Breakout Session #9: Technical Solutions for Multi-Family Buildings

Passive Cooling Options for Passive House Multifamily Residential Applications

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Executive Summary

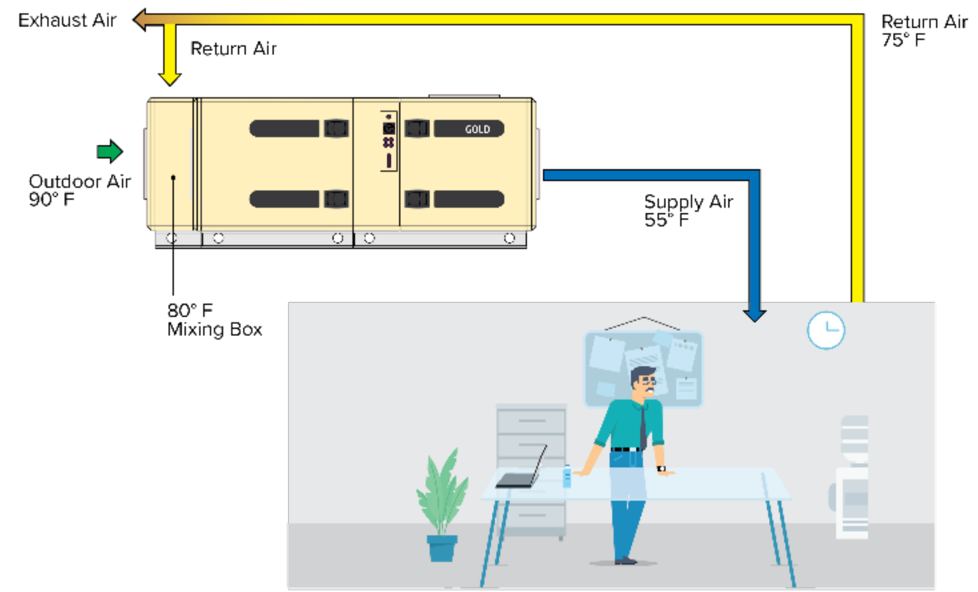
Multifamily residential buildings designed to Passive House are currently the most common commercial application of Passive House. Two key points are the buildings are extremely well insulated and air tight as well as they include a ventilation system. The first point has led buildings to require cooling when the ambient temperature is at or lower than freezing 32°F (0°C). Apartment over heating has led to occupant dissatisfaction. If there is mechanical cooling available, then the call for cooling will address occupant satisfaction but will have a negative impact on annual energy usage and it is hard on the air conditioning equipment (operating air conditioning equipment in cold weather).

Having a ventilation system creates the opportunity to use it for passive cooling. This means using the ventilation unit to deliver cool outdoor air to the space when outdoor air temperatures permit.
This approach has been used on several projects with varying degrees of success. The key issue is zone (apartment) control. Several different controls strategies have been applied with the most promising being local zone ventilation airflow control (passive cooling) as the first stage of cooling.

What is Passive (free) Cooling?

Passive cooling, *Free Coo*ling and *economizer* are all terms to describe the same concept – when weather conditions are right, use outdoor air to cool a built environment. The left hand image in Figure 1 shows an example. Most air conditioning systems are designed to deliver 55°F (12.8°C) to the space. The return air is basically the same as the space condition or around 75°F (24°C) so the air conditioning device cools the air (consuming electricity in the process) to the 55°F (12.8°C) supply air temperature. Now consider that for many climate zones, there will be days when the outdoor air temperature is 55°F (12.8°C). The right hand image in figure 1 shows the heating, ventilating and air conditioning (HVAC) system delivering 100% outdoor air to the space. There is no mechanical cooling, and there is the added benefit that the space will have very good indoor air quality (IAQ). All that is required to achieve passive cooling with this type of HVAC system is some additional controls.

MECHANICAL COOLING



PASSIVE COOLING

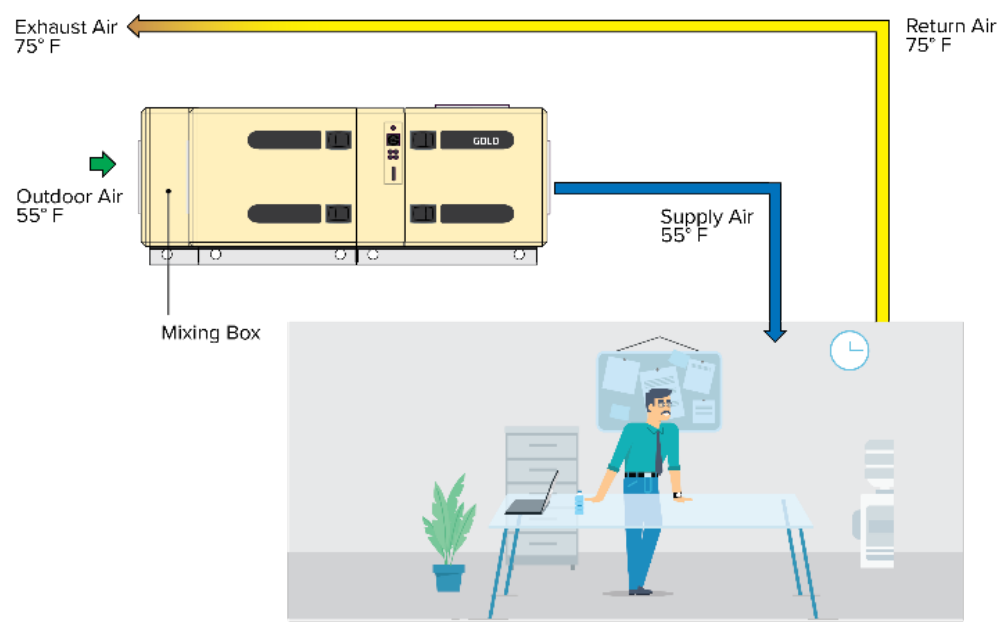


Figure 1: Economizer Operation

Expanding on this idea, consider when the outdoor air temperature is below 55°F (12.8°C), for example 40 °F (°C) and there is a need for cooling in the building. Supplying 40°F (4.4°C) air is too cold to deliver directly to the occupied space (causes drafting). However, by mixing 43% warm 75°F (24°C) return air with 57% outdoor air, it is possible to deliver 55°F (12.8°C) to the space.

Now consider when the outdoor air temperature is between 55°F (12.8°C) and 75°F (°C), say 60°F (15.5°C). Mechanical cooling will have to be performed to achieve the desired 55°F (12.8°C) supply air temperature, but it will be less work to cool the 60°F (15.5°C) outdoor air versus the 75°F (24°C) return air. Only when the outdoor air temperature exceeds the return air temperature does passive cooling no longer reduce energy consumption.

Dry bulb temperatures were used for these examples. It is also possible to use enthalpy (Btu/lb or J/kg) which takes into consideration both temperature and humidity. Both dry bulb and enthalpy are commonly used in HVAC controls strategies.

To take advantage of airside passive cooling (there is waterside passive cooling as well, which utilizes cooling towers and dry coolers), the HVAC system must have a ducted air system to deliver outdoor air to the space. Decentralized HVAC systems, such as Variable Refrigerant Flow (VRF), fancoils and water source heatpumps (WSHP), do not have a ducted system. However, all these systems will have a Dedicated Outdoor Air System (DOAS) or ventilation system to deliver ventilation air to the space for good IAQ. It is possible to expand the role of the ventilation system to include some amount of passive cooling and thus lower the annual energy usage.

Not all climate zones are conducive to air side passive cooling. Miami for example offers very few hours where passive cooling is available. Canadian (zones 4 to 8) climates zones support air side passive cooling.

Passive House Multi Family Residential

Figure 2: Hanac Corona, New York City

Multifamily residential buildings have some common traits worth noting;

- The volume to surface area ratio is much higher than a single family dwelling so they tend to heat up faster in warmer weather due to internal heat gains
- Compared to commercial space, the internal heat gains are lower
- Each apartment tends to have its air conditioning system and zone control, which promotes decentralized HVAC systems such as VRF, WSHPs, Packaged Terminal Air Conditioners (PTACs) and fancoils. All air systems are not common.
- There is some form of mechanical ventilation system, either by apartment or centralized unit.

Passive cooling in multifamily can generally be achieved with operable windows. Some challenges include cold outdoor air "dumping" through the open window, not mixing well with room air leading to drafts and cold spots. In some locations opening windows with high urban ambient noise may lower Indoor Environmental Quality (IEQ).

It is usually possible to leverage the ventilation system in multifamily buildings to achieve some level of passive cooling.

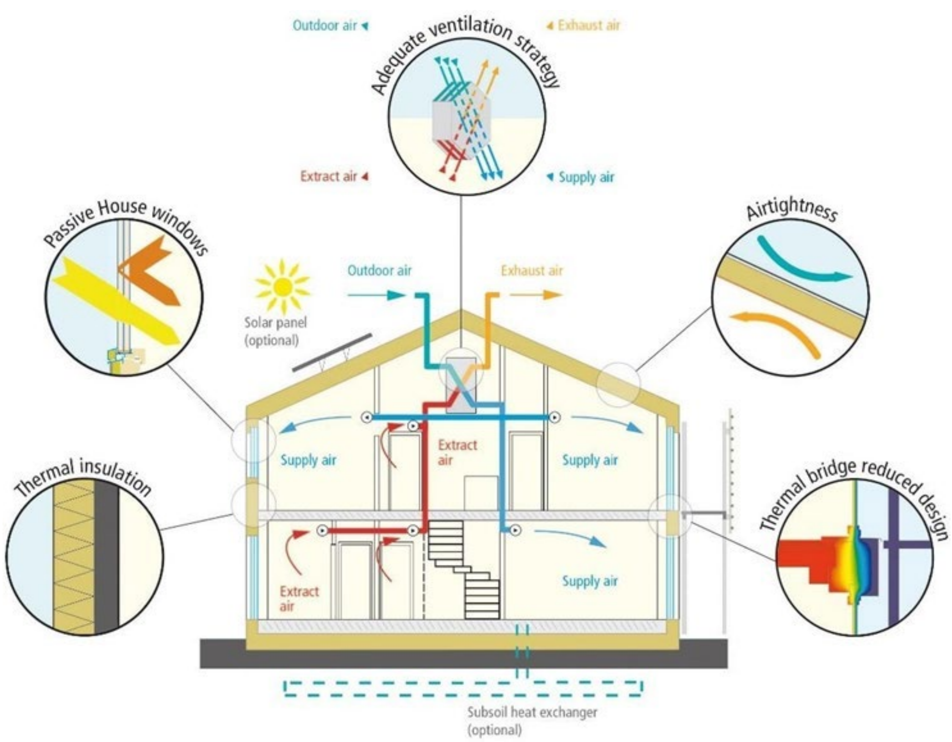


Figure 3: Passive House Principles

Figure 3 shows the Passive House principles. When applied to multifamily residential buildings, two key points should be noted. First, the buildings are very well insulated and are very air tight so they have a very low balance point. Second there is a ventilation system.

Figure 4 [Dan Nall, Syska Hennessy] shows the balance point when the internal heat gains in a space match the heat loss through the building envelope. Below the balance point, the space is in heating mode, above it the space is in cooling mode. For Passive House construction, the balance point is very low. Real world experience confirms the balance point can be below freezing ambient conditions. For Passive House projects with mechanical cooling, the cooling mode can start at freezing outdoor air temperatures. This is detrimental to the annual energy usage and is generally hard on the air conditioning equipment (reduces useful life).

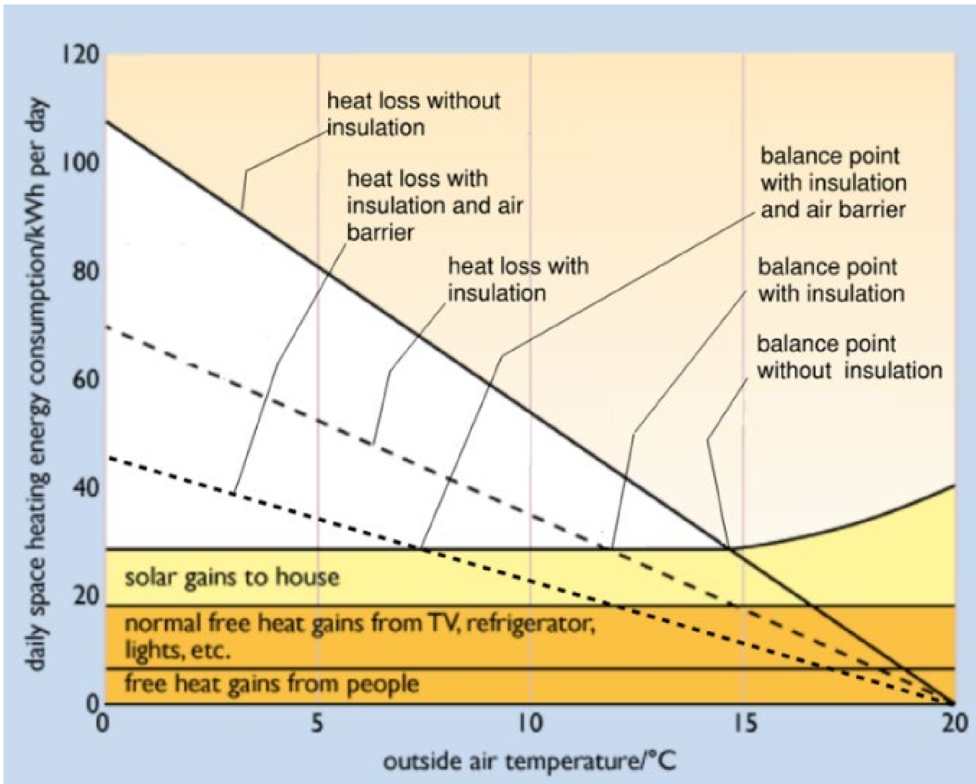


Figure 4: Heating to Cooling Balance Point

Building shape and orientation have an impact on the balance point. Generally orienting the building on an east-west axis will deliver the lowest solar heat gain and help reduce annual energy usage (air conditioning load). This will lead to a large south facing exposure. In normal construction, this is not an issue as south facing exposures peak late in the year when the sun is low in the sky and ambient temperatures are lower. With Passive House construction, the low balance point and the south exposure converge to create over heating for south facing apartments. Passive shading may not help as it is designed to provide coverage during the summer months.

Leveraging the Ventilation System

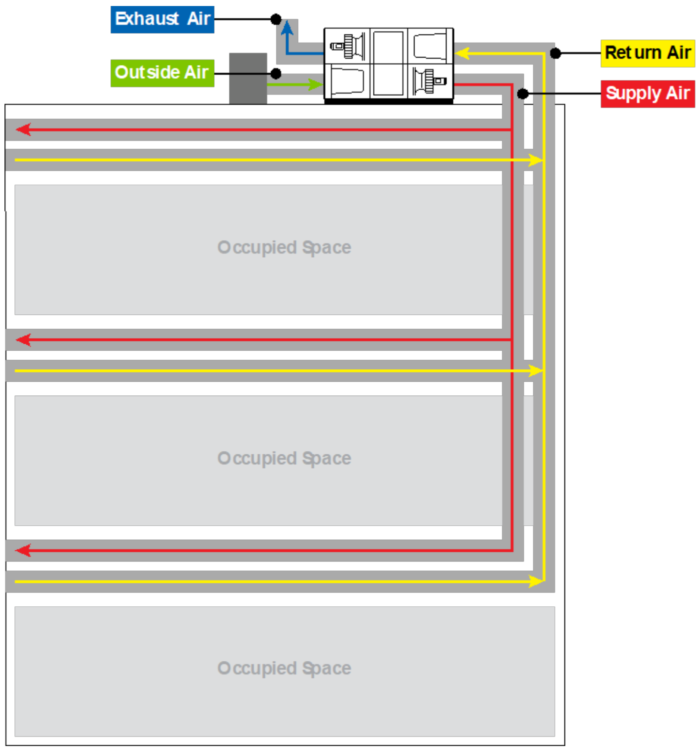


Figure 5: Ventilation System for Multifamily Residential

Ventilation system airflow rates are normally selected to provide adequate IAQ and maintain building pressurization (i.e. offset local exhaust). Passive House adds further requirements that the occupant be able to reduce the ventilation rate when they are away (Unoccupied) for energy savings and increase the ventilation rate (Boost Mode) when improved indoor air quality is desired. The Boost mode means the ventilation system should able to deliver approximately 20% more ventilation air when required. The designer has the choice to make the design airflow rate per apartment even higher for more passive cooling effect, it is just a case of first cost (larger ventilation system) vs. energy savings (extending the passive cooling season).

Generally, ventilation air temperature is meant to be close to space conditions so it does not impact occupant comfort. It is possible to reset the ventilation supply air temperature down (e.g. 55 °F (12.8°C)) to achieve passive cooling. The supply air temperature can be reset based on outdoor air temperature (see Figure 6) or on sensors placed in the building where cooling load will occur first. Resetting supply air temperature based on return ventilation air temperature is not recommend as it is the average of many zones - some zones could be very warm while others are not.

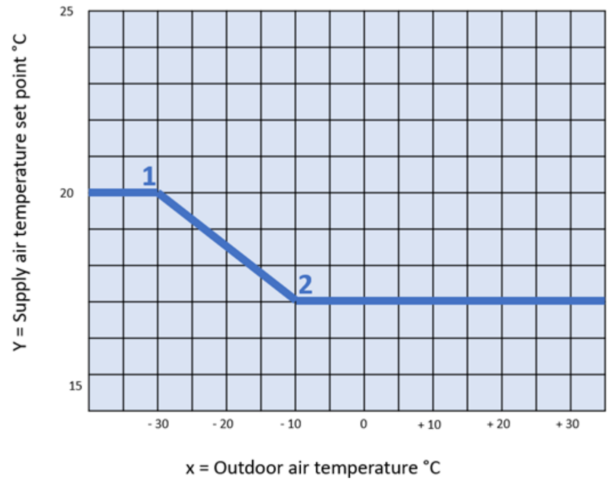


Figure 6: Ventilation Supply Air Temperature Reset

Passive House certified ventilation units have high performance energy recovery devices. When it is desired to reset the supply air temperature down to say 55°F (12.8°C) and the outdoor air temperature is lower, the energy recovery device can be used to heat the outdoor air up to set point with a passive energy source (the exhaust air).

Table 1: Ventilation Air Cooling Capacity

Space Temperature (°F)	Supply Air Temperature (°F)	Airflow Rate (cfm)	Sensible Cooling Capacity (Btu/h-ft²)
75	55	0.11	2.4
75	55	0.165	3.6
75	50	0.11	3.0
75	50	0.165	4.5
75	45	0.11	3.6
75	45	0.165	5.4
78	55	0.11	2.7
78	55	0.165	4.1
78	50	0.11	3.3
78	50	0.165	5.0
78	45	0.11	3.9
78	45	0.165	5.9

Table 1 shows the sensible cooling effect (Btu/h) delivered by ventilation air when varying the space temperature design condition, the supply air temperature and the airflow rate. It is possible to vary the cooling effect of the ventilation system from no effect (supply neutral air) to a practical goal of 5.0 Btu/h-ft².

Zone Control

The main challenge with using the ventilation system for passive cooling is zone control. The ventilation system will treat all apartments the same. While apartments on the south side during shoulder weather may require cooling, the apartments on the north side may still require heating. The supply air temperature can be changed from 72°F (22°C) to 55°F (12.8°C) with HVAC equipment but what the temperature should be at any given time is problematic, especially in a constant volume system.

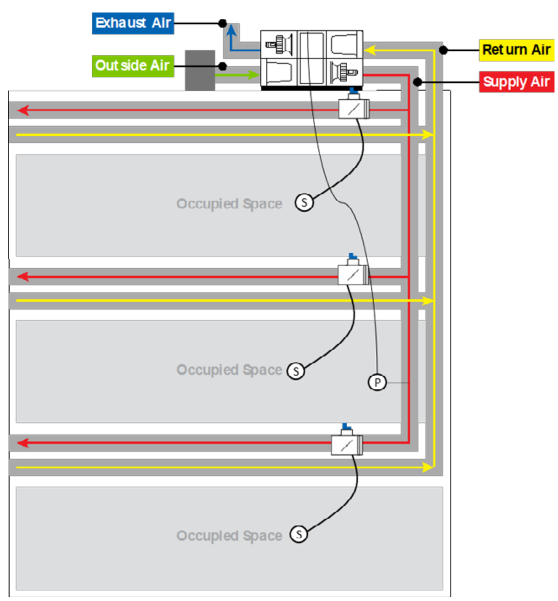


Figure 7: Ventilation system with Zone Airflow Control

Figure 7 shows a modified ventilation system, which includes airflow control to each apartment. This allows the following:

- The occupant can choose between unoccupied, normal and boost airflow from a wall mounted controller.
- A local temperature sensor can use passive cooling by increasing the airflow to the apartment when cooling is required

To achieve passive cooling, the ventilation supply air temperature will need to be reset from winter neutral temperature 72°F (22°C) to something that will provide free cooling 55°F (12.8°C) where required. Both outdoor air temperature reset and zone temperature reset have been used successfully.

Real World Lessons Learned

In warmer climates such as New York City, multifamily projects have included apartment air conditioning to deal with summer heat. The ventilation systems have included total energy (enthalpy) recovery. All the equipment is present to provide good occupant satisfaction. Anecdotal information indicates the air conditioning systems are operating at lower than expected ambient conditions and eroding annual energy savings.

Several recent projects in western Canada only have mechanical cooling for the ventilation air (nothing in the apartments) with no airflow control. In the first cooling season, the supply air temperature setpoint was reset based on return air. Blending return air from cool north facing apartments and warm south facing apartments made it impossible to recognize any cooling load and tenant dissatisfaction occurred. The controls sequence was modifed to reset supply air temperature based on outdoor air temperature, and the situation improved but was not completely resolved.

Multiple sensors located in zones that will experience the earliest cooling load is being applied to several new buildings under construction. The temperature measurements are used to reset the ventilation supply air temperature. This is expected to be a significant improvement.

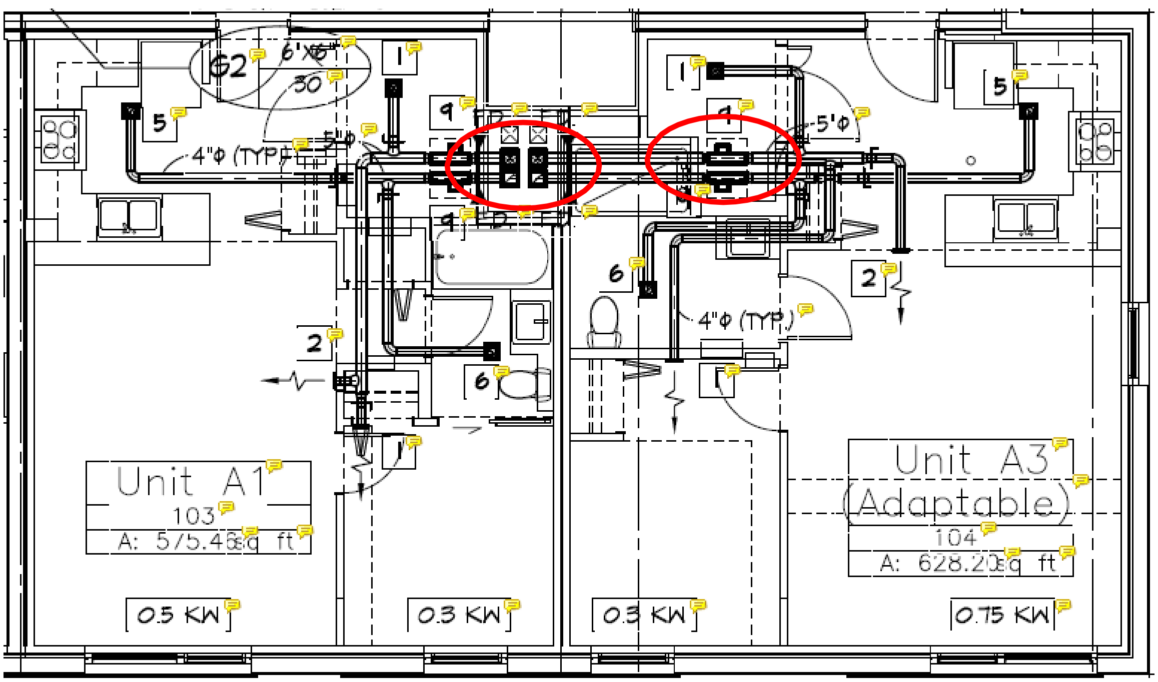


Figure 8: Passive Cooling with Local Zone Control

Several projects in design or under construction have zone control dampers with local passive cooling controls. The passive cooling is interlocked with apartment baseboard heaters to avoid simultaneous heating and cooling. This will allow passive cooling control at the apartment level and should deliver the high level of occupant satisfaction and energy savings.

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