Energy Implications of Residential Particle Control Technologies

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1 Introduction

The health implications of exposure to particles are serious and particulate matter is a ubiquitous indoor air pollutant. There are a variety of investigations of air cleaning efficiency and effectiveness for different types of air cleaners available in the literature, but relatively little information on the energy implications of different strategies. The goal of this extended abstract is to explore the energy used by different particle control strategies.

2 Methods

Four different particle control strategies were compared: portable HEPA filters, minimum efficiency reporting value (MERV) 11 filters (ASHRAE, 2007) in central heating and cooling systems, central mechanical ventilation, and spot ventilation associated with a rangehood fan. The literature was reviewed to provide values of energy use for each of these strategies. All data was reduced to consistent values of volumetric flow rate (m^3/hr) of particle-free air per unit of power draw (W). Critical assumptions for each control strategy are discussed below.

Portable HEPA filters are widely available and are often rated with a clean air delivery rate (CADR), the volumetric flow of clean air delivered by the air cleaner. There have been several studies that include both power and CADR measurements for HEPA filters, (e.g., Offermann et al., 1985; Waring et al., 2008). CADR is generally weakly particle-size dependent and different investigations have studied different particle sizes. Where possible, CADR values for 1 µm particles are used.

The analysis of HVAC filter energy use is complicated by several factors, mainly the diversity of HVAC equipment and filters that are in use, as well as installation and field performance issues. For the purposes of this assessment, the assumed central filter is a gasketed MERV 11 filter that has an efficiency for 1 µm particles of 75%. Central residential fan efficiencies came from Stephens et al. (2010) and Parker and Proctor (2002).

The energy consequences of ventilation are strongly dependent on outdoor conditions and the efficiency of conditioning equipment. For the purposes of this analysis, two heating conditions (indoor to outdoor temperature differences (Δt) of 20 ºC and 40 ºC), two cooling conditions (Δt = 10 ºC and 20 ºC), and a typical residential air conditioner coefficient of performance of 300% (Stephens et al., 2010) and typical residential heating system efficiency of 80%. Outdoor air is assumed to be free of particles. Only energy required to condition the air is included.

Cooking is one of the most serious indoor particle sources and many homes have rangehood fans that exhaust air from the stove top to the outdoors. There is a wide diversity of rangehood design and installation and there have been relatively few investigations the report flow rate, efficacy, and power draw. Typical values for a well-functioning fan from Singer et al. (2010) were used here. Similar to centralized ventilation, outdoor air is assumed to be free of particles and at a variety of temperatures. For purposes of comparison, capture efficiency and conditioning energy are not included.

3 Results

Table 1 summarizes power draw per unit of clean air delivered for each strategy. If multiple data sources were available, the range of values available in the literature is reported.

The results suggest that an energy efficient portable HEPA filter is the most efficient particle control technology, followed by typical central heating and cooling systems with a MERV 11 filter, followed by a rangehood ventilation fan, with central ventilation being the least efficient, particularly for cold climates. Of course these findings are strongly dependent on the assumptions for these calculations. The central assumptions and their impact on the results are discussed below for each technology.

Table 1. Format requirements for paper size.

Control Strategy	Energy Efficacy (m^3/W)
Portable HEPA filter	1.0 – 4.6
MERV 11 filter	2.3 – 2.5
Vent. cooling, 10 ºC	0.90
Vent. cooling, 20 ºC	0.45
Vent. heating, 20 ºC	0.12
Vent. heating, 40 ºC	0.06
Vent. rangehood	0.34 -1.9

Relatively few assumptions were made about portable HEPA filters, but the results are clearly strongly dependent on the particular filter used. Offermann et al. (1985) tested a very energy efficient filter, and one of the HEPA filters in Waring et al. (2008) was over four times less efficient. Portable HEPA air cleaners have the advantages of being able to be targeted at sources or near sensitive individuals and have several disadvantages including noise and inconsistent occupant use.

The results for central filtration span a much smaller range, but the assumption of a MERV 11 filter is critical. A much more common MERV 2 filter has a removal efficiency of less than 5% for 1 µm particles and consequently would have an energy efficacy 15 times lower than the value in Table 1. The impact of pressure drop was also neglected, but this has a firm basis in recent literature (Stephens et al., 2010). Any central system is likely to have diminished real effectiveness because of short runtimes (Stephens et al., 2010), the impacts of duct air leakage, and because of localized particle sources.

Central ventilation, especially in extreme climates, is clearly the least energy efficient approach, even if outdoor air is assumed to be free from particles. Central ventilation also suffers from many of disadvantages of central filtration including the issues of short run-times and duct leakage.

The rangehood exhaust fan is considerably more efficient and can be targeted at an important particle source. However, including capture efficiencies, particularly for certain types of rangehood fans, diminishes the values in Table 1 by a factor of three or more.

4 Conclusions

An energy efficient particle control strategy for a residential building likely involves efficient portable HEPA filters for sources and/or sensitive individuals, as well as a reasonable central filter that can provide additional protection. Ventilation is generally not an energy efficient strategy for particle control, especially in more extreme climates but spot ventilation near particle sources can be competitive with other considered strategies. The energy consequences of particle removal could be diminished with the widespread use of more efficient fans in all of the considered applications.

5 References

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