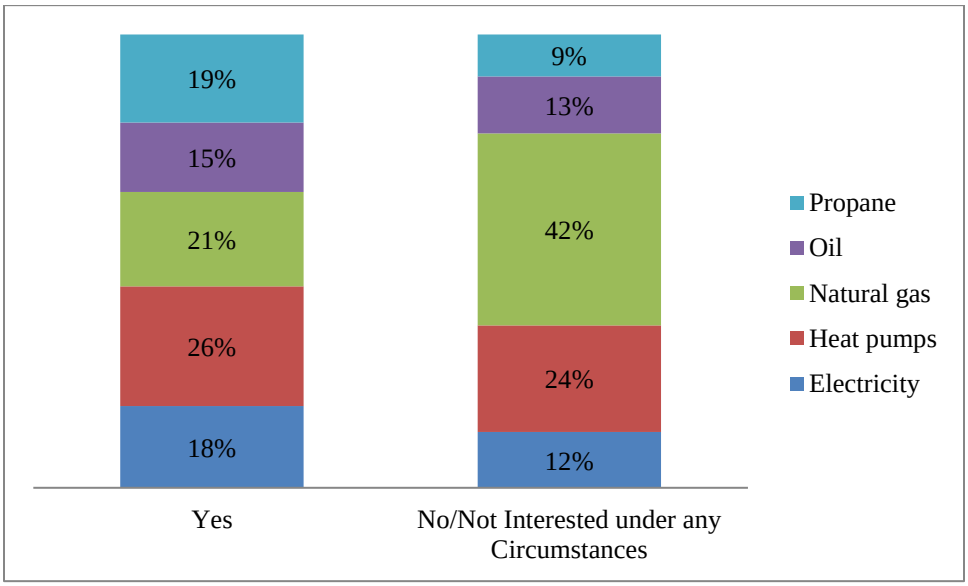


Figure 28. Primary Heating Sources and Responses to Hypothetical Incentive Increase

Part III. Estimation

1. Total volume of wood burned in 2015

This study estimates the quantity of wood burned based on the study's sampling strategy (Table 3) and the average quantity of firewood and wood pellets burned by the respondents (reported in Results section). The total estimated volume of firewood and wood pellets burned (from March 2015 to March 2016) by all Maryland single family homeowners located in rural and suburban areas is shown in Table 12.

Table 12. Total Estimated Volume of Wood Burned by Maryland Single Family Homeowners

	Total Number of Household	**Total Volume of Wood Burned**	SD	95% Confidence Interval
Firewood	142,455	**256,419** cords	713.35	[255020, 257817]
Wood Pellets	43,086	**81,863** tons	359.10	[81159, 82567]

Note:
Total number of household use firewood/wood pellet = Total population in study (443,798) × Percentage of wood users (42%=495/1,184) × Percentage of firewood/wood pellet users
Percentage of firewood users: 78% (=385/495)
Percentage of wood pellets users: 22% (=110/495)

Total volume of firewood/wood pellet burned = Mean volume of firewood (1.8 cords) / wood pellets (1.9 tons) burned by the respondents × Total number of household use firewood/wood pellet

2. Threshold prices for conversion

The threshold prices of the alternative fuels are the level of prices at which the number of additional homeowners would choose to convert is greatest with one additional unit of price increases. Determining the threshold prices of home heating fuels for homeowners to switch to use wood is one of the objectives of this study. It is assumed that if the prices of natural gas, oil, propane, and electricity increase, homeowners who do not use wood would start to convert to wood heating, or homeowners who use wood as a

secondary heating source would use more wood to keep the cost of heating more affordable.

Based on responses to Question 14 from Survey A and Question 8 from Survey B and the prices of natural gas, oil, propane and electricity, a series of conversion curves are generated (Figure 29 to 36). The baseline prices of these fuels are the residential spot prices in March 2016 (when the surveys were administered) which were obtained from the Energy Information Administration (EIA). The horizontal axis represents the baseline fuel prices (marked by*), and with fuel prices increased by 10% 25%, 50%, 75%, and 100%. The vertical axis represents the number of respondents that would change to wood heating or increase wood usage at that particular fuel price. The threshold prices are the level of prices that have the most number of respondents to convert to wood heating or increase wood usage.

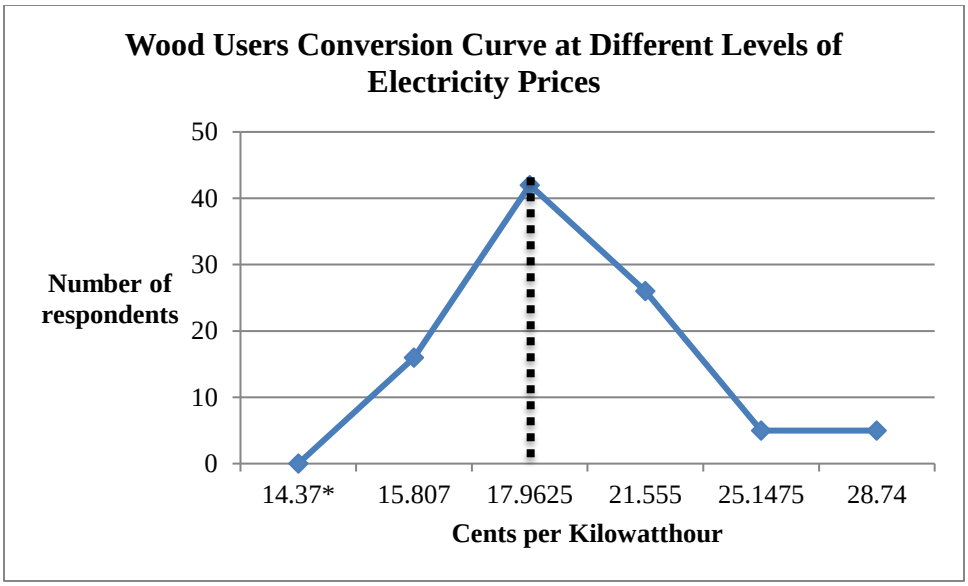


Figure 29. Wood Users Conversion Curve at Different Levels of Electricity Prices

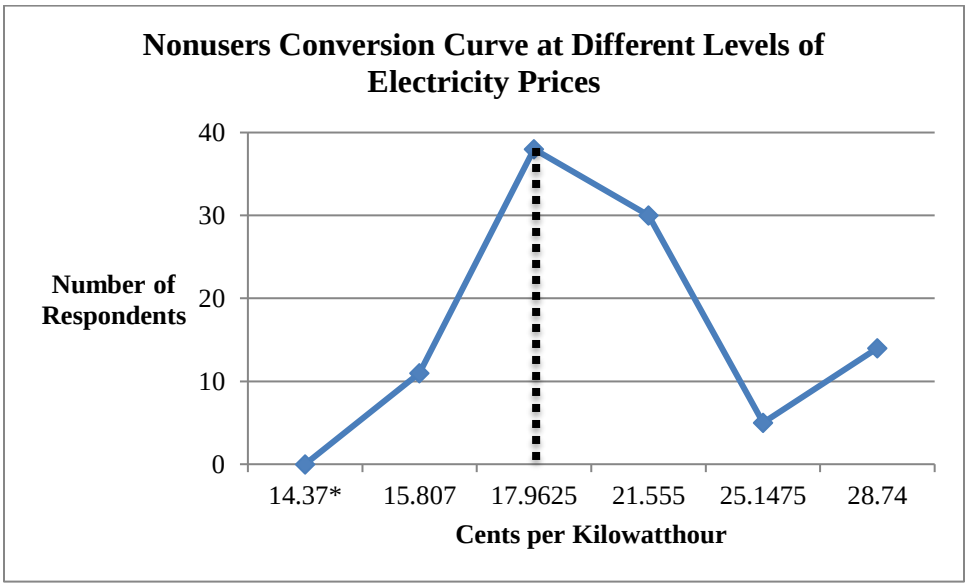


Figure 30. Nonusers Users Conversion Curve at Different Levels of Electricity Prices

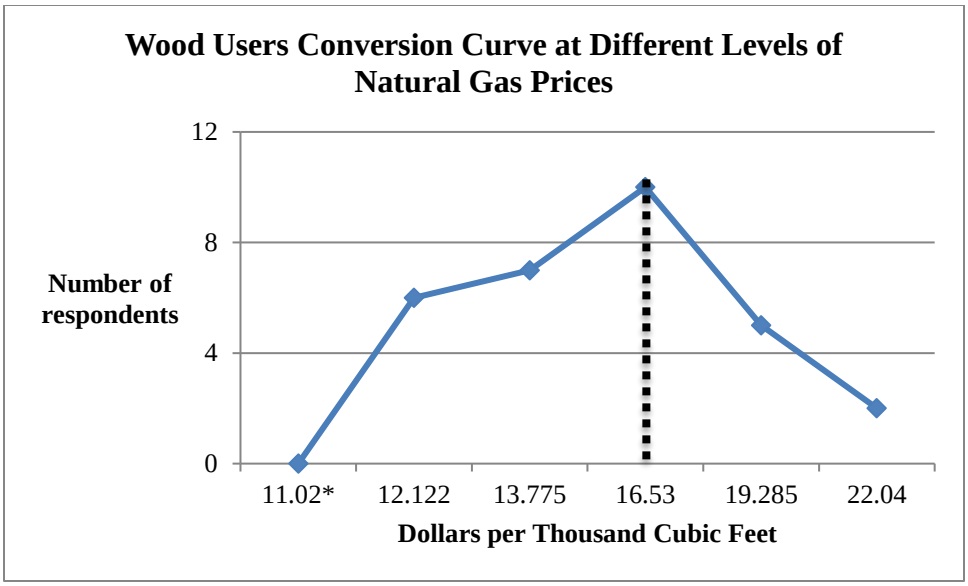


Figure 31. Wood Users Conversion Curve at Different Levels of Natural Gas Prices

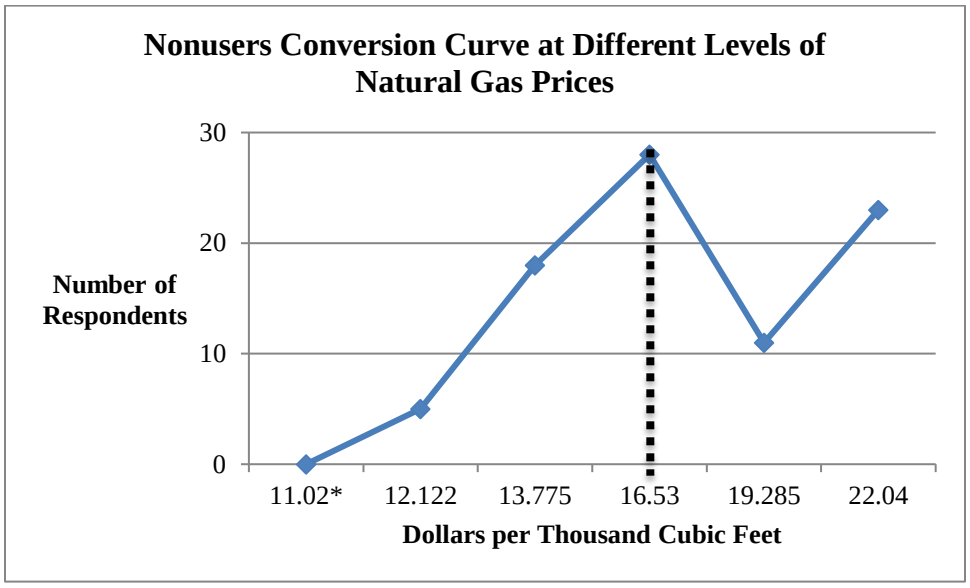


Figure 32. Nonusers Conversion Curve at Different Levels of Natural Gas Prices

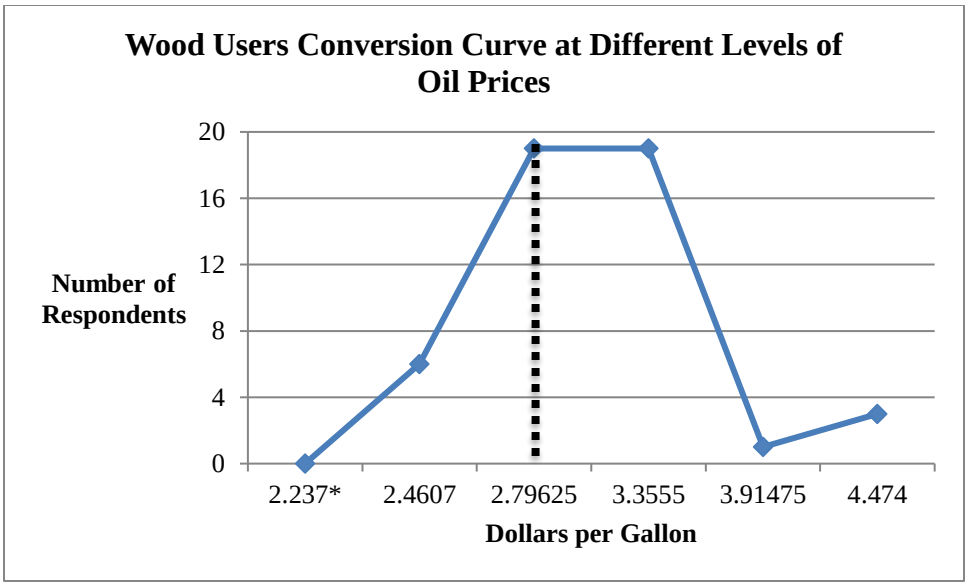


Figure 33. Wood Users Conversion Curve at Different Levels of Oil Prices

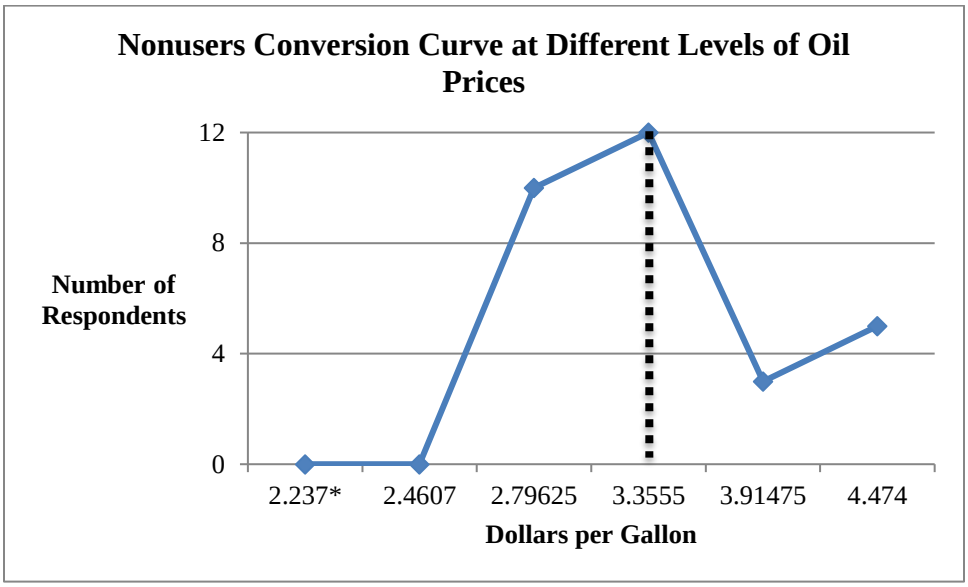


Figure 34. Nonusers Conversion Curve at Different Levels of Oil Prices

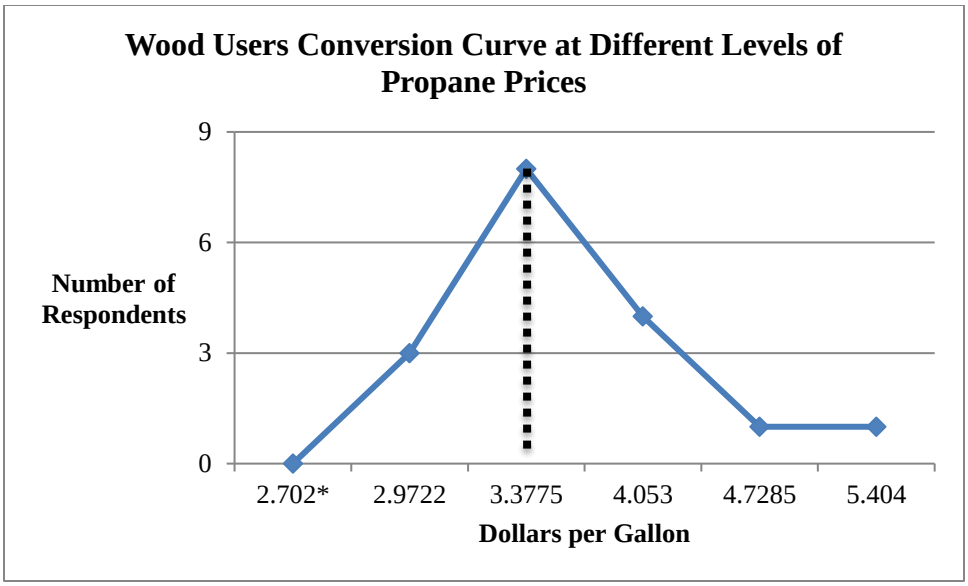


Figure 35. Wood Users Conversion Curve at Different Levels of Propane Prices

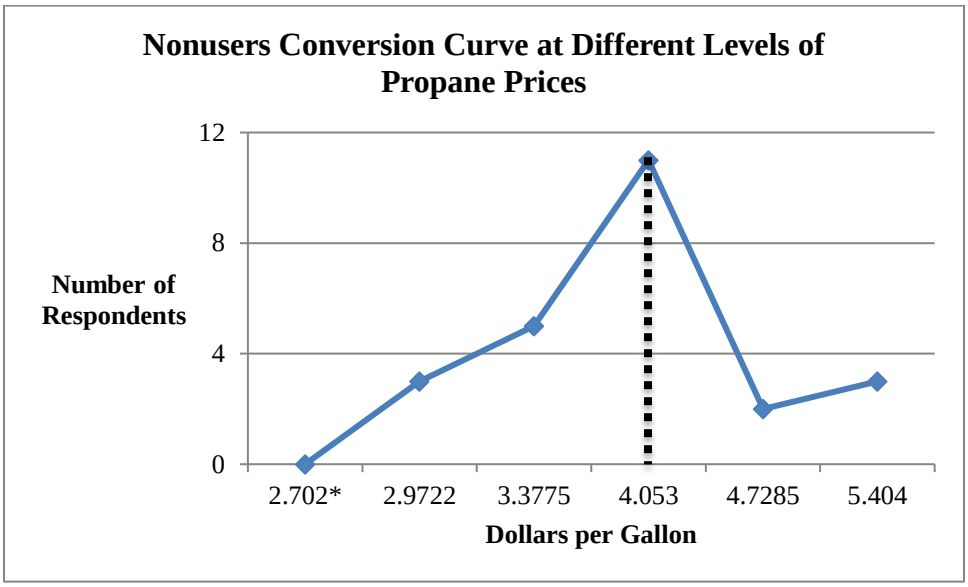


Figure 36. Nonusers Conversion Curve at Different Levels of Propane Prices

Table 13 summarizes the threshold prices for electricity, natural gas, oil, and propane for both users and nonusers. In order to further measure the impact of these threshold prices on forest product industry, Table 14 and 15 illustrate the estimated wood usage increase at the threshold prices of electricity, natural gas, oil and propane for wood users and nonusers. The estimation is based on the assumption that at the threshold prices, a proportion of wood users who are considered as supplemental wood users would increase wood usage and become major wood users. For homeowners who do not use wood, it is assumed that a proportion of them will convert to wood heating and become supplemental wood users.

Table 13. Threshold Prices of Electricity, Natural Gas, Oil, and Propane for Wood Users and Nonusers

	Baseline Price*	Threshold Price for Wood Users	Threshold Price for Nonusers
Electricity (Cents per Kilowatthour)	14.37	17.96	17.96
Natural Gas (Dollars per Thousand Cubic Feet)	11.02	16.53	16.53
Oil (Dollars per Gallon)	2.237	2.80	3.36
Propane (Dollars per Gallon)	2.702	3.38	4.05

Note: The baseline price is the residential fuel price in March 2016 (EIA)

According to the survey results, Maryland major wood users use 4.2 cords of firewood or 3.2 tons of wood pellets annually. Maryland supplemental wood users use 1.4 cords of firewood or 1.4 tons of wood pellets annually. At the baseline price, homeowners are considered as supplemental wood users. When the home heating fuel prices increase to the threshold price, a proportion of these supplemental wood users would increase wood usage and become major wood users, thus increasing firewood usage by 2.8 cords annually or wood pellets by 1.8 tons. The number of homeowners that

would increase wood usage are shown in Table 14. Similarly, when the home heating fuel prices increase to the threshold prices, a proportion of the homeowners who do not use wood would convert to wood heating and become supplemental wood users, increasing firewood usage by 1.4 cords annually or wood pellets by 1.4 tons. The number of nonusers that would convert to wood heating are shown in Table 15. For the homeowners who decide to increase wood usage or convert to wood heating, it is assumed that 74% of them would adopt firewood, and 26% adopt wood pellets based on the data summarized from the survey. If the threshold prices of these alternative fuels are met, the total annual additional firewood usage is estimated at 152,432 cords and the additional wood pellets usage is 41,634 tons (Table 16).

Table 14. Increase in Wood Usage at the Threshold Prices for Supplemental Wood Users Converting to Major Wood Users

	Threshold Price for Wood Users	# of homeowners that would increase wood usage	Annual Firewood usage (cords)	Annual Pellets usage (tons)
Electricity	17.96 cents per kilowatthour	22,831	47,306	10,685
Natural Gas	16.5 dollars per thousand cubic feet	9,117	18,891	4,267
Oil	2.80 dollars per gallon	9,656	20,008	4,519
Propane	3.38 dollars per gallon	4,249	8,803	1,988

Note:
Annual Firewood usage=# of homeowners that would increase wood usage × 74% × 2.8 cords
Annual Pellets usage=# of homeowners that would increase wood usage × 26% × 1.8 tons

Table 15. Increase in Wood Usage at the Threshold Prices for Nonusers Converting to Supplemental Wood Users

	Threshold Price for Nonusers	# of homeowners that would convert to wood heating	Annual Firewood Usage (cords)	Annual Pellets Usage (tons)
Electricity	17.96 cents per kilowatthour	19,099	19,787	6,952
Natural Gas	16.5 dollars per thousand cubic feet	20,276	21,005	7,380
Oil	3.36 dollars per gallon	8,715	9,029	3,172
Propane	4.01 dollars per gallon	7,339	7,603	2,671

Note：
Annual Firewood usage=# of homeowners that would convert to wood heating × 74% × 1.4 cords
Annual Wood Pellets usage=# of homeowners that would convert to wood heating × 26% × 1.4 tons

Table 16. The Total Estimated Firewood and Wood Pellets Usage Increase at the Threshold Prices for the Alternative Fuels

	Total Firewood Usage (Cords)	Total Pellets Usage (Tons)
Electricity	67,093	17,637
Natural Gas	39,896	11,647
Oil*	29,037	7,691
Propane*	16,406	4,659
Total	***152,432***	***41,634***

**Note: the threshold prices for oil and propane are different for users and nonusers*

If the threshold prices were met, it is estimated the total volume of firewood and wood pellets statewide would be 408,851 cords and 123,497 tons. This is a 59% increase of current firewood usage and a 51% increase of current wood pellets usage.

Discussion

Following tailored Dillman's Total Design Method, this survey received a response rate of 19%. Since this survey was sponsored by the University of Maryland, respondents are more likely to cooperate and respond (Fox, Crask, and Kim 1988). Additionally, the branching out postcard and the firewood calculation magnet helped improve the response rate to some degree. The response rate may be increased if more proactive measures had been taken. First, printing Survey A and Survey B with two distinct colors can enable respondents to easily understand that they only respond to one of these two. Second, detailed explanations of how respondents were selected may encourage them to take the survey. During the survey implementation process, several inquiries were received from the respondents. They were concerned that their identification and home address might be exposed. This sense of insecurity can be resolved by attaching one page of detailed information regarding how their address was obtained. Third, providing the option of answering the survey by telephone may encourage seniors or respondents with disabilities. According to the age distribution of the respondents, 4% of the respondents are over 80 years old. To them, answering the survey through hard copy or online may not be the best option. It is also important to note that fuel prices were low compared to previous years at time of survey. If fuel prices were higher as they were in 2012-13, it is felt the response rate would have been higher.

In addition to improving the response rate, it is essential to acquire a more accurate study result and truly understand the perspectives of homeowners and the dynamics behind wood heating adoption. Future survey studies should be combined with focus group sessions and personal interviews to overcome the limitations of the survey methodology.

Total Volume of Wood Burned Statewide in 2015

The Maryland Forest Service was the last to evaluate the Maryland's residential fuelwood usage by telephone survey as a part of cooperative program among twenty other states in the Northeastern U.S. (Rowan 1982). It was estimated that during the 1980-1981 heating season, 396,806 households burned 755,867 cords. This survey estimated that the total volume of firewood burned in the 2015-2016 heating season was 256,419 cords by 142,455 households. This is a 66% decrease in wood usage and 64% decrease in wood burning households from the estimation in 1982. However, the quantity of firewood burned per household only decrease by 5%. Also they only calculated firewood in cords but not pellets.

There is no doubt that total firewood usage in space heating is decreasing compared to three decades ago. It is certain that the firewood market in Maryland shrank significantly, which may be explained by the extensive natural gas pipelines. In 1987, the number of natural gas consumers in the residential sector in Maryland was 755,294; by 2015, this number has increased by 47% (EIA 2016b). During the same period, the number of households in Maryland has increased from 1,748,991 (U.S. Census Bureau 1990) to 2,434,307 (U. S. Census Bureau 2016), which represents a 39% increase. The extensive coverage of the pipelines has made natural gas readily accessible to more and more households. The convenience and affordability of natural gas heating have grown on homeowners. The result of the survey indicated that nonusers who primarily heat with natural gas are less willing to convert to wood heating compared to those who heat with oil or propane.

Additionally, wood pellets market expansion partly accounts for the shrinking firewood market. Wood pellets were introduced to the United States in 1970s (Mendell and Lang 2012). Even though the volume of wood pellets was not officially reported by Rowan in 1982, the popularity of wood pellets among the residential users has increased over the last thirty years. While the firewood usage is decreasing, the number of wood pellets users in the total market is increasing. Between 1998 and 2010, fireplace and wood stove sales declined by 65% while wood pellets stove sale increased by 30% (Mendell and Lang 2012).

Threshold Prices for Conversion

This study summarizes the threshold prices of electricity, natural gas, oil and propane for users and nonusers. The threshold prices of electricity and natural gas are the same for users and nonusers. Both the threshold prices of oil and propane are higher for nonusers compared to wood users. The reason behind the discrepancy for the threshold prices of oil and propane for users and nonusers is unclear.

The comparison the threshold prices against the historical prices in the residential sector sheds light on the explanations for the stagnant wood biomass market. The prices of electricity and natural gas delivered to Maryland household have been relatively stable since they are controlled by the public utility companies (Figure 37 and 38). The historical electricity and natural gas prices are below the threshold price of electricity and natural gas. On the contrary, the historical prices of residential heating oil and propane fluctuate substantially (Figure 39 and 40). The threshold prices for these fuels are below the historical highpoints.

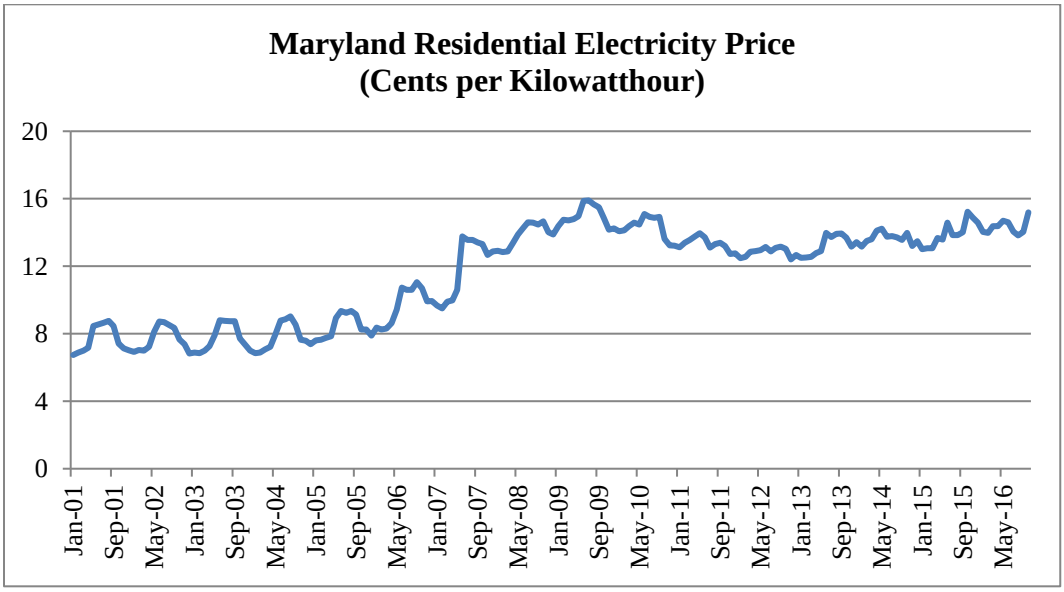


Figure 37. Historical Maryland Residential Electricity Price (EIA 2016a)

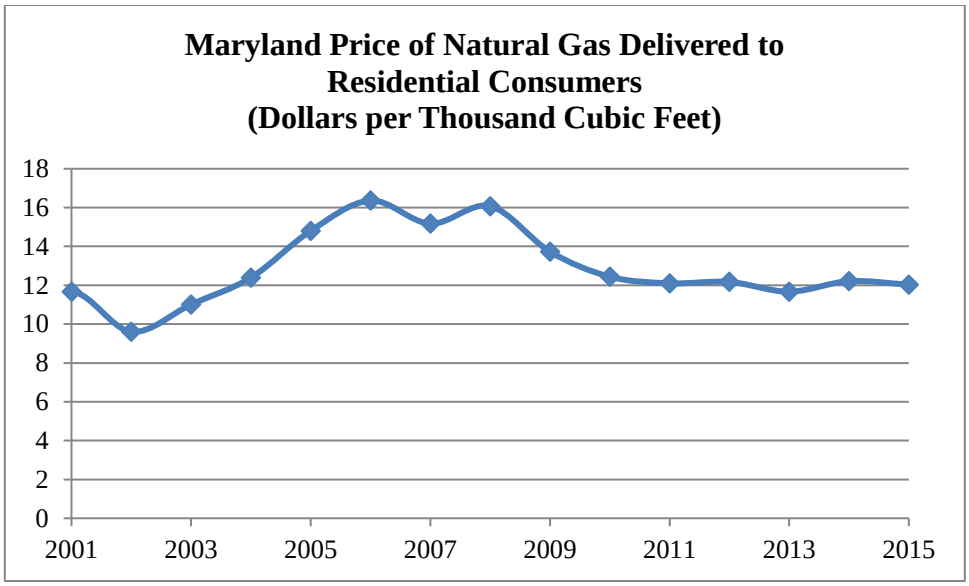


Figure 38. Historical Maryland Residential Natural Gas Price (EIA 2016d)

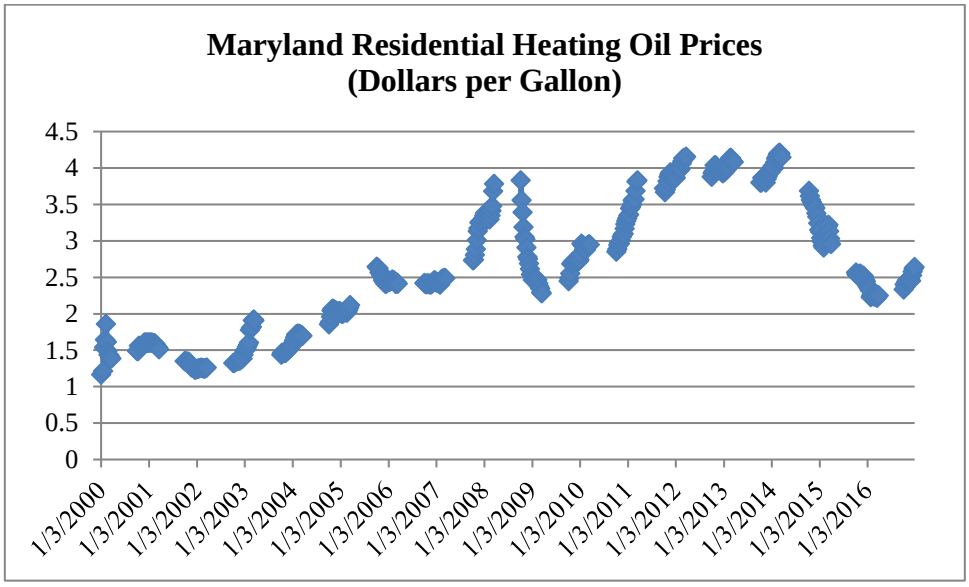


Figure 39. Historical Maryland Residential Heating Oil Price (EIA 2016c)

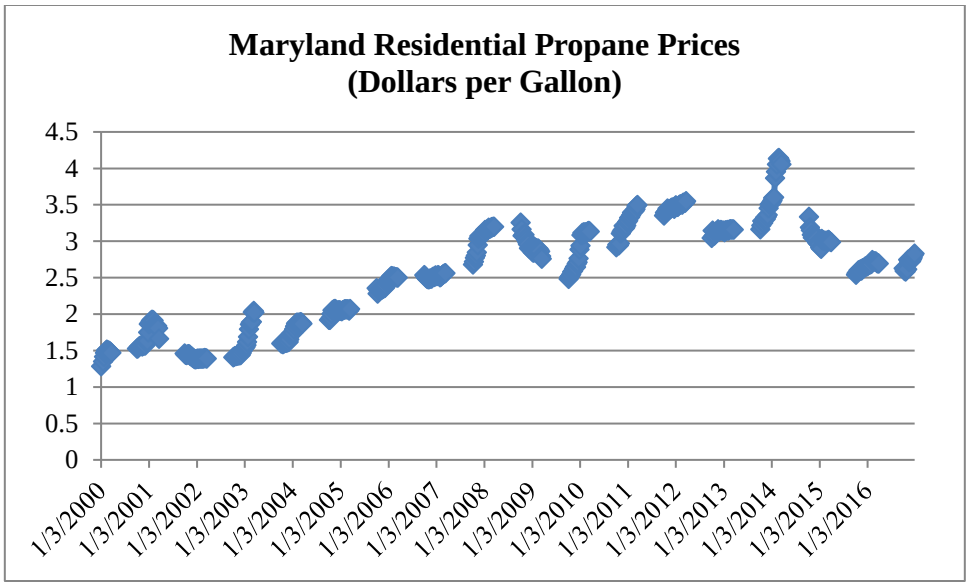


Figure 40. Historical Maryland Residential Propane Price (EIA 2016e)

From the cost effective perspective, it is unlikely for the homeowners who use electricity and natural gas as primary home heating sources to convert to wood heating due to the potential renovation and installation costs. To them, the initial investment is the main barrier for them to convert. On the other hand, oil and propane users are more likely to install wood stoves to avoid the risk of increasing home heating cost. A forward-looking homeowner would estimate the possibility of this risk, even though the prices of oil and propane are currently affordable. Therefore, the market expansion for firewood and wood pellets is dependent on the future energy outlook of oil and propane. If the prices of oil and propane remain relatively stable and under the threshold prices, the likelihood of market expansion for firewood and wood pellets is rather slim.

In order to simplify the analysis of threshold prices, one underlying assumption is that with increasing alternative fuel prices, the market prices of firewood and wood pellets remain the same. This means that at the threshold prices of these alternative fuels, the market prices of wood fuels are assumed to be fixed. However, if the market prices of wood fuels change, the threshold prices may be altered. Some factors may alter the

threshold prices. If the market price of wood is no longer a constant or decreases, the number of homeowners who would convert to wood heating may not be the greatest at the original threshold prices. The new threshold prices may be lower than the original prices if compared with a lower price of wood. Similarly, with an increased incentive for conversion, the threshold prices can be lower as well. This incentive provided by MEA can help homeowners to alleviate the initial investment in the stoves, thus providing some advantages for wood heating.

The threshold prices for electricity and natural gas analyzed with a constant wood market price may be unreachable and may not be feasible compared to the historical prices. If initiatives such as providing incentives to reduce the initial investment cost of wood stove can be taken, the threshold prices can be reduced and reachable.

Comparing the Energy Value of Wood with the Alternative Fuels

The British Thermal Unit (BTU) is used to measure the heat content and can be used to compare the costs required to generate the same amount of heat from wood with other fuels. Table 17 and 18 compare the cost to generate one million BTUs of heat value provided by wood with alternative fuels such as natural gas, electricity, oil, and propane.

The units required to generate one million BTUs of heat are related to the fuel type and the heating efficiency of the appliance used. The heating efficiency varies by the types of the heating appliances. A fireplace may only achieve 10% heating efficiency whereas an EPA approved wood burning stove may achieve 70% efficiency (Kays 2010). The latest high-efficiency automated wood stove invented by the MF Fire can even achieve a heating efficiency as high as 90%. MF Fire, founded by graduate students from

the University of Maryland, is committed to developing the clean wood stove combusting technology.

Table 17. Comparison of the Units Required to Generate 1 million BTUs of Heat (Reeb 2009)

Fuel	Unit	BTU/Unit	Heating Efficiency (%)	Available Heat (BTU)*	Units Required for One Million BTUs Available Heat**
Natural Gas	Therm	100,000	85	85,000	11.76
Electricity	KWH	3,415	100	3,415	292.83
Heating Oil	Gallon	190,900	80	152,720	6.55
Propane	Gallon	91,000	80	72,800	13.74
Firewood	Cord	19,195,000	60	11,517,000	0.09
Wood Pellets	Ton	16,500,000	80	13,200,000	0.08

Note:
** Available Heat (BTU) = BTU/Unit × Heating Efficiency*
***Units Required for 1 million BTUs Available Heat = 1,000,000/Available Heat (BTU)*

Table 18. Cost per million BTUs of Available Heat for Various Fuels

Fuel	Cost per Unit*	Cost per 1 million BTUs of Available Heat**
Natural Gas	$1.08/Therm***	$12.67
Electricity	$0.1437/KWH	$42.08
Heating Oil	$2.237/Gallon	$14.65
Propane	$2.702/Gallon	$37.12
Firewood	$192/Cord	$16.67
Wood Pellets	$266/Ton	$20.15

Note:
**The costs of Natural Gas, Electricity, Heating Oil, and Propane are the residential fuel prices in March 2016; the cost of firewood and wood pellets are the prices reported by the survey respondents.*
*** Cost per 1 million BTUs of Available Heat = Cost per Unit ×Units Required for 1 million BTUs Available Heat (Table 17)*
****$1.08/Therm = $11.02/Thousand Cubic Feet (Conversion factor: $10.23/Therm = $1/1000 Thousand Cubic Feet);*

The fuel types also make difference by generating different heat values per unit. Table 19 shows that various species of firewood vary by the amount of BTU generated per cord (Maryland DNR 2017). An experienced wood user should also understand that the price of firewood is determined by both the species of the firewood and the moisture content of the wood itself.

Table 19. Firewood BTUs Based on Air-Dried Standard (Maryland DNR 2017)

Species	**BTU/Cord**
Black Locust	26,500,000
Hickory	25,400,000
Hophornbeam	24,700,000
Beech	21,800,000
Hard Maple	21,800,000
Red Oak	21,700,000
Yellow Birch	21,300,000
Yellow Pine	20,500,000
White Ash	20,000,000
White Oak	19,200,000
Soft Maple	19,100,000
Black Cherry	18,500,000
White Birch	18,200,000
Sweetgum	18,100,000
Elm	17,700,000
Yellow Poplar	15,900,00
Hemlock	15,000,000
Red Spruce	15,000,000
Fir	13,500,000
White Pine	13,300,000
Basswood	12,600,000
Average	*19,195,000*

Table 18 shows the cost to generate one million BTUs of available heat based on the unit prices in the residential sector in March 2016. The lowest cost to generate one million BTUs heat is through natural gas and the highest is through electricity. The comparison of the costs per million BTUs among these fuels reveals firewood and wood pellets are competitive over propane and electricity. It explains why propane users are

more likely to convert to wood heating. However, it fails to support that the electricity users are less likely to convert to wood heating.

The comparative cost advantage of wood over other heating fuels may not be substantial but is subject to alteration. If the heating efficiency of firewood increases from 60% to 90% by using MF Fire's high-efficiency wood stove, the cost to generate one million BTUs through firewood is $11.11, which is lower than heating through natural gas. For the price of wood pellets, $266 per ton is relatively expensive. According to the Densified Biomass Fuel Report published by the Energy Information Administration (EIA), the average domestic sale price of wood pellets is $178 per ton in the Eastern U.S and $157 per ton nationwide (EIA 2017). If the price of wood pellets is reduced to $178 per ton, the cost to generate one million BTUs through wood pellets is $13.48. In conclusion, the relative low cost per energy value can be achieved by homeowners with the energy efficient stove and cheap wood pellets fuels.

Wood Usage at the Threshold Prices

The total additional firewood and wood pellets usage at the threshold prices are estimated in this study. At these prices, the total wood usage is calculated by adding these additional usages to the estimated total volumes of wood burned statewide in 2015-2016 shown in Table 12. The total firewood usage is estimated at 408,851 cords and the total wood pellets usage is 123,497 tons.

It is essential to examine whether timberland in Maryland can accommodate these volumes of usage. According to the U.S. Forest Service Forestry Inventory Analysis, in Maryland, the total volume of annual net of growth of growing stock trees is 123,177 thousand ft^3 and the annual volume of harvest removal of the growing stock trees is

47,353 thousand ft^3 (Lister and Widmann 2016). After subtracting the harvest and removal, the annual net of growing stock trees is 75,824 thousand ft^3, which is 592,375 cords per year (1 thousand ft^3 equals to 7.8 cords). This indicates that the timber resources in Maryland are capable of expanding and supporting the wood usage increase at the threshold prices.

MEA Clean-Burning Wood Stove Grant Program

Figure 28 shows that the proportion of respondents who use propane is higher and the proportion of respondents who use natural gas is lower in the group that is willing to participate in the program. This suggests that propane users are more likely to participate in MEA's incentive program with the hypothetical incentive increase, and natural gas users are less likely to participate. From MEA's perspective, Eastern Maryland can be an appropriate region to advocate this program since the percentage of natural gas users in this area is lowest and percentage of propane users is highest compared to other regions in Maryland (Table 20).

Table 20. Primary Heating Sources Distribution by Region (Row Percentage)

	Electricity	Heat Pumps	Natural gas	Oil	Propane	Total
Eastern	23%	32%	5%	15%	25%	100%
Northern	12%	17%	52%	12%	8%	100%
Southern	13%	35%	32%	12%	7%	100%
Western	25%	28%	25%	13%	9%	100%

In order to further understand why MEA's incentive program is not appealing to respondents who responded "No" or "Not interested under any circumstances", Figure 41 compares their responses to Question 6 against the responses of those who are interested in the program. Question 6 asked respondents to choose the listed statements that they perceived as wood heating barriers. For the respondents who responded "No" or "Not

interested under any circumstances", receiving incentives to install stoves is not a motivation for them since they are more concerned with the work associated with wood heating. Fifty-five percent of these respondents are not willing to undertake the work and mess of wood heating whereas only fourteen percent believe that installation cost can be a financial burden. Additionally, incompatibility of wood stoves with houses is another greatest barrier which explains why incentive program is not the solution.

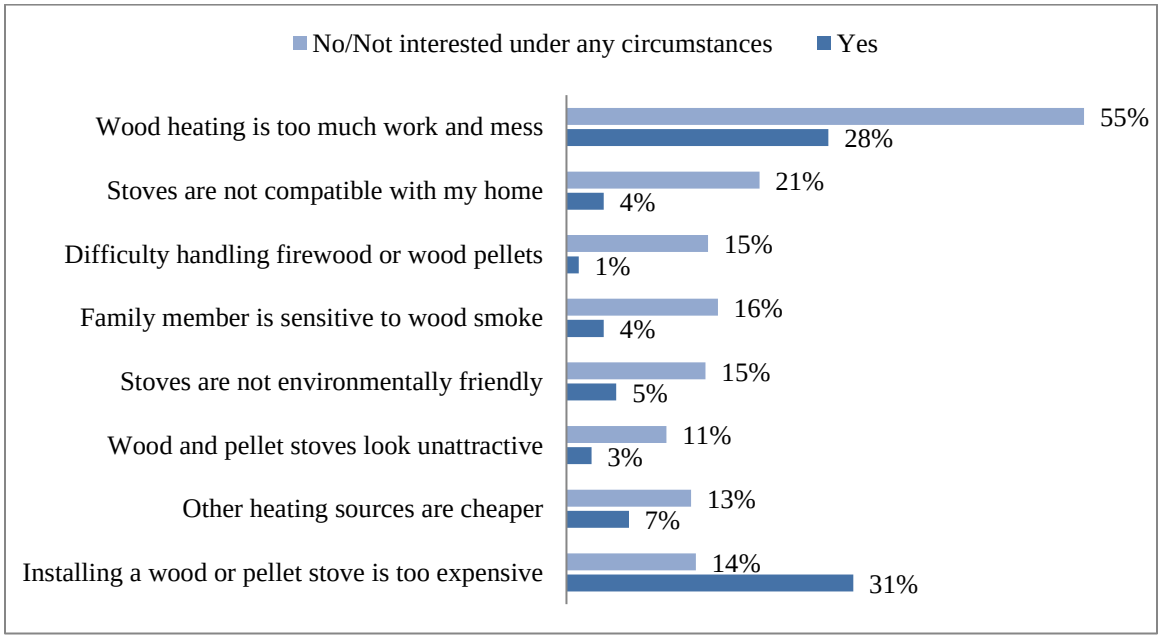


Figure 41. Comparison of barriers to wood heating by responses to incentive increase

On the other hand, for those responded "Yes" who are interested in MEA's incentive program, it is the opposite situation. First, they are much more comfortable utilizing firewood or wood pellets since only 1% of them consider it difficult to handle wood fuels, although 28% were concerned with the work and mess. Second, they believe that the installation cost is a substantial amount of money to invest (31%).

Thus, by comparing these two groups of respondents, it is recognized that the incentives provided by MEA's incentive program would not be enough to motivate homeowners who are unwilling to undertake the work and mess associated with the wood

heating. However, raising the level of incentives cam be effective in attracting other homeowners to convert, especially for respondents whose major barrier is more likely to be the initial investment costs rather than the amount of workload associated with wood heating.

Conclusions

The intent of this study is to evaluate the market potential of firewood and wood pellets as a home heating source. With rapidly diminishing fossil fuels reserves and rising population with greater energy demands, it is imperative to evaluate this alternative heating option (Shafiee and Topal 2009). Understanding the supply and demand of the market will help government agencies formulate policy to motivate homeowners to use wood and to educate these homeowners about the benefits of wood heating. More importantly, the results of the study will help the forest industry and private landowners to make more informed managerial decisions.

The first objective of this study is to establish the baseline of the residential wood usage in Maryland by estimating the volume of firewood and wood pellets burned in the 2015-2016 heating season. Such data can help monitor the firewood and wood pellets market in the long term and promote sustainable forest stewardship practices and a profitable forest industry. The population in this study is made up of Maryland single family homeowners whose home properties are located in suburban and rural areas. Homeowners in these areas are more inclined to use wood as a home heating source. Conversely, urban households are less likely to burn wood. According to the mailing list from the Maryland Department of Planning property tax database, the total population in this study was 443,798. Based on the study's sampling strategy and survey data, it is estimated that the total volume of wood burned by this population in the 2015-2016 heating season was 256,419 cords of firewood and 81,863 tons of wood pellets. Thus, this study provides an accurate amount of firewood and wood pellets consumed in the region. Determining the volume of wood consumption in the residential sector helps landowners and forest product operators to make managerial decision for the next year and beyond.

Results show that firewood usage in space heating in 2015-2016 decreased compared to three decades ago. The 1982 report estimated that during 1980-1981 heating season, 396,806 households burned 755,867 cords. This survey estimated that the total volume of firewood burned in the 2015-2016 heating season was 256,419 cords by 142,455 households. Although the firewood usage per household decreased by 5% comparing to the 1982 estimation, the total wood usage in residential sector decreased by 66% and the number of wood burning households decreased by 64%. The firewood market in Maryland shrank significantly, which can be explained by the extensive natural gas pipeline coverage and expansion of the wood pellets market. The convenience and affordability of natural gas heating are increasingly appealing for homeowners. While firewood usage is decreasing, the proportion of wood pellets in the total wood heating market is increasing. The present study explores ways to overcome this declining wood usage by studying the attitudes and perspectives of homeowners.

The second objective is to assess the motivational factors and barriers for the homeowners to utilize wood. Wood users' four major motivations for wood heating are aesthetic values, wood heat, free access to wood, and affordable cost of wood. Nonusers' three barriers are work and mess, no fireplace, and being unable to install stoves either due to the installation costs or zoning regulations. For home properties with fireplaces, converting to wood heating is achievable but the expenses vary based upon the renovation efforts needed. For homes without fireplaces, the cost of renovating can be prohibitive. Taken together, these results shed light on the factors that influence the dynamics of homeowners' heating decisions. The cultural value of wood heating that homeowners enjoy contends with the amount of maintenance required which pushes

users away, and may explain the emergence of fireplaces powered by natural gas, propane or oil. Additionally, homeowners should carefully evaluate the initial installation and renovation expenses and the future energy savings brought by wood heating.

These barriers may be overcome by applying policy instruments such as an incentive program encouraging the homeowners' adoption of wood heating by alleviating the financial burden incurred by the initial installation. The historic award data report provided by MEA documents the project cost incurred of installing a wood-burning stove. The average project cost for home renovation to install a firewood-burning stove is $4,100, and for a wood pellet stove it is $4,900. This includes the cost of the stove and stovepipe, labor costs for the installation and wall covering, and other basic expenses such as material costs. The cost to purchase an EPA-certified wood stove ranges from $500 to $5,000 depending on the product's specifications, such as heating coverage and energy efficiency. The considerable amount of upfront expenses is a barrier for homeowners to convert to wood heating, which could be addressed by increasing the incentives provided by MEA.

Increasing the level of incentive is a motivation to covert to wood heating since the cost to install the wood stoves is one of the top three barriers identified by the nonusers (Figure 7). It is further suggested that extensive outreach efforts are crucial because only 2% of the nonusers have heard of the MEA's wood stove program. Raising the awareness of the program shapes the dynamics of homeowners' heating decisions.

Educational efforts can help homeowners overcome obstacles to wood heating. These efforts include developing programs to assist them to understand possible renovating solutions and caveats since they are concerned that the stoves may not be

compatible with their houses. It is also important to provide homeowners with information on other wood heating appliances other than fireplace inserts, such as stand-alone stoves and wood burning boilers. Such programs are advantageous in changing the stereotypes of wood heating by informing the public of economic, social, and environmental benefits.

The third objective is to determine the threshold prices of electricity, natural gas, oil and propane. This will provide comprehensive information to assist the forest industry to make financial decisions. If the prices of these fuels increase, homeowners who do not use wood may convert to wood heating; similarly, homeowners who use wood as a secondary heating source may consume more wood to keep the cost of heating affordable. At the threshold prices, the number of these homeowners would be the greatest. It is estimated that a total of 152,432 cords of additional firewood and 41,634 tons of additional wood pellets would be consumed annually if these threshold prices are reached. The total annual firewood usage is estimated at 408,851 cords and the total wood pellets usage is 123,497 tons at these threshold prices. Based on the latest Forest Inventory Analysis (2016), the annual net growing of timber stock is 75,824 thousand ft^3 after discounting the removal, which is 592,375 cords per year. This indicates that the forest resources in Maryland have the capacity to support additional wood usage increase. Thus, this study suggests that there are specific points at which consumers will switch to using more wood and Maryland forests are able to meet this demand.

The future market potential of wood biomass is associated with the prices and the fluctuation of the prices of electricity, natural gas, oil and propane. Results from this study indicate that the influence of these various fuels on the market is varied. The

threshold prices of natural gas and electricity were never reached based on the historical prices in the residential sector. On the other hand, the threshold prices of oil and propane were reached in 2012- 2014 based on the historical prices in the residential sector. Additionally, the prices of natural gas and electricity are less volatile and relatively stable compared to the prices of oil and propane. This is because the prices of electricity and natural gas are controlled by the Public Utilities Commission and they are relatively affordable. If the homeowners anticipate that the electricity and natural gas prices will remain affordable and stable in the short term, then they will not consider converting to wood heating. From the cost effective perspective, it is unlikely for the homeowners who use electricity and natural gas as primary home heating sources to convert to wood heating due to the potential renovation and installation costs. On the other hand, oil and propane users are more likely to install wood stoves to avoid the risk of increasing home heating costs. Although the prices of oil and propane are currently affordable, homeowners anticipate that these prices may fluctuate.

Therefore, the market expansion for firewood and wood pellets is dependent on the future energy outlook of oil and propane. If the prices of oil and propane remain relatively stable and under the threshold prices, the possibility of market expansion for firewood and wood pellets is rather slim. Thus, the forest industry and private landowners need to actively manage their businesses to stay competitive. Increasing the demand for the wood heating products market is therefore crucial. Three proactive measures are proposed in this section. All increase in firewood and wood pellet usage will not bring back the forest industry to pre-recession times, but will have an impact on helping both

industry and forest landowners look at entrepreneurial option to help sustain existing forest industry.

First, governmental agencies should ensure adequate financial support for Maryland's Clean-Burning Wood Stove Grant Program administered by the Maryland Energy Administration (MEA). Results show that 19% of the nonusers reported that the installation costs are preventing them from switching to wood heating and 11% of the nonusers would actually participate in the program if the incentives increase to $700 for firewood stoves and $900 for wood pellets stoves. These results suggest that the level of incentives is critical in motivating homeowners to switch to wood heating. MEA need additional fiscal support for this program so it can increase the incentive amount, which in turn may spur wood usage in Maryland. Providing higher incentives addresses the homeowners concern of not being able to afford the initial investment of wood stoves. The MEA program, however, does not tackle the major obstacle of wood heating, i.e., work and mess associated with it, which can be addressed by spurring new technology innovation mentioned in the second suggestion.

Second, MEA should encourage new technologies, such as the high-efficiency automated wood stove, to stimulate the market by creating extra incentives for this type of stove. Figure 7 shows that 49% of the nonusers responded that the work and mess associated with wood heating was the principal barrier prohibiting them from using wood. Automated wood stoves are effective in elevating the user's experiences. Unlike traditional wood stoves, these stoves use sensors and computer chips to monitor wood burning which allows the users to "load and leave". Additionally, this stove has exceeded stringent EPA air quality rules for residential wood heaters, which most wood stoves in

the current market have difficulties complying with. Supporting new technologies can help change the stereotype of wood heating as messy and dirty, thus motivating homeowners to use wood.

Third, state government agencies and policy makers should support building a wood pellets manufacturing facility in Maryland. According to the Densified Biomass Fuel Report published by the Energy Information Administration, the average domestic sale price of wood pellets is $178 per ton in the Eastern U.S and $157 per ton nationwide (EIA 2017). Based on the survey data, the average price of wood pellets that our respondents paid is $266 per ton. This suggests that the consumers in Maryland are consuming wood pellets at a higher price. It is speculated that this is because of the transportation costs of the wood pellets that are borne on the consumers. Currently, there is no wood pellets manufacturing facility in Maryland and the closest ones are in Pennsylvania, West Virginia, or Virginia. The transportation cost ranges from 7% to 15% of the total cost of production (Qian and McDow 2013). Previous research on optimizing wood pellet supply chain suggests that 70% cost of the wood pellets can be reduced with lower transportation cost (Lacoa et al. 2017).

There are three advantages of building a wood pellets manufacturing facility in Maryland. First, it increases the economic impacts of the forest industry by creating job opportunities and tax revenues, which will further build up the industry's confidence of future success and profitability. Second, it can ensure the supply of wood pellets to the wood users, which has become a major problem for the wood pellet users. As the number of homeowners who are interested in burning pellets increase, retailers may start to ration their pellet supplies in order to maintain their businesses without raising the prices. Some

retailers would restrict the quantity of wood pellets sold to each customer in order to ensure wood pellet supply for the local loyal customers. In 2008, a nationwide pellet shortage was due to the increasing demand in wood pellets (Bier 2007; Goh et al. 2013). Homeowners in Maryland experienced shortage in wood pellets supply in 2013 and 2014 (Ackerly 2014). The result shows that 20% of the wood pellets users had experienced the rationing of wood pellets. Ensuring a stable wood pellets supply is a critical condition. Last and most importantly, instead of hauling pellets from other states, a pellet manufacturing facility in Maryland can reduce the wood pellets price by decreasing the transportation costs. Lower wood pellets prices can motivate homeowners to switch to wood or increase wood usage. More people seeing more homeowners using a clean burning wood pellet stoves and more affordable wood pellets may attract more users and go a long way in rejecting problematic stereotypes.

The volume of wood burned statewide during 2015-2016 was estimated from the demand perspective. However, from the supply perspective, the volume of wood sold and produced in Maryland remains unclear. In order to provide informed insight and thorough information for forest industry and government agencies, it is essential to monitor wood usage on a regular basis and assess the volume of wood sold statewide.

Much work is needed to better understand the motivations and challenges of wood heating for low income homeowners. The survey received responses from affluent and well-educated respondents who own sizeable home properties. Also, Maryland's mean annual household income is higher than the national average. The survey had only a few responses from low income households that heat with wood. These households tend be very vulnerable to heating cost changes, but they were not fully addressed in this survey.

Eligible households can receive benefits from the Maryland Energy Assistance Program to manage their home energy costs. Therefore, further research should focus on how such a program can affect wood heating adoption by low income households, and identify potential challenges they encounter when using wood.

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Appendices

Appendix A: Firewood/Wood Pellet Current Users Survey Instrument

Survey A: Firewood/Wood Pellet Current Users

Only fill out this survey if you currently use firewood or wood pellets

By participating in this survey, you indicate that you are at least 18 years old, you have read the consent language included in the introductory letter or have had it read to you, your questions have been answered to your satisfaction, and you voluntarily agree to participate in this research study. *(Circle one.)* **Yes** **No**

1. Do you own or rent your home? ❑Own ❑Rent

2. What is your home zip code? _____

3. Check the county of your primary residence.

❑Allegany County	❑Dorchester County	❑Queen Anne's County
❑Anne Arundel County	❑Frederick County	❑St. Mary's County
❑Baltimore County	❑Garrett County	❑Somerset County
❑Calvert County	❑Harford County	❑Talbot County
❑Caroline County	❑Howard County	❑Washington County
❑Carroll County	❑Kent County	❑Wicomico County
❑Cecil County	❑Montgomery County	❑Worcester County
❑Charles County	❑Prince George's County	

4. What is your primary heating source? "Primary" is source used 50% or more of the time. *(Check only one.)*

❑Wood pellet	❑Heat pump	❑Solar
❑Firewood	❑Oil	❑Propane
❑Natural gas	❑Kerosene	❑Other_____
❑Electricity	❑Coal	❑Don't know

5. What is your secondary heating source? "Secondary" is source used less than 50% of the time *(Check only one.)*

❑Wood pellet	❑Oil	❑Other_____
❑Firewood	❑Kerosene	❑Don't know
❑Natural gas	❑Coal	❑N/A (Not applicable)
❑Electricity	❑Solar	
❑Heat pump	❑Propane	

6. How old is your primary heating system?

❑Less than 1 year old
❑1 to 5 years old
❑6 to 10 years old
❑More than 10 years old

7. How old is your secondary heating system?

- ❑ Less than 1 year old
- ❑ 1 to 5 years old
- ❑ 6 to 10 years old
- ❑ More than 10 years old
- ❑ N/A

8. How many years have you used firewood or wood pellets in a wood or pellet stove, wood burning furnace, or fireplace?

- ❑ Less than 1 year
- ❑ 1 to 3 years
- ❑ 4 to 6 years
- ❑ 7 to 10 years
- ❑ More than 10 years

9. Which of the following do you use? *(Check all that apply.)*

- ❑ Fireplace
- ❑ Fireplace inserts (firewood or pellet)
- ❑ Wood stove (stand-alone)
- ❑ Wood pellet stove (stand-alone)
- ❑ Wood-burning boiler and other

10. Estimate the percentage of your overall, annual heat that comes from firewood or wood pellets.

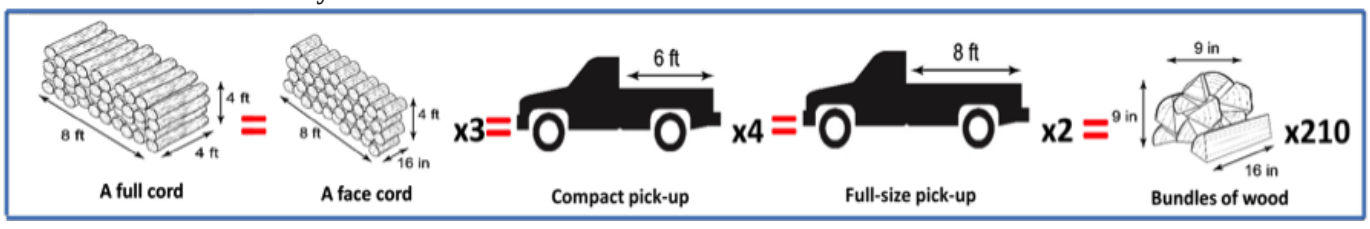
_____%

11. Please indicate the quantity of firewood or wood pellets you burned in the past 12 months in your fireplace or wood-burning appliance. *(Please answer to the best of your ability; use the enclosed card that describes cordwood amounts.)*

_____ Full cords (answer to the nearest half cord)

_____ Number of (40 lbs.) bags of wood pellets or_____number of tons of wood pellets *(Answer only one.)*

Firewood Calculation Key



12. What motivated you to use firewood or wood pellets? *(Check all that apply.)*

- ❑ Lower cost compared to other sources of fuel
- ❑ Firewood or wood pellets are renewable and environmentally friendly
- ❑ I have free access to wood
- ❑ I want to support local wood businesses
- ❑ I like the way wood heat feels
- ❑ Most of my friends and neighbors use wood
- ❑ Wood appliance is easy to maintain
- ❑ I like the aesthetics of wood-burning fire
- ❑ Maryland Clean Burning Wood Stove Grant Program
- ❑ Other_____

13. During the past 5 years, the price of many home-heating sources, such as oil, electricity, natural gas, and propane, has fluctuated greatly. How have these price fluctuations affected your firewood or wood pellet usage?

❑ Did not change my usage
❑ Decreased my firewood/pellet usage
❑ Increased my firewood/pellet usage
❑ Don't know

14. Please select your response below from the following statement: "If the price of my primary heating source were to increase by_____, I would increase my current usage of firewood or wood pellets." *(Please choose only one.)*

❑ 10%
❑ 25%
❑ 50%
❑ 75%
❑ 100%
❑ Would not change under any circumstance
❑ Don't know

15. What is the average price you paid for a cord of firewood or wood pellets over the past year?

Firewood: $_____per cord
Firewood: $_____per bundle (purchased at local store; typically 4–5 pieces per bundle)
Firewood: $ 0. I have free access to firewood
Wood pellets: $_____per ton or $_____per bag

16. Of the wood you used, please estimate the percentage of wood you had free access to._____%

17. In what state and county, if known, did you purchase or obtain your firewood or wood pellets?

❑ State_____County_____*(If known.)*
❑ Don't know

18. Did you experience any of the following when purchasing firewood or wood pellets during the past year? *(Check all that apply.)*

❑ Regular supplier was out of business
❑ Regular supplier was unable to supply or ran out
❑ Delays in delivery
❑ Unable to get seasoned firewood
❑ Rationing of wood pellets
❑ Not applicable: I have free access to firewood
❑ Supplier claimed firewood was seasoned, but it was not
❑ Other_____

19. Did you participate in Maryland's Clean-Burning Wood Stove Grant Program administered by Maryland Energy Administration?

❑ No (Skip to Question 21)
❑ Yes

20. Was this program one of the factors that led you to buy a firewood or wood pellet stove?

❑ Yes
❑ No

21. What is your sex? ❑ Male ❑ Female

22. What is the approximate square footage of your home?

- ❑Less than 1,000
- ❑1,000 to 1,499
- ❑1,500 to 1,999
- ❑2,000 to 2,499
- ❑2,500 to 2,999
- ❑3,000 to 3,499
- ❑3,500 to 3,999
- ❑4,000 to 4,999
- ❑4,500 or more
- ❑Don't know

23. What is your age?

- ❑18-29
- ❑30-39
- ❑40-49
- ❑50-59
- ❑60-69
- ❑70-79
- ❑80-89
- ❑90+

24. What is the highest level of education that you have achieved? *(Check one.)*

- ❑ Less than high school diploma
- ❑ High school diploma or GED
- ❑ 2-year community college/technical/vocational degree
- ❑ Some college at a 4-year institution
- ❑ 4-year college degree
- ❑ Advanced degree beyond 4-year degree

25. What was your approximate annual household income before taxes last year?

- ❑ Less than $20,000
- ❑$20,000 to $39,999
- ❑$40,000 to $59,999
- ❑$60,000 to $79,999
- ❑$80,000 to $99,999
- ❑$100,000 to $149,999
- ❑$150,000 to $199,999
- ❑$200,000 or over

If you would like to receive a free Firewood Calculation Key or copies of the University of Maryland Extension electronic newsletter, "Branching Out," which features articles, news of educational events, and timely tips on wood burning, trees, forest and wildlife management, and other natural resources–related topics, please fill out the enclosed postcard and return it in the mail.

For additional information on residential wood burning, please visit our University of Maryland Extension website at www.extension.umd.edu/woodland.

For information on the Maryland Energy Administrations' Clean-Burning Wood Stove Grant Program, please visit http://energy.maryland.gov/residential/Pages/incentives/woodstoves.aspx.

Please place the survey in the postage-paid envelope provided and drop it in the mail.

Thank you for completing the survey.

Appendix B: Firewood/Wood Pellet Nonusers Survey Instrument

Survey B: Firewood/Wood Pellet Non-Users

Only fill out this survey if you currently use firewood or wood pellets

By participating in this survey, you indicate that you are at least 18 years old, you have read the consent language included in the introductory letter or have had it read to you, your questions have been answered to your satisfaction, and you voluntarily agree to participate in this research study. *(Circle one.)* **Yes** **No**

1. Do you own or rent your home? ❑Own ❑Rent

2. What is your home zip code? _____

3. Check the county of your primary residence.

❑Allegany County
❑Anne Arundel County
❑Baltimore County
❑Calvert County
❑Caroline County
❑Carroll County
❑Cecil County
❑Charles County
❑Dorchester County
❑Frederick County
❑Garrett County
❑Harford County
❑Howard County
❑Kent County
❑Montgomery County
❑Prince George's County
❑Queen Anne's County
❑St. Mary's County
❑Somerset County
❑Talbot County
❑Washington County
❑Wicomico County
❑Worcester County

4. What is your primary heating source? *(Check only one.)*

❑Natural gas
❑Electricity
❑Heat pump
❑Oil
❑Kerosene
❑Coal
❑Solar
❑Propane
❑Other_____
❑Don't know

5. How old is your primary heating system?

❑Less than 1 year old
❑1 to 5 years old
❑6 to 10 years old
❑More than 10 years old

6. Why do you **not** use firewood or wood pellets as a heating source? *(Check all that apply.)*

- ❑ Other heating sources are cheaper
- ❑ Home does not have fireplace
- ❑ Wood heating is too much work and mess
- ❑ Installing a wood or pellet stove is too expensive
- ❑ Wood and pellet stoves look unattractive
- ❑ Wood and pellet stoves are not compatible with my home
- ❑ Wood stoves create too much pollution and are not environmentally friendly
- ❑ Family member is sensitive to wood smoke
- ❑ Difficulty finding firewood or wood pellets
- ❑ Difficulty handling firewood or wood pellets
- ❑ Do not know much about firewood or wood pellets as a heating source
- ❑ Other_____

7. My estimated winter monthly heating bill is $_____.

8. Please select your response below from the following statement: "If the price of my primary heating source were to increase by , I would consider using firewood or wood pellets." *(Please choose only one.)*

- ❑ 10%
- ❑ 25%
- ❑ 50%
- ❑ 75%
- ❑ 100%
- ❑ Would not change under any circumstance
- ❑ Don't know

9. To help Maryland homeowners invest in clean energy, the Maryland Energy Administration (MEA) offers a Clean-Burning Wood Stove Grant Program. This program provides a rebate (of $500 for wood-burning stoves and $700 for pellet stoves) for the purchase of clean-burning wood stoves that displace electric, fossil fuel heating systems, or old woodstoves. Are you aware of this program?

- ❑ Yes
- ❑ No

10. The cost to buy and install a wood or pellet stove can range in price from $2,000 to $4,500, depending on the quality of the stove and your existing home conditions. Hypothetically, if Maryland's Clean-Burning Wood Stove Grant Program were to increase its flat rate from $500 to $700 for a wood stove and from $700 to $900 for a pellet stove, would you consider installing a wood or pellet stove as a source of home heating?

- ❑ Yes
- ❑ No
- ❑ Not interested under any circumstances
- ❑ Maybe, if I had more information
- ❑ Would consider if the incentives were higher

11. What is your sex? ❑ Male ❑ Female

12. What is the approximate square footage of your home?

- ❑Less than 1,000
- ❑1,000 to 1,499
- ❑1,500 to 1,999
- ❑2,000 to 2,499
- ❑2,500 to 2,999
- ❑3,000 to 3,499
- ❑3,500 to 3,999
- ❑4,000 to 4,999
- ❑4,500 or more
- ❑Don't know

13. What is your age?

- ❑18–29
- ❑30–39
- ❑40–49
- ❑50–59
- ❑60–69
- ❑70–79
- ❑80–89
- ❑90+

14. What is the highest level of education that you have achieved? *(Check one.)*

- ❑ Less than high school diploma
- ❑ High school diploma or GED
- ❑ 2-year community college/technical/vocational degree
- ❑ Some college at a 4-year institution
- ❑ 4-year college degree
- ❑ Advanced degree beyond 4-year degree

15. What was your approximate annual household income before taxes last year?

- ❑Less than $20,000
- ❑$20,000 to $39,999
- ❑$40,000 to $59,999
- ❑$60,000 to $79,999
- ❑$80,000 to $99,999
- ❑$100,000 to $149,999
- ❑$150,000 to $199,999
- ❑$200,000 or over

If you would like to receive a free Firewood Calculation Key or copies of the University of Maryland Extension electronic newsletter, "Branching Out," which features articles, news of educational events, and timely tips on wood burning, trees, forest and wildlife management, and other natural resources–related topics, please fill out the enclosed postcard and return it in the mail.

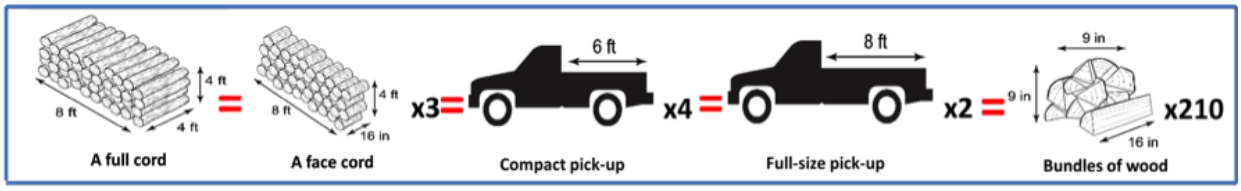
For additional information on residential wood burning, please visit our University of Maryland Extension website at www.extension.umd.edu/woodland.

For information on the Maryland Energy Administrations' Clean-Burning Wood Stove Grant Program, please visit http://energy.maryland.gov/residential/Pages/incentives/woodstoves.aspx.

Please place the survey in the postage-paid envelope provided and drop it in the mail.

Thank you for completing the survey.

Firewood Calculation Key



Appendix C: Firewood/Wood Pellet Current Users Survey Summary Statistics

Survey A (Wood Users) Summary Statistics

1. Do you own or rent your home?

	Response	%
Owner	492	99%
Missing Value	3	1%

2. What is your home zip code?

3. Check the county of your primary residence

	Response	%
Allegany	1	0%
Anne Arundel	58	12%
Baltimore	64	13%
Calvert	17	3%
Caroline	6	1%
Carroll	47	10%
Cecil	14	3%
Charles	16	3%
Dorchester	3	1%
Frederick	29	6%
Garrett	6	1%
Harford	43	9%
Howard	47	10%
Kent	7	1%
Montgomery	53	11%
Prince George's	34	7%
Queen Anne's	6	1%
Somerset	1	0%
St. Mary's	15	3%
Talbot	8	2%
Washington	7	1%
Wicomico	4	1%
Worcester	5	1%

4. What is your primary heating source? “Primary” is source used 50% or more of the time. (Check only one.)

	Response	%
Electricity	54	11%
Firewood	53	11%
Heat pump	144	29%
Natural gas	78	16%
Oil	88	18%
Other	15	3%
Propane	28	6%
Solar	2	0%
Wood pellet	28	6%

5. What is your secondary heating source? “Secondary” is source used less than 50% of the time (Check only one.)

	Response	%
Electricity	30	6%
Firewood	247	53%
Heat pump	38	8%
Kerosene	1	0%
Natural gas	12	3%
Oil	23	5%
Other	9	2%
Propane	24	5%
Solar	5	1%
Wood pellet	76	16%

6. How old is your primary heating system?

	Response	%
1 to 5 years old	128	26%
6 to 10 years old	129	26%
Less than 1 year old	27	5%
More than 10 years old	209	42%

7. How old is your secondary heating system?

	Response	%
1 to 5 years old	80	16%
6 to 10 years old	59	12%
Less than 1 year old	18	4%
More than 10 years old	285	59%
N/A (Not Applicable)	45	9%

8. How many years have you used firewood or wood pellets in a wood or pellet stove, wood burning furnace, or fireplace?

	Response	%
1 to 3 years	50	10%
4 to 6 years	48	10%
7 to 10 years	51	10%
Less than 1 year	11	2%
More than 10 years	327	67%

9. Which of the following do you use? (Check all that apply.)

	Response	%
Fireplace	197	40%
Fireplace inserts (firewood or pellet)	150	30%
Wood stove (stand-alone)	120	24%
Wood pellet stove (stand-alone)	70	14%
Wood-burning boiler	6	1%

10. Estimate the percentage of your overall, annual heat that comes from firewood or wood pellets. _____%

	Min Value	Max Value	Mean	Std Dev	Responses
Percentage of heat from wood	5%	100%	29%	29.27	469

11. Please indicate the quantity of firewood or wood pellets you burned in the past 12 months in your fireplace or wood-burning appliance. (Please answer to the best of your ability; use the enclosed card that describes cordwood amounts.)

	Min Value	Max Value	Mean	Std Dev	Responses
Firewood (cords)	0.10	18	1.80	1.89	367
Wood Pellets (tons)	0.04	13	1.9	1.73	111

12. What motivated you to use firewood or wood pellets? (Check all that apply.)

	Response	%
Lower cost compared to other sources of fuel	198	40%
Firewood or wood pellets are renewable and environmentally friendly	134	27%
I have free access to wood	202	41%
I want to support local wood businesses	18	4%
I like the way wood heat feels	266	54%
Most of my friends and neighbors use wood	12	2%
Wood appliance is easy to maintain	70	14%
I like the aesthetics of wood-burning fire	280	57%
Maryland Clean Burning Wood Stove Grant Program	8	2%

13. During the past 5 years, the price of many home-heating sources, such as oil, electricity, natural gas, and propane, has fluctuated greatly. How have these price fluctuations affected your firewood or wood pellet usage?

	Response	%
Did not change my usage	383	79%
Decreased my firewood/pellet usage	11	2%
Increased my firewood/pellet usage	85	17%
Don’t know	7	1%

14. Please select your response below from the following statement: “If the price of my primary heating source were to increase by , I would increase my current usage of firewood or wood pellets.” (Please choose only one.)

	Response	%
10%	36	7%
25%	84	17%
50%	72	15%
75%	15	3%
100%	12	2%
Would not change under any circumstance	172	36%
Don't Know	93	19%

15. What is the average price you paid for a cord of firewood or wood pellets over the past year?

	Min Value	Max Value	Mean	Std Dev	Responses
Firewood (Dollars per cord)	6	375	192	65.45	160
Firewood (Dollars per Bundle)	3.99	10	6	1.29	20
Wood Pellet (Dollars per ton)	150	500	266	52.76	105

16. Of the wood you used, please estimate the percentage of wood you had free access to.
%

	Min Value	Max Value	Mean	Std Dev	Responses
% of free wood	0%	100%	56%	45.72	409

17. In what state and county, if known, did you purchase or obtain your firewood or wood pellets?

	Response	%
DE	1	0%
MD	403	91%
MD	21	5%
NY	1	0%
PA	9	2%
VA	5	1%
WV	1	0%

18. Did you experience any of the following when purchasing firewood or wood pellets during the past year? (Check all that apply.)

	Response	%
Regular supplier was out of business	10	2%
Regular supplier was unable to supply or ran out	54	11%
Delays in delivery	17	3%
Unable to get seasoned firewood	26	5%
Rationing of wood pellets	20	4%
Not applicable: I have free access to firewood	195	39%
Supplier claimed firewood was seasoned, but it was not	25	5%

19. Did you participate in Maryland's Clean-Burning Wood Stove Grant Program administered by Maryland Energy Administration?

	Response	%
Yes	25	5%

No	470	95%

20. Was this program one of the factors that led you to buy a firewood or wood pellet stove?

	Response	%
Yes	8	32%
No	17	68%

21. What is your sex?

	Response	%
Male	344	73%
Female	130	27%

22. What is the approximate square footage of your home?

	Response	%
Less than 1,000	1	0%
1,000 to 1,499	19	4%
1,500 to 1,999	83	17%
2,000 to 2,499	130	27%
2,500 to 2,999	96	20%
3,000 to 3,499	67	14%
3,500 to 3,999	36	7%
4,000 to 4,999	20	4%
5,000 or more	18	4%
Don't Know	13	3%

23. What is your age?

	Response	%
18-29	4	1%
30-39	35	7%
40-49	70	14%
50-59	170	35%
60-69	150	31%
70-79	45	9%
80-89	13	3%
90+	1	0%

24. What is the highest level of education that you have achieved?

	Response	%
Less than high school diploma	1	0%
High school diploma or GED	62	13%
2-year community college/technical/vocational degree	75	15%
Some college at a 4-year institution	39	8%
4-year college degree	140	29%
Advanced degree beyond 4-year degree	171	35%

25. What was your approximate annual household income before taxes last year?

	Response	%
Less than $20,000	3	1%
$20,000 to $39,999	16	4%
$40,000 to $59,999	42	9%
$60,000 to $79,999	44	10%
$80,000 to $99,999	59	13%
$100,000 to $149,999	110	25%
$150,000 to $199,999	85	19%
$200,000 or over	85	19%

Appendix D: Firewood/Wood Pellet Nonusers Survey Summary Statistics

Survey B (Nonusers) Summary Statistics

1. Do you own or rent your home?

	Response	%
Owner	680	99%
Missing Value	9	1%

2. What is your home zip code?

3. Check the county of your primary residence

	Response	%
Allegany	14	2%
Anne Arundel	70	10%
Baltimore	43	6%
Calvert	24	4%
Caroline	8	1%
Carroll	34	5%
Cecil	20	3%
Charles	26	4%
Dorchester	0	0%
Frederick	44	6%
Garrett	3	0%
Harford	28	4%
Howard	75	11%
Kent	4	1%
Montgomery	128	19%
Prince George's	55	8%
Queen Anne's	19	3%
Somerset	1	0%
St. Mary's	33	5%
Talbot	17	2%
Washington	11	2%
Wicomico	16	2%
Worcester	12	2%

4. What is your primary heating source? (Check only one.)

	Response	%
Coal	1	0%
Electricity	96	14%
Geothermal	9	1%
Heat pump	164	24%
Natural gas	246	36%
Oil	80	12%
Other	23	3%
Propane	63	9%
Solar	1	0%

5. How old is your primary heating system?

	Response	%
Less than 1 year old	33	5%
1 to 5 years old	173	25%
6 to 10 years old	191	28%
More than 10 years old	286	42%

6. Why do you not use firewood or wood pellets as a heating source? (Check all that apply.)

	Response	%
Other heating sources are cheaper	78	11%
Home does not have fireplace	216	31%
Wood heating is too much work and mess	331	48%
Installing a wood or pellet stove is too expensive	130	19%
Wood and pellet stoves look unattractive	70	10%
Wood and pellet stoves are not compatible with my home	110	16%
Wood stoves create too much pollution and are not environmentally friendly	82	12%
Family member is sensitive to wood smoke	98	14%
Difficulty finding firewood or wood pellets	33	5%
Difficulty handling firewood or wood pellets	83	12%
Do not know much about firewood or wood pellets as a heating source	99	14%

7. My estimated winter monthly heating bill is $__.

	Min Value	Max Value	Mean	Std Dev	Responses
Winter heating bill	35	4000	415	469.03	644

8. Please select your response below from the following statement: “If the price of my primary heating source were to increase by , I would consider using firewood or wood pellets.” (Please choose only one.)

	Response	%
10%	19	3%
25%	71	11%
50%	82	12%
75%	21	3%
100%	45	7%
Would not change under any circumstance	286	42%
Don't Know	149	22%

9. To help Maryland homeowners invest in clean energy, the Maryland Energy Administration (MEA) offers a Clean-Burning Wood Stove Grant Program. This program provides a rebate (of $500 for wood-burning stoves and $700 for pellet stoves) for the purchase of clean-burning wood stoves that displace electric, fossil fuel heating systems, or old woodstoves. Are you aware of this program?

	Response	%
Yes	16	2%
No	673	98%

10. The cost to buy and install a wood or pellet stove can range in price from $2,000 to $4,500, depending on the quality of the stove and your existing home conditions. Hypothetically, if Maryland’s Clean-Burning Wood Stove Grant Program were to increase its flat rate from $500 to $700 for a wood stove and from $700 to $900 for a pellet stove, would you consider installing a wood or pellet stove as a source of home heating?

	Response	%
Maybe, if I had more information	139	21%
No	249	37%
Not interested under any circumstances	134	20%
Would consider if the incentives were higher	79	12%
Yes	75	11%

11. What is your sex?

	Response	%
Male	394	66%
Female	207	34%

12. What is the approximate square footage of your home?

	Response	%
Less than 1,000	1	0%
1,000 to 1,499	24	4%
1,500 to 1,999	105	16%
2,000 to 2,499	142	21%
2,500 to 2,999	144	22%
3,000 to 3,499	113	17%
3,500 to 3,999	44	7%
4,000 to 4,999	45	7%
5,000 or more	37	6%
Don't Know	13	2%

13. What is your age?

	Response	%
18-29	10	1%
30-39	35	5%
40-49	120	18%
50-59	187	28%
60-69	196	29%
70-79	87	13%
80-89	34	5%
90+	4	1%

14. What is the highest level of education that you have achieved?

	Response	%
Less than high school diploma	5	1%
High school diploma or GED	78	12%
2-year community college/technical/vocational degree	76	11%
Some college at a 4-year institution	45	7%
4-year college degree	216	32%
Advanced degree beyond 4-year degree	258	38%

15. What was your approximate annual household income before taxes last year?

	Response	%
Less than $20,000	6	1%
$20,000 to $39,999	23	4%
$40,000 to $59,999	35	6%
$60,000 to $79,999	57	9%
$80,000 to $99,999	89	14%
$100,000 to $149,999	178	29%
$150,000 to $199,999	93	15%
$200,000 or over	134	22%

Appendix E: Introductory Letter

UNIVERSITY OF MARYLAND
DEPARTMENT OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY

1426 An. Sci. / Agr. Engr. Bldg.
College Park, Maryland 20742-2315
301.405.1198 TEL 301.314.9023 FAX

February 19, 2016

Dear Maryland Homeowner:

On behalf of the University of Maryland, College of Agriculture and Natural Resources, I am conducting a study of firewood and wood pellet usage by Maryland single-family homeowners as part of a research project, with my graduate student, Ms. Cuiyin Wu.

The project's objectives are to better understand and measure:

- the percentage of Maryland homeowners who use firewood and wood pellets,
- the motivational factors for and barriers to homeowners' use of firewood and wood pellets,
- the future potential of firewood and wood pellets as a heating source.

Identifying and evaluating the market potential of firewood and wood pellets will go a long way toward achieving our goals: to inform homeowners of available home heating options, which should save money spent on heating bills; to help Maryland's forest industry remain vibrant and profitable; and, at the same time, to ensure that the state's forests remain healthy and sustainable.

Your contribution to this study, therefore, holds a high value. Survey information will assist foresters, forest business professionals, policymakers, and forest landowners, along with University of Maryland Extension Educators, to make informed decisions about the future of Maryland's forests and its forest industry.

Your participation in this research is completely voluntary. All individual information collected and analyzed will be strictly confidential and will not be shared outside this research effort. Your identity will be coded; therefore, responses will not be traceable to individuals. The survey should only take about 5 minutes to complete. We suggest you retain a copy of this letter for your records, for it will be helpful when you complete the survey. Next week, on my behalf, Mason-Dixon Polling & Research Group of Washington, DC, will be mailing you and other Maryland homeowners the survey.

Should you have questions or concerns about any survey question, please contact me, Bob Tjaden, University of Maryland, 410-827-8056 or rtjaden@umd.edu. If you should have questions about your rights as a research participant, you may contact the University of Maryland Institutional Review Board office at 301-405-0678 or irb@umd.edu.

Thank you for taking time to consider participating in this survey,

Dr. Bob Tjaden
Extension Specialist & Professor
University of Maryland
College of Agriculture & Natural Resources

Cuiyin Wu

Ms. Cuiyin Wu
M.S. Graduate Student
University of Maryland
College of Agriculture & Natural Resources

Appendix F: Mason-Dixon Instruction Letter

Mason-Dixon
Polling & Research

Memorandum

To: Maryland Homeowners

From: Larry Harris, Principal
Mason-Dixon Polling & Research
202-548-2680, lharris@mason-dixon.com

Date: 2/23/2016

Subject: University of Maryland Home Heating Survey

Recently you should have received a letter from the University of Maryland, College of Agriculture & Natural Resources encouraging your participation in an important survey of Maryland households concerning the current and potential use of firewood and wood pellets as home heating sources.

As the University's letter notes, **Mason-Dixon Polling & Research** is conducting this survey on behalf of **Dr. Robert Tjaden** and colleagues at the **University of Maryland, College of Agricultural and Natural Resources.** Your participation and responses to the survey are confidential. Mason-Dixon will not provide the University nor anyone else with your individual responses. Results of the survey will be reported in the aggregate.

Enclosed with this memorandum you will find two brief surveys.

Survey A: Firewood/Wood Pellet Current Users

Survey B: Firewood/Wood Pellet Non-Users

Please follow the directions on the appropriate survey and return the completed survey in the self addressed stamped envelope provided.

You may also complete either survey online quickly and easily by going to:

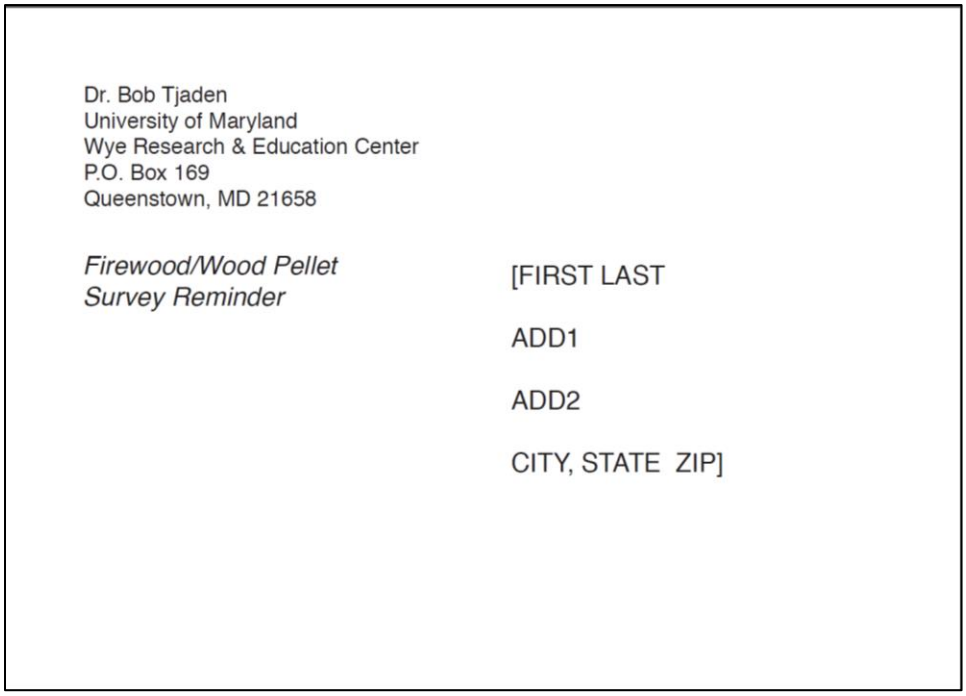
mason-dixon.com/heat

Many thanks for your participation in this important survey.

Questions concerning the administration of the survey should be directed to Larry Harris of Mason-Dixon Polling & Research. *(202-548-2680, lharris@mason-dixon.com)*

All other questions or concerns should be directed to Dr. Bob Tjaden, Extension Specialist, University of Maryland, College of Agriculture & Natural Resources.
(410-827-8056 rtjaden@umd.edu)

Appendix G: Follow-up Post Card



Dr. Bob Tjaden
University of Maryland
Wye Research & Education Center
P.O. Box 169
Queenstown, MD 21658

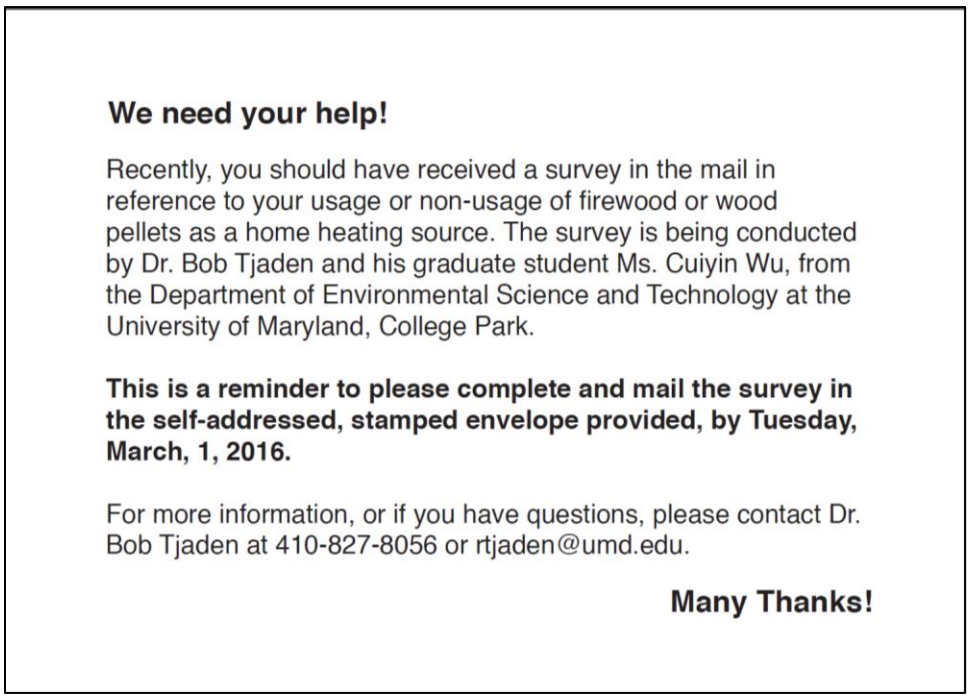
Firewood/Wood Pellet Survey Reminder

[FIRST LAST

ADD1

ADD2

CITY, STATE ZIP]



We need your help!

Recently, you should have received a survey in the mail in reference to your usage or non-usage of firewood or wood pellets as a home heating source. The survey is being conducted by Dr. Bob Tjaden and his graduate student Ms. Cuiyin Wu, from the Department of Environmental Science and Technology at the University of Maryland, College Park.

This is a reminder to please complete and mail the survey in the self-addressed, stamped envelope provided, by Tuesday, March, 1, 2016.

For more information, or if you have questions, please contact Dr. Bob Tjaden at 410-827-8056 or rtjaden@umd.edu.

Many Thanks!

Appendix H: Branching-out Post Card

DEPARTMENT OF
ENVIRONMENTAL SCIENCE
& TECHNOLOGY

Please send me information on:

___University of Maryland Extension newsletter, "Branching Out"

___Firewood Calculation Key

_____

Name:

_____

Address

_____

City, State, ZIP

_____

Email Address

If you would like to receive a free Firewood Calculation Key or copies of the University of Maryland Extension electronic newsletter, "Branching Out," which features articles, news of educational events, and timely tips on wood burning, trees, forest and wildlife management, and other natural resources–related topics, provide your contact information on the other side of this card. Please enclose it and the completed survey in the self-addressed, stamped envelope provided with the survey. If you completed the survey online, please enclose this card in the self-addressed, stamped envelope provided with the card.

Many Thanks!

Appendix I: Firewood Calculation Magnet