# Biomass Combustion, Exposures and Health Effects

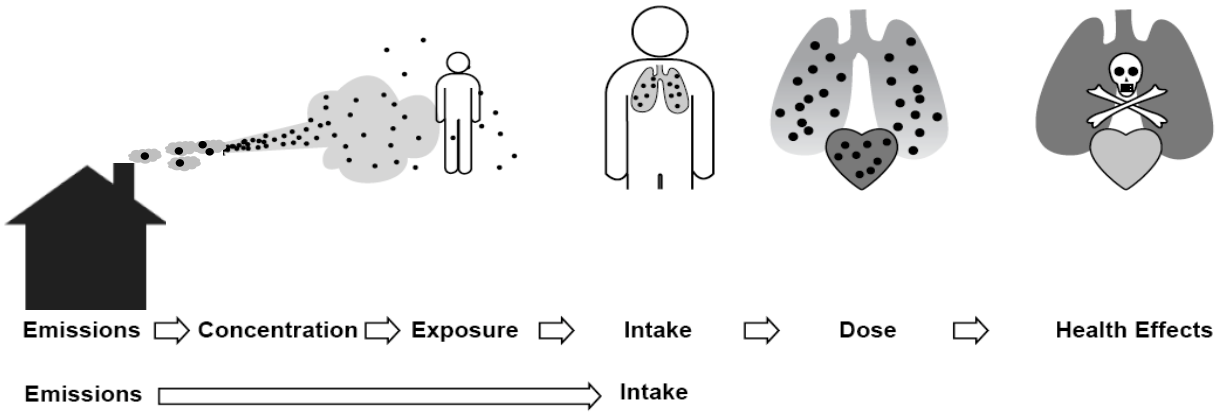
Michael Brauer

**WOOD BIOMASS FOR HEAT & POWER: ADDRESSING PUBLIC HEALTH IMPACTS**
**November 7, Massachusetts Medical Society, Waltham MA**

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

# Wood biomass in context

- Available, inexpensive, secure residential fuel
  - Increasing/fluctuating costs & taxes for other fuels
- Promoted as a renewable, GHG neutral fuel
- Relatively unregulated source
- Impact on winter air quality coinciding with stagnation
- Exposure proximity, high “intake fraction”




Ries F, Marshall J, Brauer M. Intake fraction of urban wood smoke. Environ Sci Technol, 2009 Jul 1;43(13):4701-6; Brauer M, Miller P, Allen G, Rector L. Modeling Pollution from Residential Wood Combustion. EM Magazine (Air and Waste Management Association). May, 2010. pp 24-28

POLICYFORUM

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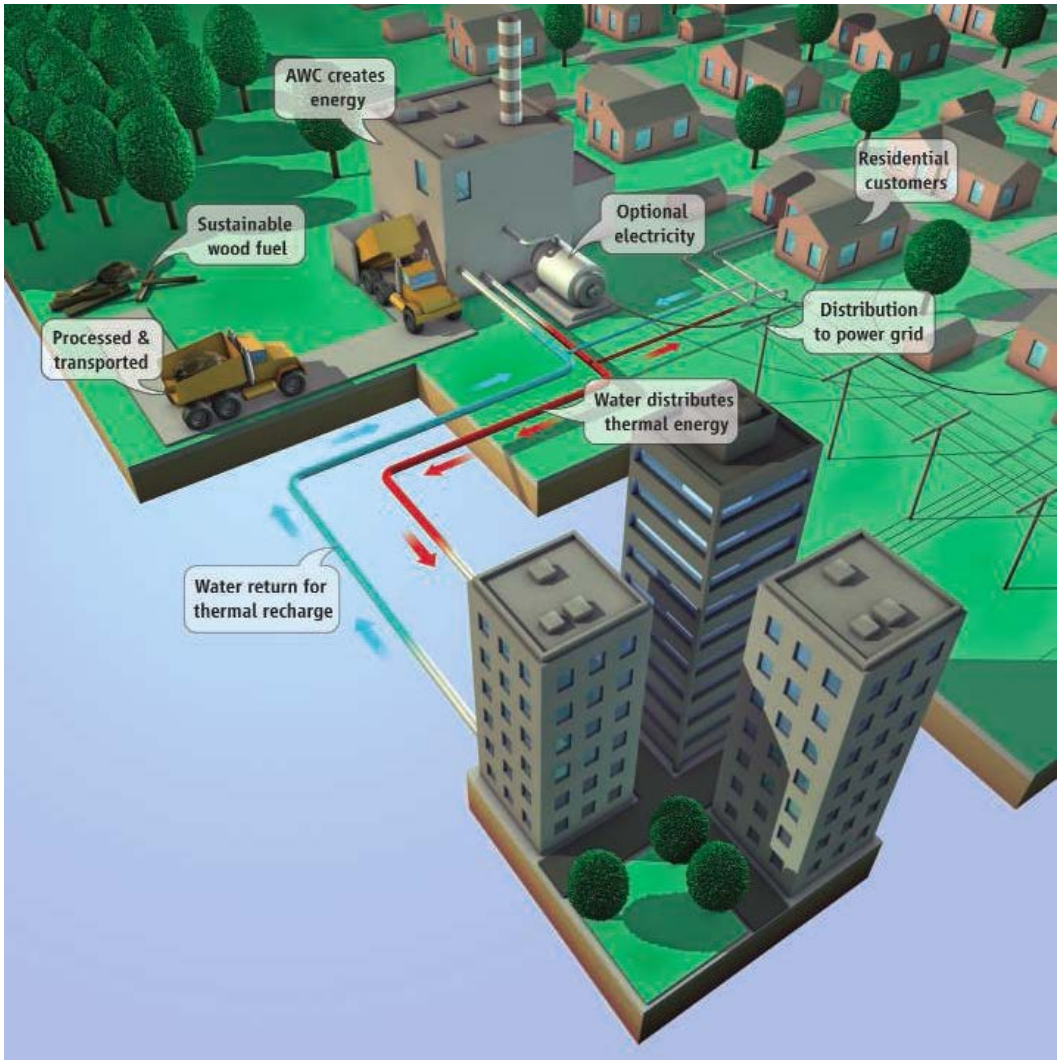
RESOURCE POLICY

# Wood Energy in America

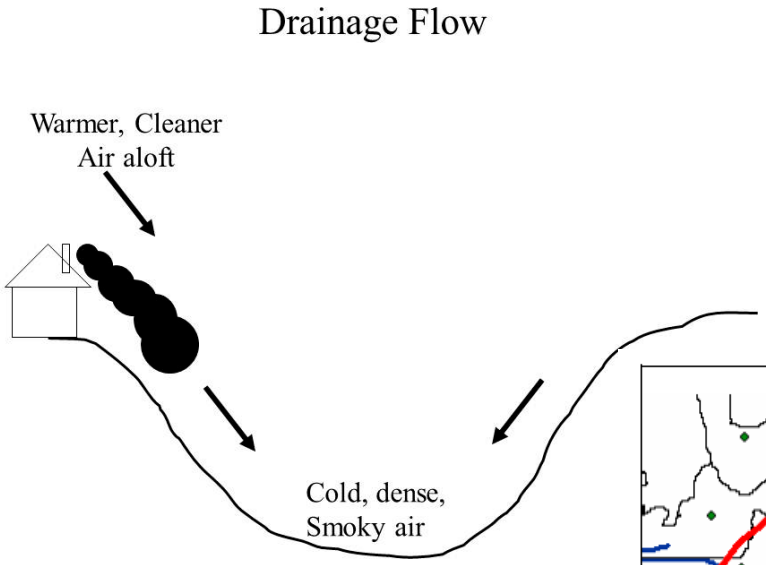
Daniel deB. Richter Jr.,[1]* Dylan H. Jenkins,[2] John T. Karakash,[3] Josiah Knight,[4] Lew R. McCreery,[5] Kasimir P. Nemestothy[6]

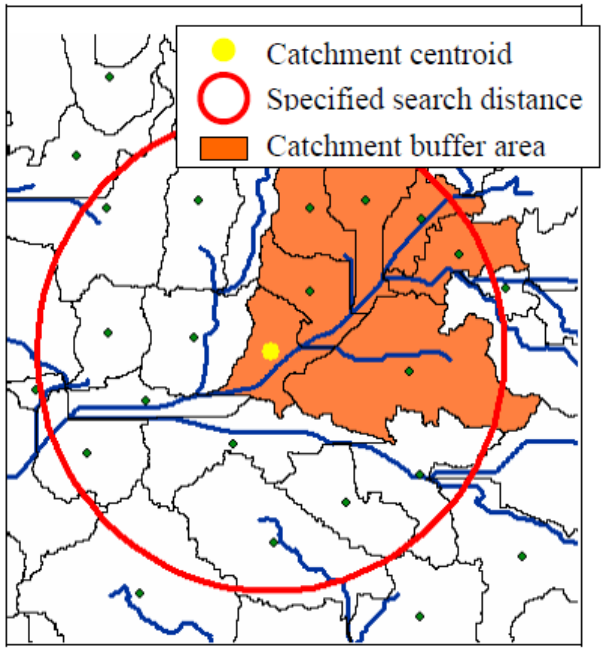
**Issues raised in response:**

- Is biomass really inexpensive?
  - more $ than oil, nat. gas
- Sufficient supply?
- Emissions of current technologies > emissions of oil, natural gas
  - need cleanest fuels/emissions controls when burned in populated areas and with distributed sources
- Carbon neutrality
  - Stock replacement
  - Black Carbon



# Spatial extent




For typical drainage wind speed (1 m/s) maintained over a 3 hour period, upslope influence ~ 10 km

Catchment modeling[1,2] suggests upslope influence of 4 – 8 km

Semivariogram analysis[3] suggests spatial extent of 2.7 km

[1]Larson T, Su J, Baribeau A-M, Buzzelli M, Setton E, Brauer M. A Spatial Model of Urban Winter Woodsmoke Concentrations. Environmental Science and Technology. 2007; 41 (7): 2429 -2436.
[2]Su JG, Allen GA, Miller PJ, Brauer M. Spatial modeling of residential woodsmoke across a non-urban upstate New York region. Air Quality, Atmosphere and Health, 2011 http://dx.doi.org/10.1007/s11869-011-0148-1
[3]Lightowlers, C et al. Determining the spatial scale for analysing mobile measurements of air pollution. Atmospheric Environment 42 (2008)

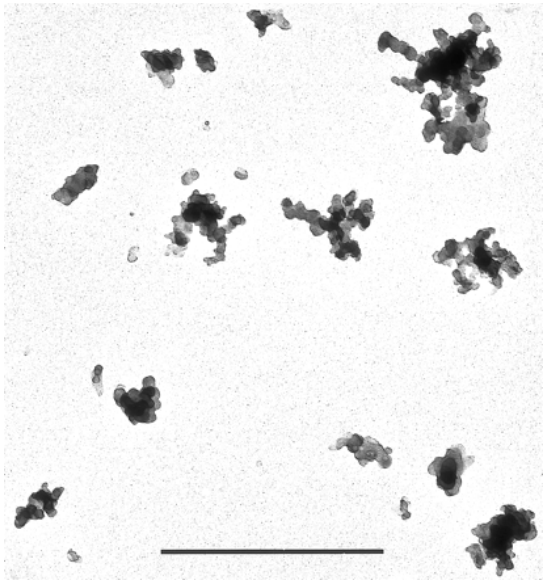
# Biomass smoke and health: evidence

- Constituents ($PM_{2.5}$, aldehydes, PAHs)
- Toxicology
- Controlled human exposures
- High concentration, chronic exposures – developing countries
- High concentration acute/sub-chronic exposures – wildland firefighters
- Firesmoke, agricultural burning
- **Residential woodsmoke**

# Do woodsmoke particles pose different levels of risk from other particles?

- **Respiratory disease: No**
- **Cardiovascular disease: ?**

Woodsmoke Particles



Bar = 1 µm = 1/1000 of 1mm

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## Woodsmoke Health Effects: A Review

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**The sentiment that woodsmoke, 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. Two of the principal gaseous pollutants in woodsmoke, CO and $NO_x$, add to the atmospheric levels of these regulated gases emitted by other combustion sources. Health impacts of exposures to these gases and some of the other woodsmoke constituents (e.g., benzene) are well characterized in thousands of publications. As these gases are indistinguishable no matter where they come from, there is no urgent need to examine their particular health implications in woodsmoke. With this as the backdrop, this review approaches the issue of why woodsmoke may be a special case requiring separate health evaluation through two questions. The first question we address is *whether woodsmoke should be regulated and/or managed separately*, even though some of its separate constituents are already regulated in many jurisdictions. The second question we address is *whether woodsmoke particles pose different levels of risk than other ambient particles of similar size*. To address these two key questions, we examine several topics: the chemical and physical nature of woodsmoke; the exposures and epidemiology of smoke from wildland fires and agricultural burning, and related**

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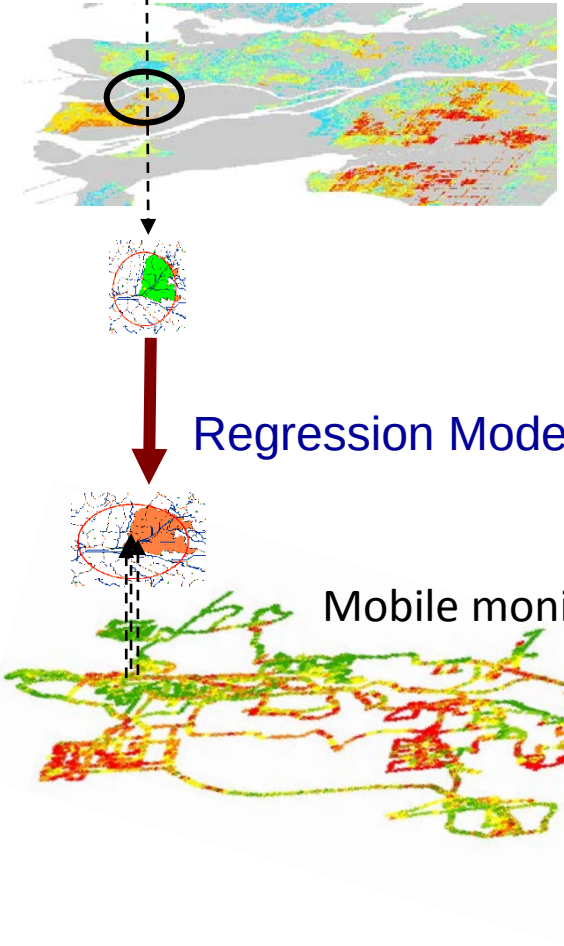
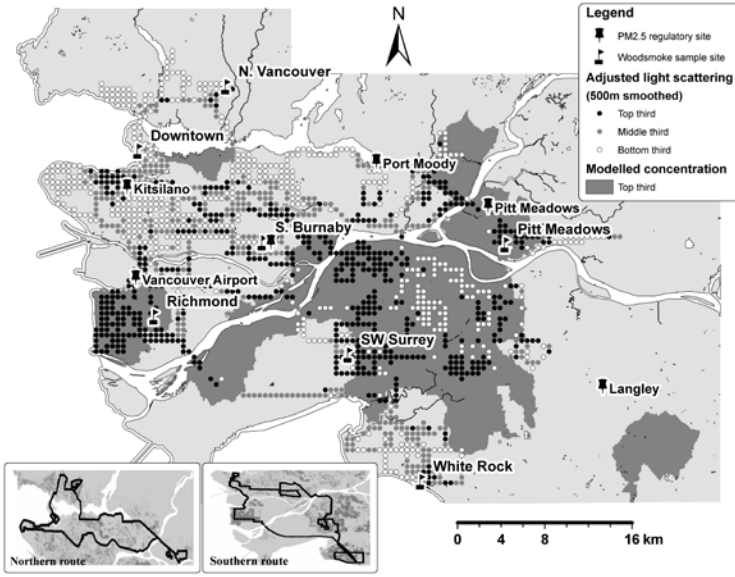
Naeher LP, Brauer M, Lipsett M, Zelikoff JT, Simpson CD, Koenig JQ, Smith KR. Woodsmoke health effects: A review. Inhal Toxicol. 2007 Jan;19(1):67-106.



Regression Model

Mobile monitoring ~12,000 points

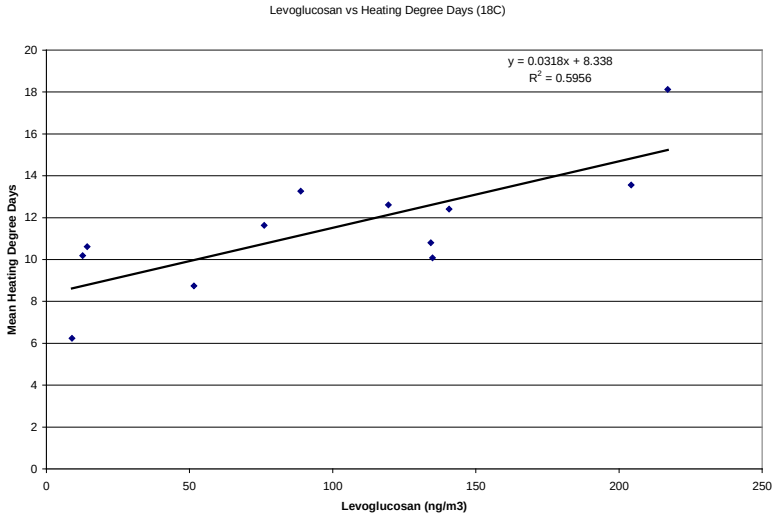
## Woodsmoke areas




## Woodsmoke nights

HDD > 12.0 ~ Levoglucosan > 115 ng/m$^3$

**~72 nights/year, ~5x increase in PM**




Larson T, Su J, Baribeau A-M, Buzzelli M, Setton E, Brauer M. A Spatial Model of Urban Winter Woodsmoke Concentrations. Environmental Science and Technology. 2007; 41 (7):2429 -2436

# Woodsmoke & multiple health measures

- 32% increase in middle ear infections**
  - Top reason for children < 2 yrs to see physician, be prescribed antibiotics
- 8% increase in bronchiolitis*
  - Top reason for children < 1 yr to be hospitalized
- No associations with:
  - low birthweight#
  - asthma *incidence*#
  - cardiovascular mortality#

** > traffic pollution, *~traffic, #<traffic

MacIntyre EA, Karr CJ, Demers P, Koehoorn M, Lencer C, Tamburic L, Brauer M. Exposure to residential air pollution and otitis media during the first two years of life. Epidemiology. 2011 Jan;22(1):81-9.; Karr CJ, Demer PA, Koehoorn MW, Lencar CC, Tamburic L, Brauer M. Influence of ambient air pollutant sources on clinical encounters for infant bronchiolitis. American Journal of Respiratory and Critical Care Medicine, 2009, 180(10):995-1001.; Clark NA, Demers P, Karr C, Koehoorn M, Lencar C, Tamburic L. Brauer M. Effect of early life exposure to air pollution on development of childhood asthma. Environmental Health Perspectives 2010, 188(2): 118:284-290.

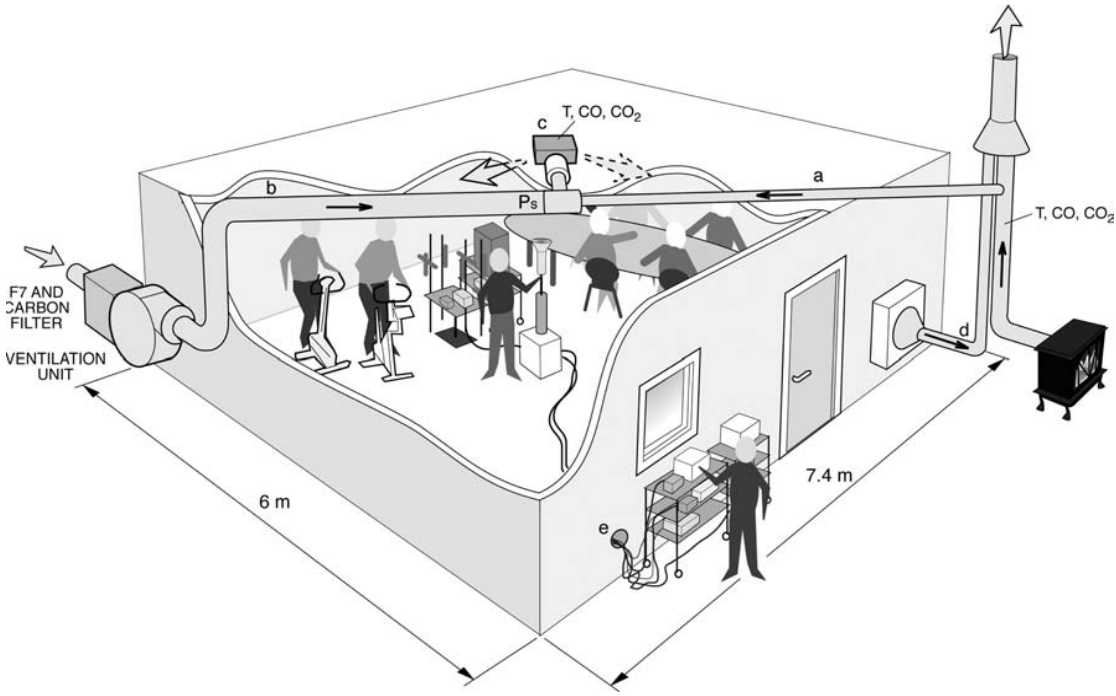
# Cardiovascular effects

- Community wildfire exposure (+/-):
  - mixed results for CVD association (mortality, cardiac arrest)
  - high bushfire exposures in Australia: (+)
- Wildland firefighters (+):
  - systemic inflammation
- Controlled exposures: (+/-):systemic inflammation

Swiston JR et al. Acute Pulmonary and Systemic Inflammatory Response Induced by Exposure to wood smoke. European Respiratory Journal, 2008; 32: 129-
Sallsten, G et al. Experimental wood smoke exposure in humans. *Inhal. Toxicol*. 18(11):855–864.; Barregard L et al. Experimental exposure to wood-smoke particles in healthy humans: effects on markers of inflammation, coagulation, and lipid peroxidation. Inhal Toxicol. 2006 Oct;18(11):845-53.; Barregard L et al. Experimental exposure to wood smoke: effects on airway inflammation and oxidative stress.. Occup Environ Med. 2008 May;65(5):319-24;
Allen RW, Carlsten C, Karlen B, Leckie S, van Eeden S, Vedal S, Wong I, Brauer M. An Air Filter Intervention Study of Oxidative Stress, Endothelial Dysfunction, and Inflammation Among Healthy Adults in a Woodsmoke-Impacted Community. American Journal of Respiratory and Critical Care Medicine, 2011. 183, 1222-1230.

# Controlled human exposure studies

- **Subjects exposed to realistic (high) concentrations (~250 $\mu g/m^3$) of woodsmoke for 4 hrs**
  - **Increases in measures of inflammation, oxidative stress post-exposure compared to clean air**




- **Pellet stove incomplete combustion**
  - **No inflammation**
  - **Early adaptive protective response**


Sallsten, G et al. Experimental wood smoke exposure in humans. *Inhal. Toxicol*. 18(11):855–864.; Barregard L et al. Experimental exposure to wood-smoke particles in healthy humans: effects on markers of inflammation, coagulation, and lipid peroxidation. Inhal Toxicol. 2006 Oct;18(11):845-53.; Danielsen PH et al. Oxidatively damaged DNA and its repair after experimental exposure to wood smoke in healthy humans.. Mutat Res. 2008 Jul 3;642(1-2):37-42.; Barregard L et al. Experimental exposure to wood smoke: effects on airway inflammation and oxidative stress.. Occup Environ Med. 2008 May;65(5):319-24.

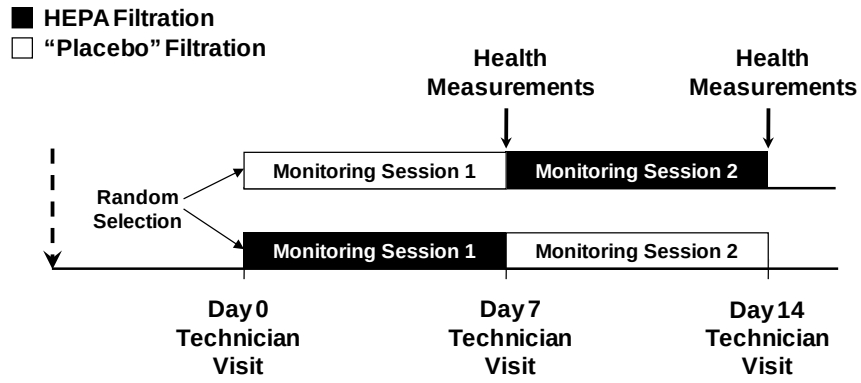


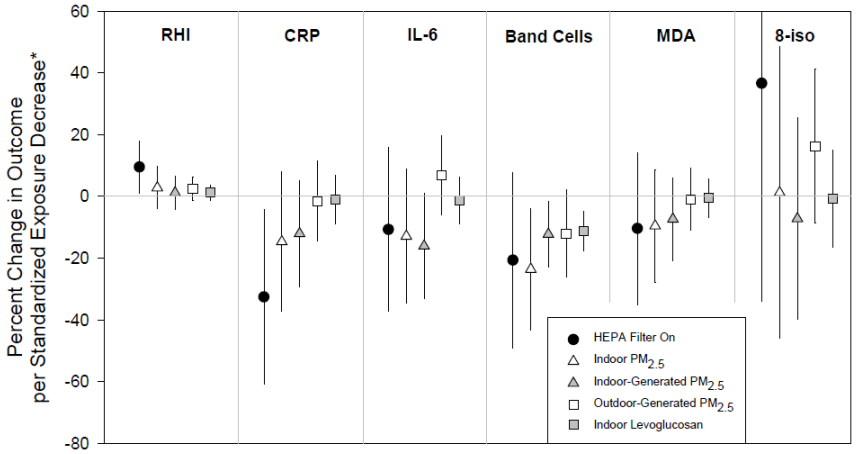


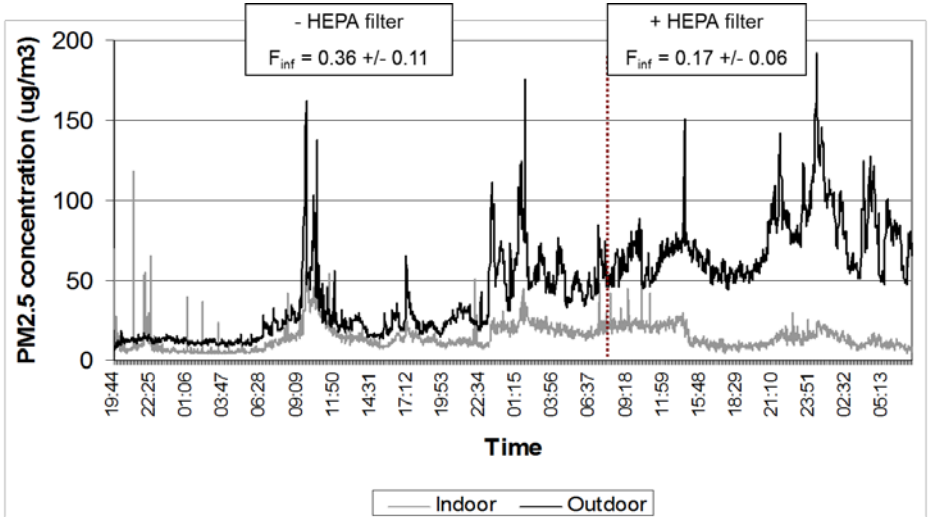
Sehlstedt, M., R. Dove, et al. (2010). "Antioxidant airway responses following experimental exposure to wood smoke in man." Particle and Fibre Toxicology 7(1): 21.

# What if you remove the woodsmoke?

- Portable HEPA filters 60% ↓ in indoor $PM_{2.5}$
- Increases in endothelial function and decreases in systemic inflammatory markers



11.2 → 4.6 ug/m$^3$ $PM_{2.5}$
127 → 33 ng/m$^3$ levoglucosan

Allen et al., AJRCCM 2011

# Towards healthier wood energy

- Location matters!!
  - Distributed sources – high intake fraction
  - Benchmark against natural gas to assess ($PM_{2.5}$) emissions and impacts
- Health impacts
  - Respiratory disease (+++)
  - Systemic inflammation (+)
  - Cardiovascular disease (+/-)
- Advanced technology
  - Lower mass emissions
  - Different composition → suggestions of lower toxicity