THE HARMFUL EFFECTS OF WOOD SMOKE AND THE GROWTH OF RECREATIONAL WOOD BURNING

barbecue

chiminea

fire pit

pizza oven

ENVIRONMENT & HUMAN HEALTH, INC.

THE HARMFUL EFFECTS OF WOOD SMOKE AND THE GROWTH OF RECREATIONAL WOOD BURNING

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ENVIRONMENT & HUMAN HEALTH, INC.
1191 Ridge Road • North Haven, CT 06473
Phone: (203) 248-6582 • info@ehhi.org
www.ehhi.org

Environment and Human Health, Inc.
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D. Barry Boyd, MD. Clinical Professor of Medicine, Yale University School of Medicine; Oncologist at Greenwich Hospital and Affiliate Member of the Yale Cancer Center; Founder and Director of Integrative Medicine at Greenwich Hospital – Yale Health System.

David R. Brown, ScD. Public Health Toxicologist and Director of Public Health Toxicology for Environment and Human Health, Inc.; Past Chief of Environmental Epidemiology and Occupational Health at Connecticut's Department of Health; Past Deputy Director of The Public Health Practice Group of ATSDR at the National Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia.

Thomas F. Harrison, Esq. Connecticut Environmental Lawyer; Past Assistant Attorney General in the New York State's Attorney General's office; Past Regional Counsel in the largest U.S. EPA Office, Region 5; Past Senior Corporate Council to the B.F. Goodrich Company; Past Partner at the Hartford law firm of Day Pitney LLP; Past Chairman of the Environmental Section of the Connecticut Bar Association.

Pinar H. Kodaman, MD, PhD. Assistant Professor of Obstetrics, Gynecology, and Reproductive Sciences, Division of Reproductive Endocrinology and Infertility, Yale University School of Medicine; Director of the Early Recurrent Pregnancy Loss Program at the Yale Fertility Center.

Sarah S. Mougalian, MD. Assistant Professor of Medical Oncology with a focus on Breast Medical Oncology, Smilow Cancer Center, Yale University School of Medicine. Recipient of many awards, including the Clifton Howe Award given for clinical excellence to a medical oncology fellow.

Hugh S. Taylor, MD. Anita O'Keeffe Young Professor of Obstetrics, Gynecology, and Reproductive Sciences; Professor of Molecular, Cellular, and Developmental Biology; Chair of Obstetrics, Gynecology, and Reproductive Sciences, Yale School of Medicine; Chief of Obstetrics and Gynecology, Yale-New Haven Hospital.

John P. Wargo, PhD. Tweedy-Ordway Professor of Environmental Health and Political Science at Yale University; Chair, Yale College Environmental Studies Major and Program; author of *Green Intelligence: Creating Environments That Protect Human Health* (Yale Press) and *Our Children's Toxic Legacy.*

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John Wargo, Ph.D.
Tweedy-Ordway Professor of Environmental Health and Political Science
Yale University

Nancy Alderman, MES
President
Environment and Human Health, Inc.

Linda Wargo, MES

EDITING AND GRAPHIC DESIGN
Jane M. Bradley, MALS
Medical/Science Writer
Environment and Human Health, Inc.

EDITING ASSISTANCE
Susan Addiss, MPH, MUrS
Editor
Environment and Human Health, Inc.

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I. Wood Smoke: Introduction

- Wood smoke poses a serious danger to human health. It is known to cause and exacerbate many pulmonary and cardiovascular diseases, and these illnesses are the primary causes of mortality in the U.S.
- Despite convincing scientific evidence of health hazards, most governments have failed to effectively regulate wood burning, and wood smoke now constitutes nearly 30% of airborne particle pollution in a number of urban areas during winter months.
- Human exposure to wood smoke appears to be increasing, as more people are burning wood within or near their homes. The use of wood for heating purposes increases along with fossil fuel prices, especially in forested parts of the country where wood is both accessible and inexpensive.
- During the past 25 years, outdoor residential fireplaces, fire pits, chimineas, cooking appliances, and wood boilers (used in the summer only to produce hot water and heat swimming pools) have become increasingly common. The dynamics of the exchange

During the past 25 years, outdoor residential fireplaces, fire pits, chimineas, cooking appliances, and outdoor wood boilers (used in the summer to produce only hot water and heat swimming pools) have become increasingly common.

Emissions from wood burning, diesel fuel combustion, coal power plants, and cigarettes contain remarkably similar chemicals.

of wood smoke from outdoor burning with indoor concentrations of particulates and gases is misunderstood.

- The ability of very fine particles and gases to enter indoor environments from outdoor burning sources is well documented, and dependent upon indoor-outdoor air exchange rates. This means that those who routinely burn wood should be vigilant that they are not polluting their indoor environments to dangerous levels.

- Emissions from wood burning, diesel fuel combustion, coal power plants, and cigarettes contain remarkably similar chemicals. For areas already out of federal compliance with pollution limits from other sources of particles and volatile organic compounds, the additional contribution of wood smoke can produce dangerous conditions.

- Wood smoke from a single source normally creates a plume of visible pollution, also identifiable by its sweetness of smell. Satellite imagery with extraordinary sensitivity can easily track wood smoke many miles from its origin, along with the buildup of haze under still conditions near the source. If the source is within or near an urban block, condominium or townhouse cluster, hundreds of people may be exposed to elevated levels of particles and gases that can diminish lung function and threaten health.

- The U.S. Environmental Protection Agency has primary federal responsibility to regulate air quality, yet this agency has long-neglected the wood-burning problem, leaving it to state, local, and municipal governments.

- This disregard has led to a patchwork quilt of largely ineffective regulation by lower levels of government, and many communities have no health-protective requirements at all. Poorly funded state and local health departments are often responsible for establishing and regulating wood smoke emissions. Many expect the federal government to establish health-protective standards. When the federal government fails to do so, states and local governments must assume the responsibility as an “unfunded mandate.”

- Effective regulation might focus on appliance emission standards; maximum health-protective air pollution levels of particles and gases at the user's property boundary; a maximum number of wood-burning devices allowable within buildings, neighborhoods, or cities; and prohibitions against burning during still weather conditions when air pollution can increase rapidly near the ground. The absence of effective legal protection leaves most individuals to fend for themselves in attempts to persuade neighbors to use cleaner sources of fuel such as natural gas, and more efficient burning appliances for heating and cooking, both indoors and outdoors.

- There is some good news. Mandatory wood smoke reduction programs in California have resulted in significant reductions in ambient PM2.5 concentrations and a decrease in measured health effects. This is consistent with a large body of data demonstrating that as particulate air pollution declines, public health improves.[1] A number of state and local governments have prohibited burning during still weather patterns, or certain times of the day.

- Decades of research demonstrate that particles with a diameter of 2.5 micrometers or less can enter the respiratory tract. Small particles created by burning wood remain airborne for longer periods of time than larger particles, meaning that they remain available for human inhalation. Small particles can have a strongly negative effect on human health, causing and exacerbating lung diseases, triggering cardiovascular events, cancers, and premature deaths. Health loss can occur at air pollution levels well below regulatory standards.

- ***Long-term exposure*** is associated with reduced lung function, chronic bronchitis, and even premature death.[2] Long-term exposure to fine particles (PM2.5) is linked to atherosclerosis (a condition that underlies many cardiovascular diseases), adverse birth outcomes, and childhood respiratory diseases. Additional studies suggest that long-term exposure to PM2.5 also increases risks of diabetes, neurodevelopmental abnormalities, and diminished cognitive function.[3] Lung cancer is also a risk of long-term exposure to wood smoke.[4]

Small particles can have a strongly negative effect on human health, causing and exacerbating lung diseases, triggering cardiovascular events, cancers, and premature deaths. Health loss can occur at air pollution levels well below regulatory standards.

Outdoor fireplaces can cause dangerous exposures, especially under still, damp conditions and temperature inversions when smoke continues to concentrate near the ground.

- ***Short-term exposure*** to wood smoke aggravates many types of lung diseases, can cause asthma attacks and acute bronchitis, and may increase susceptibility to respiratory infections.

- Low-level exposure to wood smoke, regardless of its origin, can reduce pulmonary function and lower blood oxygen concentrations. Recent studies show reduced lung function later in life following childhood exposure to wildfire smoke.[5] Studies also show a higher incidence of breast cancer in women who burn synthetic wood,[6] and shortened lifespans in women with breast cancer who are exposed to fine particles found in wood smoke.[7]

- Short- and long-term exposures to PM2.5 decrease life expectancy.[8] A 2017 study of more than 60 million U.S. Medicare beneficiaries found that, for every increase in pollution concentration of 10 $\mu g/m^3$ in outdoor PM2.5 (measured as an annual average), mortality increased by 7%. The study included populations from small cities and rural areas. The authors reported that long-term exposure to PM2.5 is associated with an increased risk of death, even at levels below the current regulatory standards.[9]

- The burning of firewood and trash is one of the largest contributors to PM2.5 in many rural, semi-rural, and suburban communities in the U.S.

- Outdoor fireplaces can cause dangerous exposures, especially under still, damp conditions and temperature inversions when smoke continues to concentrate near the ground.

- The history of second-hand cigarette smoke regulation demonstrates that local and state policy efforts are likely to be more successful than federal initiatives. Local and state regulations raised public awareness regarding the health risks of second-hand smoke to non-smokers, increasing support for policy measures to reduce these risks, and changing attitudes and norms regarding the social acceptability of smoking.

- Local burn-free zones, especially in densely populated environments, could dramatically reduce pollution, exposures and health risks. Wood burning in most societies is viewed as a natural practice to create heat, light, cook food, heat water, and provide a sense of security. Fireplaces, woodstoves, and both indoor and outdoor cooking appliances are often the center of social life and relaxation.

- Wood burning in residential settings has long enjoyed a positive cultural image in the public mind. This favorable impression was reinforced during recent decades of fossil fuel price increases, and by consumer perception that wood burning is both natural and environmentally sustainable.

- The growing scientific consensus that wood smoke causes serious and widespread human illness is disbelieved by many who rely on wood burning for heat or its social comforts at relatively small costs compared with fossil fuels. They believe they have a legitimate right to continue a traditional and natural practice spanning thousands of years. Customary or traditional patterns of wood burning help to explain constituents' resistance to new regulations, and legislators are especially sensitive to their constituents' concerns.

Wood-burning in most societies is viewed as a natural practice to create heat, light, cook food, heat water, and provide a sense of security. Fireplaces, woodstoves, and both indoor and outdoor cooking appliances are often the center of social life and relaxation.

Pittsburgh, PA

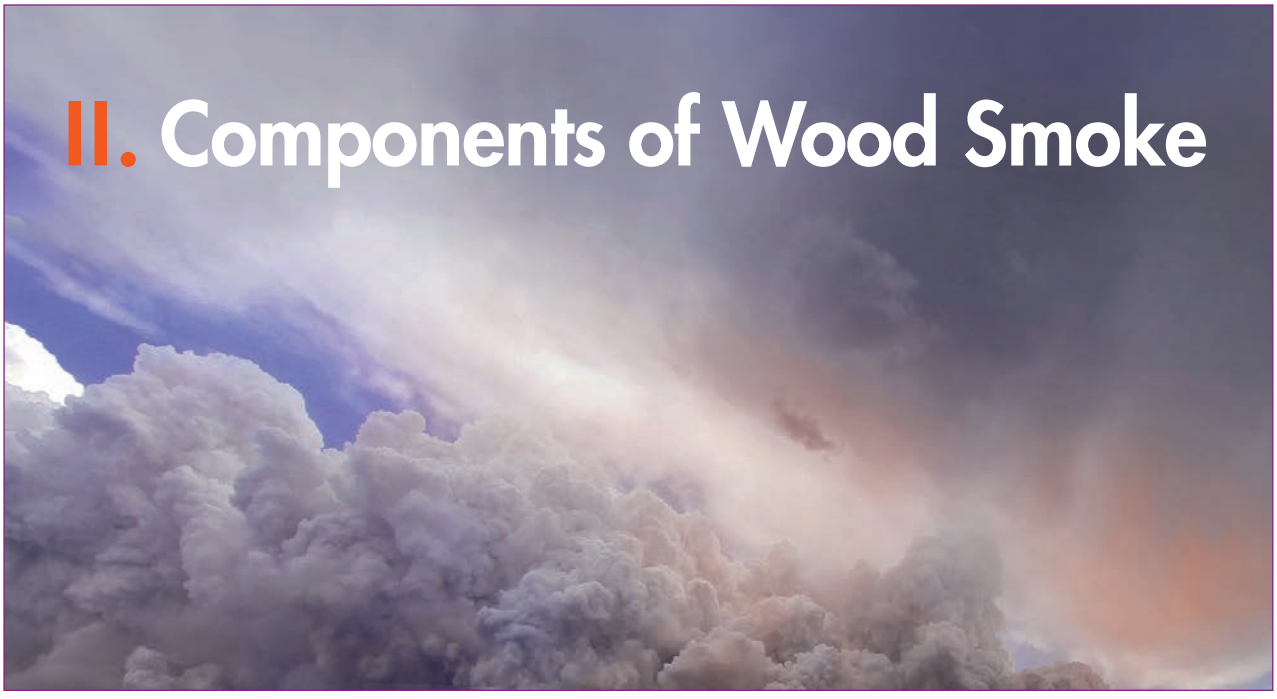
The report explores efforts in Allegheny County, Pennsylvania,, and in Connecticut to control wood-smoke exposures. It is important to note that Allegheny County has some of the highest levels of particulate air pollution in the U.S.

- This report provides an extensive review of the health effects associated with human exposure to wood smoke. At the present time, there are no accurate estimates of the current number of appliances, frequency of use, or amount of wood burned by geographic location because the data do not exist.

- This report examines state and local government efforts to reduce wood-smoke emissions. As examples, the report explores efforts in Allegheny County, Pennsylvania, and in Connecticut to control wood-smoke exposures. It is important to note that Allegheny County has some of the highest levels of particulate air pollution in the U.S. The report ends with recommendations to reduce exposures from wood-smoke emissions for all levels of government, as well as for individuals.

- The research presented in this report concludes that the health risks associated with wood-smoke exposure are serious. Finally, the report suggests a variety of policy and behavioral changes that could significantly reduce human exposures and health loss from inhaling wood smoke.

II. Components of Wood Smoke



- Wood smoke contains thousands of chemicals, many with documented adverse human health effects. Chemicals include gases such as carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3).Wood smoke contains particulate matter (PM) and toxic air pollutants, including benzene, formaldehyde, acrolein and polycyclic aromatic hydrocarbons (PAHs).

- The specific chemicals in wood smoke depend on the type of burning appliance, whether wood stove, fireplace, or fire pit. Other factors include the burn rate, type of wood, and moisture content. The appliance used and type of wood burned have the largest effect on the composition of emissions from wood combustion.[10]

- Components of wood smoke include at least five chemical groups classified as known human carcinogens by the International Agency for Research on Cancer (IARC). Wood smoke contains additional chemicals categorized by IARC as probable or possible human

Components of wood smoke include at least five chemical groups classified as known human carcinogens by the International Agency for Research on Cancer (IARC). Wood smoke contains additional chemicals categorized by IARC as probable or possible human carcinogens, and at least 26 chemicals listed by the USEPA as hazardous air pollutants.

carcinogens, and at least 26 chemicals listed by the USEPA as hazardous air pollutants.[11]

- The chemical composition of wood smoke is extremely complex.[12] Table 1 lists a handful of the chemicals of concern found in wood smoke that have been linked to cardiovascular and pulmonary diseases, immune system disorders, cancer and/or other diseases.

Table 1: Major Hazardous Pollutants in Wood Smoke

Compound	Cardiovascular	Pulmonary	Cancer	Immune	Other
1,3 butadiene*			•		•
PAHs (20+)*			•		
Benzene*			•		•
Acrolein*	•	•	?	•	
Formaldehyde*			•		
Dioxin			•		
Particulate Matter	•	•			

*Hazardous Air Pollutant

Particulate Matter

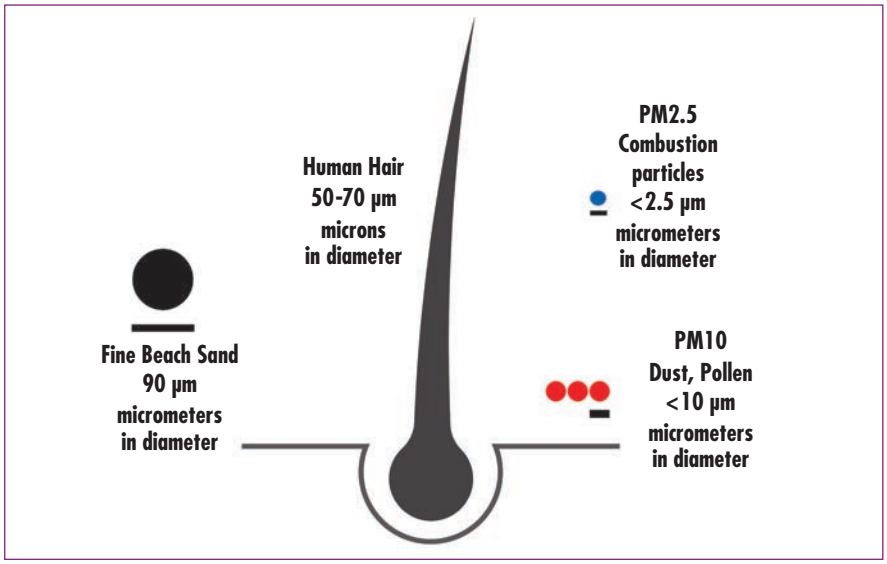
- Particulate matter, or PM, is a mixture of solid and liquid droplets suspended in the air. PM is regulated according to size by the National Ambient Air Quality Standards (NAAQS) set by USEPA.

- PM10 consists of coarse particles smaller than 10 µm in diameter, while PM2.5 is made up of finer particles that are generally 2.5 µm or smaller in diameter. Ultrafine particles, or UFP, are not currently regulated by USEPA and have diameters less than 0.1 µm.

PM2.5

- Fine particles are so small they can pass through the nose and throat and enter the lungs. Once inhaled, these fine particles can cause serious health effects, especially to those with heart or lung

Figure 1: PM Size Comparison



Source: https://www.airnow.gov/index.cfm?action=aqibasics.particle

diseases. Children, older adults and people with diabetes are also affected by fine particles.

- Researchers at Harvard found that both short- and long-term exposure[13] to PM2.5 was associated with mortality at levels below current standards.[14]

Sources of PM2.5 Pollution

- Burning firewood and trash are among the largest sources of fine particle pollution in many parts of the country.[15] According to USEPA, residential wood smoke contributes more than 345,000 tons of PM2.5 into the air throughout the country each year.[16]

- A recent study in the northwest U.S. found that residential wood burning was responsible for 31% of PM2.5 in Seattle; for 58% in Portland; for 86% in Klamath Falls; and for 92.7% in Lakeview, Oregon. At 10 monitoring sites in the study, the average December and January contribution of residential wood burning to PM2.5

Burning firewood and trash are among the largest sources of fine particle pollution in many parts of the country.

levels ranged from 11.4% to 92.7%. The highest percentages of wood smoke PM2.5 occurred in smaller towns where there were fewer other sources of PM2.5.[17]

Wood burning emits about four times the amount of PM2.5 than all the region's power plants in Southern California combined.

- In Connecticut, wood smoke particulate matter has been found to contribute as much as 100% of the hourly and 74% of the daily contribution to the total PM2.5.[18] In Westport, Connecticut, wood heating contributes 69% of PM2.5 in the fall.[19]

- A study of five rural Montana valley communities found that residential wood stoves were the largest source of PM2.5, ranging from 56% to 77% of measured wintertime PM2.5 pollution.[20]

- Wood burning is the largest source of annual PM2.5 pollution in the San Francisco Bay Area, contributing 25% of the area's PM2.5 pollution, followed by exhaust from gasoline vehicles (14%) and diesel vehicles (8%).

- On one street in Atlanta, Georgia, residential wood burning contributes an average of 50% of particulate emissions in winter, compared to an average of 33% for gasoline vehicles. Wood burning emits about four times the amount of PM2.5 as all of the Southern California region's power plants combined.[21]

PM2.5 Federal Regulations

- The Clean Air Act requires USEPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment.

- The NAAQS were established for PM2.5 in 1997, based on evidence that fine particle pollution can cause premature deaths, as well as harmful effects on the cardiovascular and respiratory systems. The current primary annual NAAQS for PM2.5 is 12 $\mu g/m^3$ and the 24-hour NAAQS is 35 $\mu g/m^3$ (see Table 2).[22]

Table 2: National Ambient Air Quality Standards for PM2.5

Date	Primary/Secondary	Averaging Time	Level µg/m³	Calculation
1997	Primary and Secondary	24-hour	65	98th percentile, averaged over 3 years
1997	Primary and Secondary	Annual	15	Annual arithmetic mean, averaged over 3 years
2006	Primary and Secondary	24-hour	35	98th percentile, averaged over 3 years
2006	Primary and Secondary	Annual	15	Annual arithmetic mean, averaged over 3 years
2012	Primary	Annual	12	Annual arithmetic mean, averaged over 3 years
2012	Secondary	Annual	15	Annual arithmetic mean, averaged over 3 years
2012	Primary and Secondary	24-hour	35	98th percentile, averaged over 3 years

Note: Primary standards protect public health, including the health of sensitive populations, such as asthmatics, children, and older adults. Secondary standards protect the public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

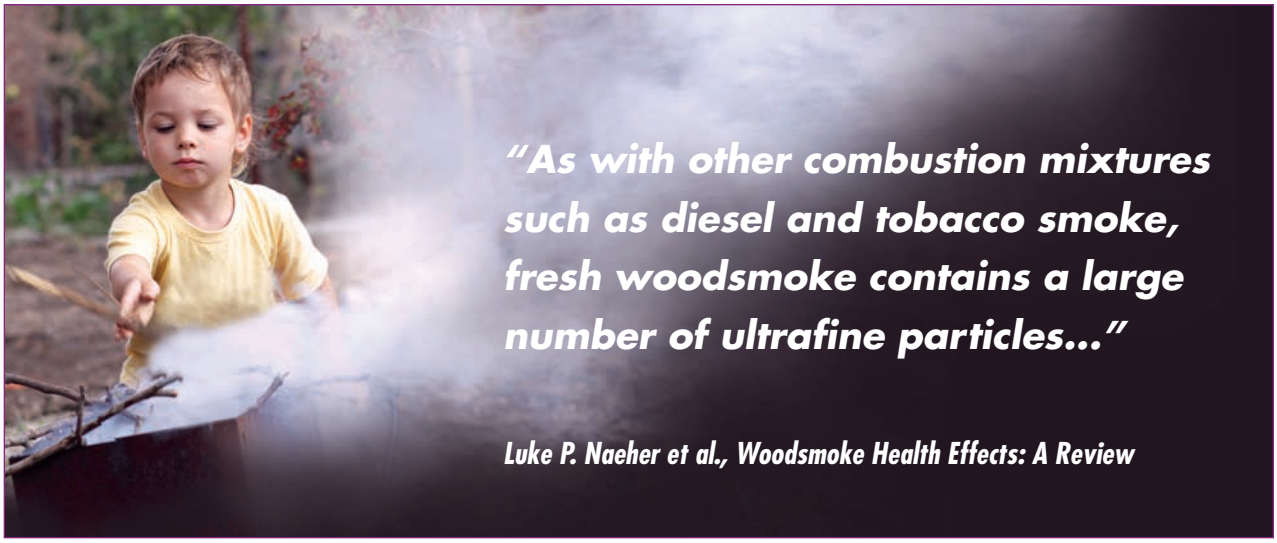
"Small particulate pollution [has] health impacts even at very low concentrations — indeed no threshold has been identified below which no damage to health is observed."

Source: http://www.who.int/mediacentre/factsheets/fs313/en/

- Although USEPA has set regulatory standards for PM2.5, recent data suggest that there is no safe level of exposure.[23] A study of over 300,000 people in nine European countries found some lung cancer risk at every level of particulate matter and confirmed that the higher the PM level, the greater the risk. Every increase of five µg/m³ of PM2.5 drove the risk of lung cancer up by 18%.[24]

Ultrafine Particles Smaller than PM2.5

- Wood smoke contains ultrafine particles that may be even more dangerous than PM2.5. These ultrafine particles (UFPs) penetrate deep into the respiratory tract, and have not only been detected in the lungs, but also in the liver, kidneys, heart, and brain.[25]



Wood smoke contains ultrafine particles (UFPs) that may be even more dangerous than PM2.5. These particles penetrate deep into the respiratory tract, and have not only been detected in the lungs but also in the liver, kidney, heart, and brain.

- The effects of ultrafine particles on the respiratory system are not well studied,[26] but a recent review suggests a causal relationship between short-term exposures to UFPs and cardiovascular and respiratory effects, including changes in lung function and pulmonary inflammation.[27]

- The ultrafine component of PM might be responsible for many observed health effects of PM2.5 and PM10 for three reasons: (1) their small diameter enables UFPs to penetrate deep into the lungs more easily than larger particles; (2) UFPs are cleared less efficiently from the respiratory tract than larger particles and are transported from the lungs to the bloodstream and into other organ systems; and (3) UFPs have a greater surface area compared to larger particles, thus providing a larger area of potentially toxic chemicals or metals to be absorbed by the lungs and other organs.[28]

- UFPs are not regulated as criteria pollutants, and are therefore not monitored at most air pollution monitoring stations in the U.S. Without a national network of UFP monitors to assess UFP ambient concentrations in the U.S., little is known about ambient UFP concentrations, and important information is lacking to support health studies.[29]

Polycyclic Aromatic Hydrocarbons (PAHs)

- PAHs are constituents of fine particles[30] produced from incomplete combustion of organic materials. Natural sources of PAHs include wildfires and volcanos, while man-made sources of PAHs sources are smoke, automobile emissions, and cigarette smoke.

- Regions of the country with dense use of wood stoves and fire-places have elevated levels of PAHs in ambient air.[31] The American Conference of Governmental Industrial Hygienists (ACGIH) has concluded that breathing smoke from open fireplaces is a major route of exposure to PAHs for the general population.[32]

- Residential wood burning is the largest source of PAHs in the U.S.[33] Factors that influence emissions of PAHs include the type of wood burned, as well as combustion conditions such as temperature, moisture, availability of oxygen, and completeness of combustion.[34]

- Higher PAH emissions from wood burning have been found at higher wind speed and lower flaming rate. Smoldering combustion is estimated to emit up to five times more PAHs than flaming combustion.[35]

- PAHs are regulated as Hazardous Air Pollutants (HAPs), and seven PAHs are classified as probable human carcinogens.[36] They are benzo[a]pyrene, benz[a]anthracene, chrysene, benzo[b]-fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene.

- The carcinogenic effects of PAHs are due to their ability to bind to DNA. Many studies show a correlation between levels of PAH-DNA adduct formation in different organs and PAH doses.[37] A DNA adduct is a segment of DNA bound to a cancer-causing chemical. This process could be the start of a cancerous cell, or carcinogenesis.

PAHs are constituents of fine particles produced from incomplete combustion of organic materials. Natural sources of PAHs include wildfires and volcanos, while man-made sources of PAHs sources are smoke, automobile emissions, and cigarette smoke.

Today, synthetic logs are manufactured from nut shells, fruit pits, coffee grounds, paper, plant oils, and small amounts of various chemicals that may be blended with biowax, a vegetable paraffin, made from soy or palm oil or wood resins. Petroleum-based paraffin wax is still the most common wax used in synthetic logs.

- Several studies report that higher PAH levels and a wider range of specific PAH compounds are found in synthetic log emissions compared to real wood emissions.[38]

- Higher concentrations of chrysene, a documented tumorigenic PAH, have also been found in synthetic log emissions.[39] A study of the organic compounds emitted in smoke from burning pine, oak, and synthetic logs in residential fireplaces in the Los Angeles area showed that the smoke from synthetic logs had the highest total PAH emission rate and the most diverse types of PAHs.[40]

- Manufacturers of synthetic logs claim that their logs emit fewer PAHs than wood. Duraflame®, the leader in the synthetic log market,[41] says its logs produce "80 percent less emissions than a typical wood fire."[42] They cite an 11-year-old study that found lower levels of PM and PAHs in synthetic wood logs.[43] The manufacturer of Goodwood All-Wood Firelogs, which are made of wood chips, shavings and sawdust without the use of petroleum or chemical binders, claims that its products emit 25-50% fewer particulates than regular firewood.[44]

- Petroleum-based synthetic logs have been on the market since the 1960s, when Duraflame® created a fire log by blending sawdust with petroleum wax. Today, synthetic logs are also manufactured from nut shells, fruit pits, coffee grounds, paper, plant oils, and small amounts of various chemicals that may be blended with biowax, a vegetable paraffin, made from soy or palm oil or wood resins. However, petroleum-based paraffin wax is still the most common wax used in synthetic logs.

- Both the burning of real wood and synthetic logs are sources of PAH exposure. Research published in 2014 showed that women who burn synthetic logs over many years are more likely to have breast cancer than those who do not burn them. The women who burned synthetic logs and developed breast cancer were more likely to have at least two genetic variants. The authors of the

study argue that the increase in breast cancer risk observed with synthetic log burning may be biologically plausible, citing reports documenting higher levels of certain PAHs in synthetic logs.[45]

VOCs and Other Organic Contaminants

- Wood smoke contains numerous volatile organic compounds (VOCs) and organic contaminants.

1,3-butadiene

- Sources of 1,3-butadiene include industry emissions, cigarette smoke, wood smoke, and the smoke of wood fires. The International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), and the USEPA all classify 1,3-butadiene as a human carcinogen.

- Wood burning has been found to increase personal exposure to 1,3-butadiene, as well as indoor levels of 1,3-butadiene. The type of wood-burning appliance and burning time are significant factors for indoor levels of 1,3-butadiene. The Agency for Toxic Substances and Disease Registry (ATSDR) recommends reducing the risk of exposure to 1,3-butadiene by minimizing the amount of smoke released during wood burning.[46]

Benzene

- Benzene, a major component of wood smoke, is regulated as a hazardous air pollutant. Benzene is a known human carcinogen, classified as Group 1 by the IARC. In occupational settings, long-term inhalation exposure to benzene can cause various disorders in the blood, including reduced numbers of red blood cells and aplastic anemia.

- Reproductive effects have been reported for women exposed to high levels of benzene by inhalation. Adverse effects on the developing fetus have been observed in animal tests.[47] Domestic wood burning contributes to indoor levels of benzene, especially

Benzene, a major component of wood smoke, is regulated as a hazardous air pollutant. Benzene is a known human carcinogen, classified as Group 1 by the IARC.

from inefficient flame combustion.[48] Hardwood burned in a wood stove emits one gram of benzene per kg of wood burned,[49] and even higher levels of benzene have been found inside wood-burning homes.[50] In Klamath Falls, Oregon, wood stoves are estimated to emit eight tons of benzene during the wood-burning season.[51]

Formaldehyde is linked to throat, nose, and blood cancers. People with asthma may be more sensitive to exposure to formaldehyde and repeated prolonged exposures have been linked to asthma attacks.

Aldehydes

- Aldehydes in wood smoke include acetaldehyde, a probable carcinogen, formaldehyde, a probable human carcinogen, and acrolein, a lung cancer agent.[52] Formaldehyde is linked to throat, nose, and blood cancers.[53] People with asthma may be more sensitive to exposure to formaldehyde,[54] and repeated prolonged exposures have been linked to asthma attacks.[55]

- Acrolein damages and inhibits DNA repair in lung cells; it interferes with the immune response in the respiratory tract;[56] is associated with increased cardiovascular disease;[57] and it suppresses the immune system.[58] Acrolein is implicated in demyelinating diseases such as multiple sclerosis.[59] Demyelinating diseases are diseases of the nervous system in which the myelin sheath of neurons is damaged.

Dioxins

- Dioxins are extremely toxic, mutagenic, and linked to the suppression of the human immune system. Dioxins are persistent, toxic and bio-accumulative chemicals and are transported over long distances from the source of emission. Forest fires, backyard trash burning, and medical waste incinerators are the top three air sources of dioxin emissions in the U.S.[60]

- In the San Francisco Bay region, emissions from woodstoves and fireplaces contribute up to 40% of the dioxins emitted into the air.[61] In Fresno, California, wood burning was shown to be the primary source of dioxins in the environment.[62] If wood with preservatives is burned in domestic stoves and fires, studies have found a significant increase in dioxin formation.[63]

III. Health Risks from Wood-Smoke Exposure

- Wood smoke produces fine and ultrafine particulate matter and many different volatile gases. Inhaling fine particles can induce and exacerbate lung diseases including asthma, as well as diseases of the brain and cardiovascular system.
- Fine particle air pollution is often from multiple sources, but in many regions in the U.S., wood burning is the single largest source during colder months.

Fine particle air pollution is often from multiple sources, but in many regions in the U.S., wood burning is the single largest source during colder months.

Lung Diseases

Chronic Obstructive Pulmonary Disease (COPD)

- COPD is a leading cause of illness and mortality worldwide.[64] While smoking has been associated with risk of COPD since the 1950s,[65] results from a growing number of published studies demonstrate that risk factors other than smoking are strongly associated with COPD, including both indoor and outdoor pollutants.
- Studies show that COPD is common among those who have never smoked. Worldwide, between 25% and 45% of patients with COPD have never smoked.[66]

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- Wood-smoke exposure in the U.S. is associated with a risk of developing COPD.[67] Among women and smokers exposed to wood smoke, the prevalence of COPD is especially high, and the risk of developing the disease is significantly increased.[68]

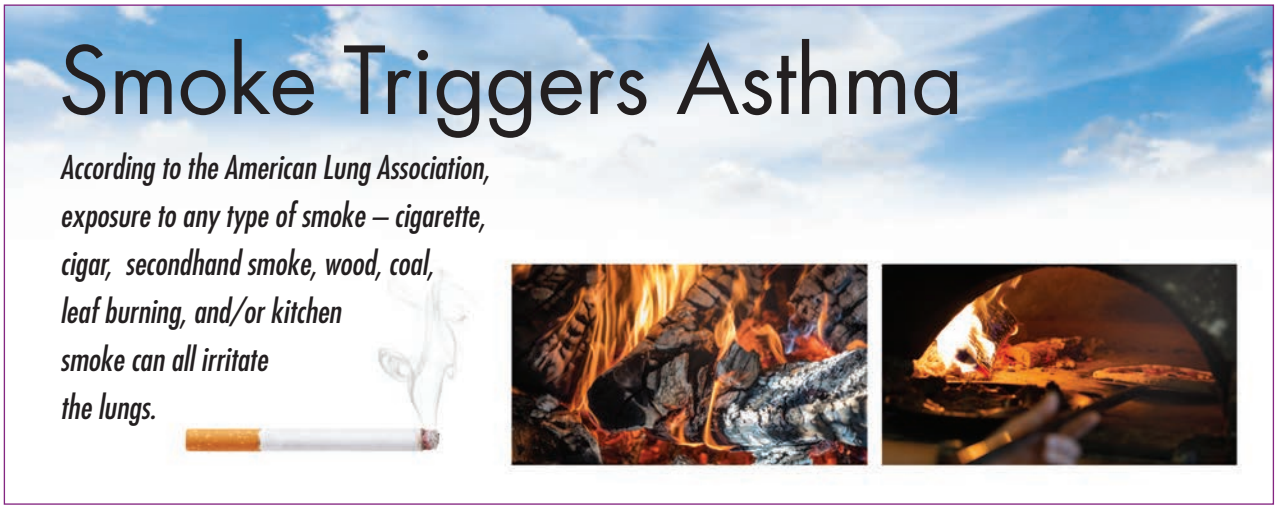
- The prevalence of COPD in individuals exposed to wood smoke increases significantly as the duration of wood-smoke exposure lengthens. Researchers recently suggested that wood-smoke COPD should be considered a distinct disease.[69] COPD associated with wood-smoke exposure (W-COPD) differs from COPD associated with tobacco smoking (T-COPD) and is related to obstruction of the airways, rather than emphysema.[70]

Asthma

- Breathing smoke from wood-burning devices can cause asthma attacks and other respiratory illnesses.[71] The Centers for Disease Control and Prevention (CDC) estimate that 24 million people (8%) in the U.S. have asthma.[72] It is one of the most prevalent chronic diseases among children worldwide.[73]

- Fine particulate matter is a risk factor for worsened asthma[74] and has been associated with higher morbidity and mortality in patients

Figure 2: Asthma Triggers



with asthma.[75] Wood smoke, in particular, exacerbates asthma symptoms with higher rates of asthma in areas where wood burning takes place over a sustained period.[76]

- A study of children with mild asthma reported associations between measures of airway inflammation and decreased lung function with measures of increased wood-smoke exposure.[77] Exposure to particulate matter (PM) increases the risk of developing asthma, and even low levels of PM2.5 exposure increase asthma symptoms.

- A large nationwide study found an association between air pollution and an increased risk of asthma symptoms in non-asthmatic women and an association with asthma development in women.[78] Also found was an association between air pollution and the development of asthma in that group.[79]

- Physicians managing asthma recognize that exposure to wood smoke, indoors or outdoors, can narrow airways and cause asthma to flare up, but many patients are unaware of the relationship between wood smoke and asthma. Asthma experts consider smoke from campfires to be among the "surprising" allergy triggers.[80]

A large nationwide study found an association between air pollution and an increased risk of asthma symptoms in non-asthmatic women. Also found was an association between air pollution and the development of asthma in that group.

Heart Diseases

Reducing exposure to fine particle pollution has been shown to be associated with decreases in cardiovascular mortality, yet over 90% of patients with cardiovascular disease are not informed of health risks related to fine particle pollution.

- Cardiovascular disease accounts for the greatest number of deaths in the U.S. One in three Americans has heart or blood vessel disease.
- Both short-term and long-term exposures to increased concentrations of fine particle pollution increase the risk of cardiovascular mortality and decrease life expectancy.
- Reducing exposure to fine particle pollution has been shown to be associated with decreases in cardiovascular mortality, yet over 90% of patients with cardiovascular disease are not informed of health risks related to fine particle pollution.
- For a person with cardiovascular disease, exposure to unhealthy levels of particle pollution can cause serious problems, including heart attacks, in a short period of time.[81] Exposure to fine and ultrafine combustion-derived PM is well-recognized as a risk factor for cardiovascular disease.[82]

Table 3: Fine Particles and Cardiovascular Health Effects

Cardiovascular mortality
Ischemic stroke
Acute coronary syndrome
Exacerbation of heart failure
Increased ventricular arrhythmias
Systemic blood pressure elevation

Source: USEPA. https://www.epa.gov/particle-pollution-and-your-patients-health/course-outlinekey-points

- Burning wood smoke produces fine particles and increases the risk for heart attacks, strokes, heart disease, and congestive heart failure.[83] Numerous epidemiologic and observational studies document effects of fine particles on the cardiovascular system in populations.[84]

- The American Heart Association warns that even very short-term exposure to PM2.5 (a few hours to weeks) can trigger cardiovascular disease–related mortality and nonfatal events (e.g., heart attacks, heart failure, arrhythmias, and strokes).[85]

- Research on populations exposed to wildfire smoke suggests that PM2.5 may act as a triggering factor for acute coronary events during wildfire episodes.[86]

- Studies from across the world have consistently shown that long-term exposures to fine PM are associated with myocardial ischemia and infarctions, heart failure, arrhythmias, strokes and increased cardiovascular mortality.[87]

- A 2017 study of over 60,000 residents in Hong Kong adds to the evidence base that long-term residential PM2.5 exposure increases the risk of stroke in older people.[88]

Research on populations exposed to wildfire smoke suggests that PM2.5 may act as a triggering factor for acute coronary events during wildfire episodes.

Cancer

According to the EPA's most recent National Air Toxics Assessment, residential wood heating accounted for 50% of all "area source" air toxic cancer risks nationwide in 2011.

- According to the EPA's most recent National Air Toxics Assessment, residential wood heating accounted for 50% of all "area source" air toxic cancer risks nationwide in 2011. That means that the air toxics from residential wood heating accounted for as much cancer risk as all the other smaller sources that often exist in multiple sites in a community, like gas stations and dry cleaners.[89]

- Cancer classifications by the International Agency for Research on Cancer (IARC) demonstrate the potential for exposure to wood smoke to cause cancer: indoor emissions from household combustion of wood are *probably carcinogenic to humans* (Group 2A);[90] outdoor air pollution is carcinogenic to humans (Group 1); and PM pollution is carcinogenic to humans (Group 1) and causes lung cancer, with the risk of lung cancer increasing with increased levels of exposure to PM and air pollution.[91]

Table 4: IARC Cancer Classifications

Group 1	Carcinogenic to humans
Group 2A	Probably carcinogenic to humans
Group 2B	Possibly carcinogenic to humans
Group 3	Not classifiable as to its carcinogenicity to humans
Group 4	Probably not carcinogenic to humans

Source: http://monographs.iarc.fr/ENG/Classification/

- The cancer-causing potential of several polycyclic aromatic hydrocarbons (s) in wood smoke warrant further concern. Benzo[a]pyrene (Group 1), Benz[a]anthracene (Group 2A), and dibenz[a,h]anthracene (Group 2A) are some of the most potent carcinogens detected in wood smoke. Five other PAHs found in wood smoke are also possibly carcinogenic to humans (Group 2B).[92]

- Wood burning is the largest source of PAHs in the U.S.,[93] and has been shown to be the top contributor to the air's mutagenicity (likely to cause mutations in DNA, including cancer).

- Levels of B(a)P and several other PAHs are significantly higher (three- to five-fold) in homes with wood combustion appliances compared to homes without them.[94]

- Carcinogenic PAHs have been detected at significant concentrations in a residential neighborhood where wood is burned, contributing 49% of the total PAHs in ambient air.[95]

- Two other IARC Group 1 human carcinogens, 1,3-butadiene and benzene, are detected in wood smoke. Residential wood combustion has been shown to increase personal exposure to 1,3-butadiene as well as indoor levels of 1,3-butadiene and benzene.[96]

- Arsenic, another possible component in wood smoke, is also classified as a Group 1 carcinogen.[97] Burning wood treated with chromated copper arsenate (CCA) in fireplaces, woodstoves, or trash releases arsenic in smoke and ash.[98]

- In the 1980s, arsenic in wood smoke was found to be the cause of neurological and medical illness in a family of eight people living in rural Wisconsin,[99] and it has been measured in wood smoke in the ambient air in Seattle.[100]

- Open burning of CCA-treated wood has been found to emit the more toxic trivalent form of arsenic in particle sizes that are most respirable.[101] CCA was used to protect wood from rot and insects in many residential wood structures for decades, until pressure-treated lumber for most residential uses was phased out at the end of 2003.

Carcinogenic PAHs have been detected at significant concentrations in a residential neighborhood where wood is burned, contributing 49% of the total PAHs in ambient air.

An analysis of seven epidemiologic studies concluded that predominant wood users in North American and European countries experienced higher risk of lung cancer.

Lung Cancer

- Lung cancer is the most common form of cancer in the world and is the number one cancer killer of both men and women in the U.S. Although most lung cancer occurs in smokers, 25% of worldwide lung cancer occurs in those who never smoked.[102]

- Recent studies show increasing rates of lung cancer in people who have never smoked, mostly in females.[103] There are wide-ranging geographic incidence and risk factors among this group, including asbestos, air pollution, radon, arsenic compounds, cadmium, chromium, ionizing radiation, and wood-smoke exposure.[104]

- An association between outdoor air pollution and lung cancer has been suspected for more than a half century. In 2013, IARC classified outdoor air pollution and the PM component of outdoor air pollution as Group 1 carcinogens, based on consistent evidence of an association between the long-term average concentration of PM2.5 in outdoor air and lung cancer incidence or mortality.[105] IARC reported that the risk of lung cancer increases as the particle levels rise.[106]

- Wood-smoke exposure is considered a risk factor for the development of lung cancer.[107] For decades, studies have found increases in the risk of lung cancer in women who burn wood inside their homes, mostly in poor rural areas,[108] with cancer linked to wood-smoke exposure.[109]

- More recently, an analysis of seven epidemiologic studies concluded that predominant wood users in North American and European countries experienced higher risk of lung cancer.[110]

- Other residues in wood are known to cause lung cancer. Wood dust is a human carcinogen and a risk factor for lung cancer;[111] wood byproducts such as benzene, 1-butadiene, formaldehyde and acetaldehyde, are well-known carcinogens;[112] wood smoke contains PAHS; and the most significant health effect from inhalation exposure to PAHs is an excess risk of lung cancer.[113]

Breast Cancer

- A recent and growing body of evidence suggests that exposure to fine and ultrafine particles may be linked to breast cancer. Hundreds of papers support the link between exposures to environmental contaminants and the increasingly high incidence of breast cancer.
- Polycyclic aromatic hydrocarbons (PAHs) are included in a list of a wide variety of toxicants that can lead to increased risk for development of breast cancer. Wood smoke contains PAHs, which have been shown to increase risk for breast cancer through a variety of mechanisms. PAHs have been found to increase breast cancer risk in epidemiological studies.[114]
- Women are exposed to PAHs from multiple sources, including cigarette smoke, diet, and indoor and outdoor air pollution, but residential wood burning is the most significant source of PAHs in many areas of the world, including the U.S.[115]
- Like other environmental chemicals associated with breast cancer risk, PAHs are lipophilic and are stored in breast fat tissue.[116]

A recent and growing body of evidence suggests that exposure to fine and ultrafine particles may be linked to breast cancer. Hundreds of papers support the link between exposures to environmental contaminants and the increasingly high incidence of breast cancer.

The Long Island Breast Cancer Study began in 1993, with funding provided by the National Cancer Institute and the National Institute of Environmental Health Sciences (NIEHS). The finding of an association between environmental exposures (including exposure to PAHs) and an increased risk of breast cancer require additional population studies for confirmation.

Decades of epidemiological research suggest that PAHs are linked to breast cancer risk. Like other environmental chemicals associated with breast cancer risk, PAHs are lipophilic and are stored in breast fat tissue.

PAHs can also bind to DNA in breast tissue.[117] DNA adducts result when segments of DNA bind to cancer-causing chemicals. PAH-DNA adducts have been associated with breast cancer incidence.[118]

- The use of an open fireplace has been associated with higher DNA adduct levels,[119] which have been related to breast carcinogenesis.[120] Benzo[a]pyrene (BaP) has been shown to cause breast cancer in rodents,[121] and cumulative BaP contributes to breast cancer metastasis.[122] The main source of atmospheric BaP in some areas, including the Great Lakes Region, is residential wood burning.[123]

- Decades of epidemiological research suggest that PAHs are linked to breast cancer risk.[124] Two recent studies suggest that some types of wood burning may increase this risk.

- Women in the Long Island Breast Cancer Study Project who burned synthetic logs instead of real wood logs in their woodstoves or fireplaces, were more likely to have breast cancer than those who did not burn synthetic logs.

- Most affected were women who burned synthetic logs in their home for more than seven years and those with genetic variations that may make them more susceptible to PAHs.[125] Women with the highest level of PAH-DNA adducts had a 50% increased risk of breast cancer.[126]

- The NIEHS Sister Study recruited more than 50,000 women across the continental U.S. and Puerto Rico who were between the ages of 35 and 74, and whose sister had breast cancer. Women in the Sister Study who had a wood-burning stove/fireplace in their longest adult residence had a slightly increased breast cancer risk.

- Women who used an indoor wood-burning stove/fireplace at least once a week had a greater risk of breast cancer than those who did not have a wood-burning stove/fireplace.[127]

- Several studies warn that exposure to high levels of particulate matter (PM) may have deleterious effects on the length of survival among females with breast cancer. Studies have shown that residential wood smoke is a significant contributor to PM emissions.

- One study focused on survival among women with breast cancer in the U.S. Women with breast cancer who lived in areas with higher levels of atmospheric particulate matter were shown to have significantly shorter length of survival than those living in areas with lower exposures. The results of the study suggest that exposure to higher PM levels was associated with early mortality among female breast cancer cases.[128]

- In several other countries, particularly Japan, PM2.5 levels have been significantly associated with mortality for women with breast cancer.[129]

Several studies warn that exposure to high levels of particulate matter (PM) may have deleterious effects on the length of survival among females with breast cancer.

Stomach and Intestinal Cancer from Smoked Foods

- The World Cancer Research Fund/American Institute for Cancer Research recommends limiting the consumption of smoked meat.[130]

Figure 3: Cancer Risks Associated with Smoked Foods

During grilling and smoking, PAHs form when fat and juices from the meat drip into the wood fire , creating flames and smoke that adhere to the surface of the meat. Wood-smoked foods contain a large number of PAHs.

- Decades of epidemiological studies link the consumption of smoked foods with various cancers. Recent studies suggest that grilled, barbecued, and smoked meat intake may also be associated with breast cancer incidence.[131]

- A 2017 study funded by the National Cancer Institute involving 1500 women found that smoked meat may increase mortality after breast cancer is diagnosed. The study, the first to examine the associations between smoked meat and mortality after breast cancer, concluded, "a link between dietary sources of PAH and breast cancer prognosis is biologically plausible and epidemiologically consistent." [132]

- Grilled and smoked meat intake is a source of PAHs, including benzo[a]pyrene, chrysene, and fluoranthene.[133] During grilling and smoking, PAHs form when fat and juices from the meat drip into the wood fire, creating flames and smoke that adhere to the surface of the meat.[134] Wood-smoked foods contain a large number of PAHs.[135]

- Levels of carcinogenic PAHs in traditionally smoked salmon over burning wood in teepees in Alaska were up to 430 times higher than those measured in commercial products.[136]

Diabetes

- Growing evidence suggests that type 2 diabetes has an autoimmune component[137] and that diabetics are particularly vulnerable to the acute effects of particle air pollution.[138]

- A study found that exposure to PM2.5 increased blood glucose and induced inflammation and insulin resistance in animals, providing a potential biological explanation for a link between PM and diabetes.[139]

- A recent literature review of over 20 studies concluded that exposure to air pollutants (including PM) was significantly associated with insulin resistance and increased incidence of type 2 diabetes.[140]

Growing evidence suggests that type 2 diabetes has an auto-immune component and that diabetics are particularly vulnerable to the acute effects of particle air pollution.

Table 5: Facts about Diabetes in the United States

30.3 million people have diabetes (9.4% of the U.S. population)
Diagnosed – 23.1 million people
Undiagnosed – 7.2 million (23.8% of people with diabetes)

Source: National Diabetes Statistics Report, 2017 Estimates of Diabetes and Its Burden in the United States

- In the last five years, dozens of studies have reported a positive association between long-term exposure to ambient PM and risk for type 2 diabetes.[141]

- A recent study in China is the largest yet to explore the association between long-term PM2.5 exposure and type 2 diabetes. It showed that long-term exposure to PM2.5 was positively associated with significant increases in diabetes prevalence.[142]

The central nervous system is sensitive to chemicals in wood smoke. Fine particle air pollution can enter the brain via the circulatory system, carrying a number of toxic molecules that contribute to central nervous system diseases.

Central Nervous System Effects and Cognitive Decline

- The central nervous system is sensitive to chemicals in wood smoke. Fine particle air pollution can enter the brain via the circulatory system, carrying a number of toxic molecules that contribute to central nervous system diseases.[143]
- Deficits in learning and memory, as well as in attention-related behaviors, have been reported in both children and adults exposed to particle air pollution.[144]
- Exposure to particle pollution also has been associated with decreased cognitive function in older men,[145] accelerated cognitive decline in older women,[146] and Parkinson's disease hospitalizations among Medicare enrollees.[147] Even short-term exposure to air pollution (including PM2.5) increased the progression of Parkinson's disease in humans.[148]
- In 2016, a large study found statistically significant associations between long-term PM2.5 exposures and dementia, Alzheimer's and Parkinson's disease in Northeastern U.S. cities.[149]
- In 2017, another study found that living where PM2.5 exceeded EPA's standard increased risks for cognitive decline and dementia in older women by 81% and 92%, respectively. The study included thousands of 65- to 79-year-old healthy women from 48 states. The adverse effects were stronger in women who had a genetic variation that increases the risk for Alzheimer's disease.[150]

Mortality

- Ambient PM2.5 was the fifth-highest ranking global cause of death in 2015.[151] Associations between PM2.5 and increased mortality have been found in both healthy and ill people.[152]

- In the U.S., both short-term and long-term exposure to low levels of PM2.5 increase mortality in older people. A 2016 New England study found that people over 65 had a higher risk of premature death from short and long-term exposure to PM2.5 pollution.

- During the New England 2016 study, the USEPA daily standard for PM2.5 was almost never exceeded, demonstrating that air pollution standards in the U.S. do not protect human health.[153]

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Toxicity of Wood Smoke

- The toxicity of emissions from wood burning depends on wood type, combustion appliance, and specific combustion conditions such as wood moisture content and burn temperatures.[154]

- Incomplete combustion produces more toxic chemicals and carbon particles than higher temperature fires.[155] When combustion is less complete, the PM contains more black carbon and volatile organic compounds, or gases.[156] PM derived from low-temperature combustion conditions has been shown to be more toxic to cells than PM derived from higher temperature burns.[157]

- While PAH emission levels in slow-burning conditions are generally higher than those in fast-burning conditions,[158] substantially *higher PAH emissions* have been found during air-starved combustion in both wood and pellet stoves.[159]

- A comparison of emissions from a wood and a pellet stove found that the highest total organic PM emissions occurred when an additional wood log was placed on glowing embers during low-temperature burns.[160]

Wood Smoke vs. Other Combustion Sources

- Emissions from burning wood have many of the same physical and chemical characteristics as other combustion sources.

However, unlike sources of fossil fuel that burn under controlled conditions, wood burns differently under different conditions, including the type of wood, how long the wood has dried, and the water content of the wood. In addition, wood is burned in a wide variety of appliances and for varying periods of time.[161]

Health effects of ambient PM exposure from residential wood combustion can be assumed to resemble those of open biomass burning—including forest, brush and peat fires — because of the similar fuels.

Wildfire Smoke Exposures

"Health effects of ambient PM exposure from residential wood combustion can be assumed to resemble those of open biomass burning — including forest, brush and peat fires — because of the similar fuels."

Source: WHO. Residential heating with wood and coal: health impacts and policy options. 2015.

- Wildfires are the leading source of formaldehyde and acrolein emissions in the U.S.[162] Nationwide, formaldehyde is one of the top three key pollutants in the air that contribute most to overall cancer risks (the others are benzene and acetaldehyde).[163]
- Studies of populations exposed to wildfire smoke have found that those with respiratory or cardiovascular diseases, as well as older adults and children, may experience more severe short-term and chronic symptoms from wood-smoke exposure.
- Children are particularly sensitive to wood smoke because their lungs are still developing. This makes them more susceptible to the loss of pulmonary function than adults are.
- Adolescent monkeys exposed during the first three months of their lives to a prolonged period of smoke from California wildfires experienced significant immune and respiratory changes, as well as reduced lung function.[164]
- These findings are consistent with those of multiple studies that link long-term childhood exposure to air pollution with deficits

in lung function in children.[165] In addition to respiratory problems, researchers found lower birth weight for babies following wildfires in California[166] and the Brazilian Amazon.[167]

- Data from areas where wildfires have occurred show large increases in cardiovascular and respiratory illnesses and higher mortality rates. A recent review of over 50 epidemiological studies links wildfire smoke exposures to increased overall mortality rates.[168]

- In 2015, agricultural fires in Southeast Asia resulted in more than 100,000 adult deaths across Indonesia, Malaysia, and Singapore brought on by breathing high levels of PM2.5.[169]

- Multiple studies confirm a relationship between wildfire exposure and increased physician visits,[170] emergency department visits,[171] and hospitalizations for asthma and COPD.[172]

Data from areas where wildfires have occurred show large increases in cardiovascular and respiratory illnesses and higher mortality rates. A recent review of over 50 epidemiological studies links wildfire smoke exposures to increased overall mortality rates.

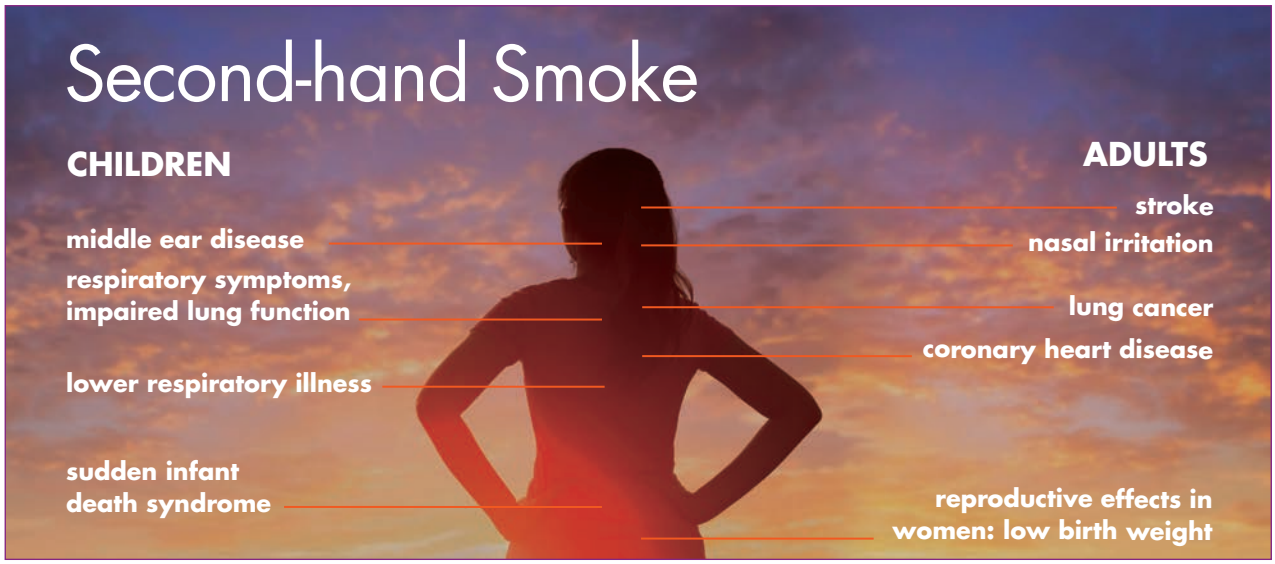
Cigarette Smoke Inhalation, Both Active and Involuntary

- There are about 600 ingredients in cigarettes. When burned, they create over 7,000 chemicals. At least 69 of these chemicals are known to cause cancer.[173] Wood smoke contains many of the same toxic and carcinogenic substances as cigarette smoke.

- Chemical components in tobacco smoke with the greatest potential for toxic effects are 1,3-butadiene, acrolein, acetaldehyde and PAHs.[174] These chemicals are also components of wood smoke. However, burning wood generates substantially higher concentrations of many hazardous molecules when compared with burning cigarettes.[175]

- Like second-hand cigarette smoke, wood smoke causes numerous health problems in infants and children, including more frequent and severe asthma attacks, respiratory infections, ear infections, and sudden infant death.[176]

Figure 4: Health Effects Linked to Second-hand Smoke Exposure



Source: CDC, https://www.cdc.gov/tobacco/data_statistics/fact_sheets/secondhand_smoke/health_effects/

The U.S. Centers for Disease Control and Prevention (CDC) has concluded that there is no risk-free level of exposure to second-hand smoke. Likewise, there is no risk-free level of exposure to particulate matter in wood smoke.

- Short-term exposure to PM can compromise the lung's immune defense against infectious agents, increasing susceptibility to infectious disease.[177] With the exception of sudden infant death, all of the health effects in Figure 4 are associated with exposure to chemicals in wood smoke.

- In an affluent region in Western Europe, where infant mortality is low, days with higher PM air pollution are associated with increased infant mortality.[178]

- The U.S. Centers for Disease Control and Prevention (CDC) has concluded that there is no risk-free level of exposure to second-hand smoke. Likewise, there is no risk-free level of exposure to particulate matter in wood smoke.

- Thus, breathing any smoke creates a threat to health, and the most vulnerable are susceptible to worsening health following even low-level exposures.

Vehicle Emissions

- Wood smoke has higher concentrations of polyaromatic hydrocarbons (PAHs) than found in vehicle exhaust. This leads some researchers to conclude that wood smoke has "a higher mutagenic and carcinogenic potential" than does traffic exhaust.[179, 180]
- Exhaust from vehicles contains numerous dangerous chemicals, many of which are also found in wood smoke. Known human carcinogens in wood smoke include PAHs, benzene, and formaldehyde, among others.
- The International Agency for Research on Cancer (IARC) has classified both wood smoke and diesel exhaust as carcinogens. Their chemical composition is similar.
- Like wood smoke, diesel exhaust is the result of incomplete combustion. The gaseous fraction of both contain volatile organics, formaldehyde and other aldehydes, 1,3-butadiene, and

The International Agency for Research on Cancer (IARC) has classified both wood smoke and diesel exhaust as carcinogens. Their chemical composition is similar.

Source: https://woodsmokepollution.org/toxins.html

The smallest particles in wood smoke have the ability to penetrate into the smallest airways of the lungs. Both diesel exhaust and wood smoke are an important source of small fine and ultrafine particles that are the most detrimental to cardiovascular health.

- Diesel exhaust releases particles at a greater rate than gasoline-fueled vehicles, on an equivalent fuel energy basis. Exposure to diesel exhaust has been associated with an increased risk of lung cancer in both human and animal studies.[181] Almost all of the diesel particle mass is PM10 or less, and about 95% percent of these particles are less than 2.5 microns in diameter.[182]

- The smallest particles in wood smoke have the ability to penetrate into the smallest airways of the lungs. Both diesel exhaust and wood smoke are an important source of small fine and ultrafine particles that are the most detrimental to cardiovascular health.[183]

Coal Burning

- Wood smoke contains many of the same chemicals as the emissions from coal burning. Both are major sources of ambient air pollution. The dangers of heating homes with coal were gradually recognized over centuries, and the 1952 Great Smog of London caused by household coal burning resulted in major policy responses to coal burning.[184]

- Wood burning has not received the same attention as coal, although it is also a major source of ambient air pollution in nearly all parts of the world where wood is available.

- WHO reports that 3.7 million premature deaths from exposure to ambient particulate air pollution occurred in 2012, including 94,000 in Canada and the U.S. The use of burning wood for heating homes is a contributor to outdoor air pollution.[185]

Table 6: Pollutants in Wood Smoke, Tobacco Smoke, and Diesel and Coal Emissions

Pollutant	Wood Smoke	Tobacco Smoke	Diesel Emissions	Coal Emissions
Carcinogens				
Benzene*	•	?	•	•
Dioxin*	•	•	•	?
1,3-butadiene*	•	•	•	•
Formaldehyde**	•	•	•	•
Lead**	•	?	?	•
PAHs***	•	•	•	•
Green House Gases				
Carbon Dioxide	•	•	•	•
Methane	?	?	•	•
Nitrogen Oxides	•	•	•	•
Other				
Acrolein	•	•	•	•
Acetaldehyde	•	•	•	•
Carbon Monoxide	?	?	•	•
PM2.5	•	•	•	•

*Known human carcinogen **Probable human carcinogen ***There are over 100 different PAHs; seven PAHs are probable human carcinogens

Wood burning has not received the same attention as coal, although it is also a major source of ambient air pollution in nearly all parts of the world where wood is available.

Populations at Greatest Risk

Pregnant Women, Infants, and Young Children

Compared to adults, children inhale a relatively larger amount of air pollutants because of their smaller body size, and they inhale at a higher respiratory rate than adults.

- Over three million children in the U.S. are estimated to live in homes with lower air quality from wood smoke.[186] Young children are especially sensitive to the chemicals emitted from wood smoke.[187]

- Compared to adults, children inhale a relatively larger amount of air pollutants because of their smaller body size, and they inhale at a higher respiratory rate than adults.[188]

- Exposure to PM affects lung development, including reversible deficits in lung function, chronically reduced lung growth rate, and deficits in long-term lung function.[189]

- A significant increased risk of low birth rate and preterm birth have been found in studies on maternal PM2.5 exposure.[190] Lower birth weights for babies occurred following wildfires in Southern California[191] and agricultural burning in the Amazon.[192]

- Pediatricians are raising awareness of the environmental health risks of wood smoke for children in developed countries. Community wood-smoke exposure is consistently associated with adverse pediatric respiratory health, according to a 2017 review of 36 studies in developed countries. The research focused on respiratory outcomes, but not cardiovascular or neurocognitive health.[193]

- Living in a smoky neighborhood has been associated with emergency department visits in the first three years of life.[194] Ambient exposure to wood smoke during childhood has been associated with bronchitis,[195] ear infections in infants,[196] and reduced lung function in children ages 6-13 years old.[197]

Older Adults and Those with Lung and Heart Diseases and Diabetes

- Wood smoke produces fine particles and increases the risk for heart attacks, strokes, heart disease, and congestive heart failure.[198] About half of Americans (47%) have risk factors for heart disease.[199] People with diabetes are more likely to have underlying cardiovascular disease, though they might not know it. Diabetics are particularly vulnerable to the acute effects of particle air pollution.[200]

- Breathing in wood smoke can exacerbate Chronic Obstructive Pulmonary Disease (COPD) and worsen lung diseases. The CDC estimates that 15 million people in the U.S. have been diagnosed with COPD, and many more likely have COPD but are not aware of it.[201] About one in 10 children and one in 12 adults in the U.S. has asthma, and the numbers are increasing every year.[202]

- The percentage of Americans ages 65 and older is large and growing. By 2060, the 65-and-older age group's share of the total population will rise to nearly 24% from 15%.[203] In 2015, nearly 30% of adults 65+ on Medicare were treated for ischemic heart disease and 11% were treated for COPD.[204]

The CDC estimates that 15 million people in the U.S. have been diagnosed with COPD, and many more likely have COPD but are not aware of it. About one in 10 children and one in 12 adults in the U.S. have asthma, and the numbers are increasing every year.

Women with Breast Cancer

- Wood smoke contains PAHS, shown to both increase the risk for breast cancer[205] and to be associated with mortality for women with breast cancer. Women with breast cancer living in the U.S. in areas with higher levels of PM have been shown to have significant shorter survival rates than those living in areas with lower exposures.[206] In several other countries, PM2.5 levels have been significantly associated with mortality in women with breast cancer.[207]

- Breast cancer is the most common cancer diagnosed among U.S. women, excluding skin cancers. Breast cancer is the second leading cause of cancer death among women, exceeded only by lung cancer. Women living in the U.S. have a one in eight lifetime risk of being diagnosed with breast cancer.[208]

Source: https://woodsmokepollution.org/wood-smoke-is-pm.html

The USEPA reports that an estimated 70% of smoke from a chimney can actually re-enter that home or a neighbor's home. A 2014 California study found that a home provides little shielding from outdoor wood smoke. The study showed that 78% of black carbon particles from the outside smoke ended up inside neighboring homes.

Wood-Burning Neighborhoods

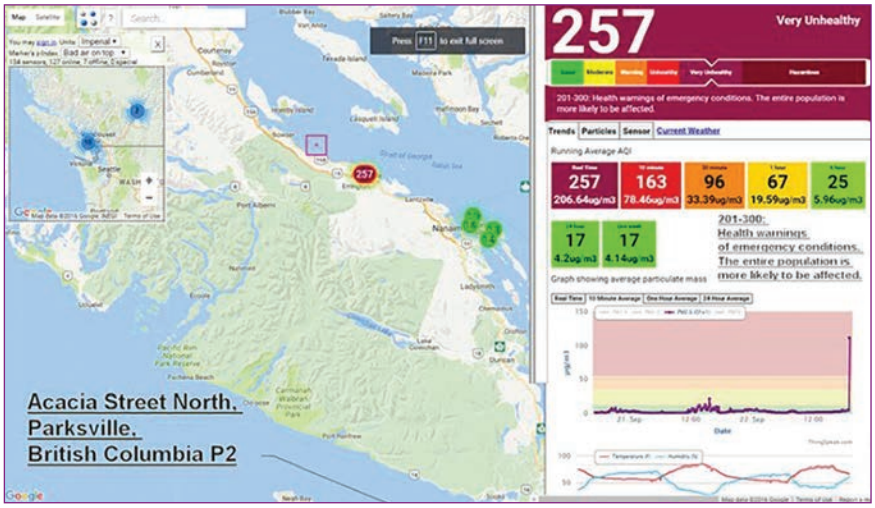
- Combustion of wood in densely populated residential areas is a major source of PM2.5 pollution in many communities.
- According to the World Health Organization (WHO), "Combustion of wood in residential areas and often under cold, calm meteorological conditions can nonetheless lead to high exposure compared to other pollution sources, owing to the principle of intake fraction."[209] The intake fraction is the proportion of released emissions inhaled by residents.
- The USEPA reports that an estimated 70% of smoke from a chimney can actually re-enter that home or a neighbor's home.[210] A 2014 California study found that a home provides little shielding from outdoor wood smoke. The study showed that 78% of black carbon particles from the outside smoke ended up inside neighboring homes.[211]

- Another study that used personal monitors showed that exposure to the damaging effects of black carbon from wood smoke infiltrated neighborhood homes.[212]

- Smoke from outdoor wood burning from a fire pit can seep into neighboring homes. A very unhealthy level of wood smoke was detected inside a home when a neighbor was burning wood in a fire pit. The result was a doubling of PM2.5 levels in the home. With even short-term exposures, there are increases in hospitalizations and death rates.[213]

- The amount of outdoor wood smoke that seeps into homes from neighboring fireplaces or from outdoor wood fires depends on a number of factors, including the home's age, construction, and condition. It also depends on the wood smoke particle size, meterological conditions, and the rate at which outdoor air enters the home.[214]

Figure 5: PM2.5 Levels Measured Inside A Home Near A Wood Burning Fire Pit in British Columbia



Source: Results measured using a PurpleAir Sensor, http://www.purpleair.org
See https://woodsmokepollution.org/recreational-fires.html

Smoke from outdoor wood burning from a single fire pit can seep into neighboring homes. A very unhealthy level of wood smoke was detected inside a home when a neighbor was burning wood in a fire pit. The result was a doubling of PM2.5 levels in the home. With even short-term exposures, there are increases in hospitalizations and death rates.

IV. Regulating Wood Smoke

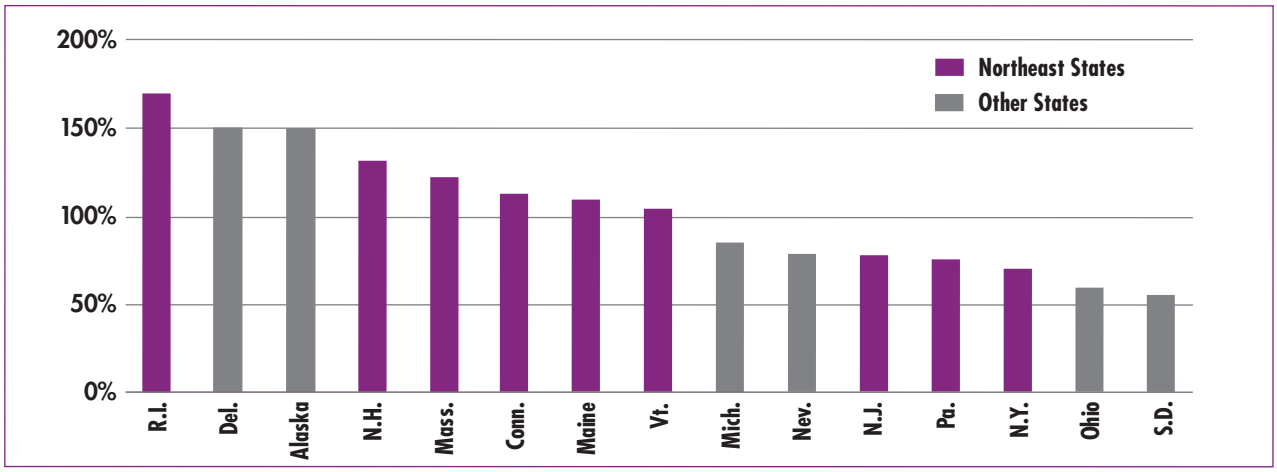
Despite scientific evidence clearly demonstrating the health effects associated with wood smoke, there has been an increase in the number of households in the U.S. that burn wood.

- Despite scientific evidence clearly demonstrating the health effects associated with wood smoke, there has been an increase in the number of households in the U.S. that burn wood. Increasing energy prices and an emphasis on renewable fuel have resulted in a rising number of households burning wood over the past two decades.

- The increase in wood as the main source of household heating is most notable in the Northeast. As shown in Figure 4 on the next page, all nine states in New England and the Middle Atlantic saw at least a 50% jump from 2005 to 2012 in the number of households that rely on wood as the main heating source.[215]

- As more people heat with wood, communities are struggling with ways to improve air quality. Wood-smoke problems are magnified in valleys prone to wintertime temperature inversions, where polluted air is trapped near the ground. In rural Montana communities[216] and in Fairbanks, Alaska,[217] for example, residential wood smoke contributes up to 80% of winter PM2.5.

Figure 6: Increase in Homes Using Wood as Main Heating Source (2005-2012)



Source: https://www.eia.gov/todayinenergy/detail.php?id=15431#

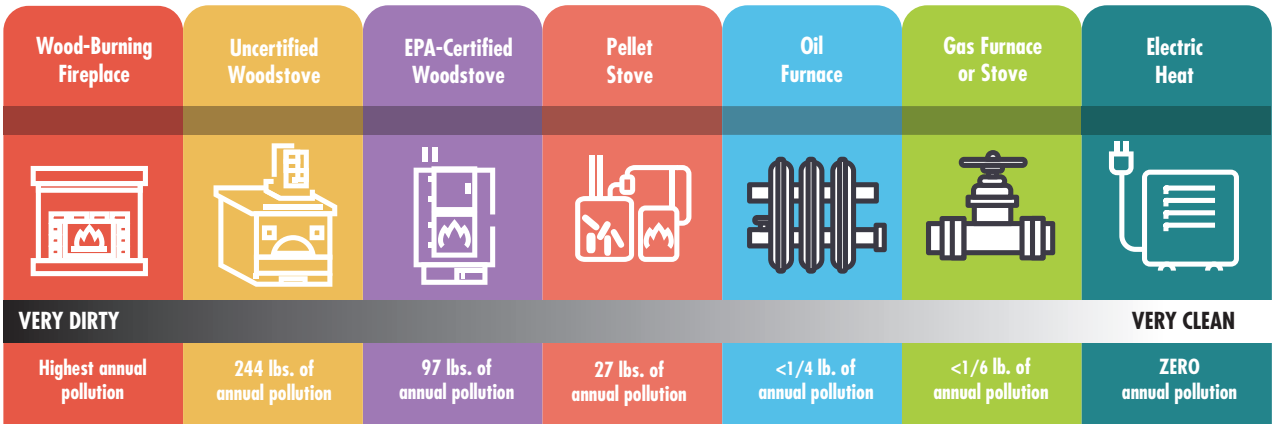
- Wood smoke also contributes to air pollution in urban settings in the U.S. In San Jose, CA, Atlanta, GA, and Seattle, WA, wood burning contributes up to 30% of winter PM2.5.[218]

- Burning wood in campfires, bonfires, chimineas, backyard fire pits, and burn barrels is considered "open burning," defined by EPA as smoke that enters the air directly, without first going through a chimney, flue, vent, or other similar path. Open burning includes recreational burning, which is generally defined as an outdoor fire burned for warmth or ambiance, as well as burning brush or other land-clearing debris.

- Open burning in outdoor fireplaces, chimineas, fire pits, wood-burning barbecues, and smokers is growing in popularity despite data that demonstrate health effects associated with wood smoke. According to a 2017 survey, outdoor fire pits/fireplaces are the most popular outdoor home design element.[219] These devices emit smoke low to the ground, directly in our breathing zone. Stagnant conditions and winter temperature inversions can result in wood smoke hanging close to the ground, easily penetrating nearby homes.

Burning wood in campfires, bonfires, chimineas, backyard fire pits, and burn barrels is considered "open burning," defined by EPA as smoke that enters the air directly, without first going through a chimney, flue, vent, or other similar path.

Figure 7: Relative Emissions of Fine Particles



Source: Puget Sound Clean Air Agency, www.pscleanair.org

Open burning in outdoor fireplaces, chimineas, fire pits, wood-burning barbecues, and smokers is growing in popularity despite data demonstrating health effects associated with wood smoke.

Air Quality Index (AQI) Alerts

- Most of the authority to regulate air pollution comes from the federal Clean Air Act (CAA). Section 110(a)(1) of the CAA requires states to regulate sources of air pollution through a state plan that provides an implementation, maintenance and enforcement plan regarding the federal air quality standards.

- The National Ambient Air Quality Standards (NAAQS) are used to notify the public when there are high levels of pollutants in the air. The Air Quality Index (AQI) is also used, and a value of 100 on the AQI generally corresponds to the NAAQS for air pollutants. When AQI values are above 100 the air quality is considered to be unhealthy. For PM2.5, an AQI over 35 $\mu g/m^3$ for 24 hours is considered to be in the unhealthy category.

- In parts of California, regional Air Districts issue a "Winter Spare the Air Alert," which prohibits wood burning indoors and outdoors when the PM 2.5 24-hour average is 35 $\mu g/m^3$, or 100 on the AQI scale. Connecticut bans open burning when the AQI is 75 and Massachusetts bans burning when the AQI is above 50. In Pennsylvania, it is up to counties to ban burning when the AQI is high.

Table 7: EPA's Air Quality Index (AQI) for 24-hour Fine Particle Pollution (PM2.5)

24-Hour PM2.5 (μg/m³)	AQI Categories	AQI Values	AQI Cautionary Statements	AQI Health Effects Statements
0–12.0	Good	0–50	None	None
12.1–35.4	Moderate	51–100	Unusually sensitive people should consider reducing prolonged or heavy exertion.	Respiratory symptoms possible in unusually sensitive individuals, possible aggravation of heart or lung disease in people with cardio-pulmonary disease and older adults.
35.5–55.4	Unhealthy for Sensitive Groups	101–150	People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease, and premature mortality in people with cardiopulmonary disease and older adults.
55.5–150.4	Unhealthy	151–200	People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion.	Increased aggravation of heart or lung disease and premature mortality in people with cardio-pulmonary disease and older adults; increased respiratory effects in general population.
150.5–250.4	Very Unhealthy	201–300	People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.	Significant aggravation of heart or lung disease and premature mortality in people with cardio-pulmonary disease and older adults; significant increase in respiratory effects in general population.
Greater than 250.5	Hazardous	Over 300	Everyone should avoid all physical activity outdoors; people with heart or lung disease, older adults, and children should remain indoors and keep activity levels low.	Serious aggravation of heart or lung disease and premature mortality in people with cardio-pulmonary disease and older adults; serious risk of respiratory effects in general population.

Who is "SENSITIVE" to PM2.5? People with heart or lung disease, older adults, children and people of lower socioeconomic status are the groups most at risk. See EPA's Technical Assistance Document (link below). Also at higher risk: prenatal children (low birth weight, pre-term birth and IQ reduction), diabetics, and people with higher exposures such as athletes exposed during exercise.

Sources:

National Ambient Air Quality Standards for Particulate Matter – Final Rule, effective March18, 2013, Federal Register, Vol. 78, No. 10, Jan. 15, 2013, p. 3181 (http://www.gpo.gov/fdsys/pkg/FR-2013-01-15/pdf/2012-30946.pdf)

Revised Air Quality Standards for Particle Pollution and Updates to the Air Quality Index (AQI), Dec. 14, 2012, p. 4 (https://www.epa.gov/sites/production/files/2016-04/documents/2012_aqi_factsheet.pdf)

Technical Assistance Document for the Reporting of Daily Air Quality, May 2016 (https://www3.epa.gov/airnow/aqi-technical-assistance-document-may2016.pdf)

Integrated Science Assessment for Particulate Matter – Final Report, Dec. 2009 (https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=216546)

Credit: Clean Air Fairbanks, cleanairfairbanks@gmail.com (http://cleanairfairbanks.wordpress.com)

Wood smoke can have a significant impact on exposures in neighborhoods where wood burning is prevalent, even during periods when the NAAQS reports general good air quality. This is because there are no air monitors in that area to pick up the wood smoke emissions.

Air Quality Index (AQI) Limitations

- The AQI is linked to a PM2.5 monitoring network. The monitors are inadequately placed in rural areas where wood burning often takes place. Since it is common for wood smoke to originate from sources within neighborhoods where monitoring networks are lacking, air monitoring networks do not adequately measure local air quality.

- Wood smoke can have a significant impact on exposures in neighborhoods where wood burning is prevalent, even during periods when the NAAQS reports general good air quality. This is because there are no air monitors in that area to pick up the wood-smoke emissions.[220]

- Studies show that the 24-hour NAAQS for PM2.5 (35 µg/m^3) may not adequately protect against sub-daily peaking at hourly concentrations associated with adverse health effects.[221] A spatial analysis of wood smoke in the Adirondack Mountains concluded that current air quality standards mask these episodic peaks through daily averaging.[222]

- Both short- and long-term exposure to PM2.5 has been associated with mortality rates from all causes at levels that are below the current USEPA 24-hour PM2.5 standard of 35 µg/m^3 daily.[223]

Open Burning Regulations

- Federal law prohibits open burning of residential, commercial, institutional or industrial solid waste with certain exceptions for land-clearing debris, diseased trees and debris from emergency clean-up operations. (40 CFR Part 257-3.7(a))

- In spite of regulations, trash burning remains a problem in some rural areas and ordinances are often poorly enforced. Some states,

such as Wisconsin and Pennsylvania, allow open burning of domestic waste. Other states, including Connecticut, only allow burning of brush.

- Some local governments regulate the material burned, while others regulate distance from property line and/or the size of the fire. Some local governments ban fires on days when AQI alerts are issued. The following is a sampling of regulations from around the country.

- In Montgomery County, MD, some recreational burning is allowed under strict conditions. However, most open burning without a permit is prohibited. Recreational fires must be at least 20 feet away from any building or structure, smoke is "not allowed to cross property lines," and burning is not allowed on "Code Orange" or "Code Red Air Quality days."[224]

- In Portland, Oregon, recreational fires must burn clean, dry, cord-type firewood and be less than three feet in diameter, with a pile less than two feet high.[225]

- Allegheny County, PA, has the same fire size requirements as Portland, and also specifies that only fire logs, paraffin logs, or wood pellets may be used. The fire must be 15 feet from the nearest neighbor's dwelling or inhabited area, any property line, roadway, sidewalk, or public accessway.[226]

- In many cities, including Denver and Boston, there are complete bans on outdoor fires, including portable fire pits and chimineas at all times of the year.[227] Outdoor burning is banned in 21 cities in Massachusetts in addition to Boston.

- The variability in state wood burning regulations demonstrates the specific risk-management challenges that wood smoke is creating throughout the U.S. State wood smoke regulatory programs in the Northeast are summarized in Table 8.

Some local governments regulate the material burned, while others regulate distance from property line and/or the size of the fire. Some local governments ban fires on days when AQI alerts are issued.

Table 8: Residential Open and Recreational Burning Restrictions in Northeast States

State	Total Burn Bans	Burn Bans During Poor Air Quality Days	PM2.5 Monitoring Stations	Recreational Burning Limits Examples: Campfire, Bonfire, Chiminea
CT[1]	No	AQI = >75	8	Prohibited if nuisance is created or is restricted by local municipality.
ME[2]	No	No	11	As long as no nuisance is created.
MA[3]	22 cities[4]	AQI = >51[5]	28	Some cities and towns regulate, limit/prohibit use of chimineas, fire pits and outdoor fireplaces.
NH[6]	No	No	14	Campfire fires < 2-foot diameter may be burned during the day. All others must be burned between 5 p.m. and 9 a.m.
NJ	No	When conditions "make such fires hazardous"	33	Unless "offensive or objectionable because of smoke emissions"; Fire pit regulations set by local officers.
NY[7]	Spring[8]	No	>50	Exceptions for ceremonial or celebratory bonfires; only charcoal or clean, untreated or unpainted wood can be burned; campfires <3' x 4'.
PA[9]	Designated air basins[10]	Varies by county[11]	44	Outside of designated air basins, if smoke cannot be seen or smelled outside of the property where the burning is taking place; does not "interfere with the reasonable enjoyment of life or property"; does not cause damage to vegetation or property; and is not harmful to human or animal health. Domestic refuse ok to burn where not more than two families are living and when generated onsite.[12]
VT[13]	No	No	5	When not prohibited by local ordinance. Only natural wood and yard waste from property maintenance. No trash can be burned.

Sources:

1 CT DEEP. http://www.ct.gov/deep/cwp/view.asp?a=2684&q=531300&deepNav_GID=1619

2 Department Of Environmental Protection Chapter 102: Open Burning Chapter l02: OPEN BURNING, http://www.maine.gov/dacf/mfs/archive/fpd/downloads/openburning.pdf

3 http://www.mass.gov/eea/agencies/massdep/air/quality/open-burning-answers-to-your-burning-questions.html#A Word About Fire Pits

4 Campfires, fire pits, burn barrels and burning of brush and yard waste prohibited

5 http://www.mass.gov/eea/docs/dep/air/community/noburn.pdf

6 https://www.des.nh.gov/organization/commissioner/pip/publications/ard/documents/quick-guide.pdf

7 http://www.dec.ny.gov/chemical/58519.html

8 Defined as smoke emitted directly into the air, including burning in barrels

9 PA DEP. Air Pollution From Household Open Burning In Pennsylvania

10 http://www.pacode.com/secure/data/025/chapter129/s129.14.html

11 http://www.achd.net/air/pubs/pdf/Article21.pdf

12 "Domestic Refuse" does not include such items as demolition waste, insulation, shingles, treated wood, paint, painted or stained objects or furniture, tires, mattresses, box springs, metal, insulating coating on wire, television sets and appliances, automobiles, automotive parts, batteries, PVC products, waste oil and other petroleum products.

13 http://dec.vermont.gov/air-quality/compliance/open-burning; http://dec.vermont.gov/tags/backyard-burning; http://dec.vermont.gov/sites/dec/files/aqc/compliance/documents/BYBFactsheet.pdf

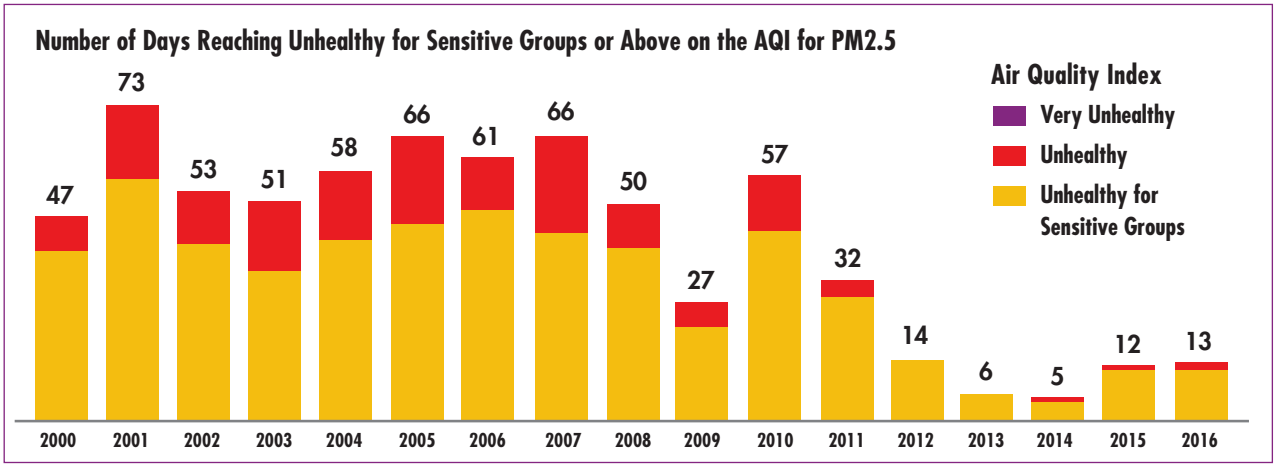
- In the state of Washington, all burning is banned in counties where there is no local clean air agency.[228]
- California's regional air pollution control agencies prohibit all wood burning, including all outdoor wood burning, during their "Spare the Air Tonight" warnings issued between the months of November and February. The ban goes into effect when the PM2.5 24-hour average NAAQS reach 35 $\mu g/m^3$ or 100 on the AQI scale.[229]
- Utah's ban on burning takes place during winter inversions, which occur between November and March. In certain counties the ban includes outdoor fireplaces, fire pits and charcoal grill smokers.[230]

Regulations in Allegheny County, Pennsylvania

- In 2017, the annual PM2.5 concentrations recorded in Allegheny County ranked thirteenth among all U.S. counties. Among U.S. cities, Pittsburgh, the county seat, was the eighth most polluted for annual PM2.5. Nearly 2.6 million people live in this metropolitan area.[231]
- Nearly 33% of those living in the Pittsburgh-New Castle-Weirton Metropolitan Area suffer from illnesses that could be caused or exacerbated by small diameter particles. Rates of childhood asthma in the region are higher than the national average at 13%; in some of the most polluted areas, rates are as high as 25%.[232] In the Monongahela River Valley, a highly populated valley with heavy industry, an estimated 1,406 more deaths occurred between 2000 and 2008 than expected, based on national rates, due to poor air quality.[233]
- Wood burning complaints are among the most common problems reported to the Allegheny County Health Department's Air Quality Program.[234] Allegheny County is hilly, with valleys that trap wood smoke near the ground during periods of still, damp air and temperature inversions. In rural parts of the county, it is not uncommon for people to use burn barrels to dispose of their trash.

Some local governments regulate the material burned, while others regulate distance from property line and/or the size of the fire. Some local governments ban fires on days when AQI alerts are issued.

Figure 8: Air Quality Index for PM2.5 in 2016 in Pittsburgh, PA



Source: Preliminary air quality data as reported to EPA's Air Quality System and AirNow.gov

In municipalities without curbside trash collection or mandated recycling, burning is the easiest and least expensive method to dispose of household and yard waste.

Burning is legal under state law, but is restricted by the Allegheny County Health Department, which is responsible for protecting the public's health by regulating air pollutants and enforcing federal pollution standards.

- Burning is legal under state law, but is restricted by the Allegheny County Health Department (ACHD), which is responsible for protecting the public's health by regulating air pollutants and enforcing federal pollution standards. Title 25 of the Pennsylvania Code allows open burning outside of designated air basins, with several conditions. Open burning is considered legal if the smoke cannot be seen or smelled outside of the property burning, if it does not interfere with the reasonable enjoyment of life or property, if it does not cause damage to vegetation or property, and if it is not harmful to human or animal health.

- Exceptions to restrictions include fires that are set to prevent fire hazards, instructions to fire-fighting personnel, prevention and control of disease or pests, fires in conjunction with the production of agricultural commodities, fires burning household waste generated in a home occupied by no more than two families, recreational or ceremonial fires, and fires used for cooking food.[235]

- During air pollution alerts, open burning is restricted. However, particulate matter (PM) must reach levels of 350 µg/m^3 over the 24-hour average before an alert goes into effect.[236]

- Allegheny County historically had a general ban on open burning, but it was loosely enforced. Because of an increase in public complaints about wood smoke, the Allegheny Health Department broadened its open-burning restrictions to include recreational burning: campfires, bonfires, chimineas, and backyard fire pits.[237]

- In open burning, only clean wood, propane or natural gas, fire logs, paraffin logs, or wood pellets may be used; fires may be no larger than 3′ wide by 3′ long by 2′ high and must be at least 15 feet from the nearest neighbor's dwelling or inhabited area; and all wood-burning activities are prohibited on Air Quality Action days. When air quality inspectors investigate citizen complaints, they may issue fines for nuisance smoke and smoke odors. Fines begin around $250 and increase with repeated noncompliance.[238]

- Despite these recently added restrictions, wood smoke is still a source of pollution in Allegheny County. Pennsylvania's non-profit Clean Air Council is concerned that the ACHD public education campaign falls short of strongly informing the public about the health threats of wood smoke.[239] The Council established the *iseesmokepa.org* website to report residential smoke, and published "How to Talk About Wood Smoke Pollution," which is a guide to negotiating with neighbors about wood burning.[240]

- In Pittsburgh, the non-profit "Group Against Smog & Pollution" (GASP) developed educational materials on wood smoke and burn barrels.[241] The group also manages a Citizens Smoke Reading Program, which empowers people to understand emissions and instructs them on how to report violations. The Heinz Endowments and the Pittsburgh Foundation provided 1,000 "Speck" air monitors to public libraries, schools and citizen groups in the region. These devices detect indoor PM 2.5.

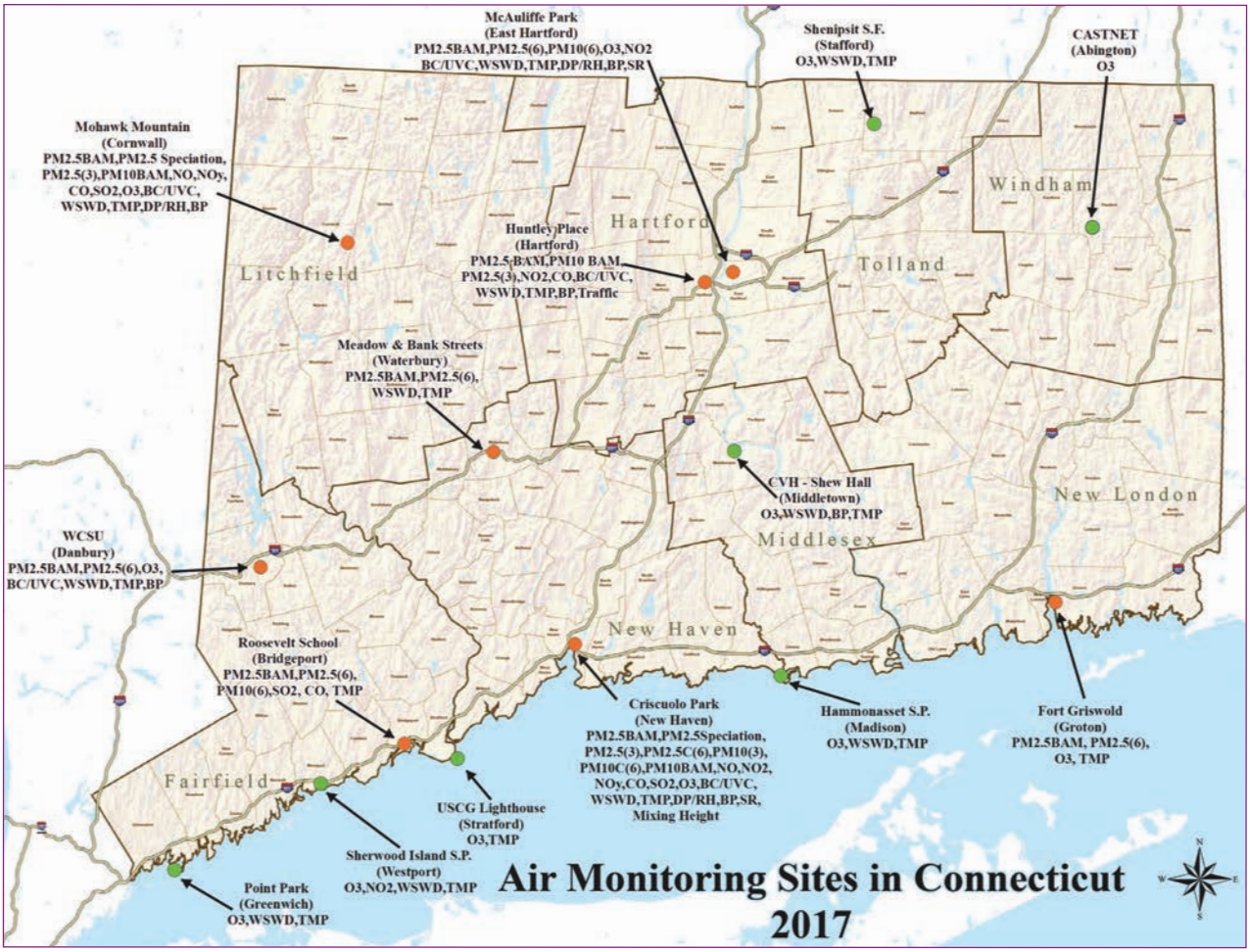
Because of an increase in public complaints about wood smoke, the Allegheny Health Department broadened its open-burning restrictions to include recreational burning: campfires, bonfires, chimineas, and backyard fire pits.

In Connecticut, particle pollution from fireplaces, wood stoves and outdoor burning creates a serious air quality problem in low-lying areas when inversions trap smoke close to the ground.

Regulations in Connecticut

- In Connecticut, particle pollution from fireplaces, wood stoves and outdoor burning creates a serious air quality problem in low-lying areas when inversions trap smoke close to the ground. Burning wood as a primary heat source in Connecticut is increasingly common—more than doubling between 2000 and 2010.[242]
- About 26,000 households in Connecticut burn wood for heat and wood burning is especially prevalent in the northeast corner of the state.[243] Families statewide burn wood both inside and outside for ambience, despite a growing population that is sensitive to the health effects of smoke.
- Statistics show that asthma rates in the state are higher than the national rates.[244] Nearly 10% of all children and 9% of adults have been diagnosed with asthma. One in 20 Connecticut adults has been diagnosed with Chronic Obstructive Pulmonary Disease (COPD).[245] In addition, 16% of the population is over 65.[246]
- Connecticut allows the recreational burning of campfires, bonfires, fire pits, chimineas, or similar devices, unless they create a nuisance for neighbors or are in violation of any restrictions imposed on such burning by a local municipality.[247] As is the case in Allegheny County, PA, defining a "nuisance" is challenging and expensive.
- Connecticut's Department of Energy & Environmental Protection (DEEP) defines a nuisance as something that substantially interferes with the use or enjoyment of another person's property.[248]
- It is very important for local health directors in Connecticut to know that the burning of wood in a campfire, bonfire, chiminea or other similar devices is prohibited if the burning is conducted in a way that creates a nuisance for neighbors. A local health director in Connecticut has the authority to shut down a wood-burning device if it creates a public health nuisance.

Figure 9: Air Quality Monitors in Connecticut



Source: http://www.ct.gov/deep/lib/deep/air_monitoring/ct_airmonitors.pdf

- There are only eight PM2.5 monitors in the state. No PM2.5 monitors are located in areas where wood burning is most common.
- There are seven additional air monitoring sites in the state that do not measure PM2.5.

- Although monitoring data from 2008 through 2012 show that Connecticut meets EPA's PM2.5 standards, there are only eight PM2.5 monitors in the state. Even more troubling, there are no monitors in areas where wood burning is most common.

- Campfires and bonfires are not defined by state statute or regulation; however, some towns have special requirements to conduct this type

of burning and may require homeowners to obtain a permit prior to burning a campfire on their property. Special requirements and permits may include limits on the size of the fires and certain setback distances from structures and/or property lines.

Although monitoring data from 2008 through 2012 show that Connecticut meets EPA's PM2.5 standards, there are only eight PM2.5 monitors in the state. Even more troubling, there are no monitors in areas where wood burning is the most common.

- In Connecticut, open burning refers to brush fires, camp fires and bonfires. Connecticut only allows clean, unprocessed wood to be burned. Processed wood is wood that has been glued or treated, including crates, pallets, and wood scraps. Campfires may not contain construction debris, wood pallets, or painted, stained, or treated wood. Unprocessed wood is untreated, natural wood and rough-cut lumber. Garbage may not be burned in campfires, bonfires, fire pits, chimineas or other similar devices.

- Open burning in Connecticut is restricted under the following conditions: when the AQI is forecast to be 75 or higher anywhere in the state; when the Forest Fire Danger Index is rated High, Very High, or Extreme; when the national or state ambient air quality standards may be exceeded; when a hazardous health condition might be created; or when there is an advisory from DEEP of any air pollution episode.[249]

- For open brush burning, residents must have a valid and signed permit from local officials, typically the town's Fire Marshal. Open burning is not permitted to clear land prior to construction activities and cannot be used as a way to dispose of construction debris, household trash, or leaves.

- Enforcement of wood smoke exposures is divided between the DEEP and local health departments in Connecticut. If the offending wood smoke comes from an Outdoor Wood Furnace (OWF), the DEEP handles the complaint. If the OWF complies with state statutes, but still harms neighbors, the DEEP will turn the issue over to the local health department.

- In Connecticut, if an outdoor wood furnace (OWF) does not comply with state statutes, the DEEP will enforce compliance or shut down the OWF.[250] All other offending wood smoke issues created by the OWF are handled by the local government, usually by the local health department in the town where the OWF is located.

Regulations in San Joaquin Valley, California

- Unique geographic and meteorological conditions and a growing population in the San Joaquin Valley contribute to poor air quality. Burning wood specifically is the leading cause of wintertime pollution in the Valley.

- In the past, the San Joaquin Valley experienced some of the nation's most polluted air, leading to a high number of hospitalizations for a variety of respiratory and cardiovascular diseases. These included asthma, acute bronchitis, pneumonia, and myocardial infarctions.[251]

- To attain the NAAQS and improve public health, the San Joaquin Valley Unified Air Pollution Control District adopted a rule to reduce emissions from winter wood smoke. Rule 4901 was the first burn regulation in the U.S. to be applied uniformly across an entire air basin.

- Rule 4901 was amended in 2003 to require mandatory curtailment of residential wood burning when the air quality index reached 150, or about 65 µg/m^3 of PM2.5.[252]

- Newer amendments to Rule 4901 allow only certain clean-burning stoves, fireplace inserts or heaters to be used when PM2.5 concentrations are forecast to reach 20 to 65 µg/m^3.[253] These regulations discourage, but do not prohibit, wood burning when PM2.5 concentrations are below 20 µg/m^3.[254]

San Joaquin Valley

Unique geographic and meteorological conditions and a growing population in the San Joaquin Valley contribute to poor air quality. Burning wood specifically is the leading cause of wintertime pollution in the Valley.

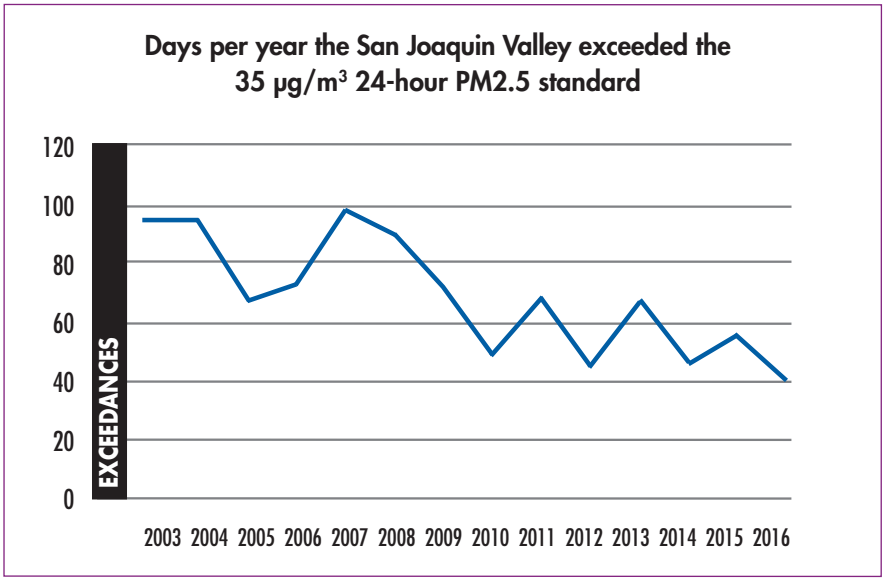
Wood smoke regulations improve air quality and public health, according to studies of the San Joaquin Valley, which has one of the oldest and most stringent wood smoke regulatory programs in the country.

- Wood-smoke regulations improve air quality and public health according to studies of the San Joaquin Valley, which has one of the oldest and most stringent wood smoke regulatory programs in the country.

- Over the past decades, cleaner technologies have been developed to reduce emissions from wood-burning devices. San Joaquin Valley residents can use EPA-certified devices unless air pollution climbs to a critical point.

- Curtailments of residential wood combustion under Rule 4901 have resulted in substantial health benefits for San Joaquin Valley residents. By 2008, wood-burning curtailments had resulted in average daily PM 2.5 reduction of 13.6% in California's ninth-largest city, Bakersfield, at the southern end of the San Joaquin Valley.[255]

Figure 10: San Joaquin Valley PM 2.5 Reduction



Source: San Joaquin Valley Air Pollution Control District. Record Setting PM2.5 Air Quality in 2016. See http://valleyair.org/pm25highlights.htm

- By 2008, air quality in the San Joaquin Valley during the winter had improved dramatically. Burn-season average concentrations of benzo(a)pyrene decreased by 32%; butadiene decreased by 44%; benzene decreased by 29%; and toluene decreased by 34%. Average concentrations of PM2.5 during the winter burn season decreased by 25%.[256]

- By 2015, the San Joaquin Valley recorded reductions in both fine particulate pollution (PM 2.5) and cardiovascular hospitalizations in the air basin.[257] In 2016, the number of days that exceeded the 24-hour PM2.5 standard reached an all-time low.

- A study of San Joaquin Valley residents aged 65 years and older found that Rule 4901 prevented 7% of cardiovascular disease cases in the entire air basin, 8% of cases in rural areas, and 5% of cases in urban regions. In addition, Rule 4901 prevented 16% of ischemic heart disease cases in the entire air basin, 17% of cases in rural areas, and 13% of cases in urban regions.[258]

- The study actually underestimates the effectiveness of the San Joaquin Valley's wood burning restrictions because PM2.5 levels near many wood-burning sites can be up to 25% higher than shown by monitoring because the monitors are not nearby.[259]

- In addition, the data do not reflect exposures to PM2.5 from ambient outdoor air that enters homes, and from the indoor air in homes that burn wood.

- Rule 4901, the first burn regulation in the U.S. that applies uniformly across an entire air basin, is considered the most stringent in the nation, and the resulting health improvements have been clearly documented. Since Rule 4901 was implemented in the San Joaquin Basin, air quality has improved and hospital admissions have fallen significantly.

Rule 4901, the first burn regulation in the U.S. that applies uniformly across an entire air basin, is considered the most stringent in the nation, and the resulting health improvements have been clearly documented.

Second-Hand Cigarette Smoke Heavily Regulated, Wood Smoke Lightly Regulated

Cigarette smoke and wood smoke contain many of the same toxic chemicals, yet cigarette smoke is heavily regulated by all levels of government while wood smoke is barely regulated.

- Cigarette smoke and wood smoke contain many of the same toxic chemicals, yet cigarette smoke is heavily regulated by all levels of government while wood smoke is barely regulated. How did cigarette smoke come to be so stringently regulated?

- Reports on the dangers of second-hand smoke were the impetus behind governmental regulations to restrict second-hand cigarette smoke. The 1986 report from the Surgeon General, "The Health Consequences of Involuntary Smoking,"[260] translated scientific evidence on second-hand smoke into policy initiatives.

- The report concluded that second-hand smoke caused diseases, including lung cancer, in healthy nonsmokers. Children of parents who smoke have an increased frequency of respiratory infections compared to the children of nonsmokers.

- The report also found that simply separating smokers from nonsmokers within the same air space may reduce, but does not eliminate, the exposure of nonsmokers to environmental tobacco smoke.

- In 2006, the Surgeon General concluded that local smoke-free policy initiatives engaged communities in an intensive process of public education and debate. It was also found that early on, local second-hand smoke-free policies were often more successful than federal or state initiatives.[261]

- "This process raises public awareness regarding the health risks that second-hand smoke exposure poses to nonsmokers, increases public support for policy measures that provide protections from these risks, and changes public attitudes and norms regarding the social acceptability of smoking. These changes, in turn, lay the

Children of parents who smoke have an increased frequency of respiratory infections compared to the children of nonsmokers.

groundwork for successfully enacting and implementing the proposed policy, which reinforces and accelerates these changes," the report stated.[262]

- As of 2018, a total of 22,661 municipalities were covered by a 100% smoke-free provision in non-hospitality workplaces, and/or restaurants and bars, by either a state, commonwealth, territorial, or local law. Forty-two states and the District of Columbia have local laws in effect that require non-hospitality workplaces and/or restaurants and bars to be 100% smoke-free.

- In addition, there were 3,676 states, commonwealths, territories, cities, and counties with a law that restricts smoking in one or more outdoor areas.[263]

- The critical factor driving adoption of these laws is the clear scientific evidence that second-hand smoke causes disease in nonsmokers. This rationale applies to wood-smoke emissions as well. Residential wood smoke is a significant contributor to PM2.5 emissions in both urban and rural areas in the U.S.

Table 9: Milestones in Establishing Second-Hand Smoke Policies in the U.S.

Year	Event
1971	The Surgeon General proposes a federal smoking ban in public places.
1972	The first report of the Surgeon General to identify second-hand smoke as a health risk is released.
1973	Arizona becomes first state to restrict smoking in several public places.
1974	Connecticut passes first state law to apply smoking restrictions in restaurants.
1977	Berkeley, CA, is first community to limit smoking in restaurants and other public places.
1986	Surgeon General's and National Academy of Sciences (NAS) reports conclude second-hand smoke is a cause of lung cancer in healthy nonsmokers.
1988	New York City ordinance bans/limits smoking in various public places; California implements statewide ban on smoking aboard all commercial intrastate airplanes, trains, and buses.
1992	USEPA classifies second-hand smoke as a Group A (known to be harmful to humans) carcinogen.
1994	San Francisco passes a ban on smoking in all restaurants and workplaces; Utah enacts a law restricting smoking in most workplaces.
1995	New York City bans smoking in most workplaces; California passes legislation that prohibits smoking in most enclosed workplaces; Vermont's smoking ban is extended.
1997	California EPA is first major report to conclude definitively that second-hand smoke exposure is a cause of heart disease in nonsmokers.
2000	The New Jersey Supreme Court strikes down a local clean indoor air ordinance adopted by the city of Princeton on the grounds that state law preempts local smoking restrictions.
2001	Surgeon General reports a causal relationship between second-hand tobacco smoke exposure and heart disease mortality among women who were nonsmokers.
2002	The Michigan Supreme Court refuses to hear appeal of lower court rulings striking down a local clean indoor air ordinance on grounds that state law preempts local communities from adopting smoking restrictions more stringent than the state standard; Delaware enacts a comprehensive smoke-free law, and repeals a preemption provision precluding communities from adopting local smoking restrictions that are more stringent than state law.
2003	Connecticut and New York enact comprehensive smoke-free laws; Maine enacts a law requiring bars, pool halls, and bingo venues to be smoke-free; Iowa and New Hampshire supreme courts strike down local smoke-free ordinances, ruling that they are preempted by state law.
2004	IARC identifies second-hand smoke as "carcinogenic to humans"; Massachusetts and Rhode Island enact comprehensive smoke-free laws.
2005	Delaware and Illinois repeal state preemption provision precluding local smoking restrictions that are more stringent than the state standard; Montana, North Dakota, Georgia, Vermont, Maine, Rhode Island strengthen or enact legislation that make most workplaces and other areas smoke-free.
2006	DC, Colorado, New Jersey, Utah, Arkansas, and Puerto Rico enact or strengthen legislation requiring most workplaces and public places to be smoke-free.

Source: The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General. Office on Smoking and Health (US). Atlanta (GA): Centers for Disease Control and Prevention (US); 2006.

V. Conclusion

- Wood-smoke exposure is a serious risk to human health. It is known to cause and exacerbate many pulmonary and cardio-vascular diseases.

- Despite convincing scientific evidence that wood smoke harms health, governments at all levels have failed to effectively regulate wood burning. Wood smoke now constitutes nearly 30% of airborne particle pollution in a number of urban areas during winter months, as heating with wood has continually increased.

- Summer wood burning has also increased. Outdoor fireplaces, fire pits, chimineas, and cooking appliances have become increasingly more common. Home furnishing catalogs sell many of these wood burning appliances for home recreational use. Supermarkets and big box stores sell them and promote them as well. Recreational wood burning often takes place in areas where homes are close together and the smoke often enters neighboring homes.

- This rise in the popularity of recreational wood burning poses a problem for regulators whose laws and regulations are often older

Despite convincing scientific evidence that wood smoke harms health, governments at all levels have failed to effectively regulate wood burning.

Raising public awareness of the potential health threats of wood smoke will increase public support for policy measures that provide protections from these risks, and change public attitudes and norms regarding the social acceptability of burning wood.

than this new craze of home outdoor wood burning. This increase places a burden on neighbors who complain about breathing other people's wood smoke without adequate regulations to protect them.

- Wood-smoke regulations and enforcement vary from state to state. Even within a state, enforcement of wood smoke issues can vary from town to town. Regulations put in place by towns, states, and the federal government have not caught up with the science on the harms of inhaling wood smoke.

- Research has shown that small particles, created by the burning of wood, remain airborne for longer periods of time than larger particles, meaning that they remain available for human inhalation.

- The particles can have a strongly negative effect on human health, causing and exacerbating lung diseases, and triggering cardiovascular events, cancers, and premature deaths. These health events can occur at air pollution levels well below regulatory standards.

- Short-term exposure to wood smoke aggravates lung diseases. It can cause asthma attacks, acute bronchitis, sinusitis, respiratory infections, and cardiac events.

- Long-term exposure to wood smoke can cause reduced lung function, chronic bronchitis, sinusitis, and lung cancer. It also can cause cardiovascular diseases, and cardiac events.

- Raising public awareness about the potential health threats of wood smoke will increase public support for policy measures that provide protections from these risks, and change public attitudes and norms regarding the social acceptability of burning wood. If governments, at all levels, could finally regulate cigarette smoke, after years without regulations, there is hope that eventually governments will better regulate wood smoke so that the public is finally protected.

VI. Recommendations

Recommendations for the Federal Government

- The federal government should adopt stricter wood-smoke standards. The current air standards are not strict enough to protect the public's health, with long-term exposures to PM2.5 causing an increased risk of harm, even at levels below the current air standards. The Clean Air Act requires that the Environmental Protection Agency (EPA) set air quality standards that protect even sensitive populations. The current laws clearly fail to protect human health as required by the Clean Air Act.

- The federal government should be required to test new wood-burning appliances for both their efficiency and emission levels before they are allowed to enter the marketplace. An example of such a failure are the outdoor wood furnaces that entered the marketplace without adequate testing, but which have proven to be harmful to both the environment and human health.

- The federal government should make clear what is allowed to be burned and what is not. Pressure-treated wood, plastics, building debris, and wood containing waxes, adhesives, and other dangerous additives should be banned from use in wood-burning appliances.

- The federal government should increase their education about wood smoke and its harms so that the public is more fully informed and can better protect their health.

- The federal government should require wood-burning appliances to contain a warning that wood smoke may be dangerous to health. Labeling requirements for tobacco products have proven to be effective in educating the public about the dangers of cigarette smoke; the same should be required for wood smoke.

Recommendations for States

- State governments should enact laws that clearly state that wood smoke entering another person's property is against the law, and violations are enforceable by shutting down the offending wood-burning appliance.
- States should use visual smoke passing onto neighbors' properties as proof of harm. Wood-smoke emissions that harm people should be recognized as proof of harm by the designated agency that inspects offending wood-smoke appliances.
- States should make clear to the public which state agencies are empowered to enforce laws to protect those being harmed by other people's wood-smoke emissions. In some states, local health departments are the agencies empowered to enforce these laws.
- States should include wood smoke in their nuisance clauses to better prevent and enforce wood smoke issues.
- States should install enough PM2.5 monitors to adequately reflect where wood-smoke emissions actually occur. For instance, although monitoring data from 2008 through 2012 show that Connecticut meets EPA's PM2.5 standards, there are only eight PM2.5 monitors in the state, and they are not located in areas where wood burning is the most common.
- States should enact wood burning bans when air quality does not meet EPA's health standards for either ozone or particulate levels. Communities that have done so have experienced significant improvements in air quality.
- State websites should include: why wood smoke is harmful to health; why wood smoke regulations should be enforced; and which state, county, or town agency enforces laws on harmful wood-smoke emissions.

Recommendations for City, Town, and County Governments

- City, town, and county governments should enact ordinances that clearly state that wood smoke entering another person's property is against the law, and is enforceable by shutting down the offending wood-burning appliance.

- City, town, and county governments should empower their local health departments to be the agency to enforce wood-smoke offenses, and encourage them to shut down wood-burning appliances when wood-smoke emissions harm other people.

- City, town, and county governments should ban outdoor wood furnaces, as they cannot be made safe for the environment or for people who live within half a mile of outdoor wood furnaces. Wood-smoke emissions from outdoor wood furnaces travel for half a mile and can enter all the homes within that area.

- The websites of city, town and county governments should include why wood smoke is harmful to health; why wood smoke regulations should be enforced; and which city, town or county government agency enforces the laws relating to harmful wood-smoke emissions.

Recommendations for Individuals

- Individuals need to understand that wood smoke is dangerous to their health. Individuals should protect themselves and their families from wood-smoke exposures. Pregnant women, infants, children, older adults, and people with pre-existing respiratory or cardiac diseases, diabetes, and breast cancer should avoid all wood-smoke exposures.

- Individuals should use natural gas-burning appliances instead of wood-burning ones. Even a cleaner or newer wood-burning stove will not necessarily improve the PM levels in your home. The U.S. Department of Energy found that about a third of homes that replaced their wood-burning device did not see indoor air quality improvements. A natural gas stove, if properly vented, will reduce emissions.
- Individuals should avoid burning wood. If they must, they should burn only clean, dry wood. Never burn trash. Most household waste is primarily comprised of plastics, which emit highly toxic compounds. Do not burn building debris, pressure-treated wood, or wood containing waxes, adhesives, or other dangerous additives. Synthetic logs should also be avoided.
- Individuals need to make sure that their wood-smoke emissions are not harming others. If their wood burning is harming others, they need to shut down the wood-burning appliance.
- Individuals should reduce all wood-smoke exposures. If wood smoke enters your home on a regular basis, you and your family need to get out of the smoke. Ask your neighbors to reduce the wood-smoke emissions that are harming you. If that fails, ask your local health department for enforcement help. If others are being harmed by the wood smoke, invite them to join you in asking for enforcement. If all fails, you may consider moving your residence. Obviously, nothing is more important than your family's health.
- Individuals who are experiencing wood smoke in their homes should purchase a HEPA filter while waiting for enforcement. A 2016 study by the Department of Energy found significant benefits from using high-efficiency HEPA air filters to reduce PM from wood smoke in homes. These filters, if properly sized for the volume of space you normally occupy, can reduce indoor particle pollution by as much as 60%.[264]
- Individuals should work to get their towns to pass ordinances that better protect people from being harmed by other people's wood burning.

VII. Glossary

Acronyms, Abbreviations, and Definitions

ACGIH - American Conference of Governmental Industrial Hygienists
ACHD - Allegheny County Health Department
ATSDR - Agency for Toxic Substances and Disease Registry
AQI - Air Quality Index
BaP - benzo[a]pyrene, a PAH that results from incomplete combustion
BC - black carbon
CAA - Clean Air Act
CCA - chromated copper arsenate
CDC - Centers for Disease Control and Prevention
CFR - Code of Federal Regulations
CNS - Central Nervous System
CO - carbon monoxide
COPD - Chronic Obstructive Pulmonary Disease
CTDEP - Connecticut Department of Environmental Protection
DOE - Department of Energy
DNA adduct - a segment of DNA bound to a cancer-causing chemical
GASP - Group Against Smog & Pollution
HAP - Hazardous Air Pollutant. Also known as toxic air pollutants or air toxics. Pollutants known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects.
IARC - The International Agency for Research on Cancer
NAAQS - National Ambient Air Quality Standards
NAS - National Academy of Science
NIH - National Institutes of Health
NIEHS - National Institute of Environmental Health Sciences, part of NIH
NTP - National Toxicology Program
Openn burning - Defined by EPA as smoke that enters the air directly, without first going through a chimney, flue, vent, or other similar path. Includes recreational burning as well as burning brush or other land-clearing debris.
PAH - polycyclic aromatic hydrocarbon; part of a large group of organic compounds with two or more fused aromatic rings
PAH-DNA adducts - Environmental PAH exposures result in PAH-DNA adducts
PM - particulate matter
PM2.5 - fine particulate matter (2.5 microns or micrometers)
PM10 - coarse particulate matter (10 microns or micrometers)
Recreational burning - Use of an outdoor fire for warmth or ambiance
SO_2 - sulfur dioxide
USEPA - U.S. Environmental Protection Agency
UFP - Ultrafine particulate matter
VOC - volatile organic compound
W-COPD - COPD associated with wood smoke
WHO - World Health Organization
WSPM - wood smoke particulate matter
T-COPD - COPD associated with tobacco smoking
$\mu g/m^3$ - The concentration of an air pollutant (e.g., PM) in micrograms (one-millionth of a gram) per cubic meter of air

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