Energy Efficiency Services • Software Development

Comparing Energy Savings of Different VAV Systems

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Comparing Energy Savings of Different VAV Systems

Realistic Models Require Turndown Schedules For Occupancy, Plug, and Lighting Loads

Abstract

This guide has been developed by EnergySoft to help designers of HVAC systems to understand the issues surrounding the application of Variable Air Volume (VAV) systems for comfort applications. The designer must never forget that the primary purpose of HVAC is comfort for the building occupants. Fortunately, comfort and saving energy can go hand in hand with a well-designed VAV system. The ultimate solution is a VAV zone for each building occupant providing temperature satisfaction and avoiding the energy waste of any overcooling or overheating. In addition to comfort and energy savings, the benefits of a VAV zone for each occupant include higher worker productivity and improved ability to lease the space.

Most buildings operate the majority of time in turndown and it is during turndown that VAV systems save energy because they match the reduced loads – both the exterior loads, such as temperature and solar, and the interior loads of occupancy, plugs, and lighting. Also the energy penalty of reheat is during turndown.

A model applying an average and using a single load schedule across a building accounts only for the portion of energy savings from the diversity of exterior loads (primarily during the spring and fall shoulder seasons) and completely misses the important year around energy savings from the diversity of interior loads. A realistic model also includes the energy savings from interior load diversity by randomly assigning one of several occupancy schedules to each occupant. This modeling guide demonstrates a good way to do realistic comparisons. For future use, the additional load schedules should be included in the energy modeling software library.

We hope this guide will provide you with ideas for VAV systems that will result in a comfortable environment for the occupants, while also delivering an energy efficient system sure to meet our modern energy codes.

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Overview

The subject here is saving energy but the designer must never forget that the primary purpose of HVAC is comfort for the building occupants. Fortunately comfort and saving energy go hand in hand with Variable Air Volume (VAV) systems. VAV systems provide small zones within the building where the temperature for each is controlled by varying the amount of conditioned air being supplied. A building with many VAV zones raises the chances of occupant comfort satisfaction. Having many VAV zones also reduces the chances of overcooling or overheating which lowers fan speeds and lowers the central conditioning requirement both of which result in lower energy use. The ultimate is a zone for each building occupant providing temperature satisfaction and avoiding the energy waste of any overcooling or overheating. Small zones can also eliminate an unexpected energy use when occupants bring in fans and electric heaters to be more comfortable.

It should be noted that, in addition to saving energy, the benefits of a VAV zone for each occupant include higher worker productivity and improved ability to lease the space. Expensive office workers are more productive when there is no distraction from being uncomfortable. Increases in office worker productivity when comfortable were 2 to 3% when measured in a study by Carnegie Mellon University under direction of the National Science Foundation. Also, the ability to lease office space is much better when offering a thermostat for each person. These should be included in any payback calculations.

A basic VAV system consists of a fan, cooling and heating coils, filters, supply and return ducting and VAV terminals each with a room thermostat. VAV terminals can be either VAV diffusers or VAV boxes with standard diffusers. See the comparison table below. The fan is almost always equipped with a Variable Speed Drive (VSD) to reduce fan speed and fan energy use when the VAV terminals can satisfy the temperature with reduced air flow. Less air flow through the coils also results in lower cooling and heating requirements allowing the chiller or packaged VAV unit and boiler to operate using less energy.

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Table 1 – A Comparison of VAV Diffuser and VAV Box Systems		
Attribute	**VAV Box Reheat System**	**VAV Diffuser Reheat System**
System Description	Central cooling fans on roof supply 55˚ to 60˚F air in ceiling mounted ducts to VAV reheat boxes in perimeter zones. Cooling only in interior zones - reheat boxes optional. Return air by ceiling plenum. Cooling fans have 100% outside air economizer.	Central cooling fans on roof supply 55˚ to 60˚F air in ceiling mounted ducts to self-powered VAV diffusers in all zones. Reheat coils in ducts to perimeter zones - optional for interior zones. Return air by ceiling plenum. Cooling fans have 100% outside air economizer.
Comfort	VAV box zones with multiple diffusers do not provide individual temperature control. Good cooling performance on exterior zones. Fair heating performance due to stratification - can be improved with high induction diffusers. Can only maintain uniform temperatures in interior office zones with similar loads.	Each VAV diffuser is a zone of temperature control with a built in thermostat allowing an individual set point for each building occupant. Good cooling performance and less stratification when heating in all zones due to the high induction almost constant discharge velocity at both full and turn down flows. Maintains uniform temperatures in all zones with the possible exception during reheat in large reheat zones with wide differences in loads.
Energy savings/operating cost	Overcooling or overheating may occur except in the space with the box thermostat. Minimum flow set point of 30% of design air flow, except for boxes with special controllers. Pressure drop over box of 0.5"wg to 1.0"wg.	No overcooling or overheating when loads vary between spaces. Lowest possible minimum flow set point of 10% of design air flow. Low pressure drop over diffuser of 0.05"wg to 0.25"wg.
First Cost	Installed cost of a VAV box with controls is usually between $2000 and $3500*. Installed cost for box zones with 4 to 8 diffusers or smaller is more than for VAV diffusers. Justify any higher incremental first costs with paybacks for energy saving features and comfort benefits. Low shell and core costs.	Installed cost of a self-powered VAV diffuser is usually between $200 and $250*. Installed cost is less than for a VAV box zone of 4 to 8 diffusers. Justify any higher incremental first costs with paybacks for energy saving features and comfort benefits. Low shell and core costs.
Indoor air quality	Outside air economizer allows 100% outside air most of the year.	Perception of improved air quality due to personal temperature set point and uniform temperature. Outside air economizer allows 100% outside air most of the year.
Maintenance cost	VAV boxes require occasional maintenance. Rooftop equipment may require frequent maintenance.	VAV diffusers require almost no maintenance. Rooftop equipment may require frequent maintenance.
Flexibility	Any number of zones may be added but at a higher cost. * ENERGY DESIGN RESOURCES. December 2009. *Advanced Variable Air Volume VAV System Design Guide.* Pacific Gas and Electric Company.	VAV diffusers are easily moved or added to accommodate changes in interior layouts.

Applications

VAV systems have been commonly applied in various kinds of commercial office buildings for over 30 years. Many of these, however, have neither provided satisfactory comfort nor met baseline energy efficiency standards due to emphasis on first cost without considering the quick paybacks on any incremental cost of energy saving features or for achieving the other comfort benefits. Energy modeling software can be used to determine the energy savings from the many ways of making VAV systems more efficient which, in turn, can provide a basis for payback calculations.

Special Considerations

Most buildings operate the majority of time in turndown and it is during turndown that VAV systems save energy because they match the reduced loads – both the exterior loads, such as temperature and solar, and the interior loads of occupancy, plugs and lighting. A model applying an average and using a single load schedule across a building* accounts only for the portion of energy savings from the diversity of exterior loads (primarily during the spring and fall shoulder seasons) and completely misses the important year around energy savings from the diversity of interior loads. Realistic modeling also includes the energy savings from interior load diversity by randomly assigning one of several occupancy schedules to each occupant. This modeling guide demonstrates a good way to do realistic modeling. For future use, the additional load schedules should be included in the energy modeling software library.

* An example is the load schedule from ASHRAE 90.1-1989 and addenda which, in the ASHRAE Standard 90.1-2010 User's Manual, is suggested for guidance where actual schedules are not known.

Modeling and Input Approaches

The input descriptions that follow assume that, other than the VAV system, all project data, including entering location, envelope data, basic mechanical, etc., has already been created. These data remain unchanged for the different VAV systems to be compared, with the possible exception of increased envelope insulation.

Select Supply Fan and Return Fan (if used)

Designing the VAV system for the lowest possible pressure drop is critical to selecting a fan with the lowest horsepower and energy usage.

1. Determine Design Air Flow – Make load calculations and determine an air flow per square foot (cfm/sqft) for each exposure and for the interior. Multiply these air flows by the respective perimeter areas for each exposure and the interior area. Keep in mind that systems rarely operate at design and avoid overly conservative estimates of lighting and plug loads.

2. Determine Design Total Static Pressure – Design each portion of the VAV system for the lowest possible pressure drop (see *Design for the lowest possible pressure drop in the VAV system* in the recommendations below). Designing a low pressure drop VAV system deserves extra attention because fans use significant energy (tending to account for more energy consumption than the chiller), because significant cost savings are possible and because fans contribute a significant amount to peak energy demand. If using VAV diffusers, lower the pressure drop accordingly. (see *Recommendations for Low Energy VAV Systems*).

3. Select the smallest and most efficient fan available (see *Select the lowest horsepower fan and control it for low turndown horsepower* in the recommendations below).

4. Determine the brake horsepower of the fan/motor/drive package from the manufacturer's data at design conditions.

5. Enter the air flow and fan break horsepower into the model. Note: Most software follows NEMA premium motor efficiencies and the VFD efficiency curve in ASHRAE 90.1 Appendix G Table G3.1.3.15.

Select VAV Terminal

Data for all VAV terminals already exists in most software. If not, enter data for any missing terminal. If using VAV diffusers, lower the turndown ratio accordingly (see *Recommendations for Low Energy VAV Systems*). Also, most software automatically calculates the minimum amount of air required to meet ventilation standards and automatically increases the turndown ratio where required to meet the standards.

Develop a Realistic Model

Realistic comparisons of different systems can only be made using the reduced loads during VAV system turndown for several reasons.

-Systems operate the majority of the time in turndown.
-The energy savings of VAV systems are in turndown.
-The energy penalty of reheat is in turndown.

Exterior load turndown is automatically modeled based on the weather data. Interior load schedules are more difficult to predict because actual turndown conditions are random due to diversity of occupancy, lighting and plug loads. Applying an average and using a single load schedule across a building[1] will not capture the energy savings of interior load diversity and allow accurate comparisons of VAV systems. Interior load schedules are best simulated by randomly assigning one of several load schedules to each of the occupants. These schedules should go up and down throughout the day.

For simplicity, use nine load schedules – three highs, three mediums and three lows. Model the same schedule for all weekdays of the year. The same schedule for occupants, lights and plug loads can be used as research has shown that plug and lighting loads correlate with occupancy[2]. Randomly assign one of these schedules to each occupant.

The appendix shows nine typical load schedules for a single occupant which can be applied randomly. These schedules can also be placed into the library and used again for other buildings.

A single room zone with a single occupant is modeled with the assigned schedule.

A single room zone with multiple occupants is modeled by adding the proportional shares of each occupant's assigned schedule for each hour of the day. See Appendix A.

A zone with multiple single occupant rooms is modeled as fully occupied for each hour with at least one occupant present because of the control/thermostat arrangement. This can be a temperature sensor in each room and a signal selector which allows the sensor farthest off set point to control. Alternatively, the zone can have one thermostat in a single room which, if the room with the thermostat is unoccupied, is adjusted by the occupants of the other rooms to remain comfortable. Both control the zone as fully occupied when at least one room is occupied. See Appendix A.

1. An example is the load schedule from ASHRAE 90.1-1989 and addenda which, in the ASHRAE Standard 90.1-2010 User's Manual, is suggested for guidance where actual schedules are not known.

2. MODELING OFFICE BUILDING OCCUPANCY IN HOURLY DATA-DRIVEN AND DETAILED ENERGY SIMULATION PROGRAMS, ASHRAE Transactions, 01-JUL-08, and Jessen Page, SIMULATING OCCUPANT PRESENCE AND BEHAVIOUR IN BUILDINGS, Ecole Polytechnique Fédérale de Lausanne, 19 October, 2007. And Newsom, Mahdavi, Beausoleil-Morrison, A STOCHASTIC MODEL FOR PREDICTING OFFICE LIGHTING ENERGY CONSUMPTION. 3rd European Conference on Energy-Efficient Lighting

Eliminate or Reduce the Need for Reheat

Reheat wastes energy and if at all possible should be eliminated (see *Eliminate or reduce the need for reheat* below). If elimination of reheat is not possible, consider raising the base supply air temperature and using supply air temperature reset during cool weather. Supply air reset may be either be a simple reset to a higher temperature or demand based using the warmest temperature that will satisfy all of the zones in cooling (warmest zone).

Results

Most software automatically compares a VAV approach to a baseline. When comparing different VAV approaches, a separate model and report is required for each simulation. The energy simulation results often report the annual predicted usage of the various energy end uses for the building. Of particular interest will be the consumption of the heating and cooling systems, as well as ventilation fan systems. Depending upon the type of system, possibly pumping and cooling tower consumption will be included. As the air system is optimized through the strategies presented here, reductions in all of these uses can be expected. In addition, as other optimizations are made to the building such as reduced internal loads from lighting, or possibly lower external loads from better fenestration, the resulting energy usage will decrease given a VAV system's ability to respond to reduced loads in the building. An efficient all low pressure design with small zones of control can result in energy savings of 15-57% over traditional VAV systems.

Summary

The lowest energy VAV systems tend to have a VAV zone for each occupant and an air system with a low pressure drop. The true advantage of such a low energy VAV system is best revealed by a model which, in addition to exterior load diversity, includes the energy savings from interior load diversity. This can be achieved by randomly assigning one of several occupancy schedules to each occupant.

Recommendations for Low Energy VAV Systems

Select the lowest horsepower fan and control it for low turndown horsepower

- Maximum fan power should not exceed 0.72 W/cfm.
- Use a more efficient scroll type airfoil centrifugal fan when noise and space limits allow.
- Use a variable speed drive (VSD) on the fan.
- Control the VSD from a static pressure sensor located close to the last VAV terminal in the duct run. Use multiple sensors for duct work with multiple branches.
- Use the lowest pressure drop air system possible. (See "*Design for the lowest possible pressure drop in the VAV system*" below.
- Specify that no balancing damper shall be installed before the last VAV terminal or the last diffuser (alternatively that the balancing damper before the last VAV terminal or last diffuser shall remain open) so that the system will be balanced at the lowest possible fan speed.

Eliminate or reduce the need for reheat

- Eliminate the need for reheat by adding enough inexpensive insulation to the building envelope until the heat loss through the envelope at outside temperature below winter design is less than the heat gain of the occupants and other internal loads in perimeter spaces. Warm-up heating may still be required.
- Eliminate the need for reheat by using separate air handling units for each heating zone such as one per exposure and one for the interior.
- Use high induction diffusers to reduce stratification. (All VAV diffusers are high induction.)
- Use the lowest possible minimum flow set point. Must be the higher of the minimum ventilation requirement or the lowest allowed by the terminal (10% of design air flow for VAV diffusers, higher for most VAV boxes).
- Use a slightly higher supply air temperature. An increase in the supply air temperature will require a larger volume of air. Use the model to find the ideal compromise between reheat energy and fan energy.
- Increasing the use of fan energy to lower use of central plant energy can seldom be justified except when also reducing reheat. One method is to reset supply air temperature during cool weather and size interior zones for 60˚F or higher supply air. Supply air reset may not be beneficial in warm climates and in high humidity locations where alternate dehumidification may be required.

Provide the smallest possible zones

- Try to provide a VAV zone and a thermostat for each occupant.

Design for the lowest possible pressure drop in the VAV system

Fan

- Minimize the fan outlet effect with a straight run duct or an elbow in the direction of the fan rotation.
- Use duct liner only where necessary for sound attenuation. Use the minimum needed. Avoid sound traps.

Coils

- Select the largest coil that can fit in the space - maximum face velocity of 450 fpm and minimum water side ΔT of 15˚F.

Filters

- Avoid pre-filters.
- Use the largest filter bank that can fit in the space.
- Select low pressure drop extended surface area filters.

Risers

- Place the shafts close to the air handler but, for sound attenuation, not directly under it (except connect ducts to rooftop units through insulated roof curb to avoid ducts outside the building envelope).
- Size for 800 to 1200 fpm at the floor closest to the air handler.
- Consider multiple air shafts for large floor plans.

Supply air ducting

- Make as straight as possible with a minimum of transitions and joints.
- Use large radius elbows and low pressure drop fittings and takeoffs.
- Size for a pressure drop no greater than 0.08"wg per 100 ft and a maximum of 1200 fpm.
- Limit use of flex ducting to a maximum of 5ft at the diffusers.
- Use duct liner only where necessary for sound attenuation. Avoid sound traps.

VAV terminals

- Use VAV diffusers instead of VAV boxes – a lower pressure drop by 0.25"wg to 0.75"wg usually reduces fan HP by 30 to 50%
- Size terminals for low static pressure drops – between 0.25"wg and 0.05"wg for VAV diffusers and 1"wg to 0.5"wg for VAV boxes

Return air

- Provide at least one return air grill for each VAV zone, more if the zone is large.
- Use ceiling return air plenums (except in high humidity locations such as DOE climate zone 1.). Seal ceiling plenums for minimum air infiltration.
- Size ducts for pressure drop no greater than 0.04"wg per 100 ft.
- Size grills for pressure drop no greater than 0.08"wg.

Provide separate auxiliary cooling systems to serve 24/7 process loads such as server rooms and telecom closets and other loads that do not operate on the normal HVAC schedule.

California Title 24 Part 6 2016 Compliance Issues

Compliance with the 2016 Building Energy Efficiency Standards in California requires careful consideration of the VAV system design, and many advantages gained from the use of VAV diffusers facilitate compliance with the code.

- **Fan Power** – Compliance with the fan power requirements will differ depending upon if the Prescriptive or Performance method of compliance has been chosen. The Title 24 restrictions look at total fan power consumption for a given HVAC system, including supply and return fans, as well as exhaust fan usage. The prescriptive limitation is 1.25 w/cfm of total fan power, where the cfm is based upon the supply fan airflow rate. The more restrictive limitation in the performance approach is about one-half that number, so low static pressure designs become crucial to achieving compliance.

- **VAV Turndown Ratio** – The turndown level dictated in Title 24 will depend upon the occupant density of the space. It is important to note that Title 24 has yet to adopt the ASHRAE 62.1 ventilation requirements but rather uses California specific ventilation rates, which tend to be higher for most spaces. In spaces with high occupant densities, the turndown level will be driven by the outside air requirement for the occupants. These types of spaces will require a higher minimum flow level for the terminal box or diffuser to meet outside air needs dictated by the code. Lower density spaces such as offices will generally require a lower turndown ratio of 20% of maximum airflow at the terminal box or diffuser. It is important to ensure stable operation of the system at these lower levels of airflow, another feature common to the VAV diffusers.

- **Demand Control Ventilation (DCV)** – Title 24 mandates the use of demand control ventilation in high density occupancies (< 40 sqft/occupant). Typical spaces that would trigger this would include conference rooms, auditoriums, theaters, dining areas and some lobby spaces. Typically control will be achieved using a carbon monoxide sensor (CO_2)

- **Direct Digital Control (DDC)** – Effective in the 2016 Title 24 standards, DDC became a mandatory measure on larger HVAC systems. In typical VAV applications, this would be triggered as a mandatory control at all zones fed by air-handlers that have cooling capacities of 25 tons or larger, or systems with an installed heating capacity of 300 kBtuh. With this requirement, monitoring of zone demand for heating and cooling as well as pumping requirements would be invoked, with the zone information passed up to the HVAC system controller.

- **Automated Demand Response (ADR**) – Prior versions of Title 24 have mandated the ability to receive a standards based signaling protocol that will activate a demand response function in the HVAC system. This would include the ability to reset zone thermostat setpoints by 4 degrees F. As an example, a local utility may have an extreme heat day, and would issue a signal to the building, resulting in thermostats being reset from 74 degrees to 78 degrees for a 2 hour period to reduce load on the utility grid.

Appendix A

Hour	Time	ASHRAE	Example Single Room Zone with a Single Occupant								
			Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy
			1	2	3	4	5	6	7	8	9
1	(12-1 am)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2	(1-2 am)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	(2-3 am)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	(3-4 am)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5	(4-5 am)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6	(5-6 am)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	(6-7 am)	10%	0%	0%	0%	0%	100%	100%	0%	0%	0%
8	(7-8 am)	20%	100%	100%	100%	0%	100%	100%	100%	100%	100%
9	(8-9 am)	95%	100%	0%	100%	0%	0%	100%	100%	100%	100%
10	(9-10 am)	95%	0%	100%	100%	0%	0%	100%	100%	100%	100%
11	(10-11 am)	95%	0%	100%	100%	0%	0%	0%	100%	100%	100%
12	(11-12 pm)	95%	0%	0%	0%	0%	0%	100%	0%	0%	100%
13	(12-1 pm)	50%	0%	100%	100%	100%	100%	100%	0%	0%	0%
14	(1-2 pm)	95%	0%	0%	100%	100%	100%	100%	0%	0%	0%
15	(2-3 pm)	95%	0%	100%	100%	100%	100%	100%	0%	0%	0%
16	(3-4 pm)	95%	0%	100%	100%	100%	100%	100%	0%	100%	100%
17	(4-5 pm)	95%	0%	0%	0%	0%	0%	100%	0%	100%	100%
18	(5-6 pm)	30%	0%	0%	0%	0%	0%	0%	0%	0%	100%
19	(6-7 pm)	10%	0%	0%	0%	0%	0%	0%	0%	0%	100%
20	(7-8 pm)	10%	0%	0%	0%	0%	0%	0%	0%	0%	100%
21	(8-9 pm)	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	(9-10 pm)	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	(10-11 pm)	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
24	(11-12 am)	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		ASHRAE 90.1 User's Manual ANSI/ASHRAE/IES Standard 90.1-2010	2 Hours in Office - Remainder Out of Office (Meetings and Sales Calls)	6 Hours in Office - 1 Hour Lunch and 2 Hours Breaks/Meetings	8 Hours in Office - 1 Hour Lunch	4 Hours in Office - Morning Out of Office (Meetings and Sales Calls)	6 Hours in Office - Morning Meeting and Lunch	10 Hours in Office - 1 Hour Lunch	4 Hours in Office - Afternoon Out of Office (Meetings and Sales Calls)	6 Hours in Office - Lunch and Afternoon meeting	10 Hours in Office - 3 Hour Lunch

Hour	Time	Example Single Room Zone with Multiple Occupants				Example Zone with Multiple Single Occupant Rooms		
		1 + 2 + 3	4 + 5 + 6	7 + 8 + 9		1 + 2 + 3	4 + 5 + 6	7 + 8 + 9
1	(12-1 am)	0%	0%	0%		0%	0%	0%
2	(1-2 am)	0%	0%	0%		0%	0%	0%
3	(2-3 am)	0%	0%	0%		0%	0%	0%
4	(3-4 am)	0%	0%	0%		0%	0%	0%
5	(4-5 am)	0%	0%	0%		0%	0%	0%
6	(5-6 am)	0%	0%	0%		0%	0%	0%
7	(6-7 am)	0%	67%	0%		0%	100%	0%
8	(7-8 am)	100%	67%	100%		100%	100%	100%
9	(8-9 am)	67%	33%	100%		100%	100%	100%
10	(9-10 am)	67%	33%	100%		100%	100%	100%
11	(10-11 am)	67%	0%	100%		100%	0%	100%
12	(11-12 pm)	0%	33%	33%		0%	100%	100%
13	(12-1 pm)	67%	100%	0%		100%	100%	0%
14	(1-2 pm)	33%	100%	0%		100%	100%	0%
15	(2-3 pm)	67%	100%	0%		100%	100%	0%
16	(3-4 pm)	67%	100%	67%		100%	100%	100%
17	(4-5 pm)	0%	33%	67%		0%	100%	100%
18	(5-6 pm)	0%	0%	33%		0%	0%	100%
19	(6-7 pm)	0%	0%	33%		0%	0%	100%
20	(7-8 pm)	0%	0%	33%		0%	0%	100%
21	(8-9 pm)	0%	0%	0%		0%	0%	0%
22	(9-10 pm)	0%	0%	0%		0%	0%	0%
23	(10-11 pm)	0%	0%	0%		0%	0%	0%
24	(11-12 am)	0%	0%	0%		0%	0%	0%
		Single occupant schedules 1, 2 and 3.	Single occupant schedules 4, 5, and 6.	Single occupant schedules 7, 8, and 9.		Single occupant schedules 1, 2 and 3.	Single occupant schedules 4, 5, and 6.	Single occupant schedules 7, 8, and 9.
		Modeled by adding the proportional shares of each occupant's assigned schedule for each hour of the day.				Modeled as fully occupied for each hour with at least one occupant present (Tip! In Excel use the MAX function over the occupant's assigned schedules for each hour of the day.)		