



Utah Physicians for a Healthy Environment

2015 Report on the Health Consequences of Wood Smoke

Executive Summary

Recent studies on the emissions of wood burning reveal that in most northern U.S. cities, wood smoke is a significant contributor to overall community air pollution. The same is true in the urban areas of the Wasatch Front. If wood smoke were evenly distributed throughout the airshed, it would be roughly quantitatively equivalent to all vehicle emissions in the same region. But wood smoke is not evenly distributed. It concentrates heavily near its sources, subjecting neighbors to extraordinarily high levels of a wide range of toxic pollution components, and it has an extremely high “intake fraction,” meaning human exposure is disproportionately greater than average atmospheric concentrations. Moreover, wood smoke itself is uniquely toxic, probably more so than any other common type of urban pollution. As a result, it deserves special attention from lawmakers and regulators beyond what would be warranted within the context of a PM_{2.5} State Implementation Plan (SIP) control

strategy or its contributions to the exceedance of National Ambient Air Quality Standards (NAAQS). Any public policy incentivizing the trading in of old wood stoves for newer “EPA-certified” stoves as a substitute for burning bans is misguided and inadequate, because homeowners will still be left with heating devices that are far more polluting than other alternatives.

Introduction

Utah Physicians for a Healthy Environment (UPHE) is the largest civic organization of health care professionals in Utah, with about 340 members whose areas of expertise include virtually every medical specialty and related disciplines such as biology, genetics, chemistry, toxicology, ecology, atmospheric modeling, and engineering. The health effects of air pollution represent the core of our expertise and therefore our engagement in public policy. UPHE has made note of the withdrawal of the wood-burning ban proposal by Governor Gary Herbert and the Utah Division of Air Quality. Nonetheless, UPHE wishes to register this report with the Utah Air Quality Board (AQB) in support of the proposal, and in fact raise issues associated with the burning of solid fuel that were not addressed by the ban.

A strong case can be made that air pollution is the largest public health threat in most urban areas and with more consequence than smoking. Every breath that every person takes—including pregnant women, infants, and children—is contaminated by air pollution to some degree. In contrast, smoking is limited to a fraction of the population, and even smokers only inhale cigarette smoke during a small percentage of their total daily respirations. Worldwide deaths due to cigarette smoking are estimated at 5 million per year,⁸⁵ and the World Health Organization (WHO) estimates air pollution kills 8 million people per year.⁸⁶ Furthermore, smoking is “voluntary” air pollution exposure, while community air pollution is primarily involuntary; this is particularly true in the case of wood smoke.

Air pollution in general is increasingly recognized as a systemic health

threat, impairing the functioning of virtually every organ system, and related to the same broad spectrum of disease outcomes as cigarette smoke. Because of this, UPHE proposes for consideration by the AQB a rule that would address wood burning by residents, restaurants, unregulated incinerators used by small businesses, and the growing popularity of essentially unregulated household incinerators, only under a new name that suggests a desirable property amenity—“backyard fire pits.”

Burning trash in backyard incinerators has long been prohibited in most urban areas, and the justification is obvious. Operating a vehicle with excessive emissions has long been prohibited through emissions inspections. The rationale has been accepted that even though it may be cheaper for the owner of an older, more polluting vehicle to continue to operate that vehicle, for the public good those vehicles must be cleaned up or retired. Why should home heating devices be any different?

Furthermore, comparing wood-burning devices used during the winter season to auto emissions, by various metrics it is a fair approximation that one household burning wood all winter produces as much pollution as between 90 to 400 automobiles driven all winter.¹ So while we have long had in place a regulatory mechanism to limit how much pollution one vehicle may emit, we have had no mechanism to limit how much pollution one home may emit, despite the potential for it being a much larger source of pollution.

Many years ago our society adopted a the norm that no one should be involuntarily subjected to secondhand cigarette smoke because of the inherent public health consequences and the infringement on the rights of nonsmokers to avoid exposure. Routine wood-burning in an urban setting should not be allowed for exactly the same philosophical, aesthetic and public health reasons as prohibition of cigarette smoking in public venues, backyard trash incineration, and excessive vehicle emissions. The smoke from wood stoves, fire pits, boilers and fireplaces creeps onto adjacent property and into nearby homes, affecting the quality of life and health of neighbors. Cheap heat or pleasant ambiance for a resident burning wood is engaged in at the expense of nearby neighbors and the community at

large, just like secondhand cigarette smoke.

1. Wood smoke is a surprisingly large contributor to overall community pollution levels.

Wood burning has an enormous impact on community-wide pollution levels. Source apportionment studies have estimated that wood/biomass combustion contributes 10 percent to 60 percent of the fine-particle concentrations (PM_{2.5}) in large cities, such as Seattle, Phoenix, Beijing, Prague and Helsinki.^{2,3,4,5} In Pierce County, Washington, 53 percent of PM_{2.5} emissions comes from wood. A study in Los Angeles showed that in the winter, residential wood combustion there contributed 30 percent of primary organic aerosols (probably the most important mass component of particulate pollution), more than motor vehicle exhaust, which contributed 21 percent.^{6,7} In Fresno, California, wood smoke contributed on average 41 percent of organic carbon and approximately 18 percent of total PM_{2.5} mass.⁸ A study in two San Jose, California, locations showed that wood smoke pollution was 4.4 times that of gasoline- or diesel-fueled vehicles.¹⁰⁴

There is no reason to think that Utah's largest cities would be much different. In fact, the common figure recited by the media, and even the governor—that wood smoke is “5 percent” of the problem—is a complete misunderstanding and/or mischaracterization of the “the problem.” The source of the “5 percent” number is a study published by AQB member Kerry Kelly.⁹ About one-third of the total PM_{2.5} emissions is “primary;” the rest is “secondary” (formed in the atmosphere from precursor gases). About one-third of the primary PM_{2.5} emissions was from wood burning and cooking combined—specifically, 38 percent, compared to 35 percent for all cars and trucks when the PM_{2.5} emissions was above 20 $\mu\text{g}/\text{m}^3$. If residential wood burning is half of the wood/cooking inventory, 5 percent is the result of $1/3 \times 1/3 \times 1/2$. So while 5 percent seems like a small number, the study shows residential wood burning and grilling are as much of the “problem” as all of our vehicles. But the bulk of medical research indicates that “primary” PM_{2.5} emissions are much more toxic than “secondary” PM_{2.5} emissions, making the real threat much greater than “5 percent”

suggests. This study further speaks to the inadequacy of the current wood-burn curtailment program in controlling the problem.

A recent program initiated in the San Joaquin Valley Air Basin (SJVAB) to reduce wood smoke demonstrated an improvement in air quality related to even a modest program to reduce wood burning. Within three years, a reduction of 15 percent in PM2.5 levels and 13 percent in hospitalizations for ischemic heart disease was achieved in their urban areas.⁹⁷ Bear in mind, this program did not incorporate a season-long ban, and the average wintertime temperatures in the SJVAB are ten degrees warmer than in Salt Lake City. Therefore, any program to reduce or ban wood smoke in Utah's urban areas would undoubtedly achieve even greater reductions.

According to the California Environmental Protection Agency Air Resources Board, the inhalable particle pollution from one wood stove is equivalent to the amount emitted from 3,000 gas furnaces producing the same amount of heat per unit. While so-called EPA-certified wood stoves might burn cleaner, they cannot begin to approach the much lower emissions levels of natural gas furnaces.

2. Wood smoke is not evenly distributed throughout the airshed. Severe hot spots of pollution and “local victims” are created.

A study in Seattle during winter months showed much higher increases in particulate pollution in residential areas where wood burning occurred, compared to the business district—67 percent compared to 9 percent.¹⁰ Another study revealed that about 90 percent of fine particulate pollution in a Tacoma neighborhood came from wood burning.¹¹ An EPA study states that “In some neighborhoods, on some days, 90% of the particle pollution is from residential wood burning.”¹⁰³

Unlike most other sources of pollution, wood-burning emissions in a home are released directly into the area where people spend most of their time, at an elevation that does not promote dispersion. A recent study in Finland confirmed both the greater impact of wood burning compared to vehicle

emissions and the concentration effect near its sources.¹⁰⁸ Studies from California show that within a single square kilometer of a residential area, concentrations of wood smoke can vary as much as 2,500 times.¹² The highest measured concentrations were up to 100 times higher than the community average. A single wood-burning household can envelope adjacent and downwind homes with a primary PM_{0.1} (the most dangerous subset of PM_{2.5}) plume. This demonstrates how significant the creation of “local victims” is in assessing the true extent of the health impacts of wood burning. Smoking on airplanes or in public buildings is not prohibited because of what that does to community PM_{2.5} levels. It is prohibited because of the direct public health consequences to those in the immediate area. The same consideration and protection should apply for neighbors in the issue of wood burning to prevent “local victims.”

“The largest single source of outdoor fine particles (PM_{2.5}) entering into our homes in many American cities is our neighbor's fireplace or wood stove. ... Only a few hours of wood burning in a single home at night can raise fine-particle concentrations in dozens of surrounding homes throughout the neighborhood and cause concentrations of PAHs (polycyclic aromatic hydrocarbons)—one of the most toxic compounds of air pollution—higher than 2,000 ng/m³.” (Dr. Wayne Ott, Stanford University, Feb. 1, 1998). Background concentrations of PAHs should be close to zero.

Wood smoke is not just an outdoor problem. In houses without current wood burning, fine-particle levels are usually lower than outdoor levels. But in areas with high levels of wood smoke, even houses not using wood stoves or fireplaces have higher indoor wood smoke levels. Wood smoke particles are very small (ultrafine), ranging from 0.2 microns at the start of the burn period to .05 microns as the burn cycle progresses. Particles of this size behave like gases. There is no practical way to prevent wood smoke pollution from seeping into nearby homes. The extremely small size of the particles results in the particles remaining suspended in the atmosphere for long periods of time, making a disproportionate contribution to airshed pollution. Stagnant conditions and winter temperature inversions result in wood smoke hanging close to the ground, easily penetrating homes and buildings.

A study by the University of Washington showed that 50 percent to 70 percent of the outdoor levels of wood smoke were found in nearby homes that were not burning wood. The EPA did a similar study in Boise, Idaho, with similar results.¹³ A study in California showed an even higher result: Indoor wood smoke was found to average 88 percent, as high as outdoors.

¹ If a homeowner follows current Salt Lake County rules recently established by the Salt Lake County Board of Health, and doesn't burn during "yellow" or "red" alerts days, but does burn during all "green" days, his/her neighbors can go an entire winter without having even one day of clean air.

An important concept in pollution and public health is that of population "intake fraction." Intake fraction is the mass of pollutant inhaled divided by the mass emitted. Obviously, regarding health consequences, what is inhaled is what matters, much more so than what is emitted. Two different pollution sources with comparable emission rates of the same pollutant can have significantly different intake fractions, depending on the surrounding population density and the juxtaposition of the point of release. Wood smoke has a uniquely high intake fraction. During the winter, people spend about 90 percent of their time indoors, and most of that time is spent in their own homes. Residential wood smoke is the only major pollution source that is released exactly in the area where people spend most of their time, at a height where dispersion is minimal. Some pregnant women and some children spend even more of their time at home. For many physiologic, metabolic and developmental reasons, children and fetuses are well known to be much more sensitive to pollution's health impacts, with the potential for long-term health impacts. The public health consequences of in-home and neighborhood wood smoke are magnified further because many members of the most vulnerable subset of the population are the most exposed.

The concept of "intake fraction" raises a troubling irony—people who burn wood are their own worst victims, subjecting themselves and especially their children (more than anyone else) to increased pollution levels. Particulate levels were found to be from 26 percent¹⁴ to as much as 500

percent higher in the indoor air of wood-burning homes compared to non-wood-burning homes,¹⁵ and levels far beyond “red alert” conditions. Benzene levels were 29 percent higher.¹⁶ Average levels of the highly toxic PAHs were 300 percent to 500 percent higher.¹⁷

Children living in homes where wood is regularly burned were much more likely to have severe respiratory symptoms compared to non-wood-burning controls.¹⁸ Children in Klamath Falls, Oregon, showed decreases in lung function during the wood-burning season in those parts of the city with the highest amount of wood-burning.¹⁹ Numerous studies of adults show the same general trend of increased symptoms of respiratory disease among those living in residences with fireplaces or wood stoves in use.

Wood boilers deserve special mention and condemnation as severe health hazards because of their shockingly high pollution results. In a 2006 report from Northeastern States for Coordinated Air Use Management (NESCAUM), wood boilers were found to produce PM_{2.5} levels over 1,000 $\mu\text{g}/\text{m}^3$ periodically, with frequent values over 400 $\mu\text{g}/\text{m}^3$ during routine operation of the boiler, with levels measured up to 150 feet away. Peak levels measured at 50, 100, and 150 feet from the stack often reached over 4,000 $\mu\text{g}/\text{m}^3$, including an astounding 8,800 $\mu\text{g}/\text{m}^3$ peak measurement at 50 feet away.

3. Wood smoke is even more toxic than other particulate pollution.

The Canadian government’s official website, Healthy Canadians, states boldly and unequivocally, “Avoid Wood Smoke.”⁹⁶ Wood smoke is an extreme public health hazard, containing over 200 toxic chemicals and compound groups. The emissions from wood smoke are almost entirely in the inhalable size range.²⁰ A study in Vancouver reported that wood smoke particles are seven times more likely to be breathed into our lungs than the average PM_{2.5} particle in Vancouver's air.^{21,22} Once inhaled, the small particles that are characteristic of wood smoke also more easily penetrate cell walls and even subcellular structures, such as mitochondria and the cell nucleus.⁸⁷ It is at this microscopic, cellular level that particulate matter

triggers its broad array of health consequences.

Components of wood smoke are similar to those of cigarette smoke. Both types of smoke include particulate matter, carbon monoxide, formaldehyde, sulfur dioxide, nitrogen oxides, dioxins, and polycyclic aromatic hydrocarbons (PAHs).²³ Furthermore, as with cigarettes, those who are doing the wood burning are the most victimized by the pollution generated.

A report by Environment & Human Health, Inc., “The Health Effects of Wood Smoke,” cites medical research indicating that wood smoke interferes with lung development in children and increases a child's risk for serious lower respiratory infections, such as bronchitis and pneumonia.²⁴ Wood smoke exposure can depress the immune system, damage the pulmonary epithelium²⁵ and increase arterial stiffness.²⁶

The very small size of the particulate emissions and high levels of PAHs from wood smoke may account for its excessive toxicity compared to fossil fuel-generated particulate matter. Ultrafine particles are more potent in inducing inflammatory responses in the human body than fine particles.^{27,28,29,30,31,32} Wood smoke produces high levels of free radicals, leading to DNA damage as well as inflammatory and oxidative stress responses in gene expression in cultured human cells.^{33,34} Exposure to PAHs has been associated with mutations in tumor suppressor genes.

The federal Environmental Protection Agency estimates that the lifetime cancer risk from wood stove smoke is twelve times greater than that from an equal volume of secondhand tobacco smoke. (The Health Effects of Wood Smoke, Washington state Department of Ecology). Organic extracts of ambient particulate matter containing substantial quantities of wood smoke are 30-fold more potent than extracts of cigarette smoke condensate in a mouse skin tumor-induction assay that was conducted.³⁵ Wood smoke exposure approximately doubles an individual's risk of getting lung cancer^{92,93} and cancers of the mouth and throat.⁹⁴ One study showed a significant increase in childhood brain tumors with prenatal and postnatal exposure to wood smoke.⁹⁰ PAH attachment to DNA (DNA adducts) has been specifically correlated with higher rates of breast cancer.

Studies of cigarette smoke and automobile traffic-generated pollution show that significant epigenetic changes, e.g., genotoxicity, can occur literally within minutes or hours after exposure,^{83,84} so there is every reason to believe that wood smoke would act just as quickly. Smokers exposed to wood smoke, either through home heating and cooking or through neighborhood pollution, are not only at increased risk of chronic obstructive pulmonary disease (COPD), but they are also more likely to have epigenetic changes in their DNA that synergistically increases their risk of COPD and related pulmonary problems, and likely also lung cancer.⁹¹

Wood smoke particles have been reported to induce DNA damage in vitro in human monocytic and epithelial cell lines and in a murine macrophage cell line. However, particles from poor combustion—e.g., low-temperature wood boilers and other inefficient wood-burning appliances—seem to have greater effects on both cytotoxicity and DNA damage than particles from more complete combustion conditions.^{88,89}

FREE RADICALS

Free radicals produced from wood smoke are chemically active for twenty minutes. In contrast, tobacco smoke free radicals are chemically active for thirty seconds. Wood smoke free radicals may attack our body's cells up to forty times longer once inhaled.³⁶ Animal toxicology studies show that wood smoke exposure can disrupt cellular membranes, depress macrophage activity, destroy ciliated and secretory respiratory epithelial cells, and cause aberrations in biochemical enzyme levels.³⁷

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

Undoubtedly, making a major contribution to the toxicity of wood smoke is the high concentrations of PAHs. The EPA estimates that a single fireplace operating for one hour, burning ten pounds of wood, will generate more PAHs than 6,000 packs of cigarettes.³⁸ Other estimates indicate an even higher rate of PAH release.^{39,40} Wood burning is the largest source of PAHs in the urban environment. In urban circumstances where wood burning is common in the winter, atmospheric PAH concentrations can be 15 times higher during the winter than during the summer.^{100,101}

Furthermore, wood-burning appliances with similar emission profiles for particulate matter may simultaneously produce dramatically different amounts of PAHs.⁴¹

Adverse health effects far beyond carcinogenicity add to the need for community control strategies to reduce wood smoke, which should be a top priority in any overall pollution reduction strategies.

PAHs have been implicated in numerous studies showing adverse pregnancy outcomes and impaired fetal development, including birth defects. Prenatal exposure to PAHs has been found to adversely change placental vascular architecture, trigger pro-carcinogenic epigenetic changes, and is associated with decreased intelligence, higher rates of behavioral and attention deficit disorders, and obesity.^{42,43,44,45,46,47,48,49,50} DNA damage induced by PAH exposure has been demonstrated by numerous studies. Fetuses are far more susceptible to DNA damage and pro-carcinogenic epigenetic changes than are adults.⁹⁵

A remarkable new study showed a direct linear relationship between the amount of PAH exposure during pregnancy and MRI scans that documented loss of volume in brain white matter and loss of intelligence and behavioral disorders in children¹¹⁰

Furthermore, PAH from wood smoke will land on indoor household and outdoor surfaces and soils, resulting in second- and third-hand ingestion and skin absorption. Studies done in soil near oil refineries (whose emissions are also high in PAHs) have shown concentrations as high as 200,000 $\mu\text{g}/\text{kg}$.⁵¹

DIOXINS

A complete review of the toxicity of the group of chemically related compounds called dioxins is beyond the scope of this review. Nonetheless, dioxins deserve special mention. Wood smoke is the third largest source of dioxin exposure in the United States.⁵² Dioxin levels are typically measured in picograms, one trillionth of a gram. Burning just one kilogram of wood

produces as much as 160 micrograms of dioxins.⁵³

An Australian study found that wood heaters were responsible for increasing background dioxin concentrations by ten times compared to during the non-heating season.⁵⁴ The burning of wood pellets and other forms of treated wood has the potential to release even higher concentrations of dioxins. Copper, a common biocide element that is chemically bound to wood, is an important dioxin catalyst. Preservative metals promote smoldering of wood char following the cessation of flaming, providing the required temperature environment for dioxin formation, and chlorinated organics added as secondary preservative components yield dioxin precursors upon thermal decomposition.⁵⁵

Dioxins are among the most toxic compounds to which humans can be exposed. Dioxins, and many of the other chemicals in wood smoke, are exactly the type of chemicals that the American College of Obstetricians and Gynecologists and the American Society for Reproductive Medicine addressed in a prepared statement in autumn 2014.

“Reducing exposure to toxic environmental agents is a critical area of intervention for obstetricians, gynecologists, and other reproductive health care professionals. Patient exposure to toxic environmental chemicals and other stressors is ubiquitous, and preconception and prenatal exposure to toxic environmental agents can have a profound and lasting effect on reproductive health across the life course. Prenatal exposure to certain chemicals has been documented to increase the risk of cancer in childhood...[we] join leading scientists and other clinical practitioners in calling for timely action to identify and reduce exposure to toxic environmental agents while addressing the consequences of such exposure.”⁵⁶

Dioxins fall into the broad category of endocrine disruptor chemicals. The Endocrine Society, internal medicine specialists in diseases of the pancreas, thyroid, adrenal and pituitary glands, and hormone dysfunction, issued this statement about dioxins in 2010:

“Even infinitesimally low levels of exposure indeed, any level of exposure at all, may cause endocrine or reproductive abnormalities, particularly if exposure occurs during a critical developmental window. Surprisingly, low doses may even exert more potent effects than higher doses.”⁵⁷

Dioxins, like PAHs, are a particularly significant threat to fetuses and infants. Greater levels of dioxin exposure are associated with pregnancy loss and pre-term delivery,⁵⁸ impaired fetal growth and smaller birth size, including smaller head size.⁵⁹ Dioxins also cause immunosuppression. Prenatal exposure is associated with a 250 percent to 500 percent increase in episodes of otitis media in 18-month-olds.⁶⁰ Many chemicals, such as dioxins, have been shown to not only impair the health of those exposed but through epigenetic changes to also impair the health of subsequent generations who are not exposed.⁶¹

ACROLEIN

Acrolein is a chemical found in high concentrations in both cigarette and wood smoke. Acrolein is well known to suppress the immune system⁶² and has recently been strongly implicated in demyelinating diseases, such as multiple sclerosis.^{63,64} The authors of a recent study stated, “We think that acrolein is what degrades myelin. ... We've discovered that acrolein may play a very important role in free radical injury, particularly in multiple sclerosis.” One day’s worth of wood burning for an average household produces as much acrolein as 26,000 cigarettes.

Several studies suggest that particulate pollution in wood smoke from wildfires is much more toxic to lung macrophages than an equivalent concentration of similarly sized particulate pollution found in typical urban smog.^{65,66,67,68} A recent study demonstrated lower birth weights among babies born to mothers who were pregnant during a two-week stretch of severe wildfires in Southern California.⁶⁹

A study of a population in Peru demonstrated significantly higher blood pressures among those living in homes that burned wood, compared to those that didn’t. Wood and other biomass fuel users had systolic blood

pressures that averaged seven mmHg higher, and diastolic blood pressures that averaged almost six mmHg higher compared to non-burners. That is a remarkable difference, and, considering all the consequences of a higher blood pressure, one to have serious consequences for all cardiovascular related health complications.¹⁰⁹

Another recent study compared daily hospital admissions and death rates related to cardiovascular and pulmonary diseases in two cities in South America where one city's pollution was predominantly from wood smoke and pollution in the other was from mobile and typical point sources. Compared to the non-wood-burning city, the city with primarily wood smoke experienced an increase of 47 percent for cardiorespiratory deaths and an increase of 104 percent for respiratory hospital admissions for every 10 $\mu\text{g}/\text{m}^3$ increase in PM10.⁷⁰

**4. “EPA-certified stoves” are not the solution.
“No natural gas service” is no longer an excuse.**

Not surprisingly, the Hearth, Patio and Barbecue Association (HPBA) has been mounting a campaign to not only fight any banning of wood burning but also to convince policy makers that the answer to wood smoke is to sell *more* of their product, not *less*. Below are eight reasons that policy makers should not accept this rationale.

1. EPA stove performance in the real world does not match their performance as tested in the lab, something that the manufactures and the EPA acknowledge.^{71,72} For example, current testing standards specify the use of kiln dried lumber precisely arranged in a crib formation—hardly representative of the way most stoves are actually operated. Emission rates reported in the certification process do not represent emission levels of stoves in homes after extended use.

The wood-burning-device industry (HPBA) and the EPA claim that wood

stoves emit 70 percent less particulate matter, and therefore the answer to community problems with wood burning is to sell more of these products, not ban them. However, the EPA's program in Libby, Montana, is proof in the real world that those claims are exaggerated. The wood-burning industry, the EPA and the state paid to change out every wood stove in the Libby area to an EPA-certified stove. They also invested in education programs and proper installation. Yet using industry's own numbers from an industry-funded study, particulate matter (PM) was reduced by only 28 percent. If EPA stoves performed as claimed, PM reduction should have been 56 percent. Before the change-out, 83 percent of Libby's winter PM came from residential wood burning. If the subsidies had gone to change to propane or electric heat, PM levels would have dropped almost 80 percent, while also reducing toxics and carcinogens.

Another change-out study in Idaho found that almost 33 percent of the homes where EPA-certified stoves replaced older models showed increases in indoor particulate matter.⁷³ A study prepared for the EPA showed that after extended use, actual emissions were over three times greater than the certified values.⁷⁴

The consistency and reproducibility of wood-heater emissions testing is very poor. Many relatively small, uncontrollable variables that are inherent in the wood combustion process, such as type of wood, substrate configuration and moisture content, can combine to significantly affect the outcome of any given test.⁷⁵ The emissions from modern combustion appliances for wood logs may increase 10-fold if they are not operated appropriately.⁷⁶

2. Wood stoves generate a large amount of emissions when they are started up, but these emissions are not "counted" in the EPA testing procedure. Testing does not begin until the stove has begun to burn "cleanly."
3. EPA wood stoves have never been shown to reduce the amount of the most deadly components of wood smoke, including dioxins, furans, and

PAHs. Some studies have shown that EPA stoves emit even more of these highly toxic compounds.^{77,78,79}

4. In-home performance is too dependent on the operator—airflow and fuel choice radically affect the actual emissions. A stove poorly operated or maintained can emit ten times more pollution than lab testing indicates. John Gulland, manager of the “pro-wood” Wood Heat Organization, puts it this way: “People who don’t care about the impacts of their actions on neighbors and are content to remain ignorant of good wood-burning practice will make a lot of smoke, regardless of the emissions rating of the appliance they choose.”⁸⁰
5. Typical wood-stove operation employs “dampering down” at bedtime or during temperate weather. Since oxygen is a necessary component of combustion, this can create much higher levels of pollutants.
6. The performance of wood-heating devices equipped with catalytic components degrades over time—if poorly maintained, in as little as two years.⁹⁸ Structurally, wood heaters also degrade with use, and emission factors increase. The negative consequences of degraded catalytic components, which can include dramatically increased emissions, occur outside the end-user’s home. Thus, there is no reason to think that owners will replace the degraded catalytic components or expend the effort and money to maintain them properly.⁸¹
7. Even if wood stoves and their pollution control devices did not degrade over time and if they were all operated the way they are tested in the lab, they are still hundreds of times dirtier than a natural gas furnace in emitting particulate pollution and even more so in emitting hazardous air pollutants (dioxins, furans, PAHs and heavy metals).
8. Exempting supposedly “cleaner” stoves from any wood-burning ban would only make sense if combined with emissions verification by actual testing in the field on a regular basis, just like how cars are tested. That would be difficult, impractical and costly but is likely to produce greater pollution reductions than the current vehicle emissions program.

Emissions checks could be paid for by a licensing fee like the one required for automobiles.

Lack of natural gas service is no longer an excuse to have to burn wood. From a report from Families for Clean Air⁹⁹:

“The reliance on wood burning for home heating in these areas is rationalized on the basis that the cost of electric heat or propane is too expensive. This rationale has even held sway with air quality regulators, who have exempted areas not serviced with natural gas from wood burning restrictions on days when the air quality is poor or predicted to be poor.

“But now, thanks to advances in technology, heating a home with an electric split ductless heat pump is cheaper than heating with natural gas. Split ductless heat pumps are extremely efficient because they move heat from one place to another rather than generating heat from energy. Installation does not require ductwork, which can be expensive and difficult to put in. In fact, the cost to purchase and install a split ductless unit is comparable to the purchase and installation of a wood stove. Note that these split ductless heat pump units can cool as well as heat.

5. Inversion season is not the only time we are at risk from wood smoke.

There is no safe level of air pollution. Medical research has well established that one unit of air pollution emitted into the community airshed when levels are relatively low has as much, or even greater, health impact as when PM or ozone concentrations are higher. In fact, plotting a curve correlating sudden cardiac death (the signature outcome of PM exposure) vs. concentration of PM yields a curve whose steepest part is at the lowest doses.⁸² In other words, eliminating wood burning in circumstances that already meet the NAAQS may be even more important in protecting public health. This is not factored into NAAQS, but it is nonetheless an important

consideration in regulating the creation of wood smoke.

The Bay Area Air Quality Management District estimates that more than \$1 billion worth of medical expenses are caused by burning wood smoke in the Bay Area, including the calculation that one wood fire can cost your next-door neighbor an average of \$40 in medical expenses.

6. Wood smoke is a large community economic liability, and it contributes significantly to global warming.

The Bay Area Air Quality Management District estimates that more than \$1 billion worth of medical expenses are caused by burning wood smoke in the Bay Area, including the calculation that a single wood fire can cost your next-door neighbor an average of \$40 in medical expenses.

Given the overwhelming scientific consensus regarding a growing, primarily human-caused climate crisis, it is also important to consider the carbon footprint of wood burning. The 2007 Nobel Prize-winning Intergovernmental Panel on Climate Change (IPCC), consisting of approximately 2,000 scientists, concluded that black carbon soot, which is a major component of wood combustion, is a significant “forcer” of global warming. However, a 2013, 232-page report from 31 international scientists using data collection over four years¹⁰⁵ concluded that the real global-warming impact of black carbon soot was double that of previous estimates. In fact, black carbon particulates may have a warming effect two-thirds as great as CO₂.

Black carbon exerts multiple effects, depending on complex altitude and atmospheric conditions. Black soot particles on snowpack decrease the reflection of sunlight and cause atmospheric warming and accelerated melt of snowpack, which is essentially a loss of available water. Dust from the Southwest has already been shown to hasten the melting of snow in the Rocky Mountains, reducing the amount of runoff into the upper Colorado River by 5 percent, ultimately causing a loss of 250 billion gallons of water a year.^{106,107} All particulate matter emitted along the Wasatch Front, including that from wood burning, will have the same type of effect on

Wasatch Front snowpack, aggravating our water supply woes.

Black carbon particles heat up the layer of the atmosphere where clouds are forming, promoting cloud evaporation, no longer allowing sunlight to be reflected back into space. Black carbon also has cooling effects, but considering both the warming and cooling effects, the amount of extra energy stored in the atmosphere due to black carbon is 1.1 watts per square meter of the earth's surface.¹⁰⁵ The same calculation for CO₂ is 1.56—particulate pollution has two-thirds the impact of CO₂.

A 2010 study concluded that the amount of carbon released per unit of energy produced is actually greater for wood than it is for fossil fuels. It is a common misconception that burning wood is carbon neutral. Considering the entire carbon life cycle of wood, burning releases carbon now when we can least afford to do so—carbon that would otherwise have been stored for decades or perhaps centuries. While sustainable forestry practices can help repay that “carbon debt,” those benefits do not accrue until the distant future, too late to be of much help. As a result of this study, the state of Massachusetts changed its renewable portfolio standard to exclude biomass projects with long carbon payback periods.

The UN Environment Program and the World Meteorological Organization recommended phasing out log-burning stoves in developed countries to reduce global warming as well as dangerous air pollution.¹¹¹ Even if the wood is from a sustainable source, methane and black carbon emissions from log-burning stoves cause more global warming than a gas heater or electric heat pump.¹¹²

Summary

We believe that government agencies have the authority—indeed the obligation—to make rules regarding wood-burning devices stricter than current rules. The fact that these wood-burning devices already exist, that companies make a profit manufacturing them, and that many people choose to use them for reasons such as cost, convenience, or ambiance, is no excuse for government agencies not to fulfill their obligation to protect

public health. Frankly, federal, state and local governments cannot protect wood-burning manufacturers and wood burners and simultaneously protect public health, and it is clearly mandated to do the latter.

It is long overdue for us to consider that subjecting one's neighbors to the high pollution consequences of wood-burning devices is as much of an anachronism as allowing cigarette smoking on airplanes. The medical science demands that the EPA act aggressively to curtail, as much as is legally possible, this serious public health menace.

Sincerely,

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