Wood Heater Change Outs –
A Reality Check

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Benefits of Change Outs

- **Health** – Reduced Air Pollutants
- Contribute to the goal of attainment of federal fine particulate (PM2.5) standards (NAAQS)
- Reduced number of home fires – less creosote (fewer chimney fires)
- Safer Units – fewer burns, less indoor carbon monoxide exposure, plus hearth and chimney inspection at time of installation
- New units have higher efficiencies – less fuel consumed – lower fuel cost for home occupants

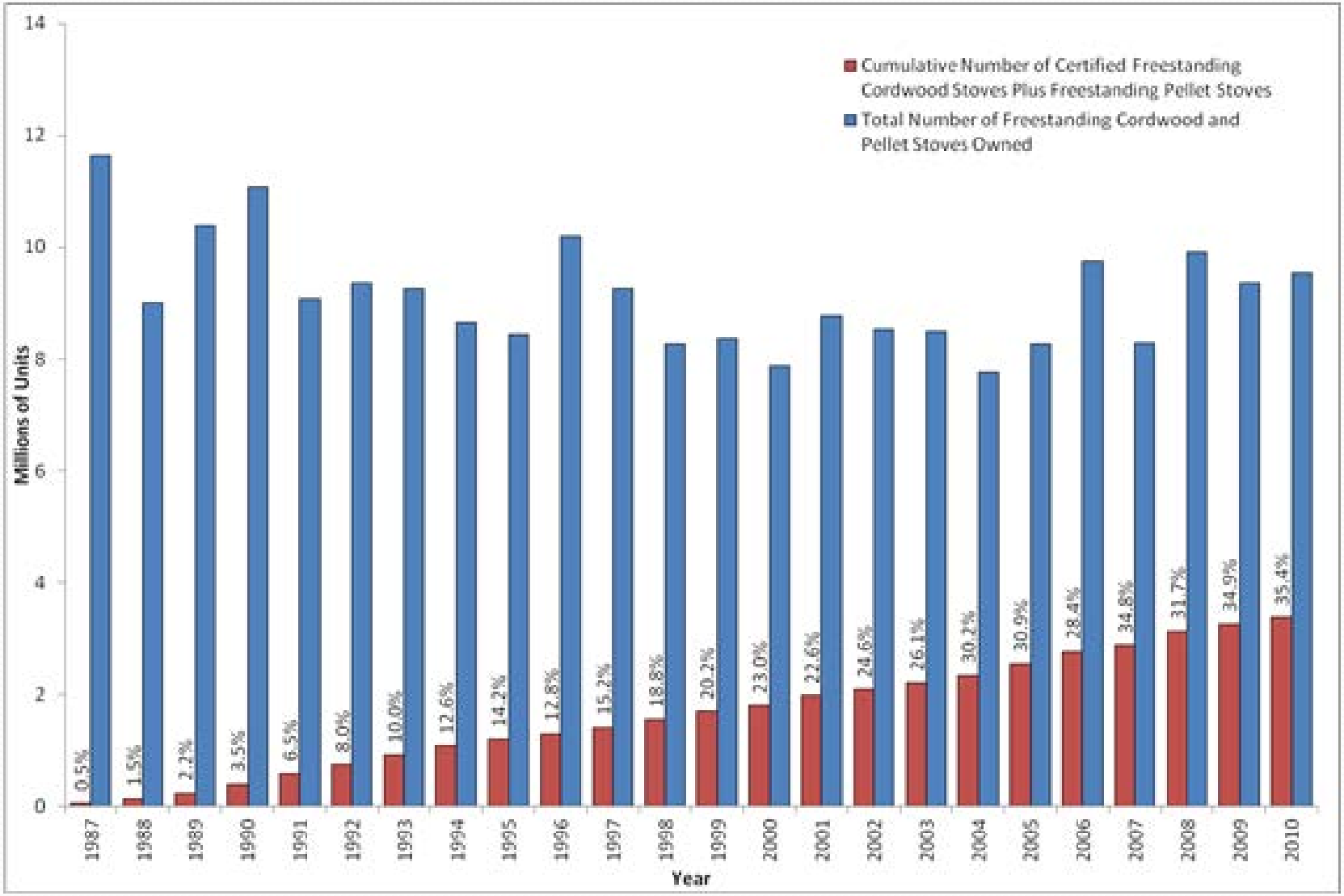
Documented Clean Wood-Burning Candidates for Installation

- Cordwood Stoves (Catalytic and Non-catalytic), new EPA certified units (40 CFR, NSPS)
- Cordwood Inserts – essentially same as stoves but designed to fit into existing fireplace cavity, EPA certified units
- Outdoor Cordwood Boilers, a.k.a. hydronic heaters, EPA qualified units (also indoor and pellet fueled) http://www.epa.gov/burnwise/owhhlist.html

Documented Clean Wood-Burning Candidates for Installation (cont.)

- Pellet Stoves, Inserts, and Furnaces – all clean burning as compared to cordwood stoves, some EPA certified, some boilers qualified
- Fireplaces – EPA qualified units http://www.epa.gov/burnwise/fireplacelist.html
- Masonry Heaters – all clean burning, high cost, upper end homes only
- Fireplace Retrofits – EPA qualified units http://www.epa.gov/burnwise/fireplacelist.html

Opportunity for Change Outs – Nationwide Most Stoves are Still Old, High- Emitting Units



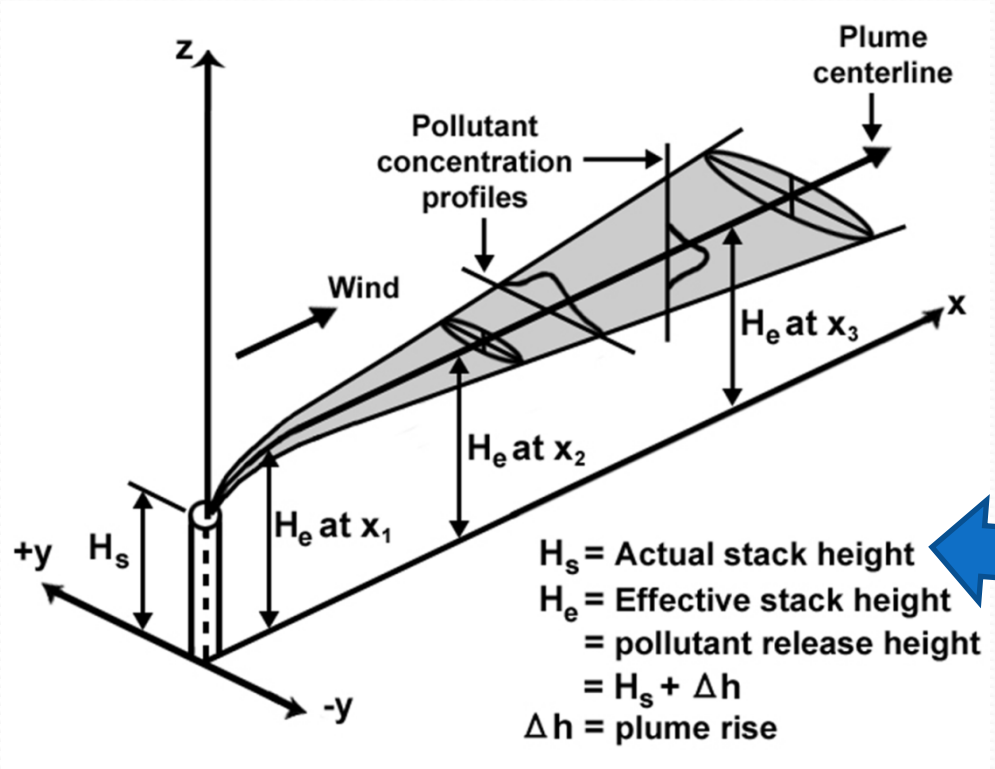
Health Concerns

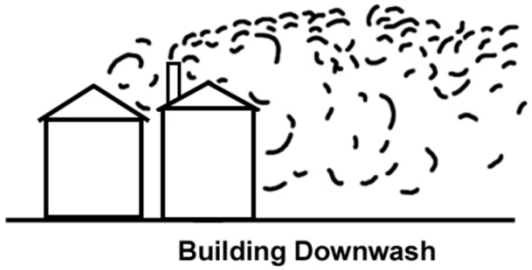
Majority of wood-burning air emissions are health injurious, incomplete combustion of organic compounds

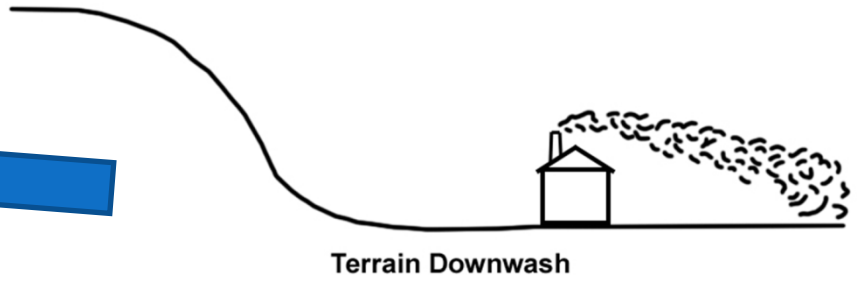
- Carbon Monoxide
- Respirable Particles, solid or liquid droplets, less than 1 micron in size from combustion sources
- Volatile Organic Compounds (VOC), vapor phase

Exposure

- Discharge at only 10 ft to 30 ft above ground level exacerbates human exposure
- 41 million single-story homes (32%)
- 43 million two-story homes (33%)
- 8.7 million manufactured and mobile homes (7%)





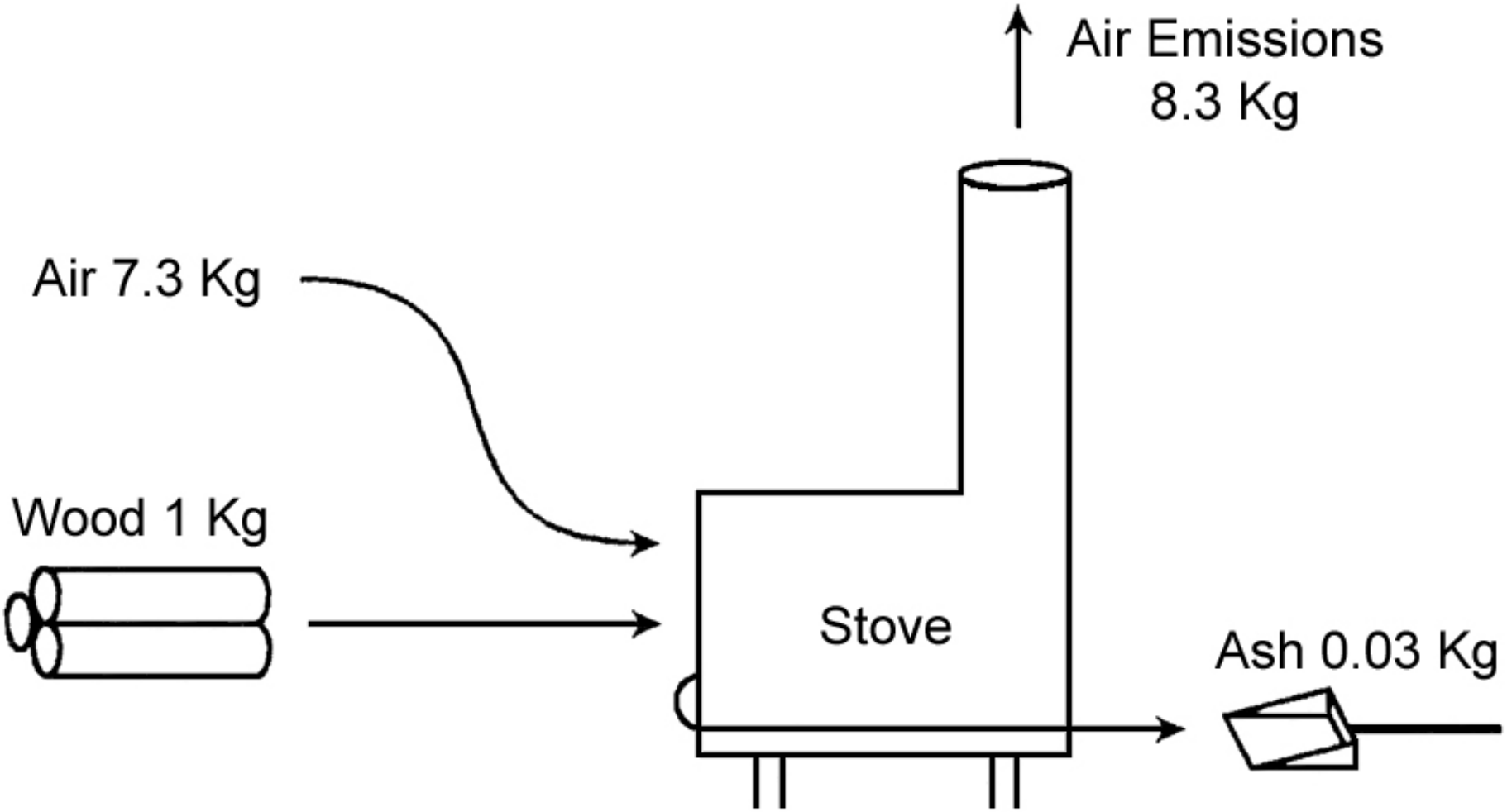


Exposure

Individuals most sensitive to air pollutants (very young, very old, infirm) spend most of their time indoors in residential settings where the home heaters are located

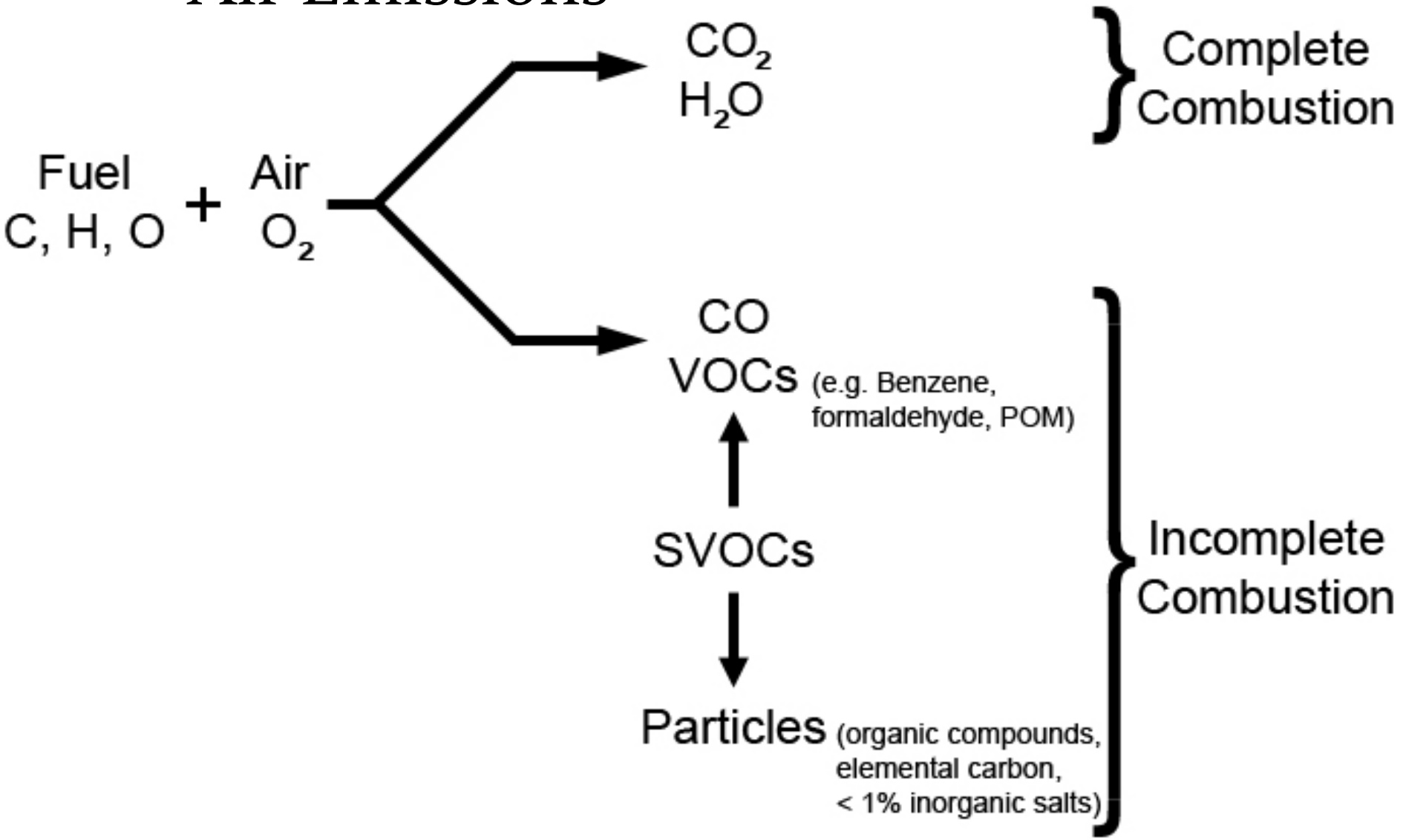
Indoor air originates from outdoor air – Occupied Single-Family Houses – 0.5 to 2.5 air exchanges per hour

Origin of Air Emissions – Mass Balance



20% Moisture Douglas Fir Fuel, Conventional Woodstove, Low Burn Rate

Characteristics of Air Emissions



Health Concerns

- Carbon Monoxide – Even though there are ambient and industrial standards, no level is good, carboxyhemoglobin
- Particles from combustion (< 1 μ) reach the deepest levels of the lungs, chemical exchange with blood, particles from wood-burning emissions are appx. 90% organic compounds, many are toxic, mutagenic, or carcinogenic
- Volatile Organic Compounds (VOC) – many are toxic, mutagenic, or carcinogenic

Conventional Uncertified Wood Heater Title III Hazardous Air Pollutants

Pollutant	Emission Factor (g/Kg)
Acetaldehyde	0.308 g/Kg
Acetophenone	0.010 g/Kg
Acrolein	0.046 g/Kg
Benzene	1.08 g/Kg
Biphenyl	2.43 mg/Kg
1,3-Butadiene	0.197 g/Kg
Catechol	0.331 g/Kg
o, m and p-Creosols	0.080 g/Kg
Dibenzofurans	1.9 mg/Kg
Ethyl benzene	ND
Formaldehyde	0.727 g/Kg
Hexachlorbenzene	13 ng/Kg
Hexane	0.012 g/Kg
Methanol	3.24 g/Kg
Naphthalene	0.091 g/Kg
Phenol	0.147 g/Kg
Polychlorinated biphenyls	0.50 pg/Kg (PCB_{TEQ})
Propionaldehyde	0.096 g/Kg
Styrene	0.117 g/Kg
2,3,7,8-Tetrachlordibenzo-p-dioxin	2.30 ng/Kg ($Dioxin_{TEQ}$)
Toluene	0.320 g/Kg
o, m and p-Xylenes	0.099 g/Kg
Polycyclic Organic Matter	0.315 g/Kg (16-PAH)

Appliance	Particulate Emissions Factor		
	Pounds/Ton	Grams/Kilogram	Reduction (%)
Conventional Stove	37	18.5	--
Non-Catalytic Stove	12	6	68
Catalytic Stove *	13	6.2	65
Pellet Stove	4	2	89
Masonry Heater	6	3	84
Conventional Stove with Densified Fuel	25	14	24

Reduction in Emissions

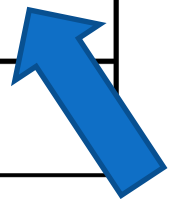
Conventional = Uncertified

Appliances	Efficiency (%)	Mass Particulate Emissions/Delivered Heat		
		lb/MBtu	g/MJ	Reduction (%)
Conventional	54	3.89	1.68	-
Non-cat. Stove	68	1.14	0.49	71
Catalytic Stove*	72	1.02	0.44	74
Pellet Stove	78	0.31	0.13	92
Masonry Heater	58	0.59	0.25	85
Conv. with Densified Fuel	57	2.79	1.20	27

Certified Woodstoves Continue to Improve

Comparison of Average Certified Emission Rates for Old and New Phase 2 Cordwood Stoves

Time Period	Woodstove Type	Number of Stoves	Average Emission Rate (g/hr, 5H equivalent)	Percent Reduction (%)
First 5 years of certification (1988-1992)	Non-catalytic	115	5.1	-
	Catalytic	110	2.9	-
Currently certified woodstoves (certified or renewed in the last 5 years)	Non-catalytic	137	4.1	19.6
	Catalytic	23	2.7	6.9



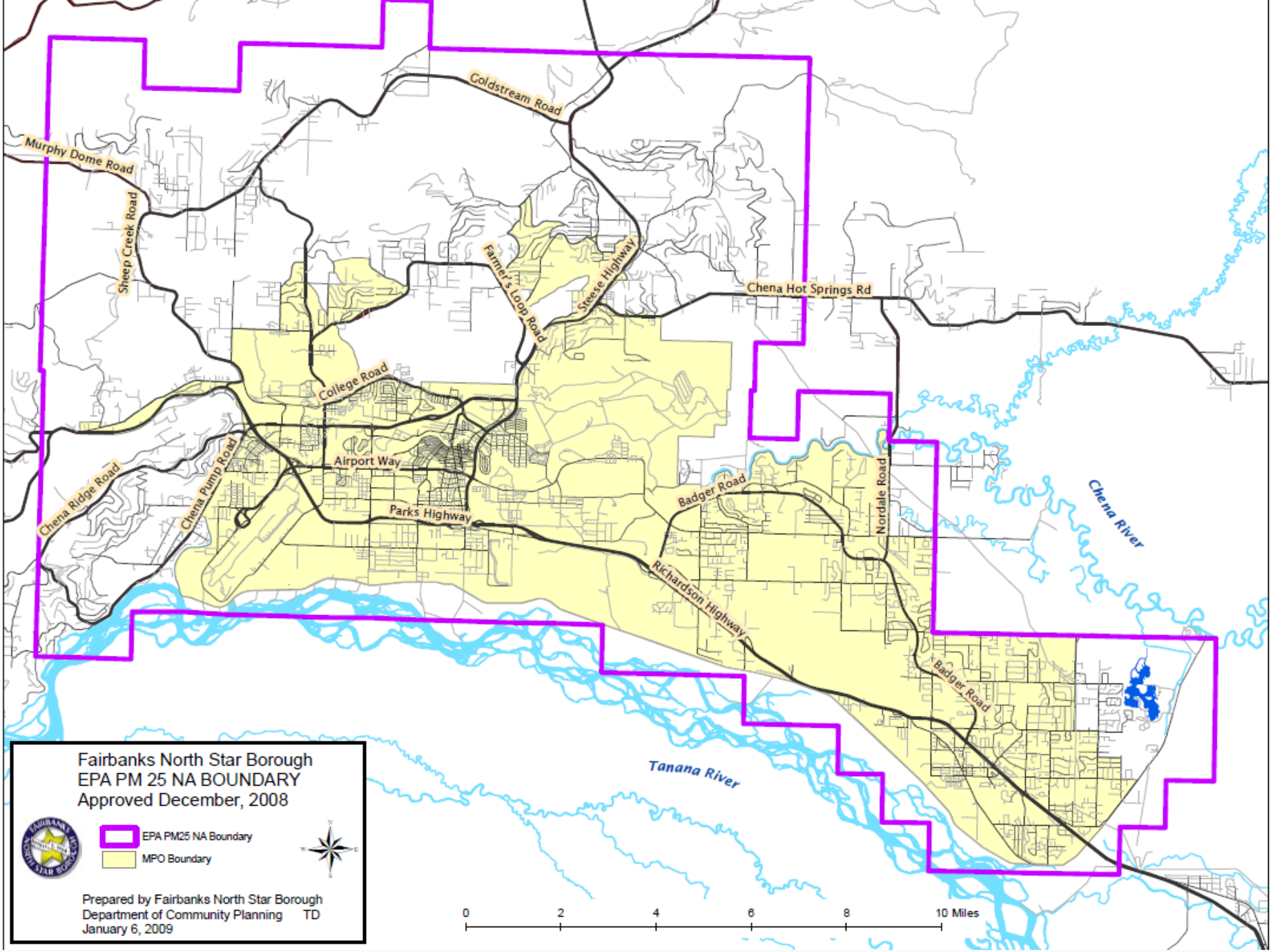
"last 5 years" was 2000 to 2005

Outdoor Wood Boilers Have Improved Dramatically

- Average of 12 models prior to 2005 — 71.6 g/h
- Average of 27 EPA qualified models (annual average values) — 4.7 g/h

Fairbanks is Federally Nonattainment for Fine Particles a.k.a. Respirable Particles or $PM_{2.5}$

- Particles produced by combustion less than 1 micron and as such less than 2.5 microns ($PM_{2.5}$)
- 24 hour standard now 35 µg/m³ (prior to Dec. 2006 was 65 µg/m³)
- Annual standard now 12 µg/m³ (prior to Dec. 2012 was 15 µg/m³)


Goldstream Road
Murphy Dome Road
Sheep Creek Road
Farmer's Loop Road
Steese Highway
Chena Hot Springs Rd
College Road
Chena Ridge Road
Chena Pump Road
Airport Way
Parks Highway
Badger Road
Nordale Road
Chena River
Richardson Highway
Badger Road
Tanana River
Fairbanks North Star Borough
EPA PM 25 NA BOUNDARY
Approved December, 2008
EPA PM25 NA Boundary
MPO Boundary
Prepared by Fairbanks North Star Borough
Department of Community Planning TD
January 6, 2009
0
2
4
6
8
10 Miles

More fuel burned (fuel oil, wood, coal, waste oil, motor vehicle fuel) in cold weather plus temperature inversions more common in cold weather

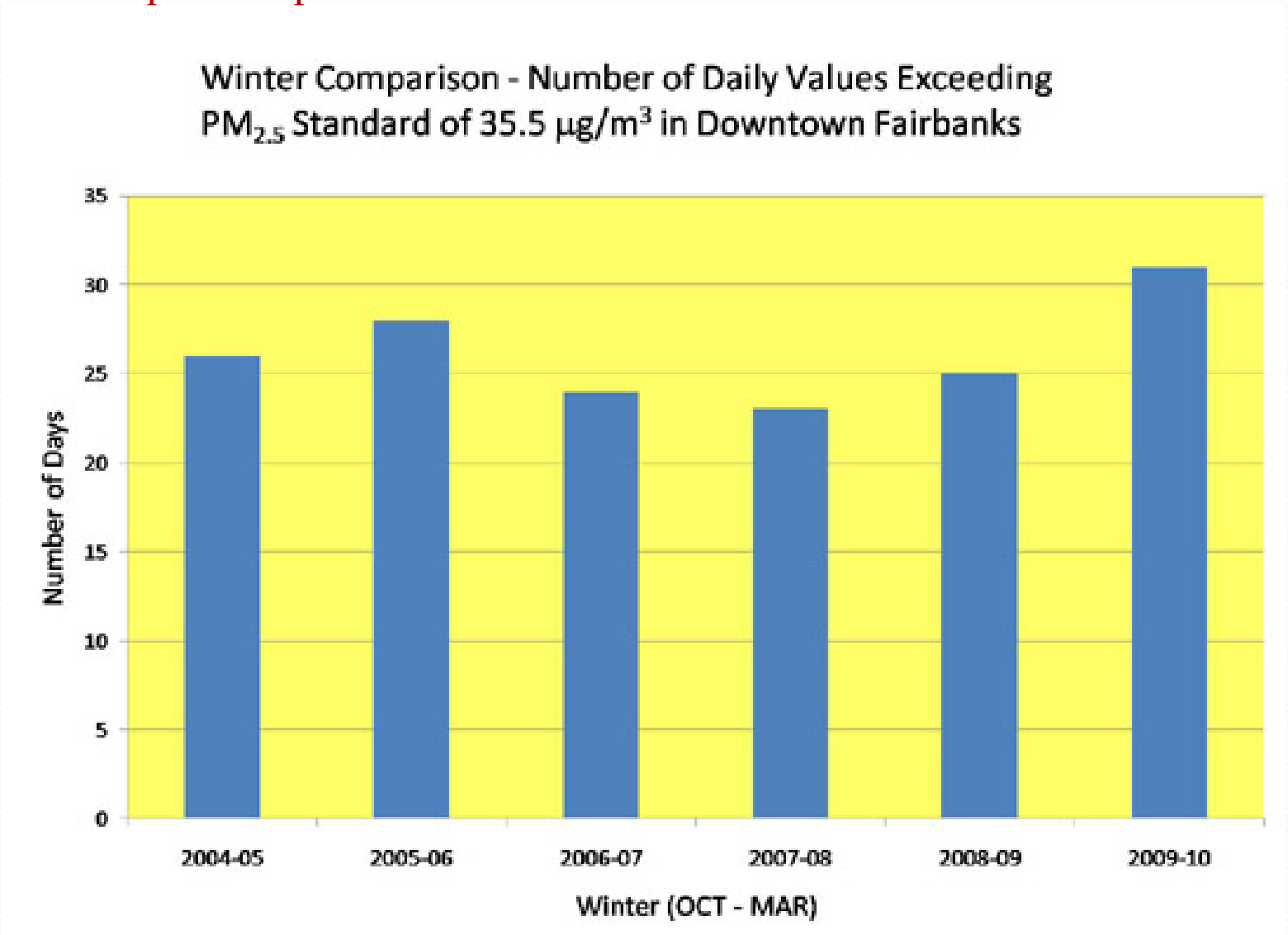


Table 6: Summary statistics for Fairbanks State Office Building site, 2004 to 2009.

	2004	2005	2006	2007	2008	2009
Max 24-hour concentration						
Days above standard						
Annual 98th percentile value	46.2	40.6	**42.2**	33.1	**46.7**	**51.0**
24-hour design value	40	40	**43**	**39**	**41**	**44**
Annual design value	10.9	10.5	11.1	11.0	11.2	11.2

Wood Heater Change Outs and Attainment

- Number of 24-hour wintertime exceedances most likely to be reduced by wood heater change outs
- With the lowering of the federal annual standard from 15 µg/m^3 to 12 µg/m^3 in Dec. 2012 and continued future growth, wood heater change outs may be of value for future attainment of annual standard (see annual design values in previous slide)
- Wood heater change outs may contribute slightly to the maintenance of the urban Fairbanks CO attainment – most CO from vehicles

Safety

- Wood heating stoves and fireplace inserts responsible for **11,000 home fires** per year in the U.S. causing **228 civilian deaths** and more than **$366 million dollars** in property damage (NFPA 2003-2006)

- **190 deaths** per year due to carbon monoxide poisoning from space heaters (CPSC 1999-2002)

- Creosote buildup in chimneys and chimney connectors is responsible for another **25% of home heating fires**

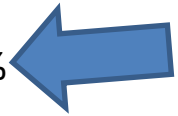
Cost Savings Due to Increased Efficiency

- Assume 5 cords/yr in uncertified stove
- Assume $275/cord
- Assume 54% efficiency for uncertified stove and 68% efficiency for certified non-catalytic stove
- Cost per year uncertified stove 5 X $275 = $1375
- Cost per year for certified non-catalytic stove for same heat output 5 X (54/68) X $275 = $1092
- Cost Savings $1375-$1092 = $283 or 21%
- Analogous cost savings by replacing uncertified stove with certified catalytic stove = $344 or 25%

Libby, Montana 2005-2008
Wood Heater Change Out – A Case Study

Libby – Heating Season Attribution of $PM_{2.5}$ Sources (2003/2004)

Local and regional dust (road and wind blown)	1%
Local and regional (15% regional) ammonium nitrate	5%
Local and regional (40% regional) ammonium sulfate	3%
Local wood smoke	66%
Cooking (commercial frying and grilling only considered)	1%+
Regional (background) organic compounds and elemental carbon	6%
Vehicular exhaust	7%
Heating oil	1%
Propane	<1%
Diesel exhaust from trains	3%
	Total 93%



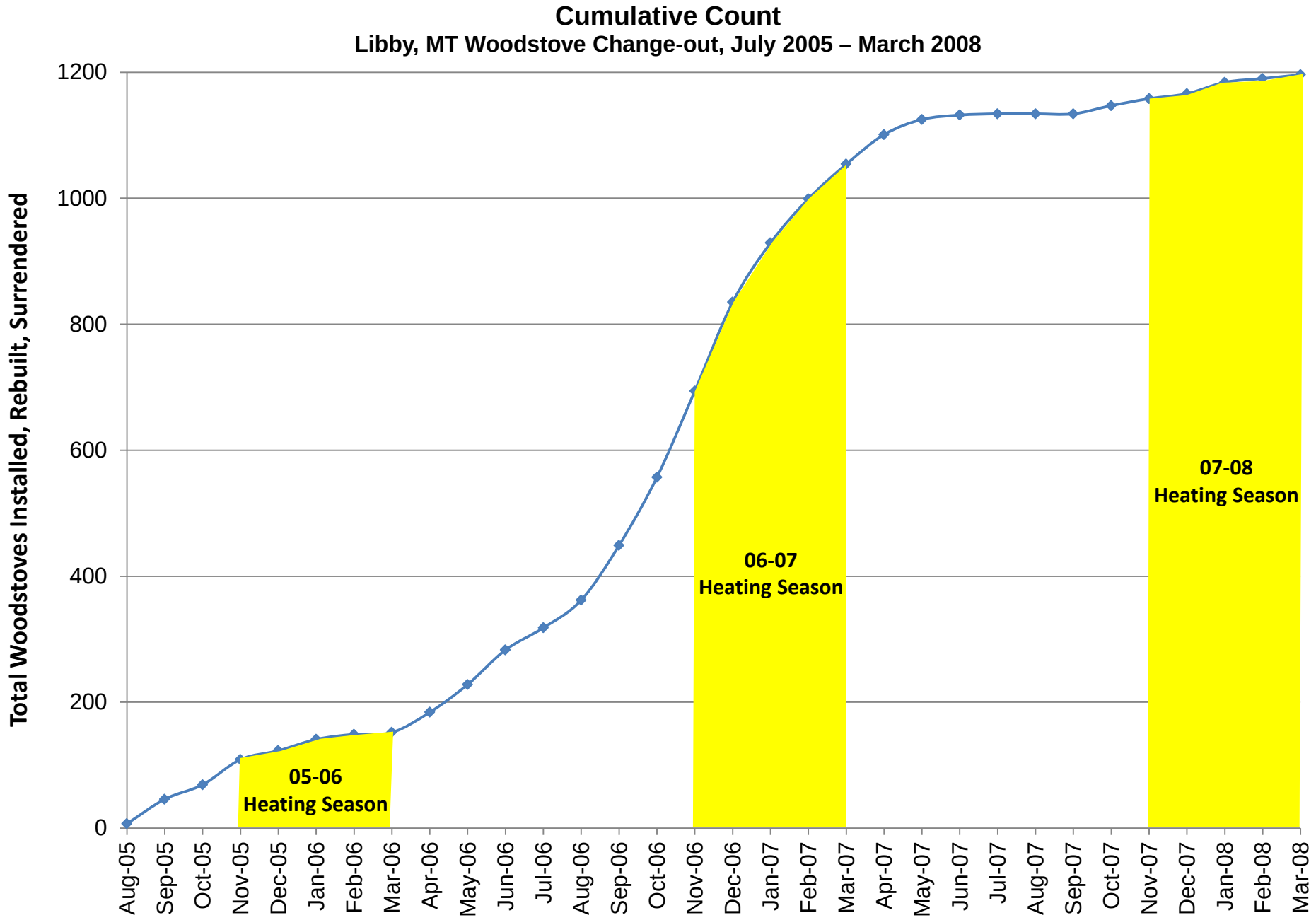
Notes: The local NH_4NO_3 and local $(NH_4)_2SO_4$ which together are about 6% of the average $PM_{2.5}$ concentration in Libby during the heating season are probably primarily from vehicular exhaust and fossil fuels emitting gaseous NO_x and SO_2, some may be from RWC. It is likely that the contribution of heating oil, vehicular exhaust, and diesel exhaust from trains is higher at the courthouse monitoring site due to its proximity to those sources and the estimate provided above for them is from an emission inventory for the airshed as a whole.

Annual and Heating Season Mean and Maximum Particulate Values

Year*	Heating Season	Means (µg/m^3)		Max. 24-hr Value (µg/m^3)		98th Percentile Value (µg/m^3)
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	$PM_{2.5}$
2003		25	15.6	91	47	43
	2003-2004	35.9	27.3	76.0 (2/3/04)	42.5 (12/17/03)	
2004		28	14.0	81	40	38
	2004-2005	40.8	27.0	106.0 (2/3/05)	75.3 (1/19/05)	
2005		30	15.8	126	75	51
	2005-2006	32.7	26.0	74.0 (2/10/06)	51.1 (11/3/05)	
2006		28	15.3	100	44	41
	2006-2007	27.1	22.0	96.0 (2/17/07)	41.2 (11/1/06)	
2007		24	**11.1**	104	**35**	**32**
	2007-2008	27.9	22.5	44.0	**42.3** (1/4/08)	
Standard		50 µg/m^3 (Annual)	**15/12 µg/m^3** (Annual)	No Standard	**65/35 µg/m^3**	

Note: 98th percentile and not the maximum 24-hour value determines compliance with 24-hour standard, i.e., surveying every three days yields 122 samples per year whereas the top two values "don't count."

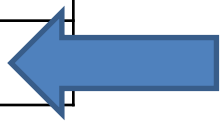
*Annual data taken from EPA Monitor Values Reports – Criteria Air Pollutants.



Note: Count is for the beginning of respective month.

Days $PM_{2.5}$ Exceeded 35 µg/m^3

Year (winter)	Days Above 35 µg/m^3
2004/2005	1/19/2005, (75.3 µg/m^3) 1/22/2005 (52.8 µg/m^3) 2/3/2005 (45.9 µg/m^3) 11/5/2004 (39.7 µg/m^3) 11/23/2004 (37.7 µg/m^3) 2/27/2005 (35.0 µg/m^3)
2005/2006	11/3/2005 (51.1 µg/m^3) 12/24/2005 (47.7 µg/m^3) 1/14/2006 (43.9 µg/m^3) 1/17/2006 (40.5 µg/m^3)
2006/2007	11/1/2006 (41.2 µg/m^3) 12/22/2006 (40.0 µg/m^3) 12/25/2006 (39.6 µg/m^3) 11/4/2006 (36.2 µg/m^3)
2007/2008	1/4/2008 (42.3 µg/m^3)



Down to one!

Summary – Air Quality Reductions from Woodstove Change-out and Potential Application to Other Nonattainment Areas

	2004-2005 Mean (Pre-Change-out)	2007-2008 Mean (Post-Change-out)	Reduction
FRM $PM_{2.5}$ ($\mu g/m^3$)	27.0	22.5	16.7%
$PM_{2.5}$ Normalized* ($\mu g/m^3$)	26.7	21.7	18.7%
PM_{10} ($\mu g/m^3$)	40.8	27.9	31.6%
PAH (ng/m^3)	351.8	104.4	70.3%
Phenolic (ng/m^3)	391.4	151.0	61.4%
Organic Carbon ($\mu g/m^3$)	17.9	12.2	31.8%
Days $PM_{2.5}$ Exceeded 35 $\mu g/m^3$	6	1	—

*Using $PM_{2.5}$ data paired with days with valid HDD data.

Note: The reduction percentages among different parameters are surprisingly different.

Consumer Reasons for Selection of Wood Heating Options

- Energy independence – Non-interruptible fuel supply

- Economic and recreational value of firewood harvesting

  58% Minnesota survey 2007-08

  66% National 1993 (DOE survey)

- Green Awareness – Climate Change Advantages

  Carbon Dioxide GHG credit for biomass

  Methane fugitive emissions from Natural Gas

- Fuel Economy

Economy – Realistic Scenarios

- 3 households, all same heating demand, 115MBtu energy input per heating season, all heaters 80% efficient

- Household #1, Electric Furnace, 22¢/kWh = $7415
- Household #2, Fuel Oil Furnace, $4.00/gal = $3316
- Household #3, Outdoor Wood Boiler, $275/cord = $1375