

Prevalence trends of wood use as the main cooking fuel in Mexico, 1990-2013

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Abstract

Objective. To determine prevalence trends of using Wood as the Main Cooking Fuel (WMCF) in Mexico and household characteristics that predict its use. **Materials and methods.** Estimates were obtained from the 1990, 2000 and 2010 censuses and from a national survey performed in 2012 and 2013. **Results.** In 2012-2013, 9.5% of the 66 321 surveyed households and 10.9% of their 252 011 residents used WMCF. Prevalence was higher in rural (40.5%) than urban areas (1.5%), $p<0.0001$. From 1990 to 2013 wood use decreased by 53% overall and by 28.6% in rural areas, gas use increased respectively by 17.5 and 52.7%. Predictors of using WMCF were living in rural or suburban areas and those associated with low socioeconomic status. **Conclusion.** Use of WMCF has decreased substantially in Mexico but at a slower pace in rural areas. Improving household characteristics and socioeconomic status may decrease use of WMCF at a higher rate.

Keywords: prevalence; trends; wood; cooking; Mexico

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Resumen

Objetivo. Determinar las tendencias temporales de prevalencia del uso de leña utilizada para cocinar (ULPC) y características del hogar que lo predicen. **Material y métodos.** Los estimados se obtuvieron de los censos 1990, 2000 y 2010 y de la encuesta nacional de 2012-2013. **Resultados.** En el periodo 2012-2013, 9.5% de los 66 321 hogares y 10.9% de sus 252 011 residentes usaron LPC. La prevalencia fue mayor en áreas rurales (40.5%) que las urbanas (1.5%), $p<0.0001$. De 1990 a 2013 el ULPC disminuyó 53% en todo el país y 28.6% en áreas rurales. Contrariamente, el uso de gas incrementó 17.5 y 52.7% respectivamente. Los predictores del ULPC fueron el vivir en áreas rurales o suburbanas, y aquellos asociados al nivel socioeconómico bajo. **Conclusión.** El ULPC ha disminuido pero a ritmo lento en las áreas rurales de México. Mejorar las características del hogar y nivel socioeconómico pudiera disminuir el ULPC a mayor ritmo.

Palabras clave: prevalencia; tendencias; madera; cocina; México

Though all home energy use can impact health in various ways, the most important direct health risk is household air pollution caused by the incomplete combustion of fuel in low-efficiency stoves and lamps used for cooking, space heating and lighting. In 2012,

the World Health Organization (WHO) estimated that close to three billion people lacked access to clean or modern energy services for cooking, resulting in 4.3 million premature annual deaths with 34% due to stroke, 26% to ischaemic heart disease, 22% to chronic obstructive

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tive pulmonary disease (COPD), 12% pneumonia, and 6% to lung cancer.^{1,2} Although the percentage of homes relying primarily on solid fuels for cooking has gradually fallen from 62% in 1980 to 41% in 2010, population growth means the actual number of users has remained stable at 2.8 billion over the same period.³ There has been minimum progress from 1990 to 2015 to reduce by half the number using solid fuels for cooking, 485 000 people daily should have access to clean fuels to achieve this. Household air pollution (HAP) is responsible for nearly 5% of the global disease burden expressed as disability-adjusted life-years (DALYs), making it globally the single most important environmental risk factor.⁴ Combustion-derived indoor pollutants that have been associated with adverse health effects include particulate matter smaller than 10 μm , benzene, carbon monoxide, formaldehyde, naphthalene, nitrogen dioxide, polycyclic-aromatic hydrocarbons including benzo[a]pyrene.¹ A Mexican projection study determined that in 2010 fuelwood and charcoal accounted for 48% of total residential energy demand. The projection of fuelwood consumption will slightly decline from 19.4 Mt (dry wood equivalent) in 2010 to 18.4 Mt by 2030.⁵ About 1.3TgCO₂ y⁻¹ are released to the atmosphere by non-renewable fuelwood burning, a value that represents less than 1% of Mexican total annual CO₂ emissions in 2002.⁶ Estimates from three previous Mexican censuses carried out in 1990, 2000 and 2010 and other studies established an overall prevalence of using solid fuels or wood for cooking in Mexico to be between 20 and 49% with the lowest rates in urban areas (0.2%) and the highest of up to 89% in rural areas.⁷⁻¹² Globally the use of solid fuels for cooking has decreased but more country specific studies in the Americas are needed, for example: Peru's use of solid fuel from 1980 to 2010 decreased respectively from approximately 80 to 40% and Colombia from 28 to 18% respectively.³

Currently there are no Mexican studies comparing the prevalence of using solid fuels in the household over time. Estimation of the current prevalence of solid fuel use is also needed for monitoring trends and informing policy. The main objectives of this country-wide study were to determine the most current prevalence of using wood in the household as the main cooking fuel (WMCF) in Mexico in the period 2012-2013 and to establish prevalence trends since 1990. We also determined household characteristics that would predict the use of WMCF.

Materials and methods

The 2012-2013 population and household prevalence estimates in use of WMCF were obtained from the data bases of the national survey on household expense in

Mexico or Engasto (Encuesta Nacional de Gastos de los Hogares) that are available online.^{13,14} The aim of Engasto is to calculate the consumer price index (Indice Nacional de Precios al Consumidor or INPC) to determine poverty levels and distribution of household expenses. This survey was performed in 2012 and again in 2013 on a representative sample of households of the whole country including rural, sub-urban and urban communities and also in 46 cities covered by the INPC. The probability method was used for sample size calculation and included the stratified and clustered sampling methods; therefore, estimates presented here are representative of the whole country. The methodology, the sample size calculation method and the survey questionnaire of the Engasto survey are described in detail in the INEGI website.^{13,14} Questionnaire information includes: residence identification number, surveyed community size, socioeconomic status (SES), number of residents and number of rooms in the residence, whether the residence has a kitchen or a chimney, garbage disposal and construction material of the residence. The survey included a question regarding the type of cooking fuel used stated as follows, "What fuel is most frequently used for cooking in the household?" with the following options: "Wood, coal, gas or LPG (liquefied petroleum gas also called propane or butane, referred hereafter as gas), electricity and others". Due to the fact that the specific fuel was not identified under "others", (n=774 households, 1.2%) and that there were few households where "coal" was used for cooking (n=291, prevalence of 0.4%), these two groups were included only in the descriptive results and excluded from the analytic part of the study. To determine household characteristics that predict the use of WMCF we grouped households that used "clean" fuels for cooking i.e. "gas" or "electricity" in one category and considered this the reference group in the multivariable analysis.

Household information from 2012 and 2013 surveys was linked to obtain the prevalence in both years together. We excluded households that were surveyed in both years. Prevalence estimates of fuel used for cooking were obtained for the whole sample of households, by surveyed population size of communities (urban: more than 100 000 inhabitants, suburban 2 500 to 99 999 and rural with less than 2 500) and by the number of residents living in the residence.

To establish trends of prevalence of wood use over time we compared the 2012-2013 estimate with those reported in the previous three Mexican censuses carried out in 1990, 2000 and 2010. Population rates of use of wood for cooking for the years 1990 and 2000 and household rates of wood use for year 2010 are available online.⁸ The Engasto survey follows the same methodology as the censuses' as both are part of the INEGI program.¹⁵

The only difference with regard to the responses of the fuel used for cooking is that in the 1990 and 2000 censuses, petroleum was included in the analysis and wood and coal were grouped in one category. In the Engasto survey the former was not included and the latter two were considered separately. The descriptive analysis was performed by using Microsoft Excel and the analytic part of the study by using SAS University Edition. Two by two tables were generated to obtain odds ratios and 95% confidence intervals of each household characteristics associated with the use of WMCF versus gas/electricity together in the univariable analysis. Statistically significant variables ($p < 0.05$) were then tested on a multivariable logistic regression using the backward elimination procedure analysis, variables were allowed in the model only if the p -value was < 0.2 . The study was approved by the Ethics Review Board of the Centro Oncológico Estatal affiliated to the Instituto de Seguridad Social del Estado de México y Municipios (ISSEMyM).

Results

There were a total of 66 321 surveyed households during the two years of the ENGASTO survey (2012-2013). Overall, the prevalence of using gas, wood, electricity, other fuels or coal as the main fuel for cooking was respectively 87.9, 9.3, 1.2, 1.2, and 0.4% of households (table I). Wood use prevalence was inversely associated with the population size of the communities surveyed, with 1.5, 7.1, 15.3 and 40.5% for communities with $\geq 100\,000$; 15 000-99 999; 2 500-14 999 and $< 2\,500$ inhabitants respectively, (p by trend $< .0001$). Conversely, gas use rates were positively associated with community size, respectively 95.5, 90.4, 81.5 and 57.7%. After excluding the "coal" and "others"

groups, there were a total of 65 256 surveyed households with 252 011 residents and 10.9, 88.4 and 0.7% of them lived in households where wood, gas and electricity were the main fuels for cooking respectively. The prevalence of residents exposed to wood fuel use was also inversely associated with community size with 1.7, 8.1, 17.7, and 44.5% prevalence for communities size $\geq 100\,000$; 15 000-99 999; 2 500-14 999 and $< 2\,500$ respectively. Gas use prevalence was positively associated with community size, respectively 97.4, 91.3, 81.8 and 55.3% of people. The mean number of residents was higher in households where wood was used for cooking (4.4, SD 2.3, range 1-20) as compared to gas (3.8, SD 3.8, range 1-25) or electricity (2.4, SD 16, range 1-14), $p < .0001$ (table II).

According to the censuses, the overall prevalence rates of using wood or coal were 23.2 and 19.6% in 1990 and 2000 respectively with a decrease of 15.4% in the decade. Higher rates of wood/coal use were reported in rural areas during the same period with 62.3 and 58.7% respectively with only 5.8% reduction. Comparing the rate from the 2000 census (19.6%) with the most recent ones from the Engasto survey of 2012-2013 (10.9%) showed an overall reduction of 44.5% in using wood or coal for cooking (table III, figure 1). The Engasto survey 2012-2013 included wood on a separate category but coal use was found to be minimum, (table I). Comparison of population prevalence from 2000 (58.7%) to 2012-2013 (44.5%) in rural areas showed a reduction of 24.2% (table III). Between 1990 and 2012-2013, use of wood decreased from 23.2 to 11% (53% overall reduction) and respectively from 62.3 to 44% (28.6% reduction) at rural areas. The analysis by household showed 14.5% prevalence of wood or coal use in 2010 and 10.2% in 2012-2013 with 29.6% reduction. Estimates in rural areas

Table I
MAIN COOKING FUEL USED IN HOUSEHOLD BY SURVEYED COMMUNITY SIZE. MEXICO 2012-2013*

Fuel	Community size:								Total	
	≥ 100 000		15 000-99 999		2 500-14 999		<2 500			
	n=	%	n=	%	n=	%	n=	%	n=	%
Gas	33 815	95.5	13 574	90.4	5 981	81.5	4 937	57.7	58 307	87.9
Wood	537	1.5	1 061	7.1	1 126	15.3	3 462	40.5	6 186	9.3
Electricity	530	1.5	131	0.9	65	0.9	37	0.4	763	1.2
Other	430	1.2	166	1.1	91	1.2	87	1.0	774	1.2
Coal	98	0.3	87	0.6	73	1.0	33	0.4	291	0.4
Total surveyed households	35 410	53.4	15 019	22.6	7 336	11.1	8 556	12.9	66 321	100.0

* n= number of surveyed households, % column percentage except for total surveyed households (row percentage)

Source: References 13 and 14

Table II
RESIDENTS LIVING IN THE SURVEYED HOUSEHOLDS BY TYPE OF COOKING
FUEL USED AND BY COMMUNITY SIZE. MEXICO 2012-2013

Community size where surveys took place:	Main fuel used for cooking												All three groups		
	Wood				Gas				Electricity						
	households	mean	residents	n=	households	mean	residents	n=	households	mean	residents	n=	households	mean	residents
	n=	residents	n=		%	n=	residents		n=	%	n=		residents	n=	%
≥ 100 000	537	4.1	2 191	1.7	33 815	3.7	126 247	97.4	530	2.3	1 226	0.9	34 882	2.3	129 664
15 000-99 999	1 061	4.5	4 760	8.1	13 574	3.9	53 449	91.3	131	2.7	357	0.6	14 766	2.7	58 566
2 500-14 999	1 126	4.6	5 196	17.7	5 981	4.0	23 976	81.8	65	2.3	147	0.5	7 172	2.3	29 319
<2 500	3 462	4.4	15 329	44.5	4 937	3.9	19 041	55.3	37	2.5	92	0.3	8 436	2.5	34 462
Total	6 186	4.4 (2.3, 1-20) [‡]	27 476	10.9	58 307	3.8 (1.9, 1-25)	222 713	88.4	763	2.4 (1.6, 1-14)	1 822	0.7	65 256	3.9 (1.9, 1-25)	252 011

* row percentage

[‡] mean (SD, range) the mean number of residents in the household was statistically different (p<0.0001) between the three groups

Source: References 13 and 14

Table III
PREVALENCE OF COOKING FUELS USED IN MEXICO OVER TIME

	Population as denominator							
	1990 Census		2000 Census				Engasto survey (2012-2013)	
	population	%	<2 500 inhabitants*	%	population	%	<2 500 inhabitants	%
Total	79 535 895		22 914 413		95 378 884		24 234 490	
Gas	59 834 210	75.2	8 300 514	36.2	75 783 943	79.5	9 815 938	40.5
Wood or coal [‡]	18 425 833	23.2	14 275 665	62.3	18 730 054	19.6	14 224 404	58.7
Petroleum	569 991	0.7	147 045	0.6	21 915	0.0	8 632	0.0
Electricity	110 109	0.1	9 653	0.04	197 810	0.2	14 253	0.1
Not specified	595 752	0.7	181 536	0.8	645 162	0.7	171 263	0.7
% change of wood use compared to previous period						-15.4		-5.8
								-44.5
								-24.2

	Households as denominator							
	2010 Census		Engasto survey (2012-2013)					
	All households	%	community size of <2 500 inhabitants	%	All households	%	community size of <2 500 inhabitants	%
Total	28 643 491		6 282 646		66 612		8 556	
Gas	24 003 245	83.8	3 140 691	49.9	58 307	87.5	4 937	57.7
Wood or coal [‡]	4 153 306	14.5	3 088 675	49.2	6 768	10.2	3 495	40.8
Other	257 791	0.9	22 923	0.4	774	1.2	87	1.0
Electricity	---	---	---	---	763	1.1	37	0.4
Not specified	229 148	0.8	30 357	0.5	---	---	---	---
% change of wood use compared to previous period						-29.8		-16.9

* Community size where Censuses or the Engasto survey took place

[‡] In the Engasto survey the main fuel used for cooking in this category was wood only

Source: References 8, 9, 10, 13 and 14

were respectively 49.2 and 40.8% with 17% reduction (table III, figure 1).

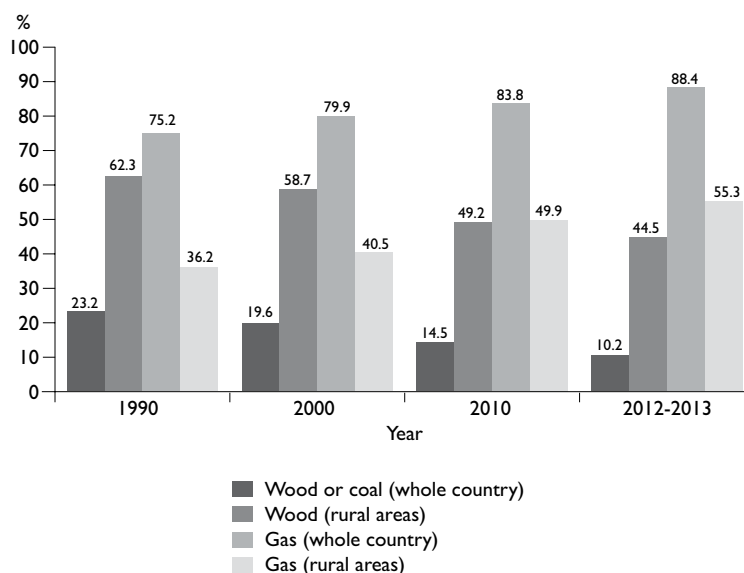
Population analysis indicated an increasing trend of using gas with overall rates of 75.2, 79.5 and 88.4% in 1990, 2000 and 2012-2013 respectively. The same trend was found in rural areas, 36.2, 40.5 and 55.3% respectively. An increasing pattern was found for gas use in the analysis by households with rates of 83.8 and 87.5% overall and 49.9 and 57.7% in rural areas in years of 2010 and period 2012-2013 respectively (table 3, figure 1). Electricity rates increased from 0.10 in 1990 to 0.72% in 2012-2013 with a 623% increase, (table III). From 1990 to 2013 wood use decreased by 53% overall and by 28.6% in rural areas, gas use increased respectively by 17.5 and 52.7%. The univariable analysis showed the following household characteristics to be statistically associated with use of WMCF in the period of 2012-2013: >4 residents living in the household, low and medium-low SES, <5 rooms, not having a kitchen, having a chimney, walls made of asbestos or metallic slats, adobe or wood, roof made of cardboard, metallic or asbestos slats, the floor made of dirt or concrete, burning garbage, surveyed community size of less than 2 500 inhabitants or between 2 500 to 14 999, all p -values <0.0001 (table IV). The following variables remained statistically significant in the multivariable analysis: floor made of dirt (adjusted odds ratio or aOR 8.0) or concrete (aOR 2.7), low (aOR 20.5) or middle-low (aOR 4.9) SES, lack of kitchen (aOR 4.0), community size <2 500 inhabitants (aOR 3.5) or

between 2 500-14 999 inhabitants (aOR 2.6), burning garbage (aOR 2.8), roof made of cardboard (aOR 2.4) metal (aOR 1.8) or asbestos slats (aOR 1.7), number of rooms ≤ 4 (aOR 1.7), number of residents living in the household ≥ 5 (aOR 1.6), walls made of wood (aOR 1.5) and having a chimney in the household (aOR 1.4). Walls made of adobe, metallic or asbestos material were no longer statistically significant (table IV).

Discussion

In this study we found that during the period of 2012-2013 the prevalence of using wood as the main cooking fuel in the household and by residents was 9.3 and 10.9% respectively with higher prevalence rates in rural areas, 40.5 and 44.5% respectively, confirming that the highest rates of wood used for cooking are seen in rural areas of Mexico.

Our household prevalence estimate of 40.5% in rural areas of Mexico is similar to the global estimate of 41% reported by the WHO for solid fuels in 2013¹⁶ or to Peru's estimate (40%) in 2010, but lower than estimates from Cote d'Ivoire or Sierra Leone in Africa (70 to 100%) and higher than Colombia's or Djibouti's (East Mediterranean) estimates of about 18%.³ This indicates that exposure to solid fuels is still high in many areas of the world representing a problem and a threat to health. The inverse relationship between wood use and community size of households speaks to SES, cultural habits or the



Source: INEGI Censuses for the years 1990, 2000 and 2010.⁸⁻¹⁰ Engasto survey for the period 2012-2013.^{13,14} For years 1990, 2000 and 2012-2013 population estimates are shown. For the year of 2010 household estimates are shown

FIGURE 1. PREVALENCE OF TYPE OF FUEL USED FOR COOKING IN MEXICO, 1990-2013.

Table IV
HOUSEHOLD CHARACTERISTICS BY PREDOMINANT COOKING FUEL USED. MEXICO 2012-2013

Characteristic	Wood		Gas		Electricity		Total		Unadjusted			Adjusted		
	n=*	%*	n=	%	n=	%	n=	%	OR [‡]	95%CI	p-Value	OR [‡]	95%CI	p-Value
Number of residents living in the household														
5+	2 741	44.3	18 104	31.0	70	9.2	20 915	32.1	1.8	1.7-1.9	<.0001	1.6	1.5	1.8 <.0001
1-4	3 445	55.7	40 203	69.0	693	90.8	44 341	67.9	1.0			1.0		
Socioeconomic status														
Low	3 966	64.1	3 853	6.6	32	4.2	7 851	12.0	25.4	23.9-27.0	<.0001	20.5	16.6	25.4 <.0001
Medium low	2 115	34.2	31 279	53.6	407	53.3	33 801	51.8	14.9	12.2-18.1	<.0001	4.9	4.0	6.0 <.0001
Medium high	102	1.6	17 622	30.2	259	33.9	17 983	27.6	1.0			1.0		
High	3	0.05	5 553	9.5	65	8.5	5 621	8.6	1.0			1.0		
Number of rooms														
1-4	5 456	88.2	36 943	63.4	664	87.0	43 063	66.0	4.3	3.9-4.6	<.0001	1.7	1.5	1.8 <.0001
5+	730	11.8	21 364	36.6	99	13.0	22 193	34.0	1.0			1.0		
Household has a kitchen														
No	1 529	24.7	2 596	4.5	139	18.2	4 264	6.5	6.8	6.3-7.5	<.0001	4.0	3.7	4.4 <.0001
Yes	4 657	75.3	55 711	95.5	624	81.8	60 992	93.5	1.0			1.0		
Chimney in the house														
Yes	362	5.9	1 469	2.5	8	1.0	1 839	2.8	2.4	2.1-2.7	<.0001	1.4	1.1	1.6 <.0001
No	5 824	94.1	56 838	97.5	755	99.0	63 417	97.2	1.0			1.0		
Garbage disposal method														
Burning	2 937	47.5	2 358	4.0	28	3.7	5 323	8.2	21.5	20.1-22.9	<.0001	2.8	2.6	3.1 <.0001
Municipal pick up	2 663	43.0	52 323	89.7	673	88.2	55 659	85.3	1.0			1.0		
other	586	9.5	3 626	6.2	62	8.1	4 274	6.5	1.0			1.0		
Community size														
<2 500	3 462	56.0	4 937	8.5	37	4.8	8 436	12.9	21.0	19.5-22.3	<.0001	3.5	3.2	3.9 <.0001
2 500-14 999	1 126	18.2	5 981	10.3	65	8.5	7 172	11.0	5.6	5.2-6.0	<.0001	2.6	2.4	2.8 <.0001
15 000-99 999	1 061	17.2	13 574	23.3	131	17.2	14 766	22.6	1.0			1.0		
≥ 100 000	537	8.7	33 815	58.0	530	69.5	34 882	53.5	1.0			1.0		
Wall material														
Wood	722	11.7	1 069	1.8	20	2.6	1 811	2.8	7.1	6.4-7.8	<.0001	1.5	1.3	1.7 <.0001
Adobe	1 061	17.2	2 598	4.5	21	2.8	3 680	5.6	4.5	4.2-4.9	<.0001	1.1	1.0	1.2 0.0915
Asbestos or metallic slats	83	1.3	294	0.5	3	0.4	380	0.6	3.0	2.3-3.8	<.0001	0.8	0.6	1.0 0.0749
Brick, stone or cement	3 975	64.3	54 130	92.8	714	93.6	58 819	90.1	1.0			1.0		
Other	345	5.6	216	0.4	5	0.7	566	0.9	1.0			1.0		
Roof material														
Cardboard slats	346	5.6	410	0.7	17	2.2	773	1.2	8.8	7.6-10.2	<.0001	2.4	1.9	2.9 <.0001
Metallic slats	2 055	33.2	4 541	7.8	60	7.9	6 656	10.2	6.7	6.3-7.1	<.0001	1.8	1.7	2.0 <.0001
Asbestos slats	665	10.8	2 313	4.0	34	4.5	3 012	4.6	3.1	2.8-3.4	<.0001	1.7	1.5	1.9 <.0001
Concrete or concrete blocks	2 329	37.6	47 968	82.3	618	81.0	50 915	78.0	1.0			1.0		
Other	791	12.8	3 075	5.3	34	4.5	3 900	6.0	1.0			1.0		
Floor material														
Dirt	747	12.1	648	1.1	16	2.1	1 411	2.2	70.5	61.6-81.0	<.0001	8.0	6.7	9.6 <.0001
Concrete	4 921	79.6	25 589	43.9	343	45.0	30 853	47.3	12.0	10.8-13.0	<.0001	2.7	2.4	3.0 <.0001
Wood, tile or other	518	8.4	32 070	55.0	404	52.9	32 992	50.6	1.0			1.0		

* Number of households, % column percentage

‡ Odds Ratio and 95% CI of using wood Vs. gas and electricity grouped together

Adjusted OR and 95% CI were obtained by using multiple logistic regression model with the backward elimination procedure, variables were allowed in the model only if the p-value was ≤ 0.2

Source: References 13 and 14

availability of wood with ready access to trees in rural areas. Our results showed that, while prevalence rates of wood use have been decreasing over time in Mexico, the rates of gas and electricity have been increasing with wood use decreasing by 53% overall and by 28.6% in rural areas over the last 23 years. Conversely, gas use increased by 17.5 and by 52.7% respectively suggesting that fewer households are now using wood in urban areas. The slighter decrease of wood use and the higher increase of gas use in rural areas might indicate that while more households are now using gas, wood is still being used even though it may not be the main fuel used for cooking. The decrease in wood use over time in Mexico may in part be attributed to enforcing laws which limit wood for domestic use to that sourced from dead trees, official clearing and pruning waste.¹⁷ There is also more awareness of air pollution problems and of the aforementioned adverse health effects associated with wood smoke exposure. Besides poverty or more accessibility to wood in rural areas, the prevalence of wood use is also likely related to the making of tortillas, a traditional Mexican staple food. Personal preference for tortillas grilled over wood fires may explain gas use for the main cooking fuel but not for tortillas. Further research is warranted to establish the prevalence of using mixed fuels and the degree of exposure to wood smoke.

According to the World Health Organization, the prevalence of solid fuels use in 2003 was about 35% in urban and 71% in rural areas of Mexico¹⁸ and the most recent estimate in 2013 was 15%.¹⁶ These and our findings agree with the recent trend reported in the Americas where the exposure to solid fuels has been decreasing and the use of "clean" fuels increasing.³ Predictors of using WMCF included low SES and having dirt flooring or cement flooring, both types of flooring may induce people to burn wood on the floor. Garbage disposal by burning was more commonly seen in households where wood was used for cooking suggesting that this method of disposal was likely due to convenience and that some houses using WMCF are likely exposed to other air pollutants in addition to those resulting from wood burning. Household construction materials associated with wood use for cooking included cardboard, metallic, asbestos or wood slats and adobe. All are cheaper materials when compared to bricks, tiles, laminated or hardwood flooring etc. Exposure to asbestos has been associated with the development of mesothelioma,¹⁹ further research is needed to establish whether exposure to both, wood smoke and asbestos have a synergistic effect in developing lung cancer or mesothelioma. Living in rural or suburban areas, having low number of rooms, having a chimney and more people in the residence were all independently associated with wood use and

all reflect the low SES. Improvement in SES will likely result in a decrease of use of WMCF, however, its complete elimination in the near future is unlikely as cultural and other factors still prevail and the use of mixed fuels will be more likely at rural areas.²⁰

There are some limitations in this study, in the previous censuses of 1990, 2000 and 2010 wood and coal were grouped in one category and this may have underestimated the recent prevalence rates, however our finding indicating very low prevalence of coal use suggests that the underestimation is minimal. Unfortunately, we were not able to determine the prevalence of using multiple fuels for cooking as the censuses and the Engasto survey allowed only one answer options. There was no information on the number of windows or eaves in the residence, whether wood was burned on the floor or in inefficient and highly polluting stoves for cooking, or the number of hours that wood was burned and the length of time that residents were exposed. It is recognized that all these aspects of home environment and behavior also play a part in the total dose of air pollutants and hence health effects.¹ Future studies that include all this information will help to determine residents' degree of exposure to solid fuels. However, exposure to indoor smoke from solid fuels is likely to remain unchanged as long as household fuel and housing conditions remain the same.²¹ Reliance on solid fuels and the inefficient, traditional open fires and stoves used by the majority of households in rural areas can impact health, development and environment in many ways.²² The use of Improved biomass cookstoves²³ and the adoption of clean fuels including liquefied petroleum gas, biogas, solar cooking and alcohol fuels²⁴ will result in high fuel efficiency and low pollution emissions. Besides the aforementioned adverse health effects associated with wood use for cooking, other problems include a high risk of burns (e.g. children falling into fires, spilled fuel, etc.). Women and children may also be at risk for injury violence during wood collection. Gathering wood for fuel is time intensive limiting other productive activities and preventing children attending school.¹ Globally, about 51 and 62%, for men and women respectively, of the total burden of COPD is not attributable to tobacco⁷ and 50% of obstructive airway disease in women may be attributable to long-term wood smoke exposure²⁵ which has also been associated with a two-fold increase in lung cancer²⁶ and particularly in nonsmoking Mexican women.²⁷ Further research is needed to determine how the decrease of use of wood for cooking in Mexico has impacted the incidence of diseases associated with this indoor air pollutant.

In summary, the 2012-2013 prevalence of using wood as the main cooking fuel in Mexico was 10.9%, a rate decrease of 53% compared to 1990. The highest current prevalence was found in rural areas of Mexico

with 40.5%, a 28.6% decrease compared to 1990. The household characteristics indicating low socioeconomic status predict the use of WMCF. This study documents the decrease of use of wood and increase of other fuels for cooking but the rate of elimination of wood as primary cooking fuel has not been fast enough. Providing cleaner fuels and better kitchens to poor people in developing countries will improve health and reduce morbidity and mortality associated to wood smoke exposure.

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References

1. WHO. Guidelines for indoor air quality: household fuel combustion [internet document]. World Health Organization, 2014 [consulted February 10, 2016]. Available in: http://www.who.int/indoorair/guidelines/hhfc/IAQ_HHFC_guidelines.pdf
2. WHO. Household air pollution and health Key facts [internet document]. World Health Organization, 2014 [consulted February 11, 2016] [1 screen]. Available in: <http://www.who.int/mediacentre/factsheets/fs292/en/>
3. Bonjour S, Adair-Rohani H, Wolf J, Bruce NG, Mehta S, Pruss-Ustun A, et al. Solid fuel use for household cooking: country and regional estimates for 1980-2010. *Environ Health Perspect* 2013;121(7):784-790. <http://doi.org/bs3p>
4. Smith KR, Bruce NG, Balakrishnan K, Adair-Rohani H, Balmes J, Chafe Z, et al. Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annu Rev Public Health* 2014;35:185-206. <http://doi.org/bs3q>
5. Serrano-Medrano M, Arias-Chalico T, Ghilardi A, Masera O. Spatial and temporal projection of fuelwood and charcoal consumption in Mexico. *Energy Sustain Develop* 2014;19:39-46. <http://doi.org/bs3r>
6. Ghilardi A, Guerrero G, Masera O. Spatial analysis of residential fuelwood supply and demand patterns in Mexico using the WISDOM approach. *Biomass Bioener* 2007;31(7):475-491. <http://doi.org/dnm46p>
7. Smith, K, Mehta S, Maeusezahl-Feuz M. Indoor air pollution from household use of solid fuels. In: Ezzati M, Lopez A, Rodgers A. Comparative Quantification of Health Risks Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. [ebook] Geneva:WHO publications, 2004:1435-1481 [accessed November 25, 2016]. Available at: <http://www.who.int/publications/cra/chapters/volume2/1435-1494.pdf>
8. Censo general de población y vivienda INEGI [internet site]. Instituto Nacional de Estadística, Geografía e Informática. Mexico, 1990 [consulted November 25, 2016]. Available in: <http://www.inegi.org.mx/est/contenidos/proyectos/ccpv/cpv1990/default.aspx>
9. Censo general de población y vivienda INEGI [internet site]. Instituto Nacional de Estadística, Geografía e Informática. Mexico, 2000 [consulted November 25, 2016]. Available in: <http://www.inegi.org.mx/est/contenidos/Proyectos/ccpv/cpv2000/default.aspx>
- 10.- Censo general de población y vivienda INEGI [internet site]. Instituto Nacional de Estadística, Geografía e Informática. Mexico, 2010 [consulted November 25, 2016]. Available in: <http://www.inegi.org.mx/est/contenidos/proyectos/ccpv/cpv2010/Default.aspx>
11. Díaz-Jiménez R. Consumo de leña en el sector residencial de México. Evolución histórica y emisiones de CO₂ [dissertation]. Ciudad de México: Universidad Nacional Autónoma de México, 2000.
12. Masera O, de Buen O, Friedmann R. In: Martínez JQ (ed.) *Proceedings Primera reunión internacional sobre energía y medio ambiente en el sector residencial Mexicano*. Ciudad de México: Universidad Nacional Autónoma de México, 1992:73-96.
13. INEGI. Encuesta Nacional de Gastos en los Hogares Engasto, Microdatos [internet document]. INEGI, 2012 [consulted November 25, 2016]. Available in: <http://www.inegi.org.mx/est/contenidos/proyectos/accesosomicrodatos/encuestas/hogares/regionales/engasto/2012/>
14. INEGI. Encuesta Nacional de Gastos en los Hogares Engasto, Microdatos [internet document]. INEGI, 2013 [consulted November 25, 2016]. Available in: <http://www.inegi.org.mx/est/contenidos/proyectos/accesosomicrodatos/encuestas/hogares/regionales/engasto/2013/>
15. INEGI. Consulta interactiva de datos Censos y conteos de población y vivienda [internet document]. INEGI, 2014 [consulted February 11, 2016]. Available in: http://www.inegi.org.mx/est/lista_cubos/
16. WHO. World Health Statistics for 2015 [internet document]. Geneva: World Health Organization, 2015 [consulted February 11, 2016]. Available in: http://apps.who.int/iris/bitstream/10665/170250/1/9789240694439_eng.pdf?ua=1
17. Cámara de Diputados del H. Congreso de la Unión. Reglamento de la Ley General de Desarrollo Forestal Sustentable. Artículo 73. Ciudad de México: Cámara de Diputados del H. Congreso de la Unión, 2014 [consulted August 26, 2016]. Available in: http://www.profepa.gob.mx/innovaportal/file/3269/1/reglamento_de_la_ley_general_de_desarrollo_forestal_sustentable.pdf
18. OMS/OPS. Energía doméstica y Salud, combustibles para una vida mejor [internet document]. Geneva: OMS, 2007 [consulted February 11, 2016]. Available in: http://www.who.int/indoorair/publications/fuelforlife_es.pdf
19. Wagner JC, Sleggs CA, Marchand P. Diffuse pleural mesothelioma and asbestos exposure in the North Western Cape Province. *Br J Ind Med* 1960;17:260-271. <http://doi.org/c9ksth>
20. Masera O, Saatkamp BD, Kammen DM. From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model. *World Dev* 2000;28(12):2083-2103. <http://doi.org/c34xgf>
21. Murray CJL, Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S. Comparative quantification of health risks: conceptual framework and methodological issues. In: Ezzati M, Lopez A, Rodgers A. Comparative Quantification of Health Risks Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. [ebook] Geneva:WHO publications, 2003:1-38 [accessed November 25, 2016]. Available at: <http://www.who.int/publications/cra/chapters/volume1/1-38.pdf>
22. WHO. Household energy database [internet site]. World Health Organization, 2015 [consulted February 11, 2016]. Available in: http://www.who.int/indoorair/health_impacts/he_database/en/
23. Ruiz-Mercado I, Masera O, Zamora H, Smith KR. Adoption and sustained use of improved cookstoves. *Energy Policy* 2011;39(12):7557-7566. <http://doi.org/dw6htk>
24. Puzzolo E, Pope D, Stanistreet D, Rehfuess EA, Bruce NG. Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. *Environ Res* 2016;146:218-234. <http://doi.org/bs3s>
25. Dennis RI, Maldonado D, Norman S, Baena E, Castano H, Martinez G, et al. Wood smoke exposure and risk for obstructive airways disease among women. *Chest* 1996;109(suppl 3):55s-56s. <http://doi.org/bf2f83>
26. Bruce N, Dherani M, Liu R, Hosgood HD, Sapkota A, Smith KR, et al. Does household use of biomass fuel cause lung cancer? A systematic review and evaluation of the evidence for the GBD 2010 study. *Thorax* 2015;70(5):433-441. <http://doi.org/bs3t>
27. Hernández-Garduño E, Brauer M, Pérez-Neria J, Vedal S. Wood smoke exposure and lung adenocarcinoma in non-smoking Mexican women. *Int J Tuberc Lung Dis* 2004;8(3):377-383.