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# Monitoring Building Systems for Schedule Compliance

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February 2013



**Pacific Northwest**  
NATIONAL LABORATORY

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Pacific Northwest National Laboratory  
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## Summary

As Pacific Northwest National Laboratory (PNNL) initiated a Core Business Hours program, it became a challenge to ensure that the hundreds of systems campus wide were operating within their programmed schedules. Therefore, a collaborative exchange between PNNL operations and PNNL researchers developing the Decision Support for Operations and Maintenance (DSOM) software package was initiated to create a tool to solve this problem.

This new DSOM tool verifies systems are operating within scheduled operation times by polling Building Automation and Control Network (BACnet) identifiers of systems' on/off or command statuses. The tool records the time spent in operation state (ON) and totalizes each system over a rolling 7-day period, highlighting systems that are running over the scheduled hours. This snapshot view allows building management to look quickly at the entire campus to ensure that systems are not operating beyond their scheduled hours.

## Acronyms and Abbreviations

BACnet	Building Automation and Control Network
BAS	Building Automation System
CBH	Core Business Hours (Tool)
DSOM	Decision Support for Operations and Maintenance
HVAC	Heating, Ventilation, and Air Conditioning
OFF	non-operative state
ON	operation state
PNNL	Pacific Northwest National Laboratory

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# 1.0 Introduction

The Core Business Hours (CBH) Tool was developed to create a top-level dashboard view of all the systems for each building on the campus. Equipment such as fans, pumps, and air compressors with two operational states in the building automation system (BAS) can be monitored by the Tool: State 0 indicates the non-operative state (OFF), and State 1 indicates ON.

The chief function of the CBH Tool is to totalize run hours for all equipment programmed into it to monitor and verify equipment operation. The layout and graphical interface displays the amount of time a system has operated over a rolling 7-day period and alerts the viewer if a system has exceeded its scheduled time. The Tool also provides building management a means to assess all systems for problems quickly rather than spending hours sifting through trends and schedules saved by the BAS.

## 2.0 Data Acquisition and Setup

To program the CBH Tool, an inventory list of all systems (fans/pumps/air compressors) in each building was created. The list includes the actual data point for each system (the equipment’s point name in the BAS) as well as the main controller, local sub-controller, and most importantly the BACnet identifier. Using an equipment’s on/off status is preferred, as a command status may not indicate the actual operational status (i.e., a command status may be ON, but the equipment could be disconnected or otherwise switched off). If this is not available, the command status may be used, but this should be noted.

In the tool’s setup screen (Figure 1), the campus is divided into a hierarchy by area, building, and system (Figure 2). Areas, buildings, or systems can be added and edited as necessary. Once selected, an individual system can then be edited. The controller name and data point type are selected, the BACnet ID number is input, and the schedule and allowable overrun hours configured (Figure 3). By default, PNNL’s core business hours schedule is automatically configured (0600–1800 hours Monday through Friday), with 5 hours of allowable error (overrun). The schedule can be configured manually or set to the hourly range choices of 0600–1800, 0700–1700, or 24/7 with the “Set” buttons below the schedule (Figure 3).

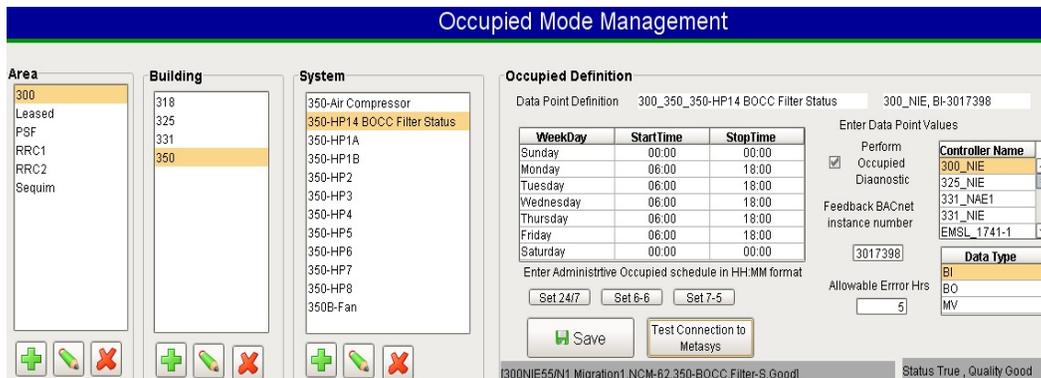
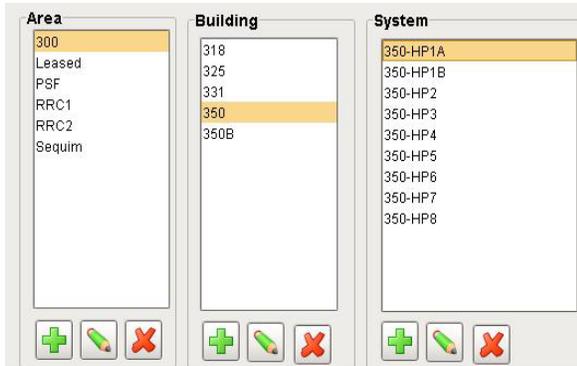
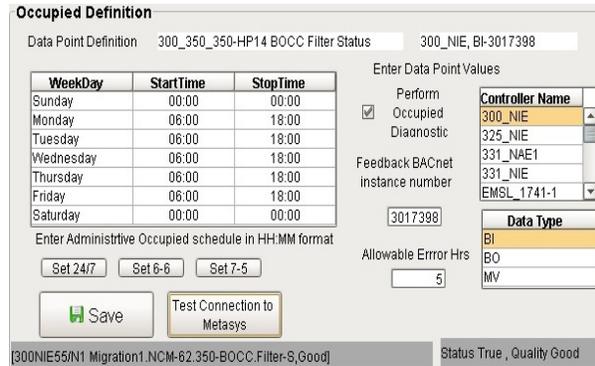


Figure 1. Main Setup Screen



**Figure 3.** Hierarchy Breakdown: Area, Building, and System Trees

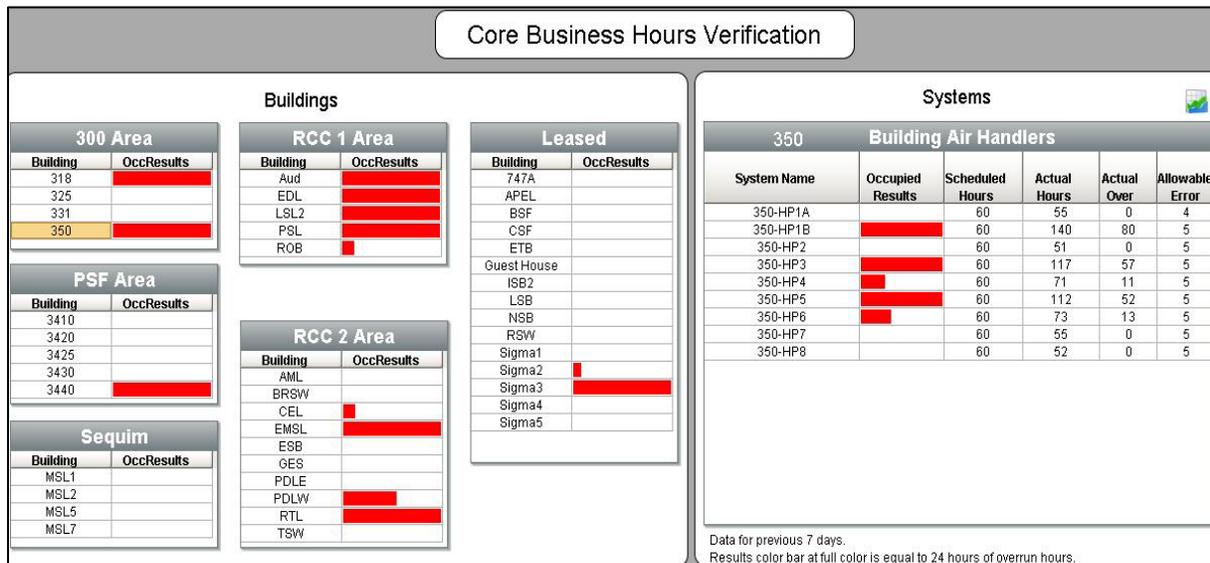


**Figure 2.** System Controller, Identifier, and Administrative Occupied Schedule Programming

Once a piece of equipment is programmed into the Tool, clicking the “Test Connection to Metasys” button will enable connection with Metasys (PNNL’s BAS) and display the name of the point, the current run status of the item, and the quality of the connection. This ensures that the correct BACnet instance number was input and the correct controller and data type selected.

### 3.0 Diagnostic Display

The main display window shows two sections (Figure 4). In the left-hand side box, each building is listed under its respective area (Figure 5). The right hand side of the screen contains a box that shows the systems of the selected building, the scheduled hours, actual run hours, hours over, and the allowable error for each system (Figure 6).



**Figure 4.** Main Display Screen

300 Area		RCC 1 Area		Leased	
Building	OccResults	Building	OccResults	Building	OccResults
318		Aud		747A	
325		EDL		APEL	
331		LSL2		BSF	
350		PSL		CSF	
		ROB		ETB	
				Guest House	
				ISB2	
				LSB	
				NSB	
				RSW	
				Sigma1	
				Sigma2	
				Sigma3	
				Sigma4	
				Sigma5	

PSF Area		RCC 2 Area	
Building	OccResults	Building	OccResults
3410		AML	
3420		BRSW	
3425		CEL	
3430		EMSL	
3440		ESB	
		GES	
		PDLE	
		PDLW	
		RTL	
		TSW	

Sequim	
Building	OccResults
MSL1	
MSL2	
MSL5	
MSL7	

Figure 5. Area Display Screen

Systems					
350 Building Air Handlers					
System Name	Occupied Results	Scheduled Hours	Actual Hours	Actual Over	Allowable Error
350-HP1A		60	55	0	4
350-HP1B		60	140	80	5
350-HP2		60	51	0	5
350-HP3		60	117	57	5
350-HP4		60	71	11	5
350-HP5		60	112	52	5
350-HP6		60	73	13	5
350-HP7		60	55	0	5
350-HP8		60	52	0	5

Figure 6. Building Systems Display Screen

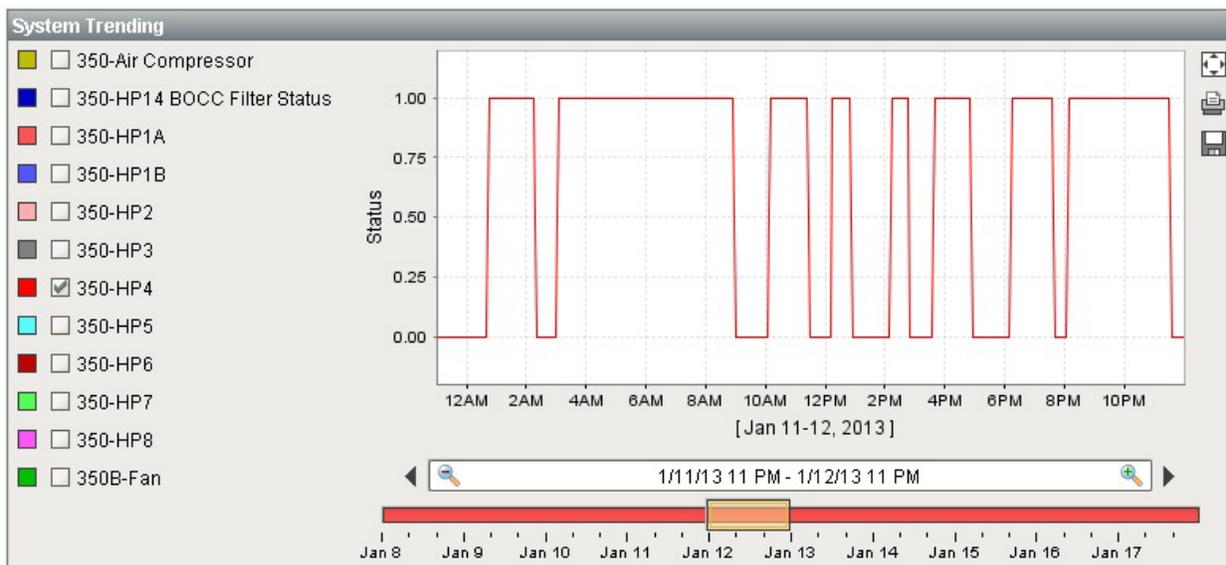
To view the systems of a building, the building of interest is clicked, which will change the content of the Systems box to that building on the Main display screen.

In each area's box, there is an open cell adjacent to each building under the "OccResults" heading. When one or more systems in that building exceed the actual hours by more than the allowable error, a red bar begins to populate. The size of this bar is proportional to the number of hours overrun, with a full bar indicating at least 24 hours of total overrun time.

When a specific building is selected, overages are displayed under the “Occupied Results” heading, which is the same as under the building list. This allows positive, rapid identification of the system(s) overrunning so that they can be immediately and effectively addressed. In addition, the scheduled hours can be verified as well as the actual run time and the number of hours each system has overrun. A full red bar indicates that the system in question has run at least 24 hours beyond its scheduled time, plus allowable error.

To investigate and trend on/off time, a trend chart is available. When a particular building is selected and its systems displayed, the user can click a small chart icon in the upper right hand corner (Figure 6). This will display a trend chart for each system in the selected building. This trend chart can be used to investigate the reason for overrun; e.g., overrides, early starts or night-time setback starts from low/high temperatures, excessive cycling, and operating on weekends or holidays due to poor scheduling control. The trend chart can be adjusted to compare systems simultaneously and change the date range of trends with ease.

Figure 7 shows one such trend for a heat pump in one of PNNL’s buildings for Saturday, January 12, 2013. This heat pump serves a carpenter’s workshop that is unoccupied on weekends. Comparison to the outdoor air recorded in the BAS shows temperatures in the 20s to low 30s in degrees Fahrenheit, a situation that could be driving the extra run time. Further investigation by the building engineer or a designee is recommended to determine the cause of the weekend operation.



**Figure 7.** Heat Pump Operation Trend (ON = 1; OFF = 0)

This trending option can be quite useful. While the primary function of the CBH tool is to totalize equipment run hours and display those results in a meaningful way, its functionality allows for other uses. If trend history was not saved in the BAS, the CBH tool’s trending option can be used as an effective replacement. Building management can also look at hour totalizations and trend data to determine if a piece of equipment is not operating when it should be.

## 4.0 Case Study – Battelle Auditorium

Implementation of the CBH tool has demonstrated the value by quick identification of poor schedule control. One such instance occurred with the Battelle Auditorium, a typical stage and seating facility used for PNNL and community events such as conferences, concerts, and film screenings. Use of the auditorium is scheduled via a Microsoft Outlook calendar, and the building's HVAC system control is tied into this calendar.

After the Auditorium was added to the CBH Tool and several days elapsed, it was noted that the auditorium supply fan was running approximately 130 hours per week or an average of more than 18 hours per day, even though it was scheduled as occupied for only about 30 hours per week in Outlook. This was diagnosed as an indication of a problem, and further investigation was performed. It was determined that the Auditorium systems were not responding to the Outlook schedule; additionally, the low and high setback band was too narrow. The connection with Outlook was repaired, and the setback band widened. These changes reduced the weekly runtime to 20–30 hours.

## 5.0 Conclusion

With the federal mandates for significant energy reduction goals, it has never been so important to abate energy waste. Building engineers and managers are often busy, but providing them with an effective tool to examine the facilities under their charge ensures that they are able to monitor the facility's systems and implement prompt, effective energy-saving changes.

A typical BAS display allows the user to view the current operating state of a piece of equipment and shows a historical trend of that data. While some conclusions can be inferred from this sort of trend, it is time consuming to locate every system in a building and manually totalize its hours of operation to ensure good system control. However, the “bird’s-eye view” provided by DSOM’s CBH Tool solves this problem in a simple, clear, and effective manner.



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