Report to NEMIC
National Energy Management Institute Committee

Impact of Fume Hood Retrofits on the Energy Performance of Laboratory Spaces

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September 2014

ACKNOWLEDGEMENTS

SPONSORS

This research project was supported by funding received from the National Energy Management Institute Committee (NEMIC).

Additional in-kind support was received by FlowSafe Inc., who contributed retrofit equipment and associated labor hours to the project.

This research was also supported by Virginia Tech's Facilities Services, who provided personnel for some of the technical installations to the project.

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EXECUTIVE SUMMARY

There are probably more than a million fume hoods operated in laboratories throughout the United States. Most of these fume hoods still run under more or less continuous conditions and thus consume an enormous amount of energy per year. There seems to be a significant savings potential if the total exhausted volumes could be reduced while all safety requirements are met. Researchers have meanwhile developed and identified high performance fume hood solutions that could facilitate a reduction of up to 75% of the consumed energy required to condition make-up air. However, most of these solutions are geared towards new construction as they require specific spatial and system design configurations. There is a lack of knowledge regarding retrofit options and their expected savings potential on energy consumption for existing laboratories. Since fume hoods interact with other systems and fulfill design requirements that are already in place, any modification will consequently impact other performance requirements within the same environment. This project set out to gain a broader understanding of direct and indirect impacts of various retrofit scenarios for individual fume hoods, their integrated function within a laboratory space, and their overall impact on energy consumption of a space.

This research project employed a long term experimental approach to measure the actual energy consumption of two different laboratory spaces, before and after retrofits. The results from measurements in the physical space were then modeled in an analytical, simulated approach to replicate the measured scenarios and consequently provide a basis for other simulation scenarios. The energy consumption of individual lab spaces was broken down by domain to disambiguate how energy is utilized in a given lab context. This approach identified the most significant contributors in terms of design requirements and their impact on actual consumption. This ultimately provided the basis for identifying the most applicable retrofit strategies.

The project showed that it is possible to reduce the energy consumption of HVAC loads for laboratory spaces up to 75% through special retrofit technologies, as demonstrated for one of the investigated laboratory spaces. However, any savings potential is highly dependent on space configuration, its actual use, and its related design context. For the second of the investigated spaces, we found several performance mandates to be conflicting with technically achievable flow rate reductions, which in turn reduced the potential energy savings to only 10%, even when considering significant additional retrofit work. The core findings of this project can be summarized as following:

- Energy consumption for space conditioning can be reduced by 75% if no other design mandates are in conflict with the employed retrofit technologies.
- Laboratory spaces with high internal heat gains, such as from equipment loads, lighting loads, or solar gains, will achieve less reduction with constant volume systems.
- Cooling loads have been found as significant drivers of overall design volume requirements, even though the resulting annual energy consumption for these volumes is typically dominated by heating requirements.
- Lighting loads have been found to be a significant driver for the cooling demand. A reduction of lighting loads will directly save energy in form of reduced electricity consumed by the individual circuits.
- Heat gains from lighting loads typically show up as a reduction of heating requirements in the HVAC analysis. However, this reduction is not a real reduction of energy, but rather a shift of heating energy to the lighting system.

- A reduction of lighting loads can significantly lower the cooling demand and thus reduce the overall ventilation needs of a space, which results not only in a reduction of cooling consumption, but even more significantly in a reduction of heating consumption.
- Controlled lighting schedules and automated lighting systems provide an opportunity to reduce overall consumption, though they do not directly contribute to a reduction of design supply volumes.
- Solar gains can offset heating loads, and reduce lighting loads. However, solar gains during summer months will increase the cooling load and thus increase the required supply volumes. In constant volume system this results in an increased heating load, which cannot be compensated by solar gains.
- Variable blinds have not been assessed and simulated yet. Variable blinds may allow for harvesting more solar gains during heating periods, while still reducing the total ventilation rate due to a reduced cooling load.
- Internal gains are always problematic in laboratory spaces. Unless alternative cooling systems, such as ductless split systems are provided, or the heat sources can be moved to separated zones that allow for local recirculation instead of operating on 100% exhaust, internal loads will always require large volumes of supply air to remove gains, whether there are fume hoods in a space or not.
- In cases with high internal gains it actually may make sense to use fume hoods as exhaust paths for the required air volumes, since this may meet other safety requirement of the laboratory space at the same time.

Ultimately, this research resulted in the development of an integrated decision-making tool for energy assessments in laboratories, the IDEAL application, which allows for investigating savings opportunities and barriers of low velocity retrofit scenarios for laboratories operating fume hoods. Laboratory spaces can be evaluated within their individual spatial, environmental, and occupational context. The application emphasizes that fume hoods are embedded terminal units of environmental systems that cover a variety of performance mandates, ranging from physical safety, to chemical safety, to thermal comfort, and ultimately fresh air requirements.

This project demonstrated that energy consumption savings of up to 75% for space conditioning can be achieved. However, the individual savings potential that can be achieved for a laboratory space depends on many factors, such as the actual climate where retrofits are installed, actual occupant and lighting schedules, and the actual space and equipment usage. Furthermore, the total savings potential is a function of load related ventilation requirements versus safety related ventilation requirements. These ratios can vary widely as our research has demonstrated, even within the same building context. Ultimately, there is no “one-size-fits-all” approach possible for fume hood retrofits, and each individual space configuration must be evaluated in its specific context. The IDEAL application developed as an outcome of this project can be a first step in this process and start the conversation with building owners and other stakeholders.

PROJECT GOALS

There are at least half a million fume hoods operated in laboratories in the United States, with some estimates going as high as 1.5 million units. Many if not most of these fume hoods operate under more or less continuous conditions and thus consume (i.e. exhaust) an equivalent of 3-4 times the amount of energy a typical home uses over a year[1]. This represents a tremendous amount of energy, which is a result of designed safety measures that are not correlated to active space conditioning. There seems to be a significant savings potential if the total exhausted volumes can be reduced while all safety requirements are met. Researchers have meanwhile developed and identified high performance fume hood and space integration solutions[2,3,4,5] that allow for cutting up to 75% of the consumed energy. However, most of these solutions are geared towards new construction as they require specific spatial and system design configurations. There is a lack of knowledge regarding less expensive retrofit options. Even more so when it comes to expected savings potentials of energy consumption, since fume hoods interact with other systems and consequently impact those in the same environment. In this context, this project proposed to gain a broader understanding of direct and indirect impacts of respective safety constrains and various retrofit scenarios for individual fume hoods as they relate to the overall energy consumption in laboratory spaces.

The overall goal of this project was to gain a broader understanding of the direct and indirect impact of retrofit scenarios of individual fume hoods on the overall energy consumption of laboratory spaces. The project did not isolate the individual energy performance of fume hoods by themselves, but rather investigated the integrated dynamics of affected airstreams as they relate to a) general indoor air quality requirements (i.e. thermal comfort) of interior spaces and b) to environmental safety provided through exhaust exchange rates for the given space.

This project attempted to find answers to the following questions:

- How can facility managers assess the impact of different energy retrofit scenarios related to fume hood operations within their specific lab facilities and infrastructure?
- Is it possible to develop and utilize a simplified energy model specifically for the assessment of fume hood labs that can assist facility managers in the decision-making process towards considering applicable energy efficient retrofit options?
- Can we identify the initially most promising retrofit scenarios based on context parameters that can be easily provided by a facility manager/operator without conducting an intensive on-site audit or an expensive simulation modeling process?

To answer the above questions the following core objectives were defined for this project:

- Selective new data must be gathered around specific retrofit scenarios of fume hoods to study their impact on overall energy consumptions of HVAC systems in laboratory spaces while understanding their role in design and safety contexts.
- A new modeling approach should be developed that allows for replicating experimental findings and ultimately predicting of energy savings through different retrofit scenarios of fume hoods and impacted systems in a given categorized context.

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[1] Mills, E. and D. Sartor (2005). "Energy use and savings potential for laboratory fume hoods." Energy 30(10): 1859-1864

[2] Bell, G., D. Sartor, et al. (2003). Development and Commercialization of an Innovative High-Performance Laboratory Fume Hood. E. A. Team, Lawrence Berkeley National Laboratory

[3] Wang, G., W. Gang, et al. (2003). "Two Energy Efficiency Measures for Constant Air Volume Exhaust Systems: Using Dampers and Variable Frequency Drives." ASHRAE Transactions: 30

[4] Bartholomew, P. (2004). "Saving Energy In Labs." ASHRAE Journal 46(2): 35-40

[5] Sharp, G. P. (2010). "Demand-Based Control of Lab Air Change Rates." ASHRAE Journal 52(2): 30-41

RESEARCH METHODS

This project investigated the actual energy consumption of two different laboratory spaces in a long term experimental approach. These laboratories, which are located on the fifth floor of Derring Hall, were selected for this study due to their proximity to one of the supporting mechanical rooms. A second rationale for selecting these labs was their partial exposure to the elements, and the different façade configuration for the adjacent rooms, one of which holding a large window wall section oriented towards the south. The larger laboratory (DER 5065) also housed significant equipment loads, which were evaluated against more typical loads found in the comparatively smaller space (DER 5061).

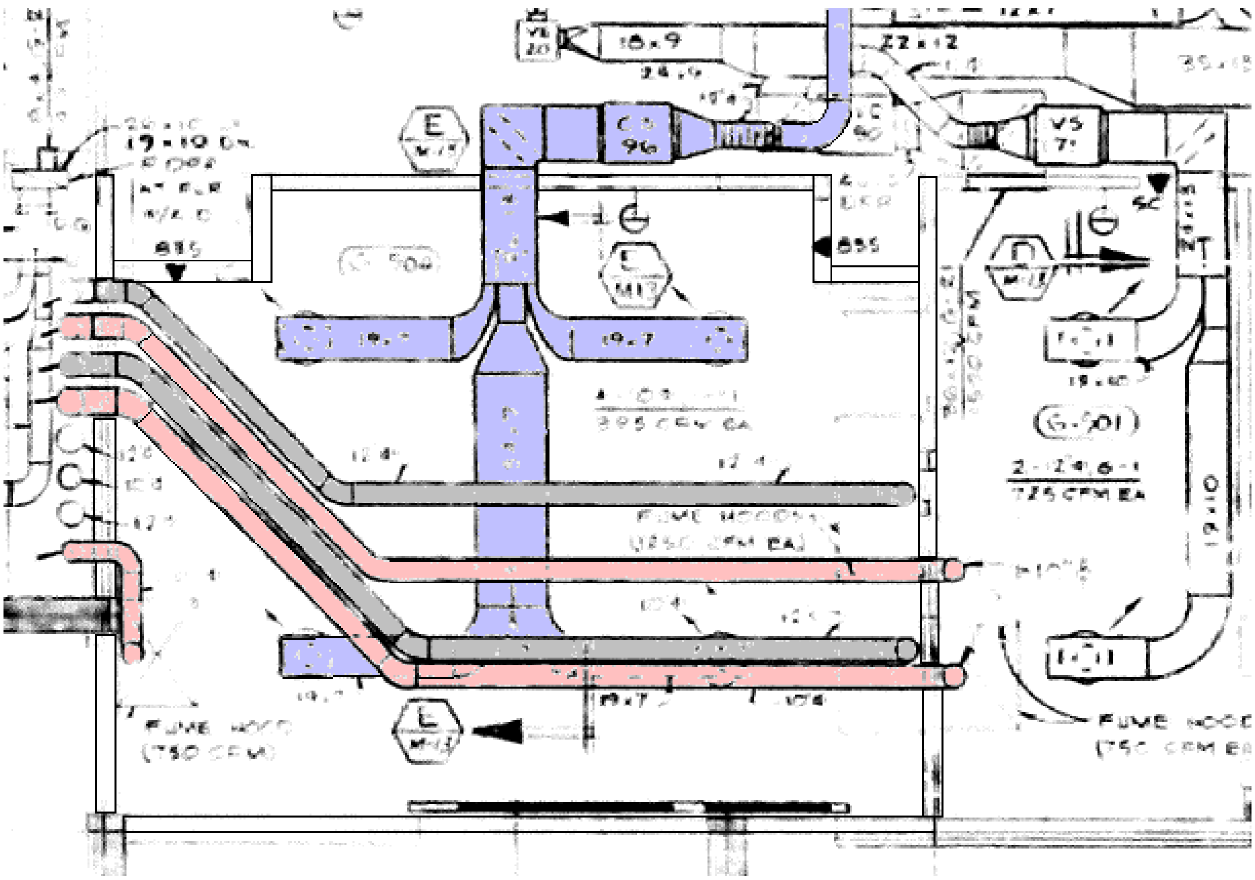

Fig. 1 Derring Hall Lab 5065 (left) with full height window wall, and the smaller Lab 5061 (right).

The two laboratories also differ by occupancy type, whereas the smaller lab is used as pure research lab, while the larger lab is also used as a teaching lab. For both labs the energy consumptions were measured over longer periods of time and captured in form of temperatures, volumes, and various circuit loads. A large set of wired and wireless sensors and data loggers was employed to simultaneously collect these records.

All sensors were calibrated and compared for linearity, and to identify faulty sensors to be sorted out. Significant effort has been put into the calibration of velocity measurements, through conducting a series of duct traverse measurements that were then mapped for deriving respective flow rate factors. These factors were then utilized to convert continuous single point measurements into actual flow rates.

During the project period a fume hood retrofit installation was carried out in one of the spaces, while the second space was not altered. For both spaces measurements were taken before and after the retrofit and compared in extended analysis procedures.

Fig. 2 Original configuration of fume hoods with vertical sash mechanism in DER 5065.

Fig. 3 Retrofitted fume hoods with new VFV control system, safety cabinet, and vertical sashes.

The results from these experimental investigations were then merged into an analytical model to replicate the various measured scenarios and consequently provide a basis for other simulation scenarios.

The energy consumption of the individual lab spaces was analyzed and broken down into different domains of energy sources and consumption items to disambiguate how energy is utilized in a given laboratory context. This approach allowed us to investigate and later categorize possible retrofit scenarios by their impact in terms of most significant contributors and provide applicable strategies to reduce these loads.

From these findings, a decision model has been developed, that allows for comparing retrofit options in a given spatial, thermal, and occupational safety context. This model was then integrated into a database driven application that can be distributed via the World Wide Web.

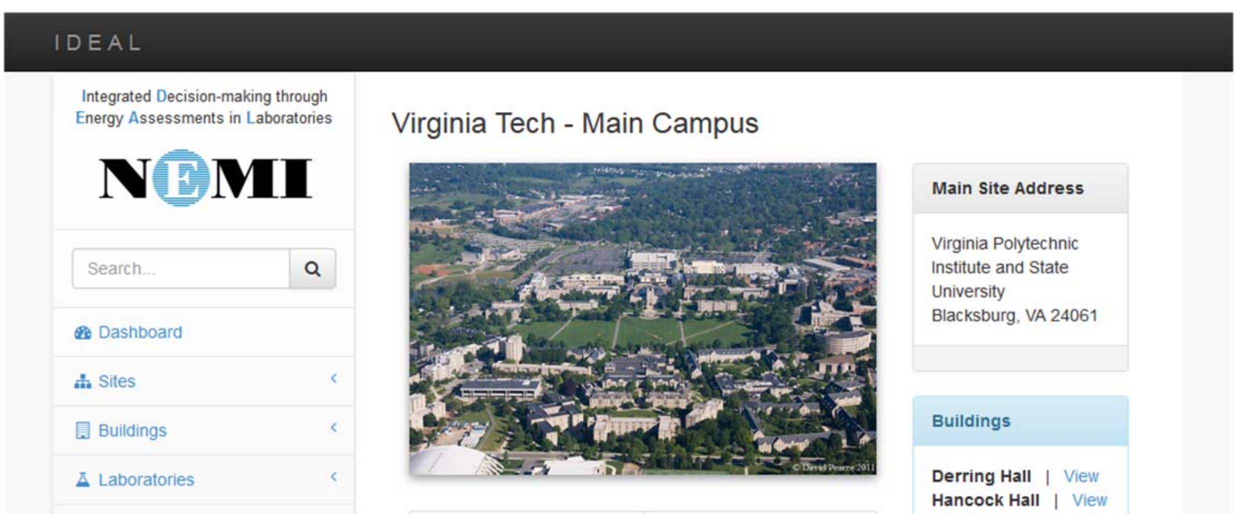

Fig. 4 The IDEAL web application: Integrated Decision-making through Energy Assessments in Laboratories.

Research Findings

Two laboratories in Derring Hall, a large research building at Virginia Tech's Blacksburg campus were monitored over longer periods during different seasons, over two years. One of these spaces underwent significant remodeling, which was captured in before-and-after measurements. These measured data were then analyzed and evaluated against individual design mandates and volume requirements for the two spaces. For both spaces, various retrofit scenarios were then simulated for comparison among each other, and to evaluate the savings potential in each individual spatial context.

Laboratory DER 5061 – The Model Lab

The laboratory in Derring Hall Room 5061, which was the smaller of the two labs studied in this project, is roughly 24 feet deep, 12 feet wide, and has an interior ceiling height of 13 feet. The lab was equipped with two 4-ft fume hoods, each with a maximum face opening area of close to 8 sf and a net work-area of 6.25 sf. The southern wall and the roof of this space are 100% exposed to the exterior. There is a narrow window band in the southern wall measuring roughly 18 sf. The space is conditioned through a central air handling unit that typically delivers between 900 and 1000 cfm to the space. During our experiments we measured the lower range of supply temperatures to be around 63°F. For heating conditions, a local re-heating coil can increase the base supply temperature driven by demand from a room side thermostat.

Baseline Scenario

During the baseline assessments we observed face velocities at times significantly above 100 fpm, a practice enforced by Virginia Tech's environmental and safety division, who also monitors these levels during regular walk-through inspections. The installed fluorescent lighting system was measured to be equal to around 3.5 W/sf when switched on. The space did not have any significant equipment loads, and only an average operational plug load of around 300W was measured.

Fig. 5 shows the simulated design flow requirements for the baseline scenario as measured for this laboratory space, where average face velocities were actually kept at 100 fpm.

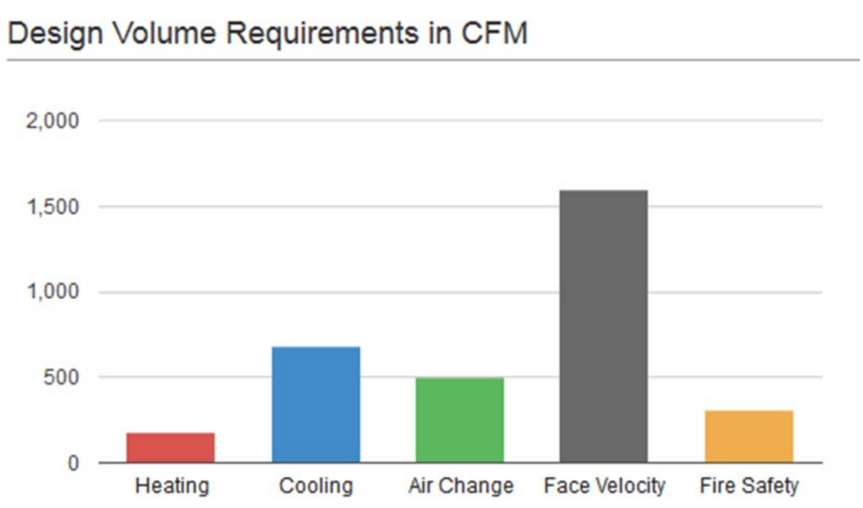

Fig. 5 Derring 5061 Baseline – Volume requirements to meet design mandates.

The various design volume rates represented in this graph are:

a) Heating: the supply volume requirement to purely compensate for the design heat losses, without any ventilation loads;

b) Cooling: the supply volume requirement to purely remove design heat gains, not including any ventilation requirements;

c) Air Change: the fresh air supply volume requirement to achieve the targeted design air changes per hour;

d) Face Velocity: the minimum exhaust volume requirement to achieve the targeted design face velocities for the installed fume hoods within the laboratory

e) Fire Safety: the minimum exhaust volume requirement to meet the numbers set forth by ANSI/AIHA Z9.5 for fire safety in fume hoods.

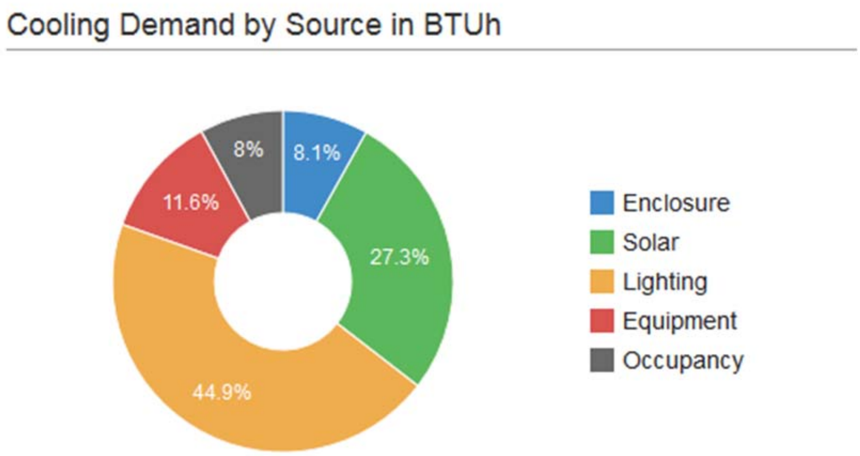

Fig. 6 Derring 5061 Baseline – Cooling loads by heat gains sources.

In this baseline scenario, face velocities were the driving factor for the required ventilation rates of this space, followed by the cooling load mandate as the second highest design volume requirement. From this pure design perspective, there seemed to be a significant potential for savings that could be tapped into by reducing the face velocity and/or reducing the net face opening area of the individual fume hoods.

When analyzing the different heat gain sources contributing to the cooling load, the most significant gains that needed to be removed for this space came from lighting loads, followed by solar gains that can entered the space through the non-shaded southern windows.

The hourly results of heat losses and gains from thermal loads, heat losses and gains from ventilation needs, and ultimately the required heating and cooling energy to compensate for losses or gains, were added into monthly bins and visualized in bar charts (Fig. 7).

The baseline scenario for DER 5061 made it obvious that the energy to remove the actual thermal loads is diminishing small and most of the energy is required for heating and cooling the makeup air ventilated through this space.

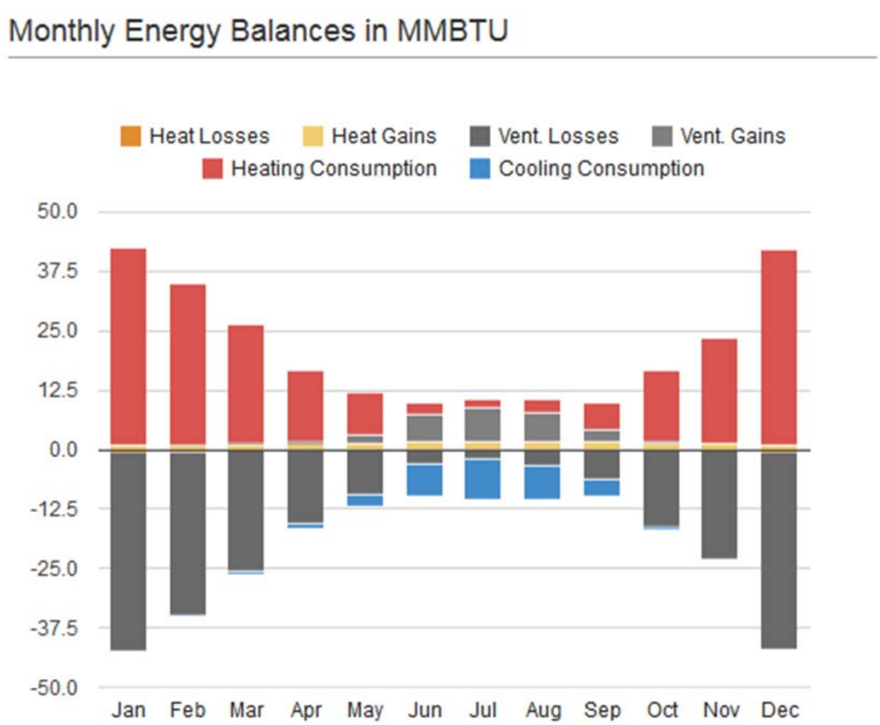

Fig. 7 Derring 5061 Baseline – monthly energy losses, gains, and consumption balances.

Though we observed times when ventilation losses (e.g. cooler outside air) could be utilized to compensate for internal heat gains, the overall consumption was heating dominated, since there were much higher temperature differentials recorded during the heating season than during the cooling season, which ultimately needed to be compensated for in the make-up supply air.

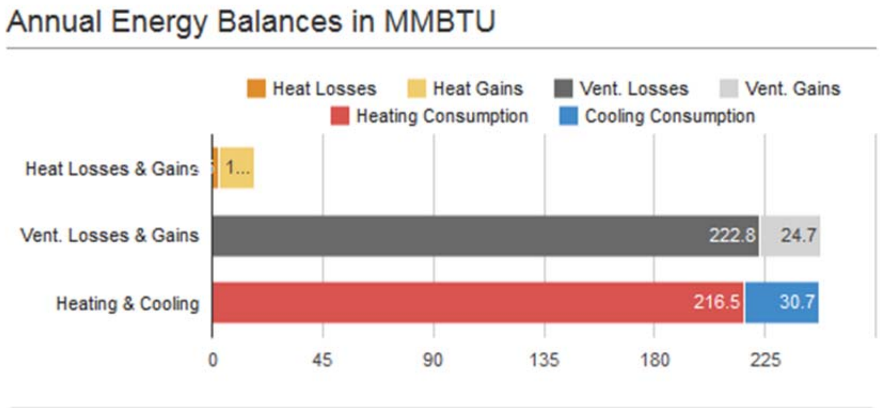

Fig. 8 Derring 5061 Baseline - Comparison of annual heating gains/losses, ventilation gains/losses and resulting heating/cooling energy consumpiton.

The spread between heating and cooling consumption became even more apparent in the annual comparison of energy loads. The annual heat gains from internal loads (14.6 MMBTU) and ventilation gains (24.7 MMBTU) was in total higher than the cooling consumption, which indicated that some of the cooling requirements were offset by ventilation losses, i.e. the introduction of colder outside air helped to meet the interior setpoint requirements. The total annual heating consumption, which mostly had to cover the ventilation losses, was by about a factor 7 higher than the total annual cooling consumption, even though the cooling load was more dominant from the design perspective. For the baseline scenario of Laboratory DER 5061 we recorded a total assessed energy consumption of 247 MMBTU.

Scenario 1 – Reduced Face Velocity

As a first alternative scenario a reduction of face velocities, closer to the lower range of OSHA recommendations was evaluated. While the baseline scenario assumed face velocities of 100 fpm, this scenario now assumed a velocity of 60 fpm. Obviously, the operational safety of such a reduction would still have to be confirmed through respective standardized tests, which were not part of this research.

In the comparison of design volume requirements we observed that the required exhaust volume resulting from the reduced face velocity had now dropped to 960 cfm. This reduction was not yet below the cooling volume requirements of 680 cfm, thus no temporary temperatures beyond the heating set point are to be expected under peak conditions.

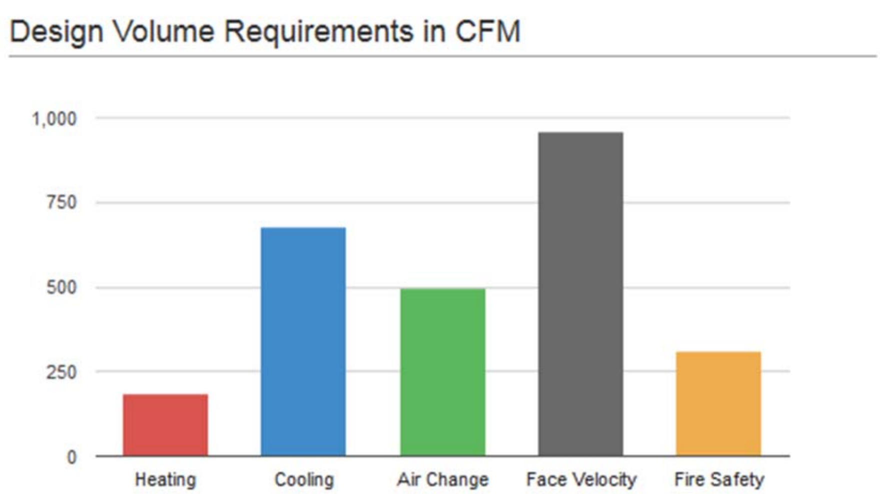

Fig. 9 Derring 5061 Scenario 1 – Design volume requirements: reduced face velocities.

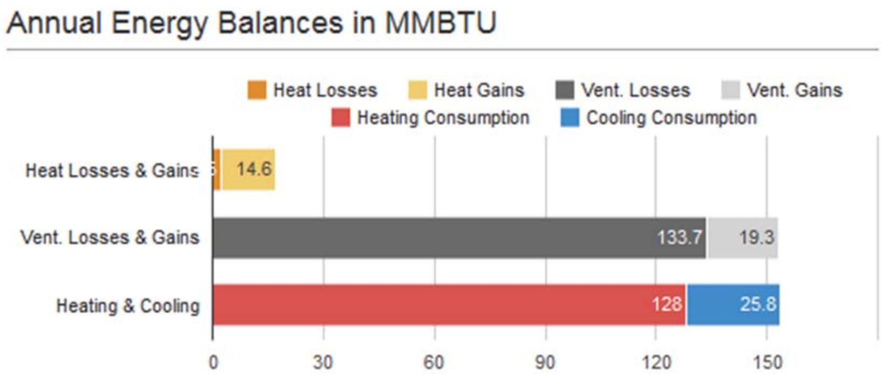

Fig. 10 Derring 5061 Scenario 1 – Comparison of annual load and consumption energy balances under lower face velocities.

Once again, the actual saving potential needed to be evaluated against an annual climate set.

Not surprisingly, this change in exhaust rates brought the annual energy consumption in this analysis down to 153.8 MMBTU, which was already a reduction of 38% compared to the consumption of the baseline scenario.

Scenario 2 – Fumehood Retrofit Kit Installation

In a next alternative scenario, the consumption savings potential of a FlowSafe retrofit kit, when applied to the fume hoods in Lab DER 5061, was evaluated. These retrofit kits reduce the maximum net open face area to 3 sf per hood, and according to the manufacturer, allow for a low flow exhaust design, where an automatically controlled baffle system ensures a stable vortex within the hood under different sash positions. Theoretically, these retrofit kits could reduce the required exhaust rate of DER 5061 to just 360 cfm.

To achieve cooling under peak design conditions, a minimum supply air flow rate of around 680 cfm would need to be provided. Consequently this means, if no other retrofit measures were pursued, the exhaust rate could not be lowered to the minimum made possible by the retrofit kit. Thus, to harvest the full potential, additional options were considered. First, a reduction of cooling peak demand was achieved by tackling the different heat gain sources. Second, a physical reduction of the lab space volume was considered, which in turn resulted in a reduction of the required air change volumes.

Evaluating the peak cooling demand loads as shown in Fig. 6 we identified the lighting load as the most significant heat gain source. Reducing the lighting load not only reduced the overall cooling and ventilation requirements, but also reduced the overall energy consumption of this space in the first place. Replacing the current lighting system with a more efficient T5 or LED system could be a viable practical implementation.

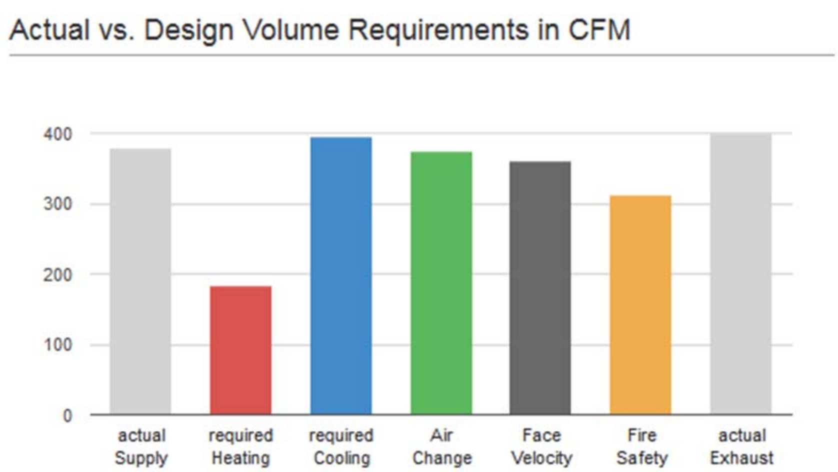

Fig. 11 Derring 5061 Scenario 2 – Design volume requirements: full retrofit.

Assuming that an air change rate of 6 changes per hour was acceptable, or otherwise a ceiling reduction would be considered, we limited the exhaust rate to 400 cfm. This change resulted in actual face velocities around 67 fpm.

In the monthly view of energy balances of this scenario the heating losses and gains from space loads now became more visible as ventilation gains and losses were reduced, specifically when compared with results from the baseline scenario as shown earlier in Fig. 7.

Overall we calculated an annual energy consumption of 65 MMBTU. This translates into a maximum energy savings potential that can be achieved with the installed retrofit kits for this space of more than 180 MMBTU or close to 75%.

Whether the required investment of installing alternative lighting and shading systems is warranted has to be evaluated separately.

Provided with this preliminary set of assessment data, building managers could now advance in decision-making and obtain estimates for remodeling cost of different applicable retrofit scenarios.

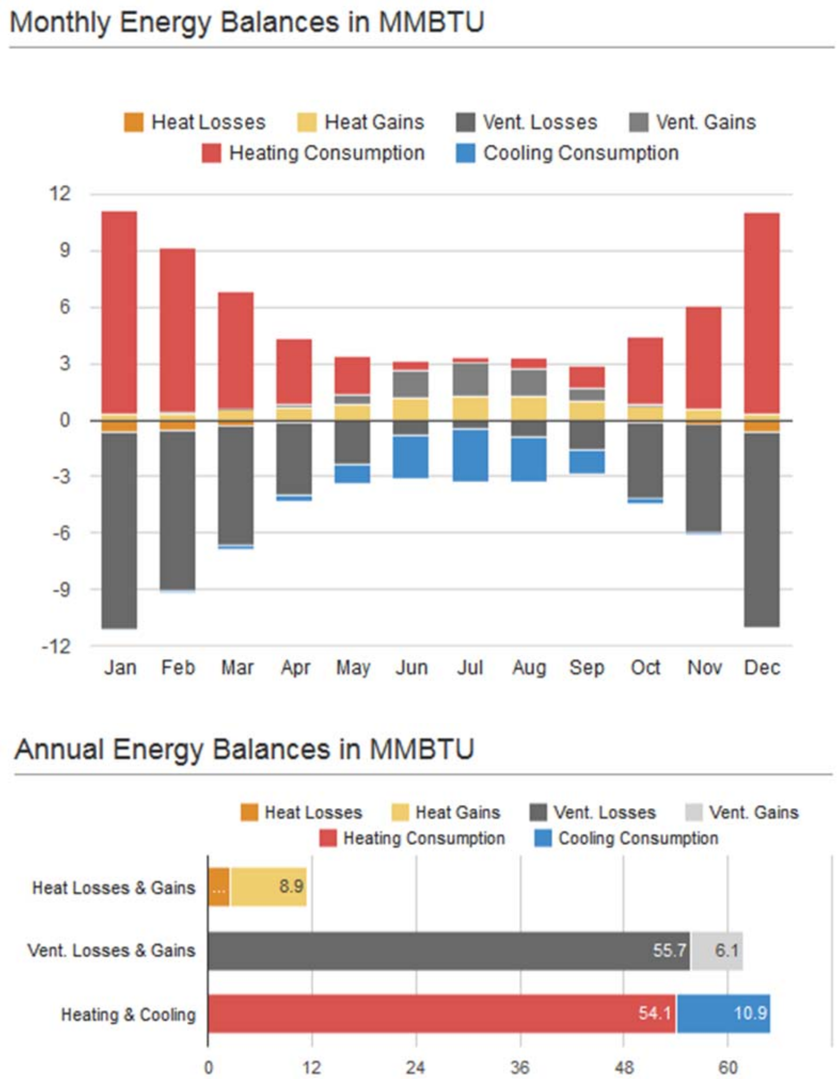

Fig. 12 Derring 5061 Scenario 2 – Monthly and annual energy balaneces after installation of retrofit kits into both fume hoods coupled with other performance improvements for the laboratory space.

Laboratory DER 5065 – The Challenge Lab

The second laboratory in Derring Hall Room 5065, which was the larger of the two labs researched in this project, was roughly 24 feet deep, 32 feet wide, and had again an interior ceiling height of 13 feet. The lab was also equipped with two 4-ft fume hoods, originally each with a maximum face opening of close to 8 sf and a net work-area of 6.25 sf. For this space 100% of the southern wall, 33% percent of the western wall, and 100% the ceiling (i.e. roof) were exposed to the exterior. The large window area in the southern wall measured 159 sf.

The space was conditioned through a duct manifold from a central air handling unit that during our measurements only delivered around 800 cfm to the space. During normal fume hood operations this left a significant air flow rate entering the space through hallway infiltration. This space regularly experienced overheating, even though there were room side shading devices installed that could be drawn during times of high solar influx.

The installed fluorescent lighting system was again measured to represent a load of 3.5 W/sf when switched on. In one side of this space there were a series of eight curing ovens installed, which contributed to a significant equipment load. We measured these ovens to have a continuous operational plug load of 2400W. Including all other plug load items, the total equipment load for this space was ultimately assessed around 3000W as a baseline. Since this laboratory was also used as a teaching lab for small groups of students, the design load occupancy rate was set to 8 people, with each person producing around 350 BTU/h of heat.

BASELINE

Fig. 13 shows the actually measured versus the calculated design flow requirements for the baseline scenario of this laboratory space. It became apparent that for this original configuration, neither the anticipated peak cooling demand was met, nor the required air change rate of 8 changes per hour was achieved. The limited cooling capacity of this configuration was well known to the regular occupants of this space, where interior temperatures in the 80ies could be observed during hot summer days.

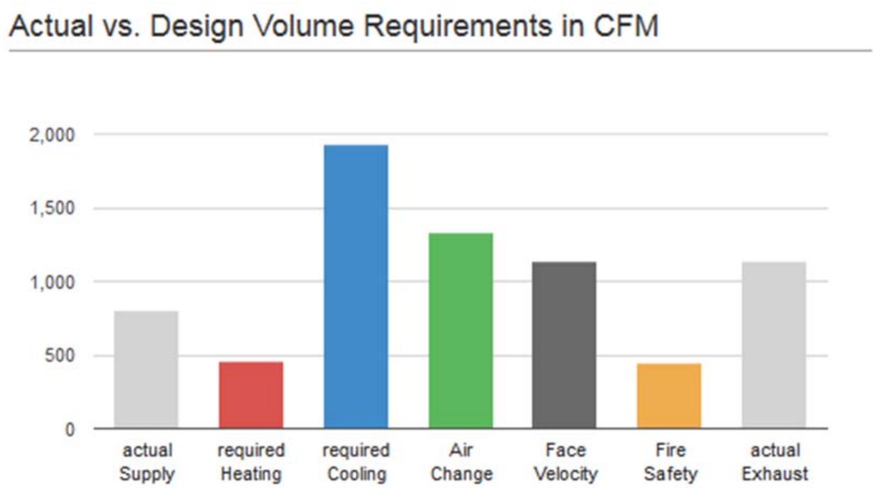

Fig. 13 Derring 5065 Baseline – Volume requirements from design mandates.

A reduced air change rate could be justified by classifying this lab as a teaching lab, which only would require an air change rate of 1.2 according to current codes.

However, the already limited cooling capacity of the current system raised some serious concerns regarding any further reductions of supply and exhaust volumes.

With the knowledge gained through this research project and the prototype version of the IDEAL decision-making tool already at hand this laboratory space could have been identified as one of the less applicable spaces for fume hood retrofit kits.

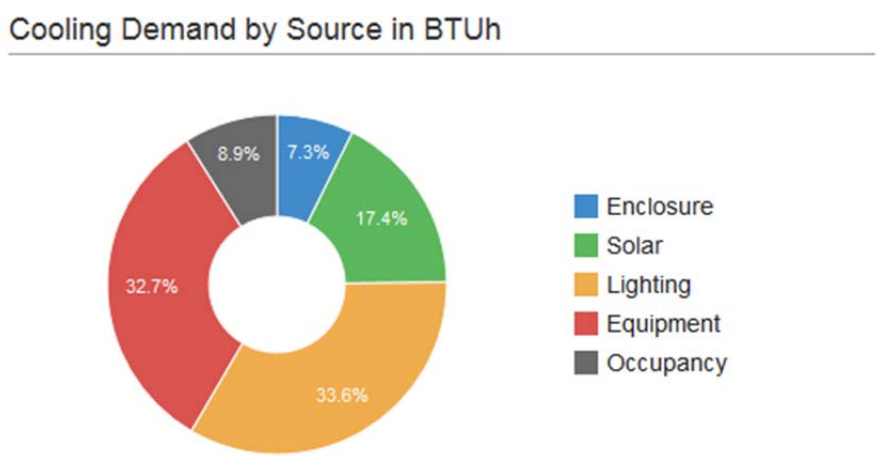

Fig. 14 Derring 5065 Baseline – Cooling load requirements by heat gains sources.

A significant contributor to the heat gains included the interior equipment installed within the space. Fig. 14 shows that these equipment loads almost matched the lighting loads, whereas lights could be shut off, while the curing ovens were operated on a continuous level.

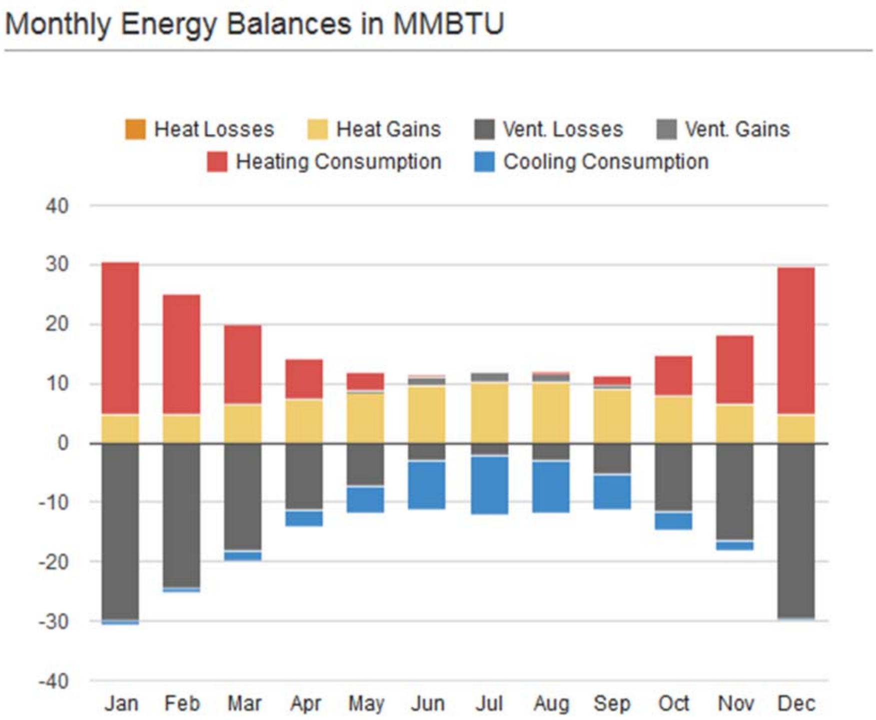

Fig. 15 Derring 5065 Baseline – monthly loads and consumptions for heating/cooling.

In Fig. 15 we can see the significant heat gains over the summer months standing out. While internal heat gains definitely reduce the actual heating demand during winter, they also contribute to the relatively high cooling demand in summer.

For this space configuration, the total annual heating consumption was still more than double as high as the total annual cooling consumption.

Another observation made for this comparatively larger laboratory space (DER 5065) was that we recorded a total energy consumption of 164 MMBTU for the baseline scenario, which was less than what we assessed for the smaller lab (DER 5061) before. The main reasons for this difference were: a) the already lower baseline ventilation rate, b) not meeting the cooling needs at peak times, c) banking on the internal gains provided by equipment loads and the lighting system, which come with their own energy consumption, and d) harvesting solar gains.

The overall energy consumption is still heating dominated, as we again have much higher temperature differentials in winter that need to be conditioned in the supply air stream.

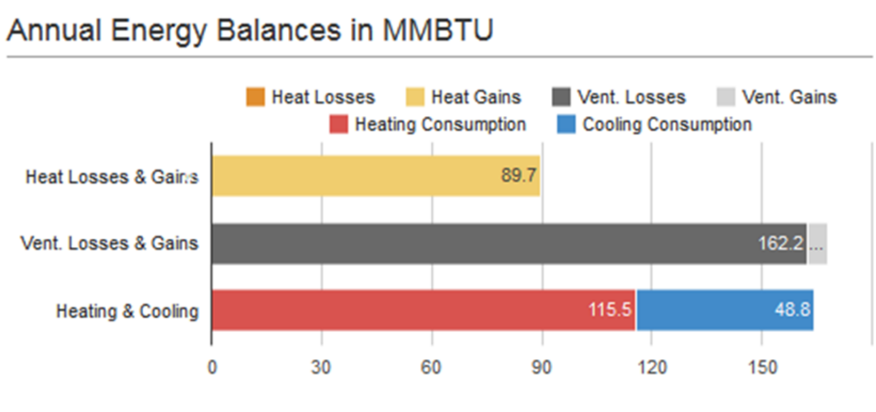

Fig. 16 Derring 5065 Baseline – Annual comparison of energy losses, gains, and systems consumption to meet heating and cooling demands.

Retrofit Scenario – Installation of FlowSafe Fume Hood Retrofit Kits

Before harvesting any of the savings potential of low flow retrofit kits for this laboratory space, significant modification had to be made to the space. Without any additional modifications, an installation of low-flow retrofit kits will not provide any annual energy savings but rather introduce additional issues that need to be addressed:

- A reduction of exhaust rates to facilitate low-flow face velocities will result in hallway exfiltration, if the supply flow rate is not reduced at the same time.
- A reduction of supply flow rate will further increase the issue of overheating since the cooling load demand cannot be met during peak times in the given HVAC configuration.
- A reduction of supply flow rate will also create issues with the required air change rate for the rather large laboratory space, unless it is specifically declared as a teaching lab, which can result in reduced requirements, if allowed by local codes.
- If exhaust rates were only partially reduced in an attempt to mitigate the above issues, a new issue arises in form of significant higher face velocities, due to the reduction in net face open area of the retrofit kits. High face velocities may introduce turbulences that could jeopardize the safe operation of these hoods.

To reduce the high demand loads the following strategies were evaluated in an attempt to increase the possible savings potential of retrofit kits installed within this space:

- The rather high equipment loads installed in one half of the space should be separated from the space where the fume hoods were installed, assuming that this separation will reduce the high ventilation requirements for the adjacent space housing the equipment.
- When introducing a separation of spaces, the space housing the fume hoods should be minimized in terms of actual required floor area, since a reduced floor area directly translates into a reduction of required air change volumes.
- A reduction of air change volume can be achieved through a suspended ceiling system.
- A suspended ceiling system would bring the lighting sources closer to the work surfaces, which in turn can reduce the required wattage of the installed system and increase the lighting efficacy.
- Reduced lighting loads will further reduce the cooling demand, and thus reduce supply ventilation requirements during peak times.

To assess this total retrofit scenario we assumed that the original space was divided into two equally sized spaces, each of which was now 16 feet wide. The window area contributing to the space housing the fume hoods was assumed to be 50% of the original area. The ceiling height was lowered to 10 feet and the lighting system load was reduced to 2.0 W/sf. The two fume hoods were retrofitted with FlowSafe low flow modification kits that reduced the open face area to 3 sf each, and allowed for safe operation with face velocities as low as 60 fpm.

The leading design flow requirement in this scenario was then the air change rate, base on 8 changes per hour as the target rate.

This design required an exhaust rate of at least 500 cfm, resulting in actual face velocities around 85 fpm. With a corresponding supply rate of 450 cfm the cooling demand could now be met even during peak hours.

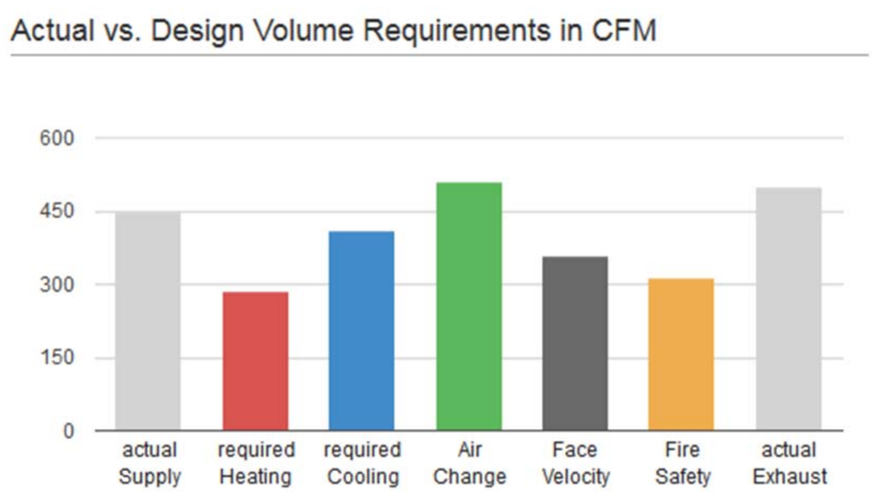

Fig. 17 Derring 5065 Retrofit Scenario – Volume requirements from design mandates

The annual energy consumption required for heating and cooling was now reduced to 70 MMBTU for heating and 18.2 MMBTU for cooling, or 88 MMBTU in total.

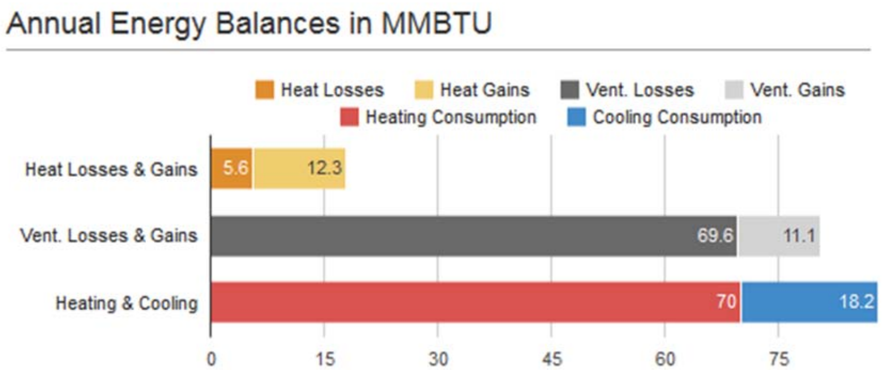

Fig. 18 Derring 5065 Retrofit Scenario – Energy balances from loads and ventilation, and required heating/cooling consumptions – New Fume Hood Lab Space.

It is important to note that a direct comparison with the baseline assessment was not valid in this case, as it would miss the additional energy consumption required to remove the heat gains that now were occurring in the adjacent space. Thus, a separate assessment of the adjacent space was carried out, for which a reduced air change rate of 4 changes per hour was assumed, while the lab would also operate with 100% outside air as make-up air. For this space the monthly loads and consumption comparison showed dominant heat gains throughout the year. While some of those heat gains helped to lower consumption rates in winter by shifting heating energy from the HVAC side to equipment circuits, the relatively high air change rates still required significant amounts of heating energy in this constant volume configuration. The annual consumption rates of this second space were assessed with 27 MMBTU for heating, and 32 MMBTU for cooling, or 59 MMBTU in total.

When comparing the combined total annual loads of the two now separated spaces with the baseline scenario of the original laboratory, we calculated a total annual consumption of 147 MMBTU, which represented an actual energy consumption reduction of only 16 MMBTU or around 10%. Admittedly, this comparison is not entirely fair since the original baseline configuration did not meet the actual thermal comfort requirements of the space (i.e. cooling load), while the remodeled configuration achieves meeting the design loads. Furthermore, the here proposed total renovation of laboratory DER 5065 would not only address the total energy consumption of the space, but ultimately remove design and comfort limitations found in the original space.

An important observation that became transparent in this comparison was the issue of high internal gains in laboratories, and how they have to be removed through the supply and exhaust system. In such scenarios the benefit of low flow fume hoods will be limited unless other methods of heat removal are applied. Some spaces could allow for adoption of variable volume systems, or space side cooling units, such as ductless mini-split systems, which can reduce peak demand from the main supply air system, assuming all other exhaust rate requirements were met.

CONCLUSION & RECOMMENDATIONS

This project successfully developed an integrated assessment and decision-making model for investigating the savings opportunities and barriers of low velocity retrofit scenarios for laboratories housing fume hoods.

Fume hoods are embedded terminal units of existing environmental systems that typically cover a variety of performance mandates, ranging from physical safety, to chemical safety, to thermal comfort, and ultimately fresh air requirements. A core finding of this project is that the environmental performance of fume hoods and any possible retrofit technology must be evaluated in their integrated function within the individual spatial systems context.

Overall, it was found that low flow fume hood systems have the potential to dramatically reduce the energy consumption of laboratory spaces, reaching savings in space conditioning of up to 75%. However, when other performance mandates are conflicting with technically achievable flow rate reductions, these savings cannot be harvested at this level. An integrated retrofit analysis is required to estimate the total savings potential of different retrofit options, such as low flow fume hoods, and what they can achieve in a given space and context.

An indicator for the possible savings potential of fume hood retrofit technologies has been found in the functional relationship of load related ventilation requirements versus safety related ventilation requirements for a laboratory space. The higher the internal heat gains contributing to the cooling load the lower the potential for deep energy savings without significant architectural and mechanical system changes. Possible steps to reduce the demand load volumes were identified as:

- Reduction of lighting load through: alternative high performance lighting systems; bringing ceiling lights closer to the work plane; introducing automated lighting systems.
- Reduction of solar gains during cooling periods, e.g. through variable shading systems.
- Reduction of the actual laboratory space volume by lowering ceiling heights and installing partition walls, resulting in lower air change volumes.

Obviously, these additional retrofit adoptions will accumulate additional cost. However, some of these changes open the door for additional, maybe even deeper savings opportunities, such as savings in primary electrical consumption. Other less tangible advantages are related to increased comfort in terms of thermal performance or visual performance.

Overall, it was found that there is no “one-size-fits-all” technology that can be utilized to retrofit laboratories with fume hoods and make them more energy efficient. Each individual space configuration and utilization must be evaluated in its specific context. The prototype of the IDEAL application developed within this project can be a first step in this process and start the conversation with building owners and other stakeholders.

The next steps will be an expansion of the IDEAL software application to allow for a wider variety of retrofit configurations, which ultimately could be combined for several laboratory spaces within larger buildings. Furthermore, it may be useful to expand the developed model with associated cost data accounting for local energy prices and retrofit investment costs.