Wood smoke – health effects and exposure

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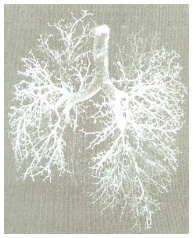
Central points

1. Inhalation of wood-biomass smoke can result in significant adverse health effects.
2. Exposure pathways can manifest in a wide range of spatial and temporal scales.
3. The Northeast magnitude of wood smoke exposure, especially in non-urban areas, presents a public health concern.
4. Wood burning-biomass trends could intensify exposure.
5. The perceptual and cultural context of wood-biomass burning can jeopardize the public health process

Overview

Perception



Health effects

Exposure

Wood burning 1983/2007 redux

"Uncertain oil supplies and steep price increases for petroleum and natural gas have led to increased use of alternative fuels for home heating."

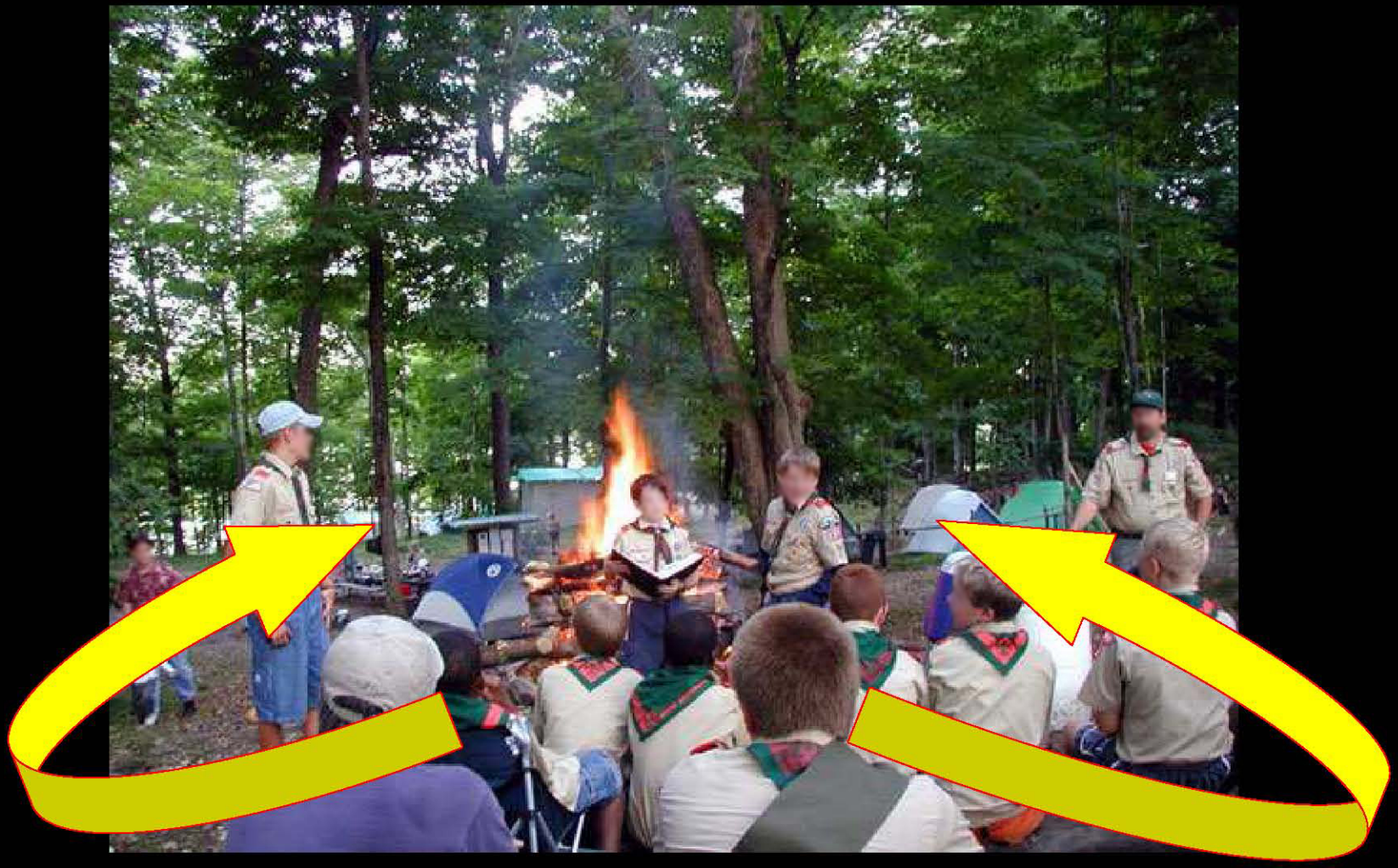
– Lipfert and Dungan

Science, 1983

Wood burning now

Uncertain oil supplies, steep price increases for petroleum and natural gas, and climate change concerns have led to increased use of biomass fuels for a variety of energy-intensive purposes, at residential and commercial scales, with probable adverse consequences to public health.


BUTTONING UP FOR WINTER
E. JOHNSON 2004 ©



Wood smoke constituents

- At least 5 chemical groups classified as known human carcinogens, others categorized probable or possible human carcinogens by IARC
- At least 26 chemicals listed HAPS by EPA
- PAHs, benzene, aldehydes, respirable PM, CO, NOx, and other free radicals
- Health impacts of these constituents well characterized in thousand of studies
- Modes of toxicity: Asphyxiant, irritant, carcinogenic, mutagenic, allergenic, neurotoxic, oxidative stress and inflammation, redox activity

Wood smoke health effects

"The sentiment that wood smoke, being a natural substance, must be benign to humans is still sometimes heard. It is now well established, however, that *wood-burning stoves and fireplaces* ***as well as wildland and agricultural fires*** *emit significant quantities of known health-damaging pollutants, including several carcinogenic compounds."*

– Naeher et al. 2007

Woodsmoke Health Effects: A Review

Scientific analysis

- Air pollution from biomass-wood smoke combustion associated with a range of adverse respiratory health impacts
- Weight of the evidence indicates biomass-wood smoke particles are hazardous to human health
  - animal and in vitro toxicology
  - human exposure data
  - epidemiologic studies of wildfires and of household wood combustion

Wood smoke $PM_{2.5}$

Among the currently regulated pollutants in wood smoke, fine particles ($PM_{2.5}$) serve as the best exposure metric in most circumstances.

Wood smoke particles are generally < 1 μm, peak in the size distribution 0.15 - 0.4 μm

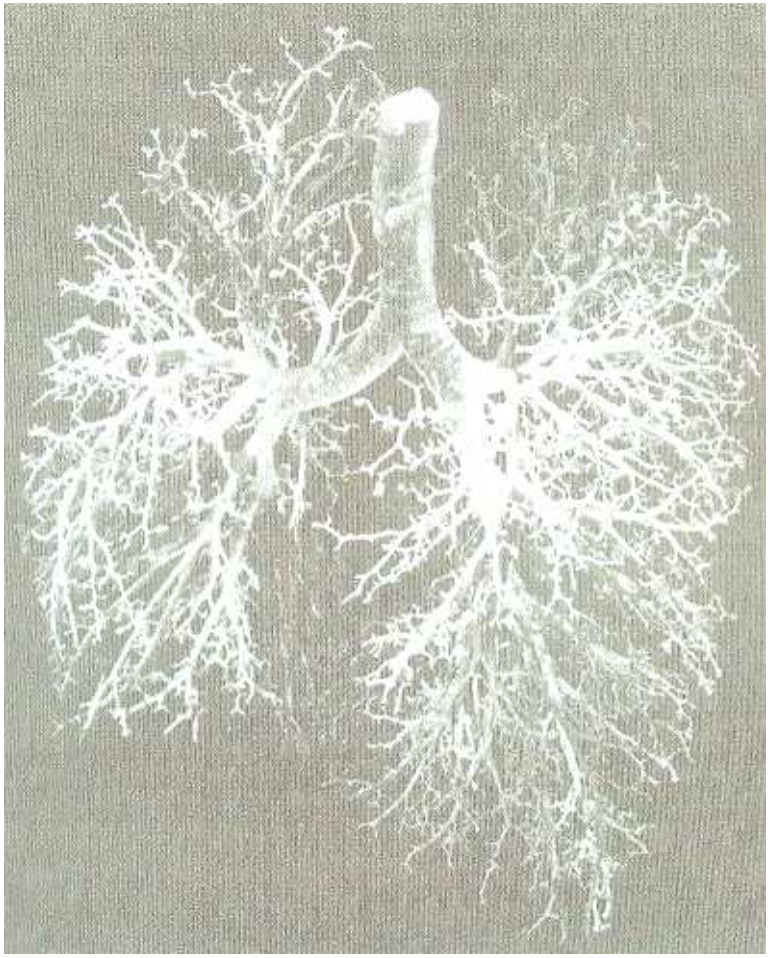
Little evidence to suggest reduced or altered toxicity from wood smoke particles relative to the more commonly studied urban air PM.

Human lung

Excellent delivery device for exogenous material.

2 m^2 (skin) vs. 50-100 m^2 (lung)

Fine particles reach the deep lung, enter system



Wood smoke epidemiology

Exposure to the concentrations and durations of wood smoke associated with RWS likely to cause a variety of adverse respiratory health effects:

- Increases in respiratory symptoms, lung function decreases, visits to emergency departments, hospitalizations.

Biological plausibility supported by:

- toxicology literature, controlled exposure studies, biomass burning data

Study examples:

- Michigan, two groups of kids, with and without wood stoves. Significant differences for severe symptoms of persistent airway irritation (Honicky et al. 1985)
- Seattle, high and low wood smoke areas. Significant respiratory differences for kids aged 1-5 (Browning et al. 1990)
- Klamath Falls, OR children high and low exposure during wood burning season (upwards of 80% of PM). Lung function decreased in high exposure area, but not the low exposure area (Heumann et al., 1991)
- Seattle, RR for 30 ug/m3↑PM_{10} 1.12 (1.04-1.20) ~85% of winter time PM mass was wood smoke (Schwartz et al. 1993)
- CT and VA: each hour-per-day use of a fireplace was associated with cough, sore throat, chest tightness, and phlegm. Use of a fireplace for 4h would increase the risk of such symptoms by about 16–20% (Triche et al. 2005)
- Review study: no reason to think that the adverse impacts of acute wood smoke exposure would be less than those associated with other sources of ambient PM (Boman et al. 2003)

Toxicology wood smoke findings

- Short-term effects on pulmonary immune defense mechanisms. Likely target seems to be the macrophage, a primary defense of the deep lung.
- Effects most dramatic after acute, high-dose exposure. More study needed regarding long-term exposure to lower concentrations of wood smoke.
- Most available animal studies indicate that exposure results in significant impacts on the respiratory immune system and at high doses can produce long-term or permanent lesions in lung tissues.
- Wood smoke is mutagenic and possibly carcinogenic in laboratory and field studies
- No toxicological data examining the effects of woodsmoke on cardiovascular outcomes.

Zelikoff et al. 2002, Naeher et al. 2007

Susceptibility to PM exposure

Sensitive subpopulations

(~40% of population)

- Infants, children, older persons
- Individuals with preexisting cardiorespiratory diseases (e.g., asthma, chronic pulmonary obstructive syndrome)
- Individuals with diabetes
- Persons in high exposure situations (e.g., close proximity to sources)

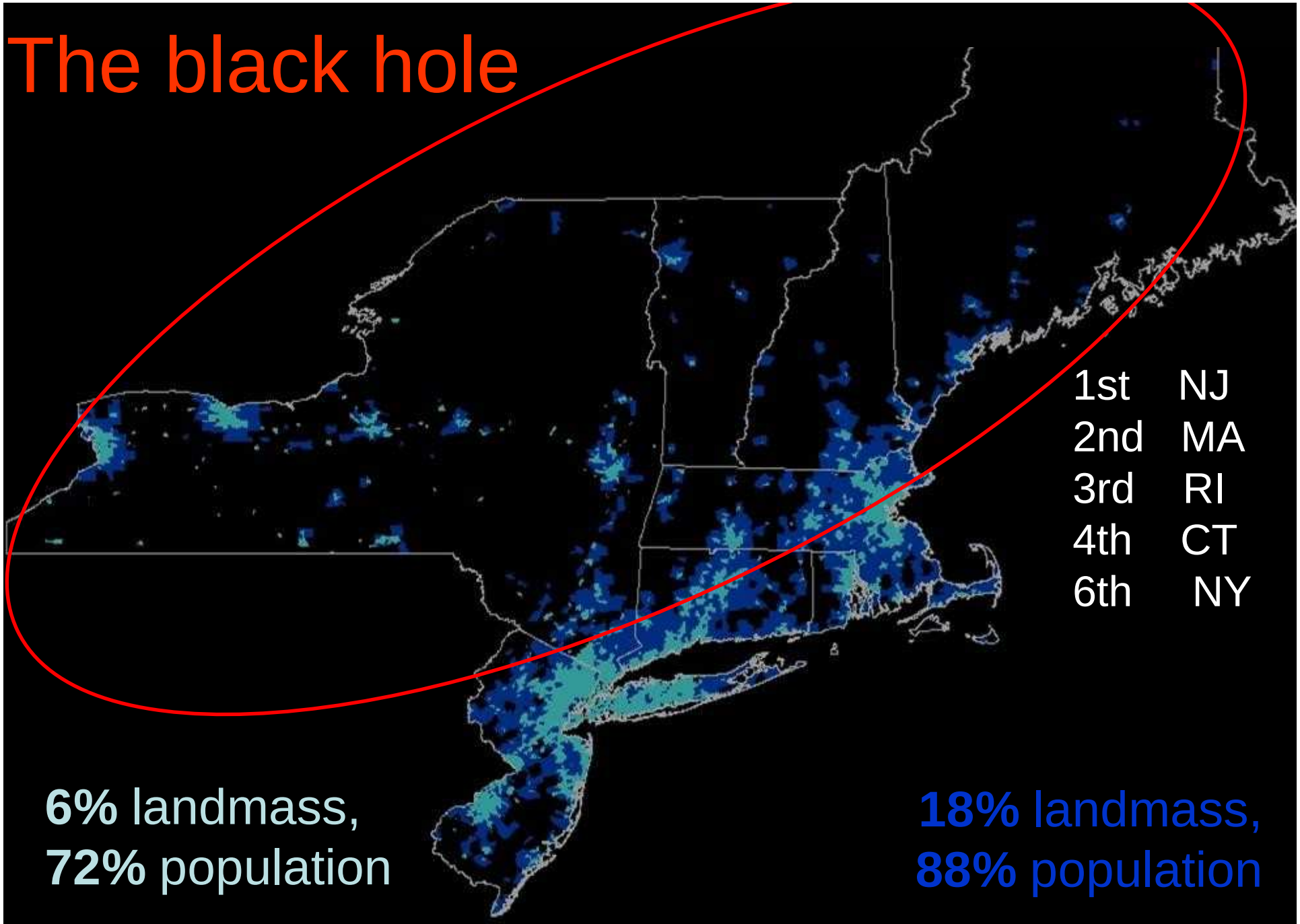
Wood smoke exposure

Individual → Residential → Neighborhood → Area

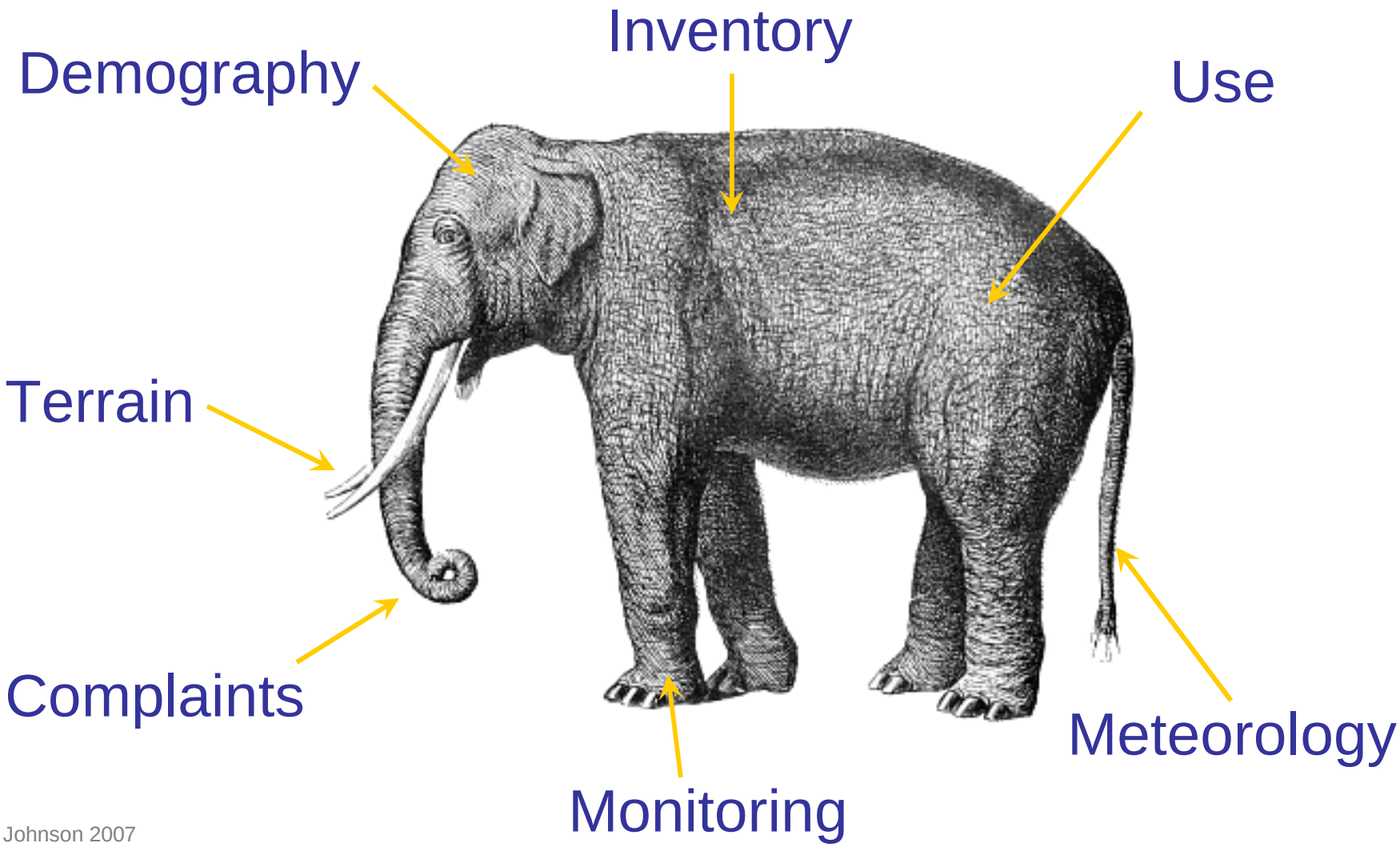
Image: Environment Canada

Northeast U.S. magnitude of exposure to residential and commercial wood combustion

The black hole



The elephant and 7 blind scientists



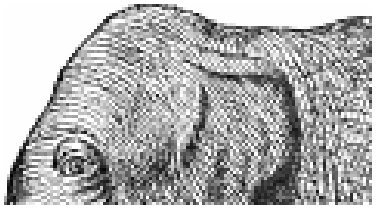
Use

- The NE Census Region (New England, NJ, NY, PA) consumes over twice the number total cords of wood in woodstoves per year than the Midwest, South, or West (Houck et al. 2001).
- Recent trends in carbon energy supplies indicate resurgence of residential wood burning and initiation-escalation of commercial biomass burning

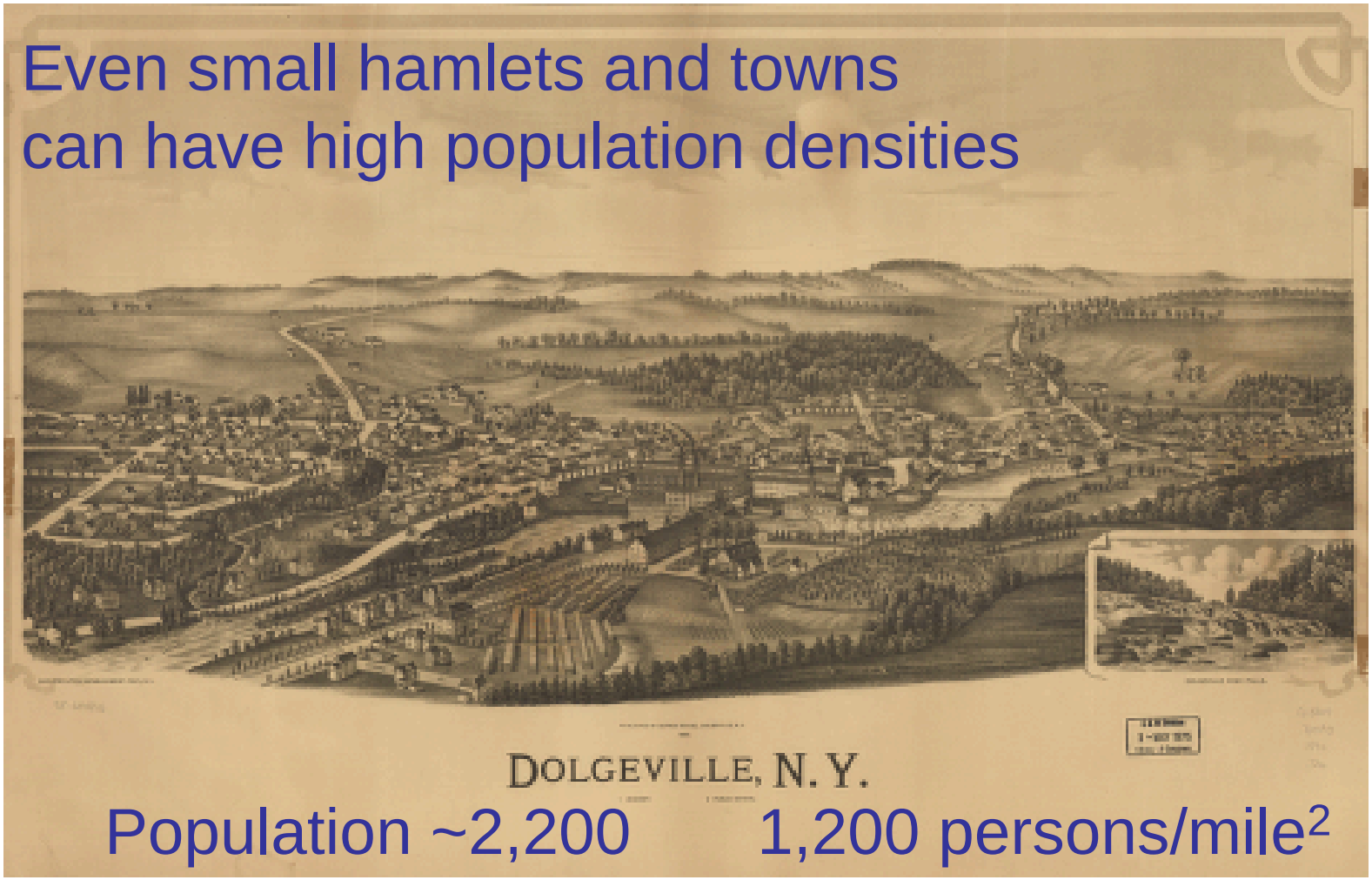
Inventory

- New England has the highest per capita woodstove ownership in the U.S.
- Vast majority of fleet are conventional (no control technology) despite EPA NSPS regulations, i.e., very slow turn-over since 1992.
- Outdoor wood boiler (OWB) use increasing rapidly (i.e., replacing dirty, old indoor technology with even dirtier outdoor technology). [*De-evolution*]
- Commercial fleet? Using what type of technology?

Demography



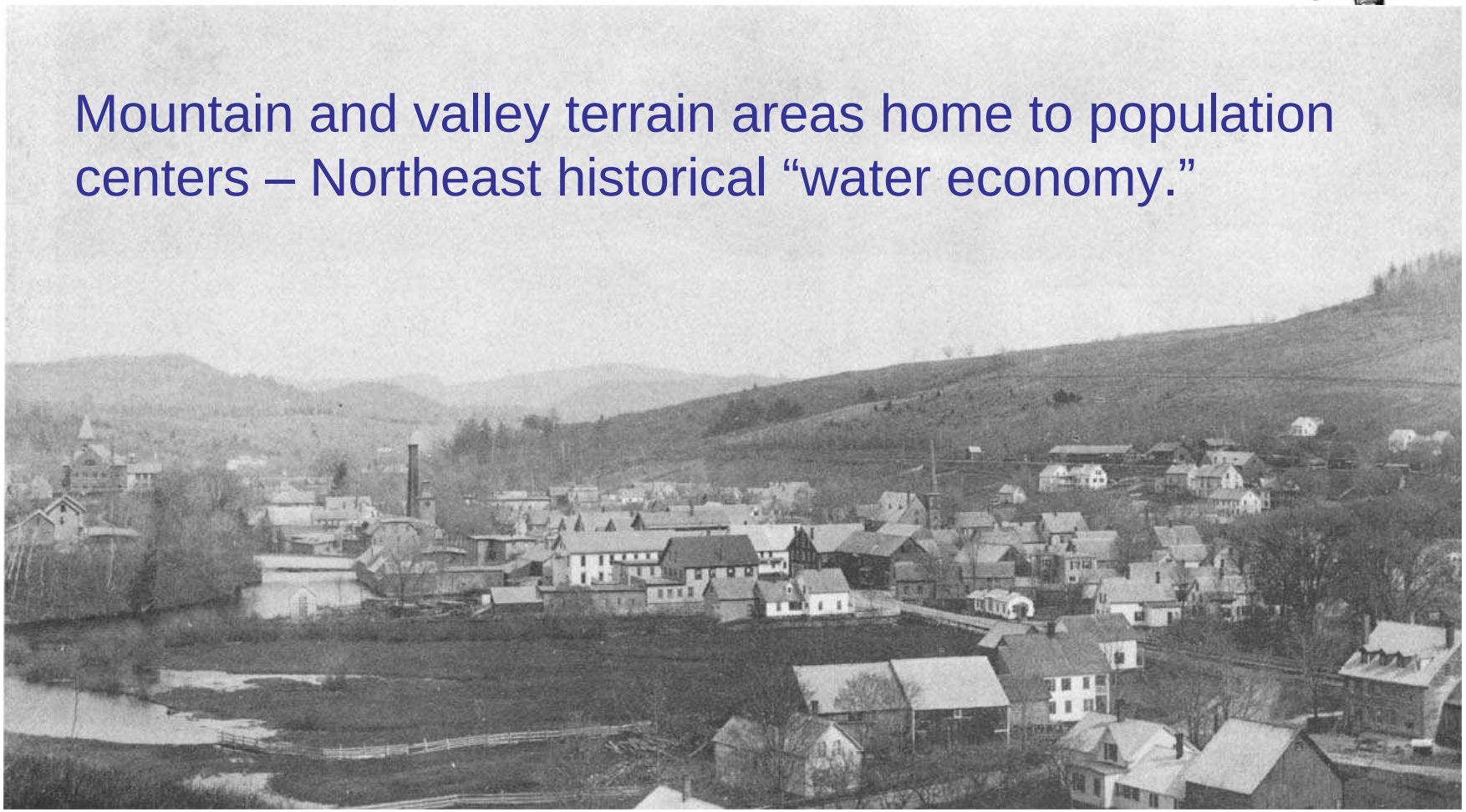
Even small hamlets and towns
can have high population densities



Population ~2,200 1,200 persons/mile^2

Terrain

Mountain and valley terrain areas home to population centers – Northeast historical “water economy.”



Meteorology

Wood burning for heat can start early autumn and last until late spring. For water year-round.

NE terrain prone to night-time diurnal inversions – when dense cold air is trapped beneath warmer air.

In these areas, even a small number of woodstoves can affect a large fraction of a community, especially in densely populated areas.

Area-scale exposure

Plywood facility hog fuel boiler (i.e., “clean” wood fuel) plume over town, western Washington.

P. Johnson, c1999

Area-scale exposure

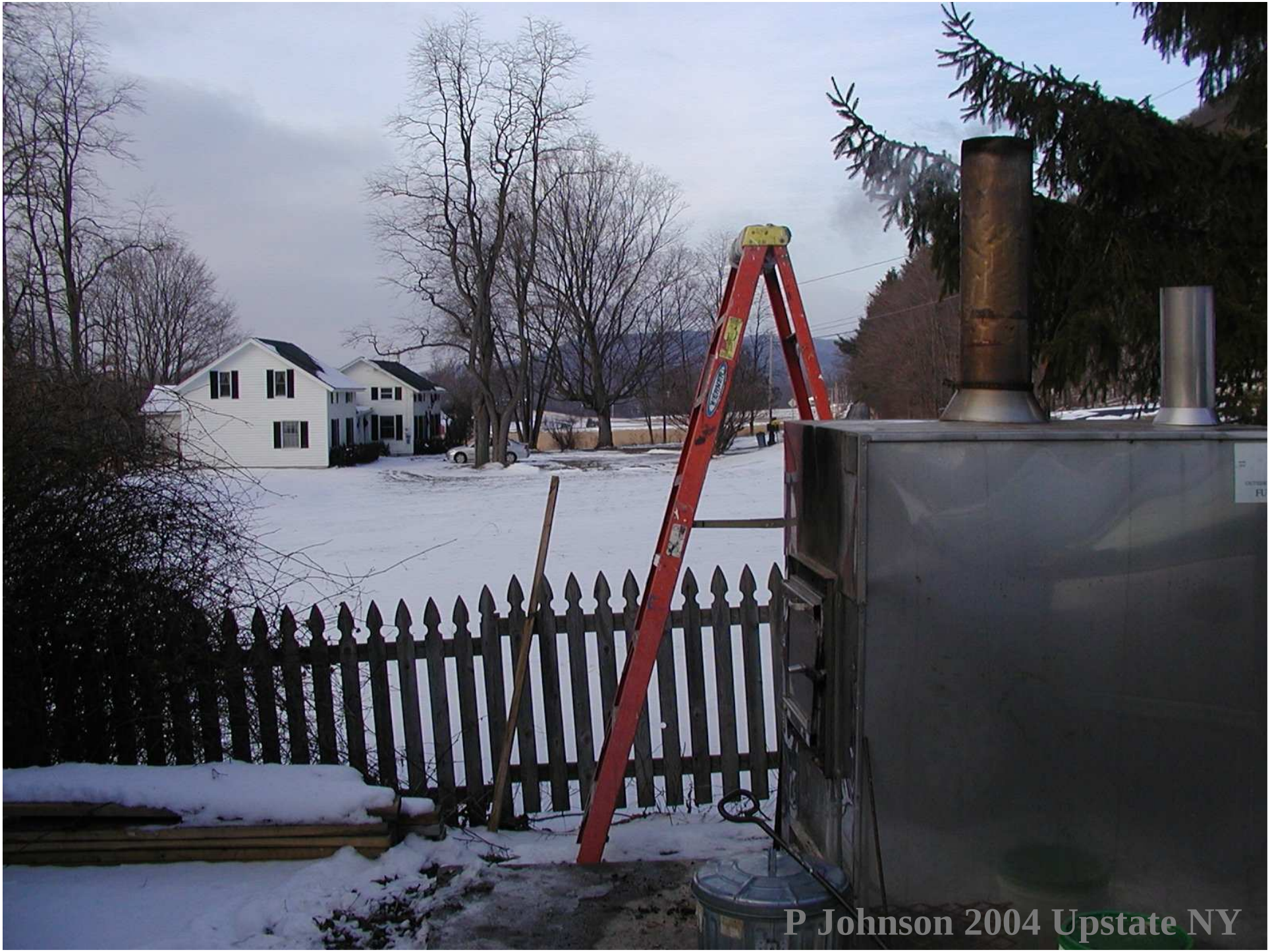
OWB plume, western Wisconsin

Downwinder, Nov 2007

Area-scale exposure

OWB valley smoke, western Wisconsin

Downwinder, Sep 2007


P Johnson 2004 Upstate NY

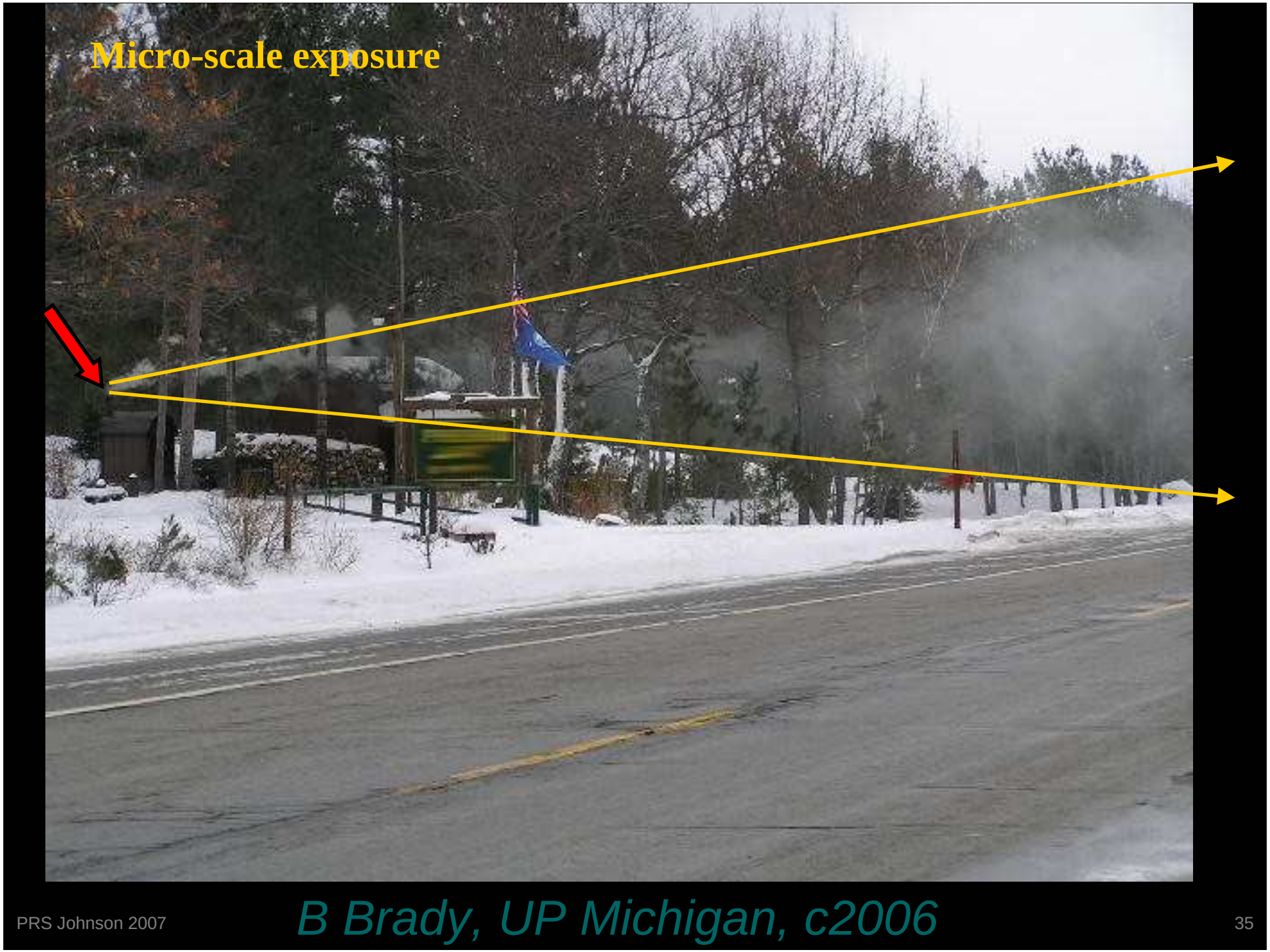
Nearly ideal technology to maximize exposure from emissions

- Human breathing zone emission points
- Plumes observed low to ground
- Microscale fumigation and impingement
- Anecdotal evidence of less than ideal fuel use

  "About any combustible substance that will fit through the doors."
- Fence line source locations

  Neighbor vs. neighbor
- Proliferation in populated areas
- Commercial scale applications


Micro-scale exposure
“Greatest potential for neighbor on neighbor violence in my career.”
P Johnson 2004 Upstate NY



B Brady, UP Michigan, c2006

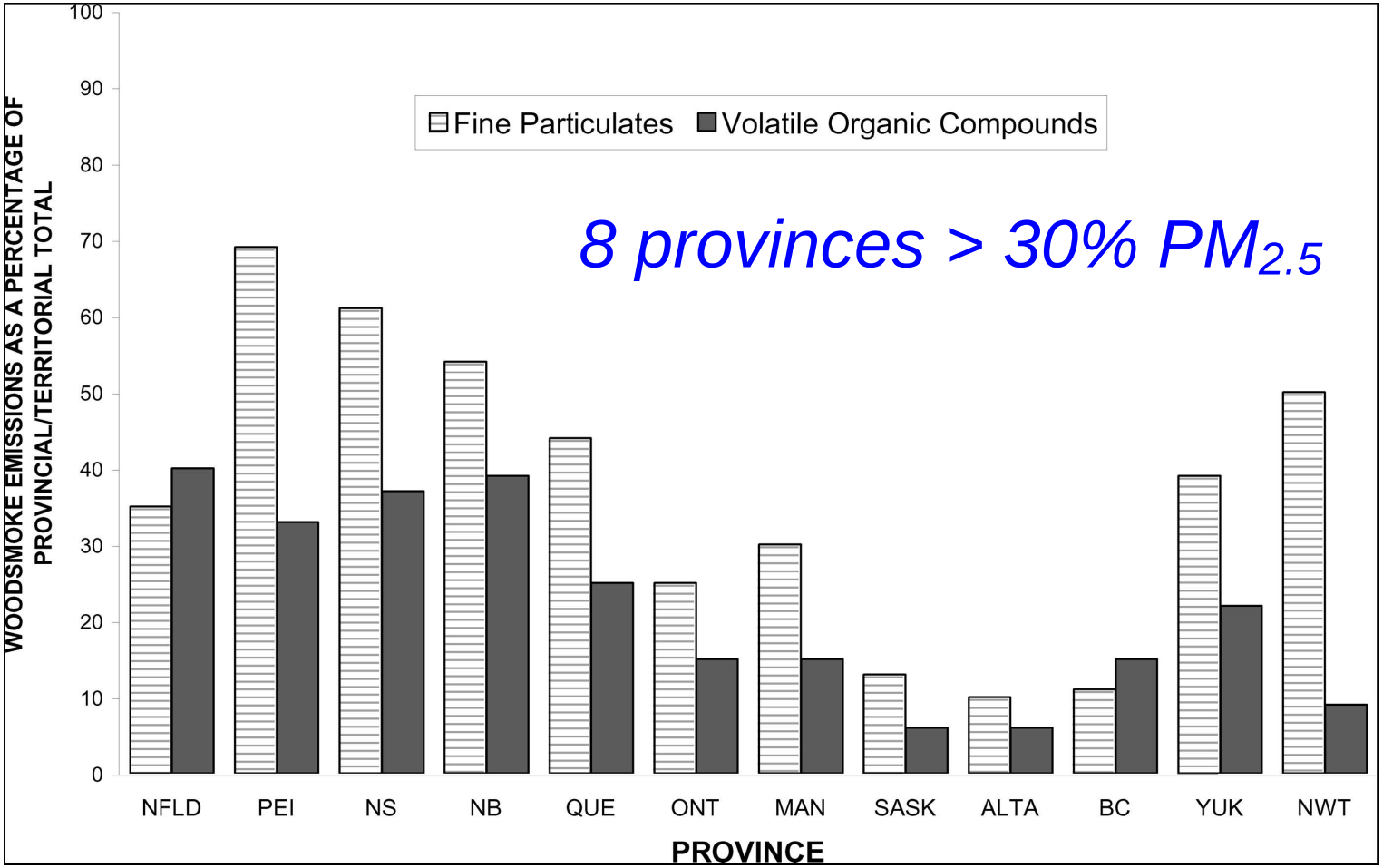
Monitoring

Studies in Northeast populated areas find RWC emissions can be chronic and severe (Sanborn et al. 1981, 1982; Sexton et al. 1984; Polissar et al. 2001; Johnson 2006)

A small number of wood burners can disproportionately affect a large fraction of a community relative to other fuel sources (Luhar 2006, Tasmania valley city: 45% of homes burn wood as main source of heat → 85% of city's PM10).

Recent studies in PNW: much of the exposure to outdoor particles can occur indoors. Indoor $PM_{2.5}$ ~20-80% of outdoor $PM_{2.5}$, depending on climate, building characteristics, and other factors (Abt et al. 2000; R Allen et al. 2003, 2004; Anuszewski et al. 1998; Dockery and Spengler 1981; Larson et al. 2004; Meng et al. 2005)

Importance of wood smoke emissions in Canada by province – emissions as a % of total provincial/territorial total



http://www.ec.gc.ca/science/sandejan99/article1_e.html

Complaints

- No “clearing house”– scattered across departments and localities
- People may just accept wood stove smoke and not bother to complain
- Frequency and severity of OWB neighbor vs. neighbor complaints have elevated issue

Northeast magnitude of exposure to RWC

Monitoring 

Terrain 

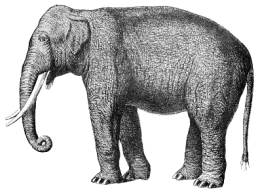
Meteorology 

Use 

Complaints 

Demography 

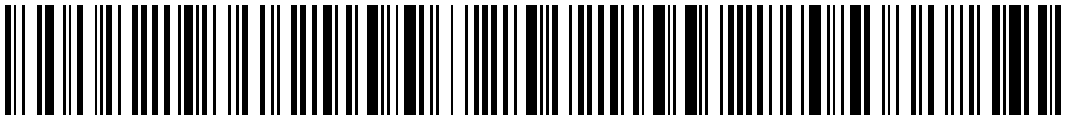
\+ Inventory 

= **Public health concern** 

Note to policy makers: remember real world factors

Forget about the porridge. I made Goldilocks stew.

Ingredients*



- Available fuel [a]
- Maintenance, operator control, fuel treatment [b]
- Civic harmony or discord [c]
- Topography and meteorology [d]
- Others…[e]

* Ingredient quantities typically vary depending upon intrinsic circumstances

a The *unknowable* unknowns? – consult a qualified epistemologist

b Can be subject to exceptionally wide and creative interpretation

c Consult your local enforcement officials or small town contacts for stories

d Can be conveniently ignored by typical Gaussian Plume-based models

e If time permits, ask audience for their own "secret ingredients" and favorite recipes

Conclusion

- Tox and epi studies conclusively show that wood-biomass smoke is dangerous to human health.
- Available evidence suggests the Northeast magnitude of exposure to wood smoke is likely significant and should not be underestimated. Exposure Assessment needed.
- Exposure scales are important to understand and quantify to inform regulatory decision making – micro-scale and area-spatial scales, acute and chronic time-scales.
- The majority of residential wood burners in use today are pre-1990 technology. OWBs with no emission controls are proliferating. Commercial biomass burning…. ?
- Perception of wood-biomass smoke as natural and benign can hinder promulgation of effective public health measures.

Thank you!

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