

Date: May 8, 2016
To: Board of Building Regulations and Standards
Re: 9th Edition of the Building Code
From: Doug Brugge, PhD, MS, Professor, Tufts University School of Medicine

1) Based on the evidence presented below, and considering that the international energy code will require mechanical ventilation in new housing, I would propose that the Massachusetts building code be amended to require MERV 13 or higher filtration in housing that is within 500 feet of highways (>50,000 vehicles/day) or within 100 feet of major roadways (>10,000 vehicles/day).

2) Long- and short-term exposures to air pollution, especially particulate matter <2.5 μm in aerodynamic diameter ($\text{PM}_{2.5}$), have been associated with cardiovascular morbidity and mortality worldwide (1–5). Evidence suggests that pollution exposures associated with traffic may be particularly harmful (6–21), which is a key issue as the US EPA estimates that 30 million Americans live within 300 m of a major roadway (22). In fact, living near major roadways and highways is a risk factor for many adverse health outcomes, including respiratory and cardiovascular disease. In 2008, for the California South Coast Air Basin, an estimated 1,300 coronary heart disease deaths were attributable to traffic density and 430 deaths due to residential proximity to a major road. Numbers of deaths are anticipated to increase due to population aging (23).

3) Ultrafine particles (UFP) are a component of PM that have an aerodynamic diameter of less than 0.1 micrometer. UFP is known to vary substantially within about 200 meters of busy roads (24-27). Short-term exposure to UFP is associated with changes in cardiovascular biomarkers of IHD risk (28-32). A longitudinal study of the association between long-term exposure to neighborhood-scale (1x1 km resolution) UFP and inflammatory and coagulation markers was recently reported (33). Urban scale (4x4 km resolution) UFP was also recently reported to be associated with cardiovascular mortality in another longitudinal study (34). Very recently, we have reported that UFP exposure near Interstate-93 in and near Boston is associated with higher levels of several blood biomarkers that indicate elevated inflammation and that predict greater risk of future cardiovascular disease (35, attached).

4) High-efficiency particulate air (HEPA) filtration has been shown to reduce PM concentrations as much as 70-80% (depending on particle size) using free standing filters in homes (36-37) and over 95% with filtration in mechanical systems in schools (38-41). In-home HEPA filtration has been found to improve asthma in children (42-43) and reduce a few, but not most, markers of cardiovascular risk in adults (44-45). We have recently completed two studies of HEPA filtration to reduce traffic-related UFP near interstate-93 in Boston. We showed that we could reduce UFP levels in near highway homes (46-47) and obtained some preliminary evidence for short term improvements in blood biomarkers of inflammation (not published).

5) The State of California has restricted the siting of schools within 500 feet of freeways (48), although there have been reports that schools continue to be built close to freeways (49). The City of Los Angeles has more recently approved a modification to their building code that requires MERV 13 filtration in mechanically ventilated buildings within 1000 feet of freeways (50). There has also been a program to install air filtration in schools in the South Coast Air Quality Management District in Southern California (51). Further, in our direct experience, it is possible to reduce UFP levels indoor relative to outdoors substantially by having MERV rated filters in mechanical ventilation systems combined with recirculation of air.

References

1. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*. 2012 Dec;380(9859):2224–60.
2. Hoek G, Krishnan RM, Beelen R, Peters A, Ostro B, Brunekreef B, et al. Long-term air pollution exposure and cardio- respiratory mortality: a review. *Environ Health*. 2013 May 28;12(1):43.
3. Brook RD, Rajagopalan S, Pope CA, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate Matter Air Pollution and Cardiovascular Disease An Update to the Scientific Statement From the American Heart Association. *Circulation*. 2010 Jun 1;121(21):2331–78.
4. Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation*. 2004 Jun 1;109(21):2655–71.
5. Pope CA, Dockery DW. Health effects of fine particulate air pollution: lines that connect. *J Air Waste Manag Assoc* 1995. 2006 Jun;56(6):709–42.
6. Laden F, Neas LM, Dockery DW, Schwartz J. Association of fine particulate matter from different sources with daily mortality in six U.S. cities. *Environ Health Perspect*. 2000 Oct;108(10):941–7.
7. Hart JE, Rimm EB, Rexrode KM, Laden F. Changes in traffic exposure and the risk of incident myocardial infarction and all-cause mortality. *Epidemiol Camb Mass*. 2013 Sep;24(5):734–42.
8. Hart JE, Chiuve SE, Laden F, Albert CM. Roadway Proximity and Risk of Sudden Cardiac Death in Women. *Circulation*. 2014 Oct 13;CIRCULATIONAHA.114.011489.
9. Jerrett M, Finkelstein MM, Brook JR, Arain MA, Kanaroglou P, Stieb DM, et al. A cohort study of traffic-related air pollution and mortality in Toronto, Ontario, Canada. *Environ Health Perspect*. 2009 May;117(5):772–7.
10. Beelen R, Hoek G, Houthuijs D, van den Brandt PA, Goldbohm RA, Fischer P, et al. The joint association of air pollution and noise from road traffic with cardiovascular mortality in a cohort study. *Occup Environ Med*. 2009 Apr;66(4):243–50.
11. Hoffmann B, Moebus S, Dragano N, Möhlenkamp S, Memmesheimer M, Erbel R, et al. Residential traffic exposure and coronary heart disease: results from the Heinz Nixdorf Recall Study. *Biomark Biochem Indic Expo Response Susceptibility Chem*. 2009 Jul;14 Suppl 1:74–8.
12. Raaschou-Nielsen O, Andersen ZJ, Jensen SS, Ketzel M, Sørensen M, Hansen J, et al. Traffic air pollution and mortality from cardiovascular disease and all causes: a Danish cohort study. *Environ Health*. 2012 Sep 5;11(1):60.
13. Adar SD, Kaufman JD. Cardiovascular disease and air pollutants: evaluating and improving epidemiological data implicating traffic exposure. *Inhal Toxicol*. 2007;19 Suppl 1:135–49.
14. Allen RW, Criqui MH, Diez Roux AV, Allison M, Shea S, Detrano R, et al. Fine particulate matter air pollution, proximity to traffic, and aortic atherosclerosis. *Epidemiol Camb Mass*. 2009 Mar;20(2):254–64.
15. Kan H, Heiss G, Rose KM, Whitsett EA, Lurmann F, London SJ. Prospective Analysis of Traffic Exposure as a Risk Factor for Incident Coronary Heart Disease: The Atherosclerosis Risk in Communities (ARIC) Study. *Environ Health Perspect*. 2008 Nov;116(11):1463–8.
16. Tonne C, Melly S, Mittleman M, Coull B, Goldberg R, Schwartz J. A case-control analysis of exposure to traffic and acute myocardial infarction. *Environ Health Perspect*. 2007 Jan;115(1):53–7.
17. Gehring U, Cyrus J, Sedlmeir G, Brunekreef B, Bellander T, Fischer P, et al. Traffic-related air pollution and respiratory health during the first 2 yrs of life. *Eur Respir J*. 2002 Apr;19(4):690–8.
18. Rosenlund M, Bellander T, Nordquist T, Alfredsson L. Traffic-generated air pollution and myocardial infarction. *Epidemiol Camb Mass*. 2009 Mar;20(2):265–71.

19. Rosenlund M, Picciotto S, Forastiere F, Stafoggia M, Perucci CA. Traffic-Related Air Pollution in Relation to Incidence and Prognosis of Coronary Heart Disease: *Epidemiology*. 2008 Jan;19(1):121–8.
20. Nafstad P, Håheim LL, Wisløff T, Gram F, Oftedal B, Holme I, et al. Urban air pollution and mortality in a cohort of Norwegian men. *Environ Health Perspect*. 2004 Apr;112(5):610–5.
21. Gan WQ, Tamburic L, Davies HW, Demers PA, Koehoorn M, Brauer M. Changes in residential proximity to road traffic and the risk of death from coronary heart disease. *Epidemiol Camb Mass*. 2010 Sep;21(5):642–9.
22. U.S. Environmental Protection Agency Office of Transportation and Air Quality (OTAQ). Near roadway air pollution and health. Washington, D.C. 2-14 [Internet]. Available from: <http://www.epa.gov/otaq/nearroadway.htm>
23. Ghosh R, Lurmann F, Perez L, Penfold B, Brandt S, Wilson J, et al. Near-Roadway Air Pollution and Coronary Heart Disease: Burden of Disease and Potential Impact of a Greenhouse Gas Reduction Strategy in Southern California. *Environ Health Perspect* [Internet]. 2015 Jul 7 [cited 2016 Jan 8]; Available from: <http://ehp.niehs.nih.gov/1408865>
24. Karner AA, Eisinger DS, Niemeier DA. Near-roadway air quality: synthesizing the findings from real-world data. *Environ Sci Technol*. 2010;44:5334-5344.
25. Durant JL, Ash CA, Wood EC, Herndon SC, Jayne JT, Knighton WB, Canagaratna MR, Trull JB, Brugge D, Zamore W, Kolb CE. Short-term variation in near-highway air pollutant gradients on a winter morning. *Atmos Chem Phys*. 2010;10:8341-8352.
26. Padró-Martínez LT, Patton AP, Trull JB, Zamore W, Brugge D, Durant JL. Mobile monitoring of particle number concentration and other traffic-related air pollutants in a near-highway neighborhood over the course of a year. *Atmos Environ*. 2012;61:253-264.
27. Patton AP, Perkins J, Zamore W, Levy JI, Brugge D, Durant JL. Spatial and temporal differences in traffic-related air pollution in three urban neighborhoods near an interstate highway. *Atmos Environ*. 2014;99:309-321.
28. Delfino RJ, Staimer N, Tjoa T, Gillen DL, Polidori A, Arhami M, Kleinman MT, Vaziri ND, Longhurst J, Sioutas C. Air pollution exposures and circulating biomarkers of effect in a susceptible population: clues to potential causal component mixtures and mechanisms. *Environ Health Perspect*. 2009;117:1232.
29. Hertel S, Viehmann A, Moebus S, Mann K, Bröcker-Preuss M, Möhlenkamp S, Nonnemacher M, Erbel R, Jakobs H, Memmesheimer M, Jöckel KH. Influence of short-term exposure to ultrafine and fine particles on systemic inflammation. *Eur J Epidemiol*. 2010;25:581-592.
30. Fuller CH, Williams PL, Mittleman MA, Patton AP, Spengler JD, Brugge D. Response of biomarkers of inflammation and coagulation to short-term changes in central site, local, and predicted particle number concentrations. *Ann Epidemiol*. 2015;25:505-511.
31. Chung M, Wang DD, Rizzo AM, Gachette D, Delnord M, Parambi R, Kang CM, Brugge D. Association of PNC, BC, and PM_{2.5} measured at a central monitoring site with blood pressure in a predominantly near highway population. *Int J Environ Res Publ Health*. 2015;12:2765-2780.
32. Samet JM, Rappold A, Graff D, Cascio WE, Berntsen JH, Huang YC, Herbst M, Bassett M, Montilla T, Hazucha MJ, Bromberg PA. Concentrated ambient ultrafine particle exposure induces cardiac changes in young healthy volunteers. *Am J Respir Crit Care Med*. 2009;179:1034-1042.
33. Viehmann A, Hertel S, Fuks K, Eisele L, Moebus S, Möhlenkamp S, Nonnemacher M, Jakobs H, Erbel R, Jöckel KH, Hoffmann B. Long-term residential exposure to urban air pollution, and repeated measures of systemic blood markers of inflammation and coagulation. *Occup Environ Med*. 2015:oemed-2014.
34. Ostro B, Hu J, Goldberg D, Reynolds P, Hertz A, Bernstein L, Kleeman MJ. Associations of mortality with long-term exposures to fine and ultrafine particles, species and sources: results from the California teachers study cohort. *Environ Health Perspect*. 2015;123:549.

35. Lane KJ, Levy JI, Peters JL, Scammell MK, Peters JL, Patton AP, Reisner E, Lowe L, Zamore W, Durant JL, Brugge D (2016). Association of long term individualized exposure to ultrafine particle with biomarkers of inflammation and coagulation. *Environ Int.* 2016;92-93:173-182.
36. Du L, Batterman S, Parker E, Godwin C, Chin J-Y, O'Toole A, et al. Particle Concentrations and Effectiveness of Free-Standing Air Filters in Bedrooms of Children with Asthma in Detroit, Michigan. *Build Environ.* 2011 Oct;46(11):2303-13.
37. Batterman S, Godwin C, Jia C. Long duration tests of room air filters in cigarette smokers' homes. *Environ Sci Technol.* 2005 Sep 15;39(18):7260-8.
38. Polidori A, Fine PM, White V, Kwon PS. Pilot study of high-performance air filtration for classroom applications. *Indoor Air.* 2013 Jun;23(3):185-95.
39. Stephens B, Siegel JA. Ultrafine particle removal by residential heating, ventilating, and air-conditioning filters. *Indoor Air.* 2013 Dec 1;23(6):488-97.
40. Brown SG, McCarthy MC, DeWinter JL, Vaughn DL, Roberts PT. Changes in air quality at near-roadway schools after a major freeway expansion in Las Vegas, Nevada. *J Air Waste Manag Assoc* 1995. 2014 Sep;64(9):1003-12.
41. McCarthy MC, Ludwig JF, Brown SG, Vaughn DL, Roberts PT. Filtration effectiveness of HVAC systems at near-roadway schools. *Indoor Air.* 2013 Jun;23(3):196-207.
42. Ying Xu SR. Effectiveness of heating, ventilation and air conditioning system with HEPA filter unit on indoor air quality and asthmatic children's health. *Build Environ.* 2010;(2):330-7.
43. Lanphear BP, Hornung RW, Khoury J, Yolton K, Lierl M, Kalkbrenner A. Effects of HEPA Air Cleaners on Unscheduled Asthma Visits and Asthma Symptoms for Children Exposed to Secondhand Tobacco Smoke. *Pediatrics.* 2011 Jan;127(1):93-101.
44. Allen RW, Carlsten C, Karlen B, Leckie S, van Eeden S, Vedal S, et al. An air filter intervention study of endothelial function among healthy adults in a woodsmoke-impacted community. *Am J Respir Crit Care Med.* 2011 May 1;183(9):1222-30.
45. Brauner EV, Forchhammer L, Moller P, Barregard L, Gunnarsen L, Afshari A, et al. Indoor particles affect vascular function in the aged - An air filtration-based intervention study. *Am J Respir Crit Care Med.* 2008;177(4):419-25.
46. Padró-Martínez LT, Owusu E, Reisner E, Zamore W, Simon MC, Brown CA, Chung M, Mwamburi M, Brugge D, Durant JL. A randomized cross-over air filtration intervention trial for reducing cardiovascular health risks in residents of public housing near a highway, *International Journal of Environmental Research and Public Health*, 2015, 12: 7814-7838.
47. Rivera S, Byrne M, Chung M, Karkhanehchi M, Simon M, Durant J, et al. An In- Home High Efficiency Particulate Arrestance Filtration Intervention for Ultrafine Particles. ISEE 2015, 27th Conference of the International Society for Environmental Epidemiology; 2015 Sep 30; Sao Paulo, Brazil.
48. http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200320040SB352
49. <http://articles.latimes.com/2007/sep/24/local/me-freeways24>
50. Barbosa T. L.A. city council adopts rules to ease health hazards in polluted neighborhoods. *Los Angeles Times*, April 13, 2016.
51. <http://www.aqmd.gov/home/library/public-information/2015-news-archives/murchinson-street-elementary-pr>