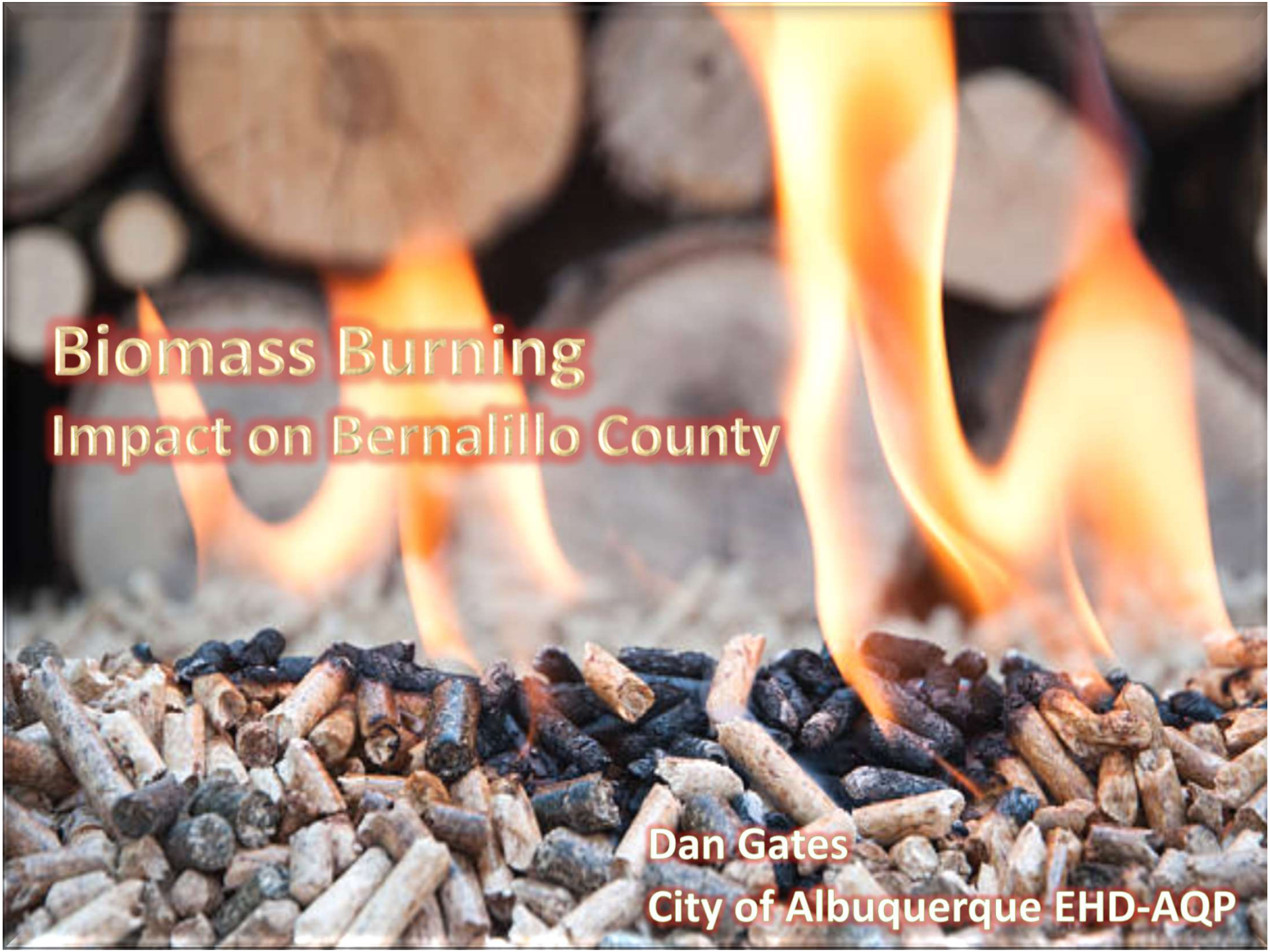

Biomass Burning
Impact on Bernalillo County
Dan Gates
City of Albuquerque EHD-AQP

Definitions

- What is Biomass?
  - Biomass is fuel that is developed from organic materials . . . Some examples of materials that make up biomass fuels are:
    - scrap lumber;
    - forest debris;
    - certain crops;
    - manure; and
    - some types of waste residues.

https://www.reenergyholdings.com/renewable-energy/what-is-biomass/

  - Biomass burning includes:
    - Burning wood for heat, cooking or ambiance
    - Burning trash and construction waste
    - Burning yard waste such as leaves, branches

- What is $PM_{2.5}$
  - $PM_{2.5}$ is particulate matter 2.5 microns and smaller

Overview

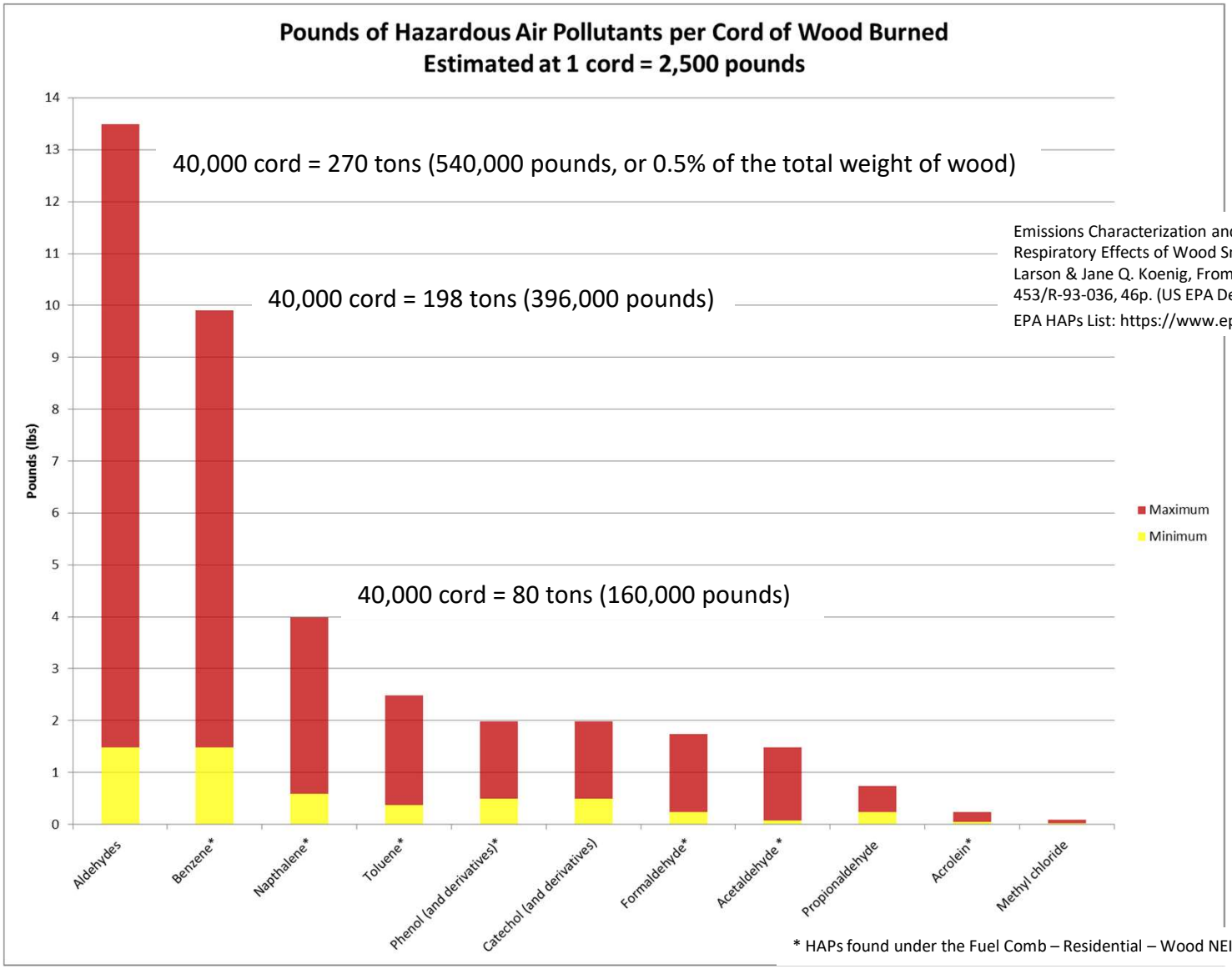
- **Can we see a difference in winter vs. summer $PM_{2.5}$?**
  - Yes
- **Evaluate data for winter wood burning impact on pollutants**
  - Feasibility of wood burning appliance replacement program
  - Identify the sources of winter time impact
  - Reduce winter pollutant impact on Bernalillo County

What we do know

- **When the temperature drops related pollutant values increase**
  - No clear delineation of temperature to the start or end of burning
    - Starts in October/November, Ends by April
- **Data analysis does show an Increase in**
  - **Markers of biomass burning in the winter**
    - Black Carbon (BC), also referred to as elemental carbon (EC) in some studies
    - Potassium (K)
- **Pollutants increase when human activities increase**
  - Wood burning
    - In 1985 35,000-40,000 cords of wood were burned in Albuquerque[1]
    - 1985-2015 Albuquerque population increased 44.8%
  - Commuting
  - Transport – what's coming in from outside county
  - Agricultural burning
  - Other?
- **Wood Burning generates significant amounts of air pollutants**
  - Including Hazardous Air Pollutants

1. Residential Space Heating with Wood: Efficiency and Environmental Performance, Urban Consortium Energy Task Force, City of Albuquerque, Energy Management Division, December 1985.

What About Hazardous Air Pollutants



Emissions Characterization and Noncancer Respiratory Effects of Wood Smoke, Timothy V. Larson & Jane Q. Koenig, From Table 2, EPA-453/R-93-036, 46p. (US EPA December 1993)

EPA HAPs List: https://www.epa.gov/haps

* HAPs found under the Fuel Comb – Residential – Wood NEI Sector

Hazardous Air Pollutants (cont.)

- In the area around Klamath Falls (population approximately 21,200), Oregon, wood stoves are estimated to emit eight tons of benzene during the wood burning season . . . [I]f all the wood burning appliances were to be changed to non-wood-burning heating sources, benzene emissions from residential heating would be near zero.
- Acetaldehyde and naphthalene levels monitored in Klamath Falls also have a higher concentration than in Portland [population appx. 639,863 in 2016] and several other communities in Oregon.

Fact Sheet, Air Toxics monitoring in Klamath Falls, Oregon DEQ, 2014, http://www.oregon.gov/deq/FilterDocs/FSKlamathFallsAirToxics.pdf

Other Air Pollutants in Wood

- Each cord of wood could produce[1]:
  - 250 - 1,300 pounds of pollution[2], including:

	Per Cord of Wood 2,500 pounds/cord		At 40,000 Cord of Wood 1985 average	
Pollutant	**Min, Pounds**	**Max, Pounds**	**Min, Tons**	**Max, Tons**
Carbon Monoxide	200.0	925.0	4,000.0	18,500.0
Methane	35.0	62.0	700.0	1,240.0
Total Particulate Mass	17.5	75.0	350.0	1,500.0
VOCs	17.5	67.5	350.0	1,350.0
Particulate Organic Carbon	5.0	50.0	100.0	1,000.0
Alkyl Benzenes (derivatives of Benzene)	2.5	15.0	50.0	300.0

1. Estimate based on an average weight of 2,500 pounds per cord of properly seasoned, mixed species wood.

2. Calculation estimates based on: Emissions Characterization and Noncancer Respiratory Effects of Wood Smoke, Timothy V. Larson & Jane Q.Koenig, From Table 2, EPA-453/R-93-036, 46p. (US EPA December 1993)

Other Air Pollutants In Wood (cont.)

- There are over 70 pollutants produced from wood burning* including:
  - Trace Elements (including Heavy Metals)
    - Strontium, Magnesium, Aluminum, Silicon, Sulphur, Chlorine, Potassium, Calcium, Titanium, Vanadium, Chromium, Manganese, Iron, Nickel, Copper, Zinc, Bromine, Lead
  - Polycyclic Aromatic Hydrocarbons (PAHs)
    - Benzo(a)pyrene, Fluorene, Phenanthrene, Anthracene, Methylanthracenes, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzofluoranthenes, Benzo(e)pyrene, Perylene, Ideno(1,2,3-cd)pyrene, Benz(ghi)perylene, Coronene, Dibenzo(a,h)pyrene, Retene, Dibenzo(a,h) anthracene
    - A Swedish study[6] found that ". . . wood-burning homes had . . . roughly 4 times the total PAH cancer potency, compared to non-wood-burning homes."[6]
    - A Norwegian study states: "Benzo(a)pyrene is the most carcinogenic PAH . . . the higher content of PAHs in the wood smoke particles indicates a higher mutagenic potential compared to vehicle exhaust."[8]
    - An EPA study estimates that wood stoves, on average, emit 432 ug/hour of benzo[a]pyrene.[9]
    - You would have to light 27,333 cigarettes to emit as much benzo(*a*)pyrene as burning one kilogram (2.2 lbs) of wood.[7] If you smoked one pack per day it would take 3.75 years to smoke 27,333 cigarettes.
  - Molds[10]
    - Thermoactinomyces vulgaris (part of Farmer's Lung[1] [aspergillosis]), Penicillium sp mixture, Aspergillus fumigatus (can cause disease in those with weakened immune systems[2]), Cladosporium herbarium (can trigger asthma attacks[3]), Micropolyspora faeni (part of Farmer's Lung[4][aspergillosis]), Alternaria tenius (allergen and asthma trigger[5])

*Emissions Characterization and Noncancer Respiratory Effects of Wood Smoke, Timothy V. Larson & Jane Q.Koenig, From Table 2, EPA-453/R-93-036, 46p. (US EPA December 1993)

1. http://www.rightdiagnosis.com/f/farmers_lung_thermoactinomyces_vulgaris/intro.htm
2. https://medical-dictionary.thefreedictionary.com/aspergillosis
3. https://www.moldbacteria.com/mold/cladosporium.html
4. http://www.rightdiagnosis.com/f/farmers_lung_micropolyspora_faeni/intro.htm
5. https://www.moldbacteria.com/mold/alternaria.html
6. Indoor Levels of Polycyclic Aromatic Hydrocarbons in Homes with or without Wood Burning for Heating, Pernilla Gustafson, Conny Östman and Gerd Sällsten, Department of Occupational and Environmental Medicine, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden, and Department of Analytical Chemistry, Stockholm University, Stockholm, Sweden, 2008
7. https://woodsmokepollution.org/toxins.html
8. Physicochemical characterisation of combustion particles from vehicle exhaust and residential wood smoke Anette Kocbach1, Yanjun Li2, Karl E Yttri3, Flemming R Cassee4, Per E Schwarze1 and Ellen Namork, 1Division of Environmental Medicine, Norwegian Institute of Public Health, http://www.particleandfibretoxicology.com/content/3/1/1
9. LONG-TERM PERFORMANCE OF EPA-CERTIFIED PHASE 2 WOODSTOVES, KLAMATH FALLS AND PORTLAND OREGON: 1998-1999, EPA/600/R-00/100, November 2000
10. Interstitial Lung Disease and Domestic Wood Burning: Ramage, Roggli, bell and Piantadosi, AM REV RESPIR DIS 1988; 137:1229-1232

Prior Reports, Current NEI Data on $PM_{2.5}$

- The Albuquerque Winter Visibility Study
  Sandia National Laboratories, Albuquerque, NM and Livermore, CA, 1984
  - Analysis showed increase in Fine Particulates in the evening
  - Visibility impairment is about 3 times more severe . . . at night than during the day. pg. VIII-1
  - Discusses differences in meteorology between the Heights and the Valley.
- The Albuquerque CO Source Apportionment Study
  Sandia National Laboratories, Albuquerque, NM and Livermore, CA, 1988
  - Includes wood burning in the carbon monoxide and PM2.5 in the apportionment study.
- 2014 National Emission Inventory (NEI) data
  - The NEI contains over 300 pollutants including criteria and hazardous air pollutants.
  - Based on the 2014 NEI data Residential wood totals 60.8% of the $PM_{2.5}$ from all fuel combustion sources

Study	% $PM_{2.5}$ Mobile	% $PM_{2.5}$ Wood Burning
1984 Albuquerque Winter Visability Study	35.2	61.4
1988 Albuquerque CO Source Apportionment	31.2/51.1	56.8/44.9
2014 National Emission Inventory Data	29.3	27.6

What is the NEI?

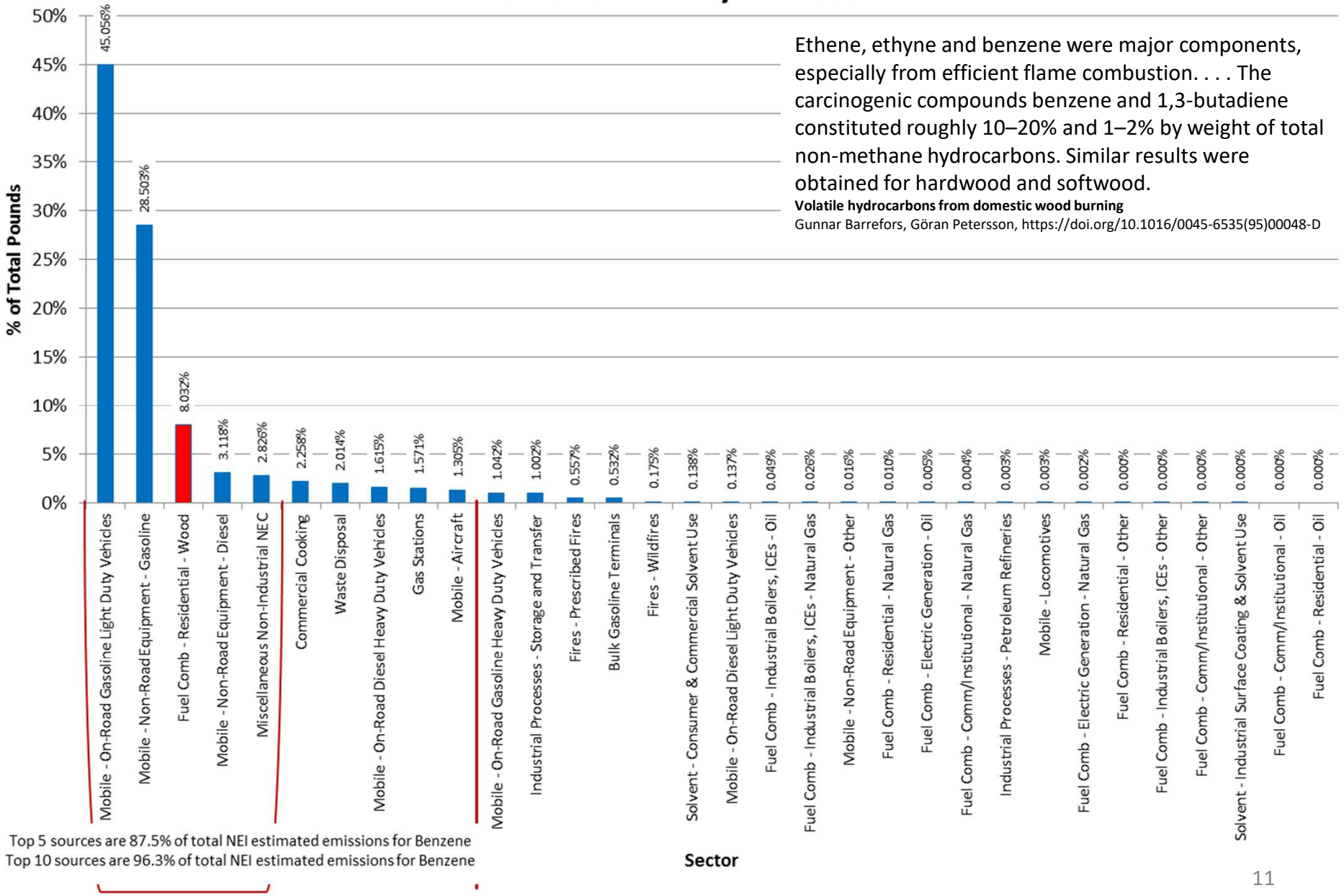
- The National Emission Inventory is

  a comprehensive and detailed estimate of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources. The NEI is built using the Emissions Inventory System (EIS) first to collect the data from State, Local, and Tribal air agencies and then to blend that data with other data sources.

  - **NEI point sources** include emissions estimates for larger sources that are located at a fixed, stationary location.
  - **NEI nonpoint sources** include emissions estimates for sources which individually are too small in magnitude to report as point sources.
  - **NEI onroad sources** include emissions from onroad vehicles that use gasoline, diesel, and other fuels. These sources include light duty and heavy duty vehicle emissions from operation on roads, highway ramps, and during idling.
  - **NEI nonroad sources** include off-road mobile sources that use gasoline, diesel, and other fuels. Source types include construction equipment, lawn and garden equipment, aircraft ground support equipment, locomotives, and commercial marine vessels.
  - **NEI "event" sources** include fires that are reported in a day-specific format: wildfires and prescribed burns. Generally, the US EPA calculates these emissions using a satellite detection approach combined with fire models and activity data provide by State, Local, and Tribal air agencies or forestry agencies.

- The National Emission Inventory is a useful tool available to everyone
  - https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data
  - The Emissions Inventory System can be found at: https://www.epa.gov/air-emissions-inventories/emissions-inventory-system-eis-gateway

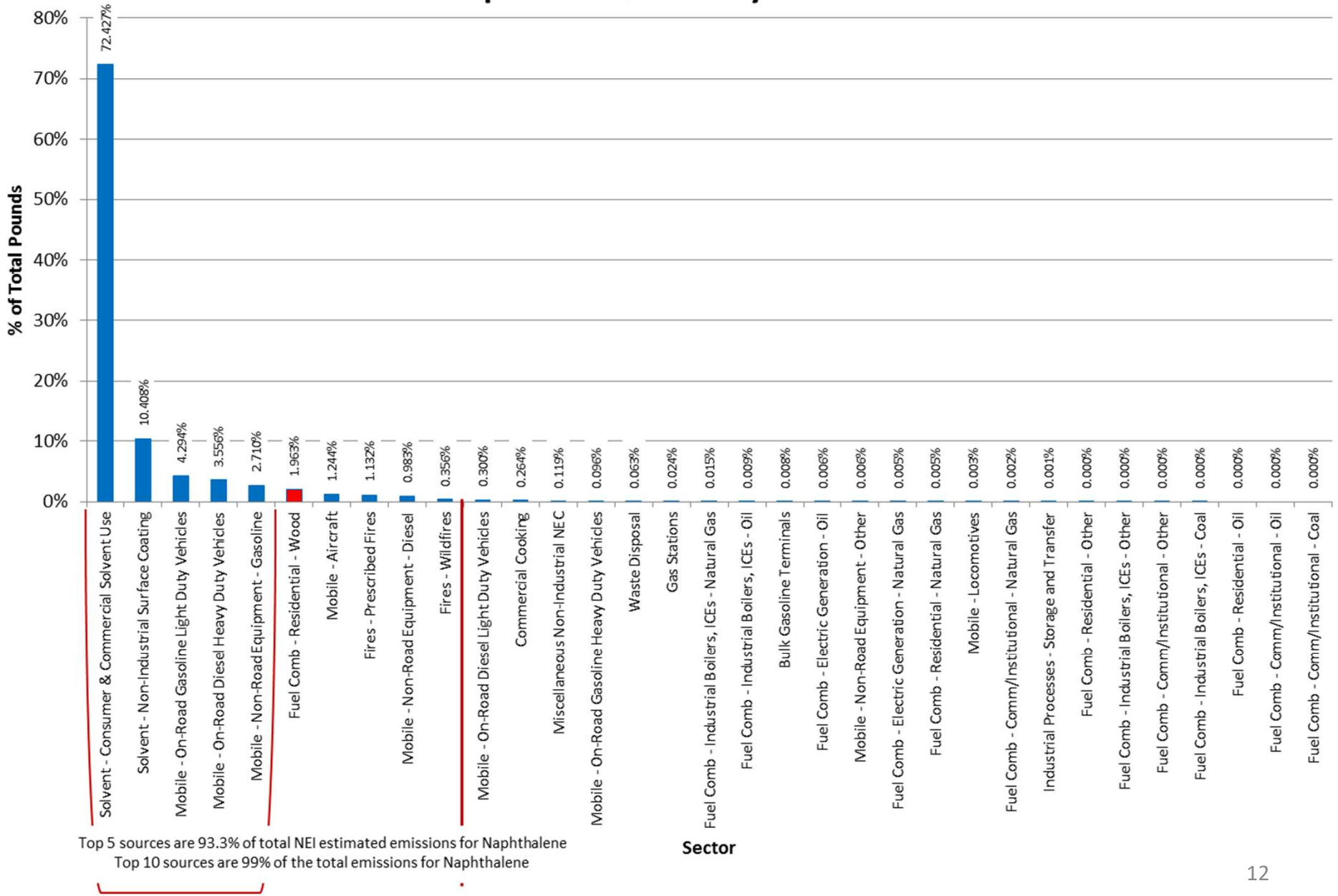
Annual 2014 NEI Hazardous Air Pollutant
Benzene Primary Sources



Ethene, ethyne and benzene were major components, especially from efficient flame combustion. . . . The carcinogenic compounds benzene and 1,3-butadiene constituted roughly 10–20% and 1–2% by weight of total non-methane hydrocarbons. Similar results were obtained for hardwood and softwood.

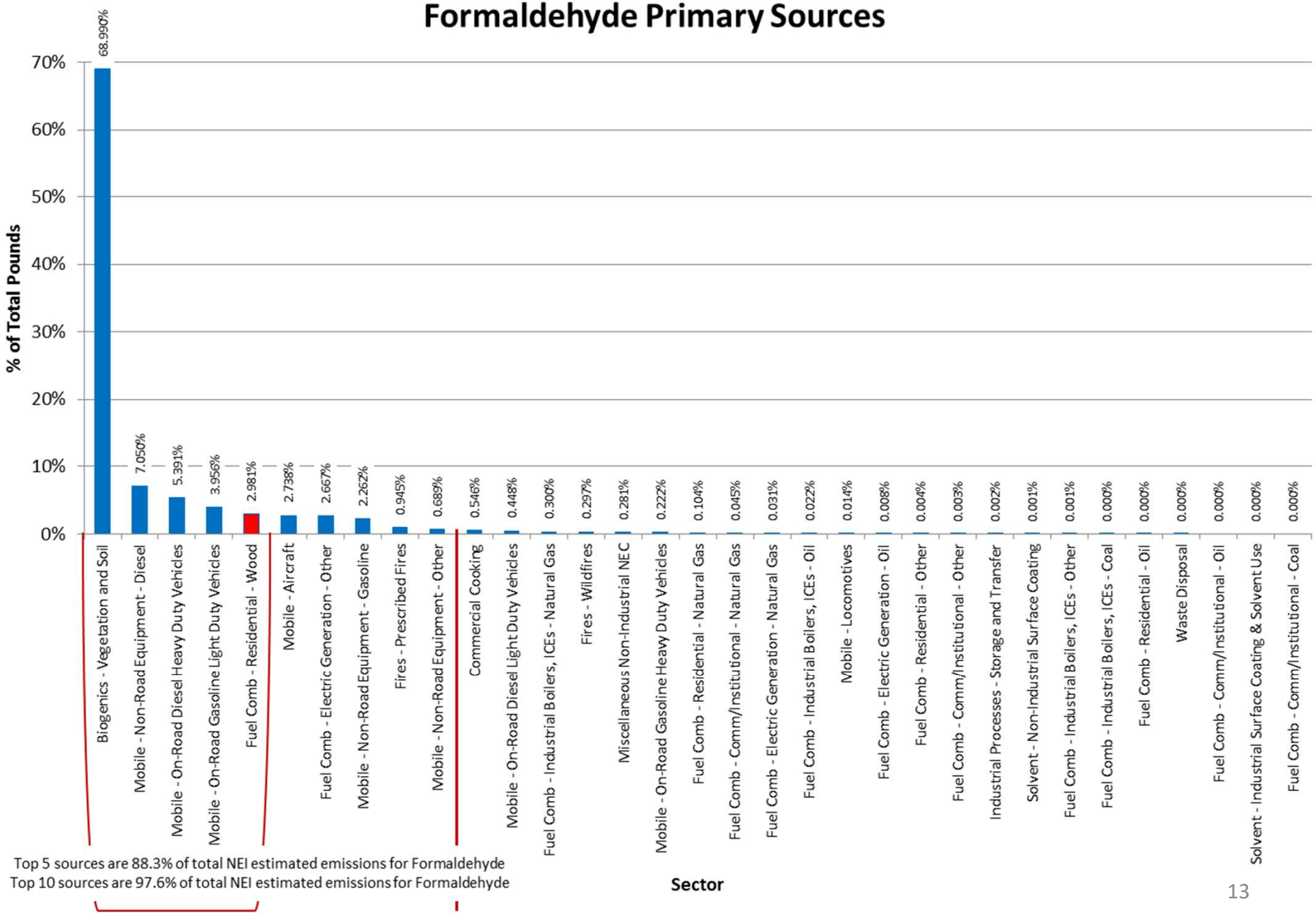
Volatile hydrocarbons from domestic wood burning
Gunnar Barrefors, Göran Petersson, https://doi.org/10.1016/0045-6535(95)00048-D

Annual 2014 NEI Hazardous Air Pollutant
Naphthalene Primary Sources



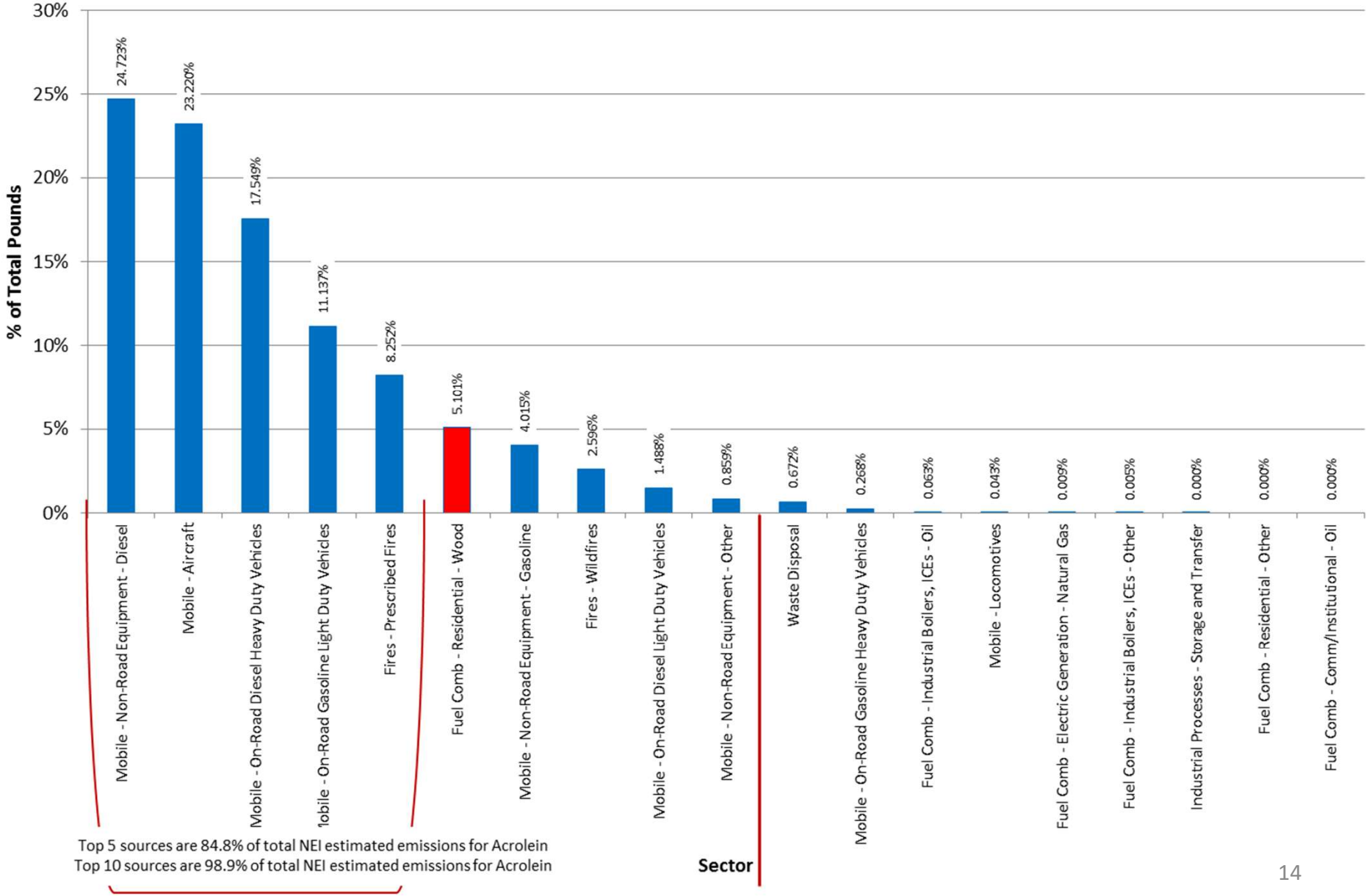
Top 5 sources are 93.3% of total NEI estimated emissions for Naphthalene
Top 10 sources are 99% of the total emissions for Naphthalene

Annual 2014 NEI Hazardous Air Pollutant
Formaldehyde Primary Sources



Top 5 sources are 88.3% of total NEI estimated emissions for Formaldehyde
Top 10 sources are 97.6% of total NEI estimated emissions for Formaldehyde

Annual 2014 NEI Hazardous Air Pollutant
Acrolein Primary Sources

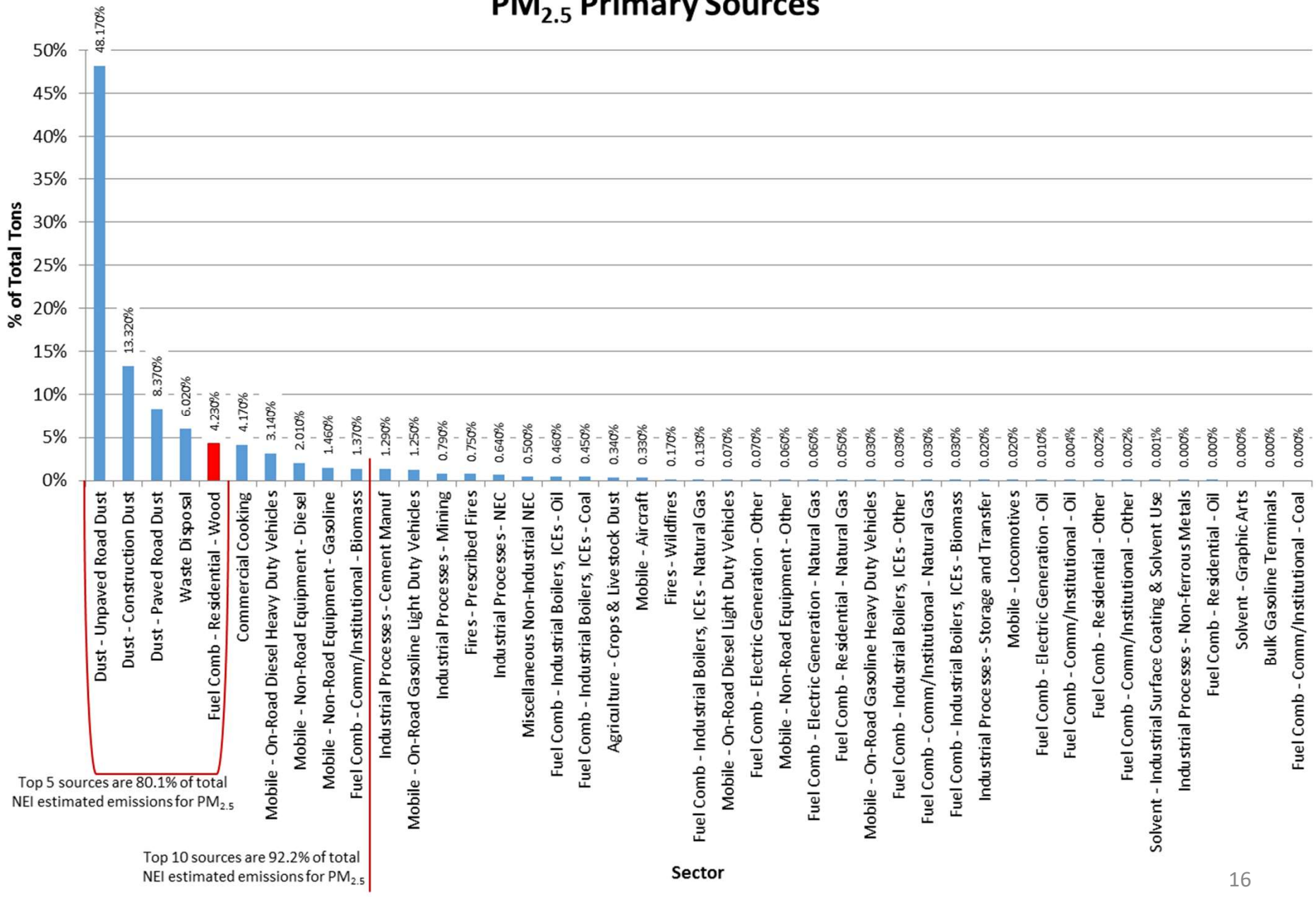


29 additional Hazardous Air Pollutants

- These are additional Hazardous Air Pollutants found under the **Fuel Comb–Residential–Wood** NEI Sector

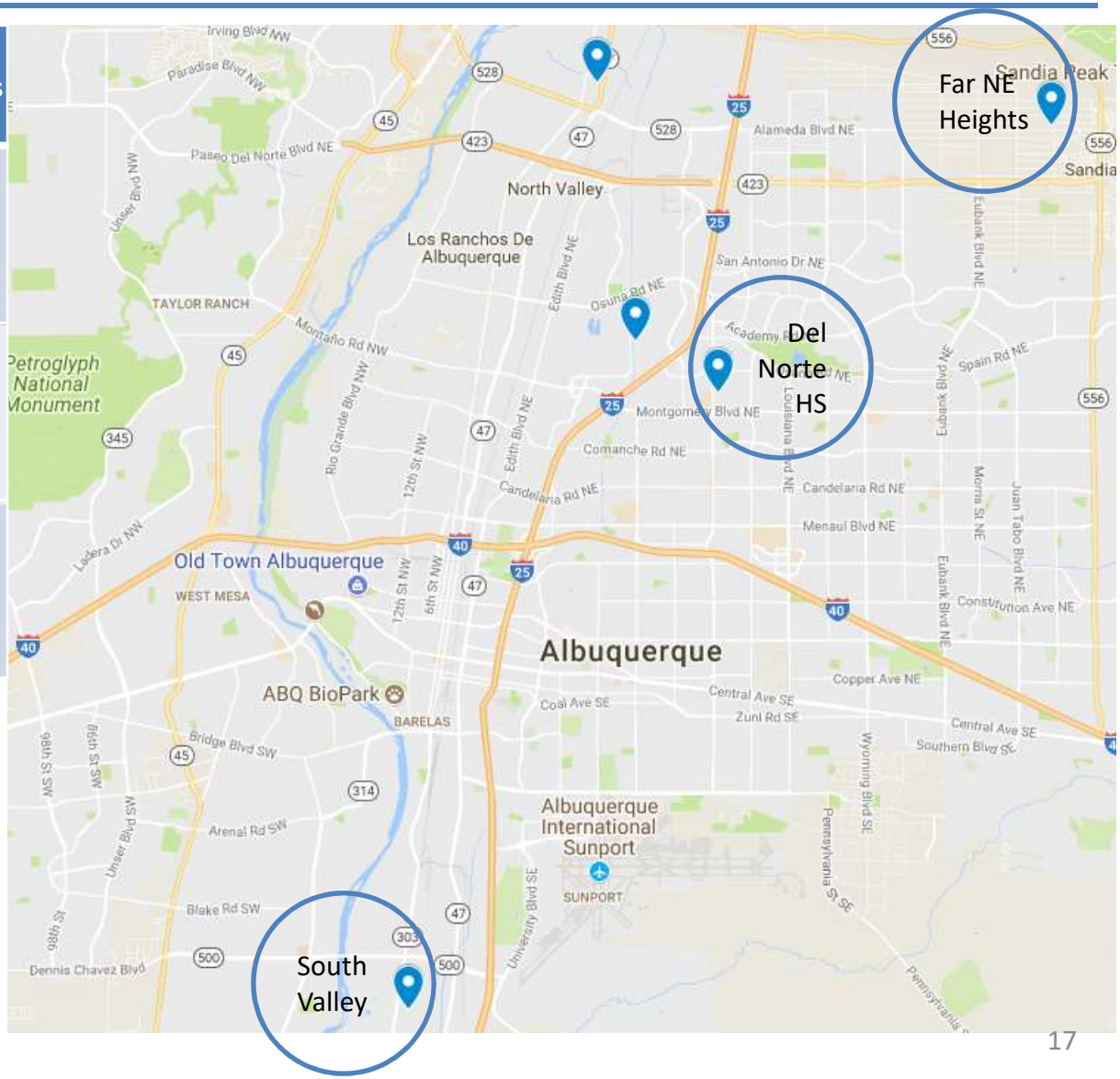
Hazardous Air Pollutant Under the Fuel Comb - Residential - Wood NEI Sector
1,3-Butadiene
Acenaphthene
Acenaphthylene
Acetaldehyde
Anthracene
Benz[a]Anthracene
Benzo(a)Fluoranthene
Benzo[a]Pyrene
Benzo[b]Fluoranthene
Benzo[e]Pyrene
Benzo[g,h,i,]Perylene
Benzo[k]Fluoranthene
Cadmium
Chrysene
Cresol/Cresylic Acid (Mixed Isomers)
Dibenzo[a,h]Anthracene
Fluoranthene
Fluorene
Indeno[1,2,3-c,d]Pyrene
Manganese
Mercury
Methylchrysene
Nickel
o-Xylene
Perylene
Phenanthrene
Phenol
Pyrene
Toluene

Annual 2014 NEI Criteria Air Pollutant $PM_{2.5}$ Primary Sources



The Local Network

Site	Del Norte (2ZM)	South Valley (2ZV)	Far NE Heights (2ZF)
PM2.5 Hourly	X	X	X
Black Carbon Hourly	X	X	X
Potassium 24 hour, one sample every 6th day	X		



What are some of the analysis issues

- **The nearest $PM_{2.5}$ monitor to Del Norte** (2/3/99) **or South Valley** (12/7/12) **to the**
  - South is in Las Cruces (4/1/17)
  - North near Santa Fe (3/23/17) and Durango (Ute 6/17/09)
  - West Navajo Nation (AZ 5/24/08)
  - Southeast Hobbs (2/17/17)

  otherwise to the East it's Seiling Municipal Airport in OK (8/21/14)

https://www.epa.gov/outdoor-air-quality-data

- **Issues**
  - Statewide data gaps
  - Limitation of what data are available even locally
  - Cost of specialized monitoring such as speciation
  - Limited census and area specific biomass burning data, including woodstove usage
  - Is there influence from outside the county?
    - If there is how do we identify the source and impact?

Which Pollutants?

- $PM_{2.5}$
  - $PM_{2.5}$ is created during biomass burning
  - Efficient wood burning generates more $PM_{2.5}$[1]

- Black Carbon (including elemental carbon)
  - BC is produced both naturally and by human activities as a result of the incomplete combustion of fossil fuels, biofuels, and biomass. [2]

- Potassium
  - A United Kingdom study found that domestic sector emissions of potassium have increased in recent years due to increased wood use and now accounts for 78% of emissions from this source. [3]
  - . . . "the release of potassium from wood combustion . . . can have a significant influence on the nature of the soot emitted from wood flames." [4]

Source:

1. Mr. Tony Wakelin, P.Eng. Unit Head Industrial Air Emissions, Emissions from Wood-Fired Combustion Equipment. Environmental Management Branch Ministry of Environment PO Box 9342, Stn Prov Govt Victoria, BC

2. https://www.c2es.org/document/what-is-black-carbon/

3. http://naei.beis.gov.uk/overview/pollutants?pollutant_id=116

4. Lea-Langton, AR, Baeza-Romero, MT, Boman, GV, Brooks, B, Wilson, AJM, Atika, F, Bartle, KD, Jones, JM and Williams, A (2015) A study of smoke formation from wood combustion. Fuel Processing Technology, 137. 327-332. ISSN 0378-3820

Why $PM_{2.5}$?

- $PM_{2.5}$ is a health based criteria pollutant
- The NM Department of Health notes that "[d]uring the wintertime, residential wood smoke is the main source of fine particle pollution causing poor air quality inside the home." [1]

- A Montana study of 5 communities ". . . showed that wood smoke (likely residential woodstoves) was the major source of $PM_{2.5}$ in each of the communities, contributing from 56% to 77% of the measured wintertime $PM_{2.5}$." [2]

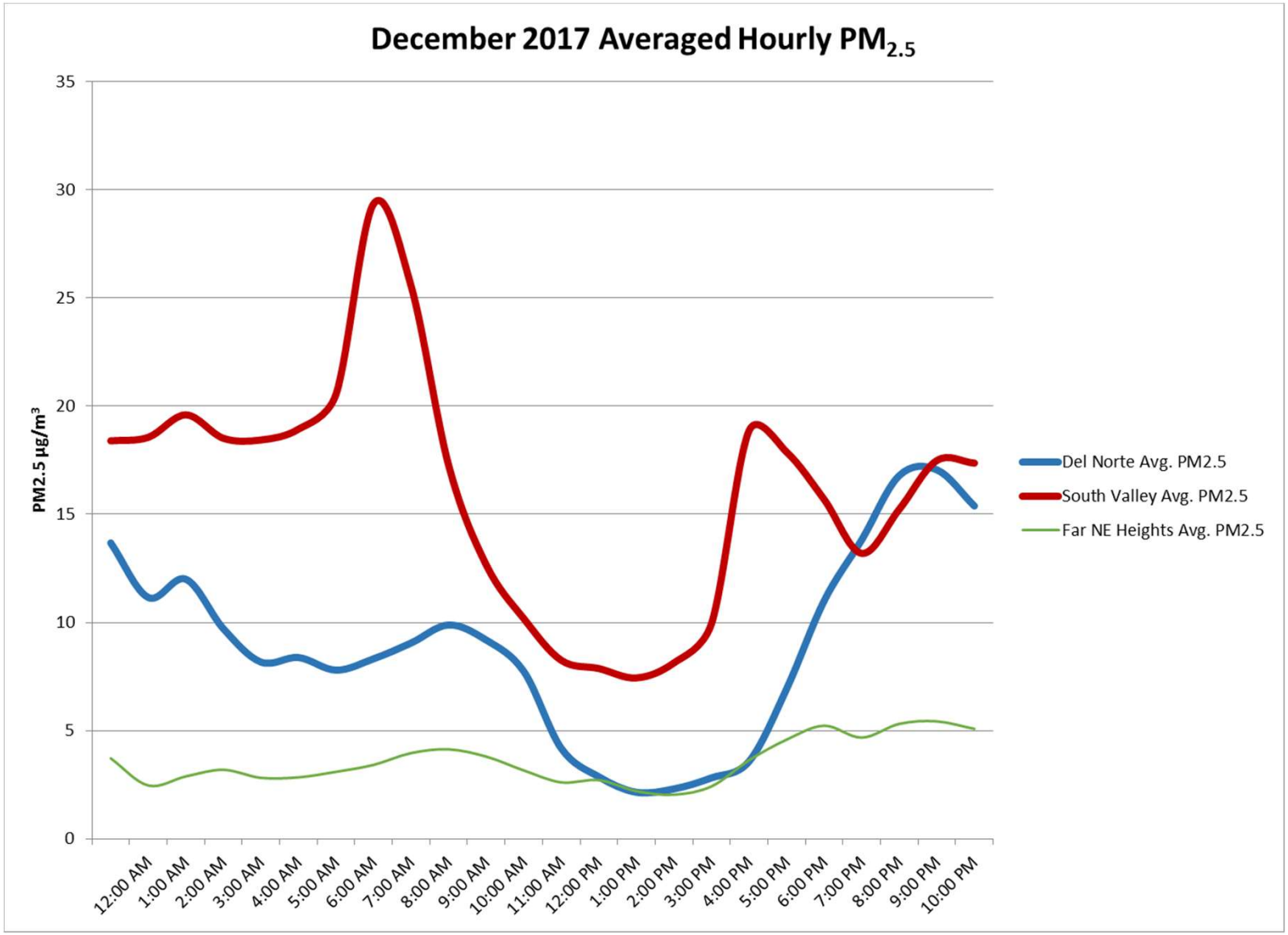
1. NM Department of Health, What You Burn Matters: Minimize the Risk, January 23, 2014, https://nmhealth.org/news/safety/2014/1/?view=32
2. The impact of wood smoke on ambient PM2.5 in northern Rocky Mountain valley communities, Tony Ward, Todd Lange, https://doi.org/10.1016/j.envpol.2009.10.016

What did we see?

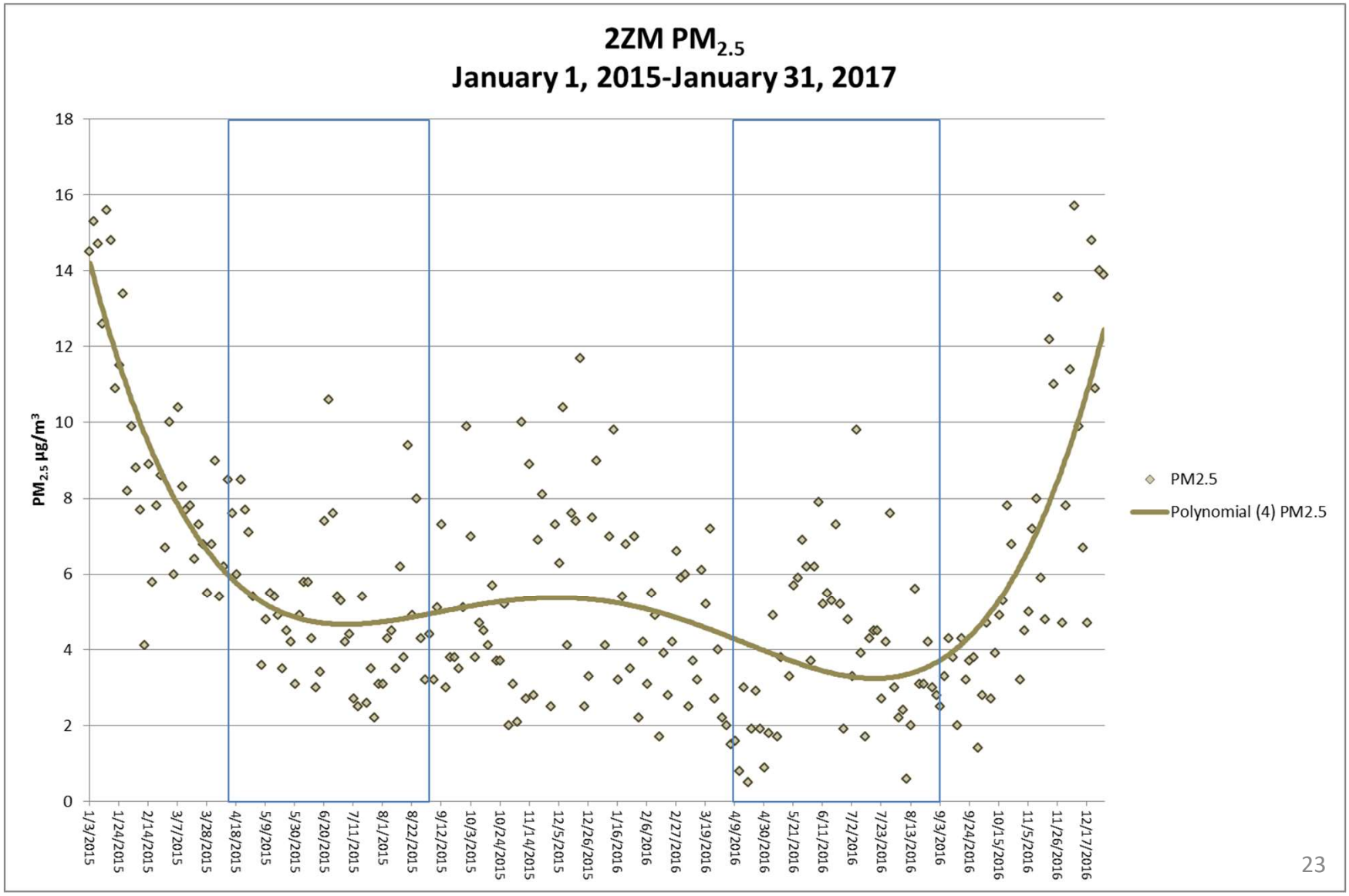
- $PM_{2.5}$
  - Over a two month period
    - Winter – Dec. 2016-January 2017 (South Valley)
      - 165 hourly alerts (11.3%)
      - Night time concentration increases
      - Early morning concentration increases
    - Summer – June-July 2017 (South Valley)
      - 50 hourly alerts (4%)
  - A 27%-33% increase in $PM_{2.5}$ from summer to winter months

2015-2016 data	Del Norte HS	South Valley
	Average $PM_{2.5}$ µg/m³	Average $PM_{2.5}$ µg/m³
Summer (Mar-Aug)	4.7	5.5
Winter (Sep-Feb)	6.5	8.3
% Difference	27.7%	33.0%

$PM_{2.5}$ Averaged December Values



$PM_{2.5}$, Del Norte



Why Black Carbon?

- Black Carbon is a useful marker for identifying wood smoke
- "Black carbon, a significant component of soot, served as an indicator compound for wood smoke." [1]
  - California Study:
  - ". . . Indicates that the indoor environment is not highly effective at reducing exposures to black carbon from residential wood smoke generated in the near-field." (page 93-94)

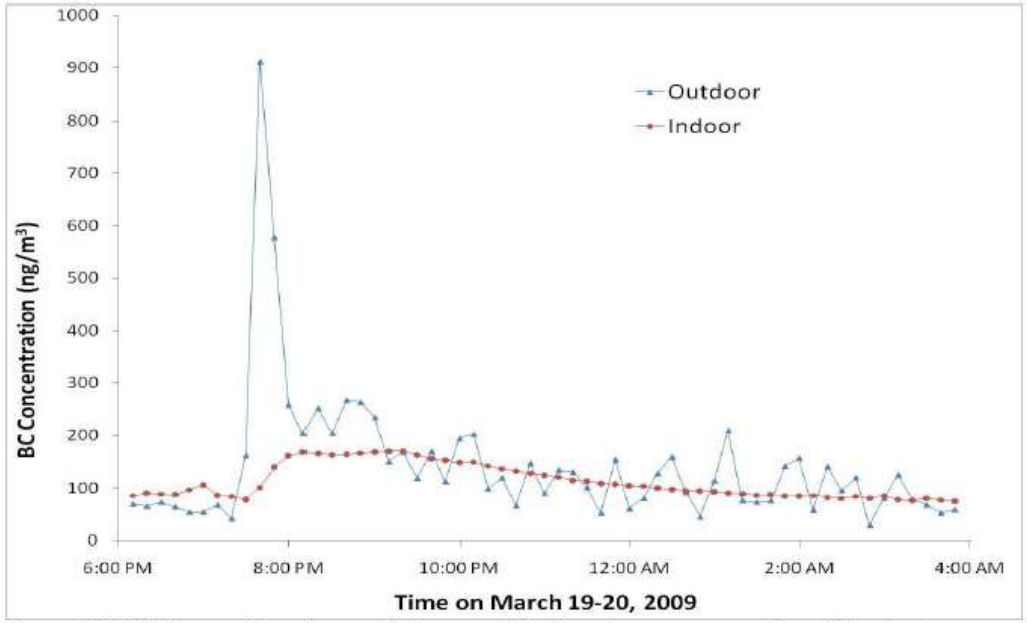


Figure 11.4 Indoor and outdoor aethalometer black carbon concentrations (10 minute averages) for home E in Cambria, CA

1. "**Assessing Near-Field Exposures from Distributed Residential Wood Smoke Combustion Sources**", California Air Resources Board and California Environmental Protection Agency, Tracy Thatcher, Stella Tan, Christopher Malejan, and Courtney Ward, Civil and Environmental Engineering California Polytechnic State University. Thomas Kirchstetter Environmental Energy Technologies Division Lawrence Berkeley National Laboratory, **September 2011.**

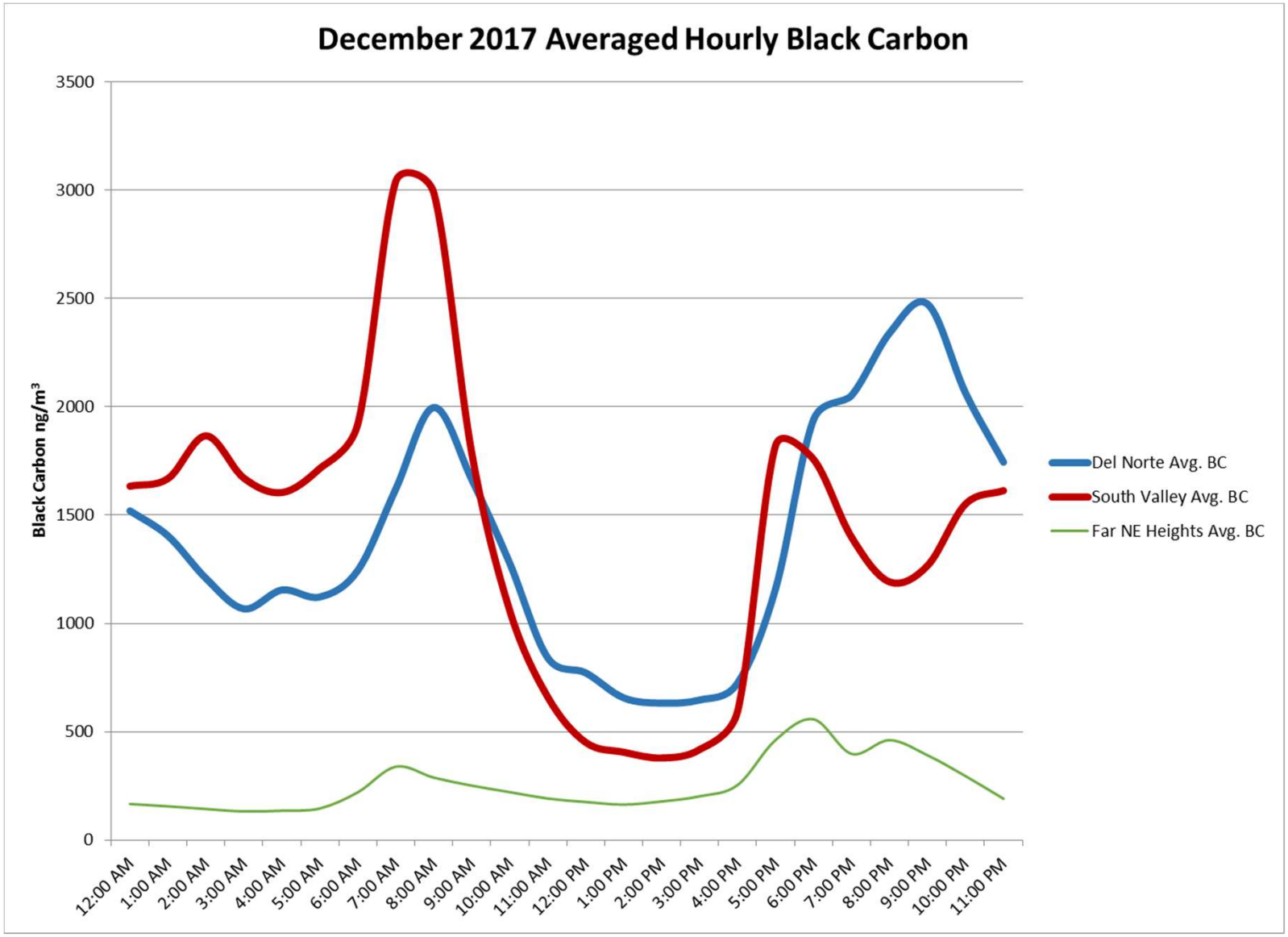
What did we see?

- Black Carbon
  - A 50.6%-51.3% increase from summer to winter months

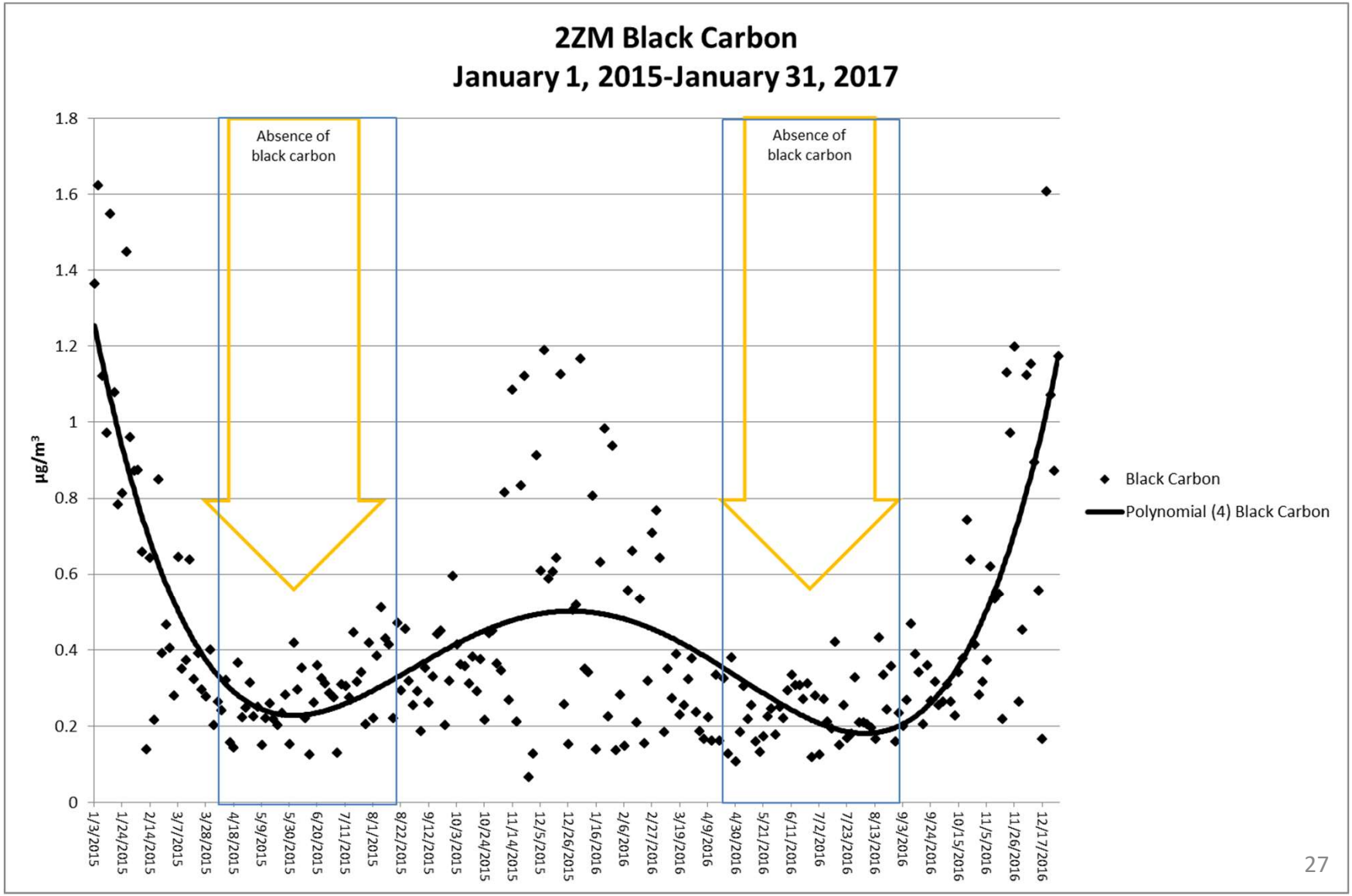
	Del Norte HS	South Valley
2015-2016 data	**Average Black Carbon µg/m³**	**Average Black Carbon µg/m³**
Summer (Mar-Aug)	0.280	0.406
Winter (Sep-Feb)	0.567	0.835
% Difference	50.6%	51.3%

  - An absence of Black Carbon above 0.55 µg/m³ during the summer months (2015-2016 data, Del Norte HS)
  - Night time increases
  - Early morning increases

Black Carbon Averaged December Values



Black Carbon, Del Norte



Why Potassium?

- Potassium is a useful marker for identifying wood smoke, many studies use Potassium as a primary marker
- Potassium is still considered better suited for biomass estimates, although different studies use different factors
  - ". . . potassium is produced in different amounts during wood-burning processes, depending on the type of fuel and combustion; it is thus a reliable wood-burning marker, but not a metric for a quantitative estimate of [wood burning black carbon] concentrations when assessing long-term data".

Wood ash composition

Table 4. Elemental analysis of ash at 600°C (wt% of ash)

Element	Pine	Aspen	Poplar	R. Oak	W. Oak	W. Oak Bark	D. F. Bark
Calcium	29.05	21.17	25.67	36.58	31.35	36.14	34.26
Potassium	16.24	11.25	7.93	6.08	10.25	0.97	2.78
Magnesium	7.03	3.55	9.09	5.20	7.57	0.34	0.37
Sulfur	1.07	0.70	1.02	1.80	1.21	0.40	0.52
Phosphorus	0.84	1.18	0.95	1.56	0.56	0.08	0.51
Manganese	4.04	0.14	0.45	1.49	0.14	0.16	0.37
Zinc	0.36	0.34	0.04	0.22	0.08	0.05	0.07
Iron	0.58	0.26	0.32	n.d.	0.09	0.01	0.26
Aluminum	0.47	0.14	0.35	0.68	<0.03	<0.03	0.59
Sodium	0.06	0.06	2.30	0.08	<0.06	<0.06	<0.06
Silicon	n.d.	0.11	n.d.	n.d.	0.13	0.12	0.24
Boron	0.06	0.05	0.05	0.08	0.04	0.007	0.07
Copper	0.04	0.03	0.03	0.07	0.02	<0.002	0.02

n.d.—not determined.

MAHENDRA K. MISRA, KENNETH W. RAGLAND and ANDREW J. BAKER, WOOD ASH COMPOSITION AS A FUNCTION OF FURNACE TEMPERATURE, Biomass and Bioenergy Vol. 4, No. 2, pp. 103-116, 1993

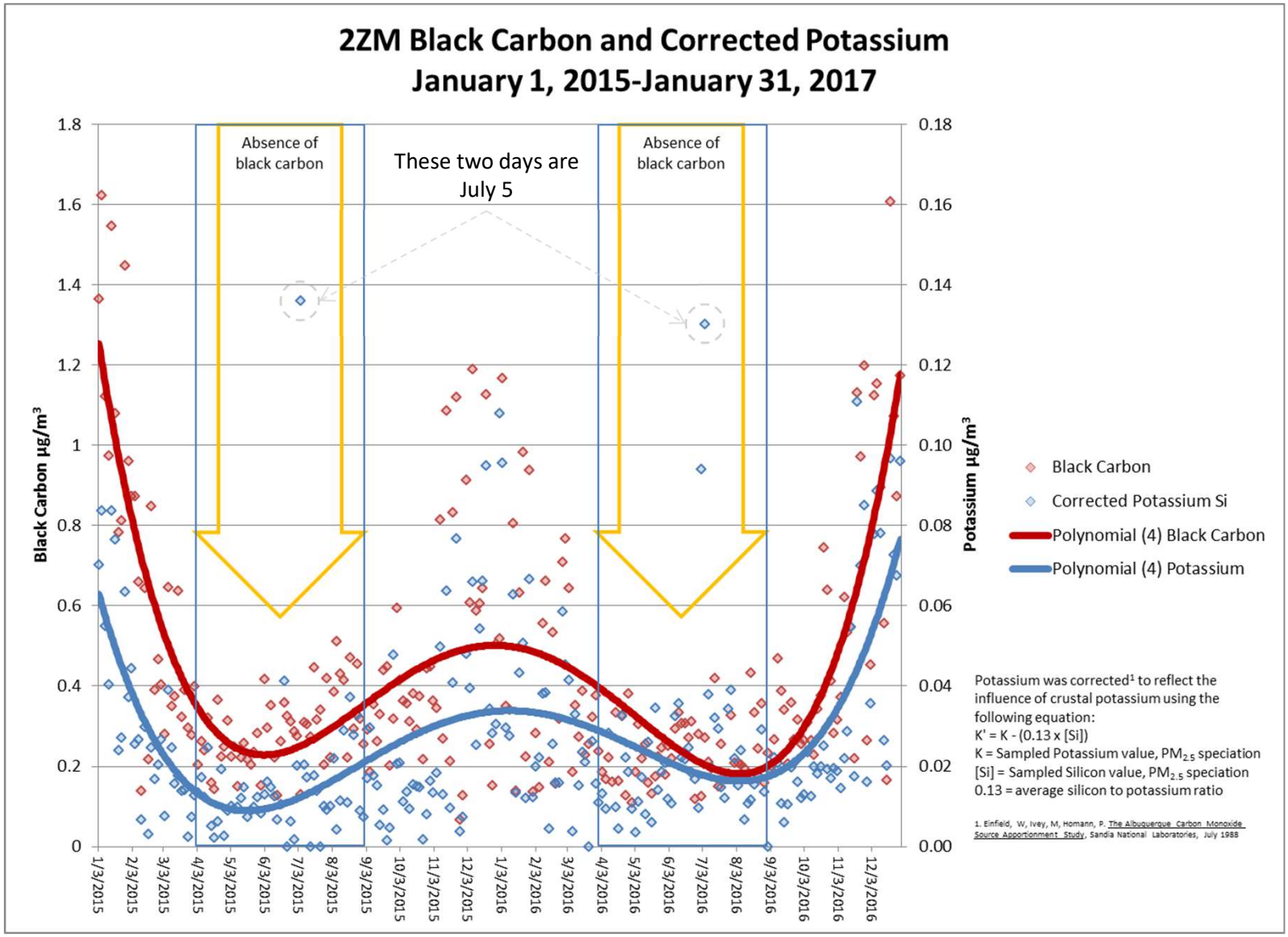
What did we see?

- Potassium
  - A 55.9% increase in Potassium from summer to winter months

2015-2016 data, Del Norte HS	Average Potassium µg/m³
Summer (Mar-Aug)	0.015
Winter (Sep-Feb)	0.034
% Difference	55.9%

  - An absence of Potassium above 0.5 µg/m³ during the summer months (2015-2016 data, Del Norte HS)

Potassium and Black Carbon, Del Norte



Conclusion

- Black carbon and potassium point toward winter time wood/biomass burning
- Night-time/early morning patterns point toward wood burning
- Quantifying and reducing the amount of wood/biomass burning in Bernalillo County should decrease citizen exposure to air pollutants including hazardous and other air pollutants

What we need:

- Differentiate sources of wood/biomass burning in the data
- Determine who uses wood as the primary heat source
- Quantify how much wood is burned
- Identify external impacts
  - Are Valencia, Sandoval Counties, Isleta Pueblo part of the issue?
  - Without data from outside the county it will be difficult to identify external sources
- Generate higher resolution data from the South Valley station
  - Speciation data
- Improved understanding of the meteorology between the Heights and Valley