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Toward Net-Zero Energy Labs in Northern Climate – Montreal Examples

Roland Charneux, Eng., M.Eng., LEED® AP
ASHRAE Fellow

ABSTRACT

Northern climate like the one in Montreal 4,557 DD (SI) – (8,200 DD (IMP)) presents huge challenges to the designers to reach Net-Zero Energy buildings. A large amount of the energy required is related to the heating of the outside air and the 24 hours/day, 7 days/week operation. It is not rare to be faced with labs designed a few decades ago which consumes in the order of 2150 kW-h equiv /m²-year (200 kW-h equiv /sq.ft.-year), compared to 540 kW-h equiv / m²-year (50 kW-h equiv / sq.ft.-year) and better for recent labs.

This paper presents a list of potential options to improve energy efficiency. Three laboratories are presented with the different measures that were applied in those buildings.

INTRODUCTION

The first step toward energy efficiency is to understand thoroughly the flow of energy in and out of the building. Creating an energy model at the early stage of design using an energy modeling software gives the design team the most efficient tool to take engineering-based decisions.

Integrated building design gives the opportunity to optimize the building planning and settings for energy performance and the integration of day lighting. The building's footprint can be reduced by sharing rooms and equipments between researchers and using an open labs approach. Then, the building envelope is optimized considering heating, cooling and day lighting.

In cold climate, laboratory ventilation air is the most energy demanding need. How to reduce the laboratory ventilation needs? The following paragraphs present different approaches which were successfully implemented over the years.

MINIMIZING OUTSIDE AIR

Throughout the years, constant continuous laboratory airflow ventilation has changed and many opportunities are currently available to minimize airflow requirements in the labs:

Roland Charneux is Executive Vice-President at PAGEAU MOREL, an engineering firm specialized in mechanical engineering, electrical engineering, energy efficiency and eco-design, Montreal, QC, Canada.

- The first major innovation was to use variable air exhaust for fume hoods and variable air supply in the labs, while keeping a face velocity of 100 FPM at fume hood opening.
- On the fume hood exhaust, there has been many innovations and there is a vast choice of technology available with different impact on energy use:
  - Horizontal sash
  - Combined vertical /horizontal sashes
  - Presence sensors in front of the hood to reduce face velocity (+/- 60 FPM) when there is no people in front of the fume hood.
  - Low flow fume hoods.

- With presence sensors in the labs, it is possible to reset the minimum airflow normally for three scenarios: day occupied day unoccupied and night / weekend modes. Presence sensors also control lighting. This approach was successfully implemented with ratios of 10, 6, and 3 in university labs.

- The applicability of those technologies to reduce airflow rates in labs should always be studied and applied while maintaining the safety level of the lab.

- Since the treatment of outside air is very expensive, the minimum ventilation rate should not be based on the "cooling load".

To minimize the required laboratory air make-up, using air to be exhausted from other building areas, such as offices, should be considered. Supplying air, first in office areas, then using the returning air, improves indoor air quality in offices (100% OA) while reducing the total energy demand of the building.

DIRECT HEAT RECOVERY

Now that the exhaust air and make-up air is at their minimum, we should look toward heat recovery. In order to improve recovery efficiency, having a dedicated exhaust network for fume hoods and one for general laboratory exhaust gives the opportunity to install high efficiency heat recovery (enthalpy wheel) on the general exhaust and safer heat recovery (glycol loop) on fume hood exhaust.

MINIMIZING HORSEPOWERS

With manifolding of the exhaust, ductworks can be economically sized to minimize pressure losses and high efficiency fans can be selected. Exhaust networks should be designed and separated as needed to avoid penalizing the whole network for a remote or high pressure losses exhaust point.

Systems can be designed at 350 FPM in filters and coils with variable frequency drives on motors.

INDIRECT HEAT RECOVERY

Local cooling is done with locally accessible fan coils. The heat from equipment rooms, freezer rooms, data room, electrical room, etc., is recovered through the condenser of a heat pump chiller. This low temperature hydronic loop can be used for all heating needs.

DUCTWORK EFFICIENCY

Duct design should be planned from the early stage to locate mechanical room in central location. Supply, return and exhaust ducts should be as symmetric as possible with special care to fittings and connections.

THE REDUCTION OF ELECTRICITY NEEDS

Electricity is a high level energy used for lighting and to drive motors and equipments. It should be used efficiently. All efforts should focus on having high efficiency equipments throughout the building.

ENERGY EFFICIENCY IN LABS

The energy efficiency in labs is a series of integrated measures. The following tables present a check list of applied measures in three (3) Montreal labs.

Table 1. Laboratories Description

Type of Laboratories			
	LAB #1	LAB #2	LAB #3
YEAR BUILT	1999	2004	2010-2011
TYPE	University, teaching / research	University, teaching / research	College, teaching
AREA	37,200 m² [400,000 ft²]	32,000 m² [345,000 ft²]	10,500 m² [113,000 ft²]
# OF FUME HEADS	160	250	24
ENERGY CONSUMPTION	898 kW-h / m² [83,5 kW-h / ft²]	624 kW-h / m² [58 kW-h / ft²]	215 kW-h / m² [20 kW-h / ft²]

Table 2. Energy Efficiency Measures

	Labs		
	1	2	3
ENERGY EFFICIENCY-REDUCTION			
Building Thermal Envelope Optimization with Energy modeling			✓
Ventilation rates reduction			
Zone Presence sensors//Night set back		✓	✓
Local sensible cooling: Fan coils, chilled beams		✓	✓
Indoor Air Quality sensors			
Decoupling of ventilation and cooling loads (fan coils; chilled beams)			
Interior / exterior light shelves			
Day lighting with controls of artificial lighting			✓
Dimming ballast			✓
High Efficiency lighting(fixtures and sources)			✓

	Labs		
	1	2	3
White ceiling / pale color walls and floor			✓
Zone Presence sensors controlling lighting and air flow setback		✓	✓
High Efficiency electrical transformers		✓	✓
Premium efficiency motors		✓	✓
Exhaust fans arrangements: paralleling, grouping, etc.	✓	✓	✓
High efficiency fan selection			
Select for maximal efficiency at most probable operating condition	✓	✓	✓
High efficiency pumps selection			
Select for maximal efficiency at most probable operating condition	✓	✓	✓
Static pressure reduction			
Low velocity HVAC Units			✓
High Efficiency duct fittings (low pressure losses)			✓
High Efficiency equipment		✓	✓
Direct driven fans		✓	✓
VAV systems with Variable frequency drives		✓	✓
More vertical shafts and fewer horizontal ducts	✓	✓	✓
Dedicated fans for high static pressure zones			✓
Free cooling (Water side)			
Outside air pre-heating			
Cooling tower free-cooling			
Recycle non-lab air as Labs make-up air	✓	✓	✓
Separate low- and high-temperature cooling loops		✓	✓
Locate Air returns above heat producing equipment		✓	✓
High performance, low flow fume hoods			
Horizontal sash fume hoods			
Limited height vertical sash opening (sash stops)		✓	✓

	Labs		
	1	2	3
Radiant hydronic heating / cooling concrete slabs			✓
Variable exhaust stack geometry to maintain constant velocity exhaust			
Booster fan on high static equipment exhaust			✓
CO_2 sensors and demand controlled ventilation in densely occupied spaces		✓	✓
Optimized design criteria (temp, RH, noise level)	✓	✓	✓
Tightly sealed ductwork	✓	✓	✓
Low pressure loss filters			✓
Timers on canopy hood exhaust		✓	✓
Use high delta "T" on water networks		✓	✓
ENERGY EFFICIENCY-RECOVERY			
Separate Fume hood exhaust and general exhaust			✓
Enthalpy "total energy" Heat recovery on general exhaust			✓
Condensing boilers		✓	✓
Chillers' condensers heat recovery		✓	✓
Exhaust air heat recovery		✓	✓
Heat pump chillers		✓	✓
Chilled water cooling for energy recovery from:			
Electrical rooms		✓	✓
Equipment rooms		✓	✓
Refrigerator rooms		✓	✓
Cold rooms compressors		✓	✓
Computer rooms		✓	✓
High efficiency frost-free alternate flow heat recovery device on general exhaust			✓
ENERGY EFFICIENCY SOURCE			
Recover excess heat rejected from an adjacent building		✓	
Low-Temperature Water Heating Loop		✓	✓

	Labs		
	1	2	3
Heat Recovery Chillers / Heat Pumps		✓	✓
Condensing Boilers		✓	✓
Direct contact boilers		✓	
Low Temperature Water Heating Loop for:			
Pre-heating outside air		✓	✓
Adiabatic humidification		✓	
Pre-heating domestic hot water		✓	
Peak load management			
Thermal energy storage			✓
Full modulation of boilers' burners			✓
Variable speed chillers			
Condenser water temperature reset		✓	✓
Ground source heat pump			✓
ENERGY EFFICIENCY-CONTROLS			
Night air flow reduction / setback		✓	✓
Local alarm reminder to close the fume hood sashes		✓	
Peak load management		✓	
Static Pressure setpoint reset			
Watchdogs from EMCS system for all exhausts		✓	
ENERGY EFFICIENCY CONTROLS | CONTINUOUS COMMISSIONING			
Continuous airflow tracking		✓	
Post occupancy performance verification		✓	✓
Annual verification of pressure set point		✓	
WATER EFFICIENCY			
Rain water collection cistern			✓

	Labs		
	1	2	3
Process cooling water loop		✓	
Central or local vacuum pumps to reduce potable water use		✓	✓
Cooling coils condensate recovery:			
To feed cooling towers			✓
To flush toilets			
To cool exhaust with evaporative cooling and improve heat recovery efficiency			✓
Low flow plumbing fixtures			
Dual flush toilets			✓
Electronically activated faucets and flush valves			✓
Waterless urinals			
Reverse osmosis reject water recovery			✓

CONCLUSION

As shown in this paper, special efforts have been put in laboratory design in the past decade so as to reduce their energy consumption.

Since the conditioning of the needed ventilation air is the greatest energy consumer, decoupling laboratories cooling needs and ventilation needs will ensure additional energy saving opportunities.

A better understanding of the risks associated with laboratories activities and the requested ventilation to minimize those risks will need additional research.

Design tools and technologies are available on the market to continue improving the labs energy efficiency. The decreasing costs of local renewable thermal and electric energy sources will permit to further reduce laboratories' consumption.

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