User's Guide to Energy Charting and Metrics plus Building Re-tuning and Measurement and Verification (ECAM+)

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June 2013

Pacific Northwest
NATIONAL LABORATORY

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[1] Version 3 of this user guide address all modifications and additions to ECAM+_v3dev27

Executive Summary

The intent of this user guide is to provide a description of the functionality of the Energy Charting and Metrics plus Building Re-tuning and Measurement and Verification (ECAM+) tool. ECAM+ facilitates the charting and analysis of energy use and point-level data from utility meters, building automation systems (BASs), and data loggers. This document describes the tool's general functions and features, including installation, use, guidance, and limitations.

Many of the features of ECAM+ are focused on ad-hoc analysis and data exploration. More prescriptive and automated features include the expanded building re-tuning functionality developed by Pacific Northwest National Laboratory (PNNL) and regression-based measurement and verification (M&V) capability per the International Performance Measurement and Verification Protocol (IPMVP) and ASHRAE Guideline 14, *Verification of Energy and Demand Savings*. This document offers detailed instructions for the PNNL building re-tuning charts, a feature in ECAM+ intended to help building owners and operators look at trend data in a series of charts (both time series and scatter) to analyze air-handler, zone, and central plant information gathered using a BAS. This document also describes the M&V capabilities and the types of models available.

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1.0 Introduction

The Energy Charting and Metrics Plus building re-tuning and measurement and verification (ECAM+) tool is intended to facilitate the examination of the utility interval data and the trend data from a building automation system (BAS). In addition to being easy-to-use, this tool is also flexible. Key features of ECAM+ include:

- Pre-processing of data to attach schedule and day-type information to time-series data;
- Filtering data by day-type, occupancy schedule, binned weather data, month/year, pre/post, etc.;
- Normalization of data based on user-entered information;
- Creation of standard charts for the points selected by the user;
- Calculation of normalized metrics for the points selected by the user;
- Creation of standard building re-tuning charts supporting the DOE-funded PNNL building re-tuning process using trend data from the BAS; and
- Change point energy models and measurement and verification (M&V) capability, based on the International Performance Measurement and Verification Protocol (IPMVP) and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Guideline 14, *Measurement of Energy and Demand Savings.*

The user's original data is not modified in the process of using ECAM+, but is copied into a new workbook automatically, where the user "maps" the data points into ECAM+ based on *A Specifications Guide for Performance Monitoring Systems*. Once mapped, the tool can automatically create nearly all of the chart types found in *Web-based Energy Information Systems for Energy Management and Demand Response in Commercial Buildings*. The tool makes extensive use of Excel® PivotTables to facilitate summarization and filtering of the data. It goes beyond normal PivotTables and PivotCharts, however, by automating the creation of scatter charts based on PivotTable data. The chart types include:

- Time series
- X-Y (scatter)
- Daily load profile
- Three-dimensional (3D) and heat map charts of daily load profiles
- Load profile calendar (calendar view of daily load profiles)
- Load profiles as grouped box plots
- Load-duration chart (histograms of frequency distributions)
- X-Y chart of hourly or daily data and energy models, plus charts of model residuals

- PNNL building re-tuning training charts (both time series and scatter) based on BAS data.

This document describes the tool's general functions and features, and offers detailed instructions for PNNL building re-tuning charts, a feature in ECAM+ intended to help building owners and operators look at trend data (recommended 15-minute time intervals) in a series of charts (both time series and scatter) to analyze air-handler, zone, and central plant performance gathered by a BAS.

1.1 Quick Start

This tool was developed using Microsoft Excel™ 2007 and 2010, and has had limited testing to confirm that it is functional with Excel 2003. There are some charts, however, that will only work with Excel 2007/2010.

ECAM+ requires continuous, uniform interval data. Change-of-value data, or data with different parameters stored at different time intervals, must be pre-processed before using it with ECAM+. The basic charting of data will work with non-uniform time stamps, but if there are multiple points from the BAS, all with different time stamps, then some pre-processing must be done. One tool designed to assist and automate such pre-processing is the Universal Translator (UT), available at www.utonline.org. UT is a program that assists in processing and merging data that has non-uniform time intervals or data that are stored in multiple files. UT interpolates data that is not uniform to form a uniform data series. The user guide that describes how to merge data with UT can be found at http://www.pnl.gov/buildingretuning/documents/pnnl_20948.pdf.

1.2 Installation

ECAM+ is a Microsoft Excel® add-in. First, download the add-in file, and save the tool file in your chosen location. Please note that Microsoft add-ins are installed, by default, in a common location, such as "Documents and Settings" folder. It can, however, be saved to any location.

To install the application, open Excel and perform the following steps:

Excel 2003:
Go to Tools, Add-Ins, and Browse to the location where the file was saved. Select the filename, and click OK. "ECAM" will be in the list of add-ins. There will also be a Menu item called ECAM in the Excel Toolbar.

Excel 2007/2010:
Click on the Office button, and then click "Excel Options." Click on "Add-Ins" on the left side of the window. At the bottom of the subsequent window, make sure that "Excel Add-Ins" is visible in the drop-down next to "Manage." Click the adjacent "Go…" button. Then Browse to the location where the file was saved. Select the filename, and

click OK. "ECAM" will be in the list of add-ins. After adding ECAM, also make sure that the "solver" add-in check-box is checked (ECAM utilizes the solver for a small portion of the analysis). After this is completed, and the user selects "OK," an ECAM menu item will be available in the Excel Toolbar under "Add-Ins."

1.3 Using the Tool to Create Metrics and Charts

Here are the top-level items in the ECAM+ menu (Figure 1-1):

- Select Data
- Definition of Points
- Create Schedules
- Input Dates for Comparison of Pre and Post
- Time Series Charts
- Load Profile as Box Plots
- Scatter Charts
- Load Duration Chart
- Chart to Check Input Schedule
- Matrix Charts
- Metrics for Points Normalized per Sq. Foot
- Create Other Metrics
- Data Summaries
- PNNL Re-Tuning
- Data-Driven Models and M&V
- ECAM Utilities
- ECAM Help
- About ECAM
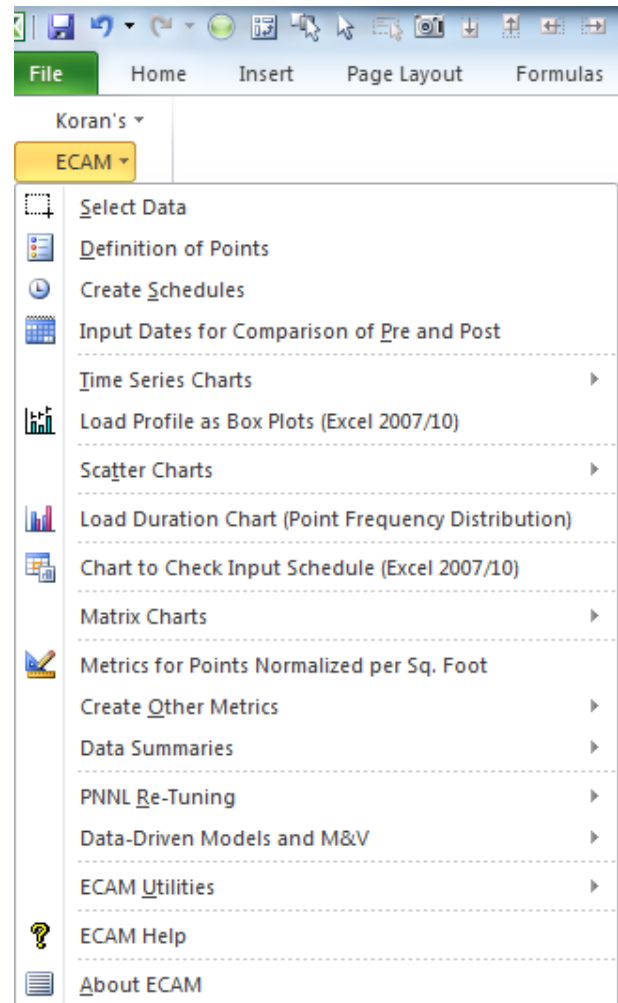
Figure 1-1: ECAM+ top-level items.

The first four items in the menu should be used in order, but all four items are not required to get useful information. To use the "PNNL Re-Tuning" feature, however, the "Definition of Points" feature must be used to define points (the process is explained later in the guide). Otherwise, only the "Select Data" menu item is required; the others are optional, as described in detail below. Defining points not only maps the point names to common names "understood" by ECAM+, but also adds additional calculated points.

A brief description of the functions of the first four menu items follows:

- **Select Data**—Select the data range (range of cells) to be included in the analysis, using either the mouse or the keyboard.

- **Definition of Points**—Map (correlate) the point names in the user's data to standard point names recognized by the tool.

- **Create Schedules**—Enter the operating schedule applicable to the building or equipment, using the input forms included.

- **Input Dates for Comparison of Pre and Post (energy project)**—If there is an energy project to be evaluated, input the date when the energy project started and the date it was completed.

Everything after "Select Data" is optional, but issues may arise depending upon what subsequent menu item(s) are used. For example, if the user does not enter a schedule, but does create metrics, then the fields for metrics that are dependent upon occupancy will show "NA." Similarly, if data for comparison of "pre" and "post" (e.g., an energy project) is not input before trying to create a "load profile by date range," the chart will only show a single line with a series name of "(blank)." Other complications may also exist, although not all of the tool's capabilities have been exhaustively tested without using all of the first four menu items.

When using the application to create metrics and charts, the workbook created by the tool must be the active (visible) workbook. Using the metrics and charts menu items will add new worksheets to the active workbook. Repeated use of the same or related menu items will overwrite prior work because the worksheet names are not changed. To avoid losing work, the user should change the names of any tool-created worksheets that they wish to save, prior to creating a related metric or chart. This is especially important if any new formulas or customization has been added.

When creating metrics or charts, select just the point name(s) to be included; do not select the data.

1.3.1 Tool Notes

All Excel formatting and other customization options should be available. Scatter charts require that the point name to be used for the independent value (to be placed on the X-axis) be selected first. Do not drag the mouse or use the "Shift" key to select subsequent point names. Use the "Ctrl" key to select the second and subsequent point names for the dependent values.

ECAM+ will not plot status points that have "On" or "Off" as designation of status. These should be converted to On=1 and Off=0 prior to the "Select Data" step in ECAM+.

Important: Do not enter any data or information in the cells directly below the PivotTables.

2.0 Menu Items for Preprocessing of Data

As mentioned above, most ECAM+ charts and metrics cannot be generated from data that has non-uniform or multiple time stamps. There is one menu item that is for preprocessing in ECAM+, but this is only to take the data and convert it to a form that ECAM+ recognizes. ECAM+ will recognize raw data files in Excel as either in "*.csv" or "*.xls", "*.xlsx" (for 2010 users), and many other text or spreadsheet formats. So before continuing, make sure the raw data file is in one of these formats.

2.1 Select Data

This menu item asks the user to select the data to be processed. The data must be continuous (i.e., there should not be any completely blank rows or columns). If there are blank rows or columns, remove them from the raw data file before continuing. Also, if there are sections of data that are missing, try removing all associated data for that range of time stamps until the data is un-interrupted. Figure 2-1 below is a "*.csv" raw data file, ready for the following steps:

Step 1: Choose "Select Data" from the ECAM+ menu
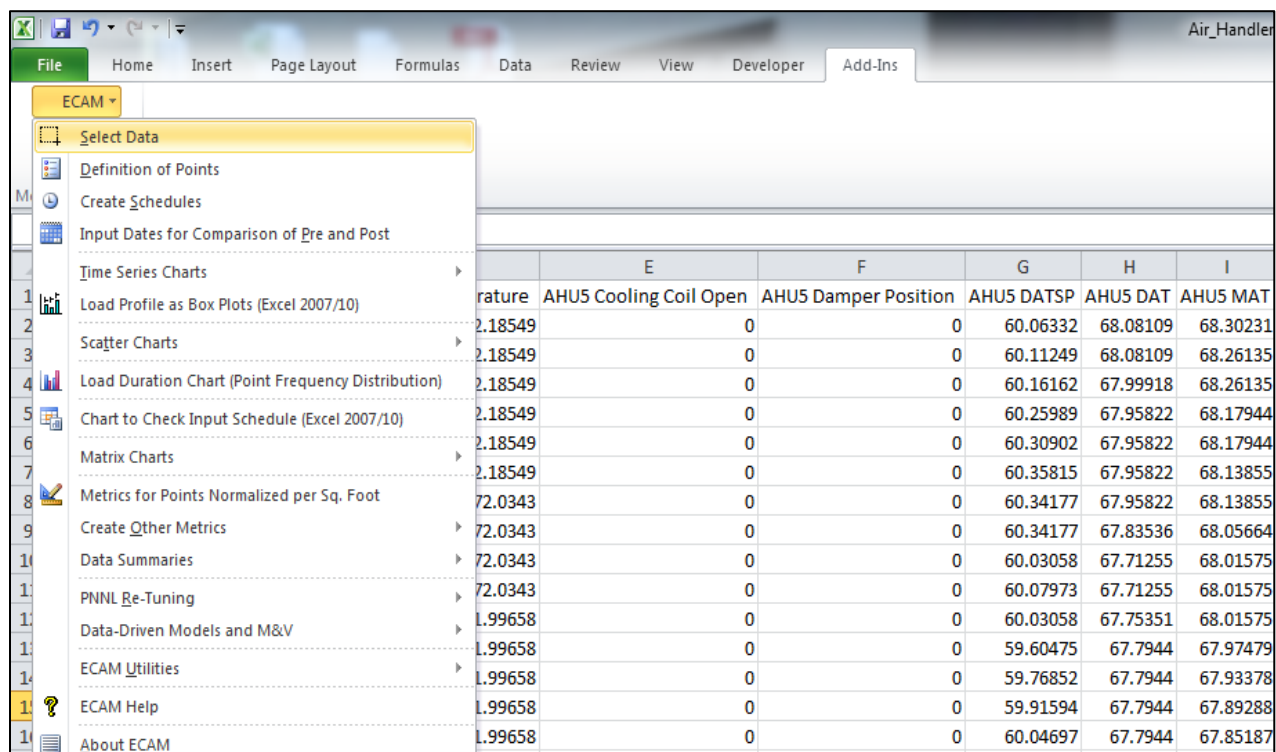
Figure 2-1: Select data from the raw data sheet.

After choosing "Select Data," ECAM+ will bring up a window that asks if the time stamp is in one column or two columns (Figure 2-2). ECAM+ will recognize different date/time formats, and it can all be in one column, or the date can be in the first column and the time in the second column. Note that if you have two columns for the time stamp, ECAM+ only will recognize the date in the first and time in the second.

Step 2: Select the correct time stamp format
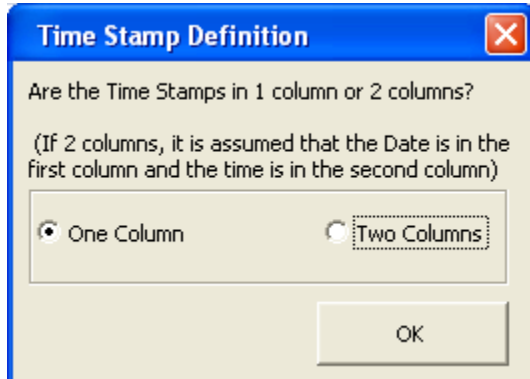
Figure 2-2: ECAM+'s time stamp definition window.

After selecting the appropriate time stamp definition from Figure 2-2, ECAM+ will then ask you to select the range of cells that contains the data (Figure 2-3 below). This can be accomplished in the following manner:
- When prompted, select the first (upper-left) cell in the data.
- Hold down the "Ctrl" and "Shift" keys, and hit the "right" arrow and then the "down" arrow. This should highlight all of the data in the workbook.
- Click "OK."

Step 3: Select the range of cells that contain the data
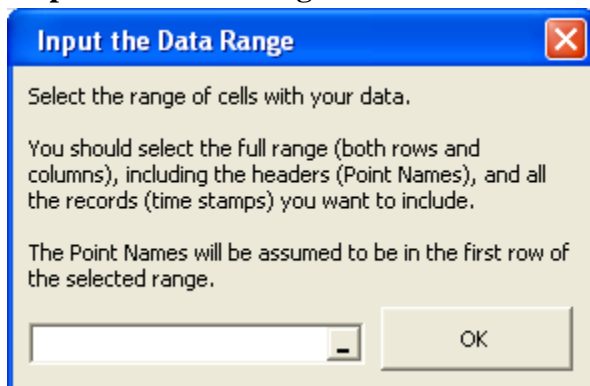
Figure 2-3: Selecting the range of cells that contain data in ECAM+.

If there are time stamps or data that needs to be excluded, then you can also select the data manually by clicking on the first (upper-left) cell and holding down the left-click on the mouse

key while dragging the mouse to the desired cell. You can also manually type the data range of interest into the blank field, as shown in Figure 2-3.

The last window that ECAM+ will show before further analysis and processing is the ambient temperature window. Here, you will be asked if the ambient temperature data is included (outdoor-air temperature data, or OAT). If so, you can click anywhere in that column and ECAM+ will recognize it (Figure 2-4). If it is not included, select "No," and ECAM+ will omit it.

Step 4: Select whether ambient temperature data is included

Ambient Temperature

Is Ambient Temperature data included?

◉ Yes   ○ No

Which column has the Ambient Temperatures?

AllData!F1   OK
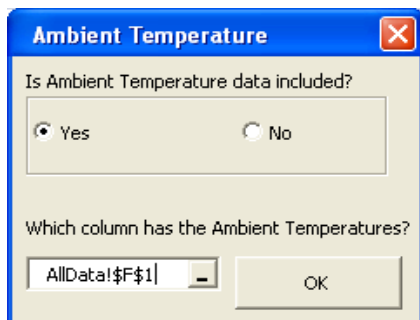
Figure 2-4: Selecting if the ambient temperature data is included in ECAM+.

Once these four steps are complete, ECAM+ will generate a new workbook with data that is recognized by the program. ECAM+ will create many new columns, and bring in the raw data as well (see Figure 2-5 below).

Book1 - Microsoft Excel

DateTime	Year	Month	MonthYr	Day	Hour	Date	Time	WeekdayNum	Weekday	Daytype	Holiday	DaySchedule	Occupancy	1degBin	5degBin	TempRng	DateRng	OAT
1/10/11 1:45 PM	2011	January	Jan 2011	10	13	1/10/2011	1:45 PM	1	Monday	Weekday	No			18	17.5	under 55		17.6
1/10/11 2:00 PM	2011	January	Jan 2011	10	14	1/10/2011	2:00 PM	1	Monday	Weekday	No			18	17.5	under 55		17.6
1/10/11 2:15 PM	2011	January	Jan 2011	10	14	1/10/2011	2:15 PM	1	Monday	Weekday	No			18	17.5	under 55		17.6
1/10/11 2:30 PM	2011	January	Jan 2011	10	14	1/10/2011	2:30 PM	1	Monday	Weekday	No			18	17.5	under 55		17.6
1/10/11 2:45 PM	2011	January	Jan 2011	10	14	1/10/2011	2:45 PM	1	Monday	Weekday	No			18	17.5	under 55		17.6
1/10/11 3:00 PM	2011	January	Jan 2011	10	15	1/10/2011	3:00 PM	1	Monday	Weekday	No			14	12.5	under 55		14.48
1/10/11 3:15 PM	2011	January	Jan 2011	10	15	1/10/2011	3:15 PM	1	Monday	Weekday	No			14	12.5	under 55		14
1/10/11 3:30 PM	2011	January	Jan 2011	10	15	1/10/2011	3:30 PM	1	Monday	Weekday	No			14	12.5	under 55		14
1/10/11 3:45 PM	2011	January	Jan 2011	10	15	1/10/2011	3:45 PM	1	Monday	Weekday	No			14	12.5	under 55		14
1/10/11 4:00 PM	2011	January	Jan 2011	10	16	1/10/2011	4:00 PM	1	Monday	Weekday	No			12	12.5	under 55		12.44
1/10/11 4:15 PM	2011	January	Jan 2011	10	16	1/10/2011	4:15 PM	1	Monday	Weekday	No			12	12.5	under 55		12.2
1/10/11 4:30 PM	2011	January	Jan 2011	10	16	1/10/2011	4:30 PM	1	Monday	Weekday	No			12	12.5	under 55		12.2
1/10/11 4:45 PM	2011	January	Jan 2011	10	16	1/10/2011	4:45 PM	1	Monday	Weekday	No			12	12.5	under 55		12.2
1/10/11 5:00 PM	2011	January	Jan 2011	10	17	1/10/2011	5:00 PM	1	Monday	Weekday	No			10	12.5	under 55		10.4
1/10/11 5:15 PM	2011	January	Jan 2011	10	17	1/10/2011	5:15 PM	1	Monday	Weekday	No			7	7.5	under 55		6.8

Figure 2-5: New ECAM+ workbook generated after completing the first menu item, "Select Data."

You can see that several columns are created by ECAM+, and some of them are blank. The blank columns (DaySchedule, Occupancy, and DateRng) will remain blank unless items 3 and 4

in the ECAM+ drop-down menu are executed ("Create Schedules" and "Input Date Ranges for Comparison of Pre and Post"). These are not required, but allow for more charts to be generated, which will be discussed later. You can see that ECAM+ defaults the workbook point names to start in cell "C6," which will always be the case, and that the OAT (if defined), will always start in cell "U6." The data starts in row 7, and all raw data in ECAM+ will appear to the right of column T.

Note: It is possible that a user may see an error at this point in ECAM+ that has to do with default Excel save options. If a bug occurs, go to File>Options>Save and make sure that the "Save files in this format" is listed as Excel Workbook (*.xlsx). Then close Excel and reopen, and try processing the data from the beginning.

2.2 Definition of Points

This menu item is required to utilize the PNNL building re-tuning capability. This process takes all of the raw data points from the BAS system and "maps" them so that ECAM+ can recognize what they are. This mapping feature enables normalizations, calculated points, and certain metrics and charts to be created automatically. The first window that comes up asks for some basic building information (i.e., building area and voltage for three-phase equipment). If you know this information, ECAM+ will normalize data and metrics by square foot, but if you do not know this, just leave the default values of 100,000 sf and 480 Volts and select "OK" (see Figure 2-6).

Step 1: Choose "Definition of Points" from the ECAM menu

Step 2: Input the building area and voltage for three-phase equipment (if known, see Figure 2-6)
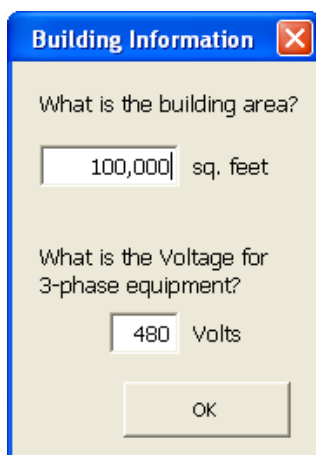
Figure 2-6: Entering building information in ECAM+'s "Definition of Points" menu item.

After selecting "OK," a new window will come up where the user defines or "maps" the points (see Figure 2-7 below). The first part of the window will have the "Points List" and "Mapped

Points." The "Mapped Points" will be empty at the beginning, and fill as the user maps different points. The "Points List" will correspond to the point names that were in the user's raw data file.

Step 3: Define or "map" the points (see Figure 2-7)
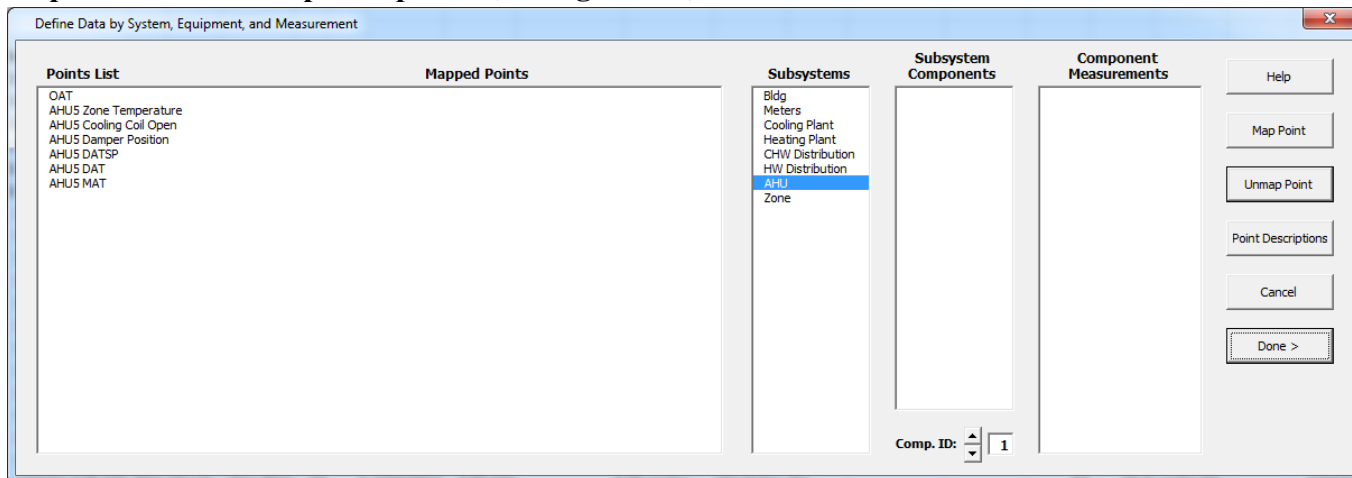
Figure 2-7: ECAM+'s Definition of Points window.

When this window first comes up, the user will see that the only columns that have anything in them are the "Points List" and the "Subsystems." The user will have to click on a different "Subsystem" than what is defaulted to refresh the "Subsystem Components" window (see Figure 2-8 below). Each "subsystem" in ECAM+ will have specific "subsystem components" and "Component Measurements" that belong to the "Subsystem." The tool point names are based on the naming convention described in *A Specifications Guide for Performance Monitoring Systems*. In addition, the user can see what these points are, and there definitions, by clicking on the "Point Descriptions" button during this step. When selected, a new sheet opens up in the workbook for the user to reference while mapping the points into ECAM+.
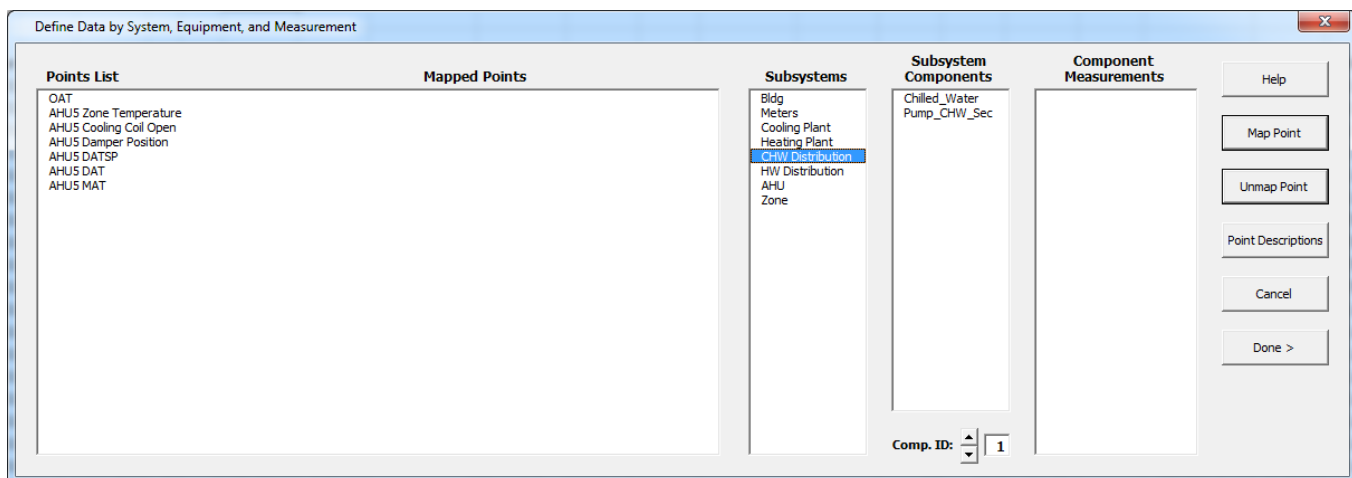
Figure 2-8: Refreshing the "Subsystems" to bring up the proper components.

Now the user is ready to map all of the points from the BAS into ECAM+. If OAT data was included in the raw data, then it will get mapped under "Bldg," under "Subsystem." First, find and click on the outdoor-air temperature in the "Points List," (In this case, it is OAT, but may not always be the case depending on who set up the BAS). Then, click on "Bldg," under "Subsystems." Now, under "Subsystem Components," click on the "Ambient" option, and under the "Component Measurements," select the "Bldg_TempOa" option and click "Map Point" on the right-hand side of the window. If done correctly, you will see something similar to Figure 2-9, where the "Mapped Points" now has "Bldg1_TempOa" under it. If the user incorrectly maps a point, there is an "Unmap Point" button on the right-hand side of the window.
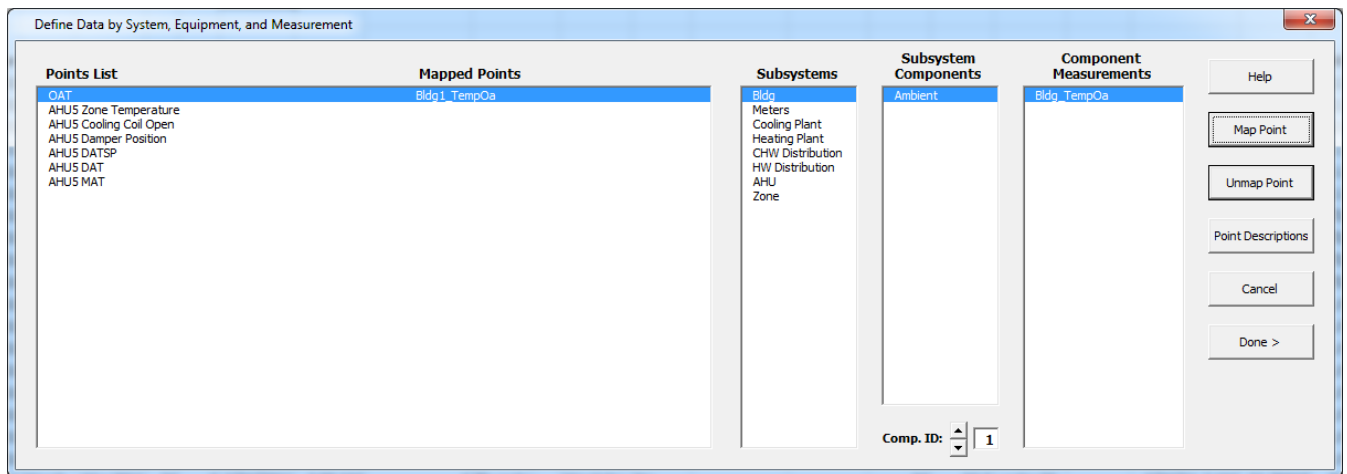
Figure 2-9: "Definition of Points" window after successfully "mapping" the outdoor-air temperature.

This approach should be used for each applicable point in the "Points List." If there are points that you do not want to map, simply omit them. Any number of points can be mapped at one given time, and modified later to include in other plots. ECAM+ also has the ability to map more than one air-handling unit (AHU), zone, or chiller/boiler at a time. This is done by using the "Comp.ID" feature at the bottom of Figure 2-9. It is defaulted to "1", or the first "Subsystem Component." That is why a "1" appears in all "Mapped Point" names. However, if you have six AHUs and want to map all of them, you would increase the "Comp.ID" for each air handler. The corresponding "Comp.ID" number will then appear in the "Mapped Points" name.

Once all points have been mapped, some normalized and calculated points will be created and added to the points list in the new workbook (these will be additional columns that automatically appear after all of the user points). Some examples include:
- All kW points will automatically have a normalized point added as Watts per square foot (W_perSF).
- All CFM points will automatically have a normalized point added as cfm per square foot (cfm_perSF).
- If a set of chilled water temperatures and the associated flow is available, the cooling capacity (tons) of that chiller or chilled water loop will be calculated.

Table 2-1 offers a detailed list of the additional points created by ECAM+.

Table 2-1: Additional points created by ECAM+ after mapping all points.

Point Type	Normalized or calculated point
kW	Watts per square foot (W_perSF)
kW	Equipment status (only if a status point is not available) >3% of max= "On" <=3% of max= "Off"
amps	Equipment status (only if a status point is not available, and kW is not available) >3% of max= "On" <=3% of max= "Off"
CFM	cfm per square foot (cfm_perSF)
gpm, T_{in}, T_{out}	Cooling capacity (tons)
kW, tons	kW_perTon
gpm, tons	gpm_perTon

2.3 Create Schedules

This is the third item in the ECAM+ drop-down menu, and it is optional. If the operating schedule of the building is known, it should be input, because there are some powerful scatter plots in ECAM+ that can show a comparison of occupied and unoccupied electricity consumption. However, if no schedule is input, the daytype will always be assumed to be occupied "Occ." To create a schedule that has a 24-hour operation schedule, select 12:00 AM as the start time and 11:59 PM stop time. To create a schedule that is always unoccupied "Unocc," select 12:00 AM as the start time and 12:00 AM as the stop time. When selecting the option from the drop-down menu, the window seen in Figure 2-10 will appear. Under "Schedule Name," there are 10 different schedule options. This gives the user the ability to have 10 different types of schedules. The user should re-name the schedule to identify what type of day it corresponds to. For example, if the building had an occupancy schedule of Monday through Friday 8:00 AM to 5:00 PM, Saturday 10:00 AM to 3:00 PM, closed on Sundays and holidays, then the user should set up three different schedules. The first one would be named something like "Weekdays," or "Mon-Fri." This will help the user identify what schedule corresponds to which day, in case changes need to be made. The "Main Occupancy" should be specified to match that of the building occupancy for each daytype (Mon-Fri, etc.). The "Typical Startup/Shut-down" options will only be used if there is a clearly defined building warm-up/shut-

down time. If unknown, just leave the defaulted values of 12:00 PM. Figure 2-10 shows what the window may look like filled in for the scenario described above.

Figure 2-10: First window for inputting the building schedule information.

Once the information is entered correctly for the building schedule, select the "Week Schedules" button at the bottom right of the window. This will bring up a new window that will allow you to select the schedule type for each day of the week specifically. The "Schedule Name" button has five drop-down options: All Year, Quarter A, Quarter B, Quarter C, and Quarter D, along with five "Sch.#" options. This allows the user to input multiple schedules based on the time of the year. For this exercise, we will select the "All Year" option and then choose the appropriate schedule for each day of the week (see Figure 2-11). You will see the name of the daytype schedule that you input in the previous window now appears by each day in the schedule. If you have multiple schedules you want to input, select the "Next Week Sched;" otherwise select the "Annual Schedule" button. The third and final window that comes up for scheduling is for the "Annual Schedule." The annual schedule is defaulted to begin on January 1st, but the user can choose the ending month and day for each schedule they have input in the previous screens. For this example, we will choose the entire year for the schedule and click "OK" (see Figure 2-12).

Figure 2-11: Inputting week schedules in the scheduling option for ECAM+.

Figure 2-12: Inputting annual schedules in ECAM+.

After selecting "OK," the updated workbook with the schedule input will appear. Comparing Figure 2-5 to Figure 2-13, the user will now see that the "DaySchedule" and "Occupancy" columns are filled in based on their building's schedule, which they input.

DateTime	Year	Month	MonthYr	Day	Hour	Date	Time	WeekdayNum	Weekday	Daytype	Holiday	DaySchedule	Occupancy	1degBin	5degBin	TempRng	DateRng	Bldg1_Ter
1/10/11 1:45 PM	2011	January	Jan 2011	10	13	1/10/2011	1:45 PM	1	Monday	Weekday	No	Mon-Fri	Occ	18	17.5	under 55		17.6
1/10/11 2:00 PM	2011	January	Jan 2011	10	14	1/10/2011	2:00 PM	1	Monday	Weekday	No	Mon-Fri	Occ	18	17.5	under 55		17.6
1/10/11 2:15 PM	2011	January	Jan 2011	10	14	1/10/2011	2:15 PM	1	Monday	Weekday	No	Mon-Fri	Occ	18	17.5	under 55		17.6
1/10/11 2:30 PM	2011	January	Jan 2011	10	14	1/10/2011	2:30 PM	1	Monday	Weekday	No	Mon-Fri	Occ	18	17.5	under 55		17.6
1/10/11 2:45 PM	2011	January	Jan 2011	10	14	1/10/2011	2:45 PM	1	Monday	Weekday	No	Mon-Fri	Occ	18	17.5	under 55		17.6
1/10/11 3:00 PM	2011	January	Jan 2011	10	15	1/10/2011	3:00 PM	1	Monday	Weekday	No	Mon-Fri	Occ	14	12.5	under 55		14.48
1/10/11 3:15 PM	2011	January	Jan 2011	10	15	1/10/2011	3:15 PM	1	Monday	Weekday	No	Mon-Fri	Occ	14	12.5	under 55		14
1/10/11 3:30 PM	2011	January	Jan 2011	10	15	1/10/2011	3:30 PM	1	Monday	Weekday	No	Mon-Fri	Occ	14	12.5	under 55		14
1/10/11 3:45 PM	2011	January	Jan 2011	10	15	1/10/2011	3:45 PM	1	Monday	Weekday	No	Mon-Fri	Occ	14	12.5	under 55		14
1/10/11 4:00 PM	2011	January	Jan 2011	10	16	1/10/2011	4:00 PM	1	Monday	Weekday	No	Mon-Fri	Occ	12	12.5	under 55		12.44
1/10/11 4:15 PM	2011	January	Jan 2011	10	16	1/10/2011	4:15 PM	1	Monday	Weekday	No	Mon-Fri	Occ	12	12.5	under 55		12.2
1/10/11 4:30 PM	2011	January	Jan 2011	10	16	1/10/2011	4:30 PM	1	Monday	Weekday	No	Mon-Fri	Occ	12	12.5	under 55		12.2
1/10/11 4:45 PM	2011	January	Jan 2011	10	16	1/10/2011	4:45 PM	1	Monday	Weekday	No	Mon-Fri	Occ	12	12.5	under 55		12.2

Figure 2-13: Updated ECAM+ workbook with building schedule input and points mapped.

2.4 Input Dates for Comparison of Pre and Post

The fourth item in the ECAM+ drop-down menu is also optional, and gives the user the ability to input two sets of dates for monitoring changes that were made to the system at any time. They can enter a date when an energy project (retrofit or re-tuning) was started (Figure 2-14), and the date when it was completed (Figure 2-15). ECAM+ will then have information filled in under the column "DateRng" (shown in Figure 2-13) to use for categorization and filtering of the data.

Figure 2-14: Entering a start date for an energy project.
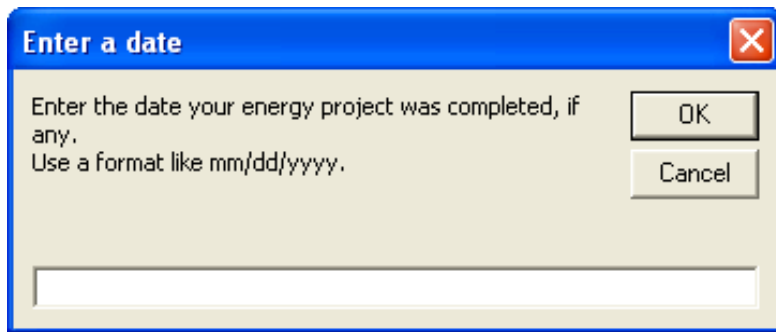
Enter a date

Enter the date your energy project was completed, if any.
Use a format like mm/dd/yyyy.

OK

Cancel

Figure 2-15: Entering an end date for an energy project.

3.0 Menu Items to Create Time Series Charts

The first four drop-down menu items in ECAM+ help prepare and organize the data for analysis. The fifth item, "Time-Series Charts," has a number of charts that are created based on different options in ECAM+ (Figure 3-1). All of these charts, with the exception of the "Point(s) History Chart," are used to create load profiles if whole building electricity consumption data is available. This user guide will briefly describe each chart, but it is recommended that users refer to "*Interval Data Analysis with the Energy Charting and Metrics Tool (ECAM+)*" for detailed instructions on how to create and analyze the charts in this section.
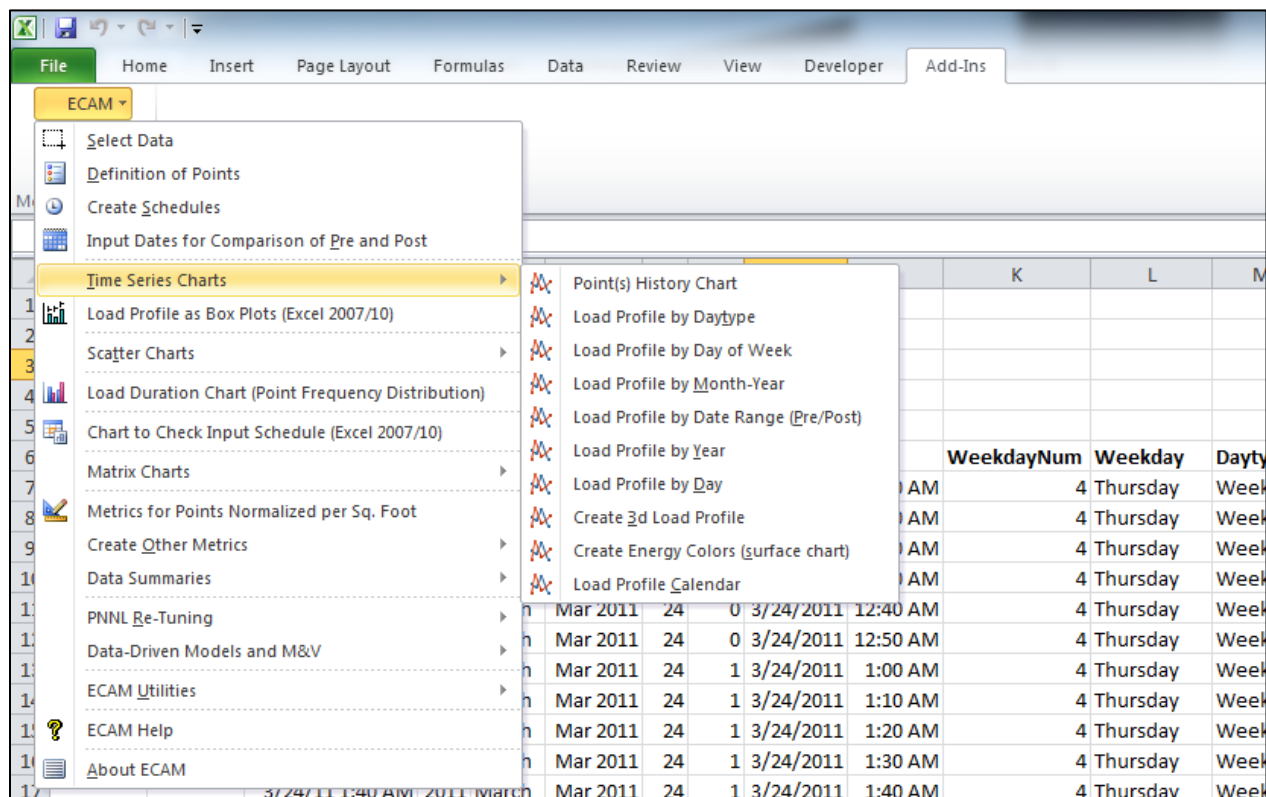
Figure 3-1: Time series charts in ECAM+.

3.1 Point(s) History Chart

This menu item creates a typical line chart, initially showing the data history for all the points selected by the user. The chart can be modified to show different time periods by selecting individual days in the left column of the data PivotTable, or using the PivotTable filters. The chart scales adjust appropriately. The day of the week is included in the time axis labels to aid in understanding. Depending on the version of Excel the user has, the more time stamps will be included in the PivotTable or chart. To create this chart, click the Point(s) History Chart Option in the ECAM+ drop-down menu. ECAM+ will then bring up a window asking the name(s) of the point(s) you want to include, as in Figure 3-2. For this chart, you can choose any point(s) of

interest, and the key in choosing the data is to click only on the header of the column and then click "OK." In Figure 3-3 below, the most recent whole building consumption data is shown; up to the maximum number of time stamps (at least 32,000 time stamps can always be shown regardless of the version of Excel).
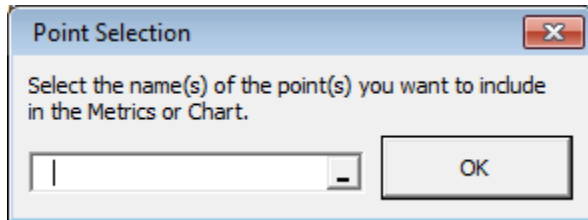
Figure 3-2: Point selection for time series charts in ECAM+.
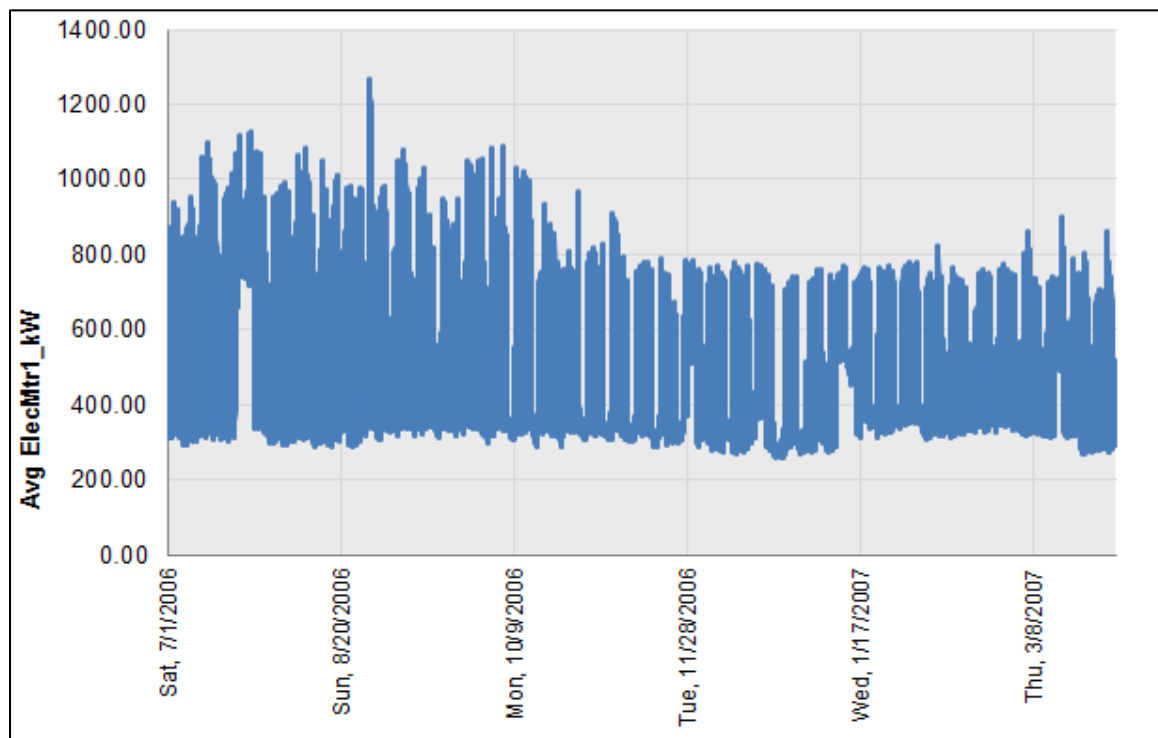
Figure 3-3: Whole building consumption point history chart in ECAM+.

This plot shows the time series of the whole building consumption for an entire year. Now, utilizing ECAM+'s PivotTable features, the user can select a specific month from the drop-down menu shown in Figure 3-4 to get the whole building consumption for only the month of August. This is accomplished by clicking the drop-down menu for "MonthYr," clicking "Aug 2006," and then "OK." Figure 3-5 shows the results.
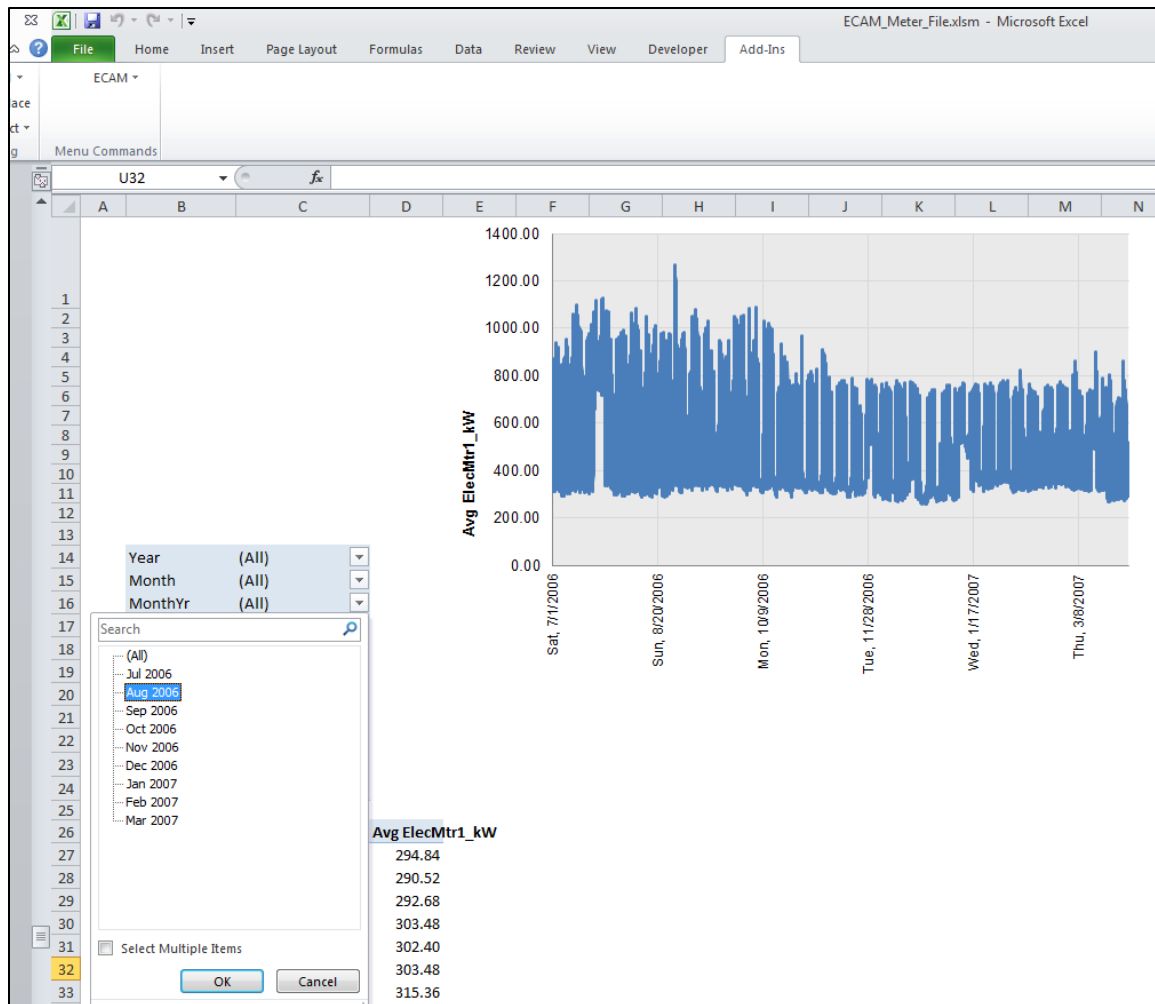
Figure 3-4: Using the PivotTable functions in ECAM+.
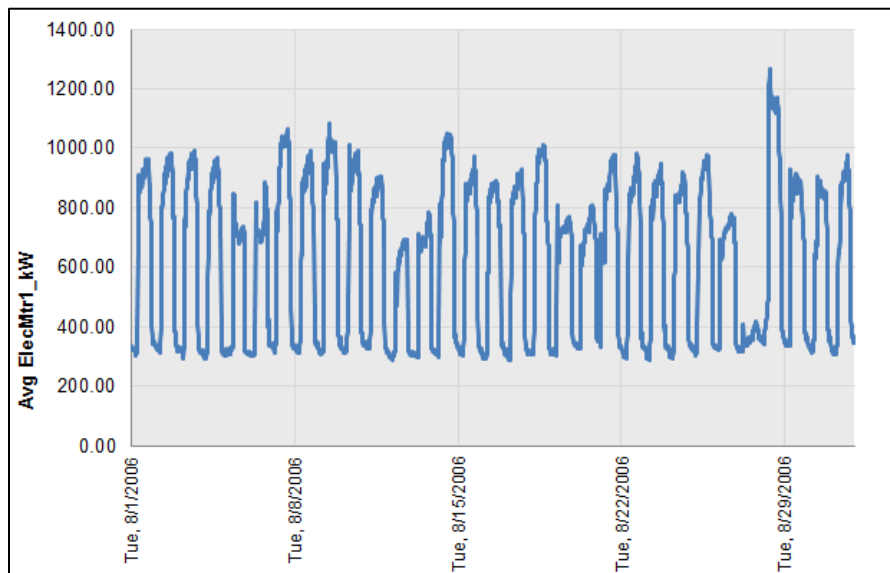
Figure 3-5: Point history chart for only 1 month of data.

The user can go even further, and utilize the PivotTable to select a group of days within the month, or 1 day specifically, by clicking on the drop-down menu under "Day" and selecting 1 day or multiple days. To select multiple days, click the "Select Multiple Items" box at the bottom of the drop-down menu, and then choose the days of interest. Figure 3-6 shows a 3-day period in May.
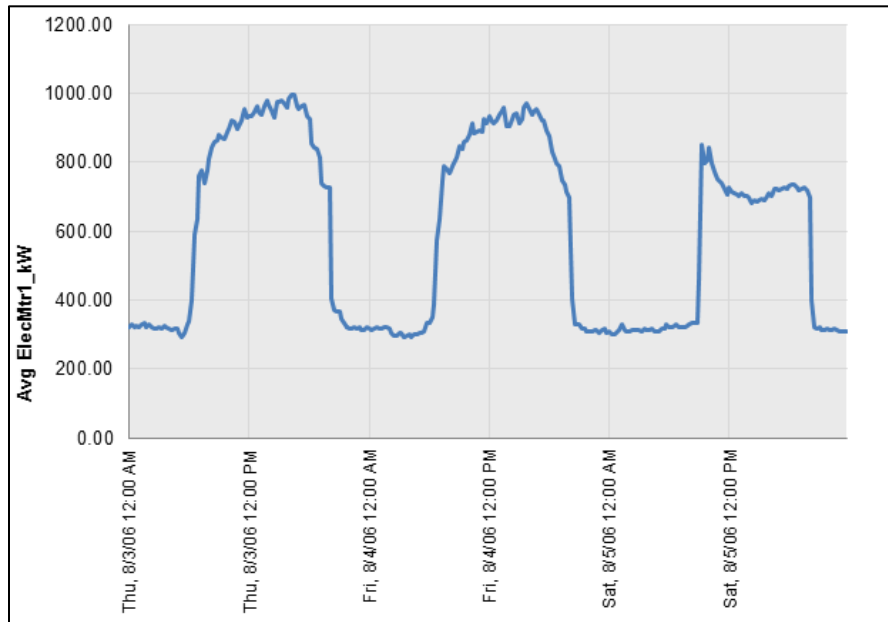
Figure 3-6: Point History Chart for a 3-day period on May.

One thing to note is that point names are prefixed with "Avg." However, this is just a consistent behavior with the ECAM+ charts that do use averages, such as the chart described in the next section. The "Point(s) History Chart" uses raw data, not averages. The user can modify the axis labels as they feel necessary.

3.2 Load Profile by Daytype

This menu item creates a line chart with four lines; the average load profiles for each of four daytypes: Weekday, Saturday, Sunday, and holiday. Generating this chart is the same as described at the beginning of Section 3.1 for the Point(s) History Chart. Figure 3-7 shows a typical "Load Profile by Daytype" chart.
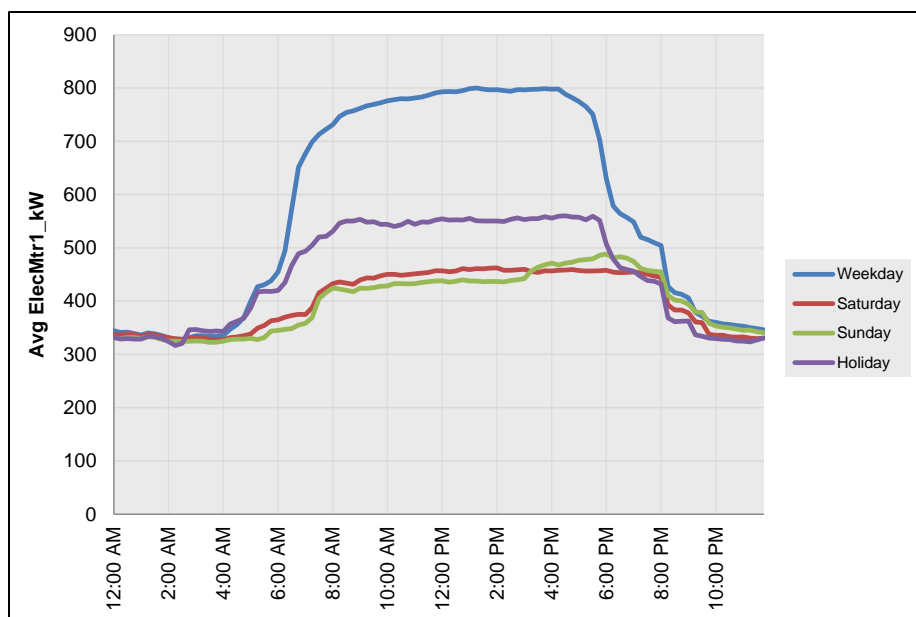
Figure 3-7: Load profile by daytype time series chart in ECAM+.

3.3 Load Profile by Month-Year

This creates a chart showing the average load profile for each month in the data set. Months with incomplete data are included. Figure 3-8 shows a typical "Load Profile by Month Year" chart.
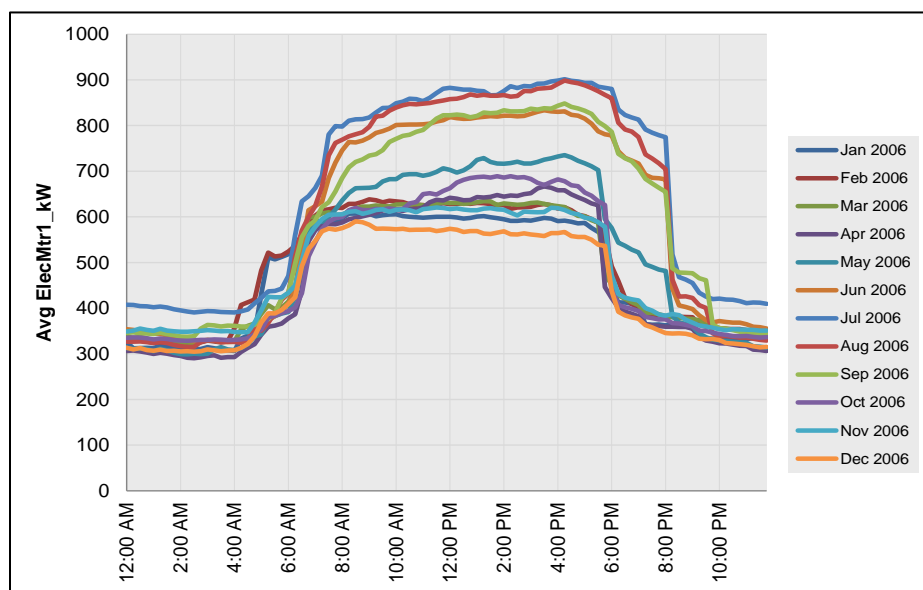
Figure 3-8: Load profile by month-year time series chart in ECAM+.

3.4 Load Profile by Date Range (Pre/Post)

This chart is only useful if the user entered dates for an energy project, as described in Section 2.4. If so, the chart will display three lines; one for the average load profile before the energy project started, one for the average load profile during the energy project, and one for the average load profile after the project was completed. Figure 3-9 below shows an example of this chart.
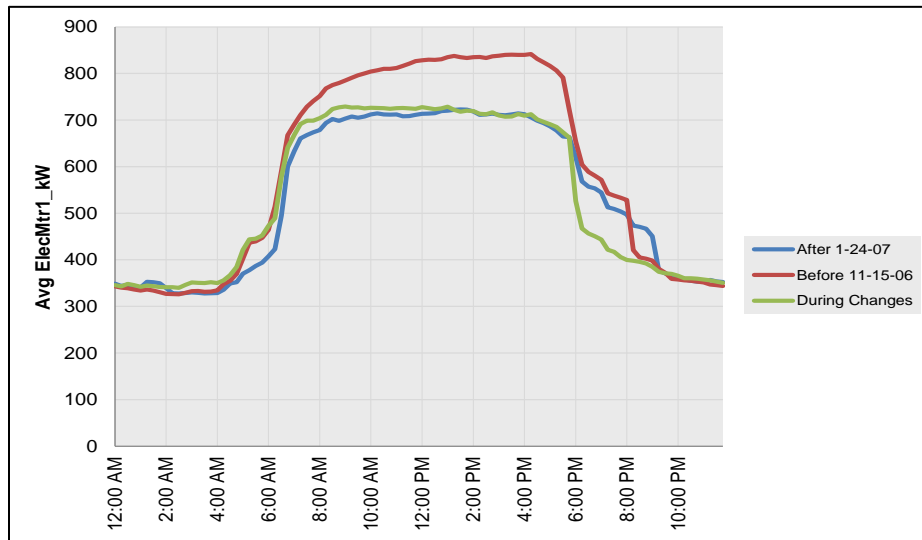
Figure 3-9: Load profile by date range (pre/post) time series chart in ECAM+.

3.5 Load Profile by Year

If there is a full year of data, or multiple years of data, the "Load Profile by Year" plot will show the average load profiles for the years in the data set, as shown in Figure 3-10.
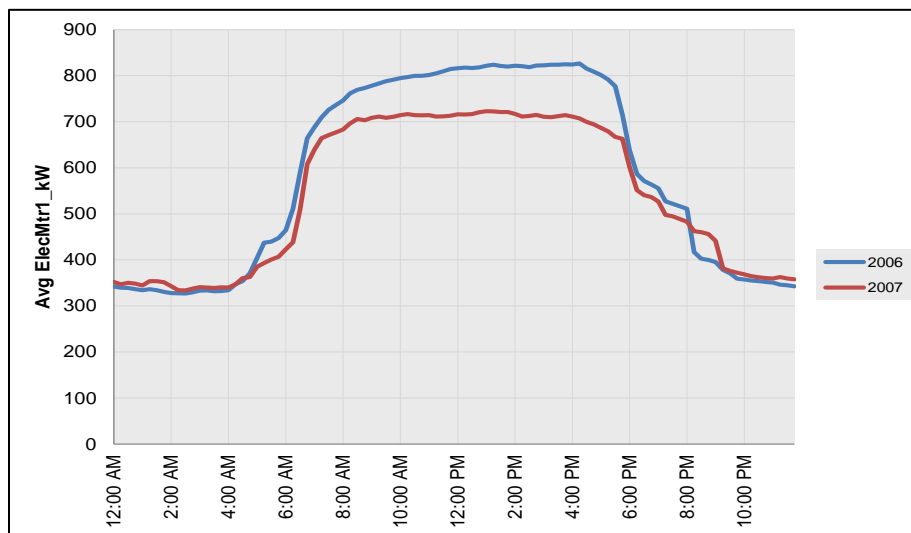
Figure 3-10: Load profile by year time series chart in ECAM+.

3.6 Load Profile by Day

This menu item requires a second step to get a meaningful chart. Selecting this item creates a line chart with up to 31 lines (one for each day of the month). Each line is the average for a day number (e.g., day number 10 is the 10th day of the month) for all of the months in the data set. By itself, this chart is not very meaningful. However, from this chart, you must specify a specific MonthYr using the PivotTable filter field drop-downs. Figure 3-11 shows a plot of the "Load Profile by Day" for a single month.

Note: Making this Month or MonthYr selection is a prerequisite for creating the last three types of load profiles under the Time Series Charts option of ECAM+: Create 3D Load Profile, Create Energy Colors (surface chart), and Load Profile Calendar.
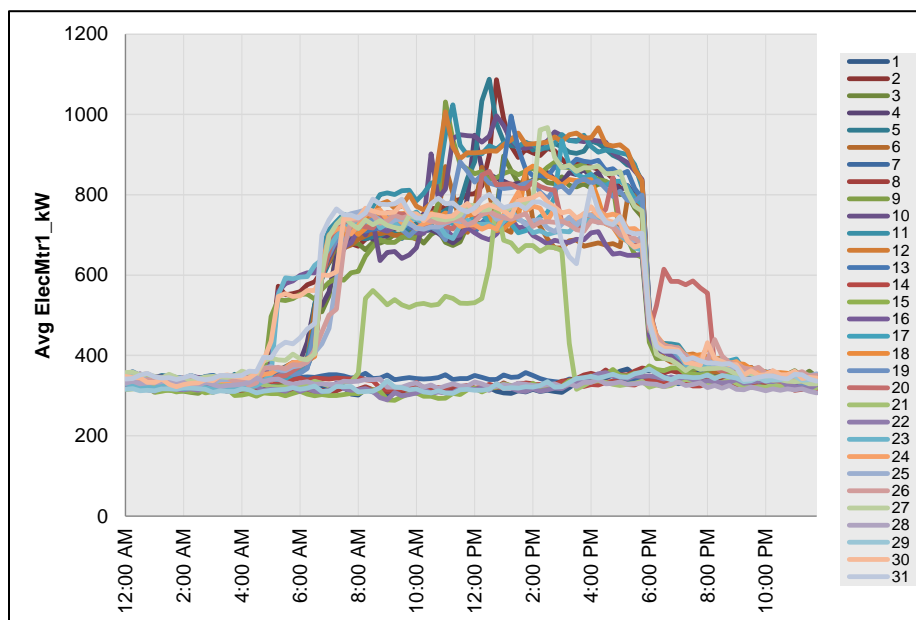
Figure 3-11: Load profile by day time series chart in ECAM+ for 1 month.

3.6.1 Create 3D Load Profile

Once the "Load Profile by Day" has been completed, and a specific month chosen, the "3D Load Profile" can be created. This chart must be generated while you are in the current sheet with the "Load Profile by Day" chart. Selecting this option will convert the months' worth of daily load profiles to a three-dimensional chart, with the weekdays and weekends separated by color. See Figure 3-12 below for a typical "3D Load Profile" chart.
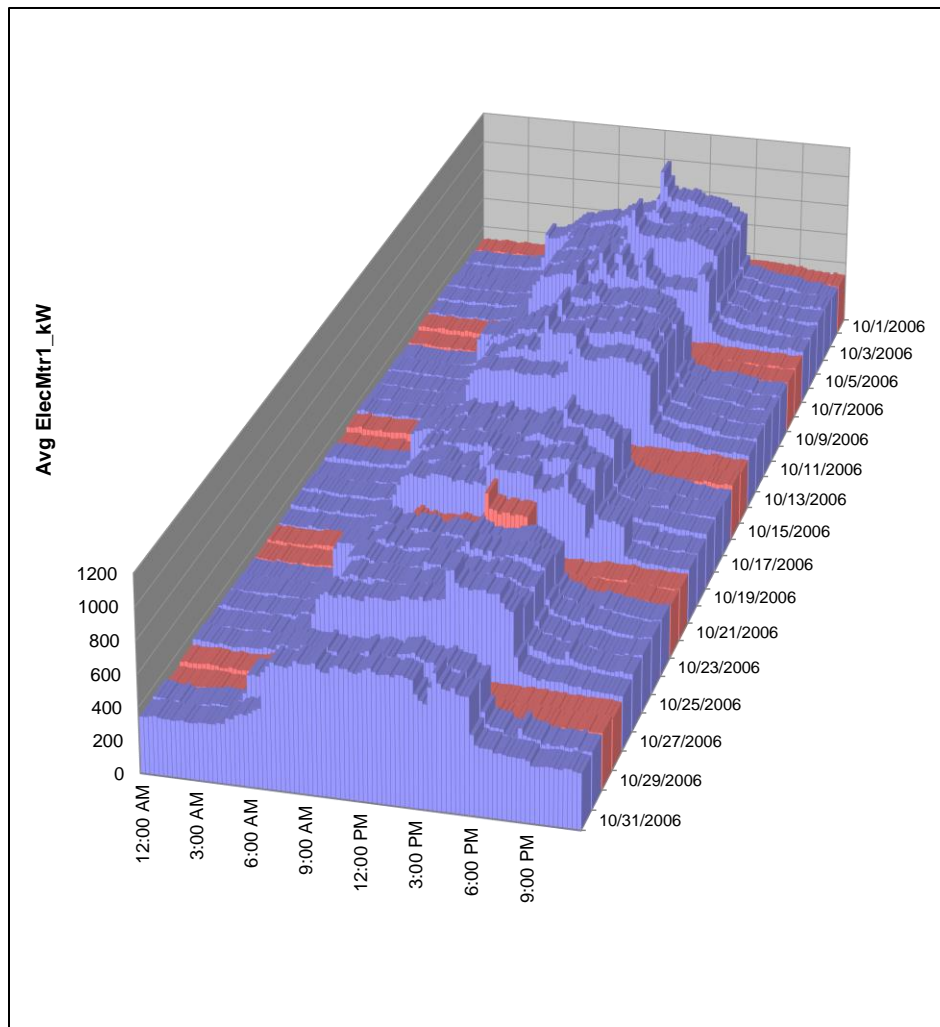
Figure 3-12: 3D load profile time series chart in ECAM+.

3.6.2 Create Energy Colors (surface chart)

Similarly to the creation of the "3D Load Profile" chart, a surface chart can be created from a specific month within the "Load Profile by Day" chart. This function will convert 1 month of daily load profiles to a surface (contour) chart, with the values shown by color. This is illustrated in Figure 3-13.

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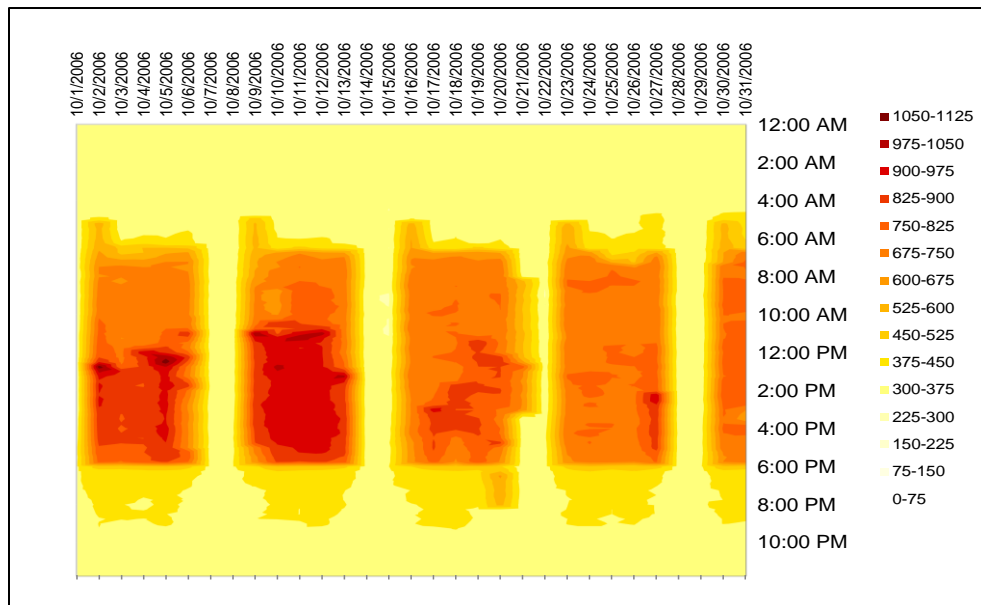
Figure 3-13: Energy density (surface chart) created from the "Load Profile by Day" chart in ECAM+.

3.6.3 Load Profile Calendar

As with the previous two items, the "Load Profile by Day" chart must be completed before using this item, and 1 month of data must be selected. The "Load Profile Calendar" will convert 1 month of daily load profiles to a calendar format, with each day shown as a thumbnail chart on the calendar (see Figure 3-14 below).
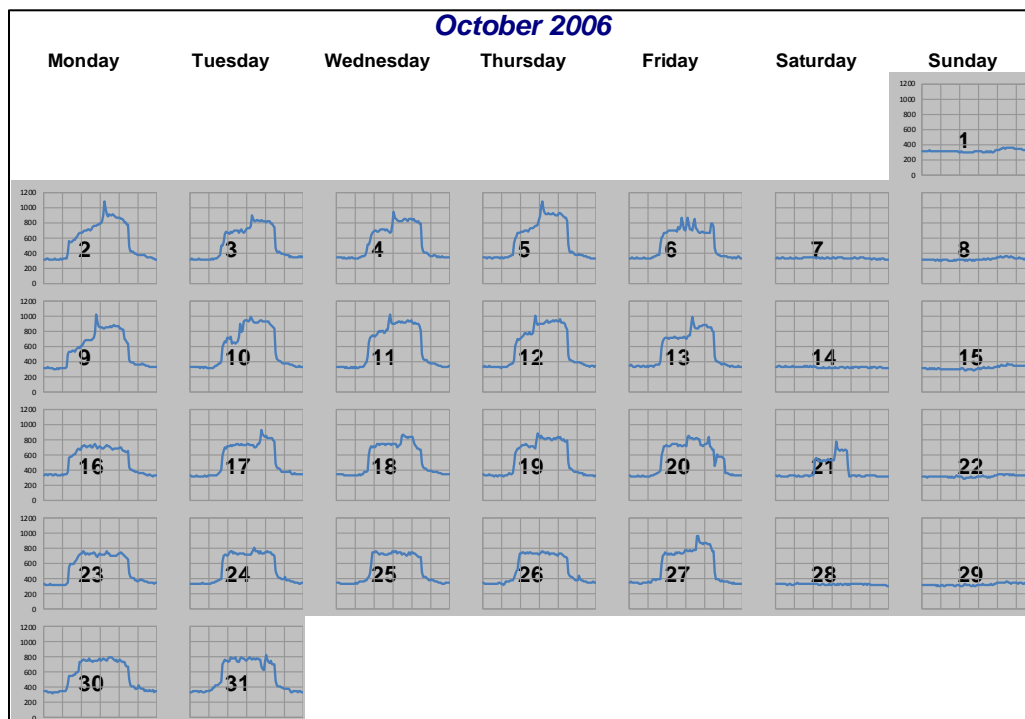
Figure 3-14: Load profile calendar created from the "Load Profile by Day" chart in ECAM+.

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4.0 Load Profile as Box Plots

Box plots, or box and whisker plots, are commonly used to provide statistical summaries of data. These charts make it easy to tell whether operation is consistent (regular) or inconsistent (irregular). To make these types of comparisons, however, the days should be filtered for similar daytypes, so that weekends and weekdays are not compared. The ECAM+ implementation of box plots for load profiles uses a percentile implementation of the box plot to better show the common range of the data, as well as the full range. Typical box plots use the data values at the 25th percentile, the 75th percentile, and the minimum and maximum. Other box plot designs use the value above and below the 25th and 75th percentiles by a distance equal to 1.5 times the interquartile range, where the interquartile range is the difference between the 75th and 25th percentile values. The ECAM+ "Load Profile as Box Plots" uses the 5th, 25th, 75th, and 95th percentiles, plus minimum, maximum, median, and mean. Figure 4-1 shows the "Load Profile as Box Plots" in ECAM+ filtered only to show weekdays using the PivotTable. Figure 4-1 shows very consistent overnight demand, but an example of a building that has very inconsistent overnight demand can be seen in Figure 4-2. This function of ECAM+ can only be utilized in Excel 2007/2010.
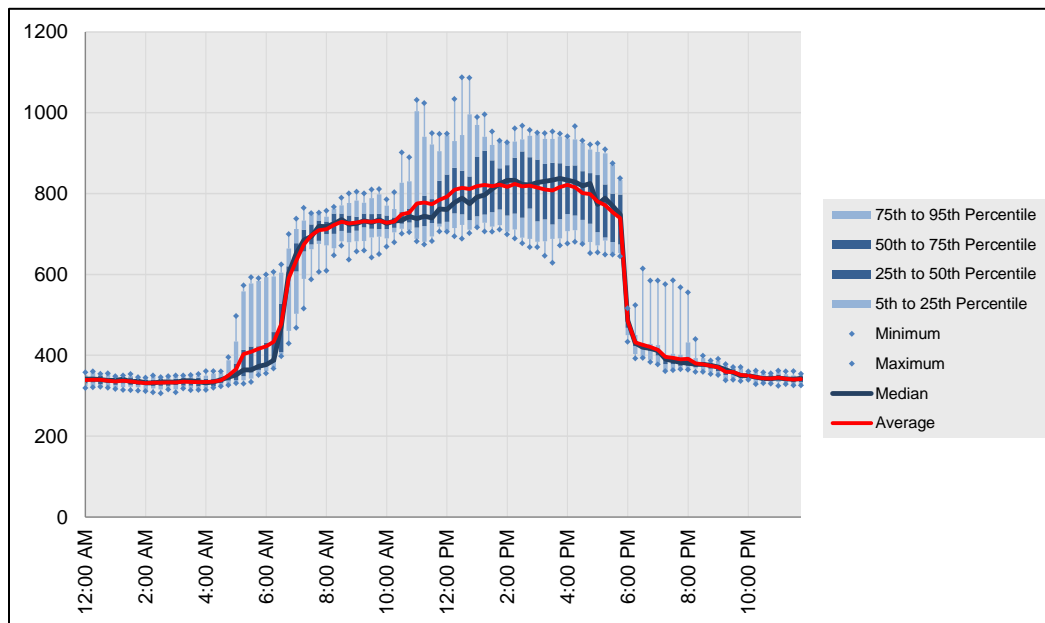
Figure 4-1: "Load Profile as Box Plots" in ECAM+, comparing only weekdays.
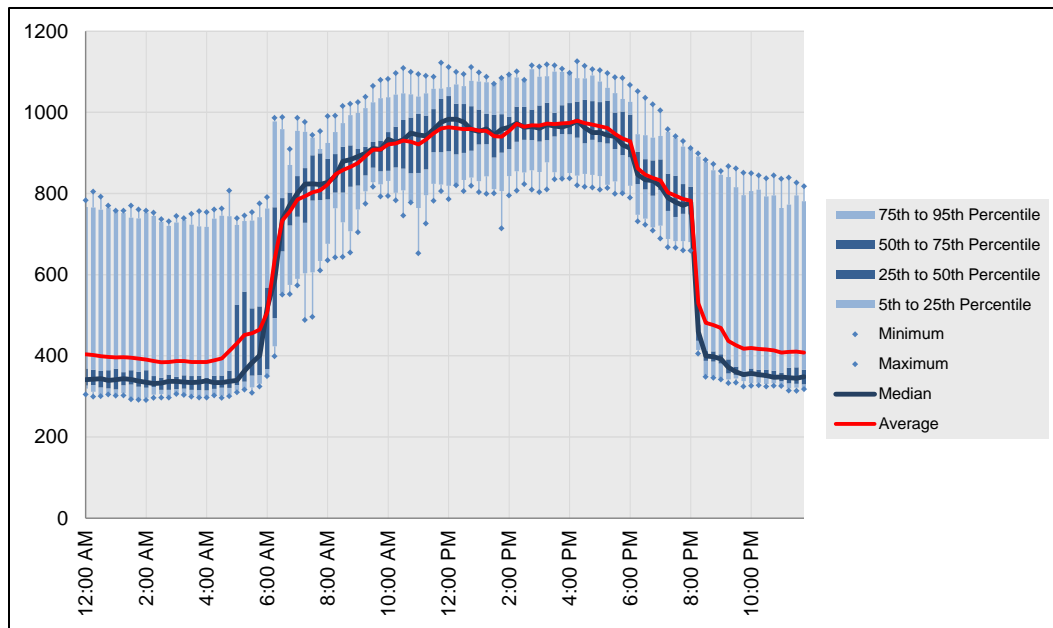
Figure 4-2: "Load Profile as Box Plots" showing inconsistent overnight behavior.

5.0 Scatter Charts

The next menu item in ECAM+ is the scatter charts. These can be used to plot points of interest, but must be created a specific way. First, the independent variable (to be placed on the x-axis) must be selected first by clicking on the point name. Then, to plot other point names against this independent variable, simply hold the "Ctrl" key and select subsequent point names. All subsequent selections made while holding the "Ctrl" key will be the dependent (to be placed on the y-axis) values. If not all of the data points can be charted, either because of the Excel chart or the PivotTable limits, the scatter charts will include some aggregation (averaging) of the values for the independent variable. For example, if the independent variable is outdoor-air temperature, and there are seven occurrences in the data set where the temperature is 77.3^{o}F, only one instance of 77.3^{o}F will show up in the chart, and the dependent variable value will be the average of the seven occurrences. There are three options under the "Scatter Charts" item in ECAM+, each to be discussed below (see Figure 5-1).
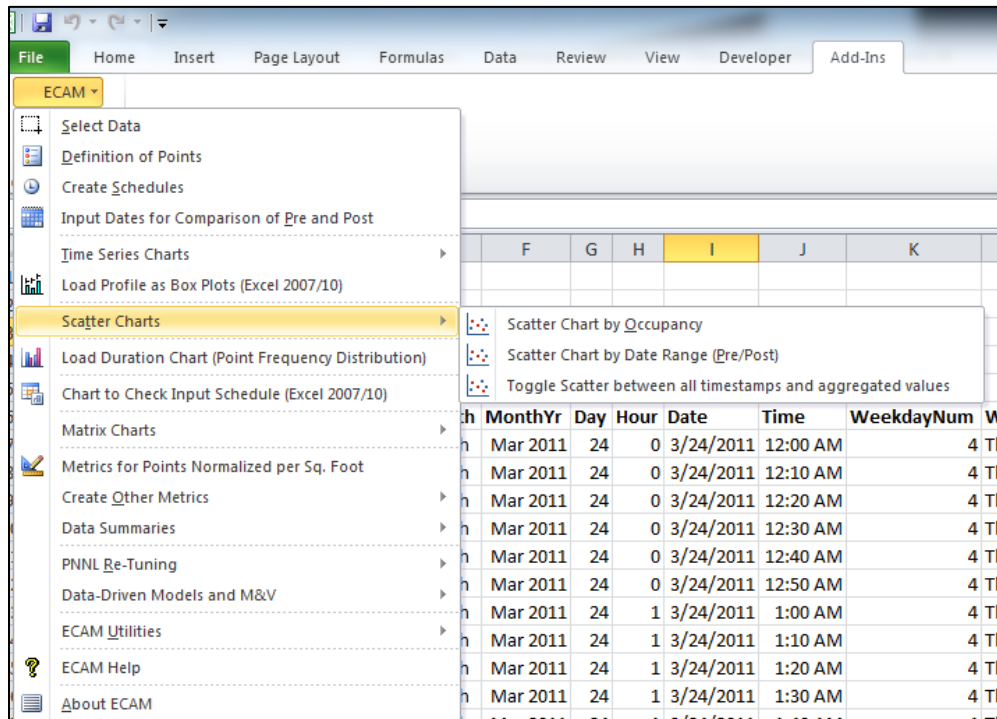
Figure 5-1: "Scatter Charts" menu item in ECAM+.

5.1.1 Scatter Chart by Occupancy

This option creates a scatter chart with one to four series', depending on whether a schedule was input, and whether the schedule included startup and shutdown times. If a schedule wasn't input, this chart will show one series, labeled as "Occ." If there is no schedule input, this chart should still be utilized if the user wants to look at any point names in the scatter format. Figure 5-2

shows an example of this scatter chart when a schedule is input for both the building and the equipment. It looks specifically at whole building energy consumption versus outdoor-air temperature. Figure 5-3 shows this chart as well, but only for "Occ" periods. Figure 5-4, on the other hand, shows a scatter chart for an outdoor-air damper position (% open) versus outdoor-air temperature for a building where no schedule was input. This chart shows the value of this option in the tool, even in the absence of a building occupancy or equipment schedule. In Figure 5-4, the values at 0% open are occurring when the equipment is off, or correspond to the minimum damper position set point. When a building is occupied and not calling for cooling, the damper should be somewhere between 5-20% open to satisfy minimum ventilation rates. The values in Figure 5-4 indicate higher ventilation or not ventilation rates.
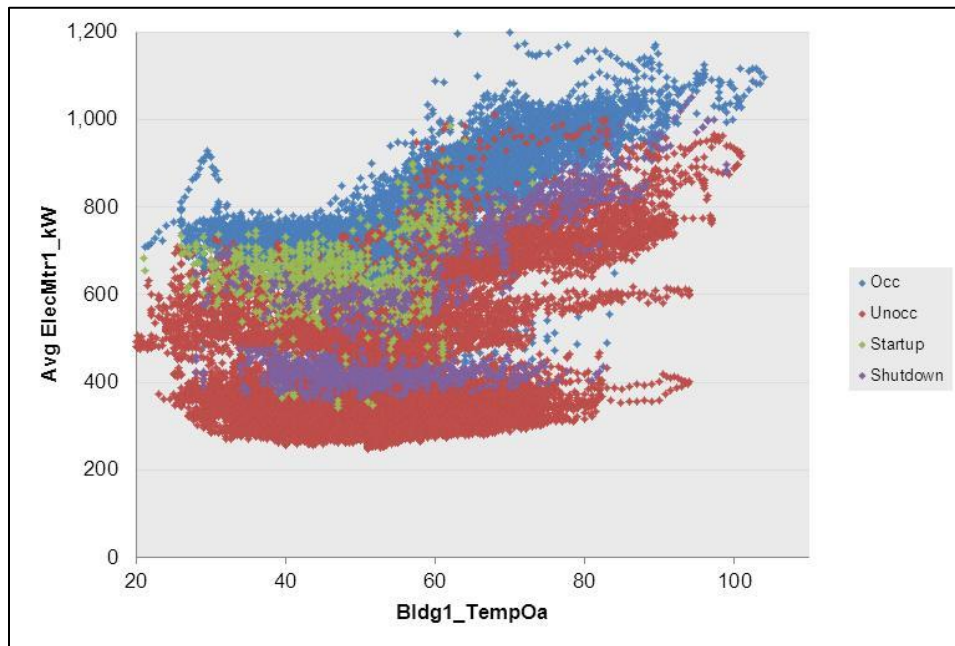
Figure 5-2: "Scatter Chart by Occupancy" and equipment startup/shutdown.
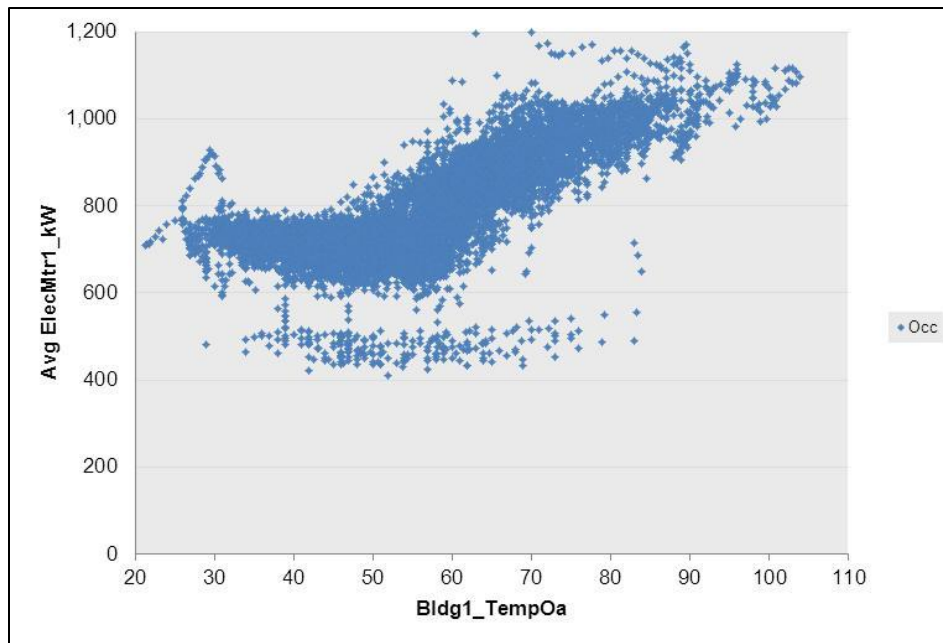
Figure 5-3: "Scatter Chart by Occupancy" showing only the "Occ" period from Figure 5-2.
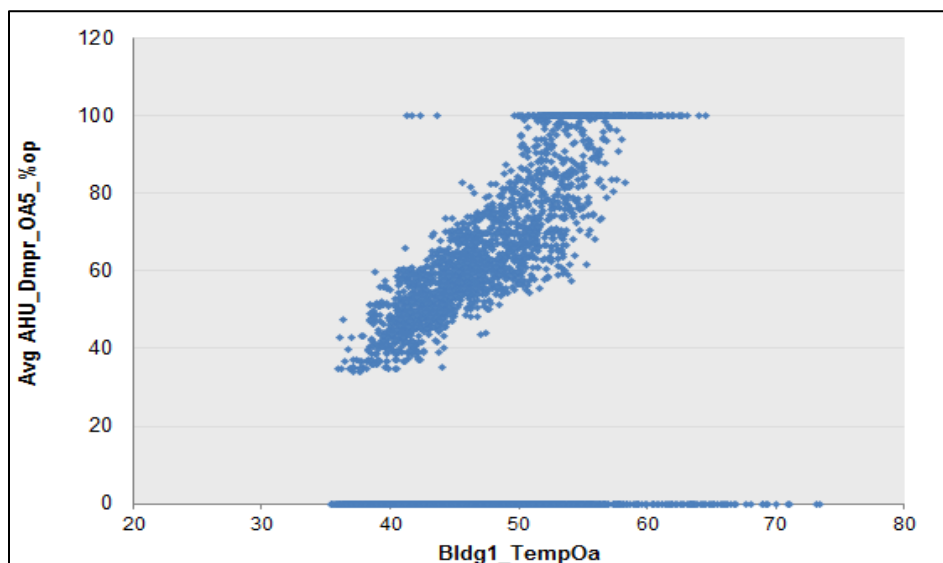
Figure 5-4: Scatter chart for outdoor-air damper position versus outdoor-air temperature.

5.1.2 Scatter Chart by Date Range (Pre/Post)

The second scatter chart option should be used if the fourth menu item in ECAM+ was used to "Input Dates for Comparison of Pre and Post." This item was discussed in Section 2.4. If dates were input, as in Section 2.4, then this scatter chart will display three different series': one with the data before the energy project started, one representing operation during the energy project, and one with data after the energy project. Figure 5-5 gives an example of what this chart may look like if done correctly. Typically, the independent variable of interest will be outdoor-air temperature, but the dependent variable can vary from whole building energy consumption to

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outdoor-damper position, fan speed, etc. Figure 5-5 looks at whole building energy consumption versus outdoor-air temperature.
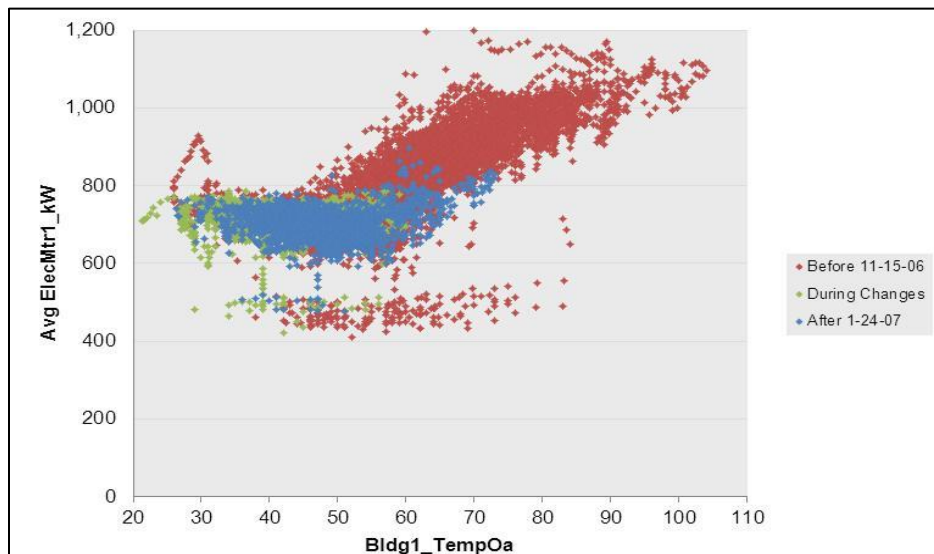
Figure 5-5: Scatter chart by date range in ECAM+.

5.1.3 Toggle Scatter between all Time stamps and Aggregated Values

The last option under the scatter charts drop-down menu in ECAM+ is the "Toggle Scatter Between all Time Stamps and Aggregated Values." This feature of ECAM+ allows the scatter chart to deliberately show aggregated values. For example, it can be difficult to determine the general trend if a piece of equipment has a discrete number of possible values, e.g., on/off, or low/high. By averaging the data, trends can become more apparent. To utilize this feature, simply select this option in ECAM+ while in the current scatter chart sheet. Figure 5-6 shows an example of the effectiveness of this feature when used on the scatter chart in Figure 5-5.
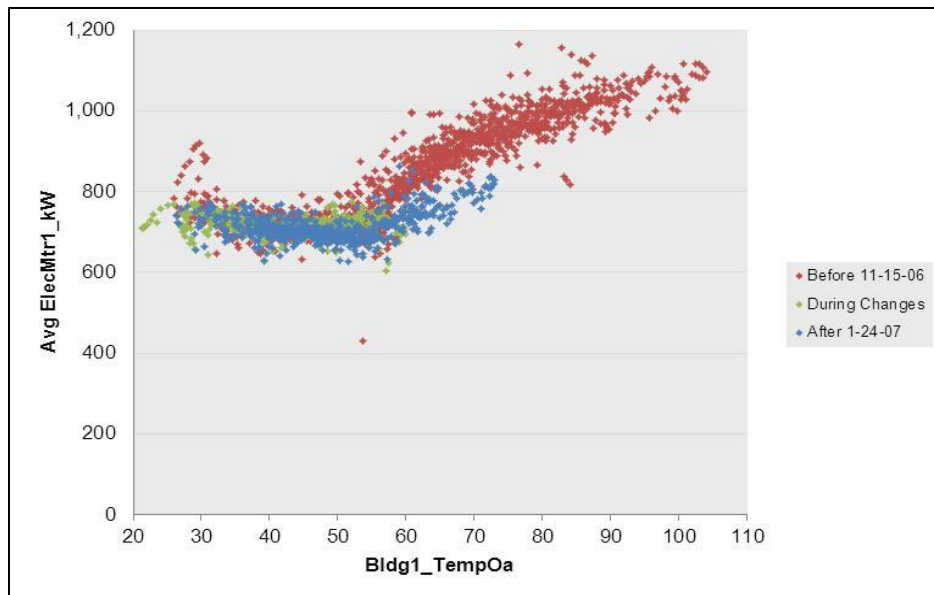
Figure 5-6: "Toggle Scatter Between all Time Stamps and Aggregated Values." in ECAM+.

6.0 Load Duration Chart (Point Frequency Distribution)

This feature in ECAM+ makes it easy to create histograms describing the time duration of the selected point. The chart, and accompanying table, provides the number of hours at various binned values. This can be used to get equipment load-hours or temperature bin-hours, for example. If a second, categorical variable is chosen, then joint frequency bins can be created as well. For example, temperature bins by month, or joint frequency bins of humidity and temperature can be created. Similarly, a joint frequency table of load-hours and occupancy could be created. It is important to note that this feature will group the values of the selected point in

ECAM+. All other PivotTables and associated metrics and charts (even existing ones) that use this point in anything other than a value field will be affected. (If the point is used in another PivotTable in a Report Filter/PageField, Column Label/ColumnField, or Row Label/RowField, referring to Excel 2007/2003 terminology, it will reflect the grouping created for the Load Duration Chart). Therefore, it is usually best to create the chart table, get the information needed, copy the information as values to a new worksheet, and then ungroup the variable.

Creating a joint frequency table is similar to a scatter chart. Select the main variable, then hold down the "Ctrl" key and select the categorical variable. To create a chart and table of temperature bins by month, click the menu item for "Load Duration Chart", and ECAM+ will bring up the window shown in Figure 6-1 asking for point selection. For this case, click the cell in "Row 6" of the "Data" worksheet that has the outdoor temperature, and then hold down the "Ctrl" key and click cell "F6" for "MonthYr," and click "OK."
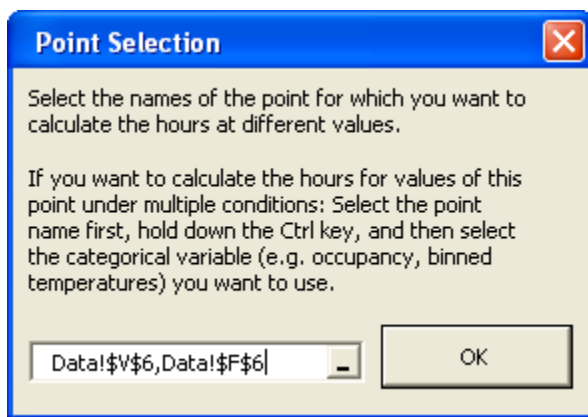
Figure 6-1: Point selection when creating a "Load Duration Chart" in ECAM+.

ECAM+ provides the 1st and 99th percentile values of the selected variable to guide the user in setting up the bins. In this case (Figure 6-2) the 99th percentile value of weather shown is $88^{o}F$, which is much cooler than the anticipated maximum temperature for the year. This is just a guide, and any temperature for low and high can be input in the table shown in Figure 6-2. Figure 6-3 shows a portion of the table created after selecting "OK," and Figure 6-4 shows the corresponding chart created.

Figure 6-2: Input parameter for the "Load Duration Chart" in ECAM+.

Total Hours Bldg1_TempOa	Feb 2006	Mar 2006	Apr 2006	May 2006	Jun 2006	Jul 2006
20-25	4					
25-30	49					
30-35	74	30				
35-40	101	106	15	1		
40-45	167	179	75	27		
45-50	194	231	195	80		
50-55	74	119	183	157	33	4
55-60	8	57	126	178	171	110
60-65		22	73	122	198	178
65-70			35	62	149	136
70-75			13	63	77	102
75-80			4	26	31	80
80-85			1	21	26	62
85-90				3	17	39
90-95				5	8	15
95-100					9	12
100-105					2	5

Figure 6-3: Example of table created using the "Load Duration Chart" option in ECAM+.
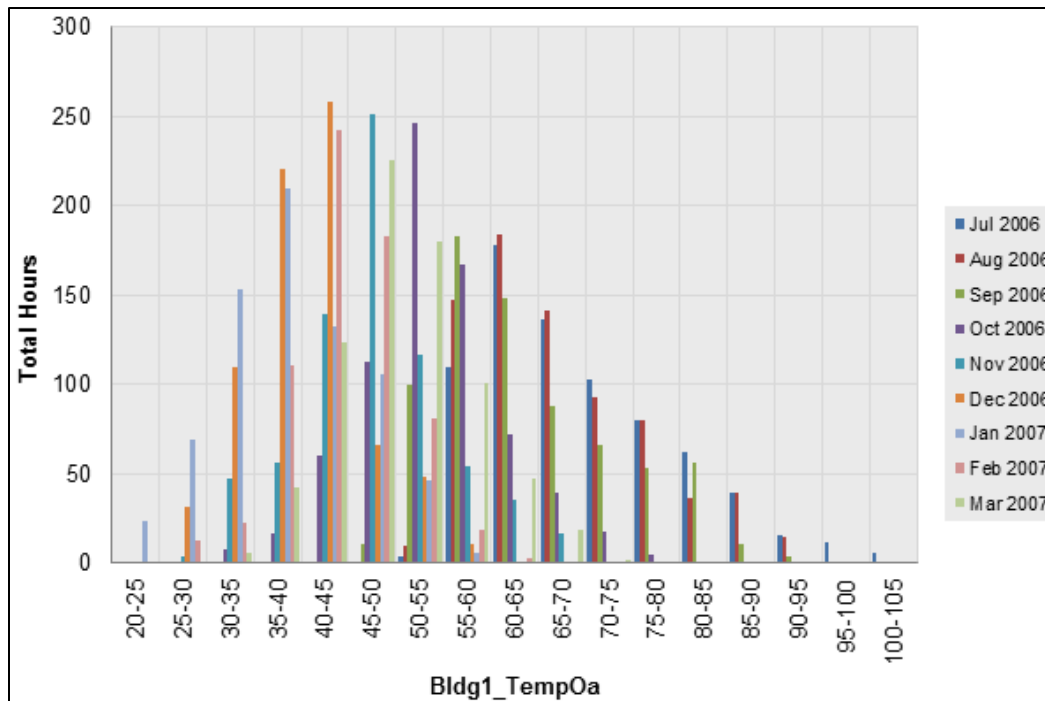
Figure 6-4: "Load Duration Chart" created for total hours at temperature bins by month.

Another example of the load duration chart can be seen below, when a schedule was input for both the building and the equipment. To create this comparison, choose the outdoor temperature first and then hold "Ctrl" and select cell "P6," which is "Occupancy." Figure 6-5 and Figure 6-6 show examples for the table and chart created for this scenario.

Total Hours	Occupancy ▼			
Bldg1_TempOa ▼	Occ	Shutdown	Startup	Unocc
20-25	2		0	20
25-30	20	2	3	91
30-35	70	6	10	259
35-40	182	19	17	436
40-45	265	24	20	647
45-50	302	26	15	611
50-55	294	20	18	498
55-60	248	15	25	508
60-65	205	10	11	441
65-70	157	16	2	265
70-75	110	12	2	156
75-80	89	17		112
80-85	60	12		82
85-90	25	3		61
90-95	8	2		24
95-100	6	1		5
100-105	3			2

Figure 6-5: Created table for hours vs. occupancy, for outdoor temperature.
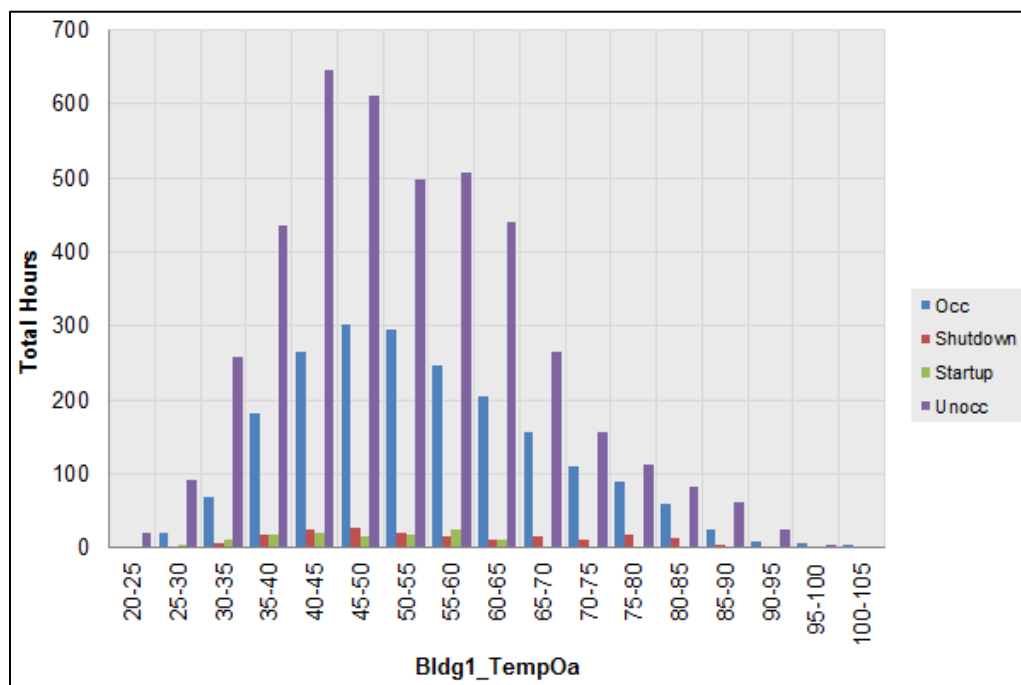
Figure 6-6: "Load Duration Chart" for total hours at specific temperature bins for occupancy.

7.0 Chart to Check Input Schedule (Excel 2007/2010)

After inputting an occupancy or operating schedule (see Section 2.3 Create Schedules), the data should be reviewed to make sure that the schedule is interpreted as intended. This can be done by utilizing the "Chart to Check Input Schedule" feature in ECAM+. When selecting this feature in the drop-down menu, a chart similar to that in   Figure 7-1 will appear. For this case, a schedule was entered for both main occupancy and equipment startup/shutdown. According to the schedule, the equipment starts up at 5:30 AM Monday morning and shuts down at 7:00 PM Monday night. Tuesday through Friday, the equipment starts up at 6:30 AM and shuts down at 7:00 PM. The main occupancy hours are Monday through Friday 7:00 AM to 6:00 PM, and the building is unoccupied on the weekends.

It is important to note that there is a slight anomaly between the chart dates. The color associated with the startup and shutdown (the lighter blue color) is shown horizontally between the date lines. This is an anomaly with the type of chart used, and should be disregarded when reading the schedule of the building. Rather, the vertical change in color should be focused on, showing the start and end times for each day.
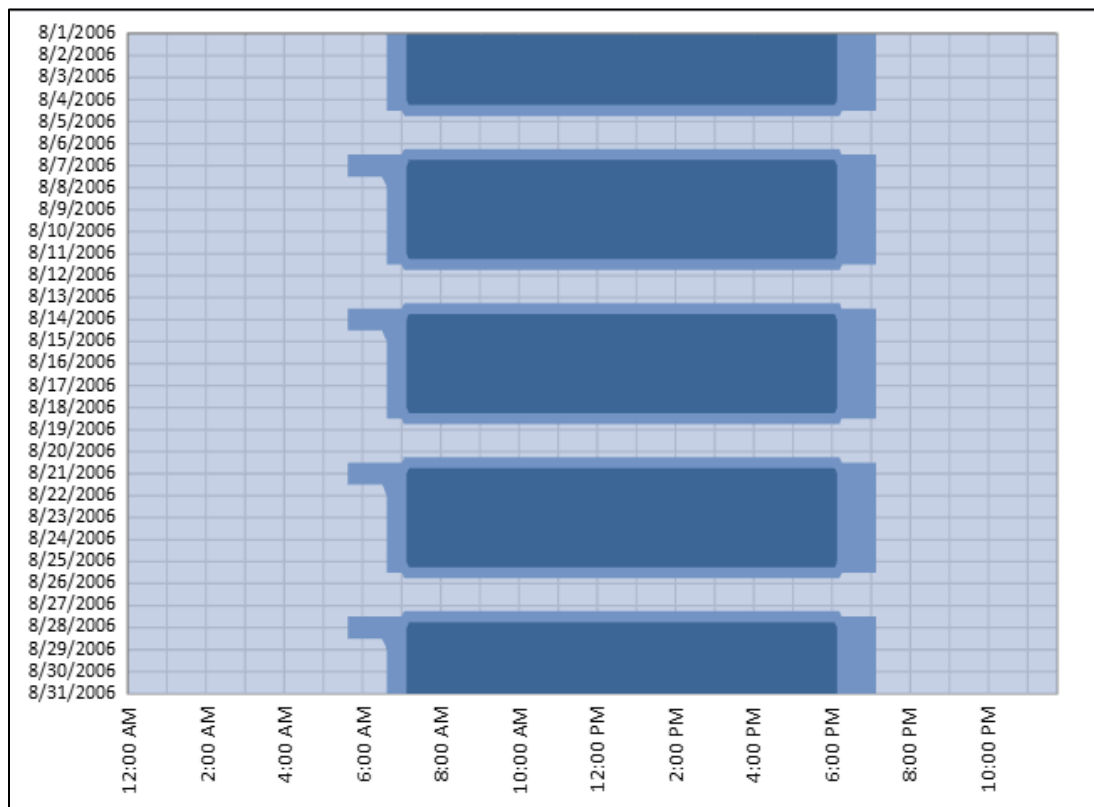
Figure 7-1: "Chart to Check Input Schedule" in ECAM+.

8.0 Matrix Charts

The "Matrix Charts" feature in ECAM+ automatically places a selected group of charts, or all charts, on a single worksheet for comparison purposes. The charts in the matrix have some re-formatting applied automatically, but it is usually not sufficient to look attractive in the reduced size. Therefore, the matrix charts will usually require re-formatting, such as elimination of or resizing of labels and legends. Because of the reduced size of the charts, it may be beneficial to edit the charts of interest before placing them in the matrix. In most cases, the x-axis for load profiles can be deleted. Legends will often need to be deleted as well to make room for the plot. Figure 8-1 shows an example of eight charts previously used/mentioned in this guide, in matrix form.
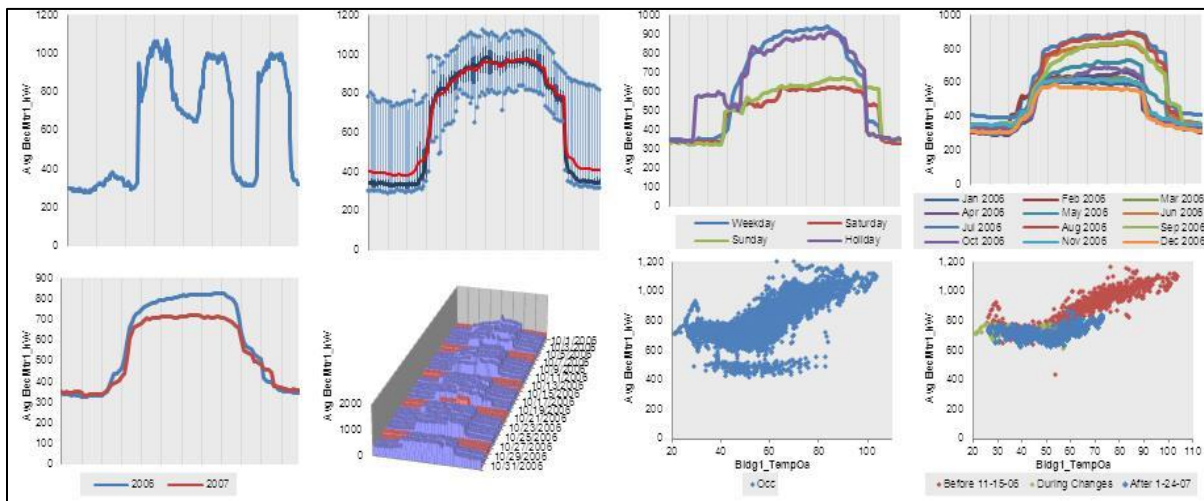
Figure 8-1: "Matrix Charts" option in ECAM+.

As you can see, the charts are quite small, and hard to read. This feature of the tool is more useful for comparison of charts side by side (similar by type). For example, Figure 8-2 shows an example of "matrix" charts with more extensive editing. This matrix is for box plot load profiles for weekdays, for each month of the year. This type of comparison offers conclusions for months that exhibit the highest energy consumption, the most spread about the mean of the data set, etc.
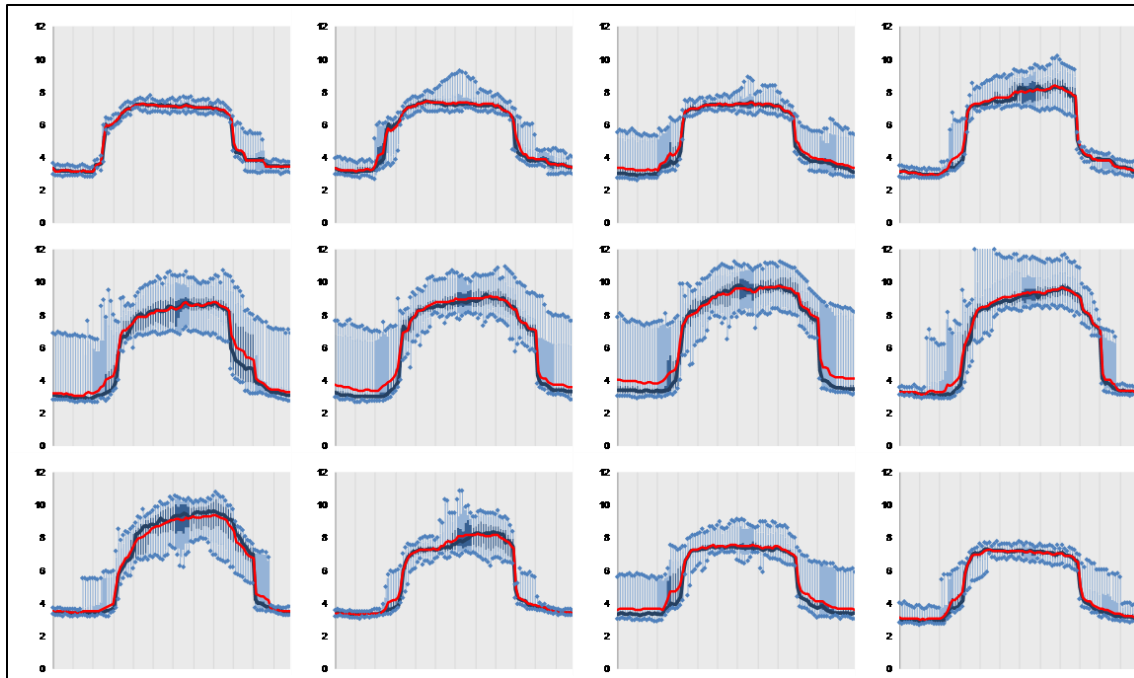
Figure 8-2: "Matrix Charts" option for box plot load profiles for weekdays, for each month of the year.

9.0 Menu Items to Create Metrics and Summaries

The next three menu items in ECAM+ deal with creating metrics and summaries from the data imported into ECAM+.

9.1 Metrics for Points Normalized per Sq. Foot

This "Metrics for Points Normalized per Sq. Foot" menu item will create metrics for all points that can be converted to watts per square foot (Watts_perSF) values. Any points that are in kW will be converted to Watts_perSF after the user enters the building size as part of the point definition process (required for this menu item). The metrics that are created are average Watts_perSF by daytype (weekday, Saturday, Sunday) and occupancy (Occ and Unocc). Figure 9-1 shows an example of these metrics for whole building energy consumption.

Points	All Data	Weekday	Saturday	Sunday	Holiday	Occ	Unocc	Startup	Shutdown
Avg ElecMtr1Watts_perSF	5.36	5.85	4.31	4.25	4.62	7.82	4.11	6.40	5.92
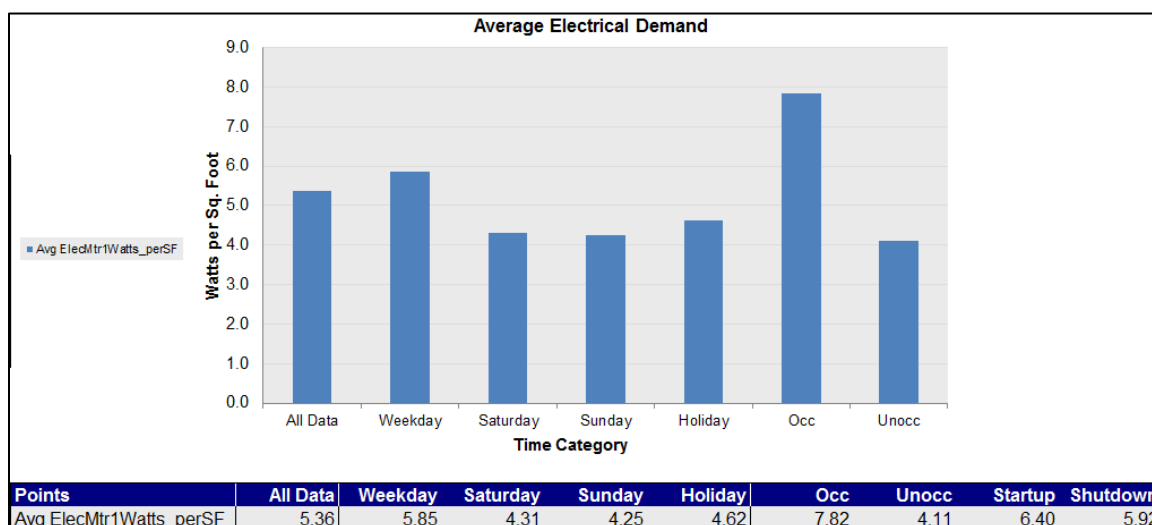
Figure 9-1: "Metrics for Points Normalized per Sq. Foot."

9.2 Create other Metrics

This section describes the following menu items, daytype and occupancy metrics, occupancy and month-year combined metrics and daytype and month-year combined metrics.

9.2.1 Daytype and Occupancy Metrics

This menu item allows the user to pick the points they want to summarize as metrics. The selected points will be averaged separately by "Daytype" and "Occupancy", and placed in a table. The average of all the data for each point is also provided. Figure 9-2 shows an example of whole building energy consumption and outdoor-air temperature as the points chosen to summarize. Choosing point names is the same as that specified in creating scatter charts section.

Click the point name, and then hold the "Ctrl" key and select any other point names of interest and click "OK."

Points	All Data	Weekday	Saturday	Sunday	Holiday	Occ	Unocc	Startup	Shutdown
Avg ElecMtr1_kW	521.8	575.1	401.9	399.1	453.1	772.3	393.6	646.9	562.2
Avg Bldg1_TempOa	52.3	52.3	52.3	53.5	48.5	54.5	51.2	47.2	57.0

Figure 9-2: "Daytype and Occupancy Metrics" example.

9.2.2 Occupancy and Month-Year Combined Metrics

This feature creates averages of the points selected by the user, with the averages based on combinations of occupancy status and the month and year (using the MonthYr column from the "Data" worksheet) in which the data was gathered. The average for all of the data for each point, averages by "MonthYr" for all occupancy statuses, and averages by occupancy for all dates are also provided. Figure 9-3 shows an example of this table for both whole building energy consumption and outdoor-air temperature.

Points	MonthYr	Occupancy Occ	Unocc	Startup	Shutdown	All Periods
Avg ElecMtr1_kW	Jul 2006	928.41	530.63	730.08	844.64	660.72
	Aug 2006	911.29	446.51	665.38	816.89	620.57
	Sep 2006	874.55	473.29	623.77	757.46	599.67
	Oct 2006	767.40	346.44	600.87	422.75	491.05
	Nov 2006	735.75	362.77	671.03	464.00	485.54
	Dec 2006	702.95	327.65	638.90	418.03	446.49
	Jan 2007	710.20	399.82	636.54	471.10	502.50
	Feb 2007	706.51	406.95	620.59	535.32	507.72
	Mar 2007	699.34	398.62	568.96	591.19	505.71
Avg Bldg1_TempOa	Jul 2006	71.38	69.08	60.12	78.81	69.84
	Aug 2006	68.79	67.39	58.77	75.67	67.94
	Sep 2006	66.49	63.09	54.41	71.92	64.17
	Oct 2006	56.45	52.17	47.27	59.32	53.66
	Nov 2006	48.15	46.61	46.27	46.56	47.08
	Dec 2006	42.14	38.93	37.73	41.51	39.93
	Jan 2007	40.81	36.91	36.67	39.66	38.20
	Feb 2007	45.36	43.05	40.08	45.01	43.77
	Mar 2007	50.26	49.68	44.85	52.49	49.85

Figure 9-3: "Occupancy and Month-Year Combined Metrics."

9.2.3 Daytype and Month-Year Combined Metrics

This feature is very similar to the "Occupancy and Month-Year" feature, but replaces "Occupancy" with "Daytype." Both of these menu items create PivotTables that can be further changed by the user to meet specific analysis needs. Figure 9-4 shows an example of this chart, but for a chilled water supply temperature and two air-handler flow rates.

Points	MonthYr	Weekday	Saturday	Sunday	Holiday	All Periods
Avg ChW1_TempOut	Aug 2004	42.4	42.4	42.9		42.5
	Sep 2004	43.2	43.0	42.6	43.9	43.1
	Oct 2004	42.3	42.6	42.2		42.3
Avg SOUTH AHU FLOW	Aug 2004	228	289	260		238
	Sep 2004	265	286	247	290	267
	Oct 2004	213	231	212		216
Avg NORTH AHU FLOW	Aug 2004	677	648	695		676
	Sep 2004	640	643	682	665	647
	Oct 2004	648	592	620		636

Figure 9-4: "Daytype and Month-Year Combined Metrics."

9.3 Data Summaries

The information provided by this tool in ECAM+ are statistical summaries of the selected points, or the points in an existing PivotTable. In the case of an existing PivotTable, the summary is placed to the right of the PivotTable, on the same worksheet. Summaries are provided for all the points in the PivotTable.

9.3.1 Summarize Data

This feature provides statistical information about the selected data points, using the raw data without aggregation.

9.3.2 Summarize Data from PivotTable

This feature provides information about the data points (value or data fields) in a PivotTable. Note that "Summarize Data from PivotTable" uses only the data shown in the PivotTable, based on the type of aggregation selected for the data. If the PivotTable uses some sort of aggregation (average, maximum, etc.), the data summary will show different values than a summary based on the full data set.

Whichever option is used, the summary is associated with a PivotTable, so all of the normal ECAM+ filters are available. The data can be filtered by daytype, month, occupancy, etc. The statistical information includes the following:

- Maximum

- ±3 Standard Deviations

- Average

- Low to High Ratio

- Percentiles (97.7, 95th, 90th, 84.1, 75th, 50th, 25th, 15.9, 10th, 5th, 2.3)

- Minimum

No checks are made as to whether the data fits a normal distribution, so both percentiles and standard deviations are provided. The unrounded percentile values (i.e., 2.3, 15.9, 84.1, and 97.7) match the percentiles associated with a normal distribution at 1, 2 and 3 standard deviations away from the mean.

The percentiles and number of standard deviations are included as inputs on the worksheet with the data summary, so users can quickly customize a data summary to meet specific needs.

The "Low to High Ratio" (LHR) is a number that is intended for use with meter data to express how well a building turns down load during unoccupied hours. It is not intended for use with other types of data points. However, it was straightforward to include with the data summaries, so it is included here[1].

The LHR is calculated as the average of the subset of data more than 0.5 standard deviations above the mean of all the data divided by the average of the subset of data more than 0.5 standard deviations below the mean of all the data. Table 9-1 shows an example of the data summary for whole building electricity consumption.

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[1] The LHR is from a 2004 ACEEE paper, *Who Left the Lights On? Typical Load Profiles in the 21st Century,* by Reid Hart, Steve Mangan, and Will Price, then with the Eugene Water and Electric Board. As of March 2011, the paper can be downloaded from: http://www.eceee.org/conference_proceedings/ACEEE_buildings/2004/Panel_7/p7_8/.

Table 9-1: Sample of data summary table in ECAM+.

Percentile	Statistical Information	Avg ElecMtr1_kW
1	Maximum	1269.00
0.98	Percentile 97.7	984.96
0.95	Percentile 95	927.72
0.90	Percentile 90	841.32
0.84	Percentile 84.1	754.92
0.75	Percentile 75	719.28
0.50	Median	470.88
0.25	Percentile 25	338.04
0.16	Percentile 15.9	325.08
0.10	Percentile 10	315.36
0.05	Percentile 5	301.32
0.02	Percentile 2.3	288.36
Percentile	Statistical Information	Avg ElecMtr1_kW
0.00	Minimum	257.04
	Std Deviation	216.91
3.00	$+3\sigma$	1186.54
2.00	$+2\sigma$	969.63
1.00	$+1\sigma$	752.72
0.00	Average	535.82
-1.00	-1σ	318.91
-2.00	-2σ	102.00
-3.00	-3σ	-114.91
	Low to High Ratio	0.43

10.0 PNNL Building Re-tuning Charts

The building re-tuning menu items are designed to support the PNNL building re-tuning process by automatically creating charts that allow identification of building operational problems. To successfully use the building re-tuning menu items, the raw data has to be mapped to predefined point names using the "Definition of Points" menu item (described in Section 2.2). After the points are properly defined, the creation of the building re-tuning charts is completely automated. The only action required by the user is to select the appropriate menu item(s) in the "PNNL Re-Tuning" drop-down menu, as seen in Figure 10-1.
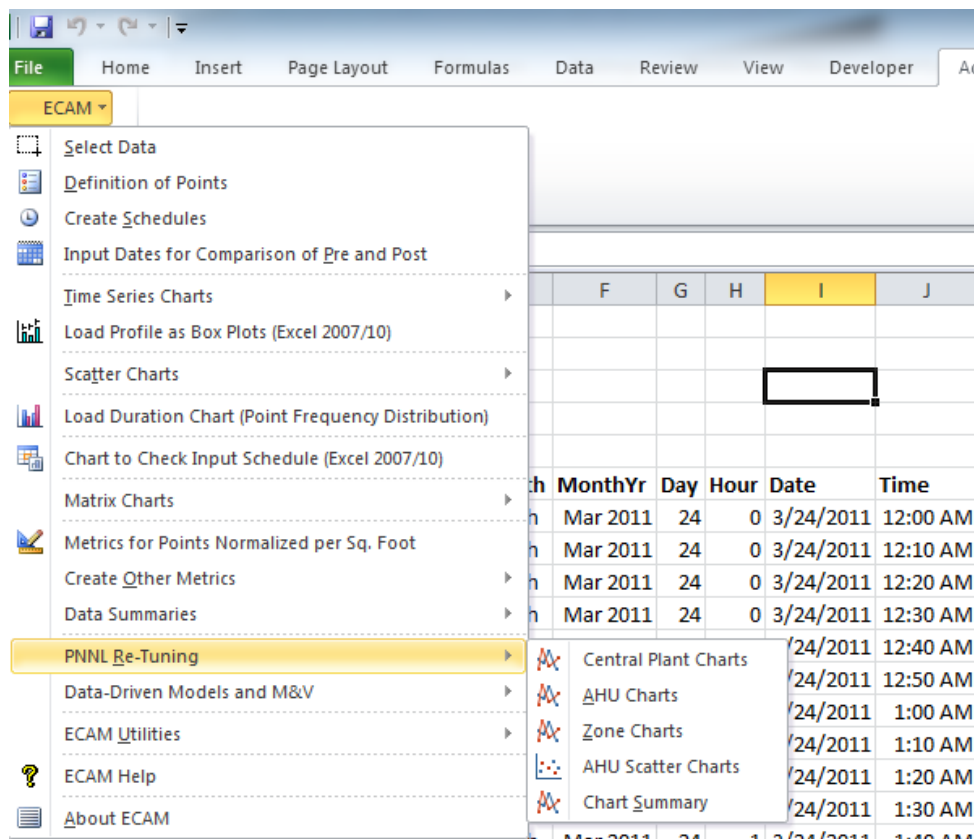
Figure 10-1: "PNNL Re-Tuning" Menu Item in ECAM+.

Selection of each menu item creates a worksheet (with the related charts) for each relevant building re-tuning focus areas. To summarize this, there is a "Chart Summary" menu item under the "PNNL Re-Tuning" menu item. When selected, a new sheet will be generated that will show the user all of the charts, focus areas, and acronyms that the re-tuning section will focus on. Figure 10-2 shows the chart summary, and the charts will be described in detail in the following sections.

The PNNL Re-tuning Charts are intended to help users identify opportunities to improve operations and control strategies at the Air-Handling Unit (AHU), Central Plant, and Zone component levels. When selected from the PNNL Retuning ECAM dropdown menu, each component will have dedicated sheets with charts for analysis. These charts are generated in accordance with the PNNL Retuning Training Guides, which can be accessed here: www.pnnl.gov/buildingretuning/retuning_measures.stm. Here is a breakdown of the sheets that will be generated, and the corresponding charts in each sheet:

AHU Charts: When selected, this menu item generates sheets for different components of an AHU, which charts in each sheet. Note that if the data doesn't have all points, the chart will be incomplete, but ECAM will still generate any chart with partial information.

"AHU_Econ"- This sheet has charts to help analyze economizer operations for the AHU. Charts generated (in order) include:
1. OAT, MAT, RAT, SAT, OAF vs. time
2. OAT, OAD, OAF vs. time
3. OAT, OAD, RAT vs. time
4. OAD, CCV, HCV, OAT vs. time
5. OAT, OAD vs. time
6. OAT, RAT, MAT, SAT vs. time
7. SATSP, OAT, CCV, OAD vs. time
8. SATSP, SAT, OAT, OAD, CCV, HCV vs. time

"AHU_OA"- This sheet has charts to help analyze outdoor air operations for the AHU. Charts generated (in order) include:
1. OAT, OAD, OAF, AHU Status (On or Off) vs. time

"AHU_SP"- This sheet has charts to help analyze static pressure operations for the AHU. Charts generated (in order) include:
1. DSP, DSPSP vs. time
2. DSP, DSPSP, Supply Fan Speed vs. time
3. Supply Fan Speed, Supply Fan Status, DSP vs. time
4. Supply Fan Speed, Return Fan Speed vs. time

"AHU_HeC"- This sheet has charts to help analyze AHU heating and cooling operations. Charts generated (in order) include:
1. HCV, CCV, OAT vs. time
2. SATSP, SAT, OAT, OAD, CCV, HCV vs. time

"AHU_SA"- This sheet has charts to help analyze supply air operations for the AHU. Charts generated (in order) include:
1. SAT, SATSP, OAT vs. time

AHU Scatter Charts: When selected, this menu item generates the following scatter charts:
1. OAT vs. MAT
2. OAT vs. OAD
3. Supply Fan Speed vs. Return Fan Speed
4. CCV vs. HCV
5. SATSP vs. SAT

Zone Charts: When selected, this menu item generates one sheet per zone mapped in ECAM, and generates the following charts:
1. Zone Temp, Zone Reheat Valve Signal, Zone Damper Position Signal, Zone Occupancy vs. time
In addition, another sheet will be generated that has the following information for all zones mapped in ECAM.
1. All Zones Damper Position Signals vs. time
2. All Zones Reheat Valve Signals vs. time

Central Plant Charts: When selected, this menu item generates the following charts for each chiller and/or boiler system in the building: (These are still in development)
1. CHWS, CHWR, delta-T, OAT vs. time
2. CHWS, CHWS SP vs. time
3. CWS, CWS SP, OAT vs. time
4. CWS, CWR, delta-T, OAT, OAH, Wet Bulb Temp vs. time
5. CHW Loop DP, CHW Loop DPSP, CHW Pump VFD Speed vs. time
6. HWS, HWR, delta-T, OAT vs. time

Acronyms and Definitions

AHU Charts:
OAT - outdoor-air temperature
MAT - mixed-air temperature
RAT - return-air temperature
SAT - supply-air temperature
SATSP - supply-air temperature set point
OAF - outdoor-air fraction
OAD - outdoor-air damper (position signal)
CCV - cooling-coil valve signal
HCV - heating-coil valve signal
DSP - discharge (duct) static pressure
DSPSP -discharge (duct) static pressure set point

Central Plant Charts:
CHWS - chilled water supply temperature
CHWR - chilled water return temperature
CHW delta - T - chilled water temperature difference (CHWR-CHWS)
CHWS SP - chilled water supply temperature set point
CWS - condenser water supply temperature
CWS SP - condenser water supply temperature set point
CWR delta-T - condenser water temperature difference (CWR-CWS)
OAH - outdoor-air humidity
CHW Loop DP - chilled water loop differential pressure
CHW Loop DPSP - chilled water loop differential pressure set point
HWS - hot water supply temperature
HWS SP - hot water supply temperature set point
HWR - hot water return temperature
HW delta-T - hot water temperature difference (HWS-HWR)
HWDP - hot water differential pressure
HWDP SP - hot water differential pressure set point

Figure 10-2: "PNNL Re-Tuning" "Chart Summary" sheet.

In addition, the charts generated in ECAM+ were designed to parallel the information developed for the commercial building re-tuning training guides. These guides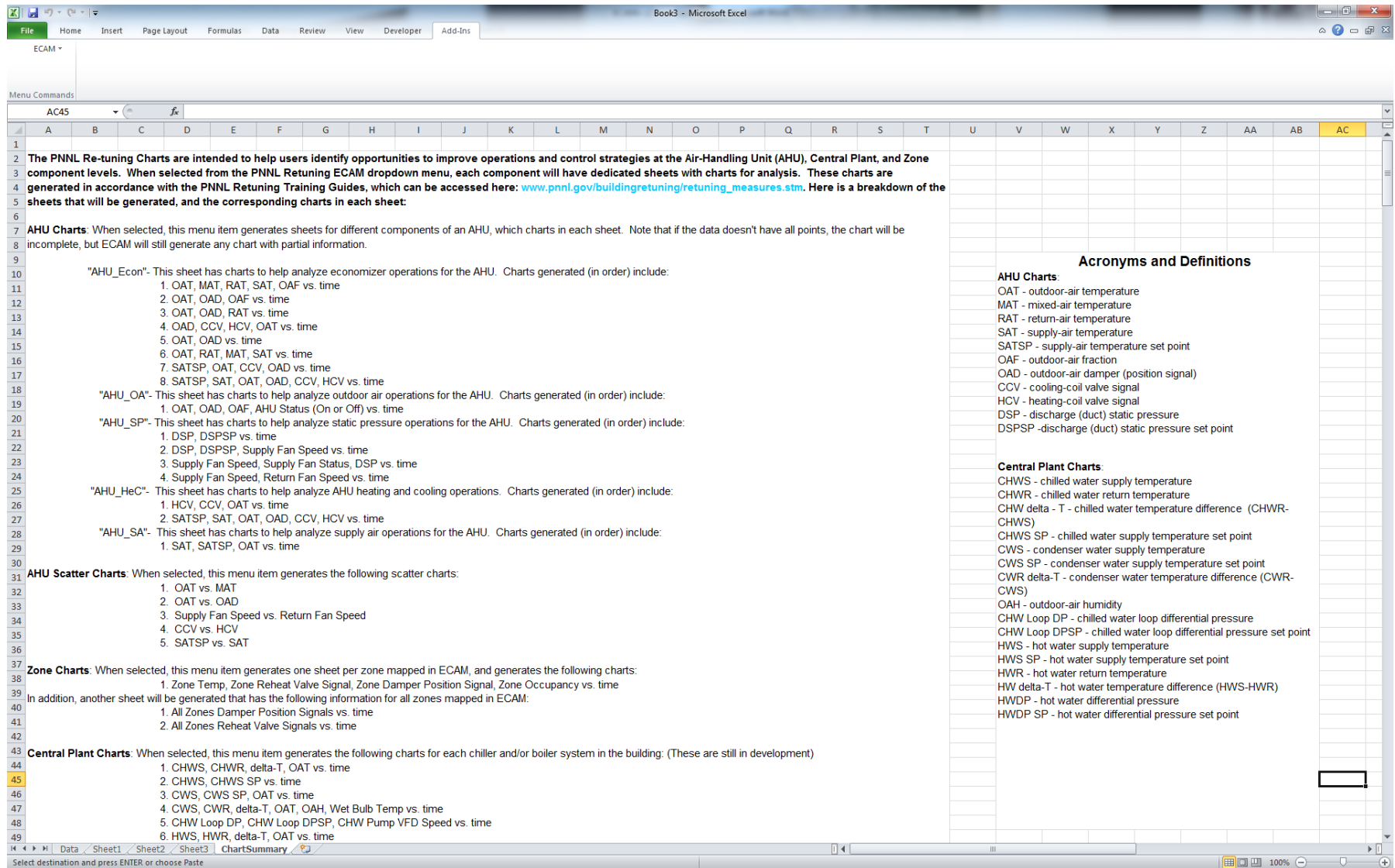 will show the user examples of good and bad operations, and ways the ECAM+ charts generated can be analyzed to identify opportunities for:

- *Air-side Economizer Operations*

- *AHU Static Pressure Control*

- *AHU Discharge-Air Temperature Control*

- *Occupancy Scheduling: Night and Weekend Temperature Set Back and Supply Fan Cycling during Unoccupied Hours*

- *Zone Heating and Cooling Control*

- *Central Utility Plant Cooling Control*

- *Central Utility Plant Heating Control*

- *AHU Minimum Outdoor Air Operations*

- *AHU Heating and Cooling Control*

Note: When utilizing the Excel PivotTable in a sheet, all charts on the worksheet will change together as the user selects various filters on the PivotTable.

Note: If any points associated with a particular re-tuning chart are not available, or not mapped using the "Definition of Points" feature, those points will not be charted. If all points for a particular chart are missing, then an empty chart will result, or a chart that only has partial information (for example, the outdoor-air temperature).

10.1 Central Plant Charts

To identify operational problems and make corrections/adjustments to the physical plant operations, the points that should be collected (recommended 15-minute intervals, no greater than 60-minute intervals) with the building automation system (BAS) include:

- outdoor-air temperature (OAT)

- chilled water (CHW) supply temperature

- chilled water return temperature

- chilled water set point

- hot water (HW) supply temperature

- hot water return temperature

- hot water set point

- condenser water supply temperature

- condenser water return temperature

- condenser water set point

- chiller load (current)

- pump status (if there are multiple pumps record all of them)

- chiller status

- chilled water flow (gpm)

- chilled water differential pressure

- chilled water differential pressure set point

- cooling tower fan speed

- cooling tower fan speed set point

- cooling tower fan status

- CHW and HW delta-T (this can be simply calculated by taking the difference between the supply and return temperatures for the hot water and chilled water loops, respectively).

The following time-series charts will be created by ECAM+, depending on the availability of the relevant points mapped in ECAM+:

1. CHW supply temperature, CHW return temperature, delta-T, OAT vs. time

2. HW supply temperature, HW return temperature, delta-T, OAT vs. time

3. CHW flow, OAT vs. time.

It is important to note that the charts in the "Chart Summary" sheet for the central plant have not yet been finished by PNNL (still under development). Therefore, the charts below will be generated in the meantime until a new version is released. Also note that ECAM+ will not create charts automatically for certain parts of the system, like the cooling tower or condenser (although additions are being made to ECAM+ to address these areas in a future version). These points should still be mapped in ECAM+ because the use of the "Point History Chart" (discussed in Section 3.1) will allow the user to plot these points and compare them to other system charts, such as chilled water or hot water.

Another note to the user: **All of the points listed above are not required for the PNNL building re-tuning feature in ECAM+.** However, as the number of points collected increases, the information available to the user during the re-tuning of the system also increases. If the BAS only has temperature information, it should still be mapped and plotted in ECAM+ because important things can be diagnosed, such as loop delta-T vs. OAT at different weather conditions.

The following example data set, shown in Figure 10-3, came from a BAS for a central utility plant (CUP). The file type is a ".csv," and the points included can be seen in the figure.

Figure 10-3 : Sample data set for a central utility plant.

Repeating the steps at the beginning of this guide, go to "Add-Ins," ECAM+, "Select Data." For this case, the time stamps are in one column, so that will be selected, and then hit "OK." Figure 10-4 shows the data being selected.
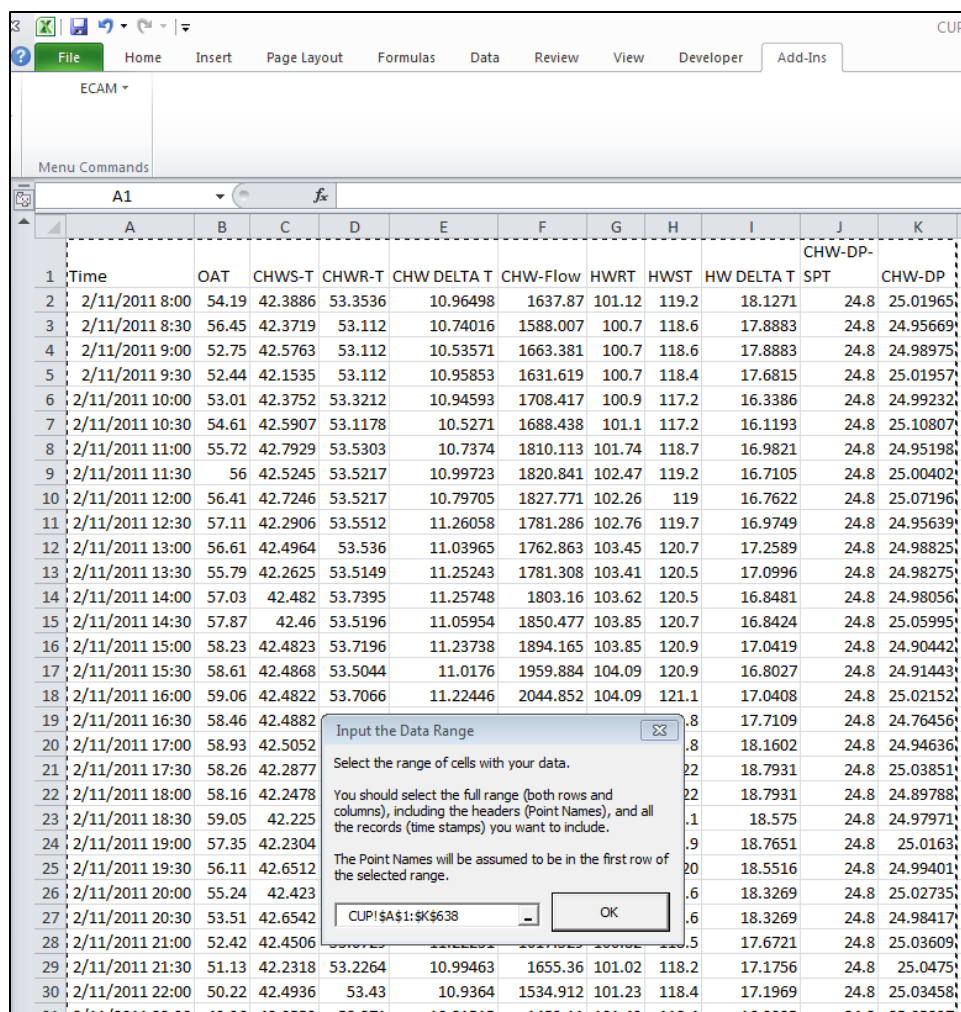
Figure 10-4: Selecting the data in ECAM+.

There is ambient temperature data in column B, so when prompted, the user can click anywhere in this column and click "OK," and then ECAM+ will open up a new workbook with the new data. Now the user can map the points for this data set by going to ECAM+, "Definition of Points." The building size is not known for this example, so the default values are left in the fields and then "OK" is clicked. Now, the user would see something similar to that in Figure 10-5, where the "Define Data by System, Equipment, and Measurement" window is open. Under the "Points List," each point that was in the data set should appear, and the subsystems should all appear. The "Subsystem Components" window is blank until the user refreshes it by clicking on a different subsystem. To map the outdoor-air temperature, the user should click on the corresponding point names under the "Points List" (OAT in this example). Then, under "Subsystems," "Bldg" should be chosen, followed by "Ambient" under "Subsystem Components," and finally "Bldg_TempOa" under the "Component Measurements." Once all of these options are highlighted, the user should click on the "Map Point" button at the right-hand side of the window. If done correctly, the user will now see "Bldg1_TempOa" under "Mapped Points" (Figure 10-6). There is a "1" added to the mapped point because ECAM+ has the ability

to map multiple buildings, chillers, air handlers, etc. To do this, simply map all of the points for the first system, and then change the "Comp. ID" at the bottom of the window (it always defaults to 1) to the desired system number (2, 3, etc.).
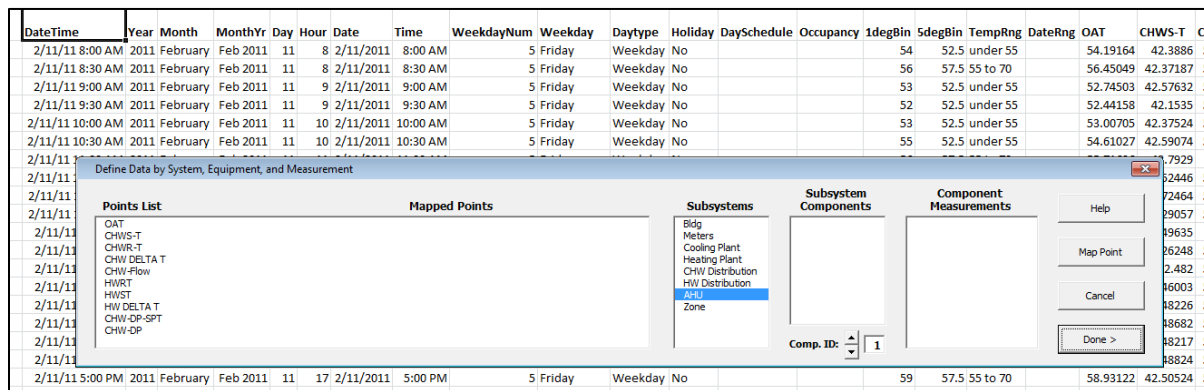
Figure 10-5: Initial window for mapping points.
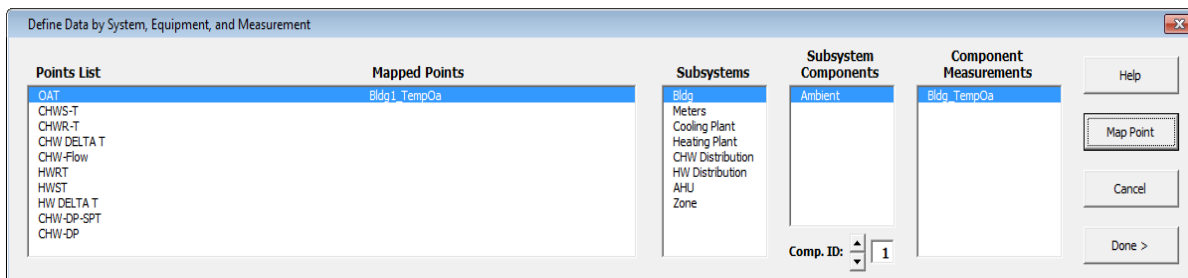
Figure 10-6: Mapping points window after outdoor-air temperature is correctly mapped.

To map the chilled-water supply temperature, click on it in the "Points List," and then click on the "CHW Distribution" under the "Subsystems" list. Now click on the "Chilled_Water" under the "Subsystem Components," and finally "CHW_TempOut" under the "Component Measurements." Once these are all highlighted, in this specific order, click on the "Map Point" button. If done correctly, the user will now have that point added to the "Mapped Points" list. To map the chilled water return temperature and the chilled water delta_T, all of the steps above are the same, except now choose the "ChW_TempIn" and "ChW_TempDiff" under the "Component Measurements" window, respectively.

To map the chilled water flow, click on it under the "Points List," click on the "CHW Distribution" under the "Subsystems," choose the "Pump_CHW_Sec" under the "Subsystem Components," and choose "Pmp_ChW_Sec_gpm" under the "Component Measurements," and click "Map Point."

Mapping the hot-water supply, return, and delta-T is very similar to the chilled-water points, but the "Subsystem" to choose for the hot-water points is "HW Distribution" and "Hot_Water" under the "Subsystem Components," and then "HoW_TempOut," "HoW_TempIn," and "HoW_TempDiff" under the Component Measurements, respectively.

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The last two points in the data set are the chilled-water differential pressure and set point, respectively. These points should be mapped under "CHW Distribution" in "Subsystems," "Chilled_Water" under "Subsystem Components," and "ChW_dPres" and "ChW_dPresSp" under "Component Measurements."

After all of the points have been mapped, the user should click "Done" at the bottom right of the window. Now, the last step for the user is to go to the ECAM+ drop-down menu, and go to the "PNNL Re-Tuning" menu item and click on "Central Plant Charts," and ECAM+ will automatically open a new sheet titled "CP1" with the charts listed above. Figure 10-7 shows the new sheet with these charts. If there was no hot water information from the BAS (could be summer time or no hot water system for the building), then the charts would look something similar to those in Figure 10-8, where the second chart only has the outdoor-air temperature.
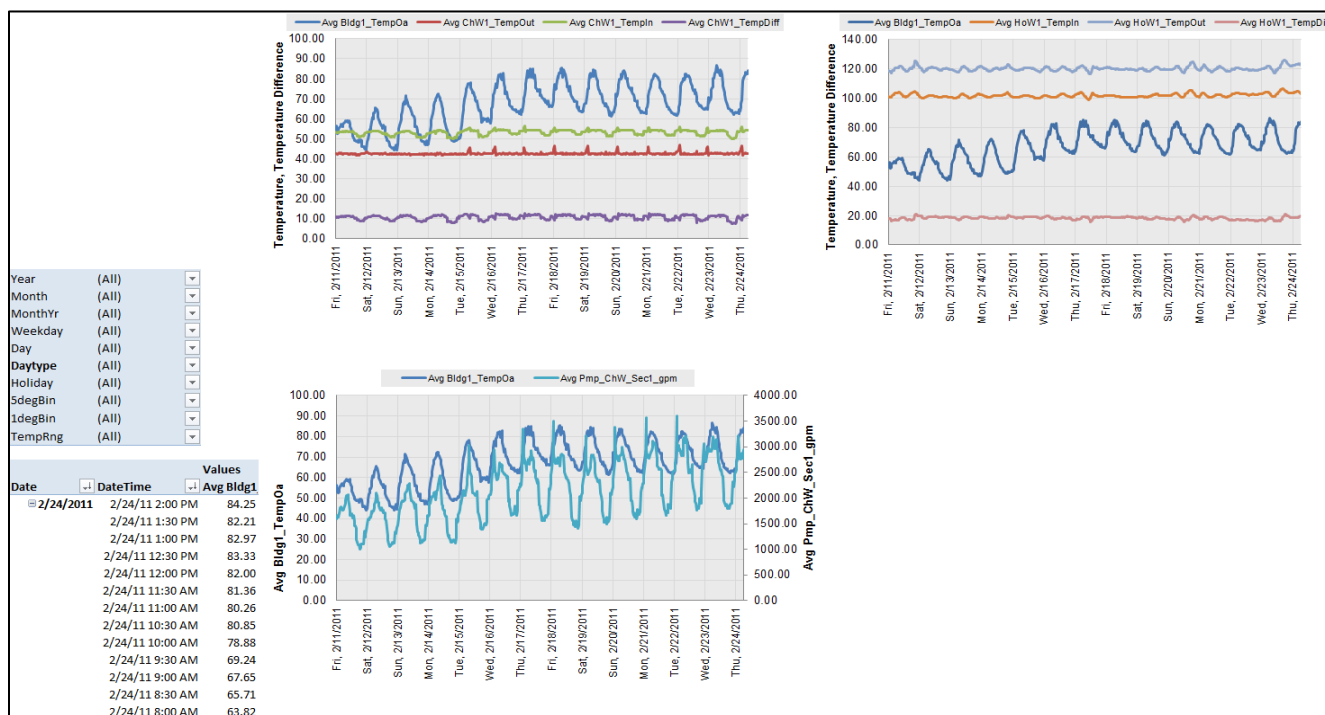
Figure 10-7: Central plant charts when all points are mapped correctly.
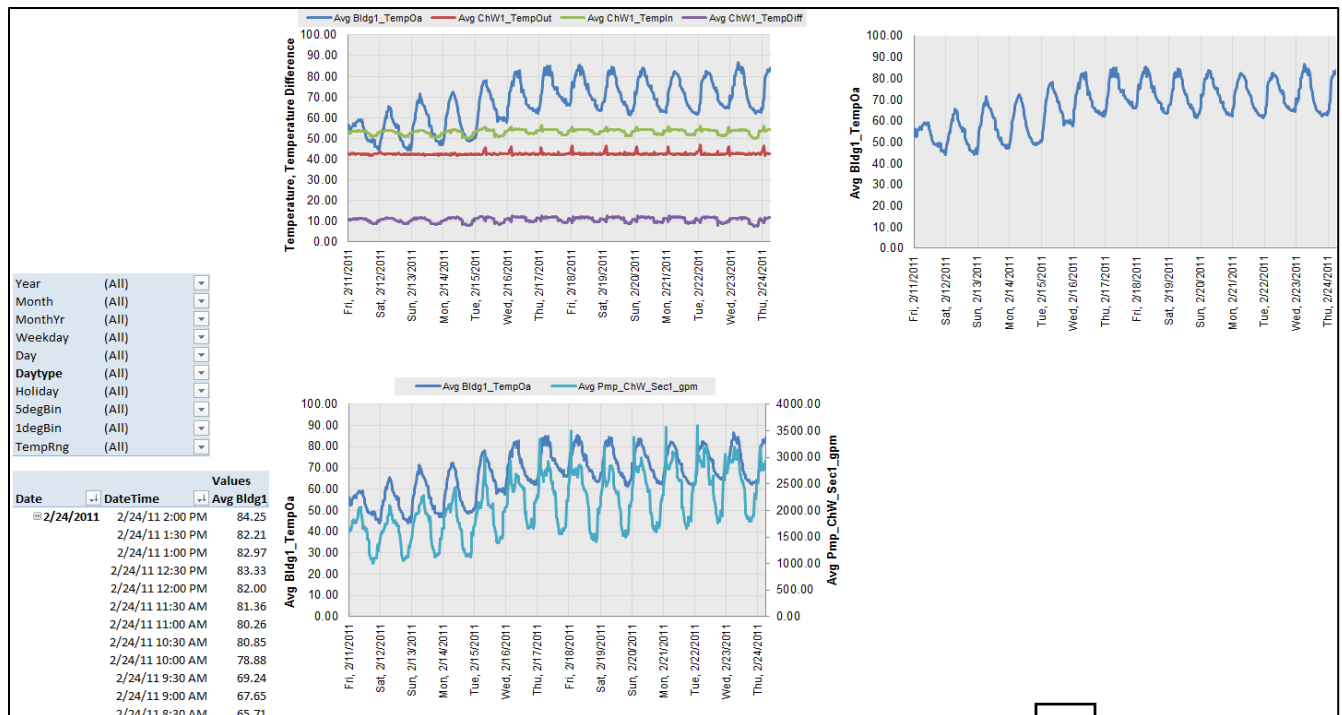
Figure 10-8: Central plant charts without hot-water distribution.

You will notice by inspecting the charts that the differential pressure trend was not plotted in any charts (it is being added in the newest version under development). This is because ECAM+ does not plot that variable in the default plots for the central plant. To create plots for the differential pressure and set point, go to the drop-down menu and select "Time Series Charts," and "Point History Chart." When prompted, select the differential pressure point name, and then hold down the "Ctrl" key and select the differential pressure set point. If you want any other point names included, simply click them while holding down "Ctrl" (Figure 10-9). Figure 10-10 shows the corresponding "Point History Chart."
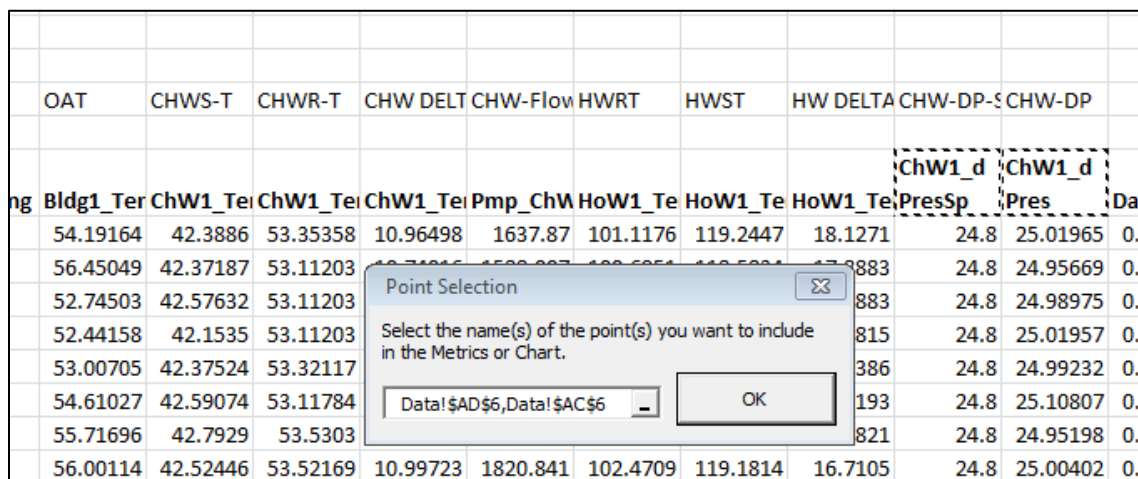
Figure 10-9: Creating a "Point History Chart" for data not included in central plant charts.
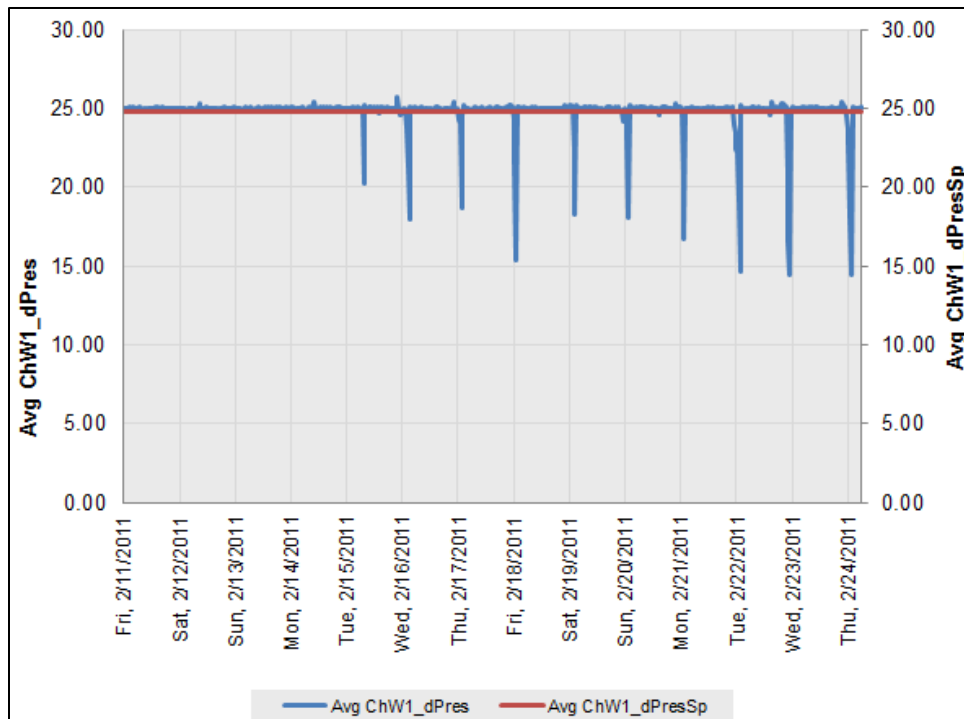
Figure 10-10: "Point History Chart" for differential pressure and set point.

"Point History Charts" should be created for all additional points collected from the BAS that are not automatically generated from ECAM+. Any combination of points can be selected when generating a "Point History Chart," all depending on what information the user is trying to diagnose about the system.

10.2 Air-Handling Unit (AHU) Charts

To identify operational problems and make corrections/adjustments to air-handling unit operation, the points that should be collected (recommended 15-minute intervals, no greater than 60-minute intervals) with the building automation system (BAS) include:

- outdoor-air temperature

- mixed-air temperature

- return-air temperature

- discharge-air (aka supply air) temperature

- discharge-air temperature set point

- discharge (duct) static pressure

- discharge static pressure set point

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- return-air damper position

- outdoor-air damper position

- exhaust-air damper position

- fan status

- fan speed (on both supply and return fans, feedback or command)

- cooling-coil-valve command

- heating-coil-valve command.

The following sheets will be generated in Excel, each with dedicated time-series charts created by ECAM+, depending on the availability of the relevant points mapped in ECAM+:

AHU_Econ –Charts to help analyze economizer operations for an AHU, which include:

1. Outdoor-air temperature (OAT), mixed-air temperature (MAT), return-air temperature (RAT), discharge (supply) air temperature (DAT or SAT), outdoor-air fraction (OAF) vs. time

2. OAT, outdoor-air damper (OAD) position, OAF vs. time

3. OAT, OAD, RAT vs. time

4. OAD, cooling-coil valve (CCV) position, heating-coil valve (HCV) position, OAT vs. time

5. OAT, OAD vs. time

6. OAT, RAT, MAT, SAT vs. time

7. supply-air temperature set point (SATSP), OAT, CCV, OAD vs. time

8. SATSP, SAT, OAT, OAD, CCV, HCV vs. time.

AHU_OA –Charts to help analyze outdoor air operations for an AHU, which include:

1. OAT, OAD, OAF, AHU Status (On or Off) vs. time

AHU_SP –Charts to help analyze static pressure operations for an AHU, which include:

1. duct static pressure (DSP), duct static pressure set point (DSPSP) vs. time

2. DSP, DSPSP, supply fan speed vs. time

3. supply fan speed, supply fan status, DSP vs. time

4. supply fan speed, return fan speed vs. time.

AHU_HeC –Charts to help analyze AHU heating and cooling operations, which include:

1. HCV, CCV, and OAT vs. time

2. SATSP, SAT, OAT, OAD, CCV, and HCV vs. time

AHU_SA –Charts to help analyze supply air operations for an AHU, which include:

1. SAT, SATSP, OAT vs. time.

The following example is for an air-handling unit with data trend from a BAS. The point names that are included in the example can be identified by the "Chart Summary" sheet in ECAM+. You can see that column L contains the supply fan status. In this example, the data comes in as a 0 or 1, but sometimes that data will have an "On" or "Off" value.

Note: ECAM+ will not plot points that have "On" or "Off" as their status. These should be converted to On=1 and Off=0 prior to the "Select Data" step in ECAM+.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Timestamp	OAT	Zone T	Clg Coil Valve	Damper	DATSP	DAT	MAT	RAT	RF-VFD	SF-VFD	SF-Command	Static Pressure	SPSP
2	3/24/11 12:00 AM	52.34167	72.18549	0	0	60.06332	68.08109	68.30231	58.16844	0	0	0	-0.027609	1.4
3	3/24/11 12:10 AM	52.21875	72.18549	0	0	60.11249	68.08109	68.26135	58.00468	0	0	0	-0.027828	1.4
4	3/24/11 12:20 AM	52.09595	72.18549	0	0	60.16162	67.99918	68.26135	57.88182	0	0	0	-0.027609	1.4
5	3/24/11 12:30 AM	51.85028	72.18549	0	0	60.25989	67.95822	68.17944	57.67711	0	0	0	-0.028047	1.4
6	3/24/11 12:40 AM	51.72742	72.18549	0	0	60.30902	67.95822	68.17944	57.55431	0	0	0	-0.028047	1.4
7	3/24/11 12:50 AM	51.60461	72.18549	0	0	60.35815	67.95822	68.13855	57.34953	0	0	0	-0.028705	1.4
8	3/24/11 1:00 AM	51.64557	72.0343	0	0	60.34177	67.95822	68.13855	57.39049	0	0	0	-0.028047	1.4
9	3/24/11 1:10 AM	51.64557	72.0343	0	0	60.34177	67.83536	68.05664	57.26762	0	0	0	-0.028266	1.4
10	3/24/11 1:20 AM	52.42352	72.0343	0	0	60.03058	67.71255	68.01575	57.47234	0	0	0	-0.027828	1.4
11	3/24/11 1:30 AM	52.30066	72.0343	0	0	60.07973	67.71255	68.01575	57.47234	0	0	0	-0.028486	1.4
12	3/24/11 1:40 AM	52.42352	71.99658	0	0	60.03058	67.75351	68.01575	57.51329	0	0	0	-0.028266	1.4
13	3/24/11 1:50 AM	53.4881	71.99658	0	0	59.60475	67.7944	67.97479	57.79991	0	0	0	-0.028266	1.4
14	3/24/11 2:00 AM	53.07867	71.99658	0	0	59.76852	67.7944	67.93378	57.47234	0	0	0	-0.028047	1.4
15	3/24/11 2:10 AM	52.71014	71.99658	0	0	59.91594	67.7944	67.89288	57.26762	0	0	0	-0.028486	1.4
16	3/24/11 2:20 AM	52.38257	71.99658	0	0	60.04697	67.7944	67.85187	57.22673	0	0	0	-0.028266	1.4
17	3/24/11 2:30 AM	52.66919	71.99658	0	0	59.93231	67.75351	67.81097	57.18578	0	0	0	-0.028266	1.4
18	3/24/11 2:40 AM	52.8739	71.99658	0	0	59.85043	67.6716	67.72906	57.06291	0	0	0	-0.028266	1.4
19	3/24/11 2:50 AM	52.25977	71.99658	0	0	60.09608	67.63065	67.68811	56.981	0	0	0	-0.028486	1.4

Figure 10-11: Example data set for an air-handling unit.

The same procedure described above for the central plant operation is used to map the points. To map the return-, mixed-, and discharge-air temperatures, click on a specific one in the "Points List," then click on "AHU" under the "Subsystems," followed by "AHU" under the "Subsystem Components." Finally, under "Component Measurements," choose "AHU_TempRa," "AHU_TempMa," and "AHU_TempSa" for each specific sensor. The discharge-air temperature set point and discharge static pressure and set point are also located here, under "AHU_TempSaSp," "AHU_DuctStcPres," and "AHU_DuctStcPresSp," respectively. You will also notice that there is an "AHU_TempOa" in the "Component Measurements" window. This is for the outdoor-air temperature if each air-handling unit has its own sensor. It is recommended that the outdoor-air temperature sensor associated with each AHU be used when analyzing individual AHUs so it is consistent with the controls, but ECAM+ gives the user the option to use an outdoor-air temperature associated with the building.

To map the outdoor- and return-air damper positions, choose the "AHU Subsystem," and then under the "Subsystem Components" choose the "Dampers." Under the "Component Measurements," choose either "AHU_Dmpr_OA_%op" or "AHU_Dmpr_RA_%op."

To map the cooling coil command, choose "AHU" under "Subsystems," "Coil_Cooling" under "Subsystem Components," and "AHU_Vlv_CC_%op" under "Component Measurements." Similarly for the heating coil command, choose "Coil_Heating" under "Subsystem Components" and "AHU_Vlv_HeC_%op" under "Component Measurements."

To map the supply and return fan speed, choose either "Fan_Supply" or "Fan_Return" under the "Subsystem Components," and then either "AHU_Fan_S_%Spd" or "AHU_Fan_R_%Spd." The fan status appears as "Fan_S_Status" or "Fan_R_Status" under the "Component Measurements" window. After all points are mapped, click the "Done" button at the bottom right of the window.

Now the user can select the "AHU Charts" under the "PNNL Re-Tuning" menu option in ECAM+. When selected, the sheets targeting specific parts of the AHU with all possible charts should be generated. The name of the sheet will have a 1 on it, for "Comp ID" 1. However, if there are multiple AHUs mapped correctly, then the user differentiates these by that "Comp ID"

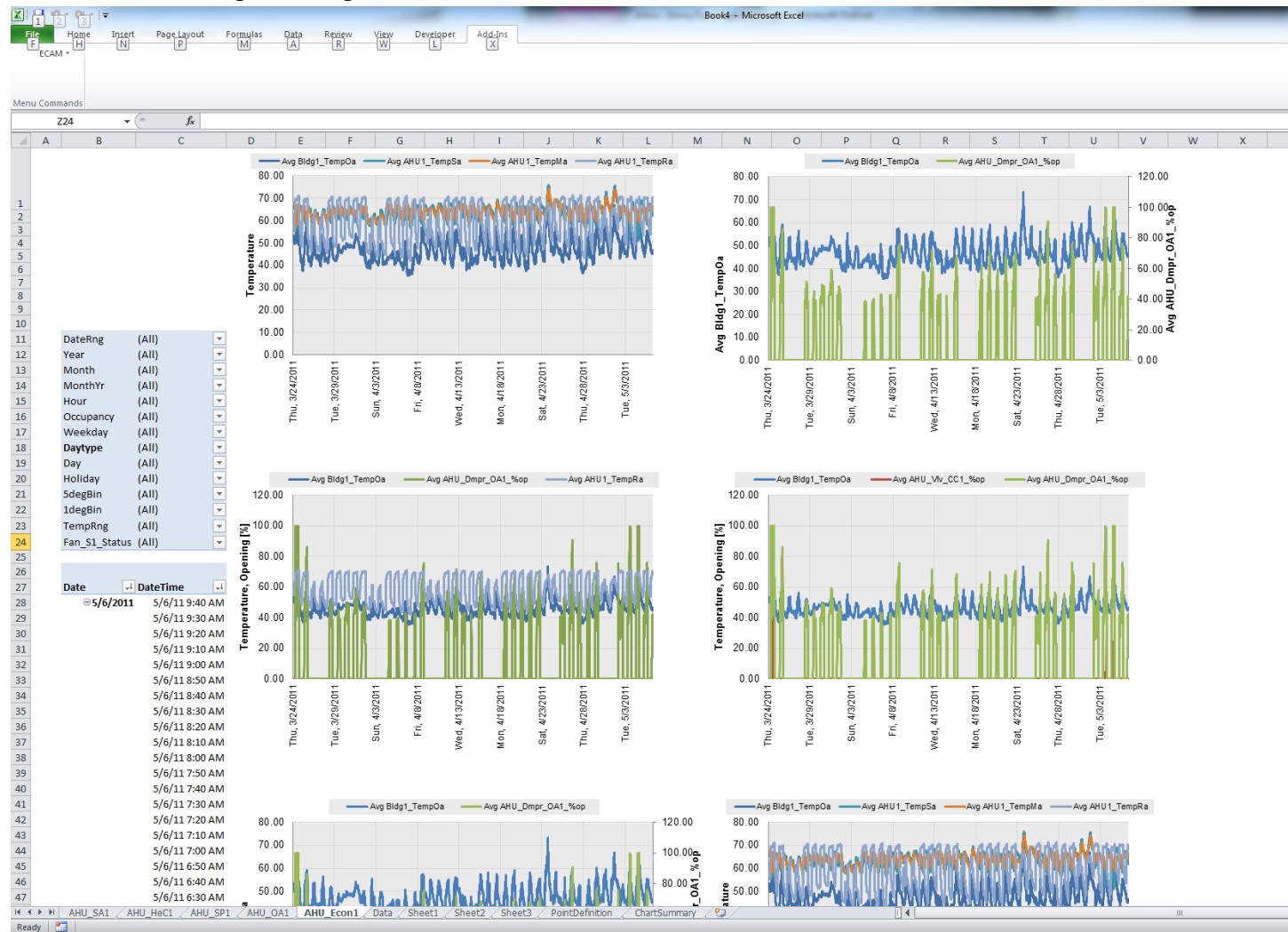on the definition of points step.

Figure 10-12 shows an example spreadsheet with all sheets generated from the "AHU Charts" option in "PNNL Re-Tuning," with the AHU_Econ sheet highlighted.

Figure 10-12: AHU charts in ECAM+ under the "PNNL Re-Tuning" option. Here the AHU_Econ sheet is highlighted, but the user can see the other sheets that have been generated such as AHU_OA, AHU_SP, AHU_HeC, and AHU_SA.

10.3 Scatter Charts

Once the points for the AHU have been mapped, the user can select the "AHU Scatter Charts" option under the "PNNL Re-tuning" menu in ECAM+. The following scatter charts will be created by ECAM+, depending on the availability of the relevant points mapped in ECAM+:

1. OAT vs. MAT

2. OAT vs. OAD

3. supply fan speed vs. return fan speed

4. CCV vs. HCV

5. SATSP vs. SAT.

After running this feature in ECAM+, another sheet will be created and called "AHUxy1." It will appear somewhat similar to that in Figure 10-13. Note that the heating and cooling coil scatter chart is missing from the figure.
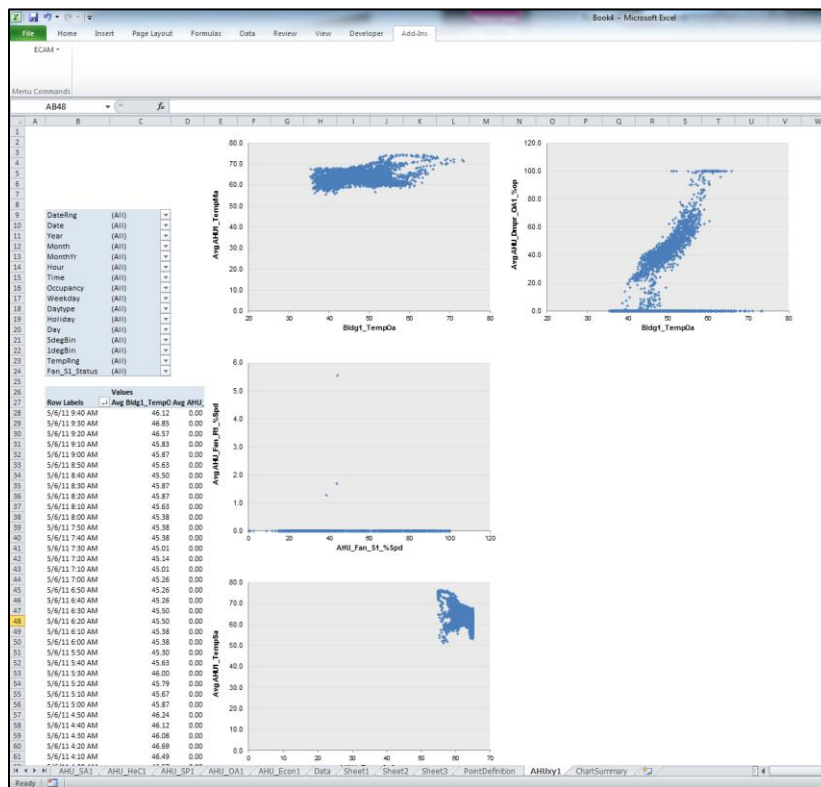

Figure 10-13: Example of AHU scatter charts in the "PNNL Re-Tuning" feature of ECAM+.

To create scatter charts for any other points of interest, the "Scatter Chart by Occupancy" can be used. This is described in detail in Section 5.1.1.

10.4 Zone Charts

To identify operational problems and make corrections/adjustments to air-handling unit operation, the points that should be collected (recommended 15-minute intervals, no greater than 60-minute intervals) with the building automation system (BAS) include:

- zone temperature

- zone temperature set point

- variable-air-volume (VAV) box damper position

- reheat valve position (if supply air is reheated at the zone)

- re-cool valve position (if supply air is re-cooled at the zone)

- zone occupancy mode (occupied/unoccupied)

- zone CFM

- zone CFM set point

- zone discharge-air temperature

- fan status, or fan command (for fan powered boxes only).

The following time-series chart will be created by ECAM+, depending on the availability of the relevant points mapped in ECAM+:

1. Zone temperature, reheat valve signal, damper position signal, occupancy vs. time.

In addition, another sheet will be generated that has specific charts for all mapped zones in the workbook:
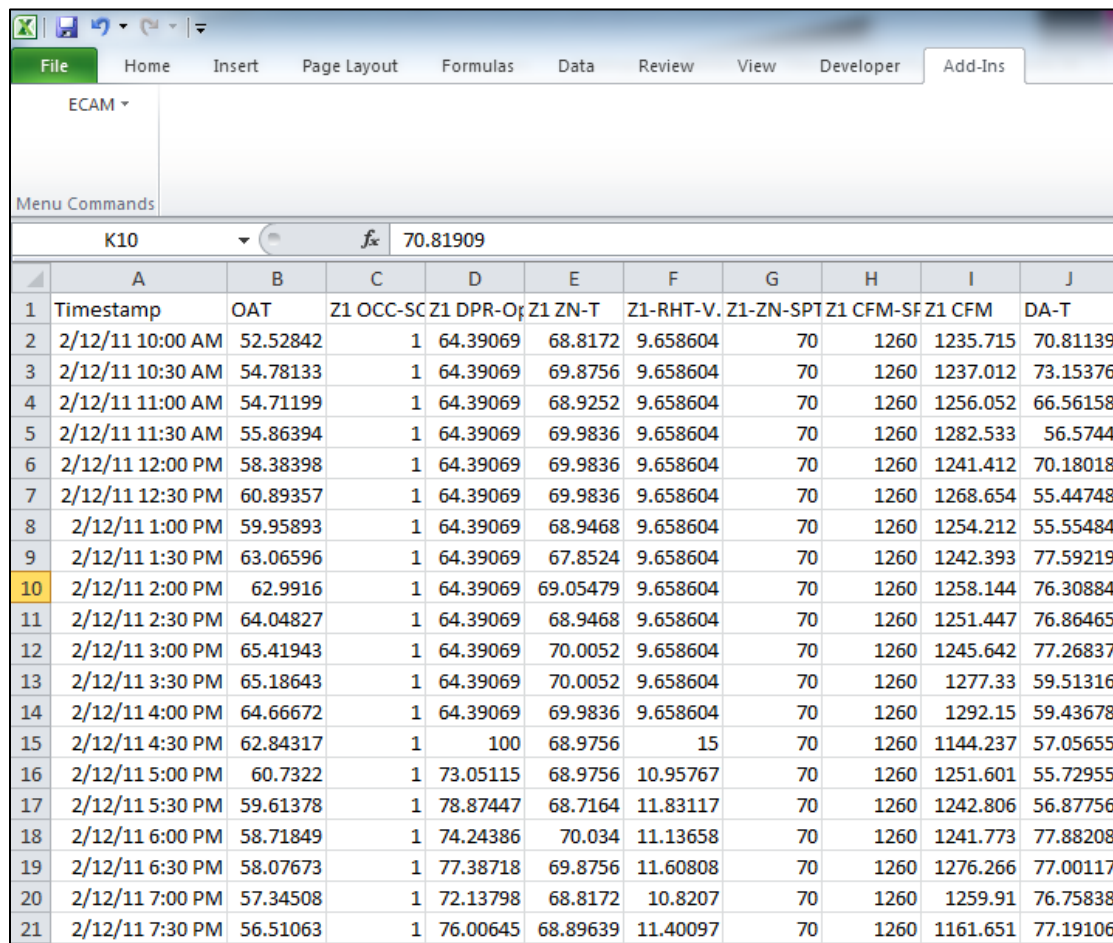
1. All zones damper position signals vs. time

2. All zones reheat valve signals vs. time.

It is important to note that each zone will be charted on a separate worksheet, so the "Comp.ID" will need to be indexed for each zone that is mapped in ECAM+. Figure 10-14 shows an example data set for zones from a BAS. When mapping the points for the zone charts, click on

the "Zone" "Subsystem." There are only two options for the "Subsystem Components," either "Terminal" or "Zone." If you click on "Terminal," you will find VAV box damper position (Z_Tl_Dmpr_%op) and reheat valve position (Z_Tl_Rht%) under the "Component Measurements" window. If you click on "Zone," you will find zone temperature (Z_Temp), zone temperature set point (Z_TempSP), and zone occupancy mode (Z_Occ_Status).

Note that there are no component measurements in the zone subsystem for zone CFM, zone CFM set point, or zone discharge-air temperature. These points can be included in ECAM+, but will have to be plotted using standard Excel plotting tools if more information is needed for any particular zone. The zone occupancy can be plotted using a "Point History Chart" in ECAM+.

Figure 10-15 shows a typical zone plot created in ECAM+ using the "PNNL Re-Tuning" feature "Zone Charts."

Figure 10-14: Example data set for zones from a BAS.
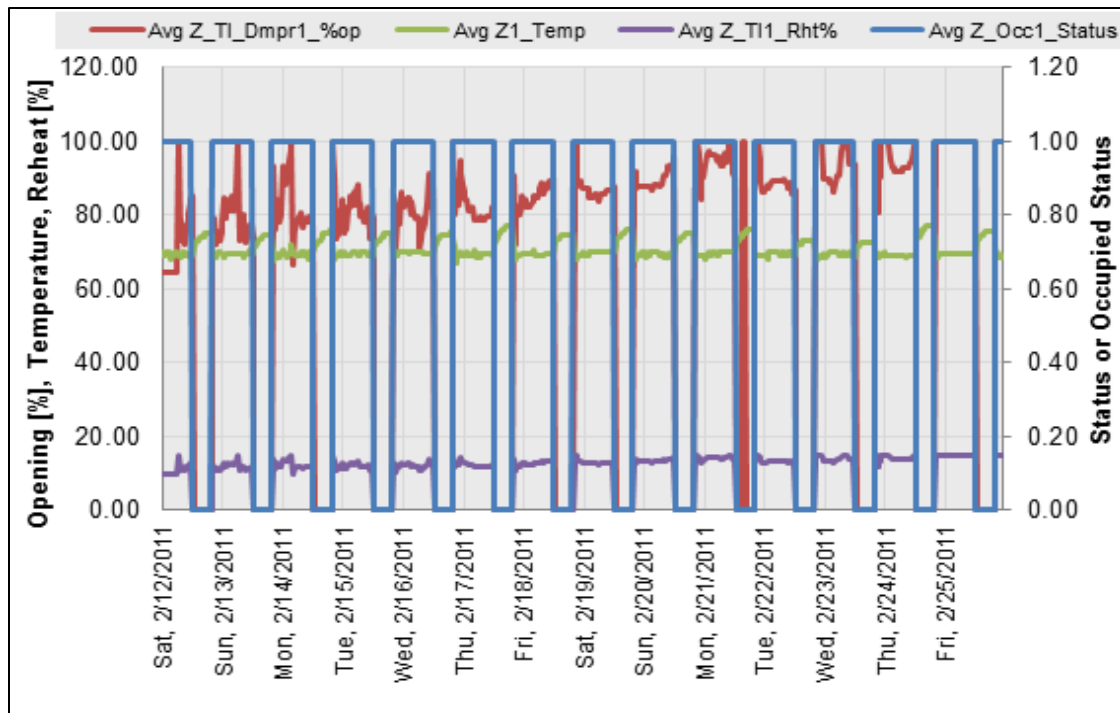
Figure 10-15: A typical zone chart using the PNNL Re-Tuning feature in ECAM+.

Figure 10-16 shows an example of the other charts generated when selecting the "Zone Charts" feature in the "PNNL Re-Tuning" portion of ECAM+ for all zones. For this example, there are only three zones for the air handler that are plotted on the zones common chart, and all three of them have reheat capability.
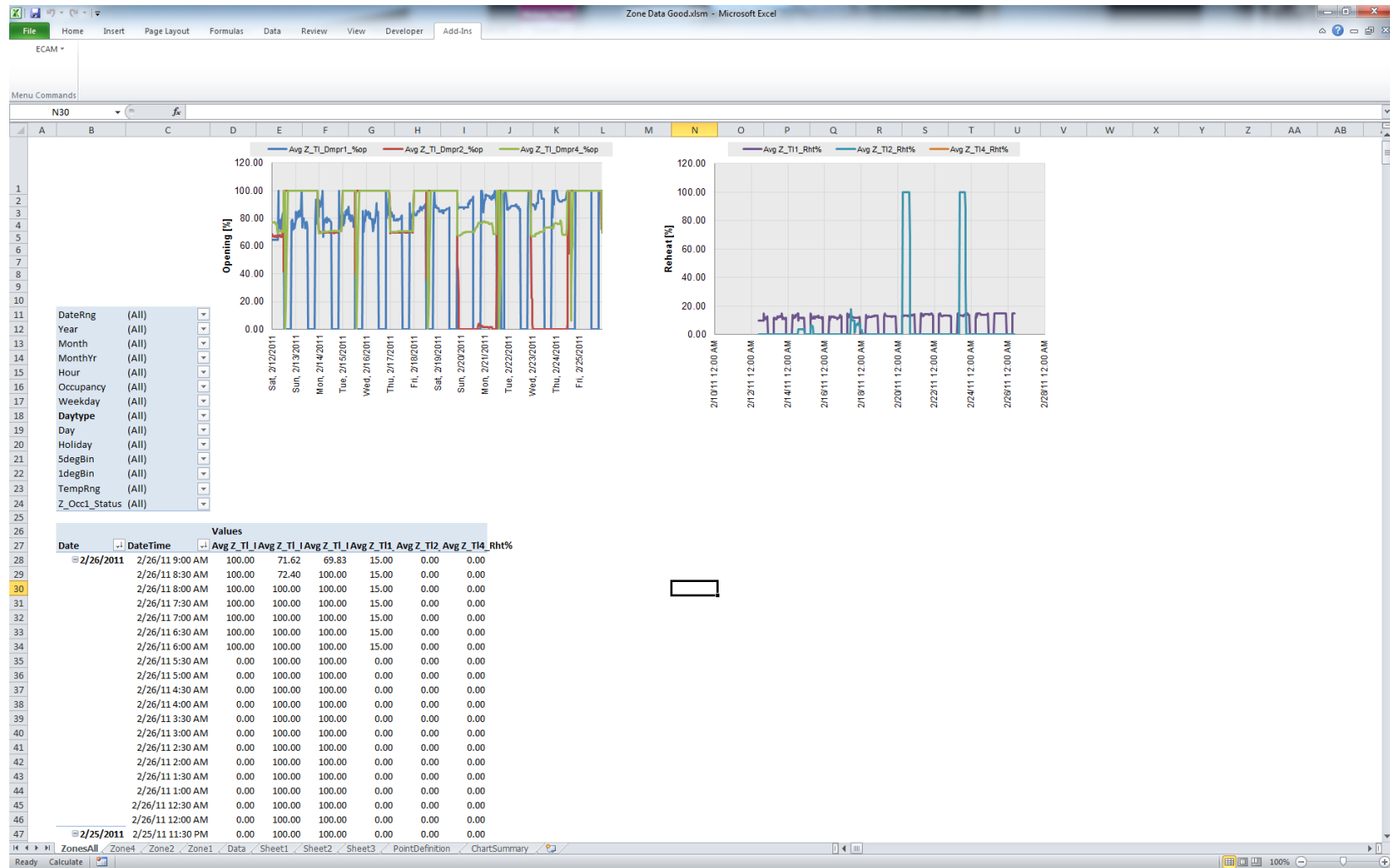
Figure 10-16: Zones common charts generated in ECAM+'s "PNNL Re-Tuning" feature.

11.0   Data-Driven Models and Measurement and Verification (M&V)

These menu items provide the capability to create various types of regression models from the data in ECAM+, and use those models for M&V of energy savings. The most common, and most tested, application for these models is to characterize energy use as a function of ambient (outdoor) temperature. However, other models can be created. ECAM+ provides a variety of linear and change-point linear regressions. **Polynomial regressions are shown on the model selection UserForm, but are not yet available.** The linear and change-point linear models, and associated uncertainty,

Input Desired Model and Savings Confidence Level
Input Values For ASHRAE Fractional Savings Uncertainty
Create Load Profile by Day of Week and Evaluate Daytypes
Evaluate Daytypes (active sheet has LP by Day of Week)
Create Baseline Models Only
Create Post Models Only
Create Baseline and Post Models
Evaluate Savings for Post Period
Bring in TMY3 Weather for Annualization
Annualize Baseline Using TMY3 Weather
Annualize Post Using TMY3 Weather
Annualize Pre, Post, and Savings Using TMY3

are based on classical statistics and ASHRAE approaches. The ASHRAE approaches were developed and documented through research project 1050-RP, *Development of a Toolkit for Calculating Linear, Change-point Linear and Multiple-Linear Inverse Building Energy Analysis Models.*
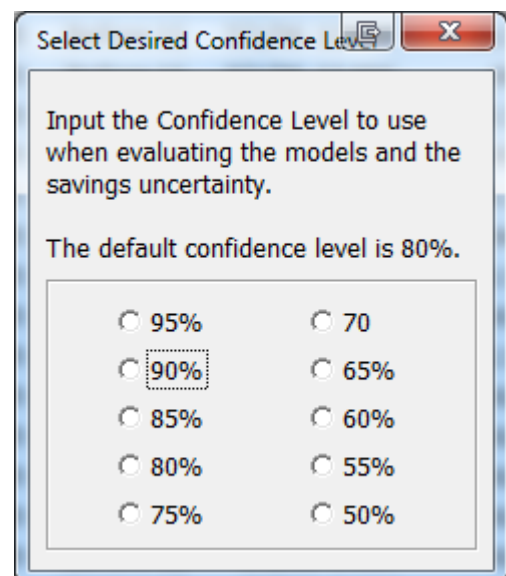
The focus of this section of ECAM+ is the development of models. A prerequisite is describing the form of the model(s) and the model inputs. Another set of inputs specify the desired settings for model uncertainty. These inputs are not required because there are defaults, but should be used if the defaults are not appropriate for a specific project.

11.1 Input Desired Model and Savings Confidence Level

When selected, a UserForm comes up (as in Figure 11-1) which allows the user to select a confidence level from 50% to 95% in 5% increments. If this input is not used, or the form is closed without selecting a value, a default confidence level of 80% will be used.

11.1.1 Background on Confidence Level

The statistical uncertainty calculations require an input confidence level. Uncertainty is associated with a given confidence level, or probability. For example, there is a 90% probability that the true value is between 433 and 511. The Confidence Level is an input number that

Select Desired Confidence Level

Input the Confidence Level to use when evaluating the models and the savings uncertainty.

The default confidence level is 80%.

○ 95%	○ 70
○ 90%	○ 65%
○ 85%	○ 60%
○ 80%	○ 55%
○ 75%	○ 50%

67

Figure 11-1: Choosing the model confidence level

establishes how certain the range of estimates include the true value. From the *Bonneville Power Administration's Regression for M&V: Reference Guide*[1]: "A 95% confidence level implies that there is a 95% chance that the confidence interval resulting from a sample contains the true parameter. Confidence intervals define the range – an uncertainty band – that is expected to band the true regression, with a certain probability. The width of the confidence interval provides some idea of uncertainty about the estimated value." For further background on confidence levels and uncertainty refer to the BPA Regression Guide or an appropriate statistics reference.

11.2 Input Values for ASHRAE Fractional Savings Uncertainty

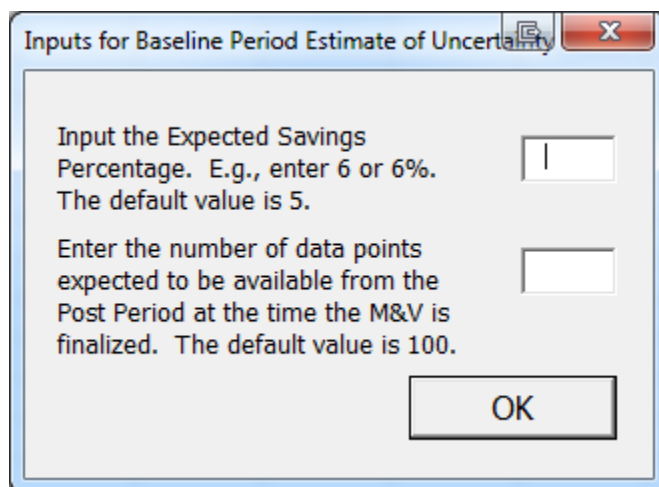"Fractional Savings Uncertainty" is described in Annex B of ASHRAE Guideline 14, *Measurement and Verification of Energy and Demand Savings*. Its purpose is to help evaluate whether a baseline model will be adequate for use in estimating savings. The uncertainty must be low relative to the expected savings. Therefore, two inputs are needed: the expected savings percentage, and the number of points that will be available in the post period. The number of post period points is needed because it will impact the uncertainty of the savings—e.g., with only a few points it is not well known how representative they are of longer-term energy use. (The number of baseline points will be known because data has been entered for creation of a baseline model.)

As shown in the input form, the default value for the expected savings percentage is 5%, and the default value for the number of points available in the post period is 100. Users don't need to use this menu item unless they wish to change these default values, or if they are not using the fractional savings uncertainty output.

Figure 11-2: Fractional savings uncertainty inputs

11.3 Create Load Profile by Day of Week and Evaluate Daytypes

This menu item should be used for many, perhaps most, M&V analyses. The M&V or modeling can be based upon three time levels. One of these is daytypes. Unless the default daytypes (weekday, Saturday, Sunday, and holiday) are to be used without change, custom daytypes should be created to model by daytypes (see Figure 11-3 and Figure 11-4).

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[1] BPA 2012. *Regression for M&V: Reference Guide*
Portland, OR: Bonneville Power Administration.
Available at: https://conduitnw.org/Pages/File.aspx?RID=506.

If the models are to be created by occupancy, the "Load Profile by Day of Week" is also valuable for reference when creating the building schedules (see Figure 11-3).
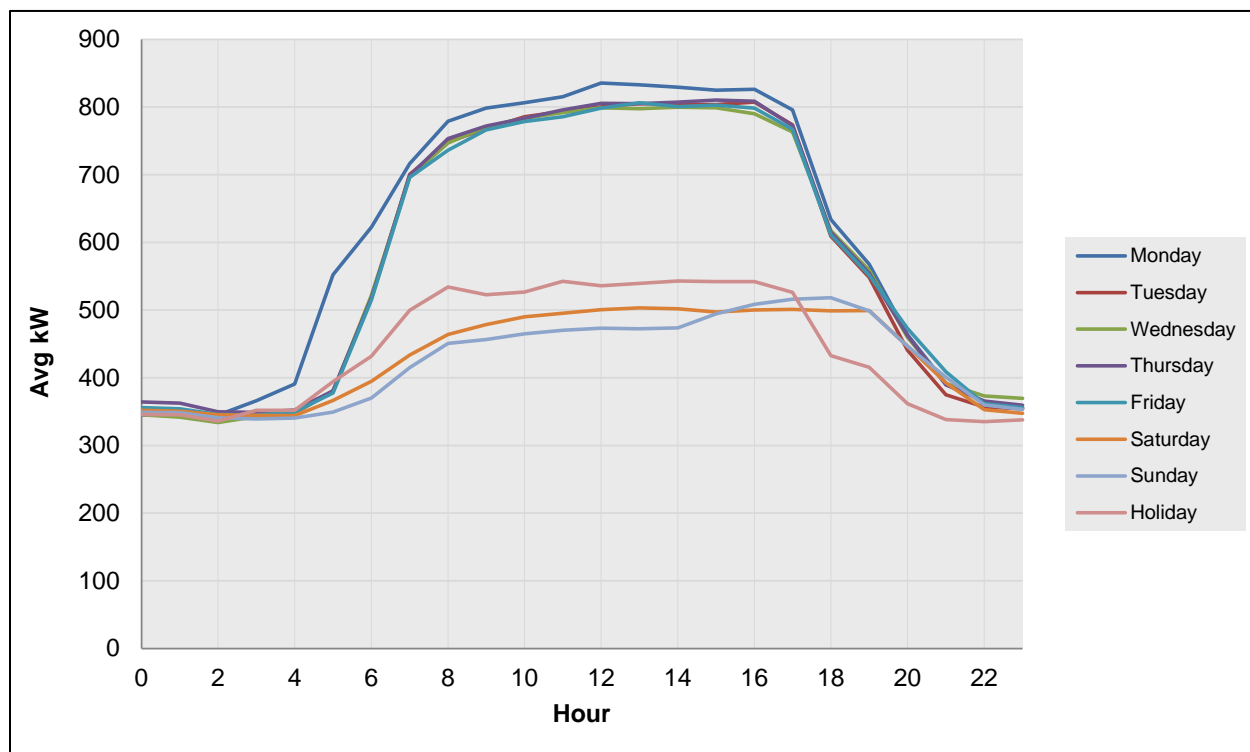
Figure 11-3: "Load Profile by Day-of-Week."

Figure 11-4: Daytyping selections progression

Place a checkmark for each day associated with an individual daytype, then click the "Update" button. In Figure 11-3**Error! Reference source not found.** we can see that Mondays start earlier than the other weekdays, so it is selected as its own daytype. After it is checked and the "Update" button selected, a new list with the remaining days of the week is presented. In this case, the other non-weekend days are checked to form another daytype. After the "Update" button is selected, only Saturday, Sunday, and holiday days are left to select.

After the remaining daytypes have been created by checking the remaining days and clicking "Update"—in this case separate daytypes were created for the weekend days and for holidays—

the final selections are shown without an "Update" button, as shown in Figure 11-5. For this example, there ended up being four daytypes created.

Figure 11-5: Final daytype selections.

11.4 Evaluate Daytypes (Active Sheet has Load Profile by Day of Week)

This menu item lets you change the daytypes if you have already created them. The active sheet isn't really limited to a "Load Profile by Day of Week," but it does require a worksheet that has a PivotTable that includes a visible "Weekday" PivotField.

11.5 Create Models

Ordinary linear and ASHRAE change-point linear models are available. Polynomial models will be available in a later version, and are shown in the model selection UserForm (Figure 11-8) but the polynomial buttons are not yet active.

The models use a combination of continuous and categorical variables (e.g., outdoor temperature and daytype). You will be prompted to categorize the data by the UserForm shown in Figure 11-6.

If you choose "Daytypes," the data will be aggregated from the interval of the raw data to the daily level, and you will create a separate

Figure 11-6: Data categorization for models

model for each daytype. ECAM+ uses the average for the aggregation—the daily aggregation for kW is the average of all the kW measurements during the day.

If you choose "Occupancy," the data will be aggregated from the interval of the raw data to the hourly level, and you will create a separate model for each occupancy period.

If you choose "Hourly," the data will be aggregated

Figure 11-7: Daytype Selection for Hourly Model

from the interval of the raw data to the hourly level, and you will create a separate model for each hour of the day, but only for a single daytype. You will be presented with a list of available daytypes to pick from, based on either the default ECAM+ daytypes or based on the custom daytypes if you have created them (see Figure 11-7).

After you select the data categorization method, you will be presented with the Point Selection form for a scatter chart. Select the independent variable and then the dependent variable as is always needed for an ECAM+ scatter chart. (This is discussed in Section 5.0).

ECAM+ will create a separate PivotTable and scatter chart for each category appropriate to your selected categorization method. After each scatter chart is created, you will be presented with a selection of model types to choose from, as shown in Figure 11-8: Model selection. You can use the same or different model types for each category.

Further description of each model type can be seen by clicking on "Show Model Descriptions" at the top of the form shown in Figure 11-8.

After a model for each category has been created, the predicted value for each point and the rest of the statistics are calculated. For information on these statistics, refer to Section 11.5.4.
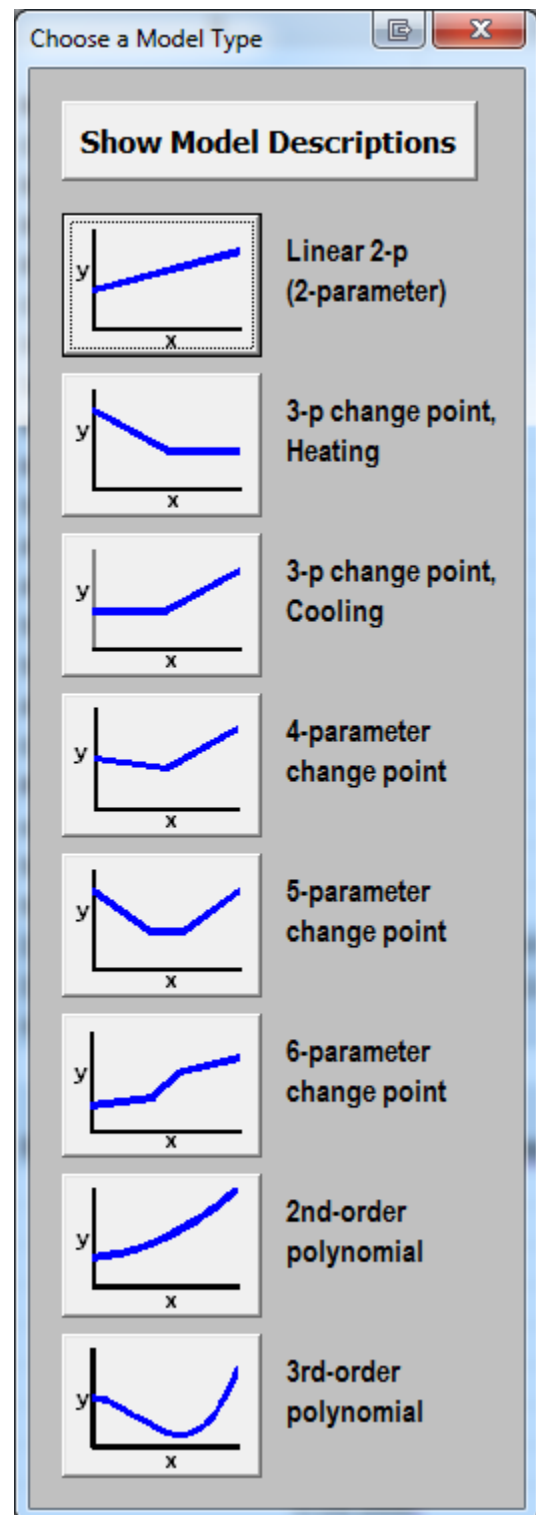
Figure 11-8: Model selection

11.5.1 Create Baseline Models Only

This will create a statistical model of building or equipment performance for the baseline period or for all of the data.

If you haven't "Input Dates for Comparison of Pre and Post" (see Section 2.4) this selection will model all of the data.

For distinguishing between pre and post time periods, the M&V tools use the keywords "Before" and "After" in the "DateRng" column of the "Data" worksheet. So, if you have pre and post data that isn't cleanly distinguished by date, you can put these keywords in the appropriate records in the "DateRng" column. (Some HVAC controllers can change operating modes periodically for evaluation purposes, and the use of these keywords can facilitate M&V in ECAM+.)

11.5.2 Create Post Models Only

This will create a statistical model of building or equipment performance for the post period.

11.5.3 Create Baseline and Post Models

This will create statistical models of building or equipment performance for both the baseline and post periods.

11.5.4 Model Statistics and Guidance on Selecting Models

Some guidance and a few of the model statistics are highlighted here. For more information refer to the BPA Regression Guide, ASHRAE Guideline 14, and/or a statistics reference.

In selecting a model, use the simplest model that reasonably matches the data. In general, data sets with relatively few data points, and/or a relatively narrow range of the independent variables, should use a model with few parameters. If a model with too many parameters is used, "overfitting" may result, and the model will not provide a good baseline projection or prediction of future points.

It can be helpful to know the expected shape of the data, based on the building or equipment being modeled, and the time categorization chosen. But because this may not be known, ECAM+ provides a scatter chart for the user to see the form of the data prior to selecting the model type.

For most M&V purposes, modeling at the daily level—by "Daytype"—will likely be best. Modeling at the hourly level can be valuable for fault detection, and in some cases, may be worthwhile for M&V. When modeling at the hourly level, schedules should usually start and end on the hour. If schedules start other than on the hour (e.g., occupancy is set to start at 7:30 AM), the models created using hourly intervals may have bias, especially when projecting the models to the post period or to an annual basis.

11.5.4.1 Net Determination Bias

Models should have little or no bias. From the BPA Regression Reference Guide,

"Net determination bias" is simply the percentage error in the energy use predicted by the model compared to the actual energy use. The sum of the differences between actual and predicted energy use should be zero. If the net determination bias = 0, then there is no bias. ASHRAE Guideline 14-2002 accepts an energy model if the net determination bias error is less than 0.005%.

ECAM+ models will usually meet the ASHRAE requirement, with little bias. However, you should always check the model bias. Rare combinations of data and model types can result in models with bias. In most cases this can be corrected by changing model types, typically to a model with fewer parameters.

11.5.4.2 CV(RMSE) or Standard Error %

The *coefficient of variation of the root mean squared error* – CV(RMSE) – is the root mean squared error (RMSE) divided by the average *y-value*. For simple ordinary linear regression models, the percentage standard error and the CV(RMSE) are the same. This is also called the normalized RMSE.

CV(RMSE) is an important metric in evaluating model performance. Many engineers look at R^2, the coefficient of determination, as a key criterion. However, R^2 includes two concepts, not just how well the model reproduces the data, but also the degree to which the dependent variable is correlated to the independent variable(s). In other words, it incorporates not just the model fit, but also the model slope. A model with a good fit but a low slope will have a lower R^2 than a model with the same quality of fit but a higher slope. While R^2 is valuable—a model with zero slope indicates that the independent variable is of no value to the model—CV(RMSE) is a more useful metric for describing model fit.

11.5.4.3 Fractional Savings Uncertainty

For M&V purposes, a key concept to understanding whether the model is sufficient is that the uncertainty be low relative to the savings. This is the fractional savings uncertainty, as described in ASHRAE Guideline 14, Annex B. Annex B provides an empirical equation that has its roots in linear regression uncertainty. That equation is implemented in ECAM+.

To obtain the Fractional Savings Uncertainty, the expected savings and the expected number of data points available in the post period must be input, as described in Section 11.1.

The savings uncertainty in both actual and percentage terms can also be calculated after the post data is available.

11.6 Evaluate Savings for Post Period

This item should only be used after baseline models have been created. It provides IPMVP "Reporting-Period Basis or Avoided Energy Use" savings estimates. The savings are estimated by subtracting the actual post period energy use from the projected baseline energy use.

The baseline is projected to the actual post conditions for each category (daytype or occupancy category), by post period interval. **Error! Reference source not found.** is an example output for a savings by daytype analysis, with custom daytypes of {Monday}, {Tuesday, Wednesday, Thursday, and Friday}, and {Saturday, Sunday, and Holidays}.

Table 11-1: Example of daily savings.

Dtyps2	Date	Avg Temp	Avg kW	Baseline	Savings	Prediction Half-Interval
TuWeThFr	1/25/2007	35.3	539.3	515	-24	44
TuWeThFr	1/26/2007	40.3	531.3	526	-6	40
SaSuHo	1/27/2007	39.3	362.6	351	-12	313
SaSuHo	1/28/2007	37.8	362.2	351	-11	340
Monday	1/29/2007	36.2	560.6	566	6	49
TuWeThFr	1/30/2007	37.8	547.5	520	-27	42
TuWeThFr	1/31/2007	39.2	553.0	523	-30	40
TuWeThFr	2/1/2007	35.6	554.1	516	-38	44
TuWeThFr	2/2/2007	35.9	537.1	517	-21	44

For each date, the associated custom daytype is determined, and the baseline for the associated temperature and daytype combination is projected.

Table 11-2 gives a similar output for a savings by occupancy period analysis:

Table 11-2: Example of hourly savings.

Occ	DateHour	Avg Temp	Avg kW	Baseline	Savings	Prediction Half-Interval
Unocc	1/25/07 5 AM	31.4	378.8	142	-237	249
Startup	1/25/07 6 AM	29.7	509.2	482	-28	227
Startup	1/25/07 7 AM	29.6	706.1	482	-224	227
Occ	1/25/07 8 AM	31.2	752.2	735	-17	69
Occ	1/25/07 9 AM	32.6	741.7	735	-7	69
Occ	1/25/07 10 AM	34.3	742.5	734	-8	68
Occ	1/25/07 11 AM	35.6	726.8	734	7	68
Occ	1/25/07 12 PM	36.6	742.8	733	-9	68
Occ	1/25/07 1 PM	37.6	717.1	733	16	67
Occ	1/25/07 2 PM	38.0	725.5	733	7	67
Occ	1/25/07 3 PM	38.6	722.0	733	11	67
Occ	1/25/07 4 PM	38.4	696.6	733	36	67
Occ	1/25/07 5 PM	38.6	645.8	733	87	67
Shutdown	1/25/07 6 PM	38.4	470.3	428	-42	233
Shutdown	1/25/07 7 PM	38.0	416.1	428	12	233

Note that the output table with the daily or hourly projections has many rows at the end with #NA in each cell. The calculations are correct because they don't include the rows with #NA. These "extra" rows are deliberately provided: The table is originally created with all the data—baseline and post—and then filtered to just show the post data. The value of having all of the data is that the baseline projection can be double-checked: "Change the PivotTable DateRng" field from the post ("After") period to the baseline ("Before") period. The resulting "savings" table now shows only the baseline data. The results should show zero savings, indicating no bias in the baseline. Each of the individual daytype models were previously evaluated for the net determination bias; this permits a second check using the combination of all of the daytype models.

ECAM+ summarizes the projections and savings in a table above the time interval results. The time intervals are totaled together to get the net savings over the post period, and the associated uncertainty in the baseline projection for each day or each hour is aggregated to get the net uncertainty. Table 11-3 shows a summary savings table for the savings by daytype:

Table 11-3: Example savings summary.

766,467	**Projected Baseline Energy**
800,316	**Measured Energy**
-33,849	**Energy Savings**
26,229	**Projected Baseline ±Uncertainty @ 95% Confidence Level**
-33,849 ±26,229	**Energy Savings and Uncertainty @ 95% Confidence Level**
3.4%	**Projected Baseline ±Uncertainty @ 95% Confidence Level**
-4.4% ±3.4%	**Energy Savings and Uncertainty @ 95% Confidence Level**

11.7 Bring in TMY3 Weather for Annualization

This feature is not limited to TMY3 data, but that will be the most common use.

If outdoor temperature is used as the independent variable, then TMY3 data can be used to estimate typical annual energy use and savings. Because TMY3 data is compiled from multiple years of data, it is necessary to pretend all the data came from a single year so that the data is sequential and daytypes can be categorized.

After selecting this menu item, you will be presented with the table and prompt shown in Figure 11-9. (This example is for savings by daytype; the table is slightly different for savings by occupancy period.)

Figure 11-9: Table and prompt for typical year data

Acquire/copy the TMY3 data, and paste it in Column D ("Temp or Indep.Var.") Afterwards, click OK, and you will be prepared for annualization. Note that TMY3 data comes as average

hourly temperature, so the user would have to calculate the average daily temperature to use the annualization for savings by daytype.

If you have a different independent variable, as long as it can be characterized on a whole-year basis, using either hourly or daily values, you can use this approach.

11.8 Annualize Baseline Using TMY3 Weather

It is often useful to extrapolate shorter-term data to an annual basis. If the shorter-term data covers the full range of operating conditions, the extrapolation should be reasonably accurate. This can also be useful to convert an actual year to a typical year for long-term estimates.

After bringing in the annual data as described in the prior section, and having already created baseline models, this menu item will estimate hourly or daily energy use for an entire year.

There is no user interaction required; just select the menu item after creating the baseline models and bringing in the TMY (or other independent variable) data as per Section 11.7.

The projection is the same as described in Section 11.6, except that the typical annual values (e.g., TMY3) are used instead of post-period values, and only the projected values are estimated instead of also including actual values and savings (Table 11-4).

Table 11-4: Example typical annual baseline projections.

Dtyps2	DateTime	Temp		Baseline		Base Prediction Half-Interval	
TuWeThFr	1/1/2013	34.0		513		45	
TuWeThFr	1/2/2013	34.7		514		45	
TuWeThFr	1/3/2013	34.9		515		45	
TuWeThFr	1/4/2013	45.0		535		37	
SaSuHo	1/5/2013	42.3		351		261	
SaSuHo	1/6/2013	41.2		351		279	
Monday	1/7/2013	40.9		558		40	
TuWeThFr	1/8/2013	45.7		537		36	

11.9 Annualize Post Using TMY3 Weather

There is no user interaction required for this; just select the menu item after creating the post-period models and bringing in the TMY (or other independent variable) data as per Section 11.7.

This is the same as annualizing the baseline, but it uses the models for the post period (see Table 11-5). Except for the purposes of getting savings, which is covered in the next section, this may not be widely used, but is included for completeness.

Table 11-5: Example typical annual projection of post period.

Dtyps2	DateTime	Temp	Post				Post Prediction Half-Interval
TuWeThFr	1/1/2013	34.0	547				66
TuWeThFr	1/2/2013	34.7	547				66
TuWeThFr	1/3/2013	34.9	547				65
TuWeThFr	1/4/2013	45.0	548				63
SaSuHo	1/5/2013	42.3	402				218
SaSuHo	1/6/2013	41.2	401				219
Monday	1/7/2013	40.9	547				108
TuWeThFr	1/8/2013	45.7	548				63

11.10 Annualize Pre, Post, and Savings Using TMY3

There is no user interaction required for this; just select the menu item after creating the baseline and post period models and bringing in the TMY (or other independent variable) data as per Section 11.7.

This annualizes both the baseline and the post, using the models developed for each. It then calculates the annual savings and uncertainty (Table 11-6 and Table 11-7).

Table 11-6: Example typical year projection of baseline and post by time interval.

Dtyps2	DateTime	Temp	Post	Baseline	Savings	Base Prediction Half-Interval	Post Prediction Half-Interval
TuWeThFr	1/1/2013	34.0	547	513	-35	45	66
TuWeThFr	1/2/2013	34.7	547	514	-33	45	66
TuWeThFr	1/3/2013	34.9	547	515	-33	45	65
TuWeThFr	1/4/2013	45.0	548	535	-13	37	63
SaSuHo	1/5/2013	42.3	402	351	-52	261	218
SaSuHo	1/6/2013	41.2	401	351	-50	279	219
Monday	1/7/2013	40.9	547	558	11	40	108
TuWeThFr	1/8/2013	45.7	548	537	-11	36	63

Table 11-7: Example summary of annual energy savings based on TMY3 data.

4,673,145	**Projected Baseline Energy**
4,458,961	**Projected Post Energy**
214,184	**Energy Savings**
55,874	**Projected Baseline ±Uncertainty @ 95% Confidence Level**
65,415	**Projected Post ±Uncertainty @ 95% Confidence Level**
86,029	**Projected Total ±Uncertainty @ 95% Confidence Level**
214,184 ±86,029	**Energy Savings and Uncertainty @ 95% Confidence Level**
4.6%	**Energy Savings, % of Baseline**
1.2%	**Projected Baseline ±Uncertainty @ 95% Confidence Level**
1.5%	**Projected Post ±Uncertainty @ 95% Confidence Level**
1.8%	**Projected Total ±Uncertainty @ 95% Confidence Level**
4.6% ±1.8%	**Energy Savings and Uncertainty @ 95% Confidence Level**

12.0 ECAM+ Utilities

The "ECAM Utilities" is comprised of four features that handle situations where new data is added to an existing ECAM+ workbook, data from a utility company needs to be converted to ECAM+ formatted data, bin data from temperatures needs to be created, or a worksheet needs to be copied. Figure 12-1 highlights this option in the ECAM+ menu.
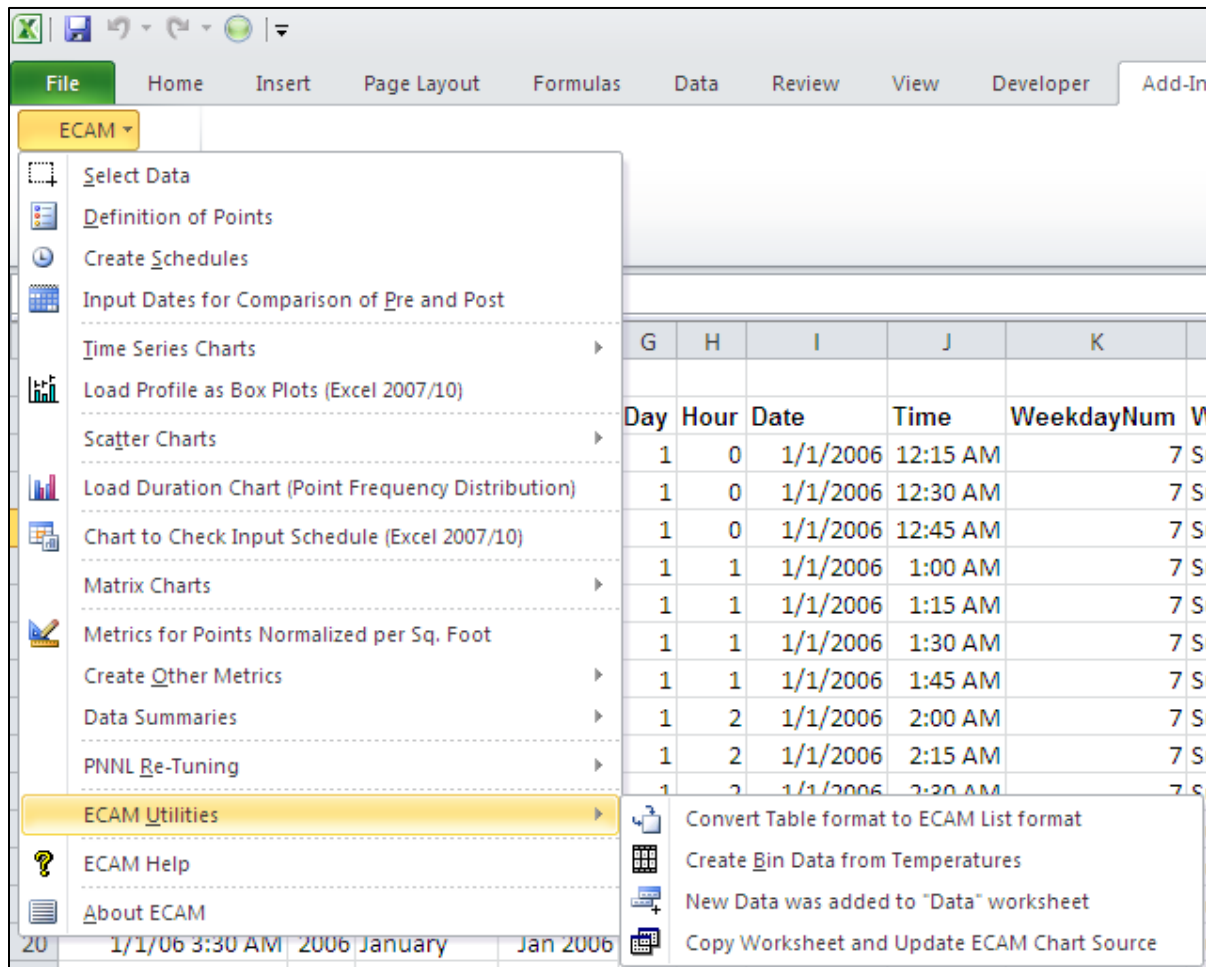
Figure 12-1: "ECAM Utilities."

12.1 Convert Table format to ECAM+ List format

This utility item in ECAM+ is for converting interval meter data received from utility companies. It is common for this data to have the time of day data in columns, and the dates down rows to the left of the data. This utility feature in ECAM+ processes the table into a list that combines the date and time into a single time stamp. Prior to using the utility, the user may need to make sure that the times are recognized as times by Excel. An example of a utility company's data can be seen in Figure 12-2. You can see that the hour of day goes across row 7 and the date goes down column A. The rest of the data is whole-building electricity

consumption. If you select this feature from the ECAM+ menu, you will be prompted to select the data to be converted. Selection of data is similar to the process described in Section 2.1. After clicking OK (after selecting the data), ECAM+ will convert the data to something similar to Figure 12-3. Now that the data has been successfully converted, the user can start with the first menu item in the ECAM+ drop-down menu, "Select Data," and then map the points and create charts.

Date	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45
4/8/08	352	352	336	336	304	320	320	320	320	320	320
4/7/08	368	368	384	368	352	352	368	352	352	368	384
4/6/08	336	352	336	336	352	320	320	320	320	288	304
4/5/08	336	352	336	336	352	304	320	320	320	320	304
4/4/08	368	384	352	352	320	320	320	336	320	320	320
4/3/08	368	384	384	384	368	368	352	352	336	352	352
4/2/08	336	336	320	320	320	320	336	320	304	320	320
4/1/08	320	336	320	320	288	288	288	304	288	288	272
3/31/08	368	352	368	336	320	320	336	336	336	320	336
3/30/08	336	352	352	352	336	320	304	320	304	304	288
3/29/08	384	368	368	320	336	336	320	320	320	320	320
3/28/08	368	336	352	352	336	336	336	352	336	352	352
3/27/08	352	352	336	352	336	336	320	320	336	336	336
3/26/08	384	400	384	336	336	320	336	352	352	352	336

Figure 12-2: Utility company data example.

Figure 12-3: Utility company data after ECAM+ has converted it.

12.2 Create Bin Data from Temperatures

This menu item is intended to be used if outdoor-air temperature data was unavailable at the onset, but was then added at a later date. When adding the temperature data to the file, make sure the time stamps for the weather match that of the ECAM+ spreadsheet. Once verified, paste the outdoor-air temperature data into a new column in the ECAM+ spreadsheet and then click on the "Create Bin Data from Temperatures." ECAM+ will bring up a window asking if ambient temperature data is included. After selecting yes, ECAM+ will prompt the user to select the column where the ambient temperature data is, and the user can click any cell in the outdoor-air temperature column. Now, ECAM+ will create bin data for temperatures, and the user should open up the "Definition of Points" feature in ECAM+ and properly map the outdoor-air temperature point.

12.3 New Data was added to "Data" Worksheet

This option in ECAM+ allows the user to add additional data to an existing ECAM+ worksheet, and the program will update to include the data when this feature is selected. If additional trend data is gathered, i.e., more time stamps or more points, it can be pasted into the "Data" worksheet in the appropriate place. This utility feature makes sure that the additional data is available to all of the features and previously-created menus and charts.

12.4 Copy Worksheet and Update ECAM+ Chart Source

It is often useful to copy a worksheet and chart so that the chart can be displayed with various filters applied using the PivotTable "PageFields." ECAM+ provides many possibilities, but a single chart is limited to one category separate from the independent and dependent variables. A built-in ECAM+ chart can show average load profiles by daytype, or average load profiles by month, but it can be useful to show load profiles by daytype for different months. This is easy to do with the PivotTable "PageFields," but it uses the same chart. The user cannot look at two different months at the same time. This utility feature of ECAM+ allows the user to do that.

To keep the chart for 1 month and create a second chart for a second month, the user needs to simply click on this feature in ECAM+ while in the chart of interest. After the copy has been made, the user can select the new month or filter of interest and re-name the sheet to identify that the two charts are comparisons of the same chart type, but for different months, etc.

Another possibility for making a copy is that the user can change the default name of the worksheet created by ECAM+, and then run the specific chart again from the menu item. Then the user could choose the filter of interest and compare the two charts. Either way works fine, but the built-in feature in ECAM+ is quicker and more efficient for making copies of charts.

It should be noted that if the user simply right clicks on the sheet and creates a copy manually, the linkage between most ECAM+ charts and PivotTables is broken. This menu item is necessary because it maintains the linkages between the charts and PivotTables.

Another note is that this utility works for most chart types, but is not necessary, and will not work properly for "Load Profiles as Box Plots." For this chart type, just copy the worksheet normally, and then click OK if any message questions pop up regarding an existing defined name.

13.0 ECAM+ Help

The ECAM+ help tool has an "ECAM+ In-tool Guidance" feature that provides users with guidance and context for all of the primary ECAM+ features. Example charts are also available to give users an idea of what the output for each of the charting functions should look like. Users can reference the "ECAM+ In-tool Guidance" feature while also working in ECAM+. In addition to the "ECAM+ In-tool Guidance," there are a series of video tutorials available at the California Commissioning Collaborative website that cover the most common ECAM+ features and functions.

In addition, a three-part webinar series was given through the Federal Energy Management Program (FEMP) and PNNL that gives an overview of ECAM+ and walkthroughs of processing data.

14.0 Known Issues and Reminders

The following list summarizes known issues of this tool:

1. Closing the "Input the Data Range" selection box using the "X" instead of the OK button will result in an error message. No other problems should result.

2. In defining the points, when first opening the form, the user needs to de-select and then re-select a choice under "Subsystems" to get the next list of "Subsystem Components" to show up.

3. Input schedules are "remembered" by the application. The schedules, however, don't show up in the "Input Schedule Information" form if the workbook is saved and re-opened.

4. In Excel 2003, the toolbar menu disappears if a chart is selected. Click on the worksheet, and the menu will reappear.

5. For most metrics and charts, number of digits displayed is not adjusted for the number of significant digits.

6. Calendar charts fail with an inapplicable message box if "Select Multiple Items" is checked for selecting "Month" or "MonthYr," even if only a single item is selected.

7. "Create 3D Load Profile," "Create Energy Colors," and "Load Profile Calendar" will all fail if a "Load Profile by Day" is not created first, and a single "Month" or "MonthYr" is selected.

The following is a list of reminders when using the tool:

- One important note regarding the automated charting; the user should not put anything in cells directly below the PivotTables.

- The name should be changed for any tool-created worksheets that you wish to save, prior to creating a related metric or chart. Otherwise the work may be lost because a new worksheet will overwrite any prior worksheet with the same name.

- Some of the filter drop-downs for metrics pages and PivotTables are redundant for certain procedures. For example, a typical metrics table shows the average value of the selected parameter(s) for the following categories: All Periods, Weekdays, Saturdays, Sundays, Occupied, and Unoccupied. The filter selections, however, include Daytype, Weekday, and Occupancy. Use of these selections will just result in an error value for the categories that filter to an empty set when using the drop-down

(e.g., selecting Weekday of "Wednesday" will result in "N.A." values for Saturday and Sunday).

- Run "Load Profile by Day," and select a single "Month" or "MonthYr" prior to creating a "3D Load Profile," "Energy Colors," or "Load Profile Calendar."