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INTRODUCTION

Passive House has gained significant momentum in North America recently particularly in multi-family residential projects. The documented energy performance that Passive House projects deliver is attractive to policy makers and owners who are looking for real world results.

What makes a Passive House project work is the focus on building envelope thermal and leakage performance. The buildings are so well insulated and air tight that they behave differently than conventional buildings in several ways. One outcome is that multifamily residential buildings have high humidity issues in winter. This Technical Building will study the issue in detail.

BACKGROUND

CERTIFIED COMPONENT
Passive House Institute

Passive House projects are tested to ensure the infiltration rate is less than 0.05 cfm/ft^2 (0.254(l/s)/m2) at 0.2 inches w.c. (50Pa) (ASHRAE Std 90.1 requires 0.18 cfm/ft^2 (0.914(l/s)/m2) at 0.2 inches w.c. (50Pa)). Passive House projects also rely heavily on Dedicated Outdoor Air Systems (DOAS) to introduce ventilation air and maintain a healthy environment. DOAS units used in Passive House projects have very high performance and are Passive House certified.

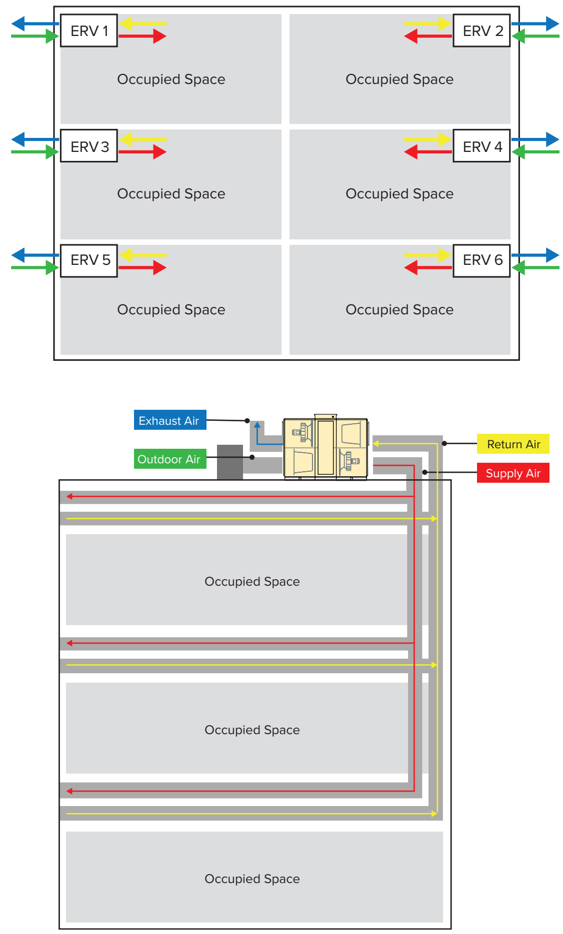


Figure 1 – Passive House Certified Centralized DOAS unit

Figure 2 – Passive House Certified Decentralized DOAS unit

Figure 3 – Centralized vs. Decentralized DOAS Systems

For multi-family residential projects, the DOAS systems can be centralized (serve multiple apartments) or decentralized (serve a single apartment). Figure 3 shows centralized and decentralized DOAS systems. There are pros and cons to both systems, so the right selection will depend on the application.

Table 1 – Advantages of Centralized and Decentralized DOAS Systems

CENTRALIZED	DECENTRALIZED
Maintenance in control of building owner	Operating cost and maintenance is in tenants control
Far fewer envelope penetrations (pressure testing)	No common area duct runs
Generally more efficient (Fans, energy recovery device) DOAS units	Minimal fire damper issues
Equipment noise away from tenants – easier to attenuate	No Common mechanical room requirement – space savings
Doesn't use up apartment space	Cost advantage - depends
Cost advantage - depends	

WINTER HUMIDITY ISSUES

The Passive House building envelope is so tight that it traps humidity generated in the building. For multifamily residential where there are many humidity sources, the humidity can climb to the point where the space is uncomfortable, and condensation can form on windows (see Table 2). This can damage the building and lead to mold.

WINTER HUMIDITY LOADS IN MULTIFAMILY BUILDINGS

Table 2 – Condensation Formation

If the outside temperature is:		Then condensation will occur on the inner glass surface if the interior relative humidity rises above:	
°C	**°F**	**Double Glazed Windows % of Humidity**	**Triple Glazed Windows % of Humidity**
-40	-40	25	36
-35	-35	28	39
-28	-20	33	44
-23	-12	38	48
-18	0	44	53
-12	10	50	63
-7	20	57	67
-1	30	63	72
*Room air temperature at 21°C (70°F)			

To understand winter humidity levels in Passive House multifamily projects it is necessary to estimate the moisture sources. Some guidance can be found in ASHRAE Standard 160 – ***Criteria for Moisture-Control Design Analysis in Buildings.*** For this paper, moisture loads were estimated based data from Minnesota Extension Service, University of Minnesota and shown in Table 3.

Table 3 – Apartment Moisture Load

Source	Pints	Grains
5 minute shower	0.5	3650
Indoor drying of clothes	4-6/load	29225-43840/load
5-7 house plants	1/day	7300/day
Washing dishes (dinner, family of 4)	0.7	5100
Cooking (dinner, family of 4)	1.2 (1.5 with gas top)	8770 (10950 with gas top)
Respiration/perspiration	0.4/hr	3040/hr
Evaporation, new construction materials	10+/day	73000+/day
1 cord green firewood, stored indoors 6 months	400-800	2.9M-5.8M

The building will naturally dry itself out by the introduction of outdoor air which has a lower humidity ratio that the space. Outdoor air will enter the building through infiltration and the DOAS system (ventilation air). Infiltration in Passive House projects is less than 1/3 of ASHRAE Std 90.1 requirements due to the great care in envelope design and construction. The low infiltration traps the moisture in the building. This is one of the main reasons that Passive House projects behave so much differently than conventional buildings.

DOAS systems for Passive House projects have efficient energy recovery systems to recover as much energy as possible. The energy recovery can be either sensible (heat only) or Enthalpy (heat plus moisture). Sensible only systems will recover the heat but let the moisture in the building escape thus drying out the space. Enthalpy systems will recover the heat and keep a large portion of the moisture in the space. Enthalpy recovery is advantageous in the summer as a form of dehumidification but in winter applications, enthalpy systems can trap some of the moisture in the building.

BUILDING SCENARIOS

To illustrate the issue regarding high humidity, a high and low-density apartment located in New York City will be considered. Each apartment type will be modeled with;

- Passive House and ASHRAE Std 90.1 infiltration rates
- Centralized and decentralized DOAS systems
- Sensible and Enthalpy based energy recovery in the DOAS unit

Table 4 –Apartment Properties

	Area (ft^2)	Bedrooms	Bathrooms	Laundry	Ventilation Rate cfm)	Std 90.1 Infiltration Rate (cfm)	PH Infiltration Rate (cfm)
High Density Apartment	952	3	2	Common Area	85	72	20
Low Density Apartment	853	2	2	In apartment	85	141	39

Table 5 –Apartment Moisture Loads (gr/h)

	Cooking	Washing Dishes	Shower	People	Total
High Density Apartment	8770	5100	7300	12,160	59.1 gr/lb
Low Density Apartment	8770	5100	3650	9,120	52.7 gr/lb

MOISTURE SOURCES

Table 5 shows the moisture generating loads in grains for both the high and low-density apartment over the course of an hour at the end of the day and through dinner. The total loads are given in gr/lb which considers the volume of the apartment.

DEHUMIDIFICATION

The ventilation and infiltration rates are given in Table 4 for both apartments types. Permeation is ignored as it a small number relative to infiltration. For the enthalpy DOAS units the latent efficiency is 79%.

RESULTS

Table 6 –Humidity Level Results for High and Low Density Apartments

Scenario	Density	Ventilation	Std.	Sensible vs. Total	New Relative Humidity at 72F (%)
1	High	Decentralized	90.1	Sensible	50.5
				Total	59
			PH	Sensible	56.5
				Total	65.7
1	High	Centralized	90.1	Sensible	50.5
				Total	56.5
			PH	Sensible	56.5
				Total	63.6
2	Low	Decentralized	90.1	Sensible	31.9
				Total	42
			PH	Sensible	47.2
				Total	56.5
2	Low	Centralized	90.1	Sensible	31.9
				Total	39.5
			PH	Sensible	47.2
				Total	53.9

Table 6 shows the expected humidity levels in each apartment type for the various scenarios. The worst case occurs with high density Passive House apartments using decentralized DOAS systems with enthalpy energy recovery. Things that can be learned are;

- Tight Passive House construction can cause moisture to build up even in winter
- While enthalpy based energy recovery is very important in summer, it can cause the moisture to stay trapped in the building in winter. Sensible only units will dry the space out more quickly in winter months.
- The diversity that comes from centralized ventilation can help remove the moisture more quickly than decentralized (apartment) DOAS units.

ENERGY IMPACT OF SENSIBLE VS. ENTHALPY BASED DOAS UNITS

The choice between sensible and enthalpy based energy recovery DOAS system will impact more that winter moisture removal, it can have a significant impact on annual energy savings.

Swegon Energy Evaluator was used to compare sensible and enthalpy based energy recovery DOAS systems for New York City for both no cooling and mechanical cooling scenarios. All parameters (load profile, fan efficiency, size, etc.) where held constant between the two systems. Sensible efficiency was 80.3% and for the enthalpy wheel, latent efficiency was 79.2%.

NO MECHANICAL COOLING

In winter months, the enthalpy based unit recovers more energy than the sensible unit because the enthalpy based unit requires less defrost. In summer months the sensible unit only recovers a small amount of sensible energy while the enthalpy based unit can recover a significant amount of latent energy thus dehumidifying the space. The enthalpy system recovered 21% more energy annually than the sensible only device. In fact, the sensible only unit would not meet ASHRAE standard 90.1 minimum requirements for a DOAS system in New York City.

MECHANICAL COOLING

Figure 5 – DOAS Unit with Mechanical Cooling

Adding mechanical cooling to the DOAS system is a means to add dehumidification to the project for summer months. When air conditioning is being used in the apartments, mechanical cooling at the DOAS unit will reduce the apartment air conditioning unit size helping space and sound considerations.

Using an enthalpy energy recovery device increased the annual energy savings to 28% and reduced the mechanical cooling equipment size by 25% over the sensible only DOAS system.

The energy savings between enthalpy and sensible DOAS systems depends greatly on location. In New York City , it can be seen the savings are significant and difficult to ignore. In Vancouver, the savings are minor so sensible systems make sense especially in light of winter humidity control.

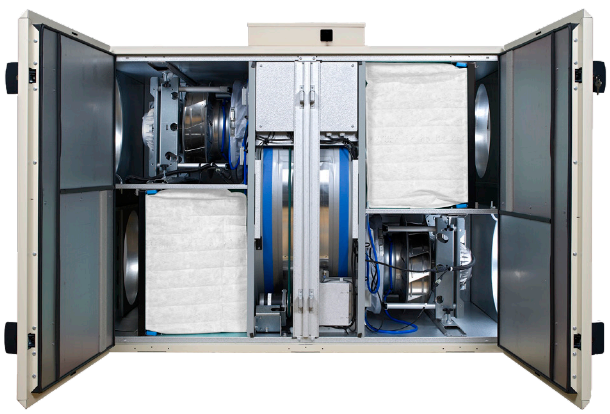
SUMMARY

The demanding envelope performance requirements of Passive House projects causes the buildings to behave differently than seen in conventional construction. For multifamily residential projects this can manifest itself as high humidity level in winter to the point where the space becomes uncomfortable and condensation can occur.

Centralized vs decentralized DOAS system choice has many variables and the right approach will depend on the application. Decentralized systems lack diversity so they can concentrate moisture in apartments. Consider sensible energy recovery to help reduce moisture levels. Centralized systems with diversity may be able to use enthalpy energy recovery without objectionable moisture levels and thus offer annual energy savings and reduce air conditioning system size. Location will greatly impact the result. When working on Passive House projects, analysis is critical.

Exceptional Energy Efficiency

SURPASS COMFORT AND ENERGY EFFICIENCY EXPECTATIONS WITH GOLD RX NA



GOLD RX units are designed to perform efficiently and quietly, making them desirable for projects that need to consider space and energy. The GOLD RX is the first air handling unit for commercial buildings to be certified as a Passive House component.

GOLD RX	Dimensions			Airflow Range for PHI Certified Operation		Max. PD (in.wc.)*	Electrical Power Consumption (w/cfm)**	Heat Recovery Temperature Efficiency %†
Size	Length (in)	Width (in)	Height (in)	Minimum	Maximum			
				CFM	CFM			
05	60	30	40	318	589	0.888	<0.77	85
07	64	40	47	318	1071	1.063	<0.77	86
08	64	40	47	635	1047	1.04	<0.77	84
11	75	55	55	635	1450	1.128	<0.77	85
12	75	55	55	1059	1530	1.128	<0.77	84
14	82	55	62	1059	2522	1.168	<0.77	84
20	82	55	62	1483	2354	1.236	<0.77	84
25	87	63	70	1483	3237	1.316	<0.77	84
30	87	63	70	2118	2254	1.236	<0.77	84
35	96	78	82	2118	4414	1.393	<0.77	85
50	105	91	93	3178	5297	1.441	<0.77	85

* Max Pressure Drop: The maximum pressure drop takes into account the external duct pressure drop, filter pressure drop, and the pressure drop of any Gold coils or accessories.

** Electric Power Consumption: Required value must not exceed 0.77 w/cfm and covers the total power consumption of the unit.

† Heat Recovery Temperature Efficiency: Required value is at least 75%