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The Potential for Residential Demand Controlled Ventilation

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Synopsis

A literature search was performed to gain as much knowledge as was available on ventilation, indoor air quality sensors and demand controlled ventilation (DCV) strategies. Field data was gathered on the time and spatial variation of indoor air quality in houses.

Appropriate designs were then developed. Design strategies are discussed elsewhere (1). Hour by hour simulations of the performance of several ventilation systems in various Canadian climates were done. Energy savings were then estimated for DCV and heat recovery ventilation with air to air heat exchange. These were compared to a base case of continuous exhaust ventilation. All systems utilized air recirculation.

Introduction

Demand Controlled Ventilation (DCV) is the control of ventilation air supply rates to the minimal rate required to control indoor air quality. These systems can reduce energy requirements and/or improve indoor air quality. The designs examined in this study are orientated primarily toward energy efficiency.

Analysis Technique

An hour-by-hour multi-zone thermal simulation program ENERPASS (2) was combined with the National Institute of Standards and Technology contaminant simulation program CONTAM87 (3). This new program ENERPASS/CONTAM was used to estimate energy use and carbon dioxide concentrations for various systems in various locations. The program allowed the ventilation system airflow to be controlled as a function of pollutant concentration. Because the two programs had to pass data between them, execution time was slow at 7 to 10 minutes per day of simulation on an IBM AT compatible with math coprocessor. Most of the annual energy performance results were projected based on simulations of January to March weather data. Fifty percent of the space heating was found to occur in this period. Results were extrapolated to annual savings from the base case.

Simulations were performed for Vancouver, Winnipeg and Toronto for a base case of continuous mechanical exhaust only ventilation, continuous balanced flow heat recovery ventilation, and DCV using carbon dioxide as the control parameter. See Tables 1 and 2. Some demand controlled heat recovery ventilation systems were also simulated. Simulations were performed with three and six occupants. Canada has an average of 2.9 occupants per dwelling. Two demand control modes were simulated - match peak and match average. The match average mode consisted of performing multiple runs to find the carbon dioxide setpoint that would result in the same heating season average carbon dioxide concentration as the base case. Similarly, for the match peak mode of control, multiple runs were carried out to find the set point which matched DCV peak concentrations with those of the non-DCV base case. It is assumed that acceptable CO2 levels lie in this range. A DCV system with matched average CO2 is a conservative comparison which results in an indoor environment with the same average CO2 levels but reduced peaks - a more comfortable environment than continuous ventilation. A matched peak mode allows the DCV system to achieve significantly greater cost savings by reducing ventilation at all times, except during periods with highest pollutant activity or occupancy.

Results

All houses simulated were assumed to have relatively large air recirculation systems. Air recirculation within dwelling units reduces the local concentration of occupant generated pollutants and thus reduces the amount of ventilation required. This would not be true in conventional housing with high building generated pollutants.

The house is a bungalow with full basement and 123 m2 per floor. Fan capacities and other information is in Tables 1 and 2. Electrical fan energy savings were assumed to be 25%. Field trials (1) showed non-optimized savings of 23 and 24% suggesting more was possible. The simulations performed were for houses that were sufficiently airtight to benefit from controlled ventilation. All houses were run using a 0.1 air changes per hour natural air leakage rate. This corresponds to houses with equivalent sharp edged orifice sizes at 10 Pascals pressure of 200 cm2 in Vancouver, 170 cm2 in Toronto, and 150 cm2 in Winnipeg.

Simulated carbon dioxide levels are shown in Figure 1, for continuous fan (base case) versus match average and match peak DCV control modes. The results are for two days one being a weekend day with higher occupancy.

Simulation results are presented in the following figures and tables. DCV rates were reduced by about 25% for match peak mode and 10% for match average from a base case level of 0.32 air changes per hour.

With DCV was able to save 9.6 Gj/yr (Vancouver) to 15.7 Gj/yr (Winnipeg). Based on local energy prices the savings were from $46 (Vancouver) to $69 (Toronto) per year. With a ten year system life, these savings could translate into an allowable economic investment opportunity of $460 to $690. These savings are about the same as current heat recovery ventilation using air to air heat exchange.

The matched average CO2 case demonstrates that DCV can improve comfort by reducing the peaks in concentration and still provide some savings. Savings ranged from $19 per year (Vancouver) to $37 per year (Toronto) translating into an allowable economic 10 year investment of $190 to $370. All space heating energy was costed as natural gas. Electrical space heating energy savings would be about double.

The DCV system as modelled would require 22 L/s more capacity than the continuous exhaust fan, wiring from a sensor in the recirculation system to a controller and a controller. Potential exists for lowering the cost of DCV controllers by integration with thermostat and home security functions.

A factor which became apparent during economic analysis is the importance of efficient fans. While the amount of energy was not large, the dollar value of fan energy became quite significant due to the disparity between natural gas and electricity rates.

For comparison purposes, a number of simulations were performed with heat recovery ventilation. Higher efficiency runs used values of about 70% heat recovery effectiveness depending upon outside temperature while lower efficiency runs used 50% without a temperature dependence.

Conclusions

The scenario examined for DCV potential is as follows; Building related pollutants such as formaldehyde are minimized, the pollutants resulting from events such as showers and cooking are removed (1), and occupant related pollutants as indicated by carbon dioxide concentration dominates the indoor pollution load. The dwellings were also assumed to be tight enough to avoid excessive air leakage. Air recirculation was then used as a mechanism to dilute occupant related pollutants. If this scenario is satisfied, it was estimated that there is a good opportunity for the reduction of ventilation air flow by demand control. DCV can use measurements of carbon dioxide concentration to control air flow rates.

Demand controlled ventilation has the potential to reduce ventilation energy consumption by about the same amount as typical heat recovery ventilators. Although the energy efficiency of heat recovery systems could be improved, demand controllers have more potential for cost reduction. Further field demonstration should be undertaken to improve the understanding of the performance of these systems.

References

(1) Moffatt, S., Moffatt, P. "A Demonstration of Low Cost DCV Technology on Five Canadian Houses" 12th AIVC Conference, Ottawa, 1991.

(2) Enermodal Engineering, "Enerpass Version 3.0" Waterloo, Ontario, 1990.

(3) Axley, J. "Progress Toward a General Analytical Method for Predicting Indoor Air Pollution in Buildings" IAQ Modelling phase III report. NBSIR 88-3814. Washington, National Institute for Science and Technology.

Figure 1 CO_2 Comparison - 3 Simulation Scenarios

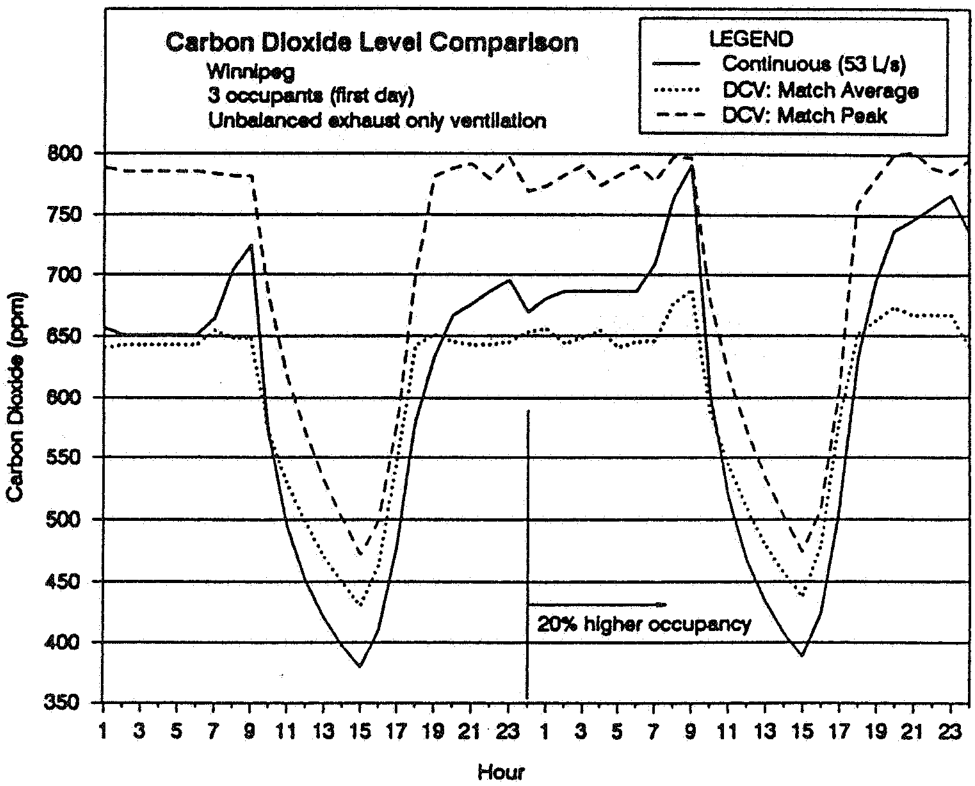

Figure 2 Comparison of DCV and HRV for Vancouver

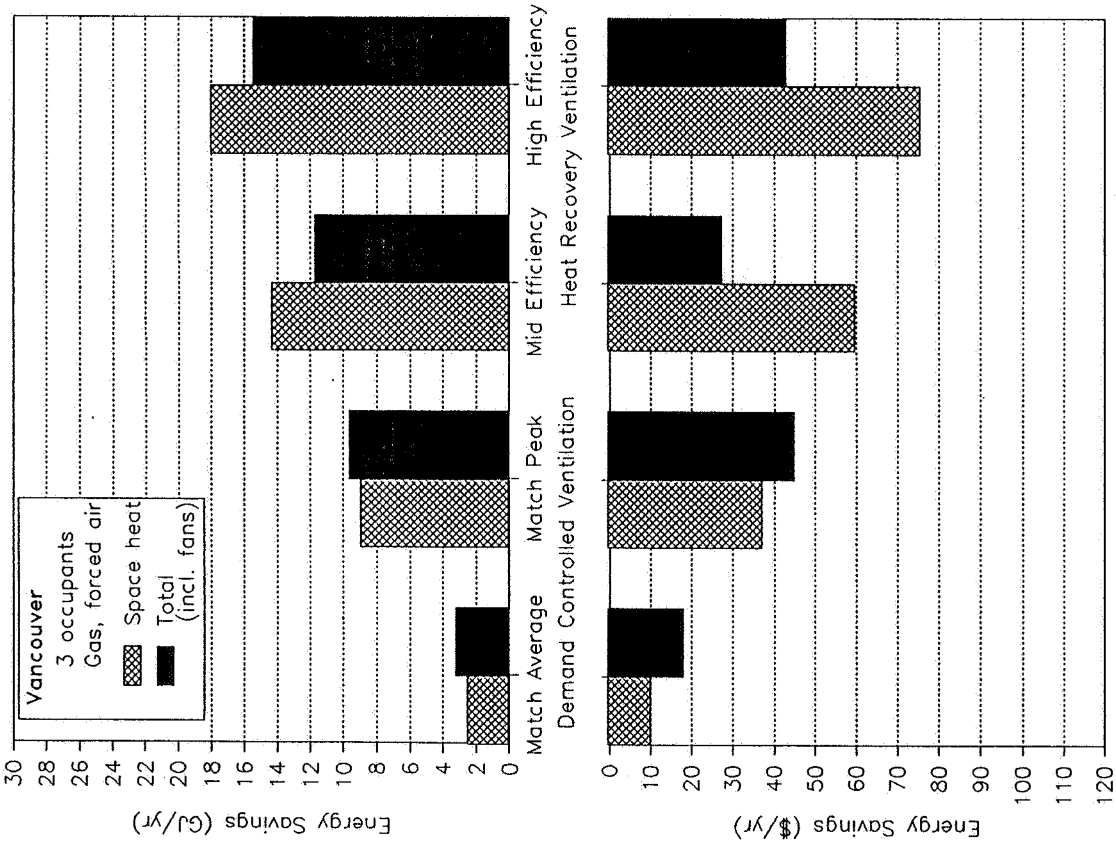

Figure 4 **Comparison of DCV and HRV for Toronto**

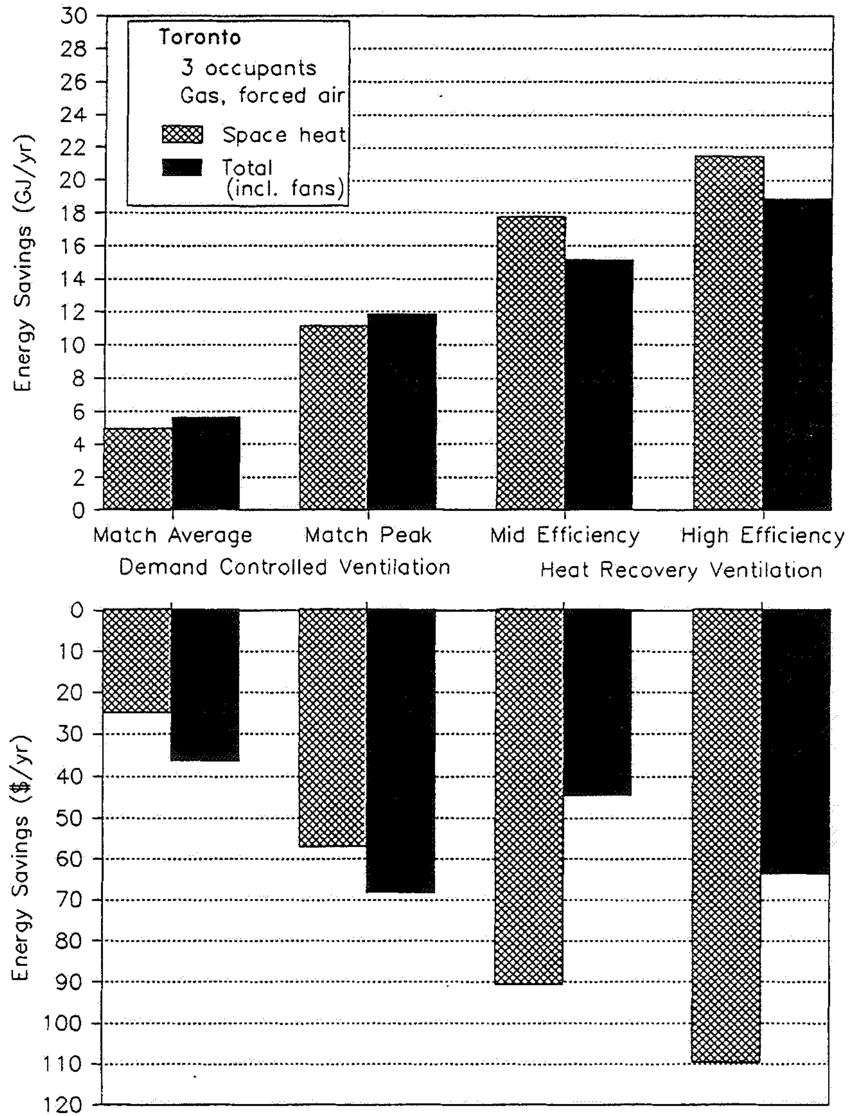

Figure 3 **Comparison of DCV and HRV for Winnipeg**

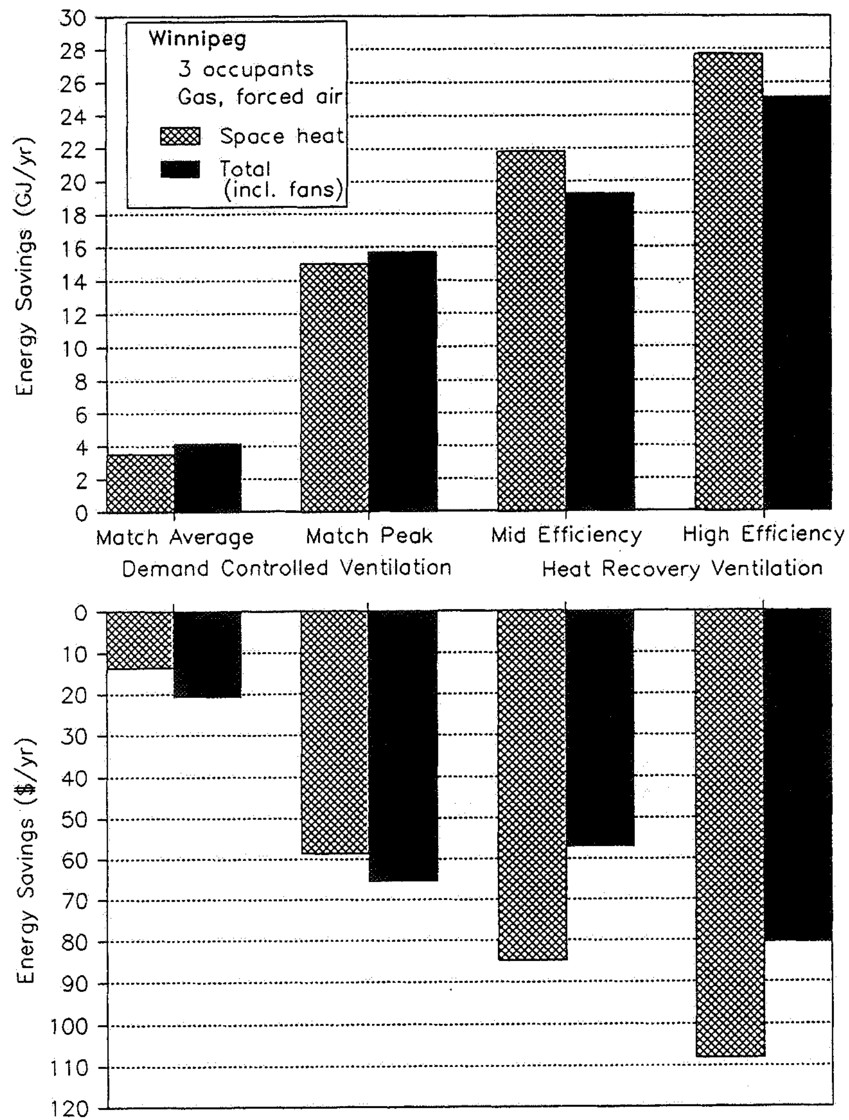

Table 1 **Simulation Results**

Gas forced air heating, 3 occupants

VANCOUVER:			BASE (continuous exhaust fan)			
	Fan Capacity	(L/s)	53			
	Ventilation + Infiltration	(ach)	0.32			
	CO2 - average	(ppm)	571			
	- maximum	(ppm)	802			
	Space Heat Energy	(GJ/yr)	59.5			
	Ventilation Fan Energy	(GJ/yr)	2.6			
			DCV:		Continuous HRV:	
			Match avg.	Match peak	low effic.	high effic.
	Fan Capacity	(L/s)	25/75	25/75		
	Ventilation + Infiltration	(ach)	0.30	0.23	0.31	0.31
	CO2 set-point	(ppm)	655	790		
	CO2 - average	(ppm)	574	659	589	589
	- maximum	(ppm)	694	804	835	835
	Space Heat savings	(GJ/yr)	2.5	8.9	14.3	18
	Fan savings*	(GJ/yr)	0.7	0.7	-2.6	-2.6
	TOTAL DCV SAVINGS	(GJ/yr)	3.2	9.6	11.7	15.4
		($/yr)	$18.60	$45.55	$27.89	$43.47
TORONTO:			BASE (continuous exhaust fan)			
	Fan Capacity	(L/s)	53			
	Ventilation + Infiltration	(ach)	0.32			
	CO2 - average	(ppm)	571			
	- maximum	(ppm)	802			
	Space Heat Energy	(GJ/yr)	82.0			
	Ventilation Fan Energy	(GJ/yr)	2.6			
			DCV:		Continuous HRV:	
			Match avg.	Match peak	low effic.	high effic.
	Fan Capacity	(L/s)	25/75	25/75		
	Ventilation + Infiltration	(ach)	0.29	0.24	0.31	0.31
	CO2 set-point	(ppm)	645	770		
	CO2 - average	(ppm)	560	695	589	589
	- maximum	(ppm)	658	801	835	835
	Space Heat savings	(GJ/yr)	4.9	11.1	17.7	21.4
	Fan savings*	(GJ/yr)	0.7	0.7	-2.6	-2.6
	TOTAL DCV SAVINGS	(GJ/yr)	5.6	11.8	15.1	18.8
		($/yr)	$36.66	$68.66	$44.94	$63.94
WINNIPEG:			BASE (continuous exhaust fan)			
	Fan Capacity	(L/s)	53			
	Ventilation + Infiltration	(ach)	0.32			
	CO2 - average	(ppm)	571			
	- maximum	(ppm)	802			
	Space Heat Energy	(GJ/yr)	112.6			
	Ventilation Fan Energy	(GJ/yr)	2.6			
			DCV:		Continuous HRV:	
			Match avg.	Match peak	low effic.	high effic.
	Fan Capacity	(L/s)	25/75	25/75		
	Ventilation + Infiltration	(ach)	0.29	0.23	0.31	0.31
	CO2 set-point	(ppm)	645	790		
	CO2 - average	(ppm)	562	707	589	589
	- maximum	(ppm)	655	823	835	835
	Space Heat savings	(GJ/yr)	3.5	15.0	21.8	27.7
	Fan savings*	(GJ/yr)	0.7	0.7	-2.6	-2.6
	TOTAL DCV SAVINGS	(GJ/yr)	4.2	15.7	19.2	25.1
		($/yr)	$20.69	$65.58	$57.16	$80.52

*based on 25% off-time

Table 2 **DCV Simulation Results**

Gas forced air heating

VANCOUVER:			Exhaust Fan		HRV	
	Occupants:		3	6	3	6
Continuous	Fan Capacity	(L/s)	53	53	39	
(base case)	Ventilation + Infiltration	(ach)	0.32	0.32	0.31	
	CO2 - average	(ppm)	571	816	589	
	- maximum	(ppm)	802	1276	835	
	Space Heat Energy	(GJ/yr)	59.5	49.7	41.5	
	Ventilation Fan Energy	(GJ/yr)	2.6	2.6	5.2	
Demand						
Controlled:	Fan Capacity	(L/s)	25/75	25/75	19/57	
(match avg.)	Ventilation + Infiltration	(ach)	0.30	0.29	0.31	
	CO2 set-point	(ppm)	655	995	675	
	CO2 - average	(ppm)	574	823	581	
	- maximum	(ppm)	694	1066	726	
	Space Heat savings	(GJ/yr)	2.5	2.6	0.3	
	Fan savings*	(GJ/yr)	0.7	0.7	1.3	
	TOTAL DCV SAVINGS	(GJ/yr)	3.2	3.3	1.6	
		($/yr)	$18.60	$19.19	$17.35	

TORONTO:			Exhaust Fan		HRV	
	Occupants:		3	6	3	6
Continuous	Fan Capacity	(L/s)	53	53	39	39
(base case)	Ventilation + Infiltration	(ach)	0.32	0.32	0.31	0.31
	CO2 - average	(ppm)	571	816	589	851
	- maximum	(ppm)	802	1276	835	1339
	Space Heat Energy	(GJ/yr)	82.0	73.3	60.6	52.2
	Ventilation Fan Energy	(GJ/yr)	2.6	2.6	5.2	5.2
Demand						
Controlled:	Fan Capacity	(L/s)	25/75	25/75	19/57	19/57
(match avg.)	Ventilation + Infiltration	(ach)	0.29	0.28	0.29	0.3
	CO2 set-point	(ppm)	645	995	675	1025
	CO2 - average	(ppm)	560	818	581	837
	- maximum	(ppm)	658	1025	726	1127
	Space Heat savings	(GJ/yr)	4.9	5.8	-0.1	0.3
	Fan savings*	(GJ/yr)	0.7	0.7	1.3	1.3
	TOTAL DCV SAVINGS	(GJ/yr)	5.6	6.5	1.2	1.6
		($/yr)	$36.66	$41.37	$22.67	$24.64
Demand						
Controlled:	Fan Capacity	(L/s)			25/75	
	Ventilation + Infiltration	(ach)			0.20	
	CO2 set-point	(ppm)			1000	
	CO2 - average	(ppm)			797	
	- maximum	(ppm)			1005	
	Space Heat savings	(GJ/yr)			5.1	
	Fan savings*	(GJ/yr)			1.4	
	TOTAL DCV SAVINGS	(GJ/yr)			6.5	
		($/yr)			$50.59	

*based on 25% off-time

DCV Simulation Results

Gas forced air heating

WINNIPEG:			Exhaust Fan		HRV
	Occupants:		3	6	3
Continuous	Fan Capacity	(L/s)	53	53	39
(base case)	Ventilation + Infiltration	(ach)	0.32	0.32	0.31
	CO2 - average	(ppm)	571	816	589
	- maximum	(ppm)	802	1276	835
	Space Heat Energy	(GJ/yr)	112.6	103.7	86.1
	Ventilation Fan Energy	(GJ/yr)	2.6	2.6	5.2
Demand					
Controlled:	Fan Capacity	(L/s)	25/75	25/75	19/57
(match avg.)	Ventilation + Infiltration	(ach)	0.30	0.29	0.31
	CO2 set-point	(ppm)	645	995	675
	CO2 - average	(ppm)	562	823	593
	- maximum	(ppm)	655	1066	735
	Space Heat savings	(GJ/yr)	3.5	4.8	1.4
	Fan savings*	(GJ/yr)	0.7	0.7	1.3
	TOTAL DCV SAVINGS	(GJ/yr)	4.2	5.4	2.7
		($/yr)	$20.69	$25.55	$12.78
Demand					
Controlled:	Fan Capacity	(L/s)	25/75		
	Ventilation + Infiltration	(ach)	0.28		
	CO2 set-point	(ppm)	675		
	CO2 - average	(ppm)	585		
	- maximum	(ppm)	700		
	Space Heat savings	(GJ/yr)	6.6		
	Fan savings*	(GJ/yr)	0.7		
	TOTAL DCV SAVINGS	(GJ/yr)	7.2		
		($/yr)	$32.53		
Demand					
Controlled:	Fan Capacity	(L/s)	25/75		
	Ventilation + Infiltration	(ach)	0.18		
	CO2 set-point	(ppm)	1000		
	CO2 - average	(ppm)	830		
	- maximum	(ppm)	1004		
	Space Heat savings	(GJ/yr)	20.5		
	Fan savings*	(GJ/yr)	0.7		
	TOTAL DCV SAVINGS	(GJ/yr)	21.2		
		($/yr)	$87.06		

Acknowledgements

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