Advanced Technologies for High Performance Laboratory Fume Hoods

Scoping Report

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Summary

Laboratory ventilation systems with fume hoods use large amounts of source energy to move, heat, and cool air. High performance hood technologies can substantially reduce this energy use. With an ultimate 75% national market penetration rate, we estimate that these hoods have an annual source technical potential of approximately 180 TBtu, which translates to about $1.5 billion annually.

This report provides information to support the need for field demonstrations that evaluate the performance, energy savings, and economic benefits persistence of high performance fume hoods relative to conventional hoods and to design intent. Five candidate sites with a wide diversity and large number of laboratory fume hoods have expressed strong interest to participate in our demonstrations. These sites include: Cornell University, Harvard University, Michigan State University, Princeton University, and the U.S. Environmental Protection Agency. We anticipate that the broad dissemination of demonstration results will showcase the energy savings provided by high performance fume hoods and help DOE develop a business case to promote more widespread use of such products.

Introduction

Fume hoods are safety devices intended to minimize worker exposure to harmful contaminants. Because large volumes of conditioned air are exhausted to remove the contaminants, hoods are often the most energy intensive technologies in laboratories. High-performance hoods are of interest because they can reduce the volume of conditioned air exhausted and, as described later in this report, have an annual source technical potential of approximately 180 TBtu (assuming an ultimate market penetration rate of 75%). End-users are not currently adopting these technologies widely enough, however, because of uncertainty about returns on investment and concerns about increased maintenance effort and associated reduced reliability.

The purpose of this field demonstration project is to evaluate energy saving and economic benefit persistence for high-performance hoods relative to design intent and also relative to conventional hoods. It will also assess relative differences, if any, regarding maintenance effort and associated reliability concerns. Our focus is on benchtop fume hoods in U.S. chemical laboratories, because these are likely the most commonly used types. By participating in the demonstrations, test sites can showcase the benefits provided by energy-efficient hoods and help DOE develop a business case to promote more widespread use of such products.

The project has three phases. Phase 1 has produced this scoping report, which summarizes current technologies and what we plan to demonstrate, characterizes the target market and estimates the energy and cost savings potential, and identifies candidate demonstration sites and their available technologies. This phase serves as a stage gate for a go/no-go decision for the remaining two phases.

Phase 2 of the project will involve field testing a variety of hoods at the candidate sites. This testing will collect data to assess the energy savings persistence, performance, and reliability of high performance hoods as installed and operated. Key aspects for the demonstration include:

- Determining a protocol and plan for measuring fume hood face velocity, airflows, sash position, and whether the hood is in use.
- Determining a protocol and plan for measuring energy use attributable to fume hood airflow – including fan energy as well as thermal conditioning.
- Documenting lab room characteristics that affect fume hood airflow – including number and types of hoods, applicable codes, supply and return air configuration, and room floor area and volume.

- Documenting system characteristics that affect fume hood airflow, such as the control sequence of operations.
- Surveying lab managers and facilities personnel regarding hood maintenance and reliability. When available, hood testing and commissioning reports will be analyzed to complement surveys.

Phase 3 of the project will involve analyses of field data and presenting the results, conclusions, and recommendations first in a final report and then in other dissemination vehicles. The report will include the technical approach, including test plans and measurement protocols; a description of each demonstration site and its context; detailed technical results of the demonstrations, including energy savings, performance, and reliability of technologies; economic results, including first cost and return on investment (ROI); and non-economic barriers and potential approaches to overcome them. Additionally, we will prepare an executive briefing of the project results, as well as fact sheets for wider dissemination. Results also will be disseminated through the International Institute for Sustainable Laboratories, Lab R&D magazine, Tradeline, and similar stakeholder organizations.

Current Technology Overview and Hoods of Interest

Fume hoods are local ventilation units designed to capture and exhaust hazardous gases. The hood itself is a box-like structure that typically is open on one side with a moveable vertical- or horizontal-sliding sash for access. As Figure 1 shows, hoods are connected to one or more exhaust system fans, which continuously depressurize the hood interior and in turn cause air to enter through the sash opening to remove contaminants generated within the hood. Makeup air is supplied by a separate air-handling system that uses another fan to draw in outdoor air to replace the exhausted air. The supply air is filtered and then heated or cooled (and reheated as needed) to maintain comfortable working conditions within the laboratory working space and to maintain working space pressure relative to surrounding spaces. Although not shown in Figure 1, general room exhaust is used to remove any contaminants that may be in the working space itself and to maintain negative pressure when hood flows are too low relative to the air supplied for space conditioning needs unrelated to hood exhaust.

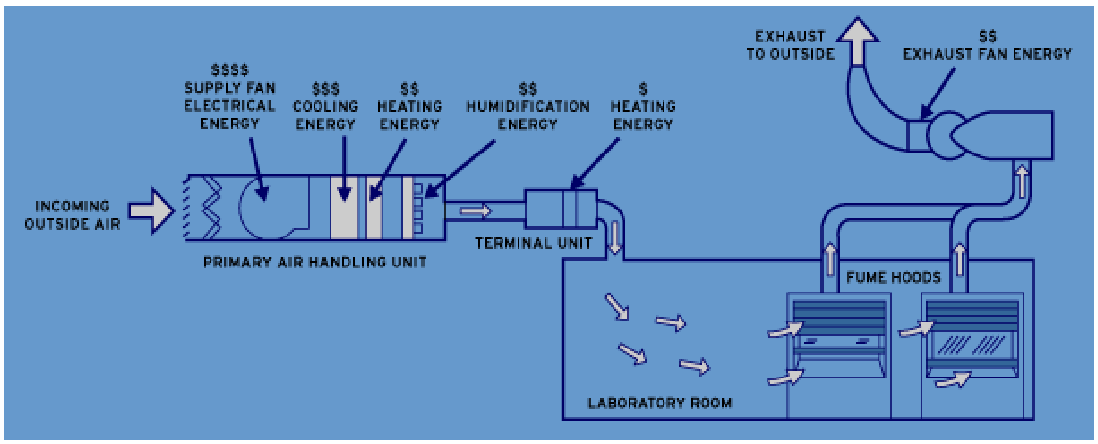

Figure 1: Schematic diagram of laboratory ventilation system. Source: LBNL (2012)

There are two principal types of conventional fume hoods used in chemical laboratories: constant air volume (CAV) and variable air volume (VAV).

- CAV hoods exhaust a constant amount of air regardless of whether the sash is closed or open. In this case, the face velocity through the sash opening increases as the sash is closed (sometimes to the point where it can disturb or damage hood contents, LabConco 1997). To avoid this problem, some of these hoods use a bypass opening above the sash that is uncovered as the sash is closed as well as a fixed opening at the sill, which together allow these hoods to maintain a more constant face velocity (SEFA 2006). Because flow is constant in either case, the air-handling system (exhaust and supply) is relatively simple and inexpensive.

- For the same maximum sash opening area and for a given face velocity, both VAV and CAV hoods have the same flow and energy use. VAV hoods, however, can save energy by automatically reducing the exhaust flow while maintaining a constant face velocity as the sash opening is reduced (or closed). Variable-position dampers and/or variable speed drives are used to control the exhaust system pressures and flows. Because the exhaust flow varies, a VAV supply airflow system is also needed to maintain space pressure relationships, which in turn results in a more complicated and costly system that potentially requires more maintenance. Sizing such systems is also more difficult because hood opening diversity must be included (i.e., the number of hoods open at any given time must be addressed). A particularly significant problem with conventional VAV hoods is that they rely on users to manually close the sash when they finish using the hood. Most hoods are “occupied” (i.e., in use by lab personnel) only a few hours each day (PGE 2007) and in many cases users do not close the sash when the hood is not in use (May 2012). In such cases, VAV hoods do not save energy.

The generally accepted average face velocity for fully-open conventional hoods is 100 ft/min (fpm, Bell et al. 2002). Some hoods have fully-open face velocities much higher than this (e.g., factor of two), even though higher velocities can result in eddies around workers that in turn lead to hood spillage into the breathing zone. For a common 62 inch wide sash that is open 29 inches, the flow corresponding to a 100 fpm face velocity is about 1250 cfm.

High performance constant volume hoods can use fully-open face velocities as low as 60 fpm to maintain or even reduce worker exposure to hazardous contaminants. They are configured to reduce sash opening turbulence and optimize internal airflow patterns to prevent contaminants from spilling out of the hood into the working space. From an energy standpoint, reducing hood face velocity is important because, for a given sash opening area, a lower velocity translates to a lower exhaust airflow, which in turn reduces associated fan power and supply air thermal conditioning.

Newer constant volume hoods and some retrofit kits for existing hoods use aerodynamically superior sash sills and handles to improve inlet flow conditions, and adjustable baffle designs to improve internal flow distributions. Automated sash closure or two-state (high/low flow) control technologies help to minimize exhaust flows when hoods are not in use by respectively reducing sash opening area over time or by directly reducing flow. In the latter case, face velocity is maintained at a low value (e.g., 60 fpm) when the hood is “unoccupied”, and is then raised (e.g., to 100 fpm) when the hood is “occupied”. The two-state type has the benefit that even if the sash is left open when the hood is unoccupied, flow is reduced and energy is saved. In some installations, room occupancy sensing is used instead of individual hood occupancy sensing.

This project will focus on field demonstrations of three underutilized high performance hood technologies relative to two widely used conventional ones:

Conventional hoods:
- High-flow constant volume (100 fpm or greater face velocity)
- Variable air volume with manual sashes

High performance hoods:
- Low flow constant volume (60 to 80 fpm face velocity)
- Low flow constant volume retrofit kits (60 to 80 fpm face velocity)
- Variable air volume with automated sash closure or
  two state (high/low flow) control based on occupancy sensing

As described later in this report, we have identified five candidate sites with hundreds of fume hoods that are interested in participating in field demonstrations of these hood types.

Preliminary Market Characterization

The principal stakeholders in the target fume hood market are owners and operators of university, private and public research, and industrial laboratories, particularly those who make decisions about purchasing, installing, operating, and maintaining high performance hoods. Other stakeholders include hood users and high-performance fume hood vendors as well as vendors of supporting services such as commissioning agents.

According to Bell et al. (2002), existing estimates of the hood population vary widely. They estimated that between 500,000 and 1,000,000 fume hoods are installed in labs, based in part on interviews of industry experts conducted on behalf of the Labs21 project (excludes an "outlier" estimate of 1.5 million). The only other published estimate that we identified indicated that there were more than 1 million units in 1989 (Monsen 1989). Based on these data, we have conservatively chosen a central estimate of 750,000 hoods for the purposes of estimating energy use and potential savings.

Lab Manager (2011, 2012) recently conducted a survey involving 274 lab professionals about fume hood operation, maintenance, and purchasing. Based on this survey, of the ducted fume hood types of interest in this project (74% of the hoods listed in the survey), 78% of these are CAV types and 22% are VAV. For comparison, Boston University has reported a similar distribution: of 385 fume hoods on their Charles River campus, 66% are CAV types and 34% are VAV (Gevelber et al. 2011). However, one needs to view the overall distribution with caution when addressing a specific site. Michigan State University (MSU 2012) recently provided us with data that indicate an opposite distribution: of 670 hoods, 27% are CAV and 73% are VAV. Consequently, our demonstrations plan to address both types of hoods.

Using earlier results of the same survey, Lab Manager also reported that the primary reasons cited for purchasing a new fume hood are additions to an existing system to increase hood capacity (34% of respondents), setting up a new lab (32%), and replacing current hoods (25%). In general, budgets cited for new hood purchases tend to be limited: 78% of respondents cited $15,000 or less (14%, however, cited greater than $30,000).

The top ten most important factors in order of importance for survey respondents in their decision to buy a fume hood are listed below in Table 1. Performance, durability, and ease of use appear to be the most important factors, followed closely by cost related factors.

Table 1: Criteria for Purchasing Fume Hoods

	Criterion	Relative Importance
1.	Performance of product	100%
2.	Durability of product	95%
3.	Ease of use; ergonomic operation	95%
4.	Low maintenance / easy to clean	92%
5.	Value for price paid	92%
6.	Safety and health features	92%
7.	Low operating costs	89%
8.	Total cost of ownership	79%
9.	Service and support	78%
10.	Vendor reputation	73%

Fume hood safety programs typically require regular inspection and testing to verify that hoods are safe to use. Maintenance by in-house facilities staff or vendors is also required to maintain performance. For example, exhaust fans require bearing lubrication, checking belt tension and alignment, and inspecting fan blades for deterioration. Almost half of surveyed respondents inspect their fume hoods at least every year, while 28% inspect every three to six months, and 12% inspect monthly. No information was provided about the motivation for more frequent inspections.

Market penetration of high performance fume hood technologies has been slow, in part because reports of problems in early installations (i.e., 1980's) have reinforced general concerns about the technology reliability and the potential need for increased inspections and maintenance (e.g., what if it closes or opens when you don't want it to). However, the current state-of-the-art seems to have overcome these barriers and concerns, and these technologies are being actively marketed and successfully used. For example, newer hoods includes features such as pneumatic sash positioning that allows one finger override (up or down), a safety eye stops sash closure before it hits any protrusion, the sash opens when the space in front of the hood is occupied, and selectable sash closure delays.

Some of the concerns can also be attributed to a perception that new hoods or retrofit kits are expensive relative to available purchasing budgets, and that energy and cost savings associated with high performance technologies are not well enough documented, so it is difficult to assess payback periods or returns on investment. However, some limited information is already available about the costs and payback periods of conventional and high performance hood technologies. The following summarizes this information.

Based on recent interviews with industry representatives (Zogg 2012), a standard CAV hood "without base cabinets with airflow alarm, average fixtures, ceiling soffit, factoring shop drawings, is around $11,000 installed. A 6-foot low-flow CAV, costs about $500 more than regular CAV."

Zogg's notes also state that: "There is a negligible cost premium for VAV for the actual hood, not including controls. However, there is an HVAC cost premium for a VAV system. A VAV system could consist of a 12" valve & controller ($2,000 adder per hood) for each hood and a VAV blower can cost $300-600 per blower (for materials only). Large blowers might be ducted to 10-20 fume hoods and could cost tens of thousands of dollars."

His notes state that "A factory-installed automated sash costs $2,500-$2,700 more than a manual sash including IR sensors and up/down closure control. Jamestown uses Phoenix's CPS sensor. If one is already using the Phoenix control, the cost can be lower .... A sash retrofit of a manual VAV system would cost $100 for the kit, plus $1,000 dollars for the on-site installation, so $3,600-3,800 total cost adder."

Zogg also states that "Penn state has 200 CAV hoods and determined that it would cost $1+ million per year to run CAV vs. VAV, so they converted all of them to VAV. Low flow CAV hoods are still more expensive in the long run than VAV hoods with a smart sash, which have a payback period of less than 4 years. All costs are based on 7-8 cents/kWh. The economics of low-flow CAV vs. VAV are dependent on usage patterns."

Mastrul (2010) reported that: "At $8,000 a hood, the retrofits probably would not happen all at once …. The cost is only about one-fourth the price of buying new energy-efficient fume hoods and having them installed by union labor contractors."

Adams and Alderman (2009) reported that: "Due to their relatively low cost, high level of energy savings, and improved safety features, Phoenix VAV valves with UBC are the most attractive solution for Welch Hall. With the addition of a fume hood monitor that alerts lab occupants if unsafe conditions exist, the total cost to retrofit a single fume hood is approximately $3,650 including installation. This is much less than the cost of purchasing a new fume hood, and also saves the current fume hoods from going to the landfill prematurely…. In some lab retrofits, installation of VAV has resulted in one-year paybacks and 50% reduction of air-conditioning costs. By also installing UBC, an additional 40% reduction in energy savings can be achieved. This results in a total energy savings of approximately 70%."

Tom Smith (2012) reported that his firm has developed a retrofit kit, which has been submitted for a patent. He is installing the kit on about 200 hoods at EPA facilities in Research Triangle Park, NC (one of our candidate sites), as well as at a few other sites. He indicated that it takes about 2 hours to do a retrofit, then rebalance and recommission the system. Estimated payback is less than 4 years.

Estimated Energy and Cost Savings Potential

Data about laboratory buildings and more specifically hood related energy use is quite limited. According to DOE (2003), using a sample of 43 buildings, there are about 9,000 laboratory buildings in the U.S. (654 million square feet) with an average annual site energy use intensity[1] of 305 kBtu/ft^2. The total annual site energy use therefore is 200 TBtu. Associated expenditures for energy are $2.85 billion.

Based on benchmark data provided by representatives for 76 U.S. buildings with chemical labs built between 2001 and 2011 (Labs21 2012), these buildings on average annually use about 660 kBtu/ft^2 of source energy. Equivalent average site energy is 343 kBtu ft^2. Of this site energy, 38 kWh/ ft^2 (130 kBtu/ft^2 or 38%) is electricity with an energy cost of $5.88/ft^2. Average building peak electrical demand is 9 W/ ft^2. Using the DOE total floor area estimate above, the electricity site energy cost translates to $3.84 billion. Although the average site energy use here (electricity and natural gas sources) is somewhat similar to that reported by DOE (343 vs. 305 kBtu/ft^2), these buildings differ from the ones used in the DOE dataset and caution is needed when interpreting the data.

Compared to EIA (2003) data for commercial buildings as listed in Table 2, the average source energy use intensity (EUI) for lab buildings (660 kBtu/ft^2) is about the same as the average for food sales buildings, but it is much larger compared to the averages for other buildings. In the latter case, EUI ratios range from 1.9 to 8.6. For example, compared to a similar sized average office building, an average lab building will use about three times more energy. A single fume hood can use as much energy as 3.5 average houses (Stuart 2012).

Table 2: Building Average Source EUIs and Laboratory EUI (660 kBtu/ft^2) to Building EUI Ratios

Building Principal Use	Average Source EUI, kBtu/ft^2	Lab/Building EUI Ratio
Food Sales	535	1.2
Health Care	346	1.9
Office	212	3.1
Mercantile and Service	204	3.2
Lodging	193	3.4
Education	159	4.2
Warehouse and Storage	94	7.0
Religious Worship	77	8.6

Few data are available to disaggregate the whole-building values for laboratories into end uses (and most are only estimates and not based on measurements). The number of buildings reporting such data in the Labs21 dataset ranges from 1 to 11. Based on these data, Figure 2 shows the average fractions of the whole-building electricity consumption and demand. The primary electrical energy uses are for

[1] Energy data stated here and in the remainder of this section are in terms of gross floor area of the building.

ventilation and cooling (61% of whole-building electricity consumption). Related peak demand is 88% of whole-building demand. Clearly, reducing the ventilation-related energy use, which in turn affects the cooling energy use, is a key step toward reducing lab building energy use.

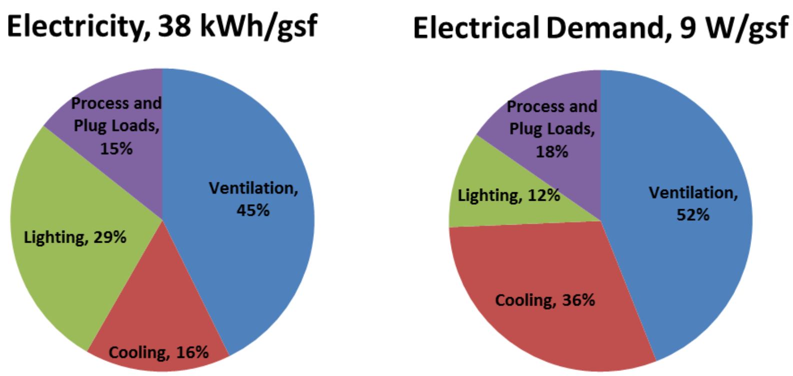

Figure 2: Electrical energy and peak demand end use fractions. Source: Labs 21 (2012)

Mills and Sartor (2005) estimated the electricity and natural gas energy consumption and electricity demand associated with conventional hood use, and the potential savings attributable to reducing airflows by 50% using high performance hoods, with an ultimate market penetration rate of 75%. In their analyses, they assumed that conventional hoods are represented by a CAV hood continuously exhausting 1250 cfm of room air, which is replaced by 100% outdoor air. They assumed that this makeup air is cooled to 55°F during the cooling season, and is heated to 55°F during the heating season. Reheat energy (provided by natural gas heated hot water)[2] is added year-round to warm the supply air to 65°F (such that the reheat sensible energy is 94,608 Btu/(cfm-yr)). Cooling plant efficiency was assumed to be 1 kW/ton of cooling load and heating system efficiency (primary and reheat) was assumed to be 70%. Specific fan power (supply and exhaust combined) was assumed to be 1.8 W/cfm, based on a "standard" system pressure drop (9.7 in.w.c., Weale et al. 2002) and assuming the system efficiency is about 62%.

Mills and Sartor used climate factors taken from Kjelgaard (2001) to account for annual weather effects on ventilation-related cooling and heating loads. In particular, they averaged the factors for four climates (Chicago, Los Angeles, Miami, and New York) to determine U.S. average factors for cooling and heating. Although these factors were not published, one can calculate them from the published results. In this case, the factors were 12.15 ton-hrs/(cfm-yr) for cooling and 0.50 therms/(cfm-yr) for heating.

For this scoping report, instead of only selecting four representative cities to determine a U.S. average climate, we averaged the factors together for cities that either represent one of the 15 climate zones in the U.S. (Briggs et al. 2002) plus cities that are in the top 25 population rank in 2011 (total of 37 cities). The resulting factors are 11.06 ton-hrs/(cfm-yr) for cooling and 0.72 therms/(cfm-yr) for heating, and are similar to the factors for Washington, DC by itself (10.83 and 0.75 respectively).

We also used 2011 U.S. average nominal energy prices (EIA 2012), weighted in the same way that Mills and Sartor did (75% for commercial sector use and 25% for industrial sector use). The resulting prices are 0.0946 $/kWh for electricity and 7.72 $/million Btu for natural gas. According to the EIA, the electricity prices include: "State and local taxes, energy or demand charges, customer service charges, environmental surcharges, franchise fees, fuel adjustments, and other miscellaneous charges applied to

[2] Electric reheat is not widespread, but incurs a large energy penalty where used (i.e., it is nearly twice the combined fan power and almost doubles heating costs).

end-use customers during normal billing operations. Prices do not include deferred charges, credits, or other adjustments, such as fuel or revenue from purchased power, from previous reporting periods".

Table 3 summarizes the estimated per-hood and national-scale annual energy use and national savings potential from our updated analyses with the assumptions described above.

Table 3: Estimated Annual Energy Use and National Savings Potential

PER-HOOD ANNUAL VALUES	
Electricity (kWh, site energy)	33,497
Peak power (kW)	6.7
Natural gas (million Btu)	297
Total energy cost ($)	5,460
$/cfm	4.37

NATIONAL-SCALE BASELINE ANNUAL VALUES	
Number of hoods	750,000
Total electricity (TBtu, source energy)[3]	266
Total peak power (GW, non-coincident)	5.1
Total natural gas (TBtu)	222
Total energy (TBtu)	488
Total energy cost ($ million)	4,095

NATIONAL-SCALE ANNUAL SAVINGS	
Per hood savings	50%
Ultimate potential market penetration	75%
Total electricity (TBtu, source energy)	100
Total peak power (GW)	1.9
Total natural gas (TBtu)	83
Total energy (TBtu)	183
Total electricity ($ million)	891
Total natural gas ($ million)	644
Total energy cost ($ million)	1,535

In summary, with a 75% market penetration rate, high performance fume hoods have a substantial source technical potential of approximately 180 TBtu/yr, which translates to about $1.5 billion annually. The energy savings are comprised of about 54% electricity and 46% natural gas, with a peak demand savings of about 1.9 GW. If instead only 10% of the installed base of fume hoods adopts high performance technologies, the hypothetical savings would still be significant: 24 TBtu/yr of source energy and $205 million.

Candidate Test Sites and Available Technologies

We intend to field-demonstrate hoods at several sites that have already installed, or are about to install high performance hoods, focusing on the performance as operated in actual use. More specifically, our objective is to test about five to ten hoods of each type, totaling 25 to 50 hoods, across five sites. The following candidate sites have expressed strong interest, and three have provided signed letters of intent (attached in Appendix A):

[3] Assumes the site to source conversion factor for electricity is 3.10 (DOE 2012).

- Cornell University, Ithaca, NY; Contact: Ralph Stuart (rstuart@cornell.edu)

  Cornell has numerous hoods (number yet to be determined) available for testing. In particular, it has two-state (65 fpm/100 fpm) VAV hoods with occupancy sensors. A few of these sensors are located on the hoods, while most are room occupancy sensors. The site also has at least two CAV hoods with low face velocities (80 fpm). The tests will be carried out in assorted campus laboratories, including Weill Hall and Biotech, both of which include building automation systems that can provide energy use data. We have a signed letter of intent to participate.

- Harvard University, Cambridge, MA; Contact: Jamie Bemis (jamie_bemis@harvard.edu)

  Harvard has numerous hoods (number and specific types yet to be determined - mostly VAV) available for testing. They have a building automation system that can monitor flow rates – in some cases total exhaust; in other cases for individual fume hoods. At this site, we may be able to obtain data without adding additional instrumentation. They also had a fume hood competition before, and got an exhaust flow reading for 20 labs every 30 minutes. Site staff has already proactively begun work with their controls vendor to determine the process for collecting the data we will need, to determine what data points are readily available, and what the process would be for setting up reports to collect any additional information required. We expect to receive a signed letter of intent to participate by December 7, 2012.

- Michigan State University, Lansing, MI; Contact: Jennifer Battle (jennifer@msu.edu)

  MSU has approximately 410 hoods available for testing. The hoods include CAV and VAV types with 70 high-performance and 202 conventional VAV hoods, 20 VAV two-state hoods, 27 high-performance and 31 conventional CAV hoods without bypass, and 21 high-performance and 42 conventional CAV hoods with bypass. We have a signed letter of intent to participate.

- Princeton University, Princeton, NJ; Contact: Robin Izzo (rmizzo@Princeton.EDU)

  Princeton has approximately 400 hoods available for testing. The hoods include CAV and VAV types, some with retrofit kits. VAV hoods include both manual sash closure and automatic sash closure types (the latter with occupancy sensors). Hood ages range from 50 years old to new. A couple of the HVAC systems have energy-recovery wheels. Site staff is working to sign a letter of intent to participate.

- U.S. Environmental Protection Agency, Research Triangle Park, NC; Contact: Greg Eades (Eades.Greg@epamail.epa.gov)

  The EPA facility has approximately 270 hoods available for testing. The hoods are all CAV types, with about 170 having retrofit kits. The facility already has extensive sub-metering capabilities installed, so there may be little additional instrumentation needed. We have a signed letter of intent to participate.

Representatives at each of the five sites have each indicated that they understand the nature of the demonstration and their basic responsibilities, including:

- Providing access for the installation of monitoring equipment,
- Maintaining power to and not disturbing the normal operation of the monitoring equipment,
- Allowing our staff to remove the monitoring equipment at the end of the demonstration,
- Reporting any problems or anomalies with the hoods or monitoring equipment,
- Allowing our staff access to the site to inspect and repair monitoring equipment (if needed),
- Periodically collecting test data and sending the data to our staff, and

- Providing feedback on equipment operation, performance, and overall experience periodically during and at the conclusion of the demonstration.

Even if one or two of these sites ultimately cannot participate, we will still have a large selection of hoods to test at the remaining sites. As a result, there is little risk that we would not be able to complete the field demonstrations as planned.

We contacted several other potential sites as well, but they have not confirmed their interest yet (i.e., University of Wisconsin-Madison), they do not have suitable hoods, they are unable to participate due to time constraints, or they did not respond. These sites include the National Institute of Environmental Health Sciences (NIEHS), University of Notre Dame, Novartis, SLAC National Accelerator Laboratory (Stanford), University of California-Berkeley, University of California-Davis, University of Colorado, and University of North Carolina-Chapel Hill.

Data Collection and Demonstration Schedule

The following is a preliminary list of parameters that we anticipate needing to monitor in our field demonstrations:

- electrical power to the exhaust fans serving the selected hoods and related HVAC supply fans;
- fan airflows and pressure rises;
- hood airflows and pressure drops, as wells as sash position and hood occupancy;
- airflows, air inlet temperatures, and air outlet temperatures and humidities for associated heating, cooling, and reheat coils (as an alternative, if coil water flows and inlet and outlet temperatures are already monitored, we will use those parameters instead to determine coil thermal loads);
- room supply airflows, and supply and room air temperatures and humidities;
- outdoor temperature and humidity.

Data will be collected using the building automation system (BAS) where possible, and with standalone data loggers where needed (with the capability of storing at least 2 weeks of data). Where sensors do not already exist or where BAS bandwidth limits the needed data collection frequency (one minute frequency would be desirable where parameters change rapidly, five minutes could likely be used elsewhere), we will work with site staff to provide instrumentation to collect those data (within the limitations of the project's budget). We will plan for a team member or site staff to download data and send us data at least once per week. If regular data collection is not possible, we will investigate the possibility of using real-time data transmission.

We plan to carry out the demonstrations principally during the period of February through September 2013. Data will be collected for a minimum of two weeks, preferably in each of the heating and cooling seasons to capture weather-related effects. Where needed, longer data collection periods will be considered, subject to site staff availability to provide support.

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APPENDIX A: Letters of Intent from Candidate Sites

The three candidate sites listed below have provided signed letters of intent to participate in the fume hood field demonstrations. Those letters are attached on the following pages.

1. Cornell University
2. Michigan State University
3. U.S. Environmental Protection Agency

The other two candidate sites (Harvard University and Princeton University) are in the process of reviewing and completing their letters of intent.

Cornell University
Environmental
Health and Safety

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November 29, 2012

Paul Mathew, PhD
Staff Scientist and Group Leader, Commercial Building Systems
Lawrence Berkeley National Laboratory

Re: Host site letter of intent – DOE field demonstration project for high-performance fume hoods

Dear Paul,

This letter expresses the intent of Cornell University to participate in the above-named project with the U.S. Department of Energy (DOE), Navigant Consulting, Inc. (Navigant), and Lawrence Berkeley National Laboratory (LBNL), which will involve field demonstrations to evaluate the performance, energy savings, and economic benefits of high performance fume hoods.

The laboratory in which the demonstration will take place is **assorted campus laboratories, including Weill Hall and Biotech, both of which include building automation systems which can provide energy use data of the kind you are interested in. Other buildings on campus may also be of interest.** We understand that your intent is to test conventional against fume hoods that have been operating under other conditions (specifically with occupancy sensors controlling air flow) for at least 6 months in chemical labs where the make-up air for the hood exhaust is the principal component of the building's outdoor air intake. So that you can capture energy use data as well as installation, operation and maintenance issues that might occur. We confirm that the laboratory buildings on campus have at least five fume hoods of these two types.

We accept that monitoring equipment might be installed on the supply and exhaust sides of the HVAC system(s) serving the fume hoods for the duration of the demonstration (about 2 to 6 months) if necessary to provide data supplementary to what we currently collect. We understand that our responsibilities include providing access to install and remove the monitoring equipment, and maintaining power to the monitoring equipment and not disturbing its normal operation. We will promptly report any problems or anomalies with the hoods, associated HVAC system(s), and the monitoring equipment and will provide site access for inspecting and repairing monitoring equipment if needed. We agree to periodically collect test data and send such to LBNL, and to provide feedback on equipment operation and our overall experience periodically during and at the conclusion of the demonstration. We understand that DOE will use our name, location, description of application, demonstration results, and installation photos for the purpose of publicizing results. We confirm that lab occupants will be made aware of the demonstration and the responsibilities of the host site.
Our commitment is subject to negotiating a mutually acceptable field-demonstration participant agreement between LBNL, Navigant, and ourselves. We understand that this agreement will require us to indemnify and hold harmless LBNL, Navigant, and DOE for any loss.

We look forward to working with LBNL, Navigant, and DOE on this important effort to demonstrate the significant energy savings of high-performance laboratory equipment.

Sincerely,

Ralph Stuart, CIH
Chemical Hygiene Officer

Ellen M. Sweet, MS
Lab Ventilation Specialist

MICHIGAN STATE UNIVERSITY

November 28, 2012

Craig Wray
Mechanical Engineer
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

Re: Host site letter of intent – DOE field demonstration project for high-performance fume hoods

Dear Craig,

This letter expresses the intent of Michigan State University to participate in the above-named project with the U.S. Department of Energy (DOE), Navigant Consulting, Inc. (Navigant), and Lawrence Berkeley National Laboratory (LBNL), which will involve field demonstrations to evaluate the performance, energy savings, and economic benefits of high performance fume hoods. The specific laboratory in which the demonstration will take place will be confirmed upon speaking with the faculty investigator.

We understand that your intent is to test high flow (conventional) and low flow (high-performance) fume hoods that have been operating for at least 6 months in chemical labs where the make-up air for the hood exhaust is the principal component of the building's outdoor air intake, so that you can capture installation/operation/maintenance issues that might occur. We confirm that the laboratory has at least five fume hoods of these two types.

We accept that monitoring equipment will be installed on the supply and exhaust sides of the HVAC system(s) serving the fume hoods for the duration of the demonstration (about 2 to 6 months). We understand that our responsibilities include providing access to install and remove the monitoring equipment, and maintaining power to the monitoring equipment and not disturbing its normal operation. We will promptly report any problems or anomalies with the hoods, associated HVAC system(s), and the monitoring equipment and will provide site access for inspecting and repairing monitoring equipment if needed. We agree to periodically collect test data and send such to LBNL, and to provide feedback on equipment operation and our overall experience periodically during and at the conclusion of the demonstration.

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MICHIGAN STATE
UNIVERSITY

We understand that DOE will use our name, location, description of application, demonstration results, and installation photos for the purpose of publicizing results. We confirm that lab occupants will be made aware of the demonstration and the responsibilities of the host site.

Our commitment is subject to negotiating a mutually acceptable field-demonstration participant agreement between LBNL, Navigant, and ourselves. We understand that this agreement will require us to indemnify and hold harmless LBNL, Navigant, and DOE for any loss.

We look forward to working with LBNL, Navigant, and DOE on this important effort to demonstrate the significant energy savings of high-performance laboratory equipment.

Sincerely,

Jennifer Battle

Jennifer Battle
Director

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Research Triangle Park, NC 27711

November 30, 2012

OFFICE OF
ADMINISTRATION
AND RESOURCES
MANAGEMENT

Mr. Craig Wray

Lawrence Berkeley National Laboratory

1 Cyclotron Road MS-90R2000

Berkeley, CA 94720

Re: Host site letter of intent – DOE field demonstration project for high-performance fume hoods

Dear Craig:

This letter expresses the intent of the U.S. Environmental Protection Agency (EPA) to participate in the above-named project with the U.S. Department of Energy (DOE), Navigant Consulting, Inc. (Navigant), and Lawrence Berkeley National Laboratory (LBNL), which will involve field demonstrations to evaluate the performance, energy savings, and economic benefits of high performance fume hoods.

The laboratory in which the demonstration will take place is at the EPA facility in Research Triangle Park, NC. We understand that your intent is to test high flow (conventional) and low flow (high-performance) fume hoods that have been operating for at least 6 months in chemical labs where the make-up air for the hood exhaust is the principal component of the building's outdoor air intake, so that you can capture installation/operation/maintenance issues that might occur. We confirm that the laboratory has at least five fume hoods of these two types.

We accept that monitoring equipment will be installed on the supply and exhaust sides of the HVAC system(s) serving the fume hoods for the duration of the demonstration (about 2 to 6 months). We understand that our responsibilities include providing access to install and remove the monitoring equipment, and maintaining power to the monitoring equipment and not disturbing its normal operation. We will promptly report any problems or anomalies with the hoods, associated HVAC system(s), and the monitoring equipment and will provide site access for inspecting and repairing monitoring equipment if needed. We agree to periodically collect test data and send such to LBNL, and to provide feedback on equipment operation and our overall experience periodically during and at the conclusion of the demonstration. We understand that DOE will use our name, location, description of application, demonstration results, and installation photos for the purpose of publicizing results. We confirm that lab occupants will be made aware of the demonstration and the responsibilities of the host site.

Our commitment is subject to negotiating a mutually acceptable field-demonstration participant agreement between LBNL, Navigant, and ourselves.

We look forward to working with LBNL, Navigant, and DOE on this important effort to demonstrate the significant energy savings of high-performance laboratory equipment.

Sincerely,

William G. Eades