User's Guide to ECAM Version 4

Energy Charting And Metrics Version 4

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EXECUTIVE SUMMARY

ECAM facilitates the charting, summarization, and analysis of energy use and point-level data from utility meters, building automation systems, and data loggers. The intent of this user guide is to provide information on the use of the Energy Charting and Metrics (ECAM) tool, covering all of the features, including installation, use, guidance, and limitations.

ECAM is a powerful tool for analysis of energy data. While it is not difficult to use the tool, meaningful analysis often requires knowledge of engineering and Measurement and Verification (M&V) principles. Familiarity with modeling and energy efficiency projects are helpful. This document is intended to walk a user through the process of using the ECAM tool for data analysis, but it will not create expert users. It does not (and cannot) delineate every single concept required to do this analysis; common sense and judgment are also necessary for any successful analysis. And, of course, no guide can replace experience.

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 M&V capability per the International Performance Measurement and Verification Protocol (IPMVP) and ASHRAE Guideline 14, *Verification of Energy, Demand, and Water Savings*.

This document describes how to use the extensive M&V capabilities, the types of models available, and how ECAM supports the IPMVP savings types—avoided energy use and normalized savings. The use of related features supporting Strategic Energy Management and Monitoring and Targeting is also explained. These features have a high degree of automation and make ongoing tracking of performance quite easy.

This document also 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 data to derive useful and actionable information.

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INTRODUCTION

The Energy Charting and Metrics (ECAM) tool is intended to facilitate the examination of the utility interval data and the trend data from the building automation system (BAS). The general intent is to maximize the user's ability to benefit from whatever data is available. Key features include the following:

- Pre-processing of data to attach schedule and day-type information to time-series data;
- Filtering by day-type, occupancy schedule, 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;
- Automated creation of the diagnostic charts supporting the DOE-funded PNNL building Re-tuning process; and
- Change point energy models and Measurement and Verification (M&V) capability, based on IPMVP and on ASHRAE Guideline 14, *Measurement of Energy and Demand Savings*.

The tool takes advantage of earlier research by using the naming convention and many of the metrics recommended by *A Specifications Guide for Performance Monitoring Systems*. It 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 chart types in ECAM include the following:

- Time series
- X-Y (scatter)
- Daily load profile
- 3D and heat map charts of daily load profiles
- Calendar (chart of daily load profiles laid out as a calendar)
- 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

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 in a series of charts (both time series and scatter) to analyze air-handler, zone, and central plant information gathered using a BAS.

1.0 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.

Most ECAM features require 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 timestamps, but if there are multiple points from the BAS, all with different timestamps, then some pre-processing must be done. ECAM has extensive capabilities to pre-process data to common timestamps. There can be separate handling of power and energy data, and of interval and change-of-value data.

Another tool designed to assist and automate such pre-processing is the Universal Translator (UT), available at www.utonline.org. The UT has many other features that make it valuable for analysis of data from buildings. There are overlaps between the UT and ECAM capabilities, but the tools can be considered complementary.

1.1 Installation

ECAM is an Excel Add-In. First, download the add-in file, and save the tool file in your chosen location. Please note that Microsoft Add-Ins is 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:

1.1.1 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. An ECAM menu will be available under the Add-Ins menu.

1.1.2 Excel 2013/2016

A "single document interface" was introduced in Excel 2013. This caused some changes in the treatment of Add-ins and the ECAM installation behavior. Installation is similar to Excel 2010, but you will need to close Excel all the way, and then re-open Excel, for the ECAM menu to display.

1.2 Using the Tool to Create Metrics and Charts

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

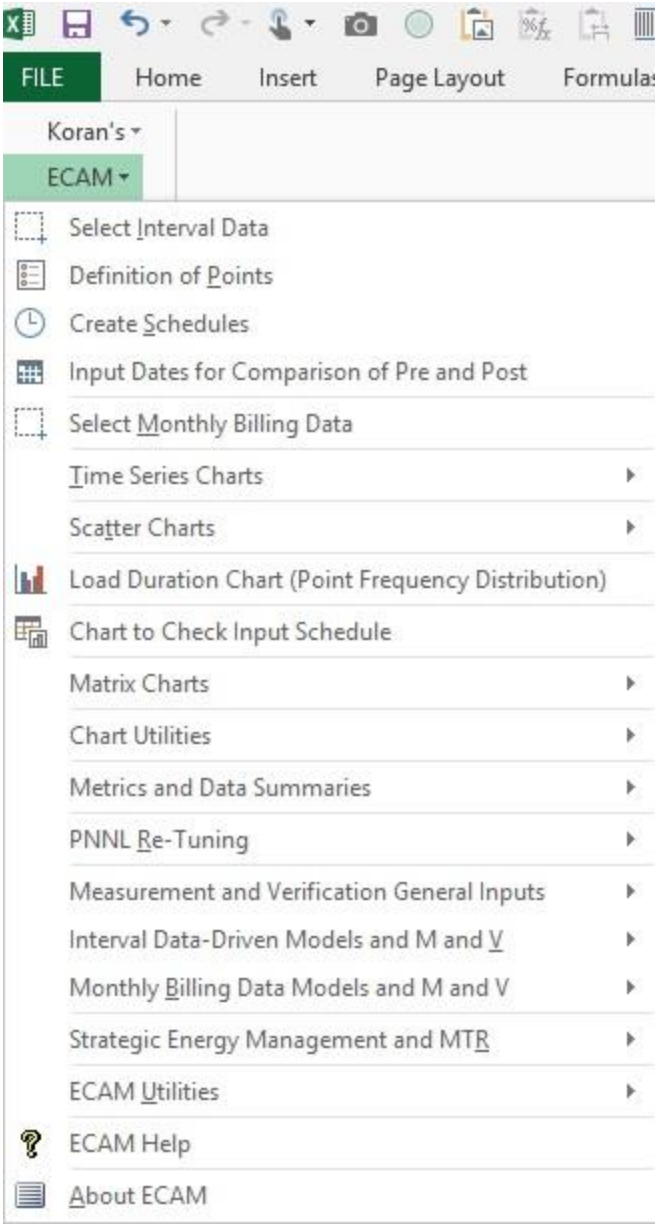


Figure 1: ECAM top-level items

The first four items in the menu should be used in order, but all four items aren't required to be used 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**—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" 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, though 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, since 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.

1.2.1 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.

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 timestamps. The capabilities to “resample” data to a single set of uniform interval timestamps are covered later in this document under “ECAM Utilities.” This section assumes that you already have data with uniform timestamps.

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 Interval 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 timestamps until the data are continuous.

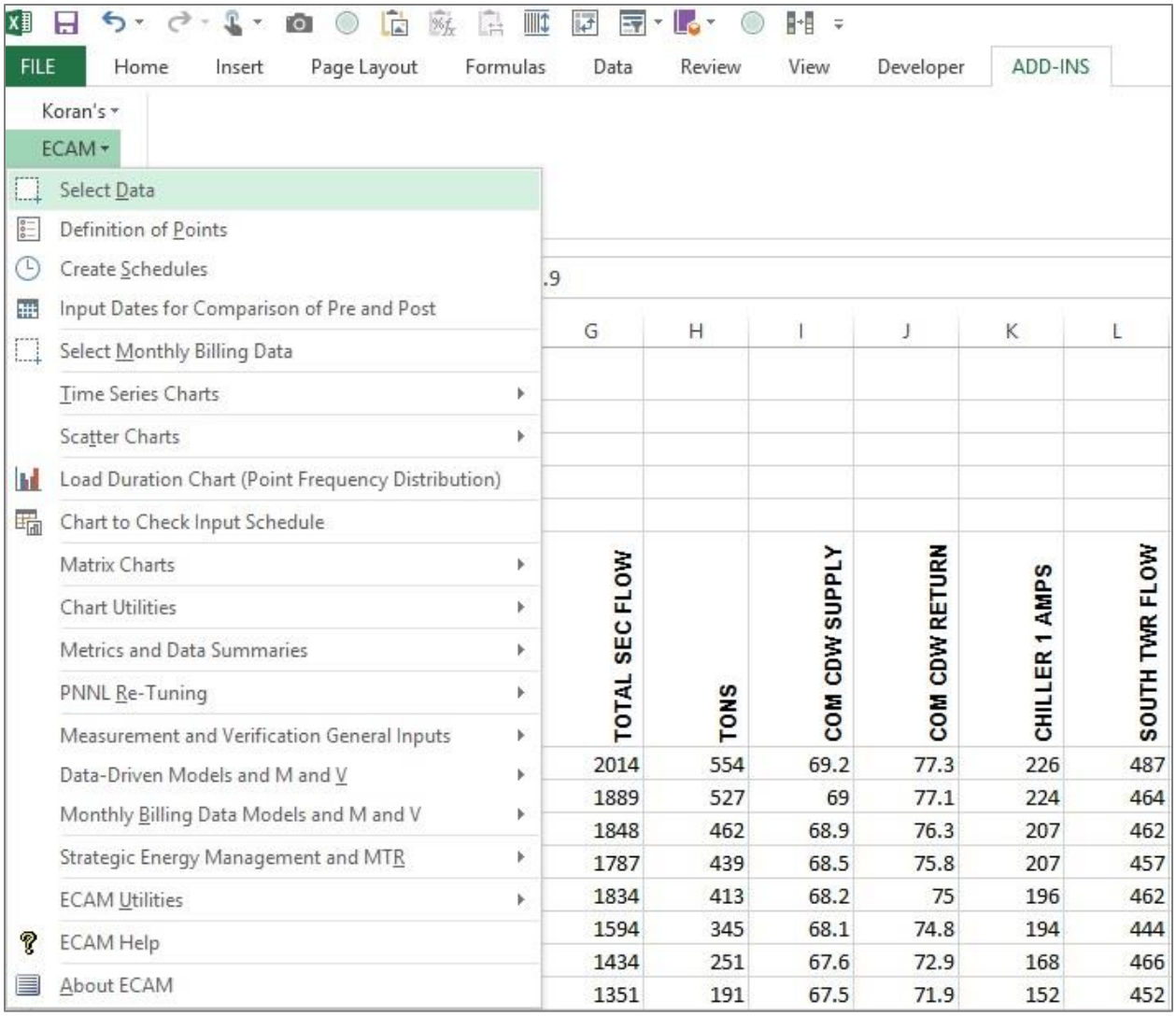


Figure 2: Select Data from the Raw Data Sheet

Below is a "*.csv" raw data file, ready for the following steps:

Step 1: Choose "Select Data" from the ECAM menu

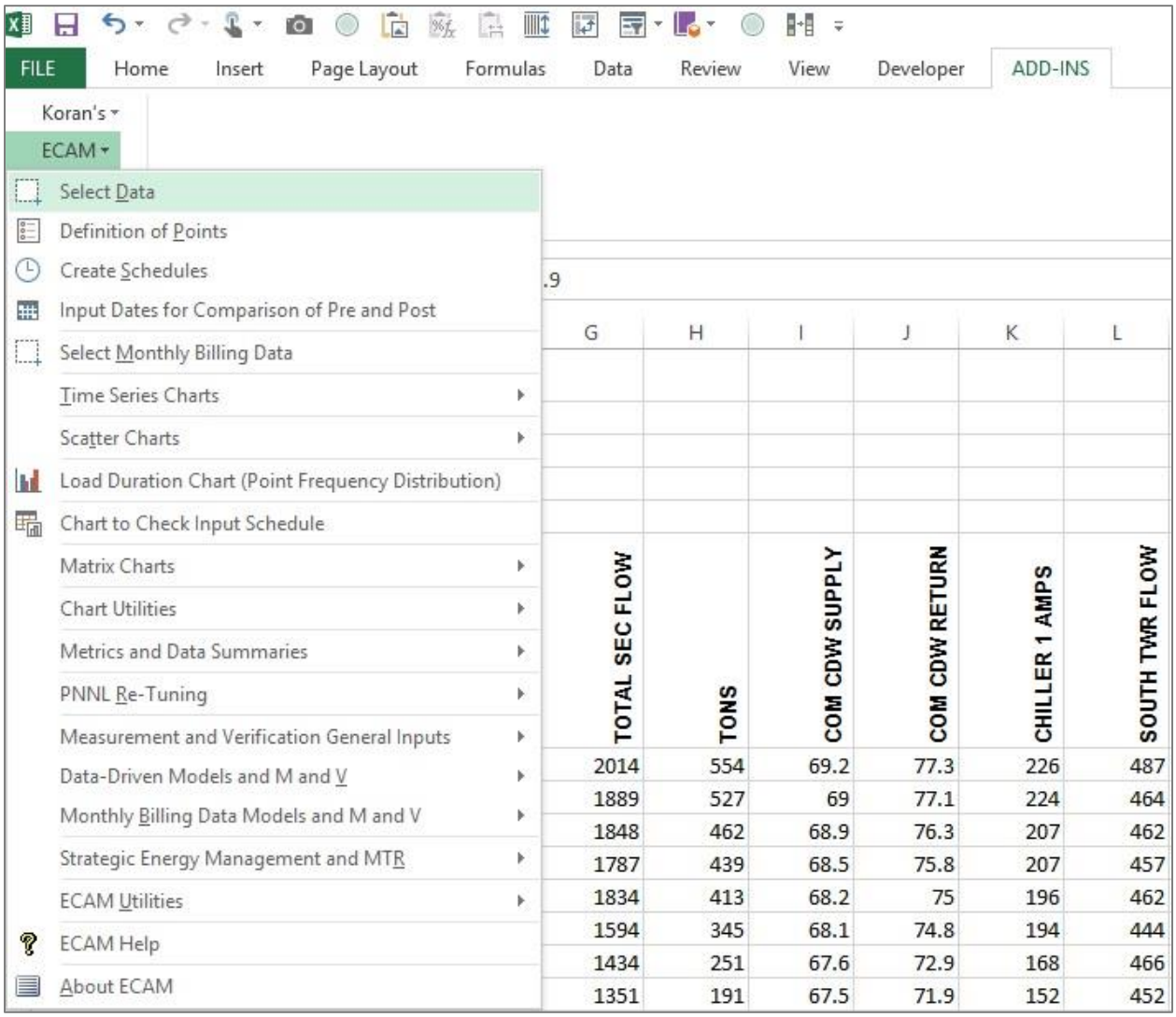


Figure 2: Select Data from the Raw Data Sheet

After choosing "Select Data," ECAM will bring up a window that asks if the timestamp is in one column or two columns (Figure 3). 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 timestamp, ECAM only will recognize the date in the first and time in the second.

Step 2: Select the correct timestamp format

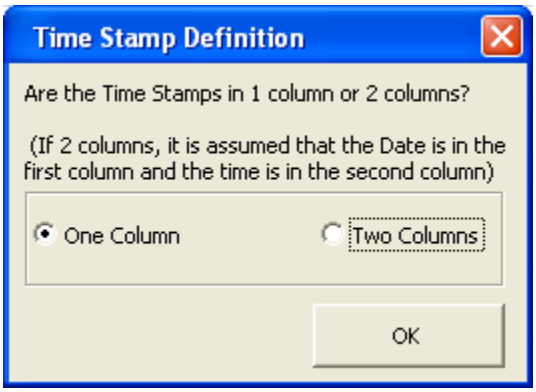


Figure 3: ECAM's timestamp definition window

After selecting the appropriate timestamp definition from Figure 3, ECAM will then ask you to select the range of cells that contains the data (Figure 4 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 contiguous data.
- Click "OK."

Step 3: Select the range of cells that contain the data

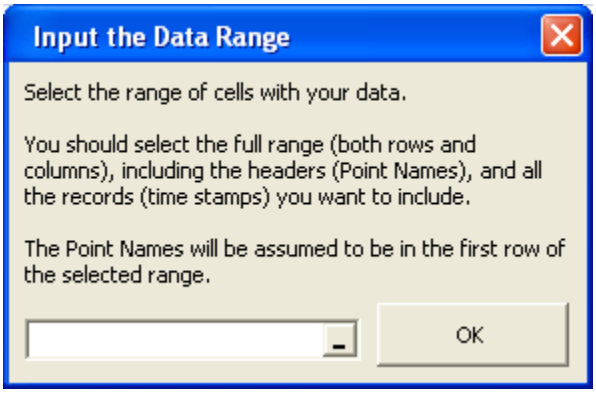


Figure 4: Selecting the range of cells that contain data in ECAM

If there are timestamps 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 mouse key while dragging the mouse to the desired cell. You can also manually type the data range of interest into the field in Figure 4.

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 process it into bins (Figure 5). If it is not included, select “No.”

Step 4: Select whether ambient temperature data is included

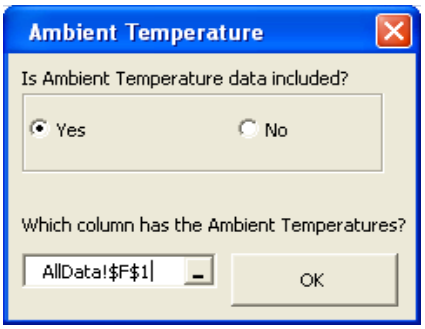
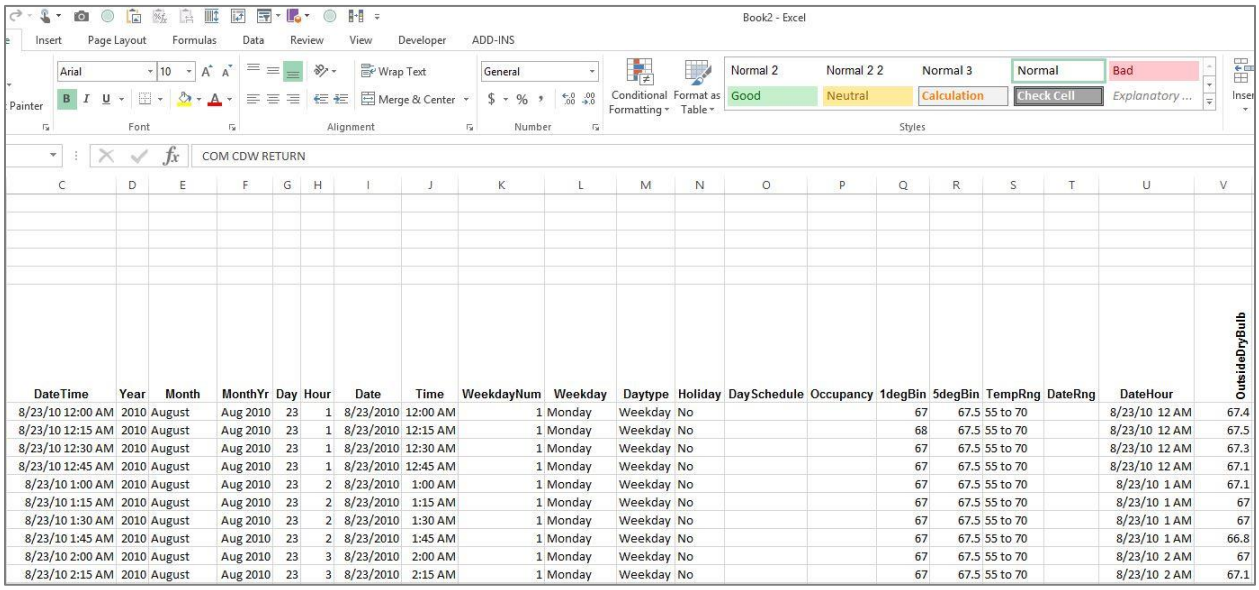


Figure 5: Selecting if the ambient temperature data is included in ECAM

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 6 below).



DateTime	Year	Month	MonthYr	Day	Hour	Date	Time	WeekdayNum	Weekday	Daytype	Holiday	DaySchedule	Occupancy	1degBin	5degBin	TempRng	DateRng	DateHour	OutsideDryBulb
8/23/10 12:00 AM	2010	August	Aug 2010	23	1	8/23/2010	12:00 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 12 AM	67.4
8/23/10 12:15 AM	2010	August	Aug 2010	23	1	8/23/2010	12:15 AM	1	Monday	Weekday	No			68	67.5	55 to 70		8/23/10 12 AM	67.5
8/23/10 12:30 AM	2010	August	Aug 2010	23	1	8/23/2010	12:30 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 12 AM	67.3
8/23/10 12:45 AM	2010	August	Aug 2010	23	1	8/23/2010	12:45 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 12 AM	67.1
8/23/10 1:00 AM	2010	August	Aug 2010	23	2	8/23/2010	1:00 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 1 AM	67.1
8/23/10 1:15 AM	2010	August	Aug 2010	23	2	8/23/2010	1:15 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 1 AM	67
8/23/10 1:30 AM	2010	August	Aug 2010	23	2	8/23/2010	1:30 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 1 AM	67
8/23/10 1:45 AM	2010	August	Aug 2010	23	2	8/23/2010	1:45 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 1 AM	66.8
8/23/10 2:00 AM	2010	August	Aug 2010	23	3	8/23/2010	2:00 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 2 AM	67
8/23/10 2:15 AM	2010	August	Aug 2010	23	3	8/23/2010	2:15 AM	1	Monday	Weekday	No			67	67.5	55 to 70		8/23/10 2 AM	67.1

Figure 6: 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 dropdown menu are executed (“Create Schedules” and “Input Date Ranges for Comparison of Pre and Post”). These are not required, but allow more charts to be generated, which will be discussed later. You can see that ECAM defaults the workbook to start in cell “C6.” This allows the user to create calculations separate from ECAM in the cells above or to the left of cell “C6.” All other raw data will appear to the right of column U.

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 3-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" (Figure 7).

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

Step 2: Input the building area and voltage for 3-phase equipment (if known).

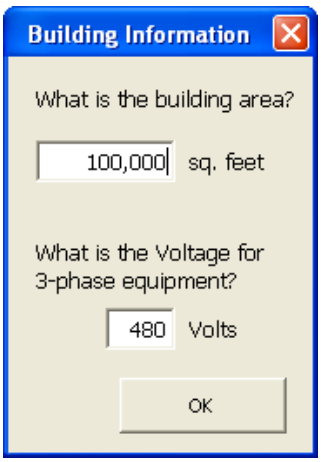


Figure 7: Entering building information after selection the "Definition of Points" menu item

After selecting "OK," a new window will come up where the user defines or "maps" the points (See Figure 8 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.

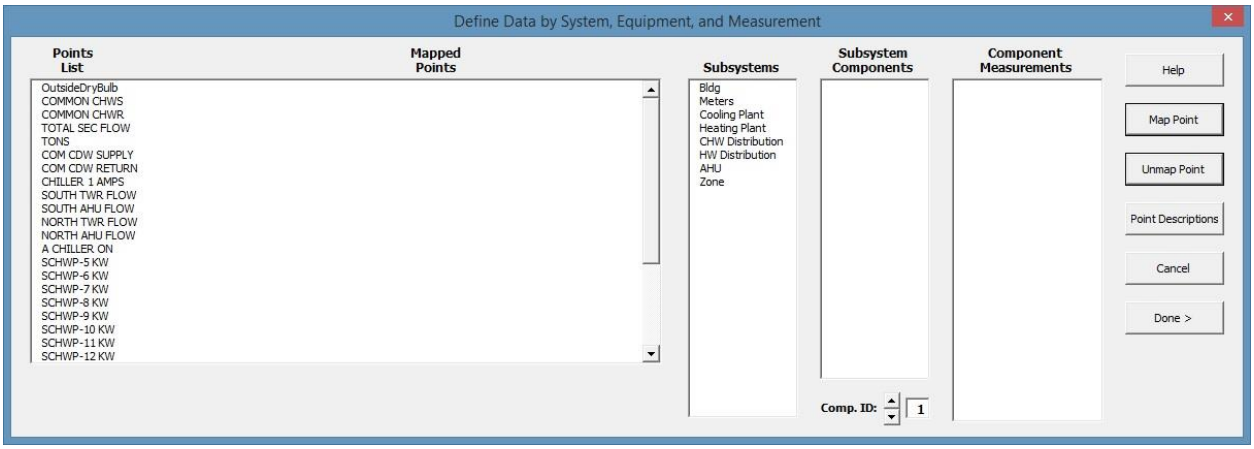


Figure 8: ECAM's Definition of Points form

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 is defaulted to refresh the "Subsystem Components" window (See

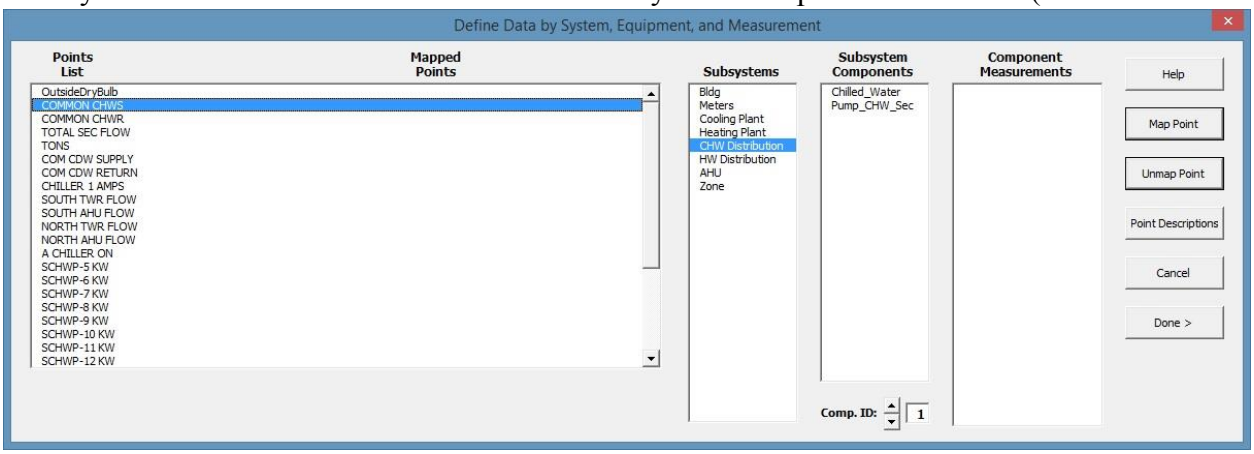


Figure 9 below). Each "Subsystem" in ECAM will have specific "Subsystem Components" and "Component Measurements" that belong to the "Subsystem." The tool point names are based on the naming convention in *A Specifications Guide for Performance Monitoring Systems*.

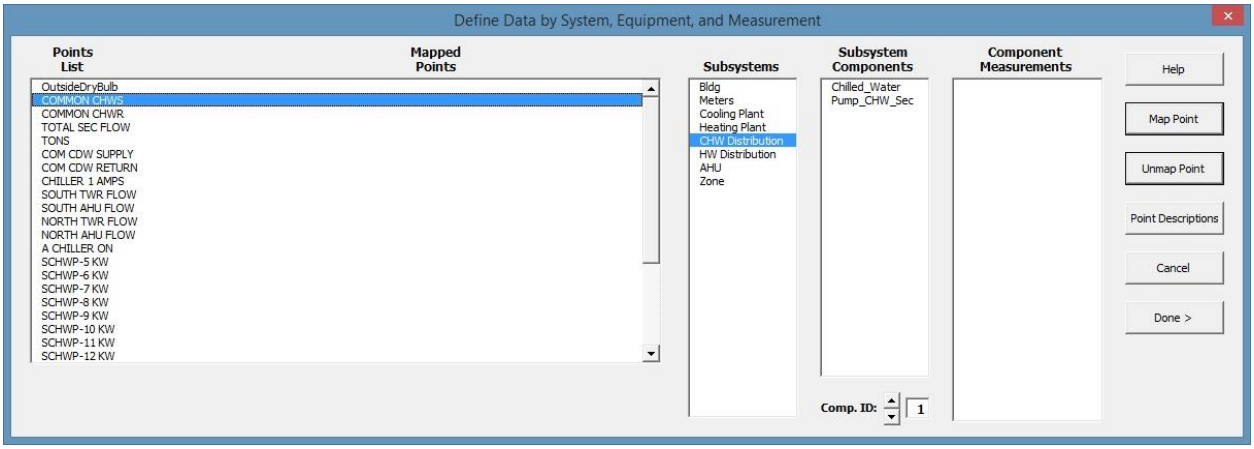


Figure 9: Refreshing the "Subsystems" to bring up the proper Subsystem Components

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 the "Bldg Subsystem." First, find and click on the outdoor-air temperature in the "Points List" (In this case, it is OutsideDryBulb, but could be something different from your BAS system). Then, 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

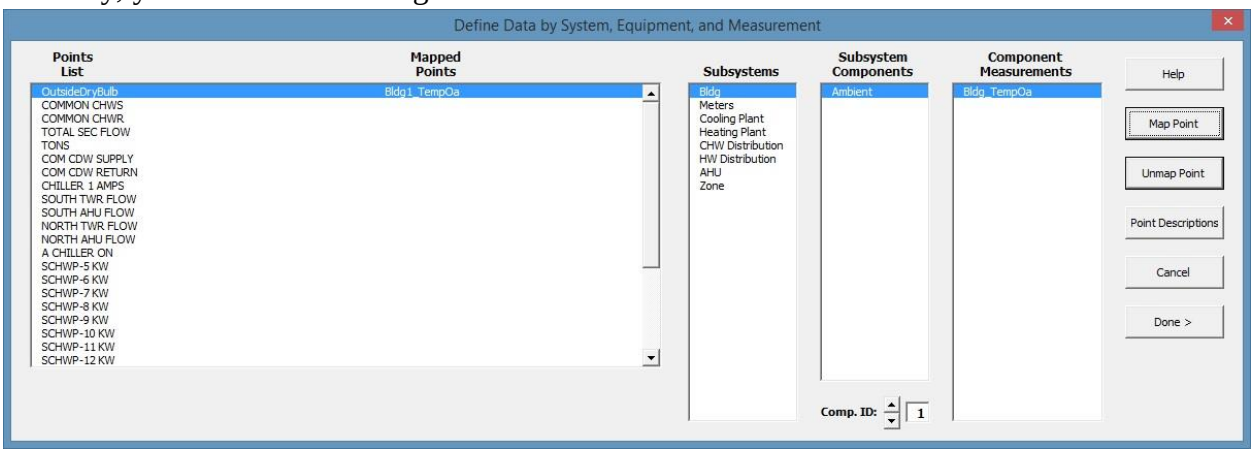


Figure 10, where the Mapped Points now has "Bldg1_TempOa."

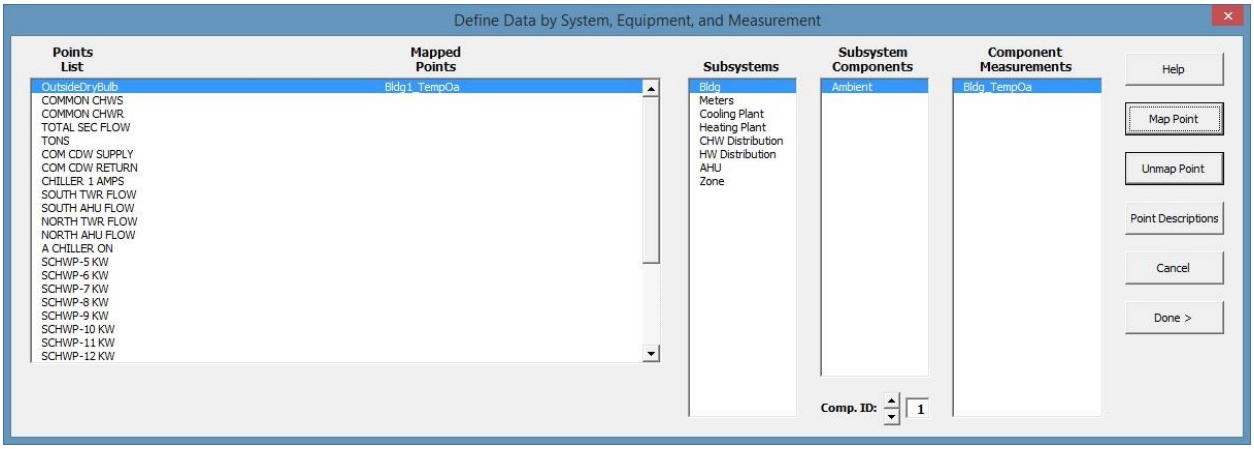


Figure 10: "Definition of Points" window after "mapping" the outdoor-air temperature

This approach should be used for each applicable point in the "Points List." If there are points that you do not want to map, then simply omit them. Any number of points can be mapped at one given time, and modified later to include other plots. ECAM also has the ability to map more than one AHU, zone, or chiller/boiler at a time. This is done by using the "Comp.ID" feature at the bottom of

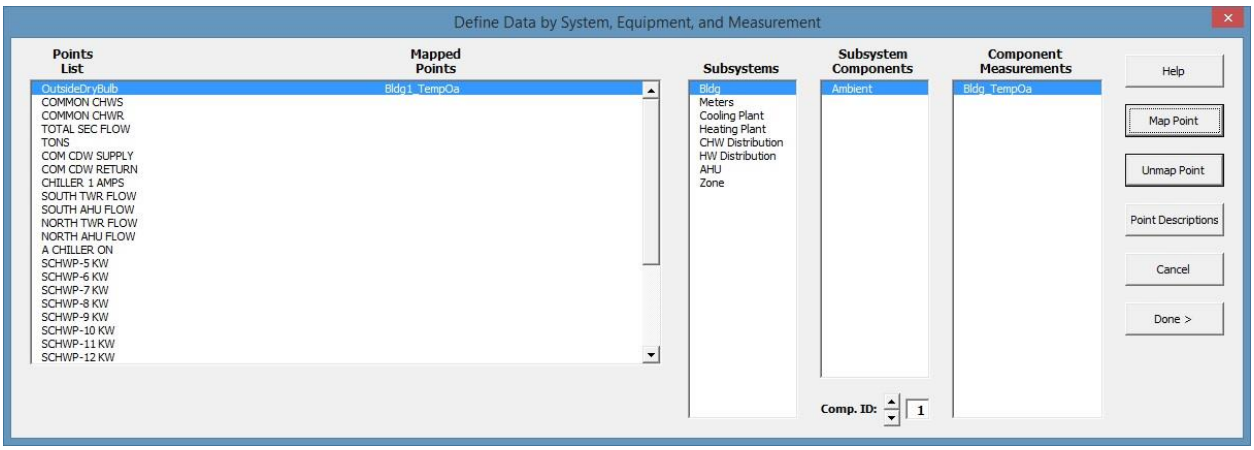


Figure 10. It is defaulted to "1", or the first "Subsystem Component." That is why a "1" appears in all "Mapped Point" names. However, if you have 6 AHUs and want to map all of them, then you would increase the "Comp.ID" for each air-handler. The corresponding "Comp.ID" number will then appear in the "Mapped Points" name.

Once all points have been mapped, some normalized and calculated points will be created and added to the points list automatically in the new workbook (these will be additional columns that 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 are available, the cooling capacity (tons) of that chiller or chilled water loop will be calculated.

Table 1 below offers a detailed list of the additional points created by ECAM.

Table 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, Tin, Tout	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, as there are some powerful metrics and scatter plots in ECAM that can show a comparison of occupied and unoccupied electricity consumption. However, if no schedule is input, then 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 11 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 3 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 in the future. The "Main Occupancy" should be specified to match that of the building occupancy for each daytype (Mon-Fri, etc.). The "Typical Startup/Shutdown" 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 11 shows what the window may look like filled in for the scenario described above.

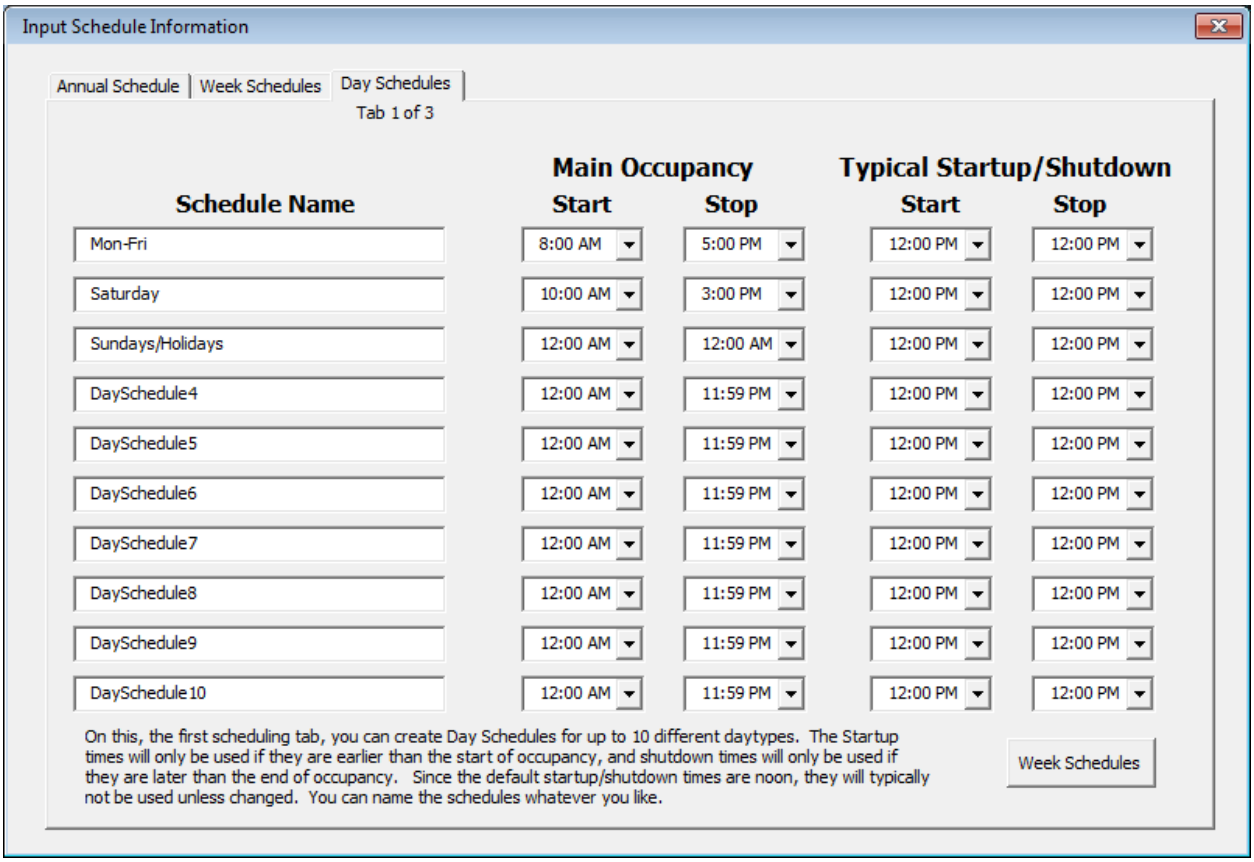


Figure 11: First window for inputting the building schedule information

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 have 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 schedule 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 12). 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 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 13 below).

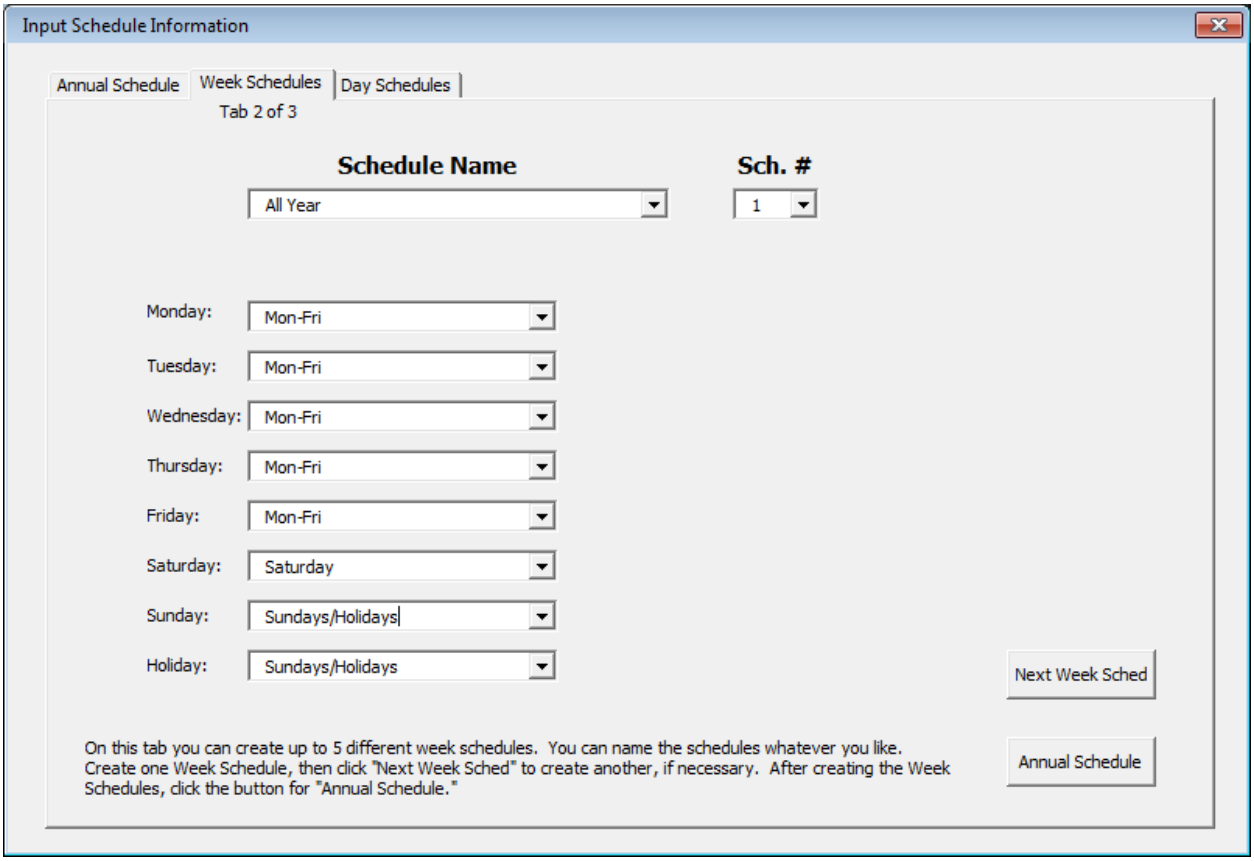


Figure 12: Inputting week schedules in the scheduling option for ECAM

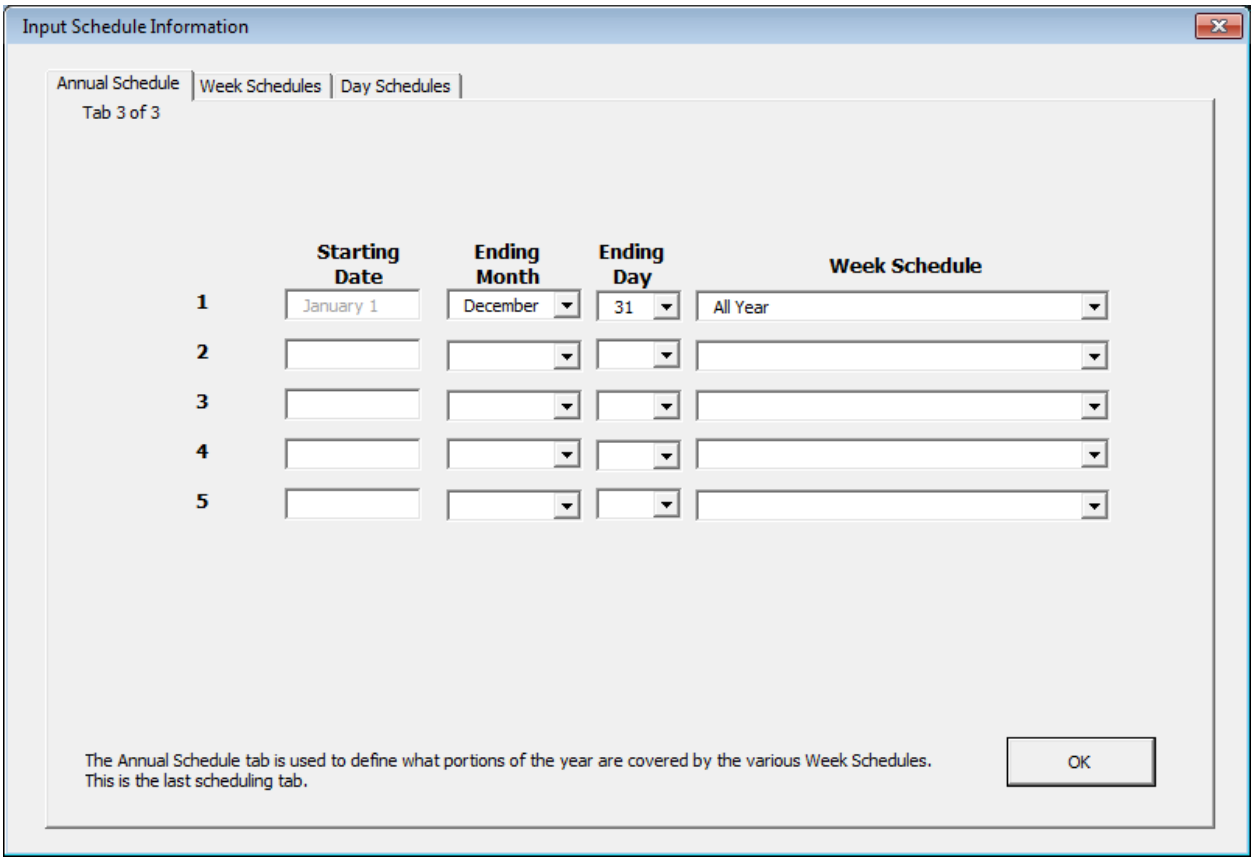
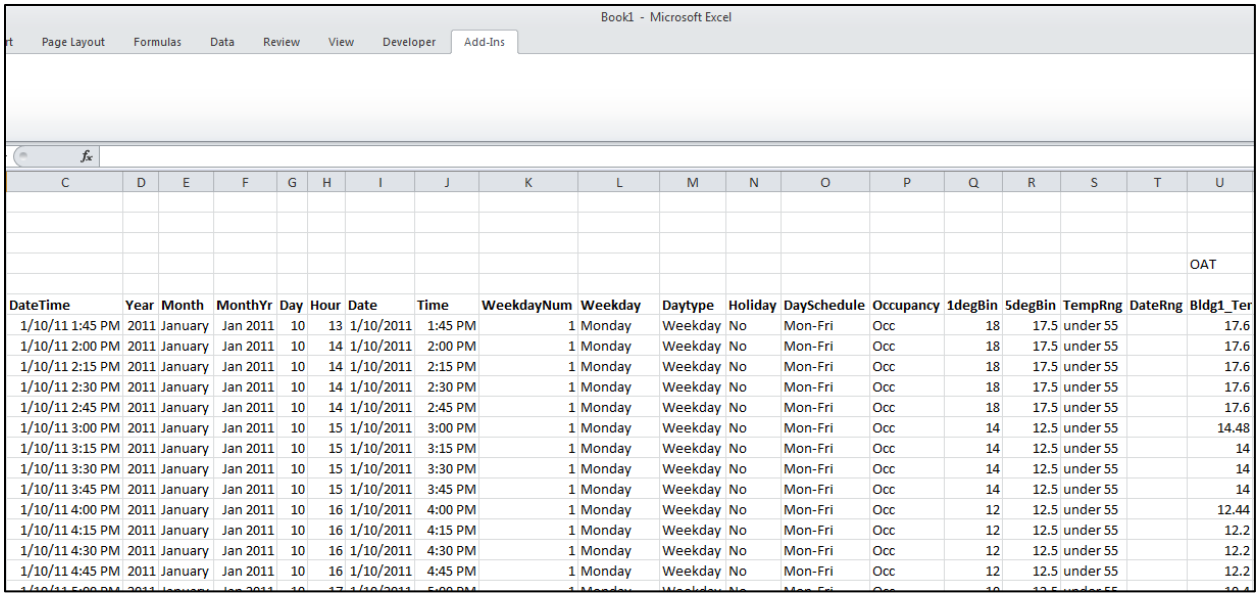


Figure 13: Inputting annual schedules in ECAM

After selecting "OK," we will see the updated workbook with the schedule input. Comparing to Figure 14 below, the user will now see that the "DaySchedule" and "Occupancy" columns are filled in based on their building's schedule that they input.



Book1 - Microsoft Excel

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C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
																		OAT
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 14: 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. You can enter the following dates relevant to an energy project. These dates define various time periods for analysis. ECAM will then have information in filled in under the column "DateRng" in Figure 14 to use for categorization and filtering of the data.

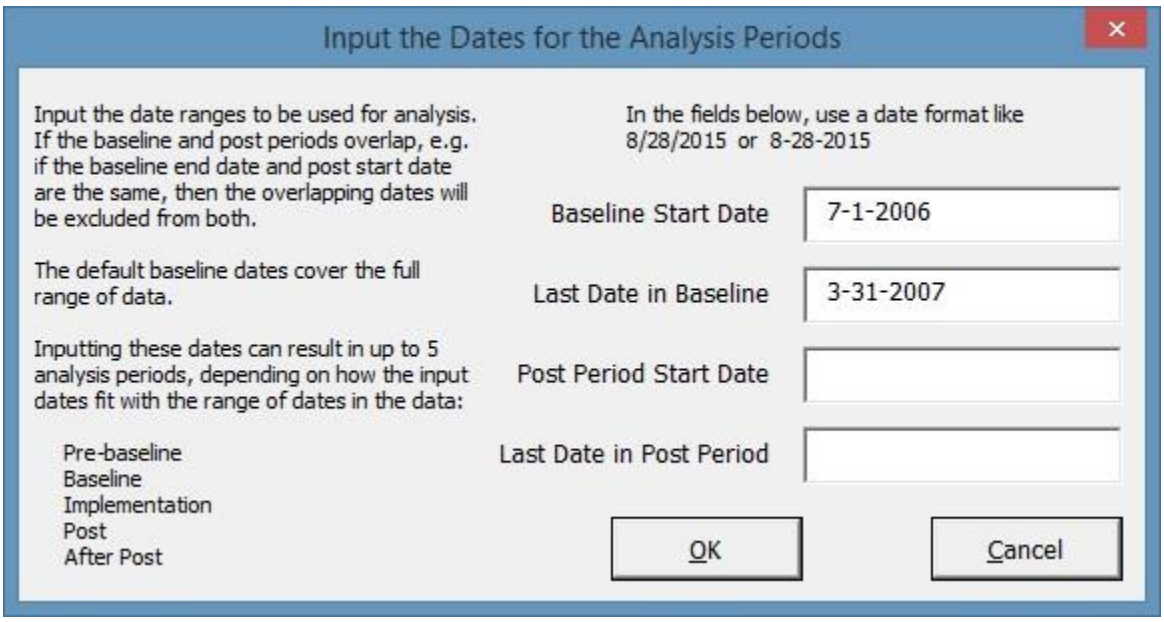


Figure 15: The Form for Entering Dates to Define Analysis Periods

The form defaults to the baseline starting with the first date in the dataset, and baseline ending with the last date in the dataset. Either of these dates can be changed. If the "Last Date in Baseline" is changed to an earlier time, then the "Post Period Start Date" will default to the first date after the end of the baseline period, and the "Last Date in Post Period" will default to the last date in the dataset.

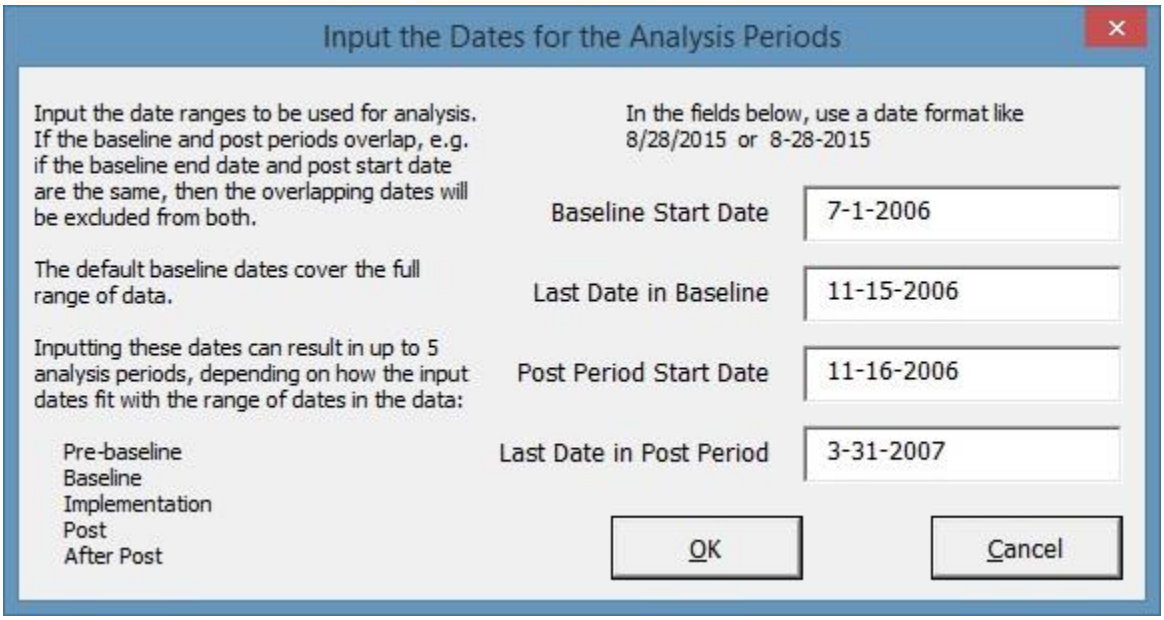


Figure 16: The Form for Entering Dates After Changing "Last Date in Baseline."

As noted on the form, inputting up to four dates allows the definition of up to five analysis periods. For distinguishing between Pre and Post time periods, the ECAM uses the following keywords in the DateRng column of the "Data" worksheet.

- Pre-Baseline
- Baseline
- During Changes
- Post Period
- After Post Period

You can also directly input these keywords into the DateRng column, and then run the ECAM Utility for "'Data' Worksheet was Changed" as described in Section **Error! Reference source ot found.**.

2.5 Select Monthly Billing Data

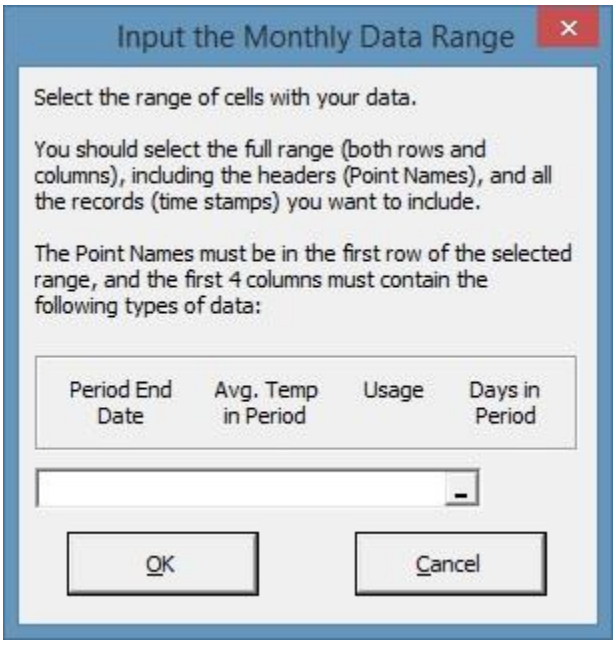


Figure 17: The Form for Selecting Monthly Billing Data

This menu item must be used if the data set has monthly billing data. Billing periods can be a varying number of days, so monthly billing data is not at even intervals. Therefore, it requires special treatment. Monthly billing data is usually used only for creating energy models, although other uses are possible.

The billing data must be organized as shown in the form:

Billing Period End Date	Avg Temp in Billing Period	Energy Use, kWh	Days in Billing Period
12/12/2009	39.6	369,206	33
1/13/2010	44.2	497,978	32
2/15/2010	48.1	376,262	33
3/11/2010	48.2	226,322	24
4/13/2010	48.8	388,610	33

Figure 18: Organization of Monthly Billing Data

ECAM will automatically calculate the energy use per day in each billing period.

To get the average temperature in the billing period, the utility described in Section 13.2 Resample to Get Avg Temp for Billing Data is used.

3.0 Menu Items to Create Time Series Charts

The first four drop down menu items in ECAM are to 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 19). 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 briefly describes each chart. Additional information on how to create and analyze these charts is available in "Interval Data Analysis with the Energy Charting and Metrics Tool (ECAM)" available at http://sbwconsulting.com/index.php/component/content/article/93-tools/133-ecam.

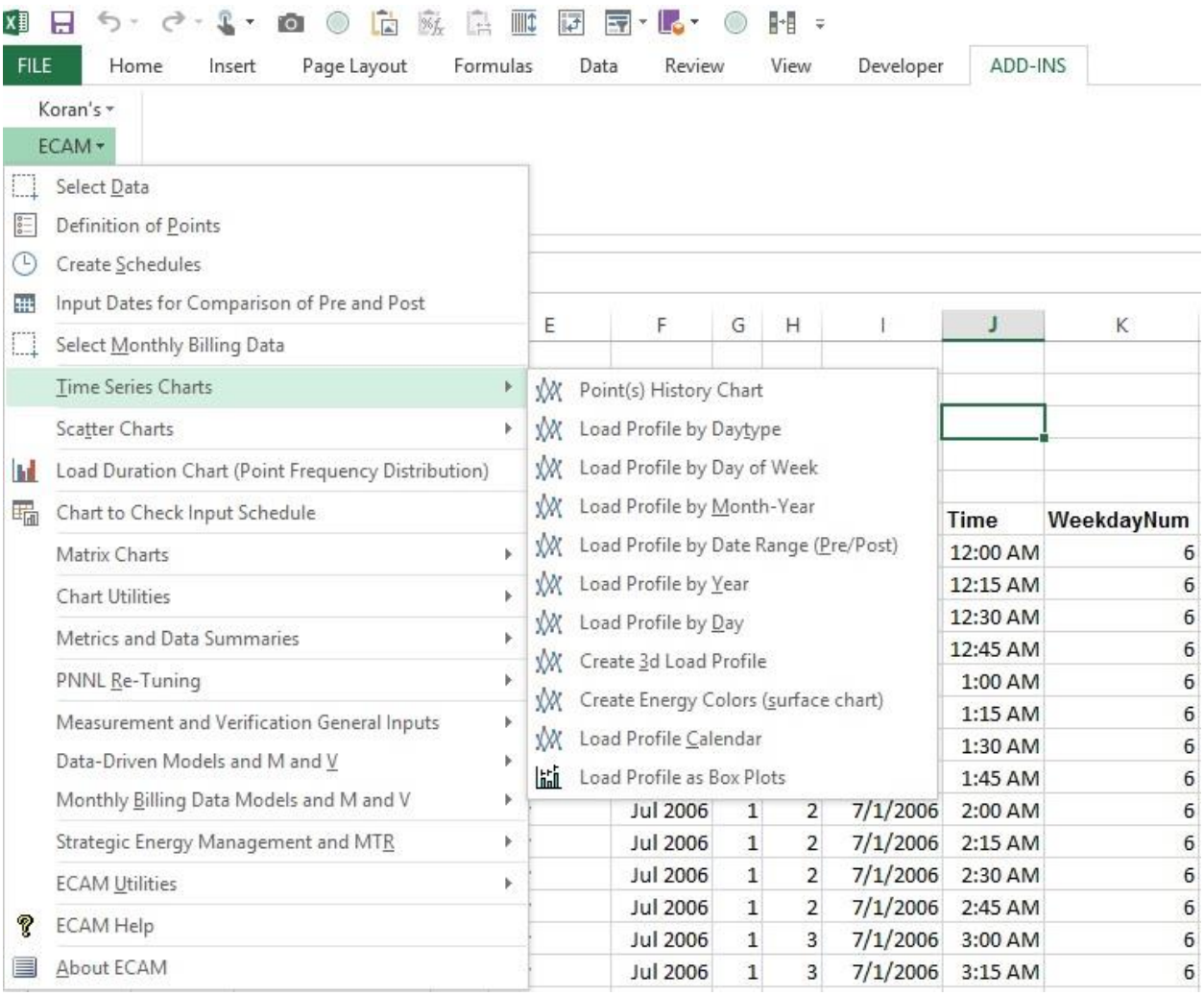


Figure 19: Time series charts in ECAM

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 timestamps 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 20 below. For this chart, you can choose any point(s) of interest, and the key in choosing the data is that you have to only click on the header of the column and then click "OK." In Figure 21 below, the most recent whole building consumption data is shown; up to the maximum number of timestamps (at least 32,000 timestamps can always be shown regardless of the version of Excel).

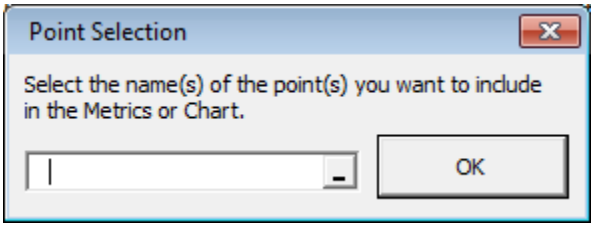


Figure 20: Point selection for time series charts in ECAM

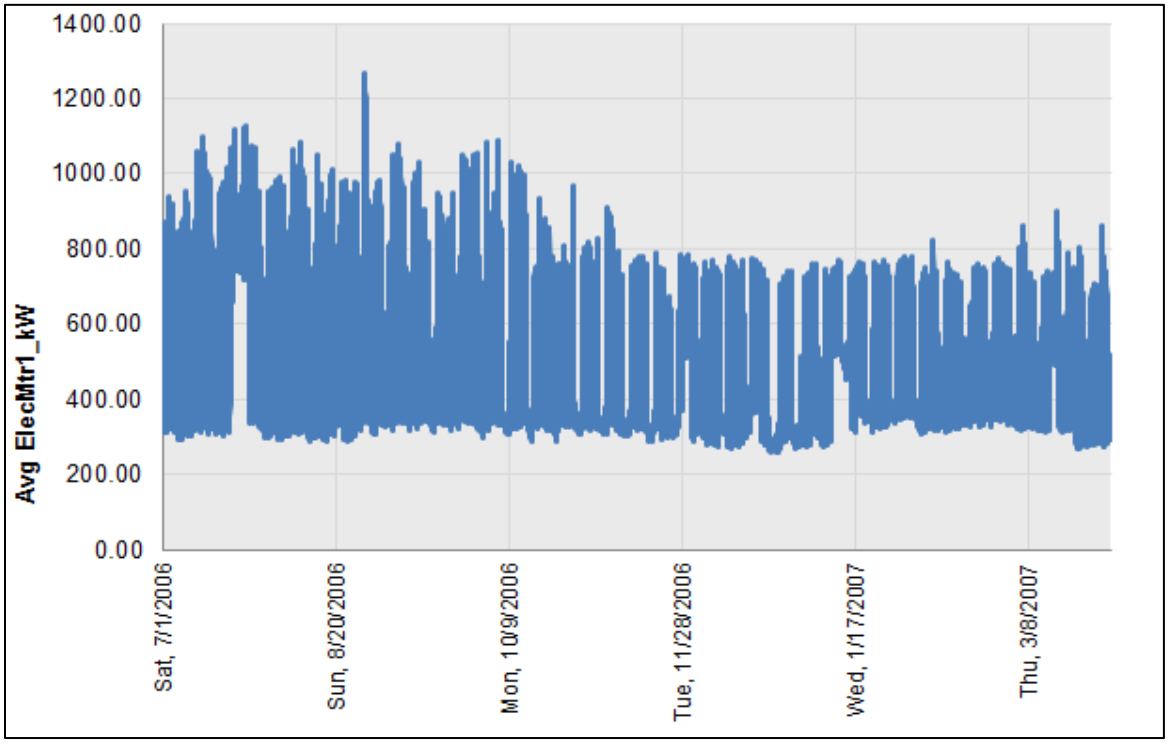


Figure 21: Whole building consumption point history chart in ECAM

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 22 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 21 shows the results.

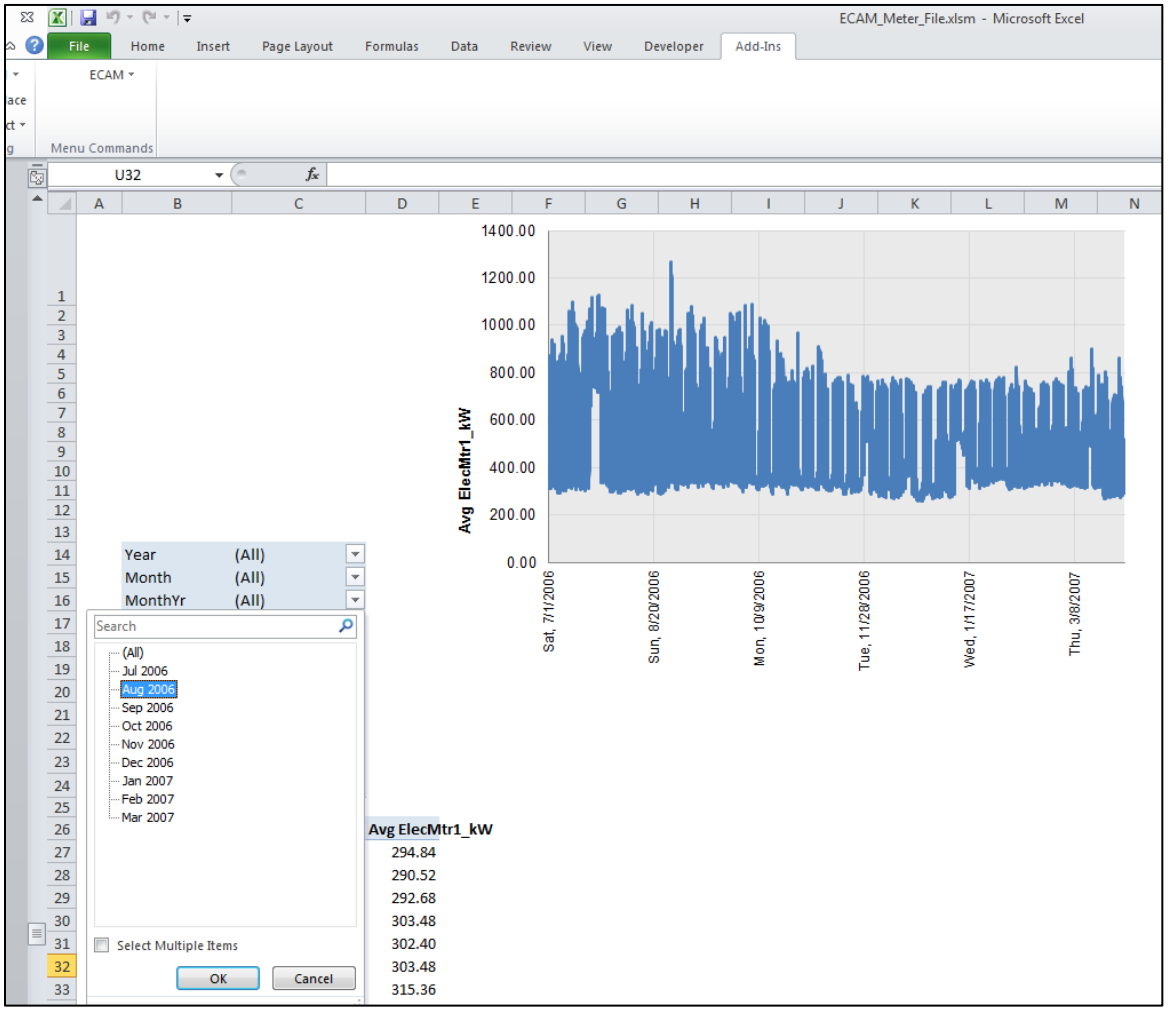


Figure 22: Using the PivotTable functions in ECAM

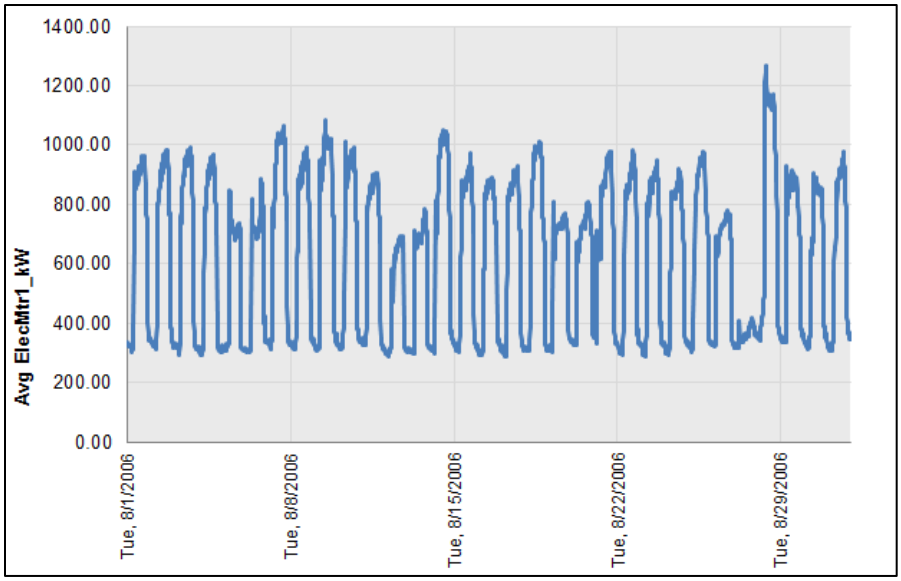


Figure 23: Point history chart for only one month of data

The user can go even further, and dial down to a group of days within the month, or one day specifically, by clicking on the drop down menu under "Day" and selecting one day or multiple days. To select multiple days, click the "Select Multiple Items" box at the bottom of the drop down, and then choose the days of interest. Figure 24 shows a 3-day period in May.

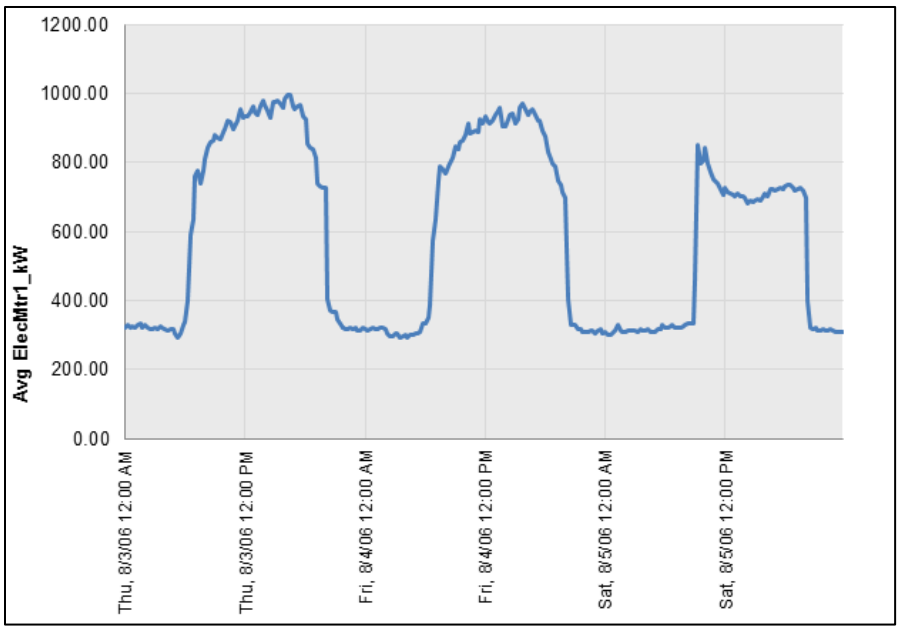


Figure 24: Point history chart for a 3-day period on May

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 what is described at the beginning of Section 3.1 for the Point(s) History Chart. Figure 25 shows a typical "Load Profile by Daytype" chart.

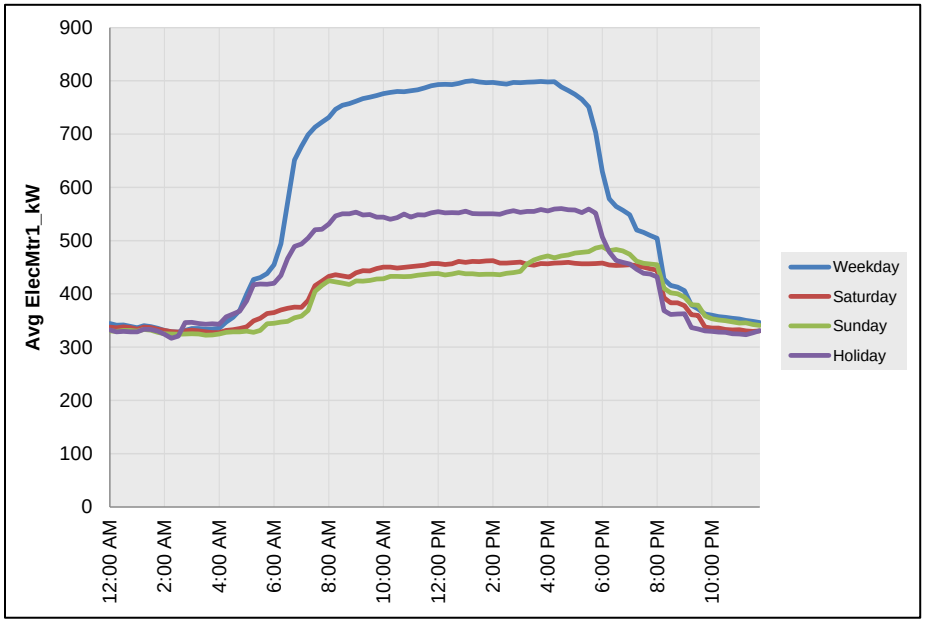


Figure 25: Load profile by daytype time series chart in ECAM

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 26 shows a typical "Load Profile by Month Year" chart.

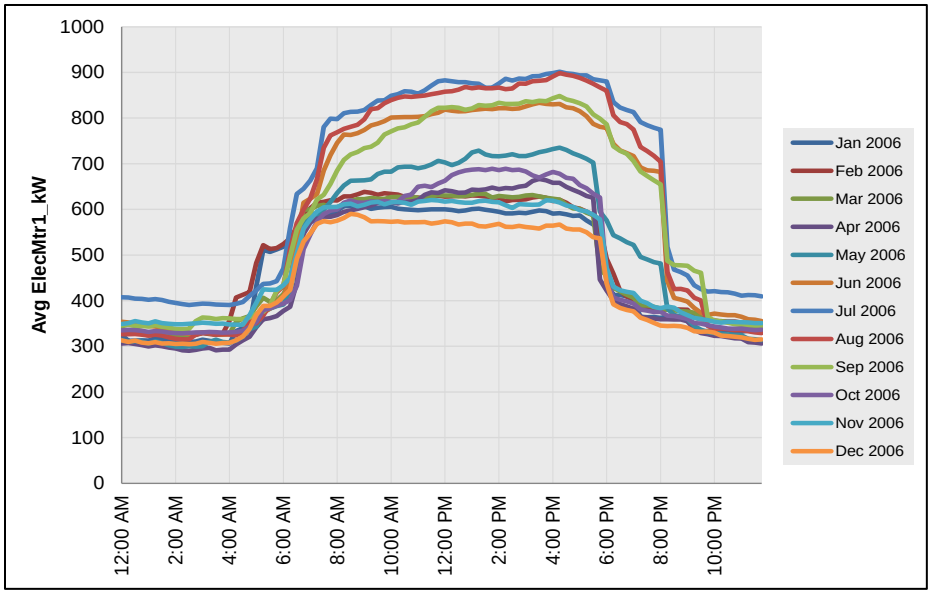


Figure 26: Load profile by month-year time series chart in ECAM

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 27 below shows an example of this chart.

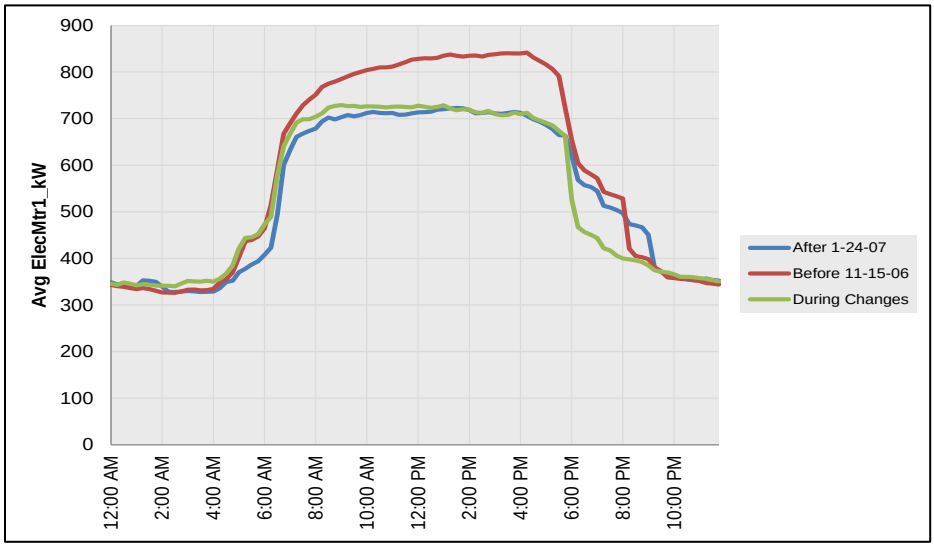


Figure 27: Load profile by date range (pre/post) time series chart in ECAM

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 in Figure 28.

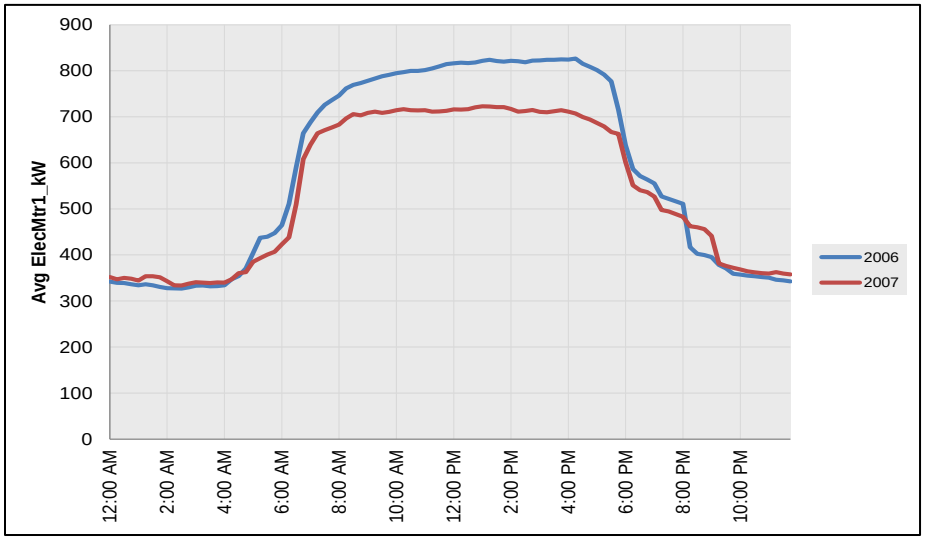


Figure 28: Load profile by year time series chart in ECAM

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 29 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.

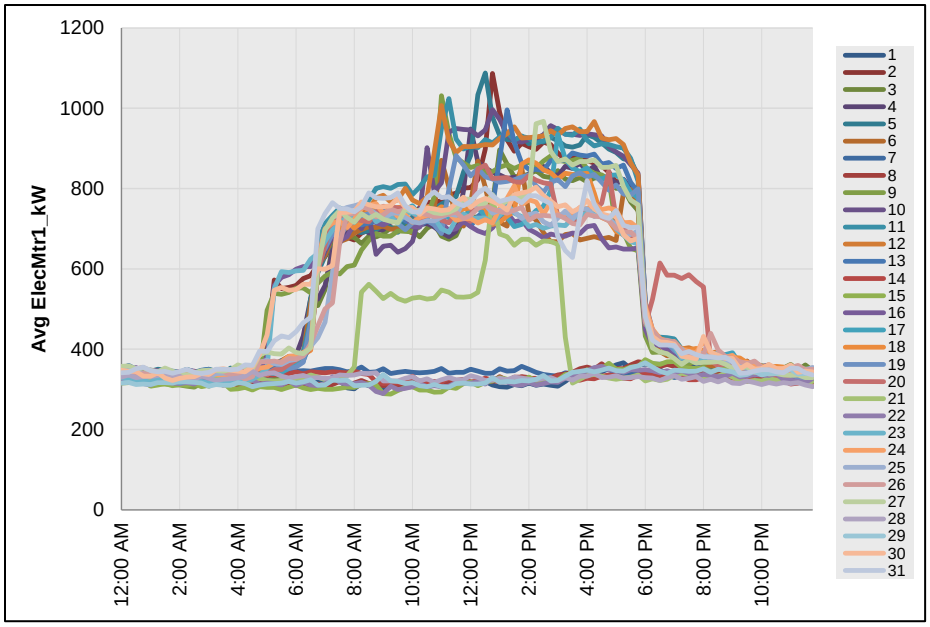


Figure 29: Load profile by day time series chart in ECAM for one month

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 3d chart, with the Weekdays and Weekends separated by color. See Figure 30 below for a typical "3d Load Profile" chart.

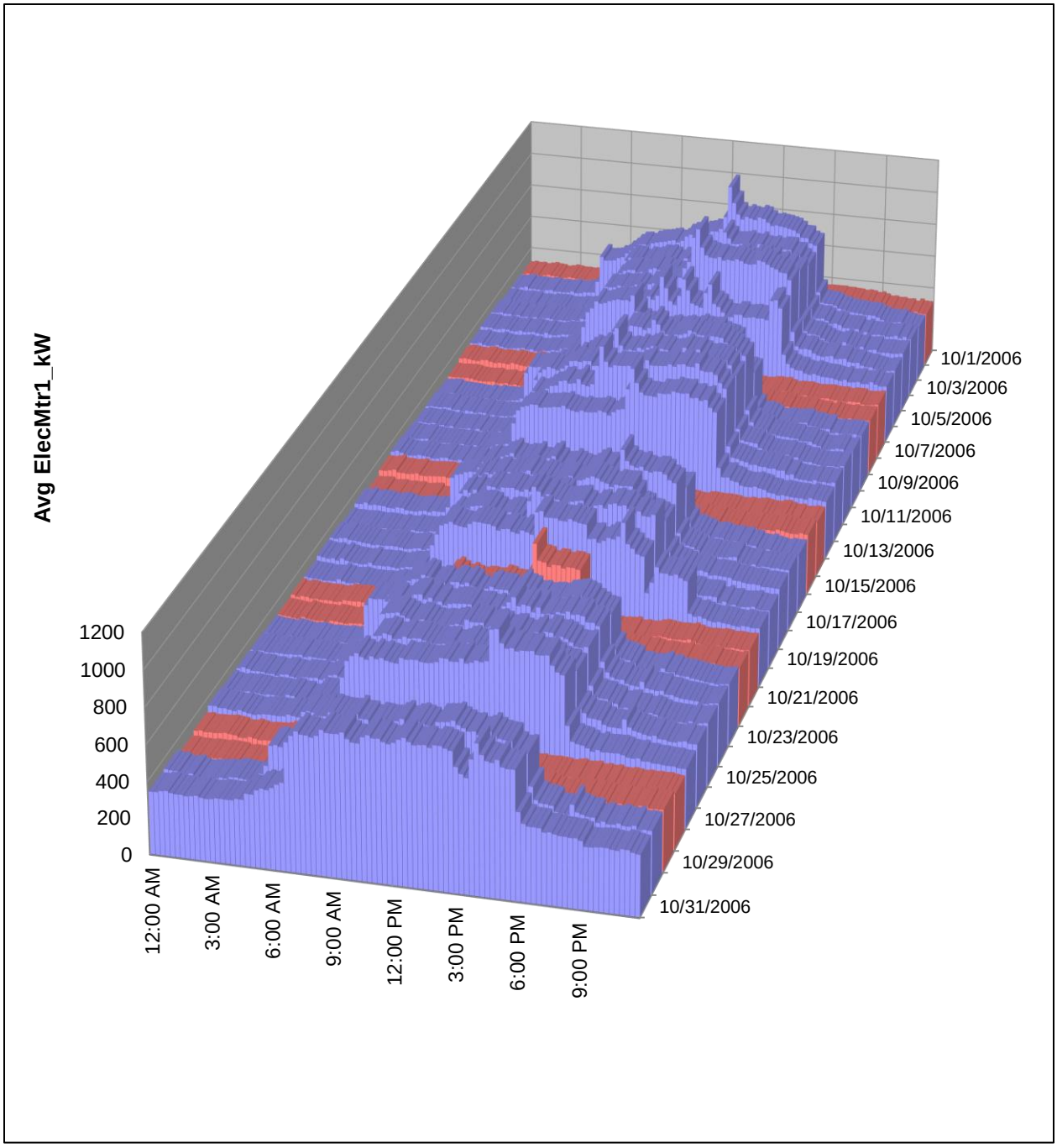


Figure 30: 3-d load profile time series chart in ECAM

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 a month's worth of daily load profiles to a surface (contour) chart, with the values shown by color. This is illustrated in Figure 31 below.

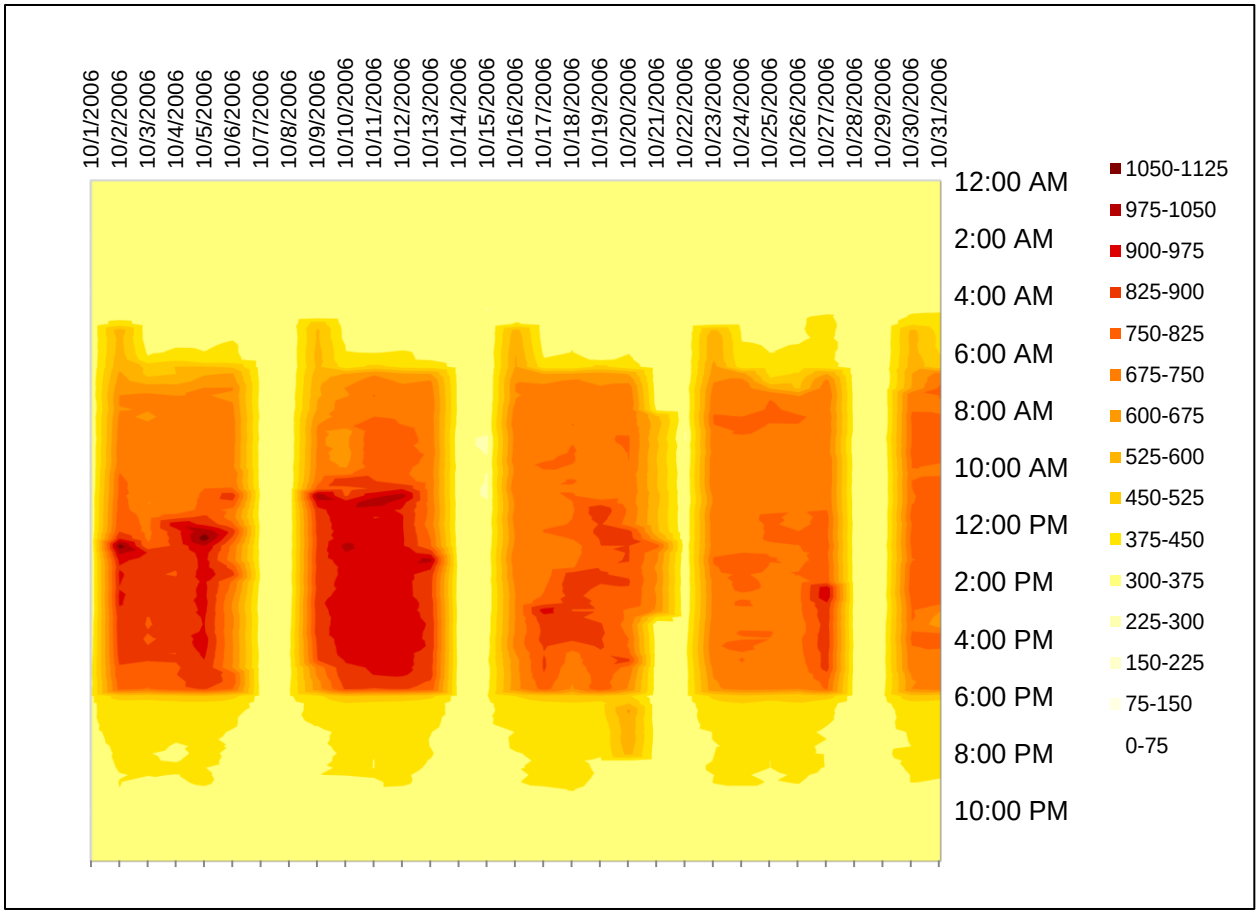


Figure 31: Energy density (surface chart) created from the "Load Profile by Day" chart in ECAM

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 a single month of data must be selected. The "Load Profile Calendar" will convert a month's worth of daily load profiles to a calendar format, with each day shown as a thumbnail chart on the calendar (See Figure 32 below).

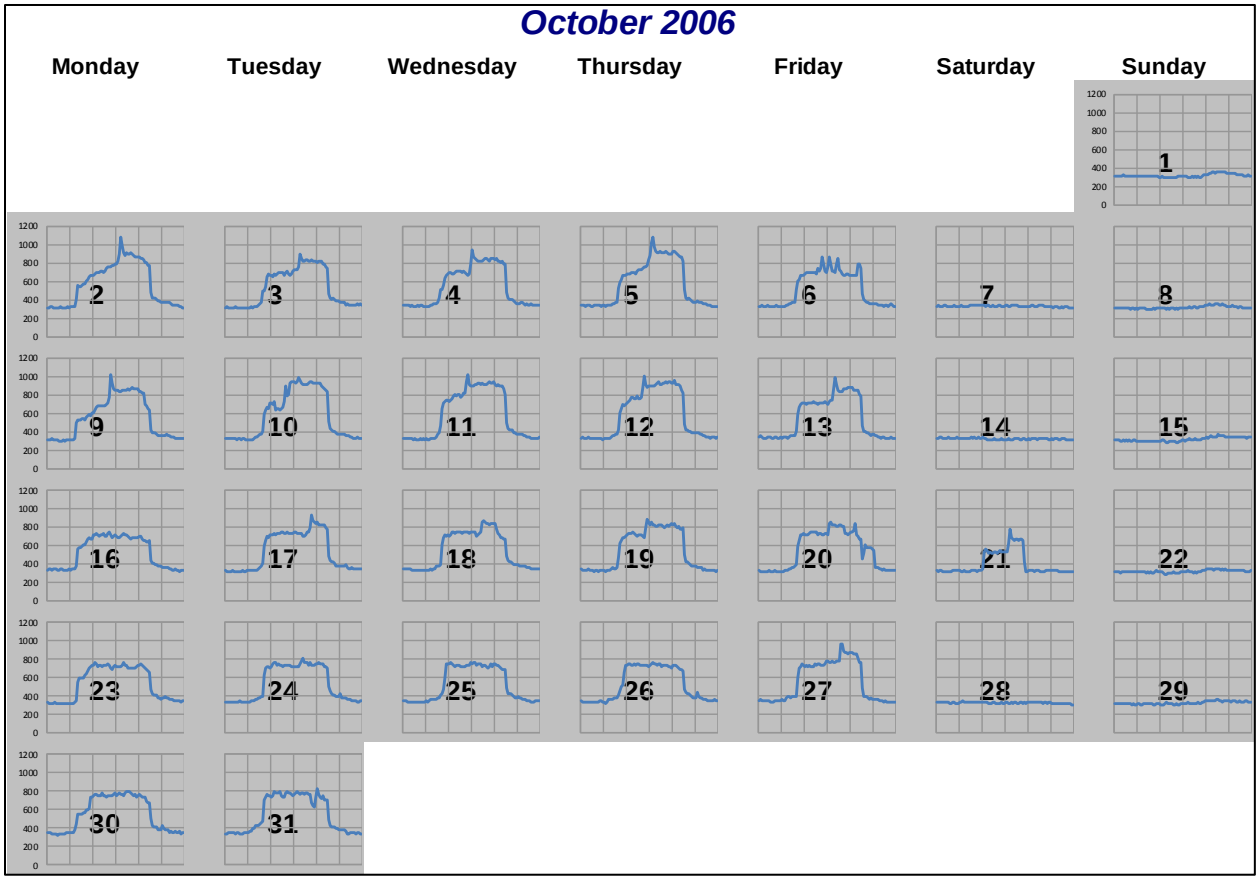


Figure 32: Load profile calendar created from the load profile by day chart in ECAM

3.7 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 33 shows the "Load Profile as Box Plots" in ECAM filtered only to show weekdays using the PivotTable. Figure 33 shows very consistent overnight demand, but an example of a building that has very inconsistent overnight demand can be seen in Figure 34.

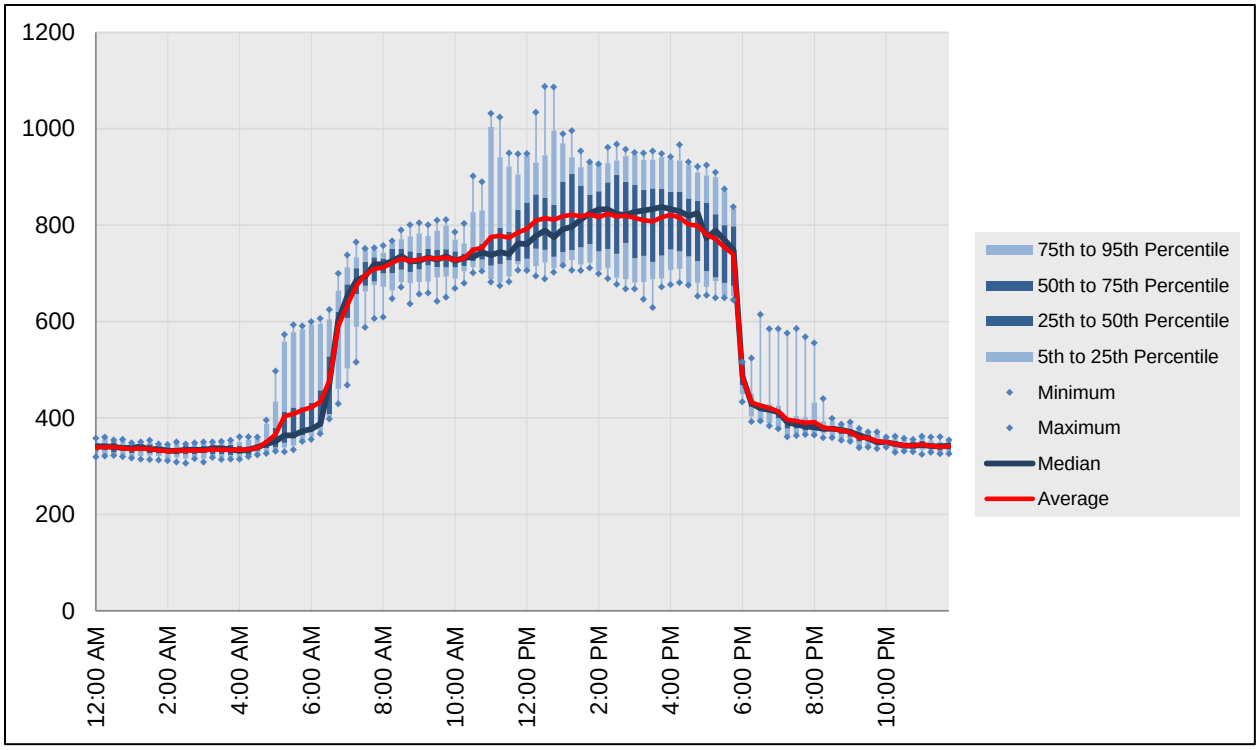


Figure 33: Load profile as box plots in ECAM, comparing only weekdays

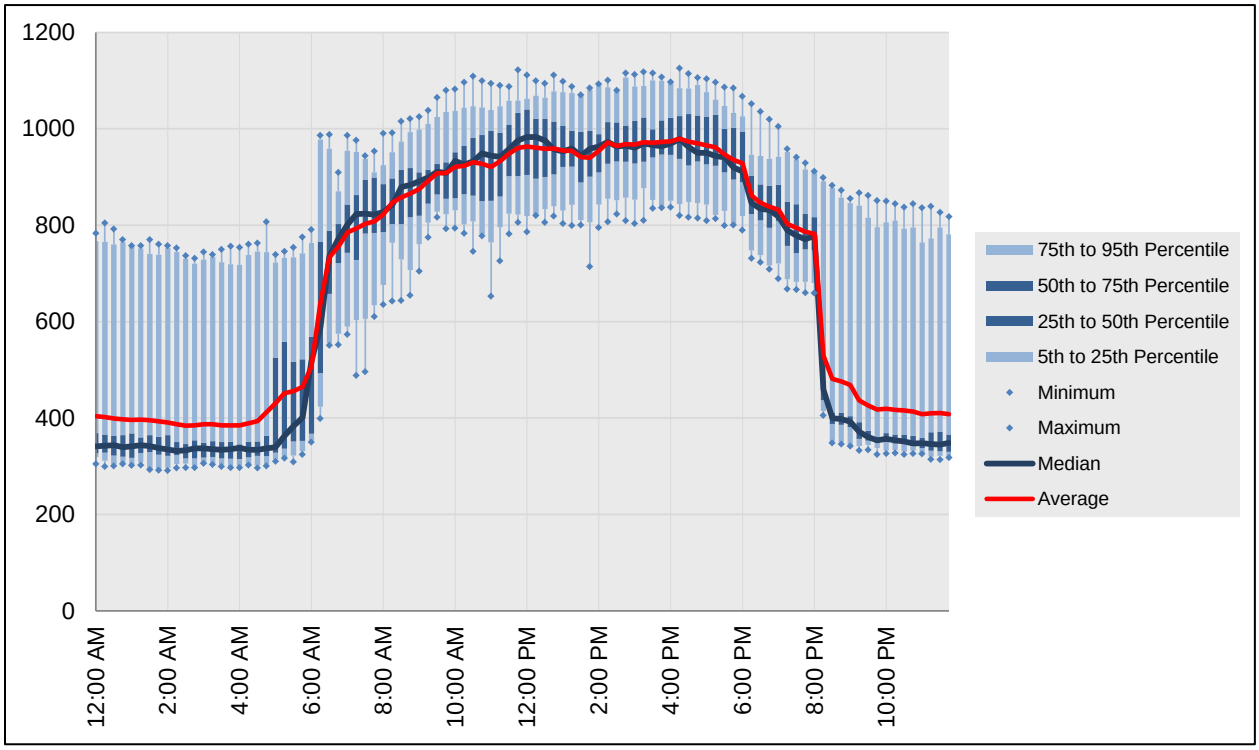


Figure 34: Load profile as box plots showing inconsistent overnight behavior

4.0 Scatter Charts

The next menu item in ECAM is the scatter charts. These can be used to plot any 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 (Figure 35).

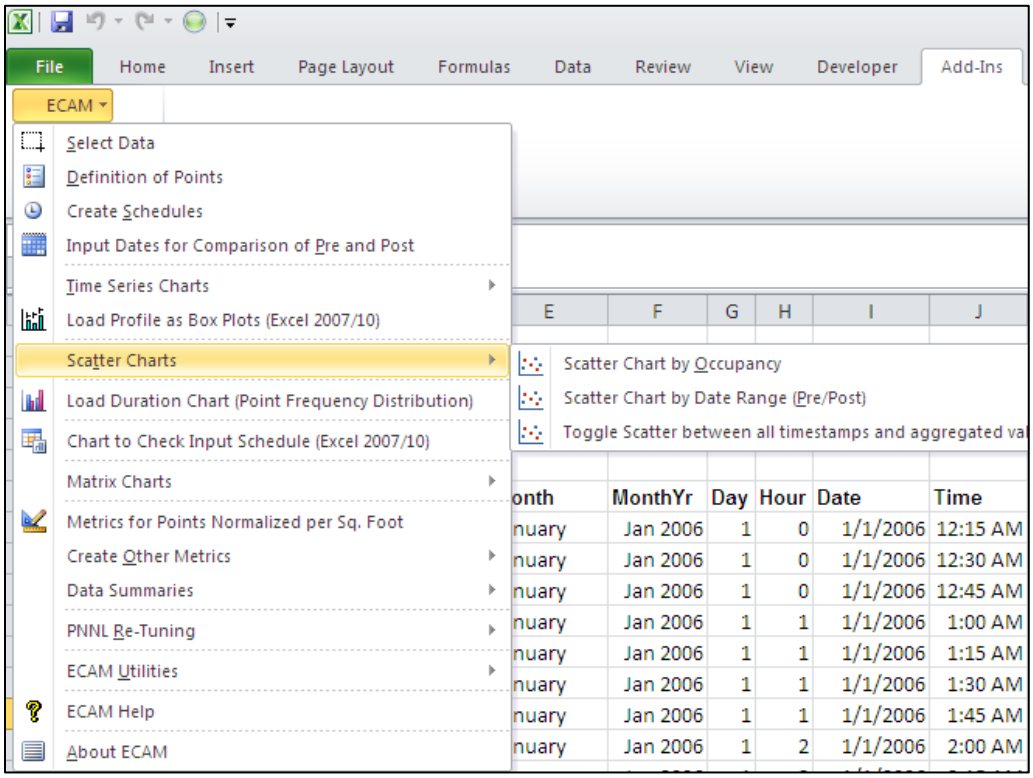


Figure 35: Scatter chart menu item in ECAM

4.1.1 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, then this chart will show one series, labeled as "Occ." If there is no schedule input, then this chart should still be utilized if the user wants to look at any point names in the scatter format.

Figure 36 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 consumption versus outdoor-air temperature. Figure 37 shows this chart as well, but only for "Occ" periods. Figure 38, 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.

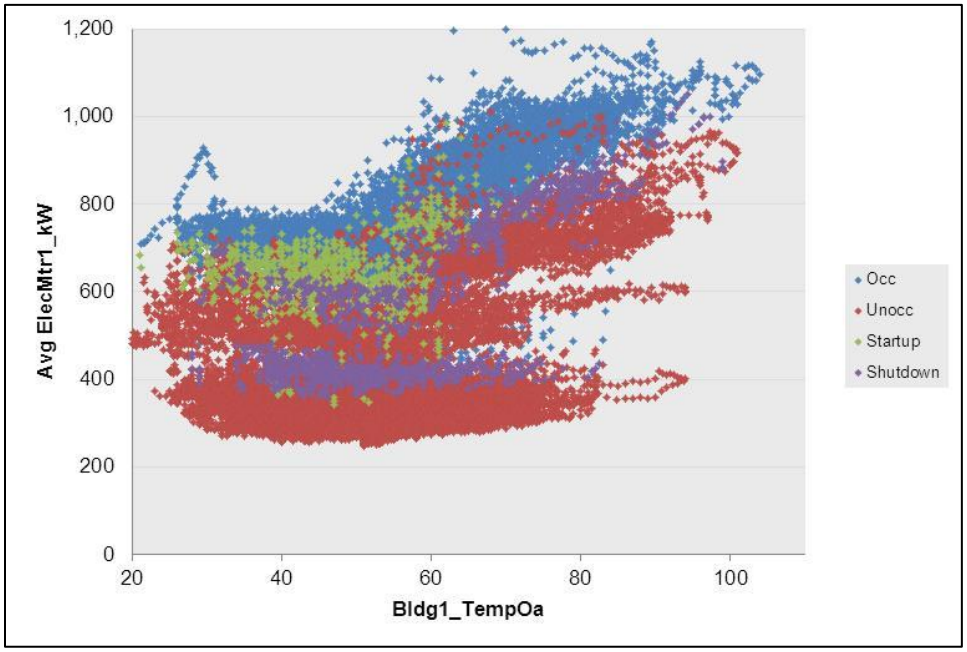


Figure 36: Scatter chart by occupancy and equipment startup/shutdown

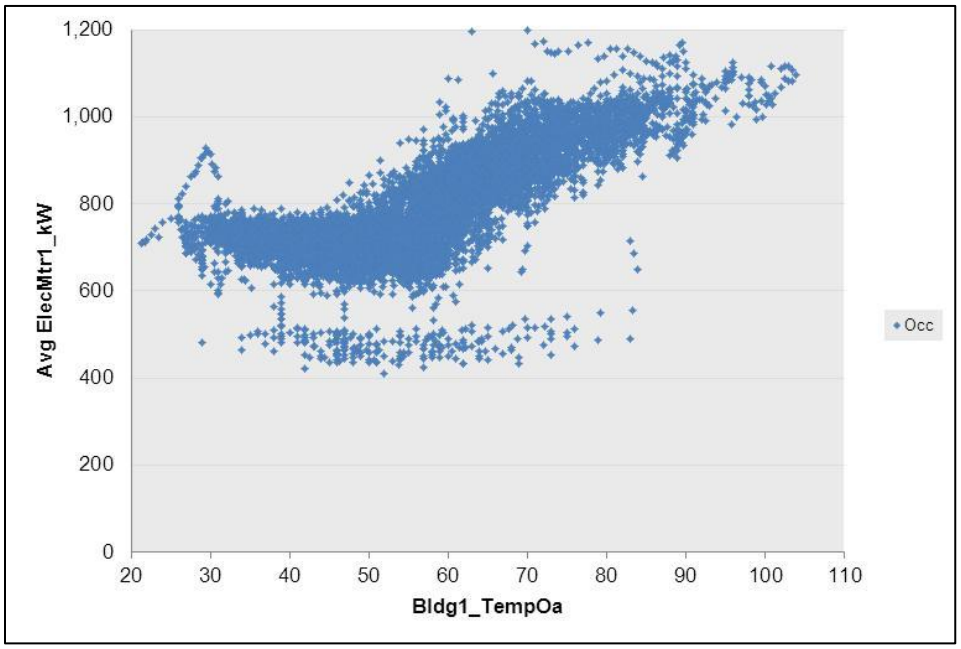


Figure 37: Scatter chart showing only the "Occ" period from Figure 36

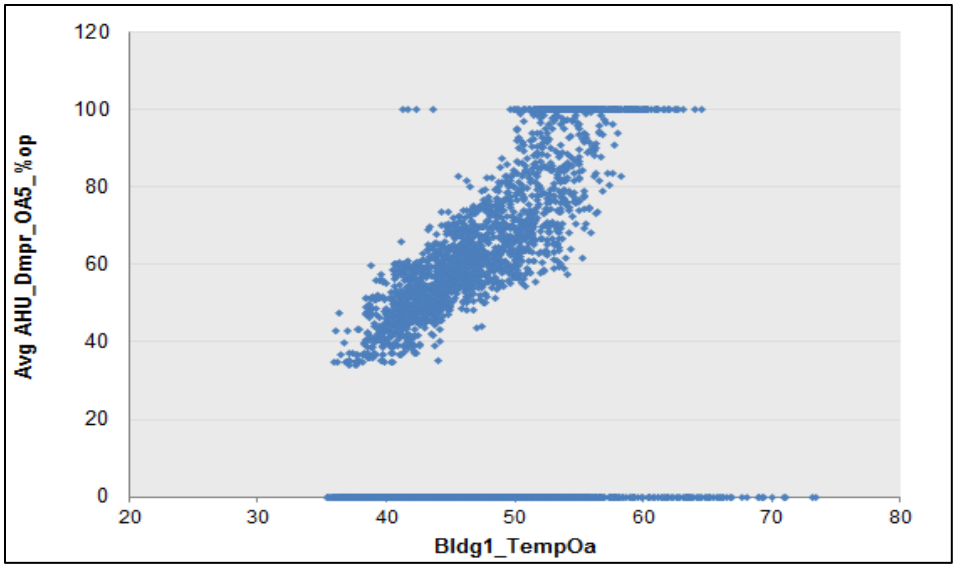


Figure 38: Scatter chart for outdoor-air damper position versus outdoor-air temperature

4.1.2 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 above. 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 39 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 consumption to outdoor-damper position, fan speed, etc. Figure 39 looks at whole building consumption vs. outdoor-air temperature.

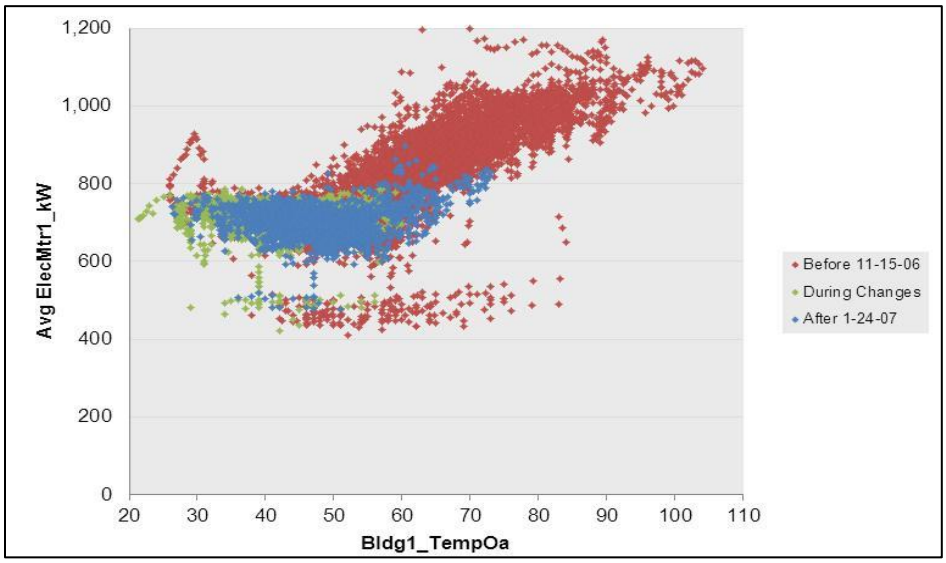


Figure 39: Scatter chart by date range

4.1.3 Toggle Scatter between all Timestamps and Aggregated Values

The last option under the scatter charts dropdown menu in ECAM is the "Toggle scatter between all timestamps 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 40 shows an example of the effectiveness of this feature when used on the scatter chart in Figure 39.

The impact of this aggregation will depend upon the number of decimal places present in the data for the independent variable. For scatter charts with outside air temperature as the independent variable, the maximum effect can be seen by using the 1-degree bins instead of the raw temperature data.

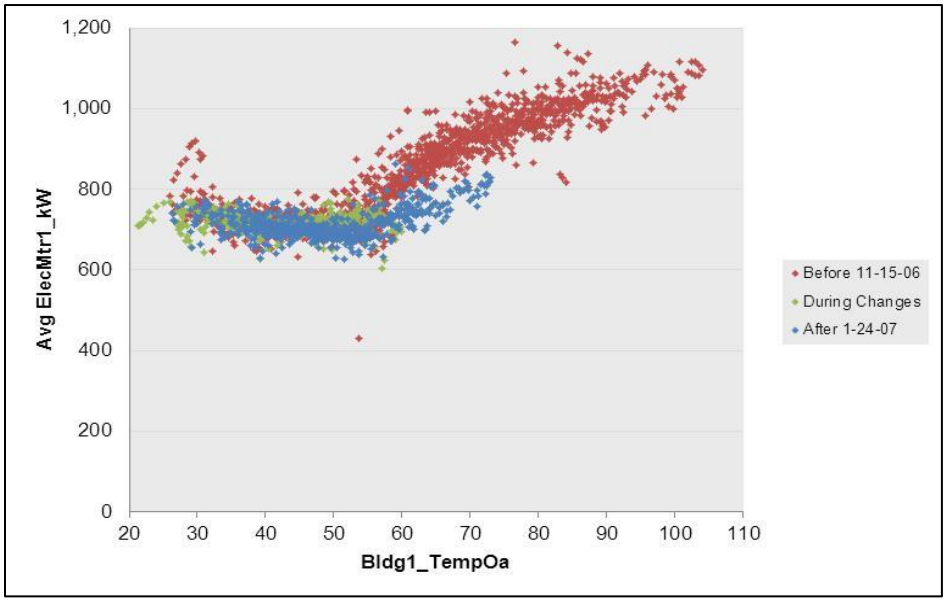


Figure 40: Toggle scatter between all timestamps and aggregated values in ECAM

5.0 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 41 below 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."

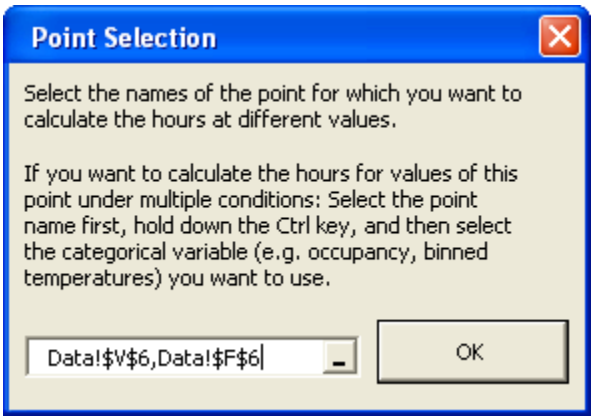


Figure 41: Point selection when creating a load duration chart in ECAM

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 42 below), the 99th percentile value of weather shown is 88°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 42. Figure 43 shows a portion of the table created after selecting "OK," and Figure 44 shows the corresponding chart created.

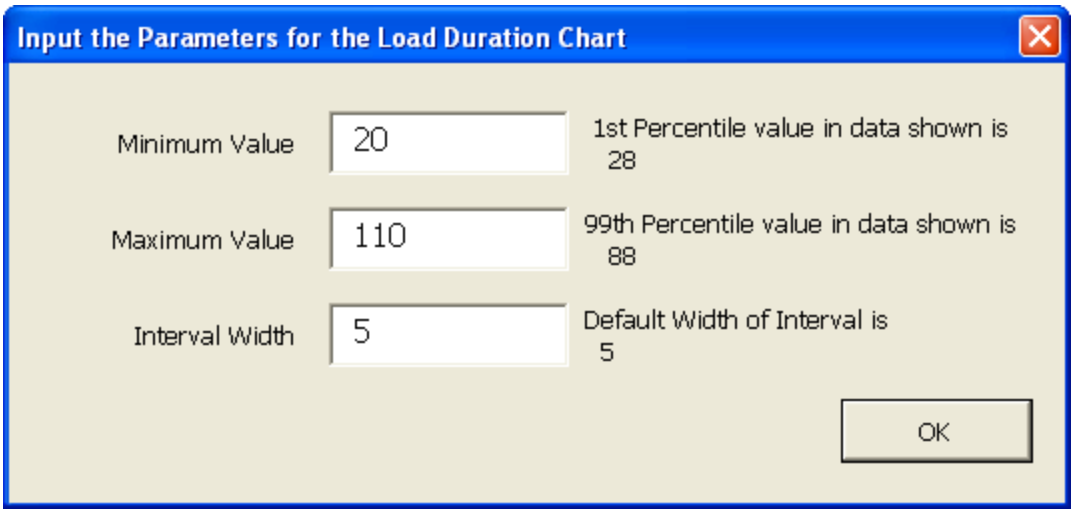


Figure 42: Input parameter for the load duration chart in ECAM

Total Hours	MonthYr					
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 43: Example of table created using the load duration chart option in ECAM

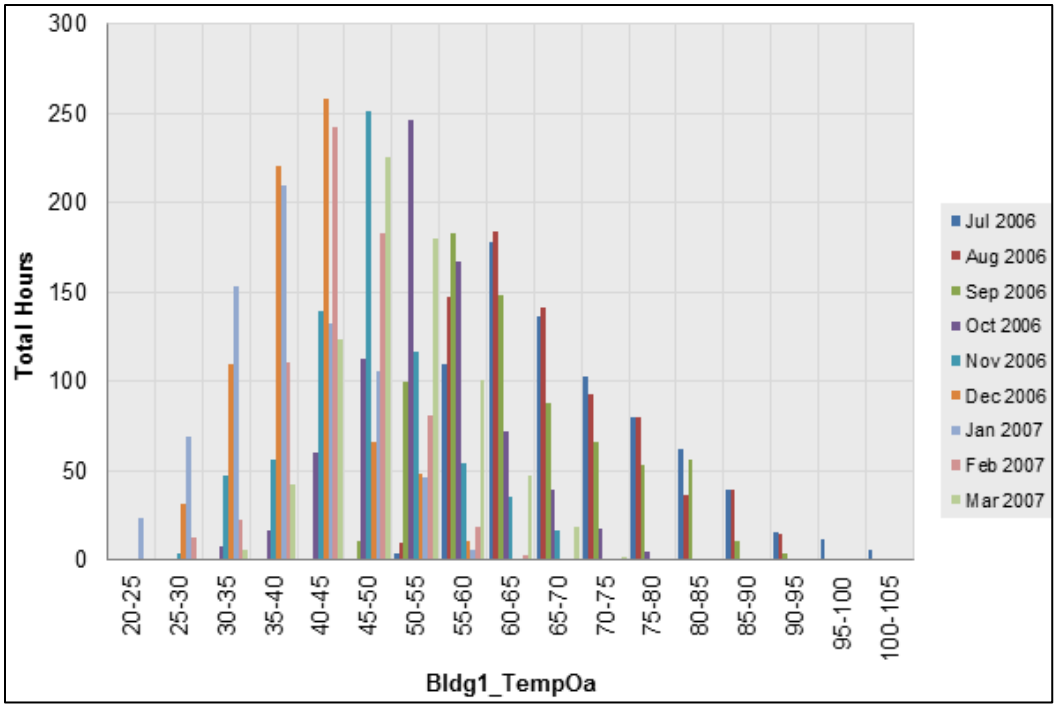


Figure 44: Load duration chart created for total hours at temperature bins by month

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 45 and Figure 46 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 45: Created table for hours vs. occupancy, for outdoor temperature

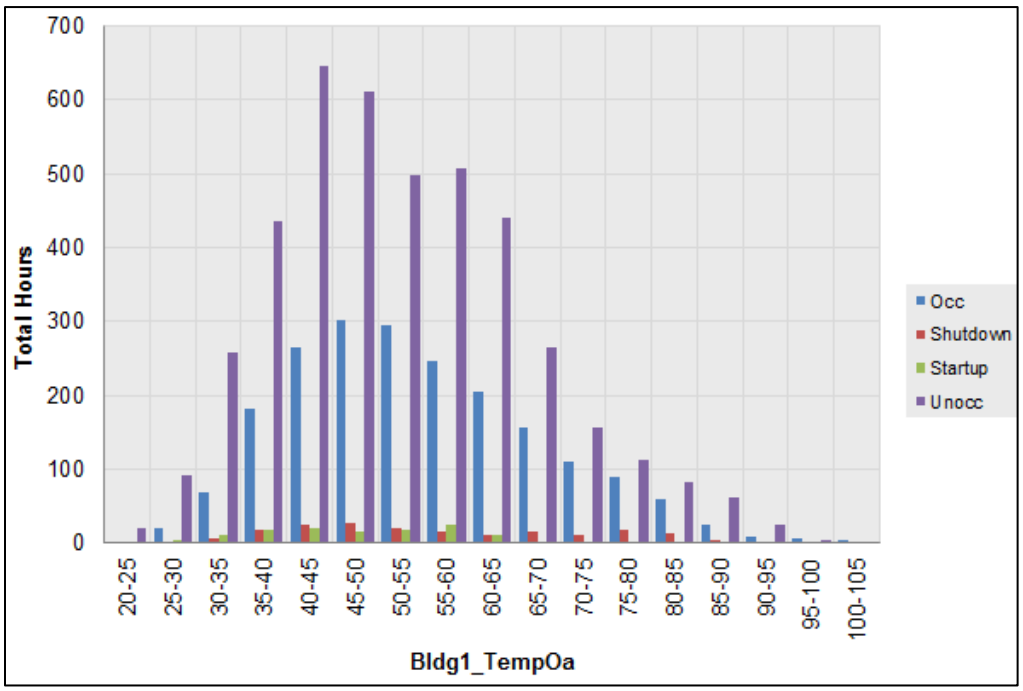


Figure 46: Load duration chart for total hours at specific temperature bins for occupancy

6.0 Chart to Check Input Schedule (Excel 2007/10)

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 47 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.

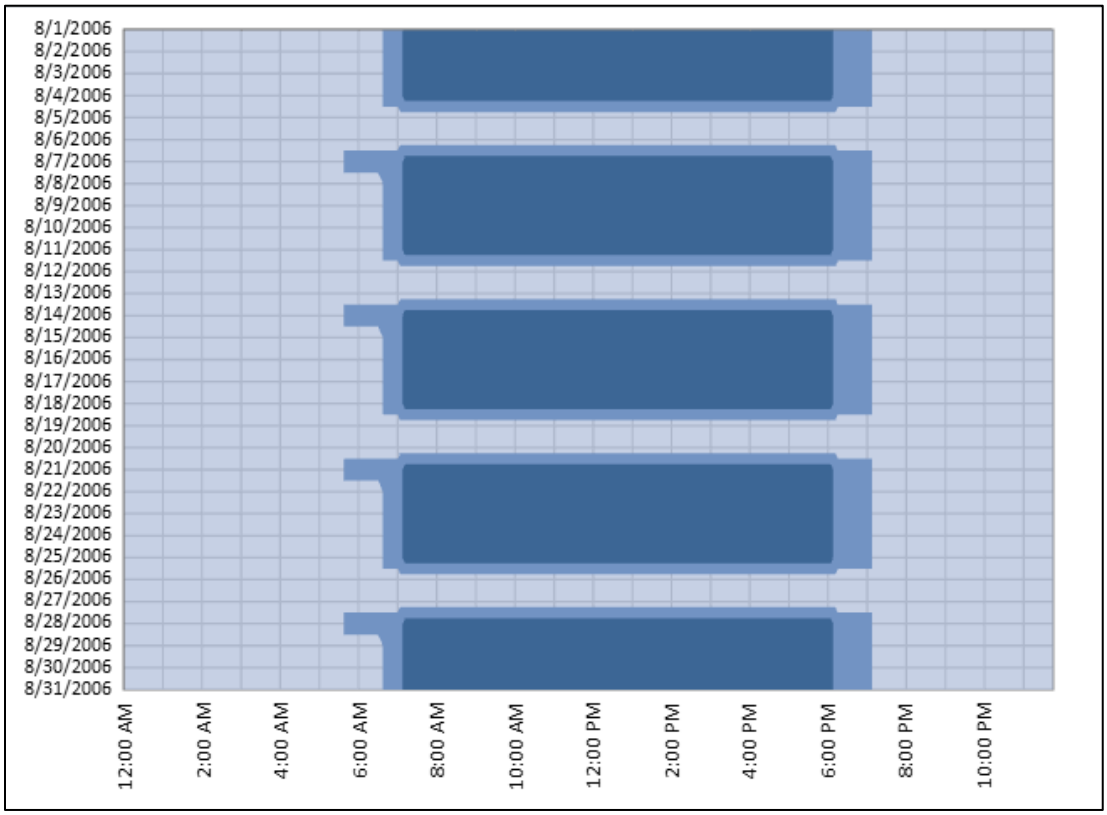


Figure 47: Chart to check input schedule in ECAM

7.0 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 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 48 shows an example of eight charts previously used/mentioned in this guide, in matrix form.

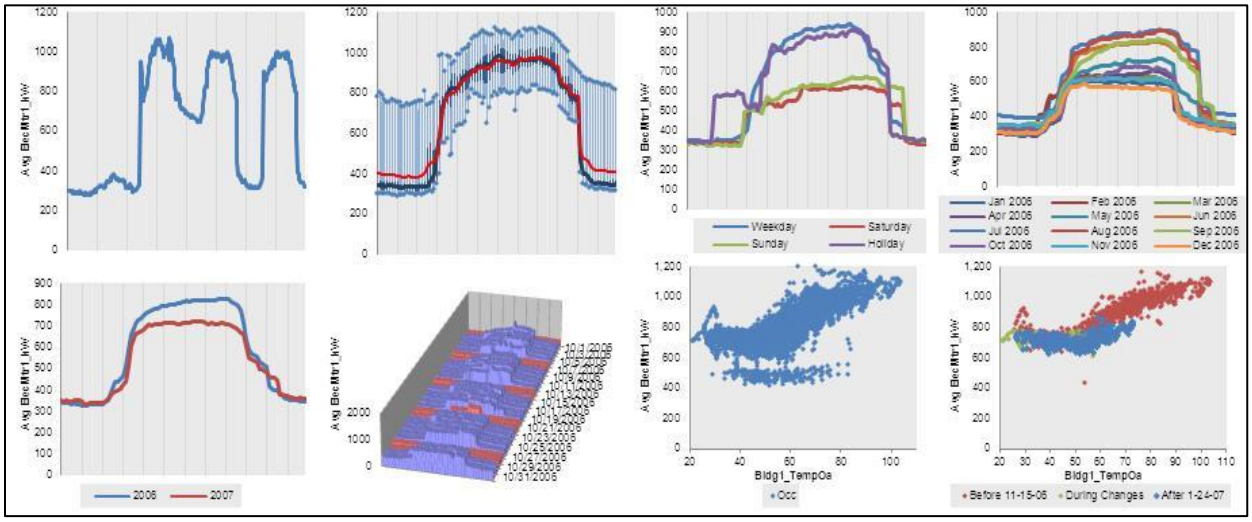


Figure 48: Matrix charts option in ECAM

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 49 below shows an example of “matrixed” 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 can lead to conclusions regarding which month has the highest energy consumption, the most spread about the mean, etc.

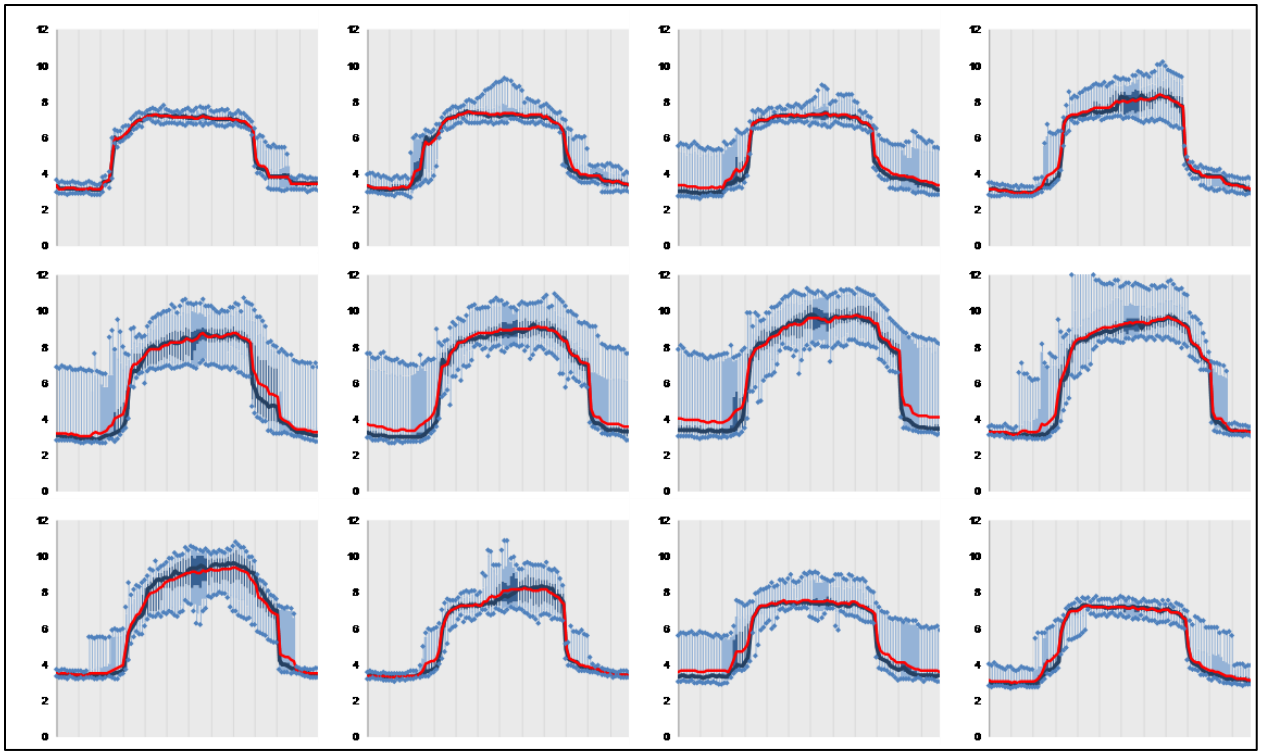


Figure 49: Matrix charts option for box plot load profiles for weekdays, for each month of the year

8.0 Chart Utilities

At this time of writing this User Guide, there is only one item under Chart Utilities: Set Scales the Same for a Group of Charts.

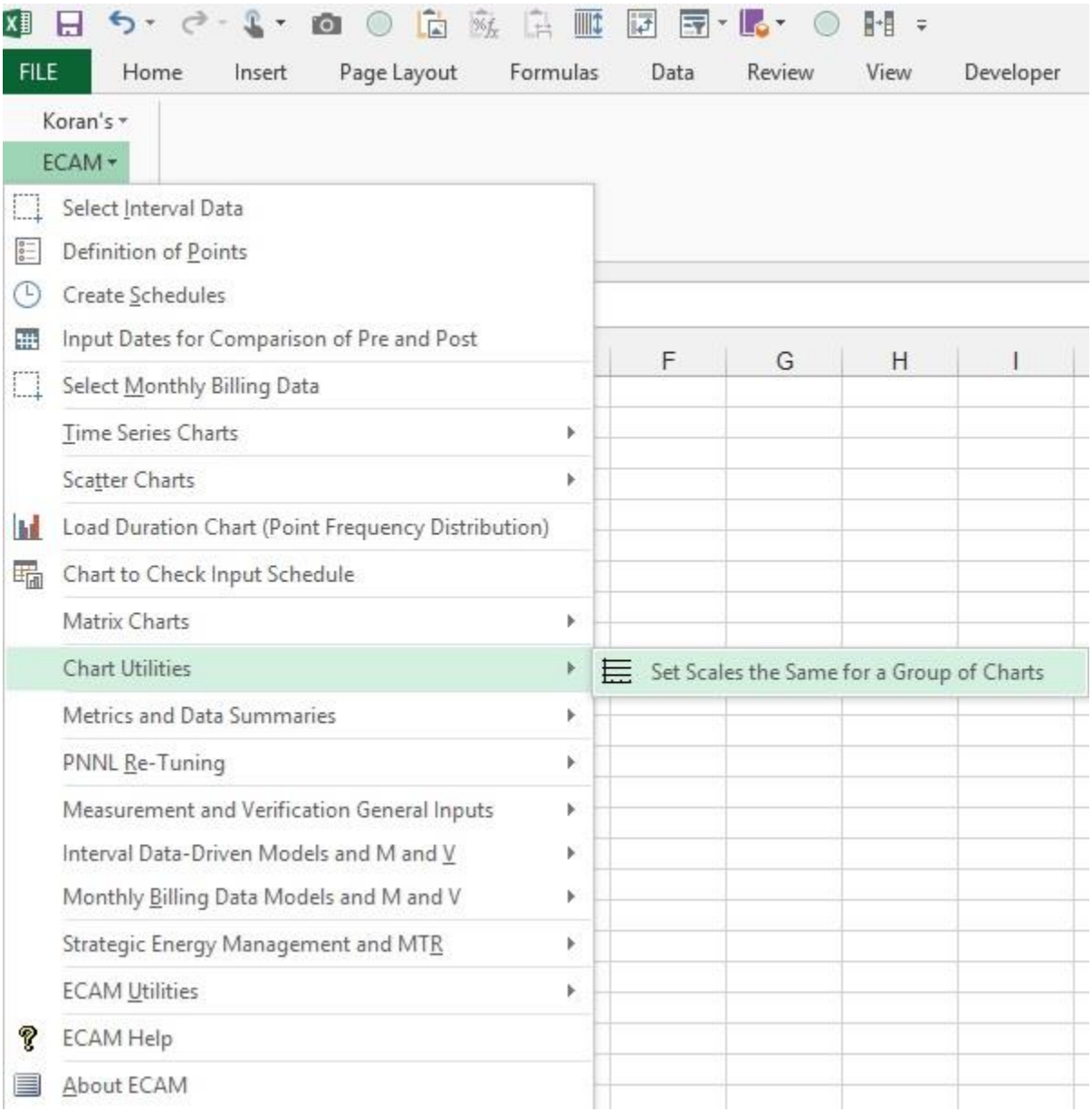


Figure 50: Chart Utilities Menu

8.1 Set Scales the Same for a Group of Charts

This capability is pretty self-explanatory: If you have multiple similar charts, it can be tedious to adjust all the axis scales for the best sizing of the chart and hence chart readability. For example, scatter charts with outside air temperature as the independent variable, with temperature in ºF

and for a climate without very cold weather, will typically start at 0 ºF using Excel's autoscaling. However, the coldest temperature in the data set may be 35 or 40 ºF, so the scales should start, perhaps, at 30 ºF. If you have multiple of these charts, this menu item makes it relatively easy to change all the x-axis scales at once.

Similarly, you may have multiple load profiles which you need to compare. The Excel autoscaling may provide multiple different scales. This capability makes it easy to quickly change all the y-axis scales.

To use the group scaling, first a group of charts must be selected. This is easily done by clicking on the first chart, holding the keyboard Shift key, and clicking on the other charts. Then select the menu item.

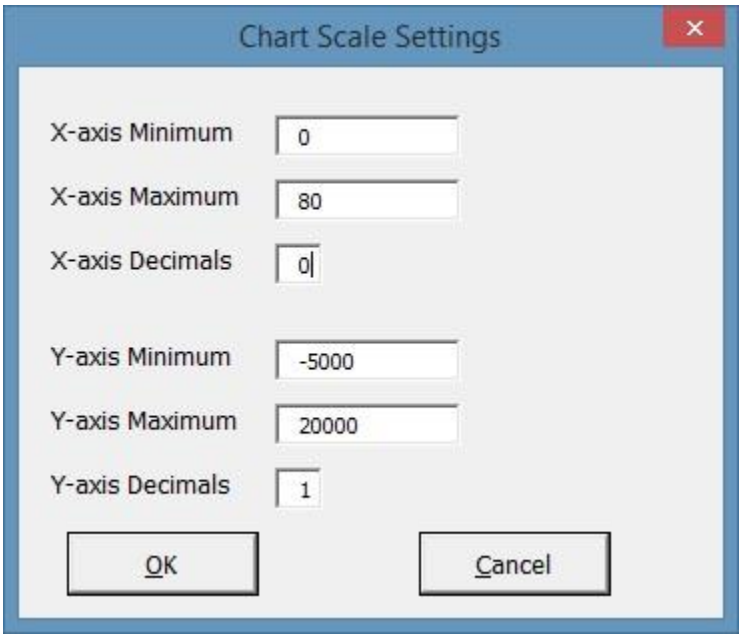


Figure 51: Form to Set Chart Scale Settings for a Group of Charts

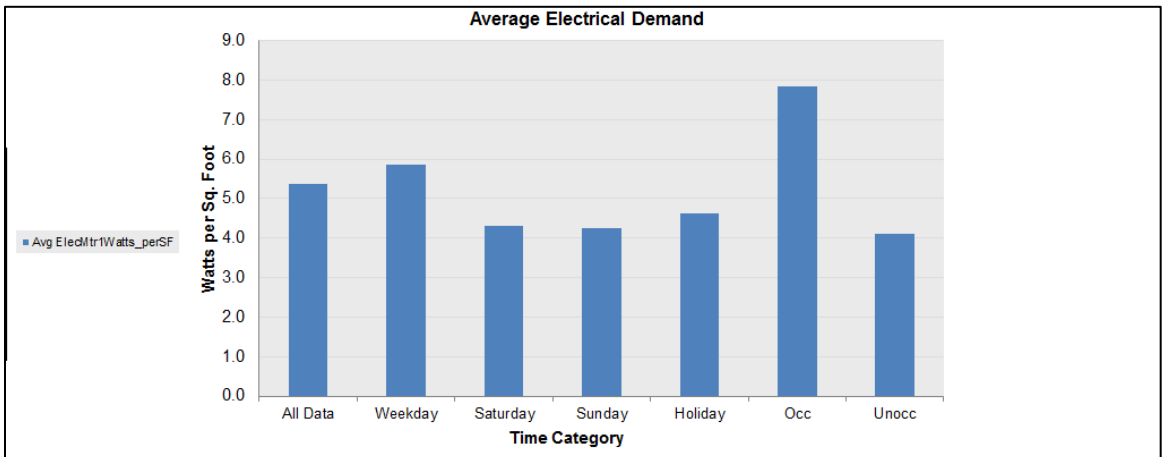
When Figure 51 opens, it has some default values from one of the charts selected. You can leave these values without changes, or make changes, and all the chart axes in the selected group of charts will be changed to match the selections.

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 a Watts per square foot (W/sf) value. Any points that are in kW will be converted to W/sf after the user enters the building size as part of the point definition process. The metrics that are created are average W/sf by daytype (Weekday, Saturday, Sunday) and occupancy (Occ and Unocc). Figure 52 shows an example of these metrics for whole building 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 52: Metrics for points normalized per square 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 53 shows an example of whole building 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 53: 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 54 54shows an example of this table for both whole building consumption and outdoor-air temperature.

		Occupancy				
Points	MonthYr	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 54: 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 55 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 55: Daytype and month-year combined metrics

9.3 Data Summaries

These ECAM menu items provide 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 selected or 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 2 shows an example of the data summary for whole building electricity consumption.

[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 2: 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[2] by automatically creating charts that allow identification of building operational problems. In order 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 above). 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.

Selection of each menu item creates a separate worksheet (with the related charts) for each relevant building re-tuning focus areas. For example, if there are five air-handling units (AHUs), five worksheets will be created, one for each AHU. All charts on a single worksheet change together as the user selects various filters. For example, the data history charts will all use the same date/time range per the selections in the PivotTable on the worksheet containing the charts.

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
- Each chiller load (current)
- Each pump status (if there are multiple pumps record all of them)

[2] www.pnnl.gov/buildingretuning
http://buildingefficiency.labworks.org/publications/PNWD-SA-8654.pdf

- Each 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).

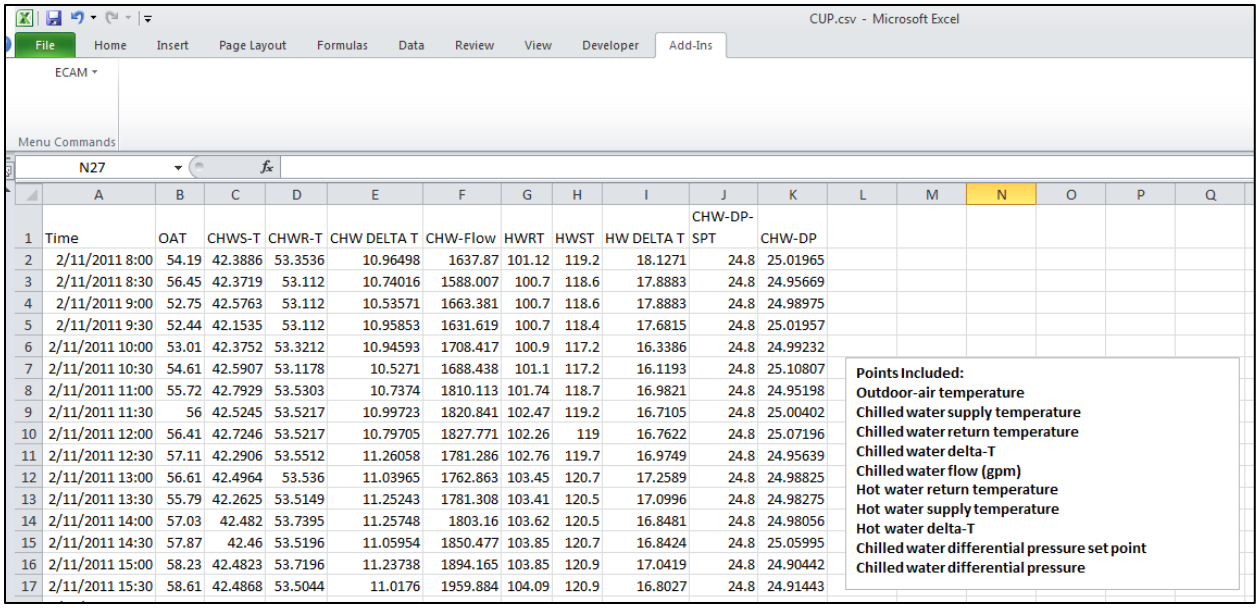
The following time-series charts will be created by ECAM, depending on the availability of the relevant points mapped in ECAM:

- CHW supply temperature, CHW return temperature, delta-T, and OAT vs. time
- HW supply temperature, HW return temperature, delta-T, and OAT vs. time
- CHW flow and OAT vs. time.

It is important to note that ECAM will not create charts automatically for certain parts of the system, like the cooling tower or condenser. 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 still 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.

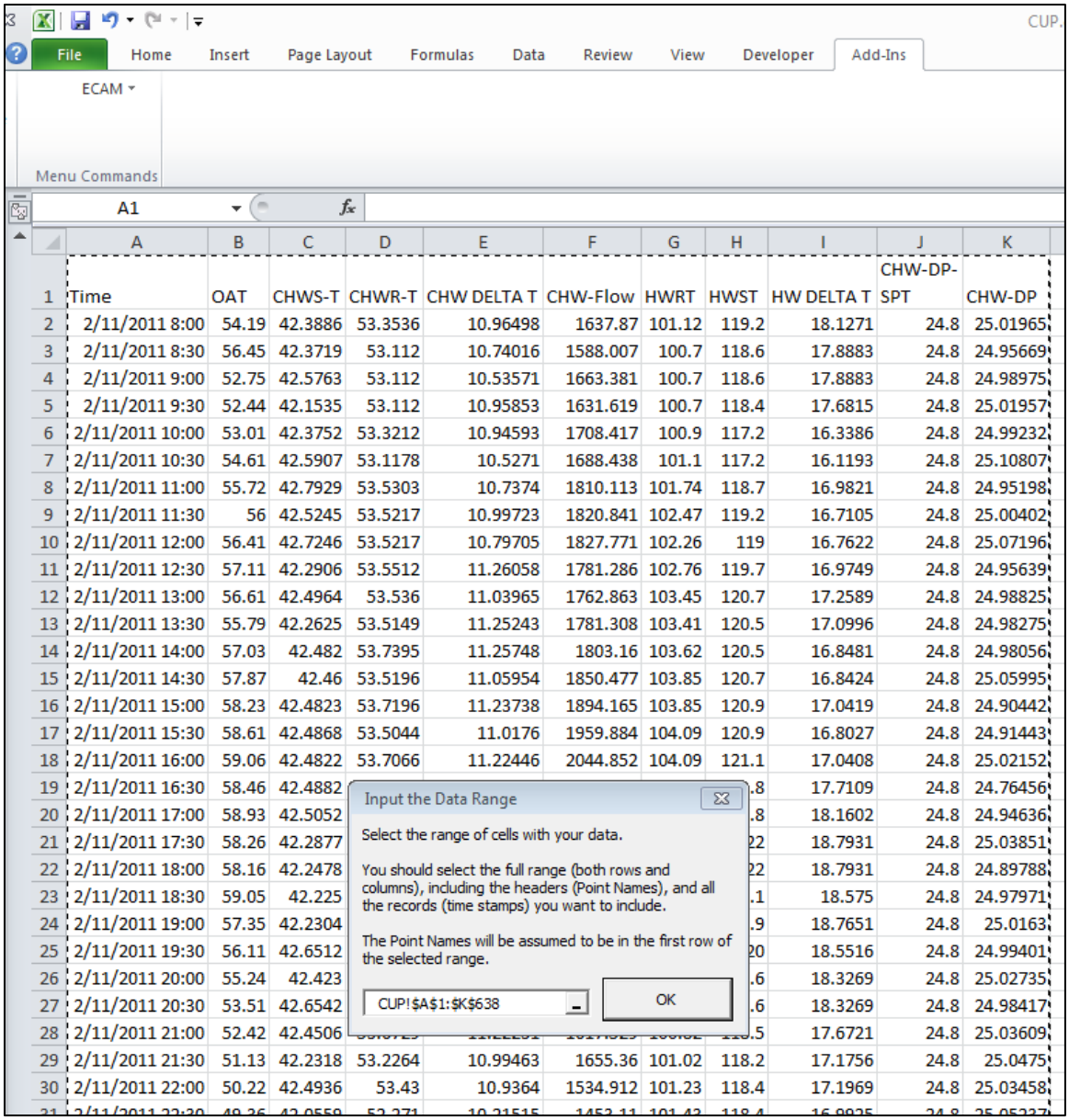
The following example data set in Figure 56 came from a BAS system for a central utility plant (CUP). The file type is a ".csv," and the points included can be seen in the figure.



	A	B	C	D	E	F	G	H	I	J	K
1	Time	OAT	CHWS-T	CHWR-T	CHW DELTA T	CHW-Flow	HWRT	HWST	HW DELTA T	CHW-DP-SPT	CHW-DP
2	2/11/2011 8:00	54.19	42.3886	53.3536	10.96498	1637.87	101.12	119.2	18.1271	24.8	25.01965
3	2/11/2011 8:30	56.45	42.3719	53.112	10.74016	1588.007	100.7	118.6	17.8883	24.8	24.95669
4	2/11/2011 9:00	52.75	42.5763	53.112	10.53571	1663.381	100.7	118.6	17.8883	24.8	24.98975
5	2/11/2011 9:30	52.44	42.1535	53.112	10.95853	1631.619	100.7	118.4	17.6815	24.8	25.01957
6	2/11/2011 10:00	53.01	42.3752	53.3212	10.94593	1708.417	100.9	117.2	16.3386	24.8	24.99232
7	2/11/2011 10:30	54.61	42.5907	53.1178	10.5271	1688.438	101.1	117.2	16.1193	24.8	25.10807
8	2/11/2011 11:00	55.72	42.7929	53.5303	10.7374	1810.113	101.74	118.7	16.9821	24.8	24.95198
9	2/11/2011 11:30	56	42.5245	53.5217	10.99723	1820.841	102.47	119.2	16.7105	24.8	25.00402
10	2/11/2011 12:00	56.41	42.7246	53.5217	10.79705	1827.771	102.26	119	16.7622	24.8	25.07196
11	2/11/2011 12:30	57.11	42.2906	53.5512	11.26058	1781.286	102.76	119.7	16.9749	24.8	24.95639
12	2/11/2011 13:00	56.61	42.4964	53.536	11.03965	1762.863	103.45	120.7	17.2589	24.8	24.98825
13	2/11/2011 13:30	55.79	42.2625	53.5149	11.25243	1781.308	103.41	120.5	17.0996	24.8	24.98275
14	2/11/2011 14:00	57.03	42.482	53.7395	11.25748	1803.16	103.62	120.5	16.8481	24.8	24.98056
15	2/11/2011 14:30	57.87	42.46	53.5196	11.05954	1850.477	103.85	120.7	16.8424	24.8	25.05995
16	2/11/2011 15:00	58.23	42.4823	53.7196	11.23738	1894.165	103.85	120.9	17.0419	24.8	24.90442
17	2/11/2011 15:30	58.61	42.4868	53.5044	11.0176	1959.884	104.09	120.9	16.8027	24.8	24.91443

Figure 56 : Sample data set for a central utility plant

Repeat the steps at the beginning of this guide: Go to Add-Ins, ECAM, and "Select Data." For this case, the timestamps are in one column, so that will be selected, and then hit "OK." Figure 57 shows the data being selected.



	A	B	C	D	E	F	G	H	I	J	K
1	Time	OAT	CHWS-T	CHWR-T	CHW DELTA T	CHW-Flow	HWRT	HWST	HW DELTA T	CHW-DP-SPT	CHW-DP
2	2/11/2011 8:00	54.19	42.3886	53.3536	10.96498	1637.87	101.12	119.2	18.1271	24.8	25.01965
3	2/11/2011 8:30	56.45	42.3719	53.112	10.74016	1588.007	100.7	118.6	17.8883	24.8	24.95669
4	2/11/2011 9:00	52.75	42.5763	53.112	10.53571	1663.381	100.7	118.6	17.8883	24.8	24.98975
5	2/11/2011 9:30	52.44	42.1535	53.112	10.95853	1631.619	100.7	118.4	17.6815	24.8	25.01957
6	2/11/2011 10:00	53.01	42.3752	53.3212	10.94593	1708.417	100.9	117.2	16.3386	24.8	24.99232
7	2/11/2011 10:30	54.61	42.5907	53.1178	10.5271	1688.438	101.1	117.2	16.1193	24.8	25.10807
8	2/11/2011 11:00	55.72	42.7929	53.5303	10.7374	1810.113	101.74	118.7	16.9821	24.8	24.95198
9	2/11/2011 11:30	56	42.5245	53.5217	10.99723	1820.841	102.47	119.2	16.7105	24.8	25.00402
10	2/11/2011 12:00	56.41	42.7246	53.5217	10.79705	1827.771	102.26	119	16.7622	24.8	25.07196
11	2/11/2011 12:30	57.11	42.2906	53.5512	11.26058	1781.286	102.76	119.7	16.9749	24.8	24.95639
12	2/11/2011 13:00	56.61	42.4964	53.536	11.03965	1762.863	103.45	120.7	17.2589	24.8	24.98825
13	2/11/2011 13:30	55.79	42.2625	53.5149	11.25243	1781.308	103.41	120.5	17.0996	24.8	24.98275
14	2/11/2011 14:00	57.03	42.482	53.7395	11.25748	1803.16	103.62	120.5	16.8481	24.8	24.98056
15	2/11/2011 14:30	57.87	42.46	53.5196	11.05954	1850.477	103.85	120.7	16.8424	24.8	25.05995
16	2/11/2011 15:00	58.23	42.4823	53.7196	11.23738	1894.165	103.85	120.9	17.0419	24.8	24.90442
17	2/11/2011 15:30	58.61	42.4868	53.5044	11.0176	1959.884	104.09	120.9	16.8027	24.8	24.91443
18	2/11/2011 16:00	59.06	42.4822	53.7066	11.22446	2044.852	104.09	121.1	17.0408	24.8	25.02152
19	2/11/2011 16:30	58.46	42.4882					.8	17.7109	24.8	24.76456
20	2/11/2011 17:00	58.93	42.5052					.8	18.1602	24.8	24.94636
21	2/11/2011 17:30	58.26	42.2877					22	18.7931	24.8	25.03851
22	2/11/2011 18:00	58.16	42.2478					22	18.7931	24.8	24.89788
23	2/11/2011 18:30	59.05	42.225					.1	18.575	24.8	24.97971
24	2/11/2011 19:00	57.35	42.2304					.9	18.7651	24.8	25.0163
25	2/11/2011 19:30	56.11	42.6512					20	18.5516	24.8	24.99401
26	2/11/2011 20:00	55.24	42.423					.6	18.3269	24.8	25.02735
27	2/11/2011 20:30	53.51	42.6542					.6	18.3269	24.8	24.98417
28	2/11/2011 21:00	52.42	42.4506					.5	17.6721	24.8	25.03609
29	2/11/2011 21:30	51.13	42.2318	53.2264	10.99463	1655.36	101.02	118.2	17.1756	24.8	25.0475
30	2/11/2011 22:00	50.22	42.4936	53.43	10.9364	1534.912	101.23	118.4	17.1969	24.8	25.03458

Figure 57: 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 58 below, 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 59). 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 starts defaulted at 1) to the desired system number (2, 3, etc.).

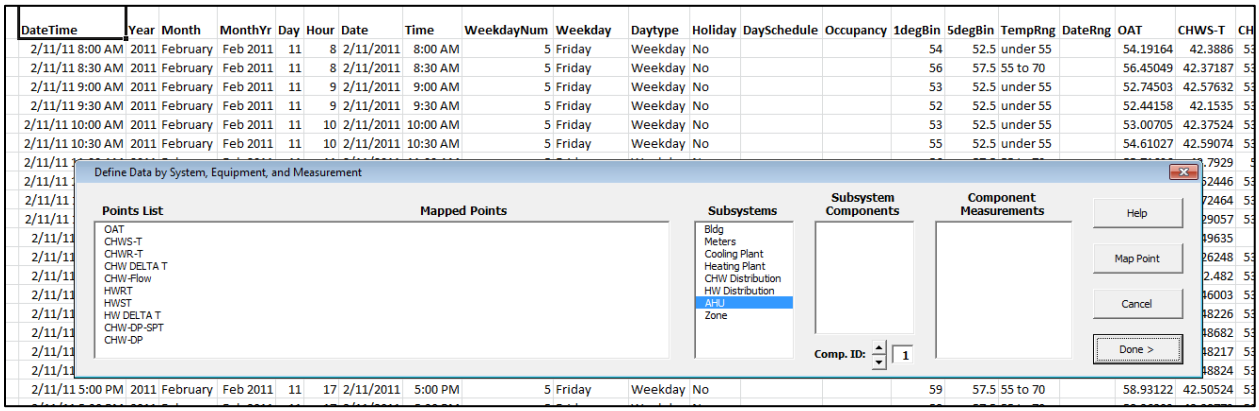


Figure 58: Initial window for mapping points

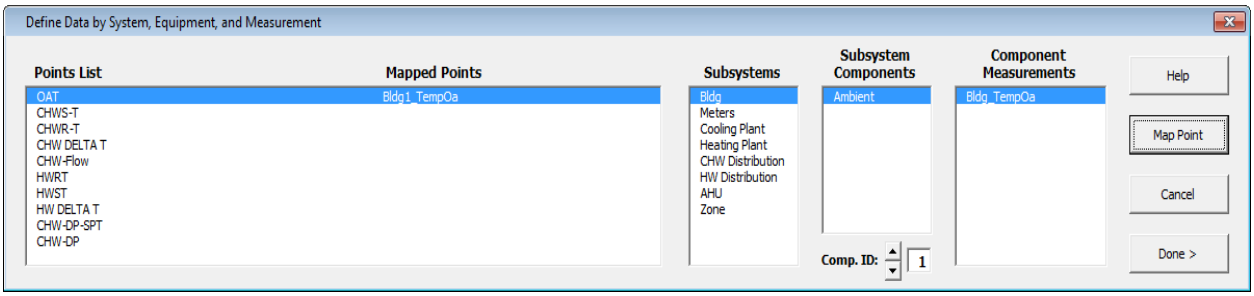


Figure 59: The Point Mapping Window after outdoor-air temperature is correctly mapped

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 “Chilled_Water” under the “Subsystem Components,” and finally “CHW_TempOut” under “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 ΔT, 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 “CHW Distribution” under “Subsystems,” choose the “Pump_CHW_Sec” under “Subsystem Components,” and choose “Pmp_ChW_Sec_gpm” under “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 “Subsystem Components,” and then “HoW_TempOut,” “HoW_TempIn,” and “HoW_TempDiff” under Component Measurements, respectively.

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” and click on “Central Plant Charts,” and ECAM will automatically open a new sheet titled “CP1” with the charts listed above. Figure 60 shows the new sheet with these charts. If the 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 that in Figure 61, where the second chart only has the outdoor-air temperature.

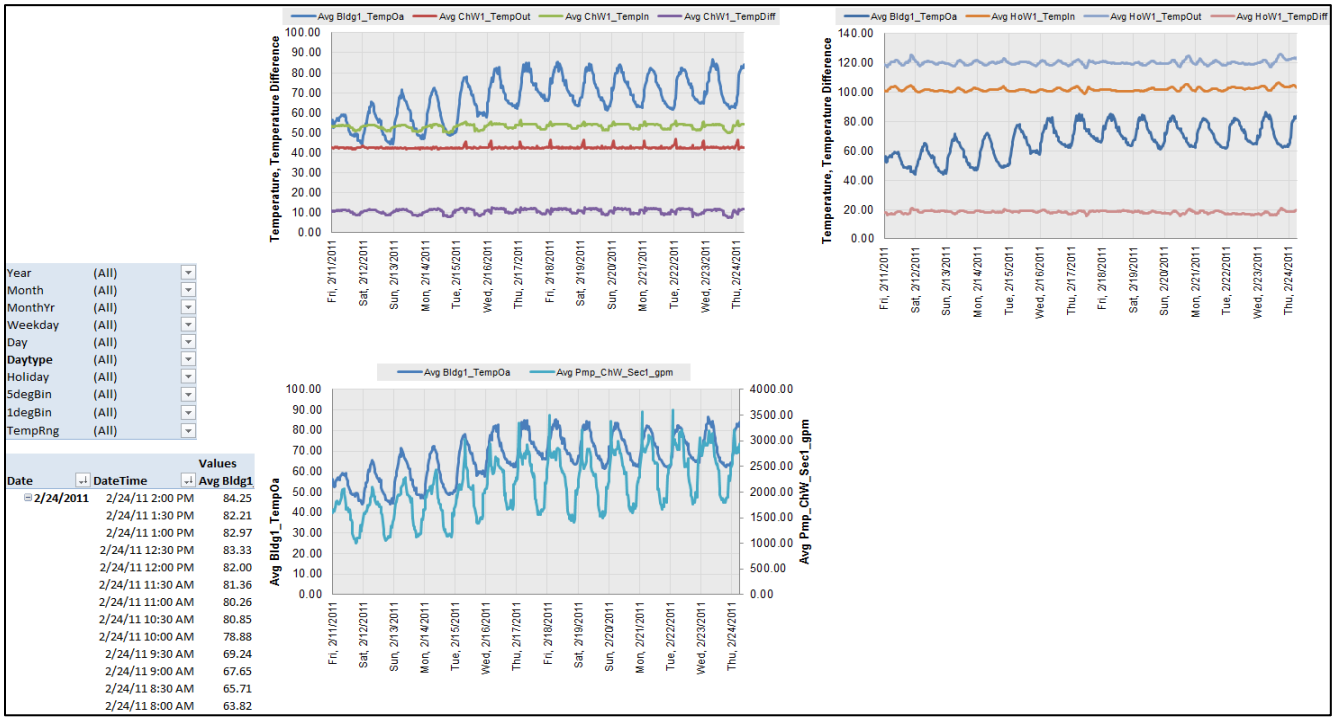


Figure 60: Central plant charts when all points are mapped correctly

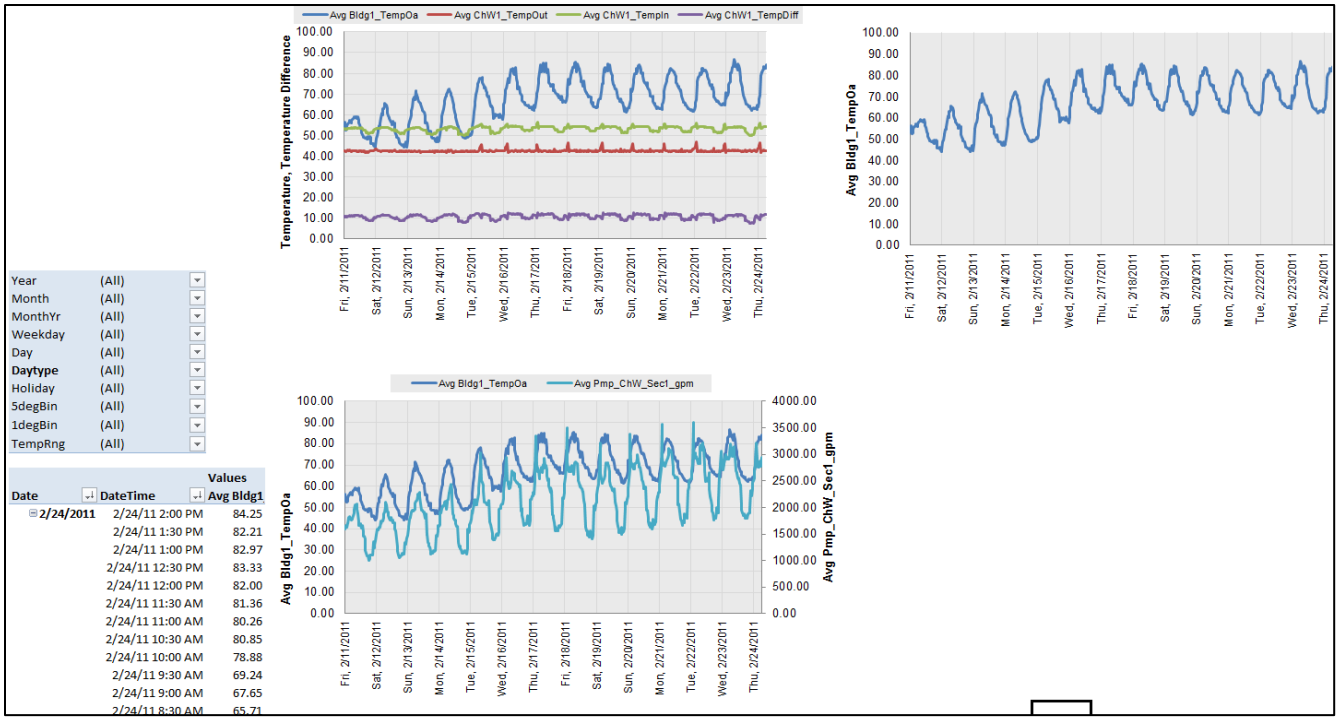


Figure 61: Central plant charts without hot water distribution

You will notice by inspecting the charts that the differential pressure trend was not plotted in any charts. 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 62). Figure 63 shows the corresponding point history chart.

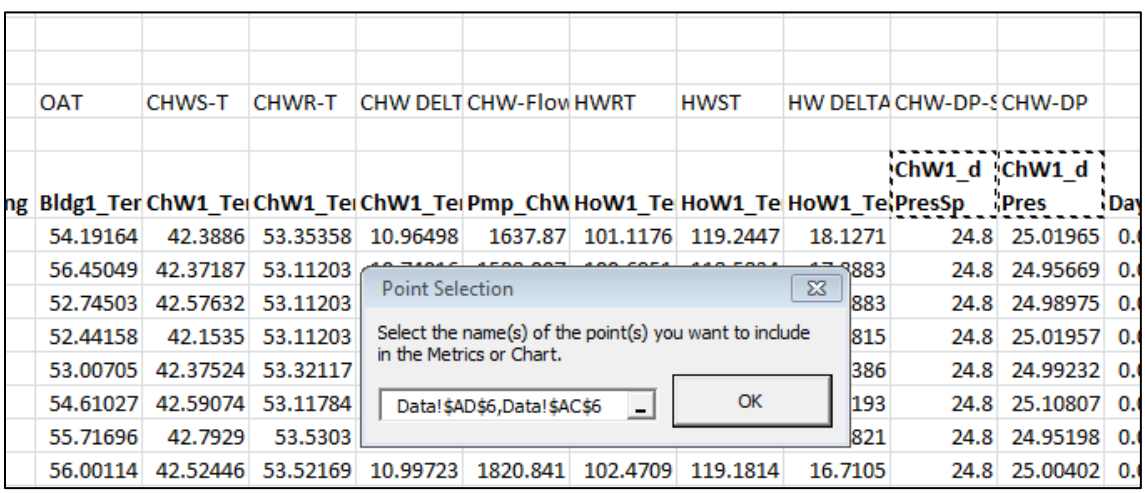


Figure 62: Creating a point history chart for data not included in central plant charts

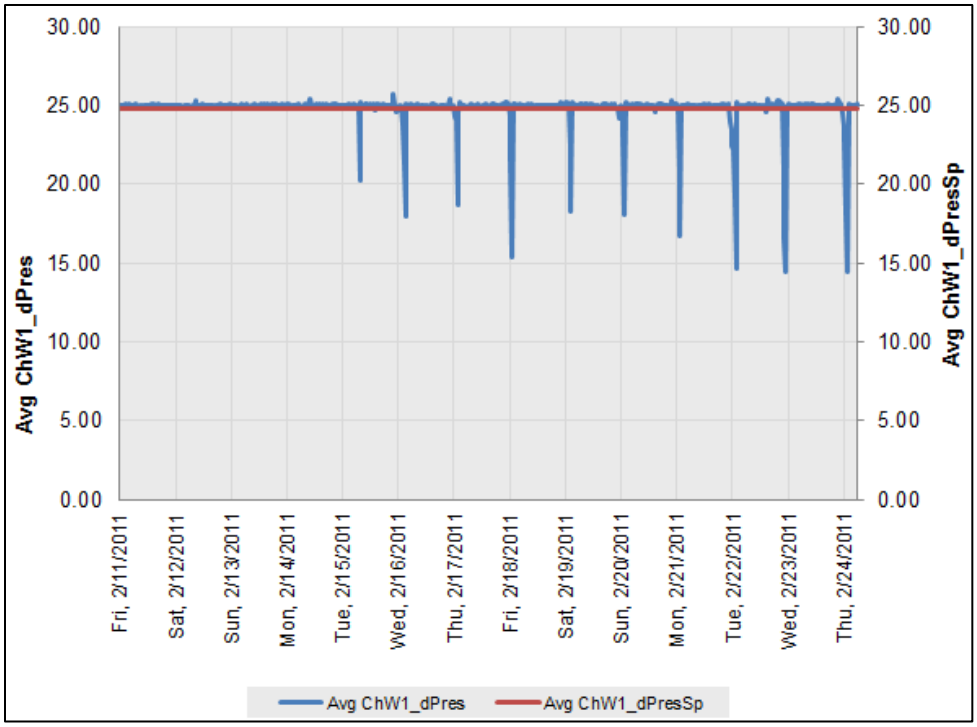


Figure 63: Point history chart for differential pressure and set point

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 looked at, 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:

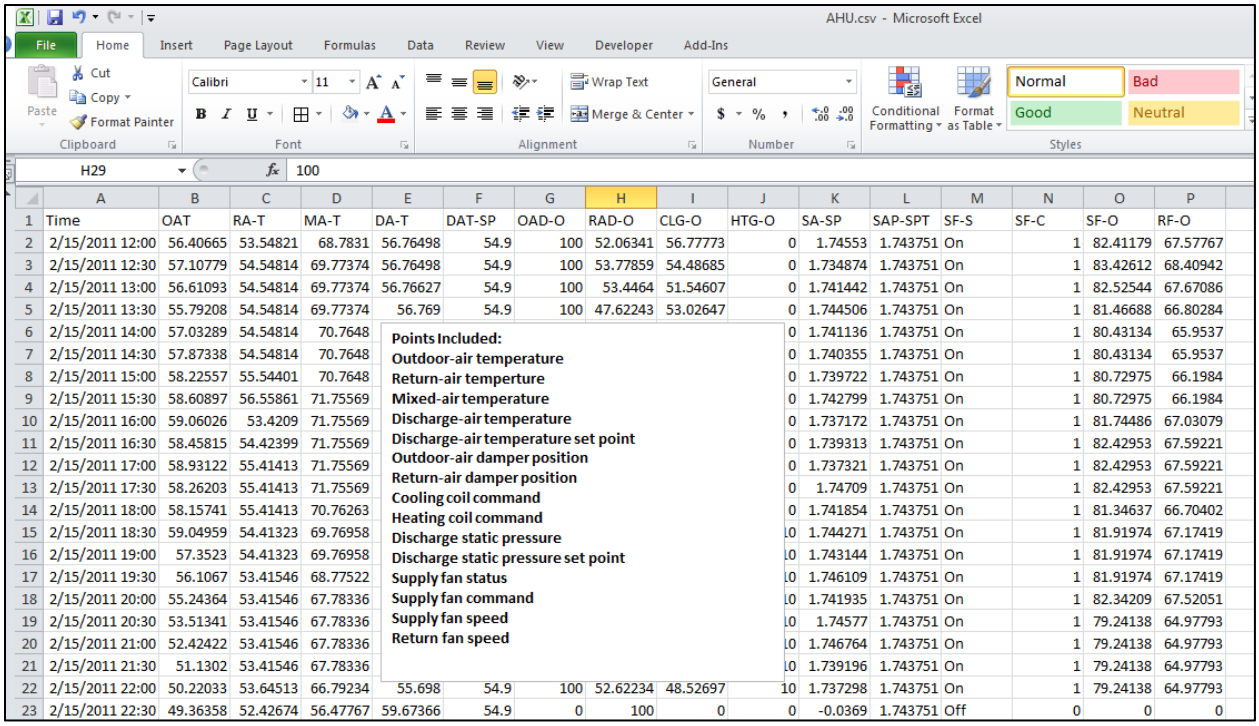
- Outdoor-air temperature
- Mixed-air temperature
- Return-air temperature
- Discharge-air (supply-air) temperature
- Discharge-air temperature set point
- Discharge (duct) static pressure
- Discharge static pressure set point
- Return-air damper position
- Outdoor-air damper position
- Exhaust-air damper position
- Fan status

- Fan Speed (on both supply and return fans, feedback or command)
- Cooling coil valve command
- Heating coil valve command

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

- Outdoor-air, return-air, mixed-air, and discharge-air temperatures vs. time
- Discharge-air temperature and discharge-air temperature set point vs. time
- Outdoor damper position vs. time
- Outdoor- and return-air temperatures, damper position signal(s) vs. time
- Outdoor damper position, cooling coil and heating coil valve commands vs. time
- Outdoor- and return-air damper position signals vs. time
- Discharge (duct) static pressure and set point vs. time
- Supply fan speed, discharge static pressure vs. time
- Return fan speed and status vs. time
- Supply fan speed, return fan speed vs. time

The following example is for an air-handling unit with data trend using a BAS. The point names that are included in the example are listed in Figure 64 below. You can see that columns M, N, and O contain supply fan status, command, and speed. The status is listed as an “On” or “Off” value. It should be noted that 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 importing into ECAM.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Time	OAT	RA-T	MA-T	DA-T	DAT-SP	OAD-O	RAD-O	CLG-O	HTG-O	SA-SP	SAP-SPT	SF-S	SF-C	SF-O	RF-O
2	2/15/2011 12:00	56.40665	53.54821	68.7831	56.76498	54.9	100	52.06341	56.77773	0	1.74553	1.743751	On	1	82.41179	67.57767
3	2/15/2011 12:30	57.10779	54.54814	69.77374	56.76498	54.9	100	53.77859	54.48685	0	1.734874	1.743751	On	1	83.42612	68.40942
4	2/15/2011 13:00	56.61093	54.54814	69.77374	56.76627	54.9	100	53.4464	51.54607	0	1.741442	1.743751	On	1	82.52544	67.67086
5	2/15/2011 13:30	55.79208	54.54814	69.77374	56.769	54.9	100	47.62243	53.02647	0	1.744506	1.743751	On	1	81.46688	66.80284
6	2/15/2011 14:00	57.03289	54.54814	70.7648						0	1.741136	1.743751	On	1	80.43134	65.9537
7	2/15/2011 14:30	57.87338	54.54814	70.7648						0	1.740355	1.743751	On	1	80.43134	65.9537
8	2/15/2011 15:00	58.22557	55.54401	70.7648						0	1.739722	1.743751	On	1	80.72975	66.1984
9	2/15/2011 15:30	58.60897	56.55861	71.75569						0	1.742799	1.743751	On	1	80.72975	66.1984
10	2/15/2011 16:00	59.06026	53.4209	71.75569						0	1.737172	1.743751	On	1	81.74486	67.03079
11	2/15/2011 16:30	58.45815	54.42399	71.75569						0	1.739313	1.743751	On	1	82.42953	67.59221
12	2/15/2011 17:00	58.93122	55.41413	71.75569						0	1.737321	1.743751	On	1	82.42953	67.59221
13	2/15/2011 17:30	58.26203	55.41413	71.75569						0	1.74709	1.743751	On	1	82.42953	67.59221
14	2/15/2011 18:00	58.15741	55.41413	70.76263						0	1.741854	1.743751	On	1	81.34637	66.70402
15	2/15/2011 18:30	59.04959	54.41323	69.76958						10	1.744271	1.743751	On	1	81.91974	67.17419
16	2/15/2011 19:00	57.3523	54.41323	69.76958						10	1.743144	1.743751	On	1	81.91974	67.17419
17	2/15/2011 19:30	56.1067	53.41546	68.77522						10	1.746109	1.743751	On	1	81.91974	67.17419
18	2/15/2011 20:00	55.24364	53.41546	67.78336						10	1.741935	1.743751	On	1	82.34209	67.52051
19	2/15/2011 20:30	53.51341	53.41546	67.78336						10	1.74577	1.743751	On	1	79.24138	64.97793
20	2/15/2011 21:00	52.42422	53.41546	67.78336						10	1.746764	1.743751	On	1	79.24138	64.97793
21	2/15/2011 21:30	51.1302	53.41546	67.78336						10	1.739196	1.743751	On	1	79.24138	64.97793
22	2/15/2011 22:00	50.22033	53.64513	66.79234	55.698	54.9	100	52.62234	48.52697	10	1.737298	1.743751	On	1	79.24138	64.97793
23	2/15/2011 22:30	49.36358	52.42674	56.47767	59.67366	54.9	0	100	0	0	-0.0369	1.743751	Off	0	0	0

Figure 64: 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 be used for analyzing AHUs.

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 “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, and then select the “AHU Charts” under the “PNNL Re-tuning” menu option in ECAM. If all points are mapped correctly, you should see all 10 charts appear in a new sheet labeled “AHU1,” as in Figure 65 below. As with the central plant charts above, if there are any points missing or not mapped correctly, ECAM will skip over them and show either a blank chart or a chart with partial data. As before, the “Point History Chart” should be utilized to chart any other points or combinations of points that are of interest to the user.

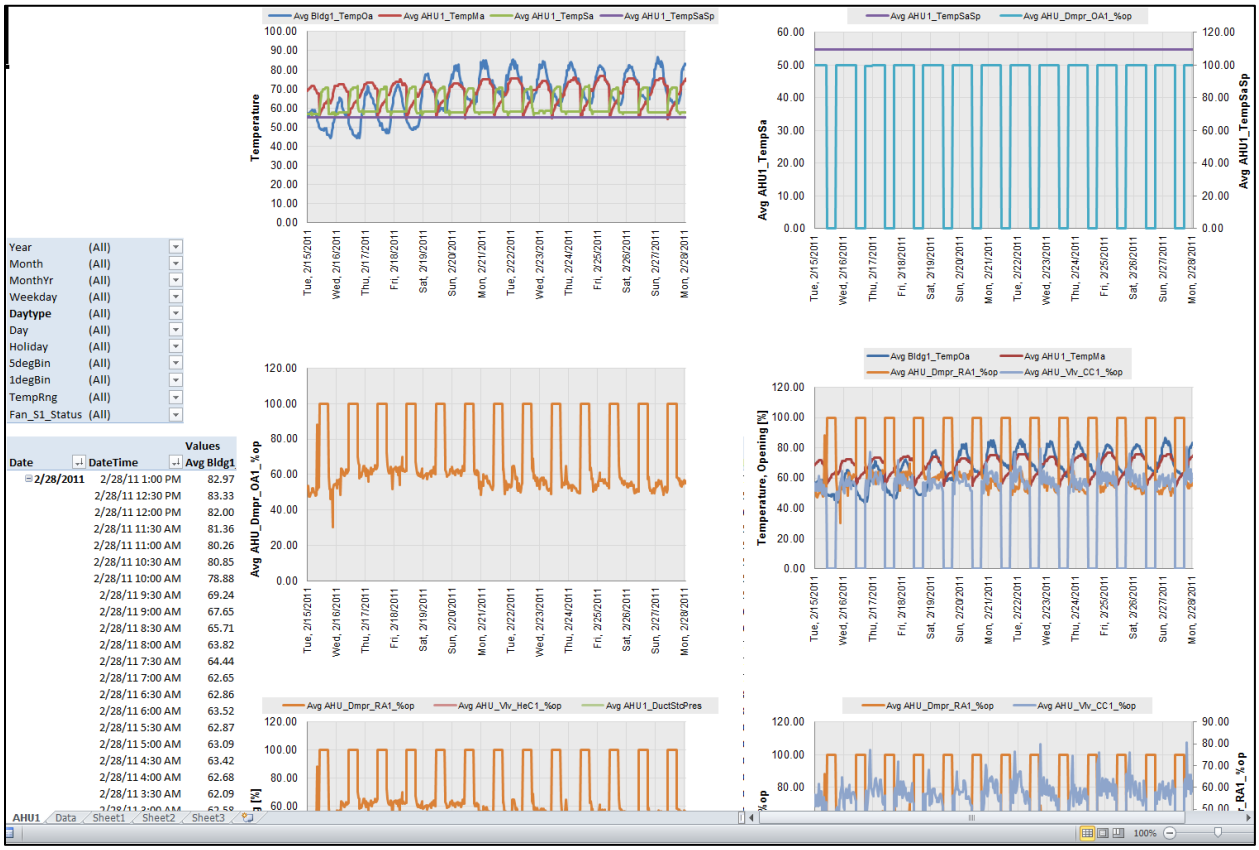


Figure 65: Air-handler charts in ECAM under the PNNL Re-Tuning option

10.3 AHU 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:

- Discharge-air temperature vs. discharge-air temperature set point
- Cooling coil command vs. heating coil command
- Outdoor-air damper command vs. outdoor-air temperature

- Mixed-air temperature vs. outdoor-air temperature

After running this feature in ECAM, another sheet will be created and called “AHUxy1.” It will appear somewhat similar to that in Figure 66.

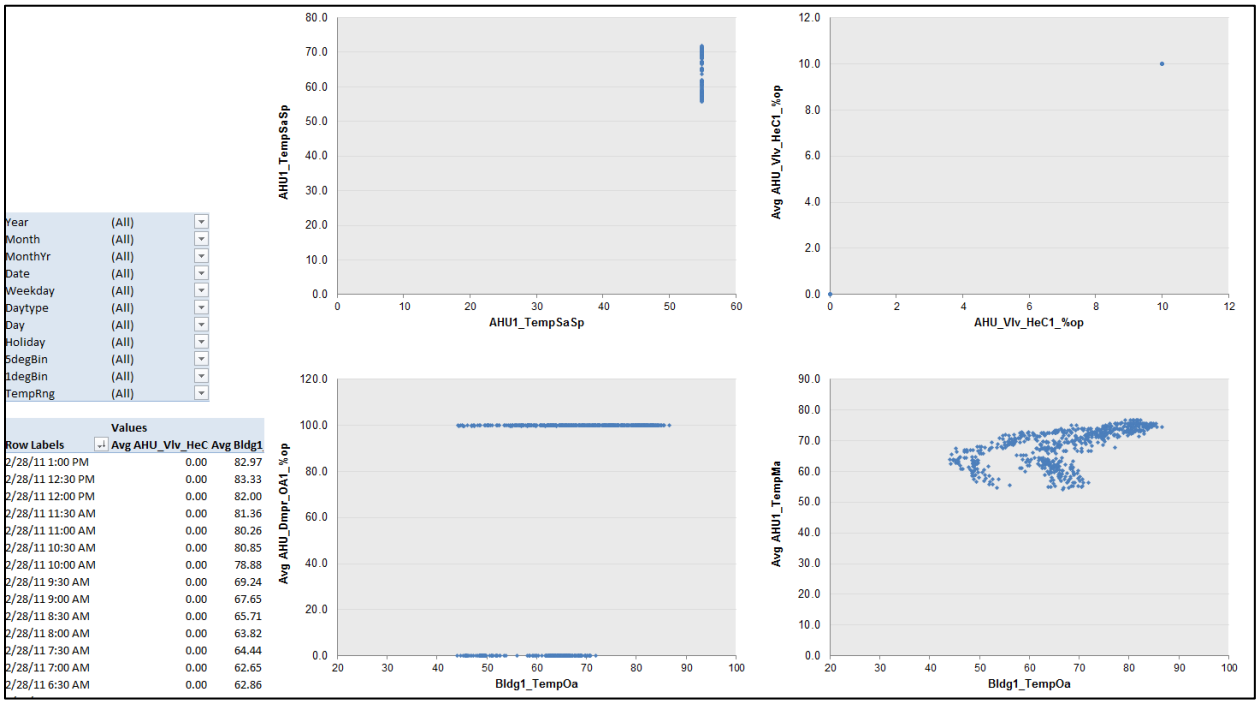


Figure 66: Example of AHU scatter charts in the PNNL Re-Tuning feature of ECAM

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 4.1.1.

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
- 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)

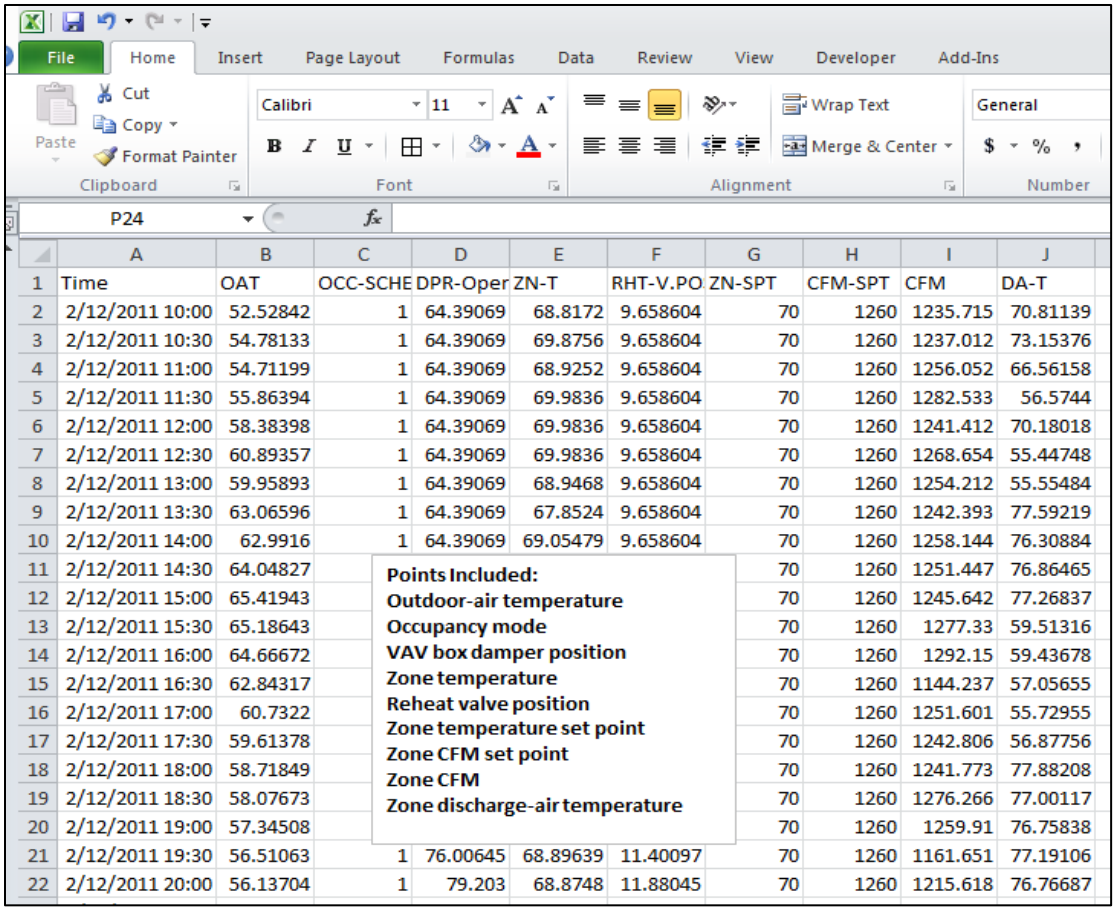
The following time-series charts will be created by ECAM, depending on the availability of the relevant points mapped in ECAM:

- VAV box damper position, reheat valve position, and zone temperature vs. time

It is important to note that each zone will be charted on a separate worksheet, so the "CompID" will need to be indexed for each zone that is mapped in ECAM. Figure 67 below 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 not any 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 68 shows a typical zone plot created in ECAM using the PNNL Re-tuning feature "Zone Charts."



	Time	OAT	OCC-SCHE	DPR-Oper	ZN-T	RHT-V.PO	ZN-SPT	CFM-SPT	CFM	DA-T
2	2/12/2011 10:00	52.52842	1	64.39069	68.8172	9.658604	70	1260	1235.715	70.81139
3	2/12/2011 10:30	54.78133	1	64.39069	69.8756	9.658604	70	1260	1237.012	73.15376
4	2/12/2011 11:00	54.71199	1	64.39069	68.9252	9.658604	70	1260	1256.052	66.56158
5	2/12/2011 11:30	55.86394	1	64.39069	69.9836	9.658604	70	1260	1282.533	56.5744
6	2/12/2011 12:00	58.38398	1	64.39069	69.9836	9.658604	70	1260	1241.412	70.18018
7	2/12/2011 12:30	60.89357	1	64.39069	69.9836	9.658604	70	1260	1268.654	55.44748
8	2/12/2011 13:00	59.95893	1	64.39069	68.9468	9.658604	70	1260	1254.212	55.55484
9	2/12/2011 13:30	63.06596	1	64.39069	67.8524	9.658604	70	1260	1242.393	77.59219
10	2/12/2011 14:00	62.9916	1	64.39069	69.05479	9.658604	70	1260	1258.144	76.30884
11	2/12/2011 14:30	64.04827					70	1260	1251.447	76.86465
12	2/12/2011 15:00	65.41943					70	1260	1245.642	77.26837
13	2/12/2011 15:30	65.18643					70	1260	1277.33	59.51316
14	2/12/2011 16:00	64.66672					70	1260	1292.15	59.43678
15	2/12/2011 16:30	62.84317					70	1260	1144.237	57.05655
16	2/12/2011 17:00	60.7322					70	1260	1251.601	55.72955
17	2/12/2011 17:30	59.61378					70	1260	1242.806	56.87756
18	2/12/2011 18:00	58.71849					70	1260	1241.773	77.88208
19	2/12/2011 18:30	58.07673					70	1260	1276.266	77.00117
20	2/12/2011 19:00	57.34508					70	1260	1259.91	76.75838
21	2/12/2011 19:30	56.51063	1	76.00645	68.89639	11.40097	70	1260	1161.651	77.19106
22	2/12/2011 20:00	56.13704	1	79.203	68.8748	11.88045	70	1260	1215.618	76.76687

Figure 67: Example data set for zones from a BAS

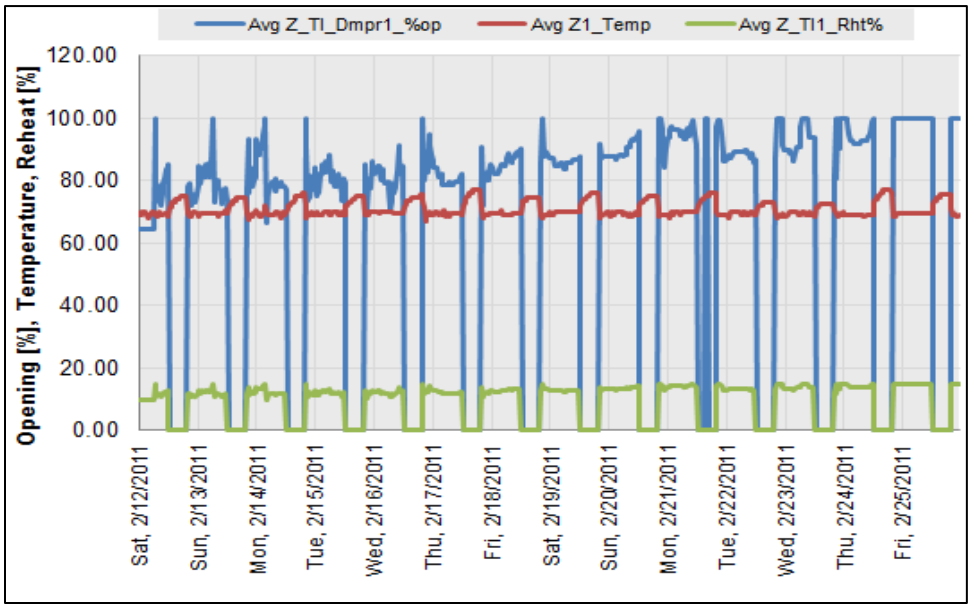


Figure 68: A typical zone chart using the PNNL Re-Tuning feature in ECAM

10.5 Zones Common (compare zones on one chart)

Once the points have been mapped for the zone charts, there is no additional work in creating the "Zones Common" chart in ECAM. The user just needs to go to the PNNL Re-tuning feature in ECAM and select the "Zones Common." This will create one chart that has all of the VAV box damper positions versus time for the building. The following time-series chart will be created by ECAM, depending on the availability of the relevant points mapped in ECAM:

- VAV box damper position vs. time (all zones)

If done correctly, the user will see a chart similar to that in Figure 69 below. For this example, there are only five zones for the air-handler that are plotted on the zones common chart.

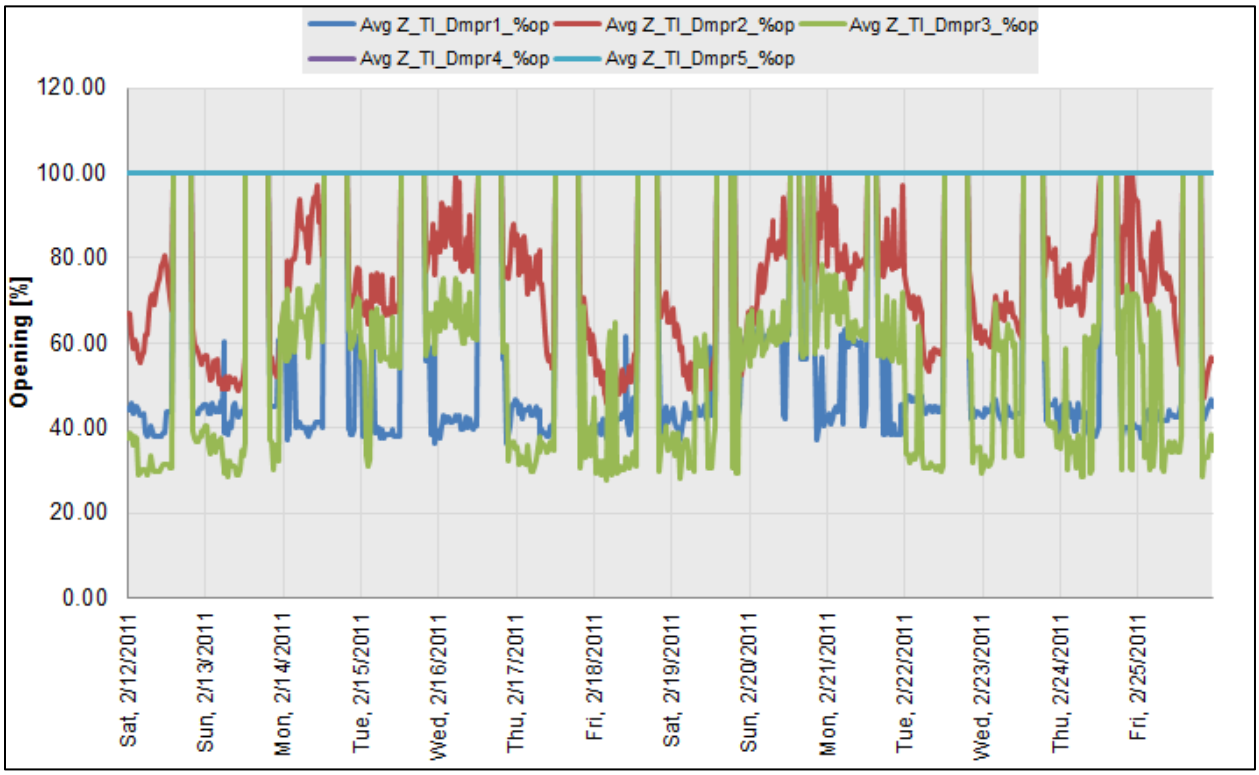


Figure 69: Zones common chart in ECAM's PNNL re-tuning feature

11.0 Regression Modeling with ECAM

These menu items provide the capability to create various types of regression models from the data in ECAM, and use those models for Measurement and Verification (M&V) of energy savings. The most common, 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. The linear and change-point linear models, and associated uncertainty, 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, since there are defaults, but should be used if the defaults are not appropriate for a specific project.

There are three sections for the ECAM Regression Modeling as shown in Figure 70.

1. Measurement and Verification General Inputs
2. Interval Data-Driven Models and M and V
3. Monthly Billing Data Models and M and V.

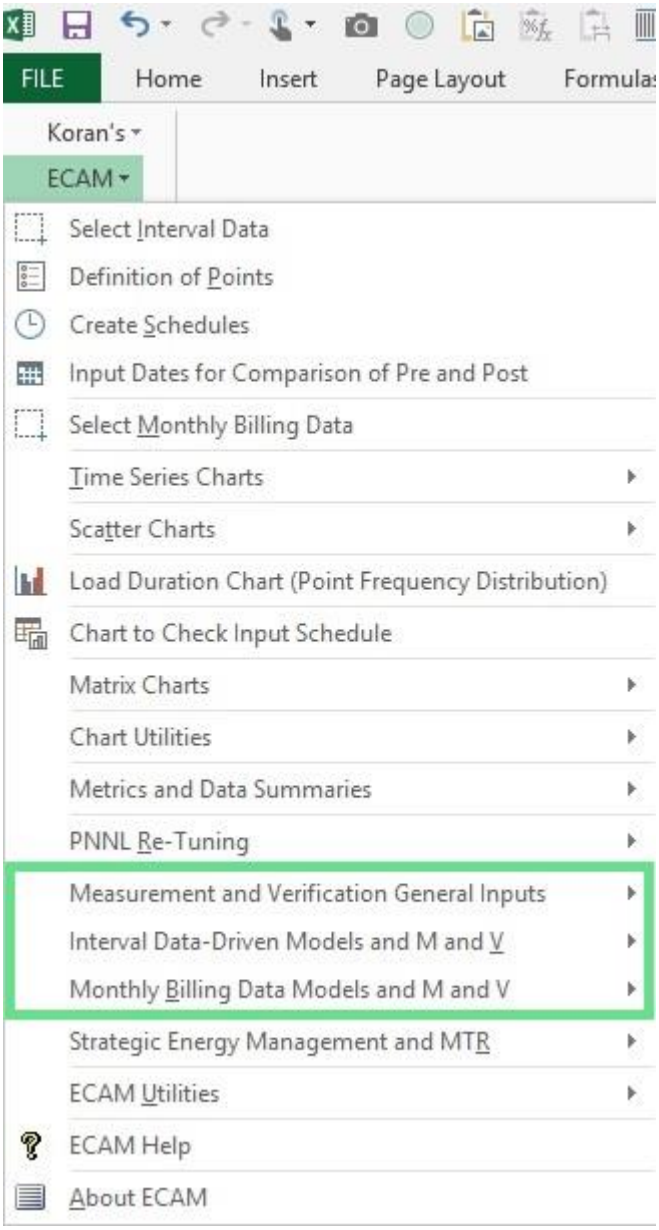
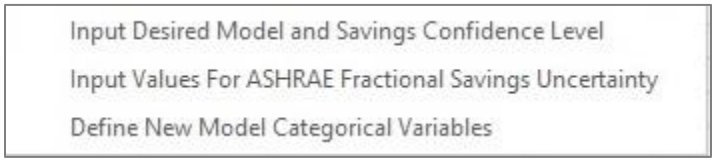


Figure 70: Regression Modeling Menu Sections.

11.1 Measurement and Verification General Inputs



11.1.1 Input Desired Model and Savings Confidence Level

Input Form

This input allows the user to select a confidence level from 50% to 95%. If this input is not used, or the form is closed without selecting a value, a default confidence level of 80% will be used.

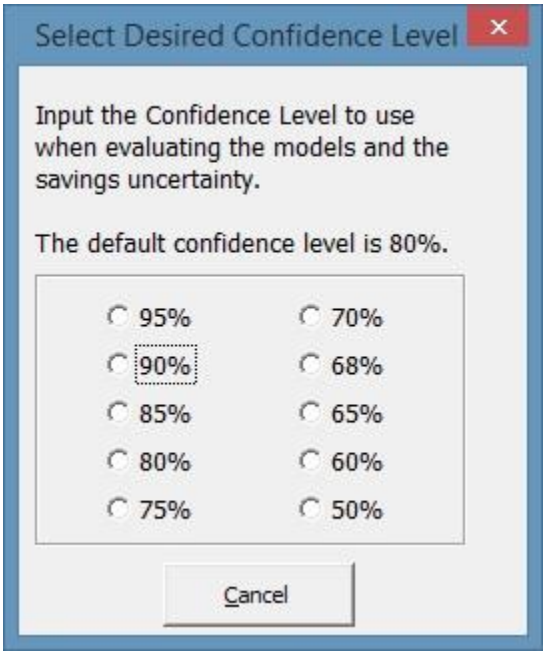


Figure 71: Model Confidence Level Form

Background on Confidence Level

The statistical uncertainty calculations require an input confidence level. Uncertainty is associated with a given confidence level, or probability. E.g. there is a 90% probability that the true value is between 433 and 511. Confidence Level is an input number that establishes how certain we need to be that the range of estimates include the true value. From the Bonneville Power Administration's Regression for M&V: Reference Guide[3]: "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 for M&V: Reference Guide or an appropriate statistics reference.

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

11.1.2 Input Values for ASHRAE Fractional Savings Uncertainty

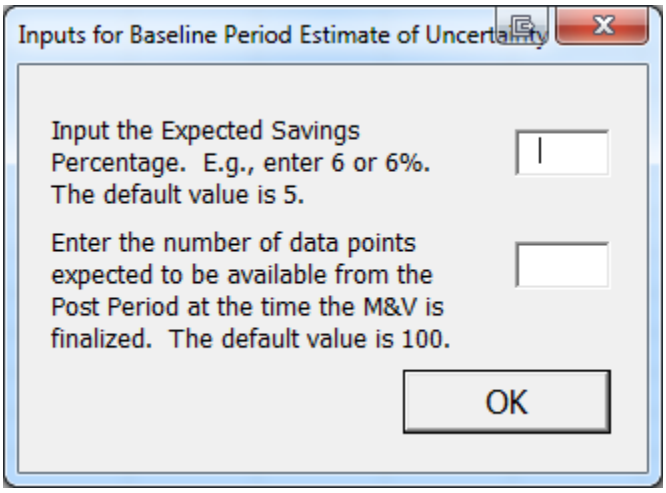


Figure 72: Fractional Savings Uncertainty Inputs

"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 since 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, since 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.

11.1.3 Define New Model Categorical Variables

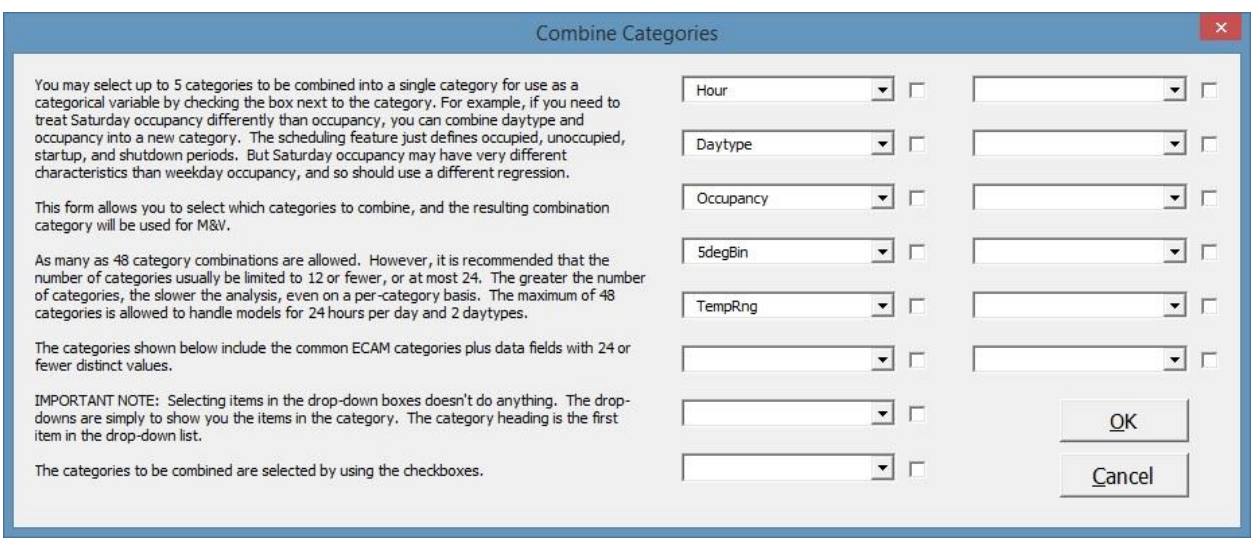


Figure 73: Form to Define New Model Categorical Variables

This menu item brings up Figure 73, which contains a set of drop-down boxes (ComboBoxes) and check boxes. In this case, the drop-downs are there just to provide visibility to the items into the category; selecting items in the drop-downs doesn't have any impact. The starting categories shown above include the common ECAM categories plus data fields with 24 or fewer distinct values.

To create a new category, two or more of the existing categories must be selected using the checkboxes. You may select up to 5 categories to be combined into a single category for use as a categorical variable. For example, if you need to treat Saturday occupancy differently than occupancy, you can combine daytype and occupancy into a new category. The scheduling feature just defines occupied, unoccupied, startup, and shutdown periods. But Saturday occupancy may have very different characteristics than weekday occupancy, and so should use a different regression.

This form allows you to select which categories to combine, and the resulting combination category will be used for M&V. After the OK button is checked, an additional data field called "ComboCats" is created on the "Data" worksheet. The records in this field are used for the modeling.

As many as 48 category value combinations are allowed. However, it is recommended that the number of categories usually be limited to 12 or fewer, or at most 24. The greater the number of category combinations, the slower the analysis, even on a per-category basis. The maximum of 48 categories is allowed to handle models for 24 hours per day and 2 daytypes. ECAM provides a warning if more than 12 category values are created, and a stronger warning of more than 24 category values are created.

Other constraints perhaps should be included, but are not at this time: Suppose the user has selected to model by Daytypes, via the form shown in Figure 79. Selecting to model by Daytypes does not preclude the user from selecting "Hour" as one of the categories to combine. Or, a user could include Occupancy as a category to combine, but choose to model by Daytype. Some of these possibilities will not make sense, but no other issues were found during testing. However, as a new feature, it is possible there will be some issues if selections are unusual.

11.2 Interval Data-Driven Models and M&V

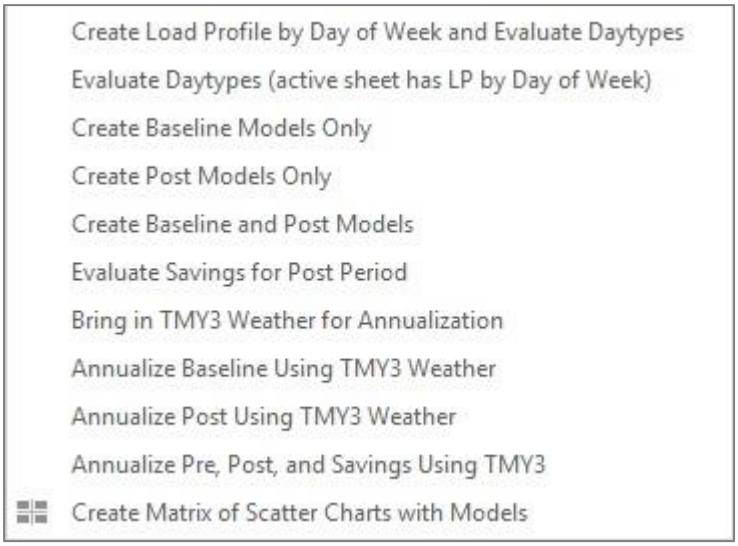


Figure 74: Interval Data Models Menu Items

11.2.1 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.

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.

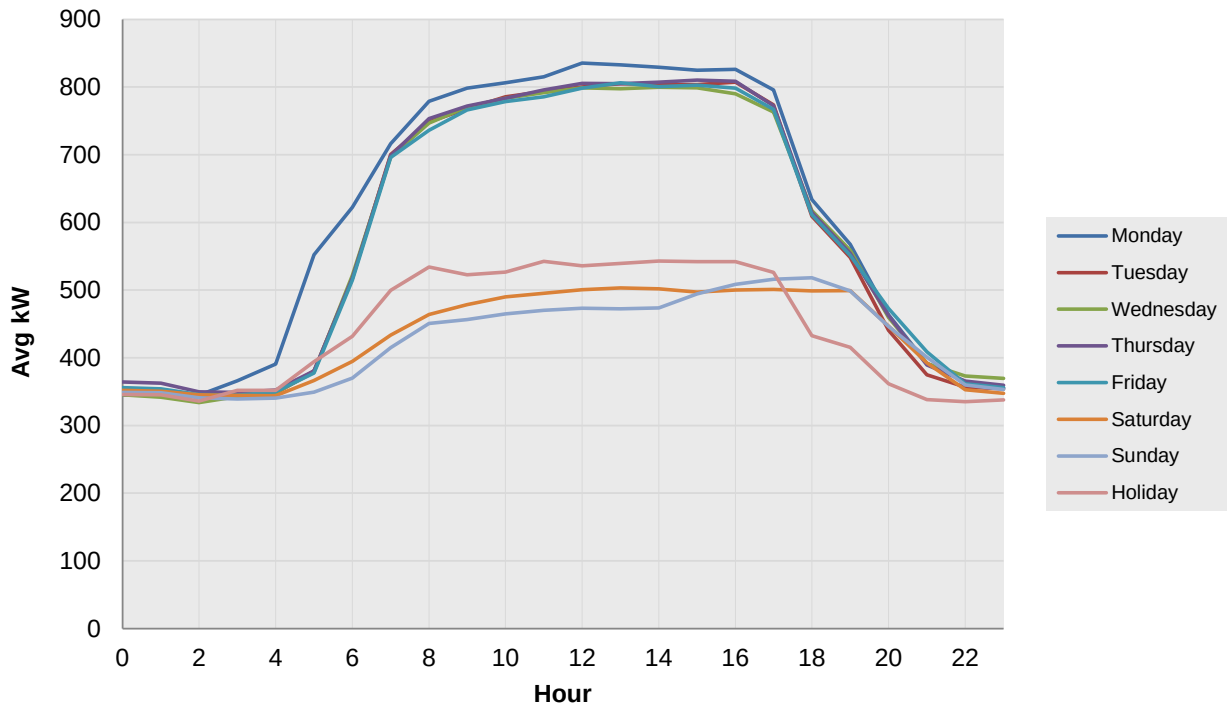


Figure 75: Load Profile by Day-of-Week

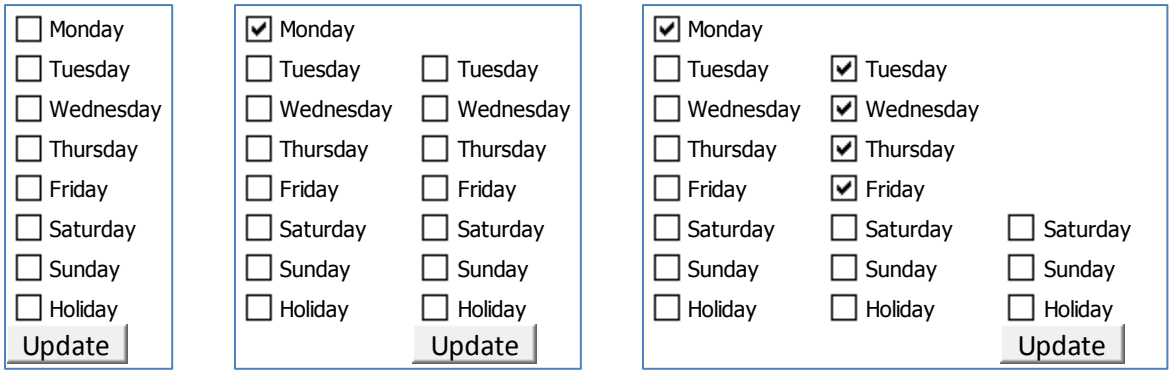


Figure 76: Daytyping Selections Progression

Place a checkmark for each day associated with an individual daytype, then click the update button. In Figure 75 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 pushed, 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 pushed, 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 77.

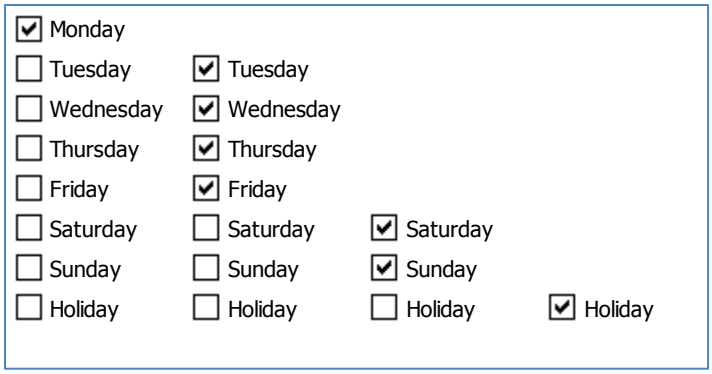


Figure 77: Final Daytype selections.

In this case 4 custom daytypes were created.

11.2.2 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.

11.2.3 Create Models (for Baseline and/or Post Periods)

Ordinary linear and ASHRAE change-point linear models are available.

The models use a combination of continuous and categorical variables, e.g. outdoor temperature and daytype. You will be prompted for how you want to categorize the data by the form shown in Figure 78.

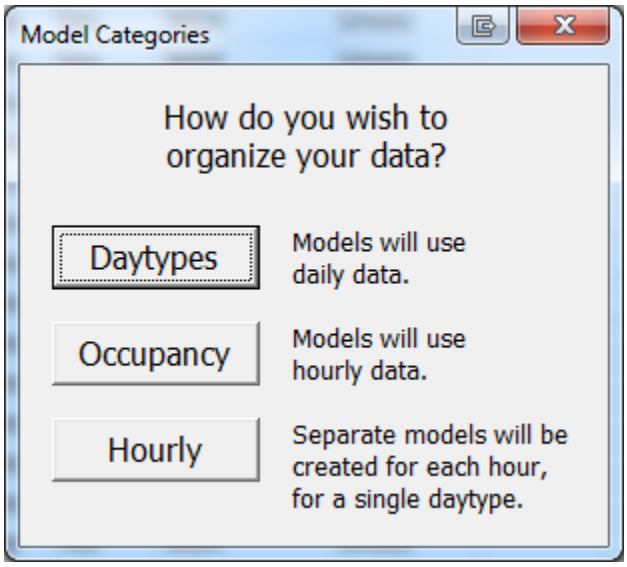


Figure 78: Data Categorization for Models

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 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," then 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," then 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 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.

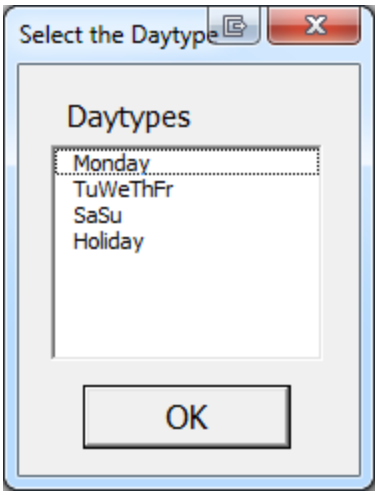


Figure 80: Daytype Selection for Hourly Model

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 4.0.)

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 in Figure 79: 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 79.

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.

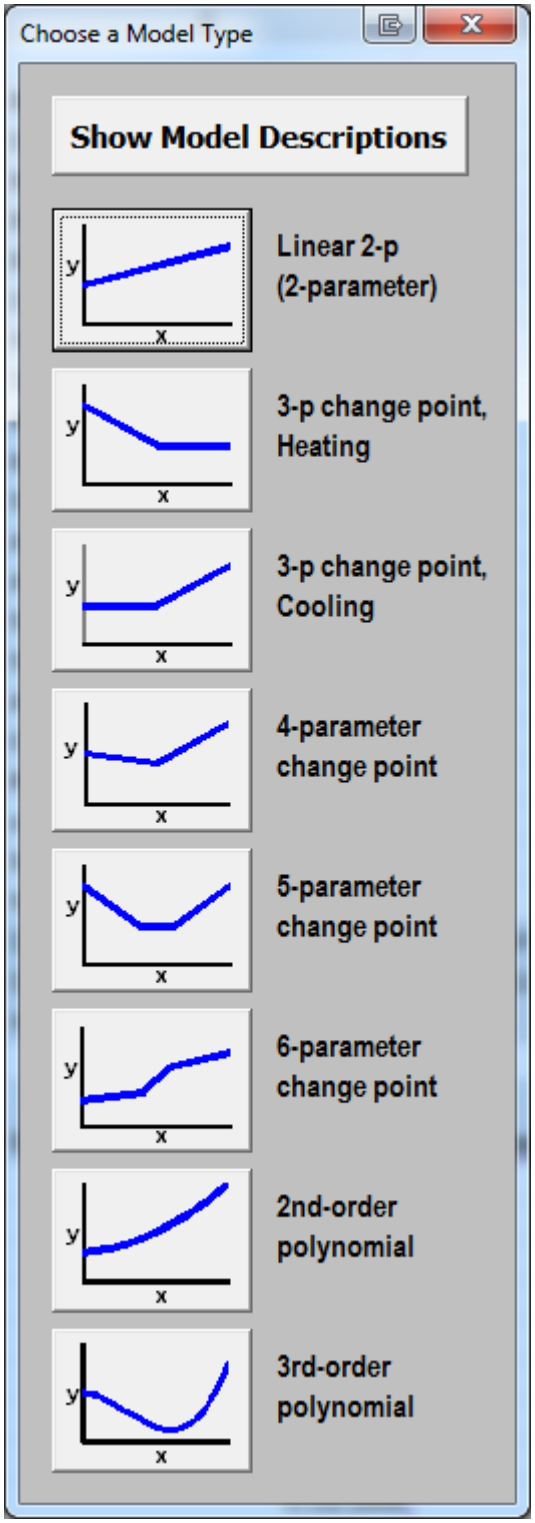


Figure 79: Model Selection

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 Input Dates for Comparison of Pre and Post) this selection will model all of the data.

For distinguishing between Pre and Post time periods, the M&V tools use the following keywords in the DateRng column of the "Data" worksheet.

- Pre-Baseline
- Baseline
- During Changes
- Post Period
- After Post Period

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.)

Create Post Models Only

This is similar to Create Baseline Models Only, but will create a statistical model of the building or equipment performance for the post period.

Create Baseline and Post Models

This is similar to Create Baseline Models Only, but will create statistical models of building or equipment performance for both the baseline and post periods.

11.2.4 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. Figure 81 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}.

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

Figure 81: Table of Daily Savings

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

Here is a similar output for a savings by occupancy period analysis:

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

Figure 82: Table of Hourly Savings

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 since 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. Figure 83 shows a summary savings table for the savings by daytype:

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

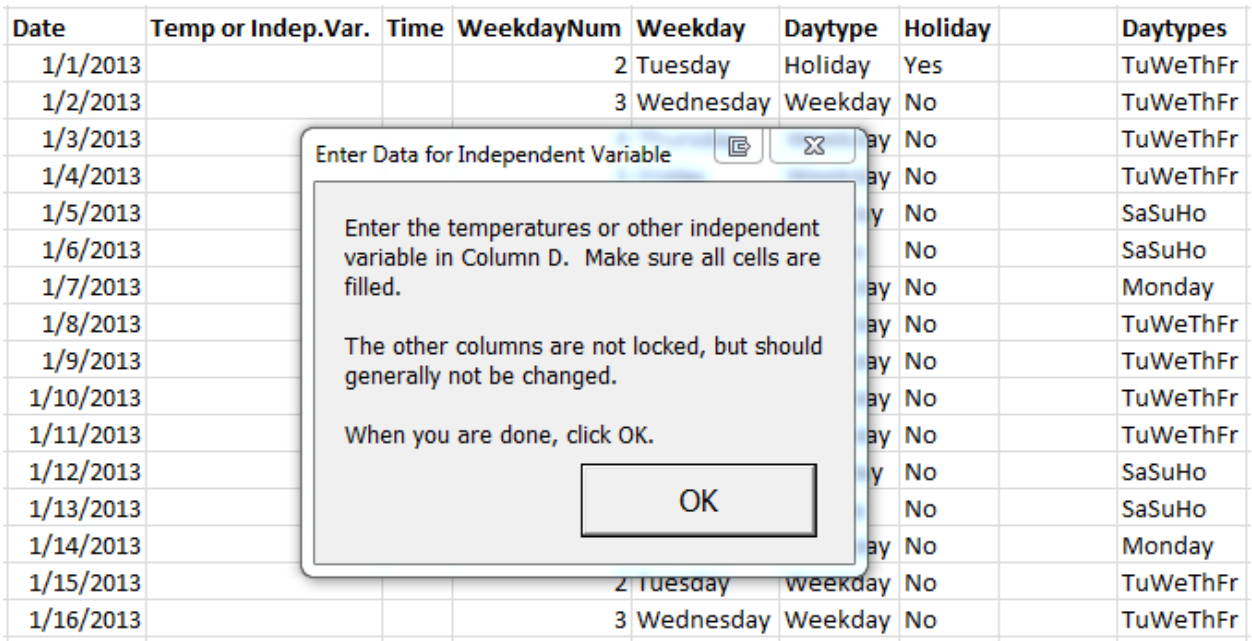
Figure 83: Savings Summary Table

11.2.5 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. Since 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 84. (This example is for savings by daytype; the table is slightly different for savings by occupancy period.)



Date	Temp or Indep.Var.	Time	WeekdayNum	Weekday	Daytype	Holiday		Daytypes
1/1/2013			2	Tuesday	Holiday	Yes		TuWeThFr
1/2/2013			3	Wednesday	Weekday	No		TuWeThFr
1/3/2013					ay	No		TuWeThFr
1/4/2013					ay	No		TuWeThFr
1/5/2013					y	No		SaSuHo
1/6/2013						No		SaSuHo
1/7/2013					ay	No		Monday
1/8/2013					ay	No		TuWeThFr
1/9/2013					ay	No		TuWeThFr
1/10/2013					ay	No		TuWeThFr
1/11/2013					ay	No		TuWeThFr
1/12/2013					y	No		SaSuHo
1/13/2013						No		SaSuHo
1/14/2013					ay	No		Monday
1/15/2013			2	Tuesday	Weekday	No		TuWeThFr
1/16/2013			3	Wednesday	Weekday	No		TuWeThFr

Figure 84: 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.

11.2.6 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 for this; just select the menu item after creating the baseline models and bringing in the TMY (or other independent variable) data as per Section 11.2.5 Bring in TMY3 Weather for Annualization.

The projection is the same as described in Section 11.2.4 Evaluate Savings for Post Period, 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:

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	

Figure 85: Table of Typical Annual Baseline Projections

11.2.7 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 11.2.5 Bring in TMY3 Weather for Annualization.

This is the same as annualizing the baseline, but it uses the models for the post period. 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.

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

Figure 86: Table of Typical Annual Projection of Post Period

11.2.8 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 11.2.5 Bring in TMY3 Weather for Annualization.

This annualizes both the baseline and the post, using the models developed for each. It then calculates the annual savings and uncertainty (Figure 87 and Figure 88).

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

Figure 87: Typical Year Projection of Baseline and Post by Time Interval

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

Figure 88: Summary of Typical Year Projections and Savings

11.2.9 Create Matrix of Scatter Charts with Models.

For better understanding of the differences in models for each category, e.g. for each daytype, each occupancy period, or each hour, it is useful to have each of these "sub-models" in one place, contiguous to each other. This menu item creates a matrix for each of the sub-models on a given modeling worksheet. Therefore, it can be used when a worksheet with the baseline models is active, or when on a worksheet containing the post period models.

Figure 89 is an example matrix for a set of hourly models.

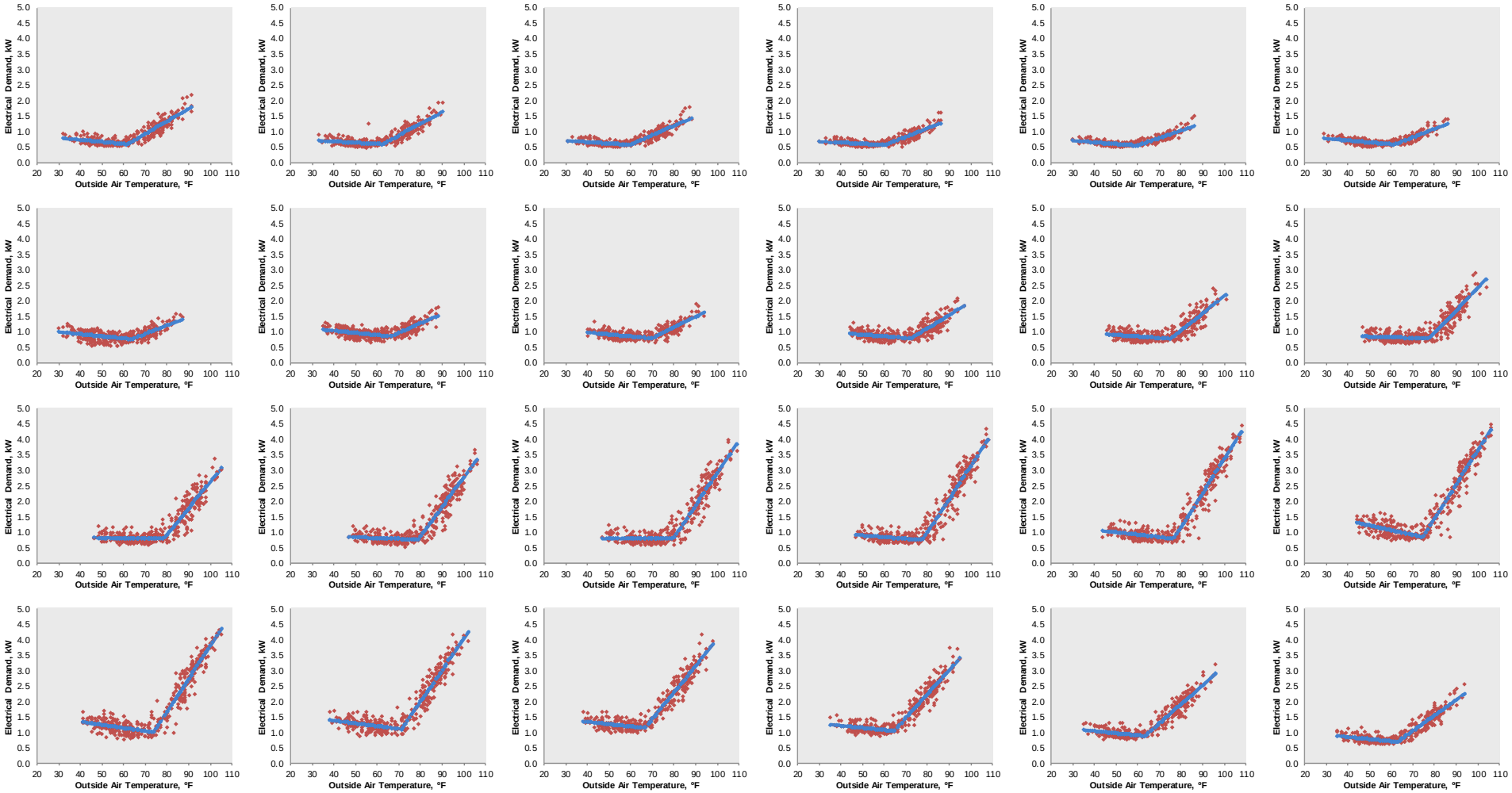


Figure 89: Matrix of Hourly Models, kW versus Temperature, for a Large Group of Homes

11.3 Monthly Billing Data Models and M&V

Making models using monthly billing data is very similar to using interval data. The changes to the process are that:

- The average temperature over the billing period must be calculated before creating the ECAM file.
- The data must be organized in a specific fashion before creating the ECAM file.
- The ECAM menu item to "Select Monthly Billing Data" is used.

Calculating the average temperature over the billing period is easily done using the procedure described in Section 13.2 Resample to Get Avg Temp for Billing Data.

The required organization for the billing data is shown in Section 2.5 as well as the form used to select the data.

ECAM will automatically perform the unique calculations needed for models based on monthly billing data:

- All days of the week are combined into a single daytype.
- The modeling is done using energy use per day in the billing period.
- Billing periods with more days are appropriately weighted more than billing periods with fewer days so that there is no bias in the modeled monthly total energy use.

Other than those changes, modeling by billing period is identical to modeling using interval data. Since all days of the week or combined into a single daytype, there is no need for any other daytyping. Hence, the menu for models based on monthly billing data is very similar to the menu for models based on interval data, except for the exclusion of the daytyping items and the item to matrix the model charts. There is usually only a single model chart from billing data, so there is no need to matrix the charts.

It is especially important to not over-specify the model. Use the simplest model possible as described in the Section 11.4.

11.4 Guidance on Selecting and Developing Data Models

Some model development guidance is provided in this section. For more information refer to the BPA *Verification by Energy Modeling Protocol*.

In selecting a model, use the simplest model that reasonably matches the data. This means you should use a model with as few parameters as will reasonably fit the data.

In general, data sets with relatively few data points, and/or a relatively narrow range of the independent variable, 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.

This guidance is especially important when modeling with monthly billing data. There may never be a need for a 6-parameter model with monthly data, and such a model is seldom needed even with daily data. However, even with monthly data a 5-parameter model can be useful in some circumstances. W**hen using higher-parameter models with monthly data, the model should be built on 2 or more years of data. It is not appropriate to use a 5-parameter model when only 12 monthly data points are available.**

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. Often, a building or residence with heat pumps will use a 5-parameter model even with monthly data. Sometimes a 4-parameter model will suffice. (If the heating and cooling setpoints are spaced apart, the data will show a 5-parameter shape; if the setpoints are close together, a 4-parameter model will suffice because there won't be the flat section at the bottom.) But since this detailed information about the site 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 using interval data, 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, then models created using hourly intervals may have bias, especially when projecting the models to the post period or to an annual basis.

11.4.1 Before You Begin

The following information pertains to developing regression models with temperature as the primary independent variable and daytypes or another parameter is the categorical variable. These instructions are generally applicable for situations where a different parameter than temperature is the primary independent variable. Just substitute the appropriate variable where outside air temperature is indicated here.

You should have the following available before starting:

- ECAM Add-in (Of course!) See the installation instructions at the beginning of this document.
- Actual (not typical or bins) outside air temperature for the entire period of analysis. The temperature data should be at the same or higher frequency than the anticipated frequency to be used for the modeling. If hourly models are used, the temperature data should be hourly, or sufficiently close to hourly that interpolation will provide a reasonable temperature. If modeling based on monthly billing data, then at least daily average temperatures will be needed, so that the average temperature over the actual billing period can be calculated. Hourly temperature data could also be used.
- If this is post-project, and you are estimating savings, you will need the dates your energy efficiency project installation began and ended. You will enter these dates as described in Section 2.4. ECAM will automatically exclude the installation period from the energy models.
- TMY3 data will be needed if calculating IPMVP Normalized Savings. There is a companion file that has all of the TMY3 data for the Pacific Northwest that will provide data summarized by hour, by day, or by month. The companion file will have a name something like,
  "TMY3-2013-07-08plusWRCC.xlsm" or "TMY3selector-aggregator-emu.xlsm"

  Other TMY3 data can be found at
  http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

  Long-term average Daily (and Monthly) data can also be found at
  http://www.wrcc.dri.edu/summary/ but TMY3 data should be preferred since it may better include the ranges of temperatures as well as the averages.

11.4.2 Step-by-Step Instructions for Creating Models and Estimating Savings

STEP ONE: Gather and Format the Necessary Data

Get interval energy or demand data for the time period you are analyzing. ECAM will automatically roll up short-interval (e.g. 15-minute) data to the requested modeling See Figure 78: Data Categorization for Models.

For baseline models, when available, it is generally best to use time periods of one year. Other periods may skew the baseline. Also, note that IPMVP does not presently allow for extrapolation, so if you intend for the analysis to be adherent to IPMVP, you may need a full year of data unless the post period conditions (e.g. outside air temperature) are included in the available baseline data.

Obtain interval outside air temperature for the site. You can use the ECAM capability described in Section 13.1 Resample Data to match up the timestamps for the energy data and temperatures before creating the ECAM file.

STEP TWO: Create the ECAM File

Follow the instructions in Section 2.1 Select Interval Data. Note the instructions on using the keyboard to select all the contiguous data. Note that our data does include ambient temperature, so click yes when prompted, then click anywhere in the column that has outside air temperature.

As mentioned in Section 2.1, a new file is created. It is a good idea to save the file at this time. Note that the file must be saved in .xlsm format; ECAM files won't work without macros. Name the file something descriptive. I usually have both "ECAM" and something indicating the project in the filename.

STEP THREE: Harness the Power of ECAM! (Review the Data)

Like any analysis tool, ECAM is only as good as its inputs. Luckily, ECAM has some really neat built-in ways to sanity check the data. This step seems optional, but a quick review before analysis can catch problems before you start! It is very highly recommended to look at these graphs before every analysis. Data problems that might be identified include incorrect project dates, major usage changes in baseline, even projects that were never turned on.

1. *If this is a baseline model only, skip this step.*
   If this analysis includes baseline and post, input the project dates. Under the ECAM menu, "Input dates for comparison of pre and post".
   - Tip! You need to know when project installation started and stopped. For a major project, this could be several months, but it could also be just one day.
2. Plot Energy and Temperature over time
   - Go to ECAM > Time Series Charts > Point History Chart (See Section 3.11.0
     - Select the column for temperature
     - Hold the Control key ("Ctrl") and select the column for energy
   - A new tab called **chtHistory** will pop up.
     - Interval data will look very "spiky", as shown in Figure 90:

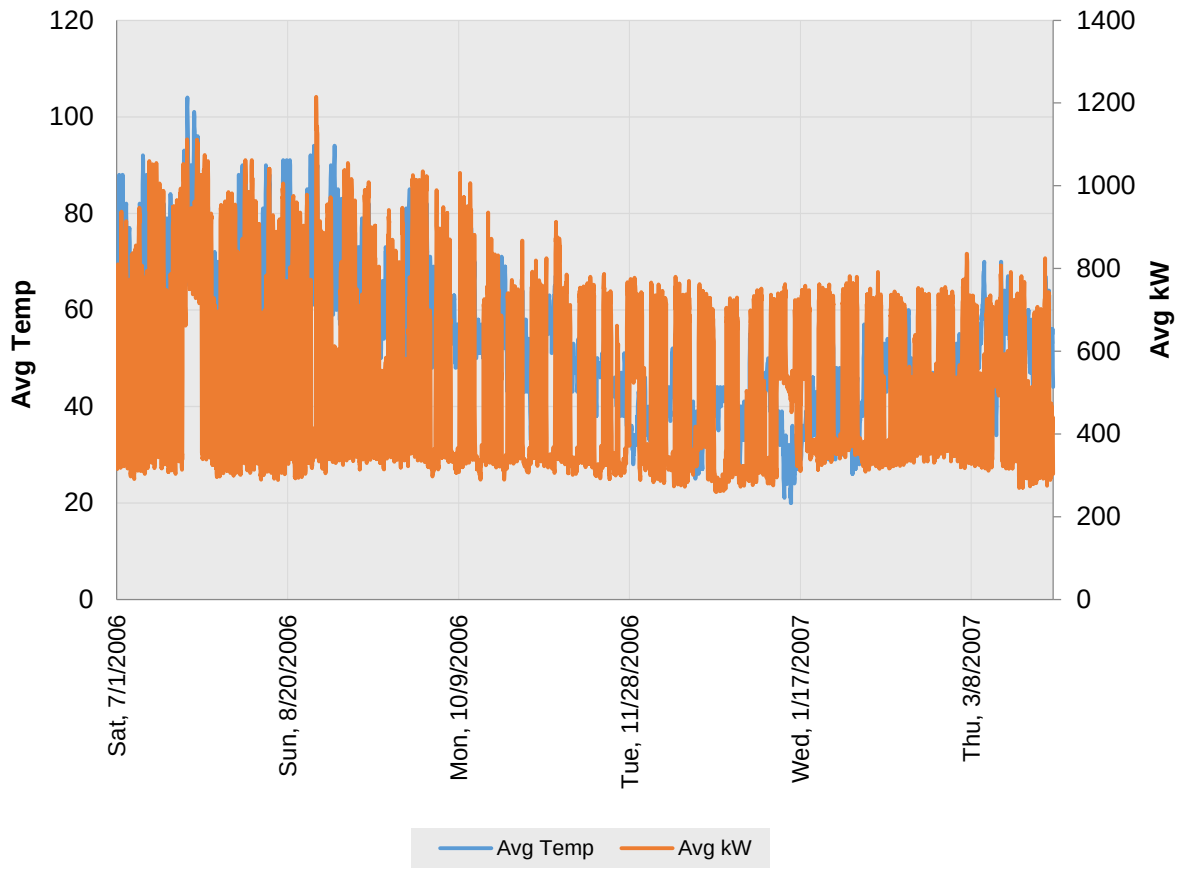


Figure 90: Points History Chart of Temperature and kW

- Review this graph to make sure you get the results you expect. For cool, heating-dominated climates, lower temperature will generally correlate with higher energy use. The converse is true for warm climates.
- One specific check is to make sure there are not gaps or bad points in the temperature data (or the energy/power data.) Watch for unusually high, unusually low, or missing values. Many sources for weather data will use a very negative number (e.g. -999) for bad or missing data. Plotting the data beforehand will make it easier to spot this bad or missing data.

➢ Tip! If plotted consumption data increases every day (see below), it may indicate you are using the cumulative meter read, not the reads for individual timestamps.

➢ Tip! You can convert the short-interval data to daily data by using the scatter chart (!) option described in Section 4.1.3 Toggle Scatter between all Timestamps and Aggregated Values. At first the chart may appear blank. You will need to change any one of the PivotFields briefly—change it then change it back—and then you will get a chart with the data aggregated to the daily level. See Figure 91.

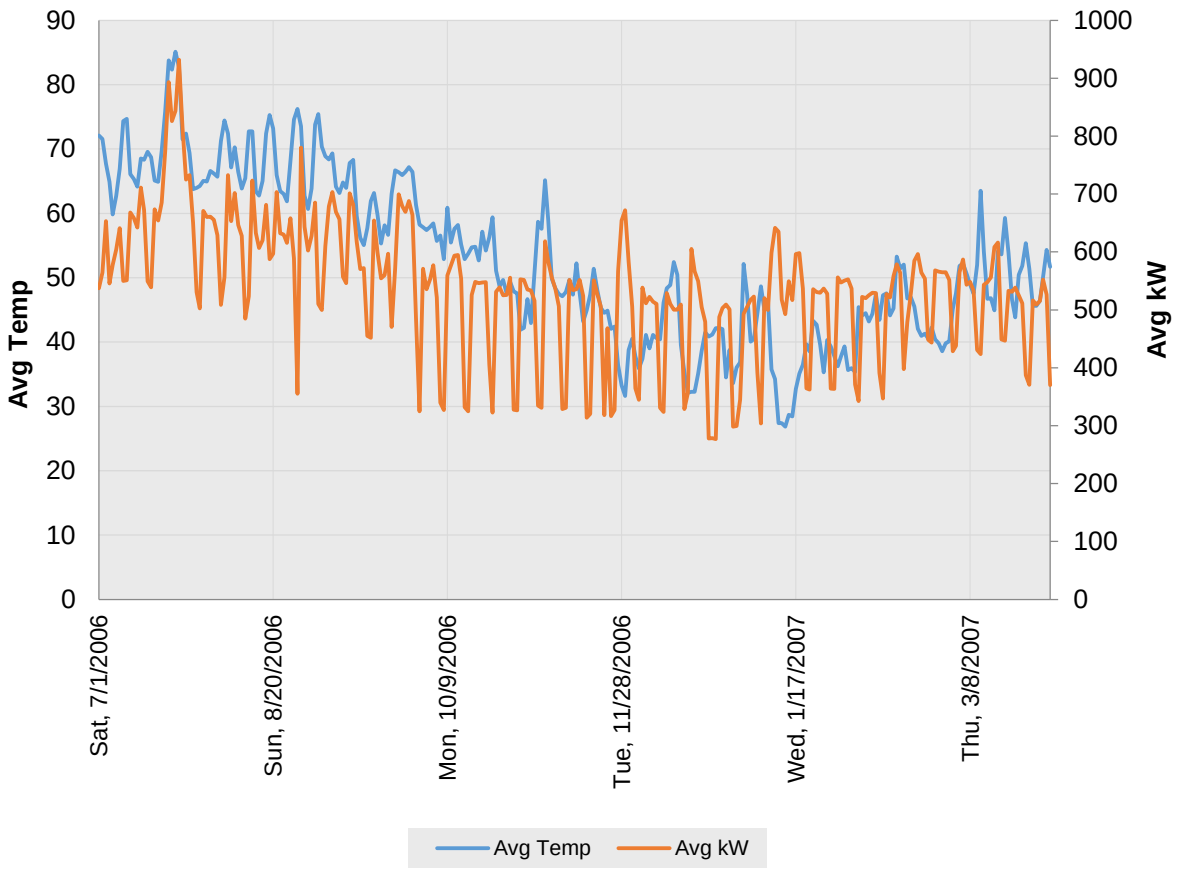


Figure 91: Points History Chart of Temperature and kW, aggregated to the Daily Level.

3. Plot Energy vs. Temperature
    - If this is a pre/post model, go to ECAM > Scatter Charts > Scatter Chart by Date Range (Pre/Post)
        - Select temperature as your independent variable and energy as your dependent variable
        - Select the column for temperature
        - Hold the Control key ("Ctrl") and select the column for energy
    - If this is a baseline only model, go to ECAM > Scatter Charts > Scatter Chart by Occupancy
        - Select temperature as your independent variable and energy as your dependent variable:
        - Select the column for temperature
        - Hold the Control key ("Ctrl") and select the column for power or energy.
    - Review this graph to make sure you get results you expect.
        - For an all-electric building, there will be a clear correlation of energy and temperature. Energy will be higher when temperature is lower and flatten

as temperature rises. Buildings with mechanical cooling (AC) will show an increase in energy as temperatures rise again.

- For a gas-heated building, points may be more scattered. ECAM should only be used for large projected savings (as a percentage of baseline) in this type of building.

STEP FOUR: Model the Data

1. (This step is not used with monthly billing data.)
   Group Days (This is shown in Section 11.2.1 Create Load Profile by Day of Week and Evaluate Daytypes)
   - ECAM can break out usage by any day of the week, or group of days. While most commercial buildings don't have different usage profiles every day of the week, a common case has similar usage Monday through Friday and Saturday/Sunday/holiday. Separate models can be created for these groupings.
   - *Unless you are using the default daytypes, you need to do this step. Even if you aren't going to separate usage by day of week, you have to do this step to combine all the days of the week into a single daytype.*
   - Go to ECAM > Data-Driven Models and M and V > Create Load Profile by Day of Week and Evaluate Daytypes
   - Select the column name of the dependent (energy or demand) variable.
   - Continue following the instruction is Section 11.2.1.
2. ECAM > Interval Data-Driven Models and M and V <u>or</u> Monthly Billing Data-Driven Models and M&V, as appropriate
   > Create Baseline Model (or baseline and post, if that's what you're doing….the command titles are pretty straightforward)
   - Select a model based on data shape/project information
3. Look at the model. Does it look reasonable? Is one outlier skewing the whole model?
   - **Tip! The slope of the residuals vs time line can show trends in your data.**
4. Model statistics can be used to help choose a model.
   - Guidelines:
     - $R^2 > 75\%$
     - CV(RMSE) or Standard Error % < 20% (*this is more important than R^2*)
     - Fractional Savings Uncertainty $\leq$ 50% (*this is only for use in model development and estimating number of observations needed in treatment period, considering t-statistic for desired confidence level, coefficient of variation, estimated savings in treatment period and number of observations in baseline period.)*
     - Net Determination Bias <0.005% (ECAM models will almost always meet this requirement. If not, try a different model type.)

STEP FIVE: Normalize the Model Results to a Typical Year

1. Using TMY3:
    - ECAM > Data-Driven Models and M and V > Bring in TMY3 Weather for Annualization
        - Paste in the hourly or daily values, depending on the data interval requested. The TMY3 data form will request the appropriate data interval based on your selection in the form for Data Categorization for Models, shown in Figure 78. (If you are copying from the aggregator worksheet—see STEP ZERO—paste-special values.)
        - Click OK
2. ECAM > Data-Drive Billing Data Models and M and V > Annualize Pre, Post, and Savings using TM3
3. Look at the results. Is the uncertainty less than the savings? If so, (if the post period is representative of the range of temperatures and everything makes sense), you are done!
    - Tip! Graphing the pre and post values and savings over time can demonstrate when savings occur (some projects save more in the summer than the winter). This information can be used to target future energy savings projects.

11.5 Model Statistics

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.

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 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.

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.

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 11.1.2.

12.0 Strategic Energy Management and MT&R

The Strategic Energy Management (SEM) and Monitoring, Targeting, and Reporting (MT&R) capabilities of ECAM add worksheets for project documentation, automate the modeling features, and annotate the chart of modeled and actual energy use to make it easier to see the results of individual projects or actions.

This tool will help compare avoided energy use for a facility for up to 5 years. At some point during or by the end of those 5 years, a new baseline should be developed, and the process can start over. ECAM is used to develop the model.

The tool brings together several data streams:

- Energy use data. This can be from interval data or monthly energy bills.
- Local temperature data. This information can be measured or pulled from the web.
- ECAM model of the facility. This serves as the baseline by which progress is judged.
- Project Log. This records capital and behavioral projects undertaken. It could also serve as a record of activities by an onsite staff person.

Six additional worksheets—beyond the regular energy modeling worksheets—are added when using the SEM menus:

- Project Data
- Project Log
- Call Log
- Invoices
- Results
- Ongoing Energy Use Chart

These worksheets are included for the record-keeping convenience of the user, to keep all project information in one place.

The project is summarized graphically in the "Ongoing Energy Use Chart" tab and numerically in the "Results" worksheet.

In many or most situations, using these SEM features will be easier than using the regular data-driven modeling features, because so much is automated. Only a single menu item needs to be used, although that menu item will be clicked three times if using interval data, and two times if using billing data.

For both interval data and billing data, the raw data must be organized in a specific fashion prior to creating the ECAM file. The ECAM file is created automatically.

12.1 SEM Process with ECAM

12.1.1 SEM-MT&R with Interval Data

Prior to using this menu item, the data must be organized as shown on the form.

Important: Each timestamp field must have a unique name, e.g. DateTime1, DateTime2, etc. They can't all be named DateTime.

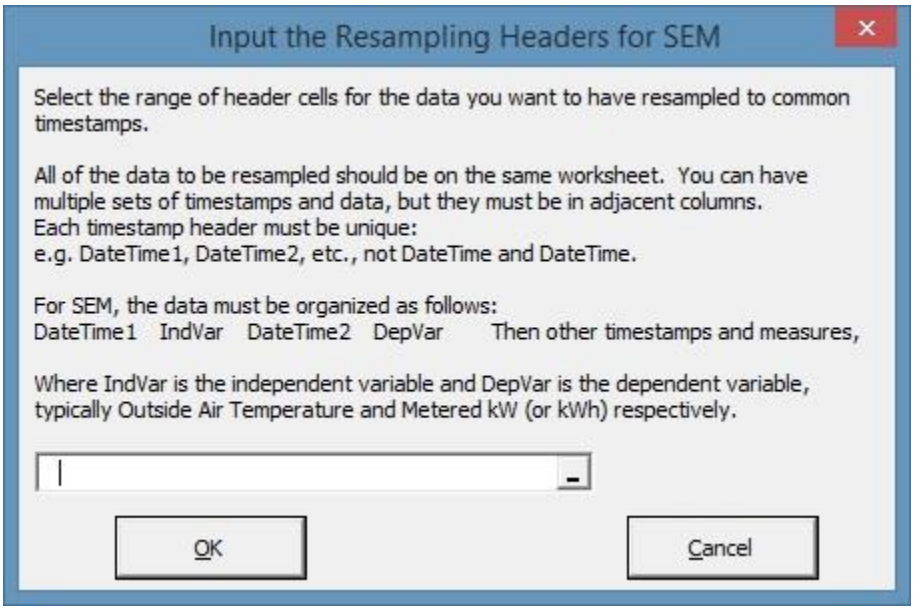


Figure 92: Interval Data Selection Form for SEM

This is similar to regular resampling, except the first four columns must be the following:

DateTime1	Independent Variable, e.g. Temperature	DateTime2	Dependent Variable, e.g. kW

12.1.2 SEM-MT&R with Monthly Billing Data

SEM with Monthly Billing Data is almost identical to its use with interval data. The only change is to the data selection, and the number of times the menu item needs to be clicked as discussed below (2 times for billing data; 3 times for interval data).

The data selection uses the form described in Section 13.2 Resample to Get Avg Temp for Billing Data:

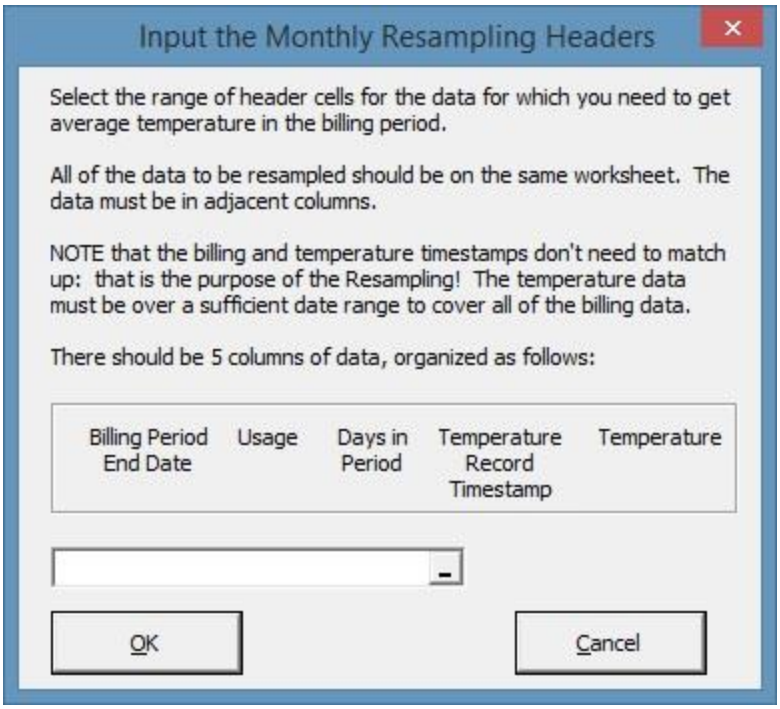


Figure 93: Monthly Billing Data Selection Form for SEM

Note the data organization required prior to selecting the menu item.

12.1.3 SEM-MT&R Processes that are the Same With Interval Data or With Monthly Billing Data

After selecting your data, you will be presented with this prompt:

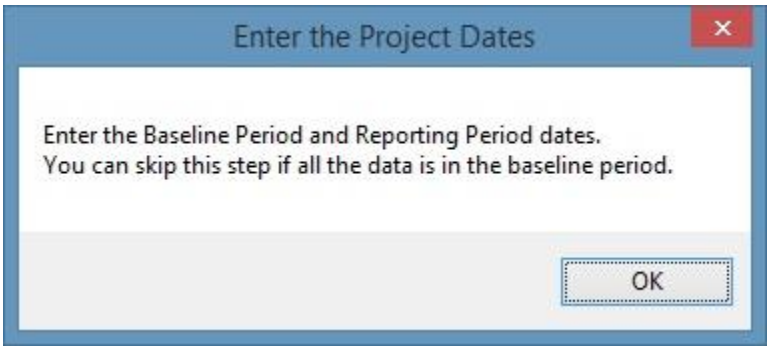


Figure 94: Prompt to Enter Project Dates

Just click “OK,” then enter the project dates in the upper-right portion of the worksheet table that displays next. These entries take the place of the regular “Input Dates for Comparison of Pre and Post” form.

If all of the data is to be treated as baseline, you don't need to enter anything. If the earliest data is to be included in the baseline, and the last data is to be included in the post, those dates do not need to be entered.

	BPA RCM TOOL DRAFT		
		Today's Date:	
	PROJECT INFORMATION		
Site Name:		**Baseline Start Date**	
		Last Date in Baseline	11/15/2006
Site Service Address		**Post Period (Project) Start Date**	1/24/2007
City:		**Last Date in Post Period**	
State:			
Zip:		**Building Heat Source?**	
		Does Building Have Cooling?	
Account Number:		**Rate per kWh**	
Utilty Project Manager		**Facility Project Manager**	
Job Title		**Job Title**	
Phone		**Phone**	
Email		**Email**	

Figure 95: Project Data Worksheet Form

At the start of the project, the "Project Data" should be filled out. While much of this information is for recordkeeping purposes, the Project Dates are crucial the modeling and SEM process.

Other worksheets will also have been created at this time:

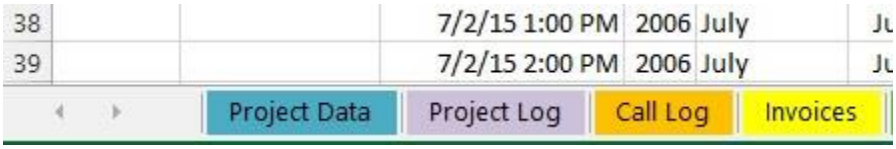


Figure 96: SEM Initial Worksheets

As mentioned above, these worksheets are included for the record-keeping convenience of the user, to keep all project information in one place.

Click the appropriate SEM menu item again. If you are using interval data, you will be asked to create the custom daytypes.

If you are using interval data, you will need to click the SEM menu item a third time. With monthly billing data, this next step occurs with the second click of the SEM menu item. Select the model type. If using interval data and there are multiple categories, you will need to select the appropriate model type for each category.

That's it for the basic modeling. As capital or behavioral projects are implemented, they should be recorded on the "Project Log" tab. Other events relevant for documentation may be recorded

here as well (e.g., “school year start”). All events recorded will be marked (although not labeled) on the “Ongoing Energy Use Chart.”

12.1.4 “Project Log” Worksheet

- Project Start Date – this value determines where events are logged on the “Ongoing Energy Use Chart”
- Project End Date – this value is used for pro-rating energy usage over the course of the year. For example, a project that finishes 4 months into Year 1 will have 8 months of savings. This value also establishes the length of the project in days, and therefore the length of the project bars on the “Ongoing Energy Use Chart.”
- Program Year (e.g., 1, 2, 3) – this value is used for data in the “Results” tab
- Project/Event Description – this column is informational only
- Project Type (Capital, Behavioral, Baseline Adjustment, etc.)
  - If the event recorded is not one of these three types, any description (except these three) can be used.
  - If the project is Capital, put “Capital” in this cell. If it is “Behavioral”, put behavioral here.
  - In the rare case where a baseline adjustment is necessary, this should be noted as a “Baseline Adjustment”. The “Suggested Baseline Adjustment” column is where baseline adjustments should be logged. If approved, put the amount in (hidden) column “Baseline Adjustment”.
- Project Lifespan (Years) – this column is important for capital projects. If project lifespan is unknown, see Appendix A for guidance
- "Estimated Energy Savings (kWh per month)
  - For Capital projects, an estimated monthly savings is required in “Estimated Energy Savings (kwh per month)”. This information is only used for annual reporting. So although any projects will have savings strongly tied to the seasons, annual savings should be divided by 12 for this cell.
  - For behavioral, this is optional (but will be noted for tracking purposes). Please note that estimated behavioral savings are only recorded for the duration of the project year, however actual savings will continue to be recorded.

All columns with “calculated” in the column header are used for results or graphs and should not be changed.

- # of months in Program Year (calculated)
- Program Year Deduct (calculated)
- Suggested Baseline Adjustment (must be approved)
- "Project Start Month (used for event marking on graph) (calculated)"

As information is filled out on the ”Project Log”, “Billing Data”, and “Daily Weather Data” tabs, the “Ongoing Energy Use Chart” will being to populate. This chart shows:

- Baseline – actual recorded energy use during the baseline period.
- Modeled Baseline– The modeled energy use during the baseline period, from the baseline model.
- Post– actual recorded energy use during the post period.

- Projected Baseline– what the energy use would have been in the absence of any changes, based on the actual temperature during that period. The shaded area around this number indicates uncertainty at the 80% confidence level in the baseline model; models with large shaded bands have greater uncertainty than those with small shaded bands.
- CUSUM – the cumulative sum of the savings for the year, as calculated by subtracting the measured usage from the modeled usage. This number resets to zero at the beginning of each year after the start of the post period.
- Dates entered on the "Project Log" are displayed as green bars at the lower area of the chart, similar to a Gantt chart. A future version of ECAM may provide a more completely annotated chart.

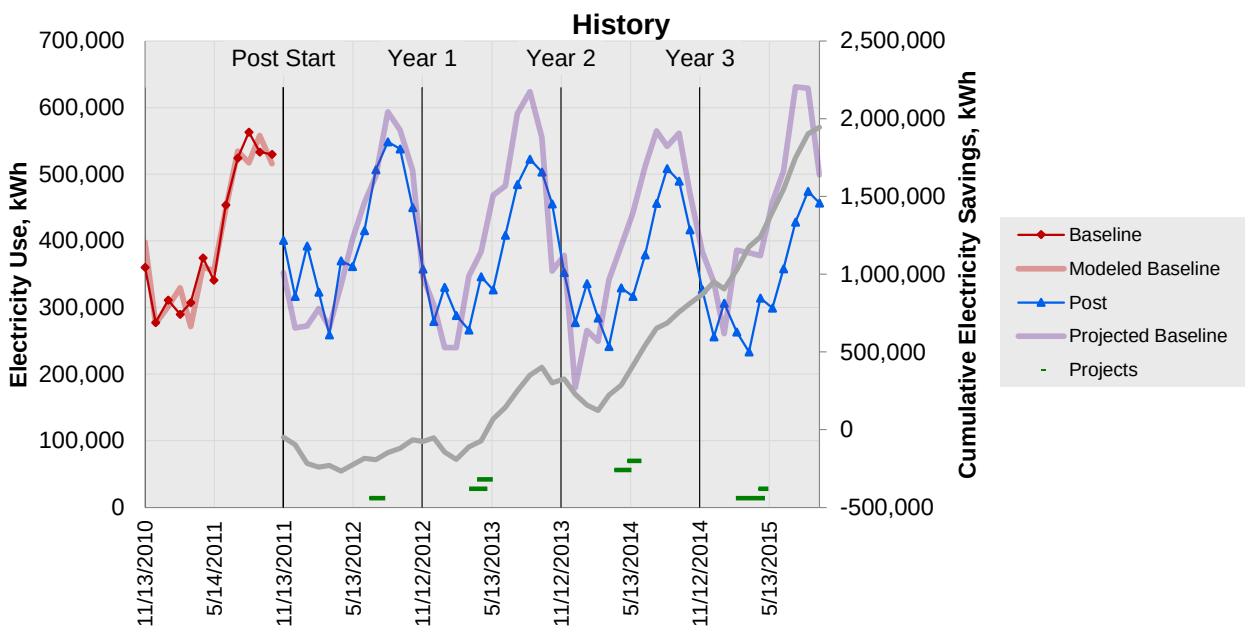


Figure 97: Ongoing Energy Use Chart

This chart can be used to visually view progress to date and help the project correct problems on an ongoing basis.

12.1.5 Results Worksheet

While monthly data is helpful, generally annual data is used for incentive and performance tracking purposes. This information is summarized on the "Results" tab.

- Days in the Year or in the (Reporting) Period
- Baseline with Routine Adjustments – What the energy use would have been in the absence of any changes, based on the energy model and actual temperature during that period.
- Non-Routine Baseline Adjustment (Can Be Positive or Negative)– In case of major unexpected changes in energy use. Sums up values from the "Project Log". This will usually not be used.

- Final Adjusted Baseline (kWh) – Program year baseline with all routine and non-routine adjustments.
- Program Year Measured/Billed Usage (kWh) – annual total of monthly bills.
- kWh Difference (Adjusted Baseline - Measured Use)
- Ongoing Capital Projects (kWh) – any capital projects completed in previous years. Tracking these totals helps avoid double-counting savings.
- New Capital Projects (kWh) – any capital projects accomplished in this year, pro-rated for when in the year they were finished.
- Total Capital Projects Deduction (kWh) – the total of new and ongoing capital projects.
- Program Site Savings (kWh) – Adjusted Baseline Usage minus Measured Usage minus Total Capital Projects Deduction.
- Program Busbar Savings (kWh) – Metered savings multiplied by a factor to account for busbar losses.
- Estimated Behavioral Savings (kWh) – this cell totals estimates for projects tagged "behavioral" on the project log.
- Program Targets (kWh) – Default targets are 3% the first year, and 5% each year for years 2 & 3.
- Program Cost – this sums up any items recorded on the "Invoices" tab

13.0 ECAM Utilities

The ECAM utilities are six features that handle situations where data needs to be resampled to different or common timestamps, 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 98 highlights this option in the ECAM menu.

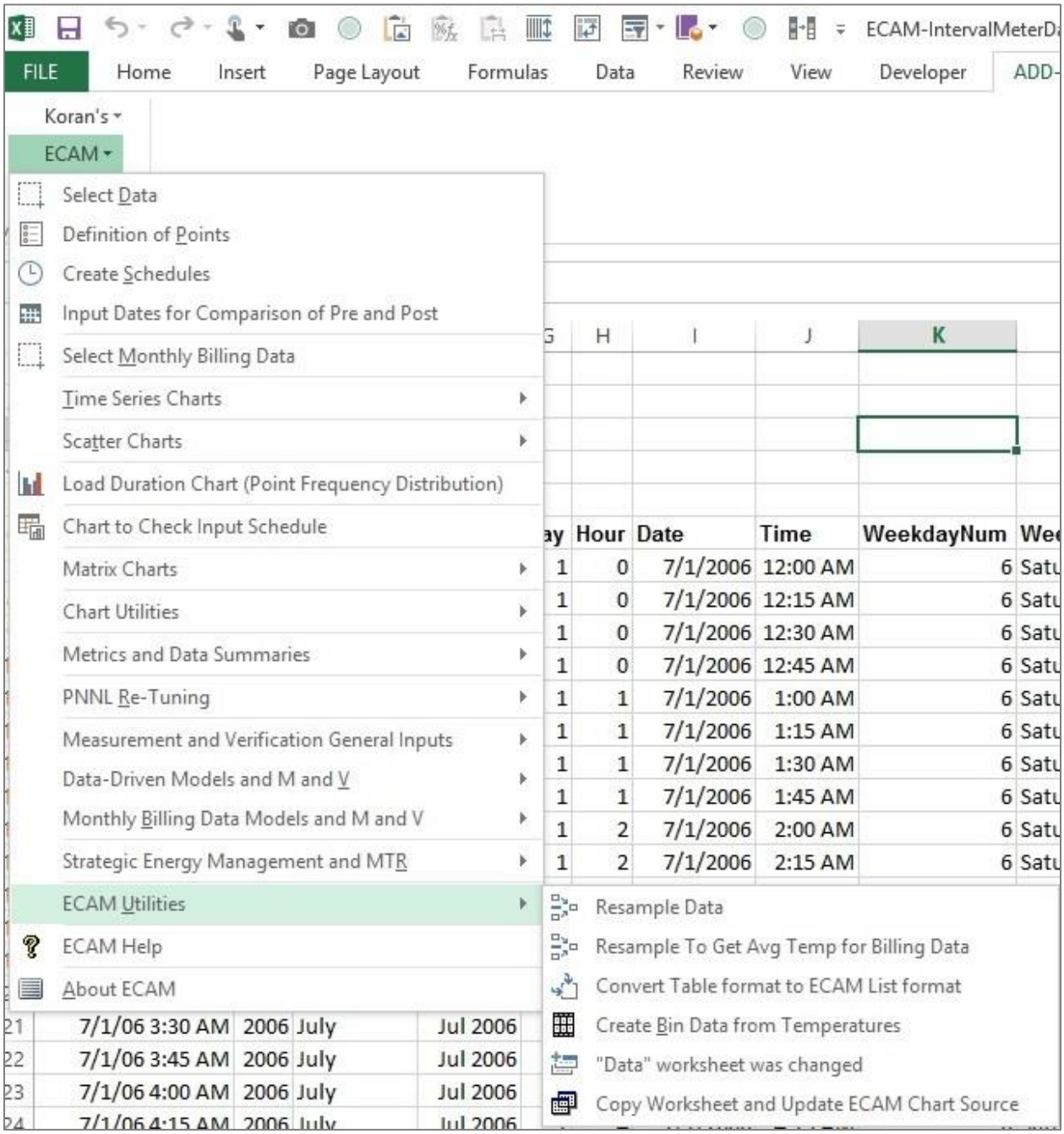


Figure 98: ECAM Utilities

13.1 Resample Data

The resampling utility in ECAM allows the combining of data gathered at different timestamps and/or different time intervals into a single data set with a single set of timestamps, with a constant interval between timestamps. There are multiple options so that each data field can be resampled appropriately. The capability is intended to be useful for using energy as well as power data. (ECAM typically assumes that the data is power (e.g. kW) or another instantaneous value rather than a value that accumulates over time, such as kWh.) Resample estimates can be made for uniform and non-uniform (change-of-value) time intervals in the original data set.

The resampling method can be different for each field in the original data set. ECAM will try and guess the most appropriate resampling method, which the user can override if necessary. There are five possible types of resampling methods available.

1. Interpolated Average
2. Time Weighted Average
3. Time Weighted Sum
4. Nearest Prior Value
5. Don't resample (Only use known values.)

ECAM uses the following defaults for the resampling: Analog data with be resampled using interpolation. Digital data will be resampled using the most recent prior value. The resampling methods are further described later in this section.

Figure 99 shows the form to select the data to be resampled. Note that you can have multiple sets of data as long as it is all adjacent.

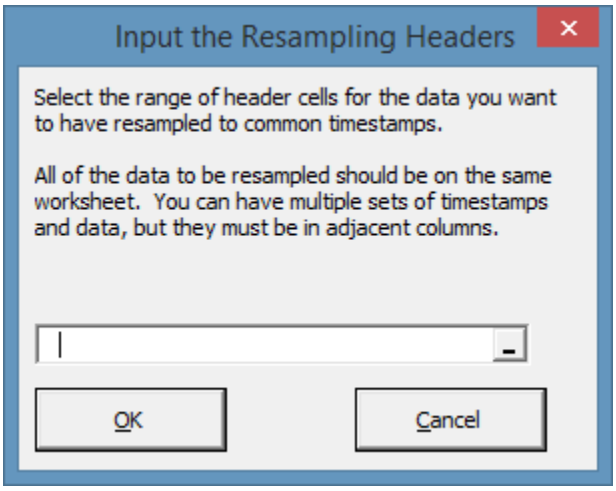


Figure 99: Input Form for Resampling

Figure 100 shows the form to setup the options for resampling. The top left list shows all the fields, including both timestamps and data. ECAM will try and discern which fields are timestamps and which are data, and with most data sources will get this correct, since the

timestamps need to be recognized by Excel. The field in the middle is for information as to whether each timestamp field has uniform or non-uniform intervals. The lower left field shows each data field with the default resampling method.

Important: Each timestamp field must have a unique name, e.g. DateTime1, DateTime2, etc. They can't all be named DateTime.

ECAM uses the following defaults for the resampling:

Analog data will be resampled using interpolation.

Digital data will be resample using the most recent prior value

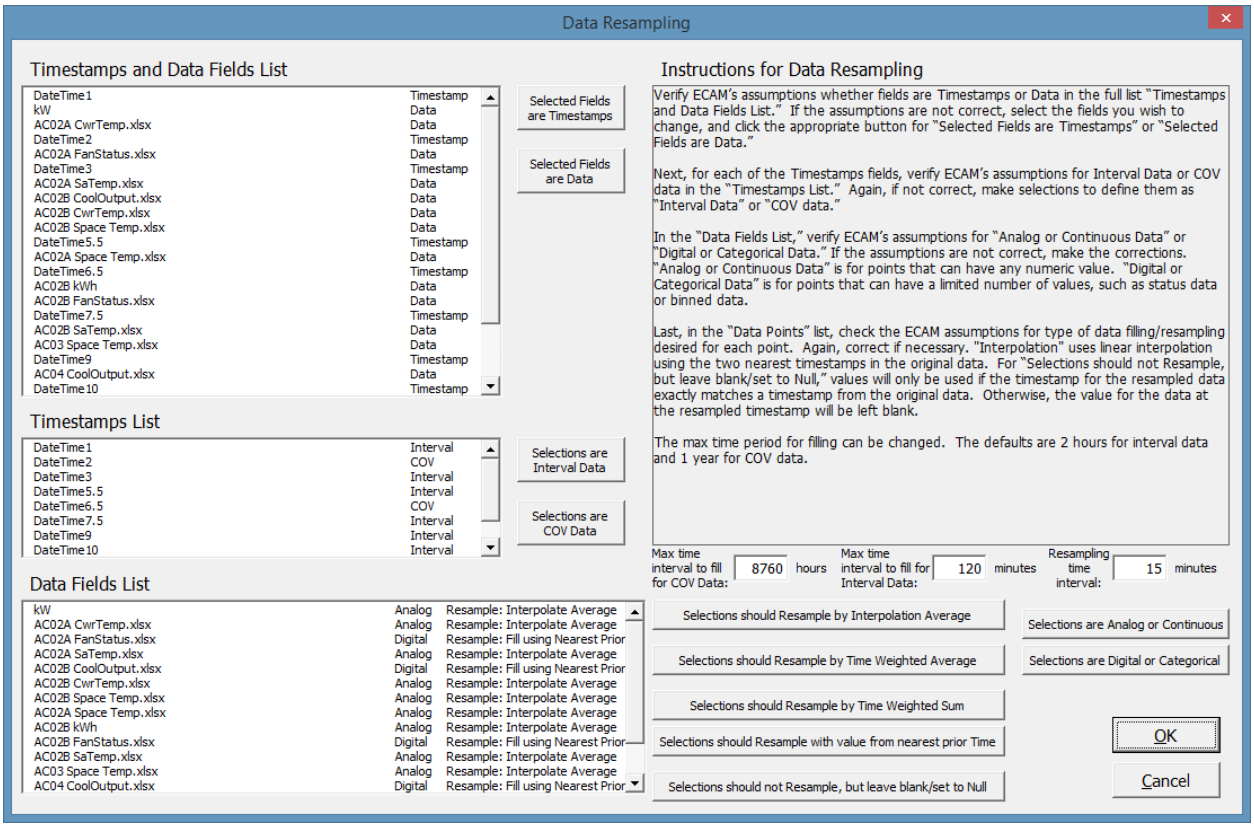


Figure 100: Resampling Setup Form

13.1.1 Resample by Interpolation Average

The Interpolated Average uses using the two nearest timestamps in the original data to provide a value for the timestamp in the resampled data. Timestamps in the resampled data set that have matching timestamps in the original data set will have exactly the same measure values.

Figure 101 shows a scatter chart of some data gathered at varying intervals and resampled to hourly intervals using interpolation.

Figure 102 shows a stairstep chart of the same data. This chart is provided for comparison with Figure 104 in the next section.

In many cases, interpolation will provide a good representation of the original data. However, when upsampling—going from shorter time interval in the original data to a longer interval in the resampled data, e.g. from 15-minute data to hourly data—simple linear interpolation uses only the nearest points. Substantial information can be lost with this approach. Other approaches, such as a spline fit, could be better. Resampling by a time-weighted average incorporates all the relevant information, and ensures a close match of total energy between the original and resampled data.

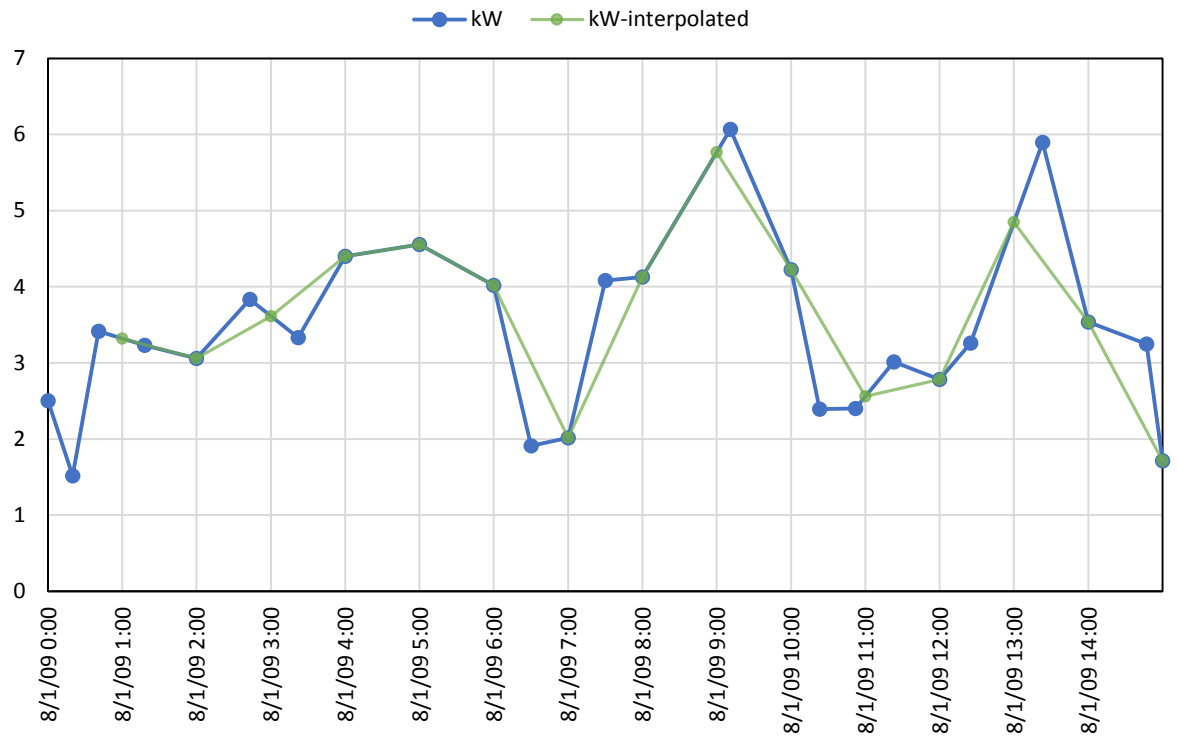


Figure 101: Scatter Chart of Actual Data and Data Resampled Using Interpolation

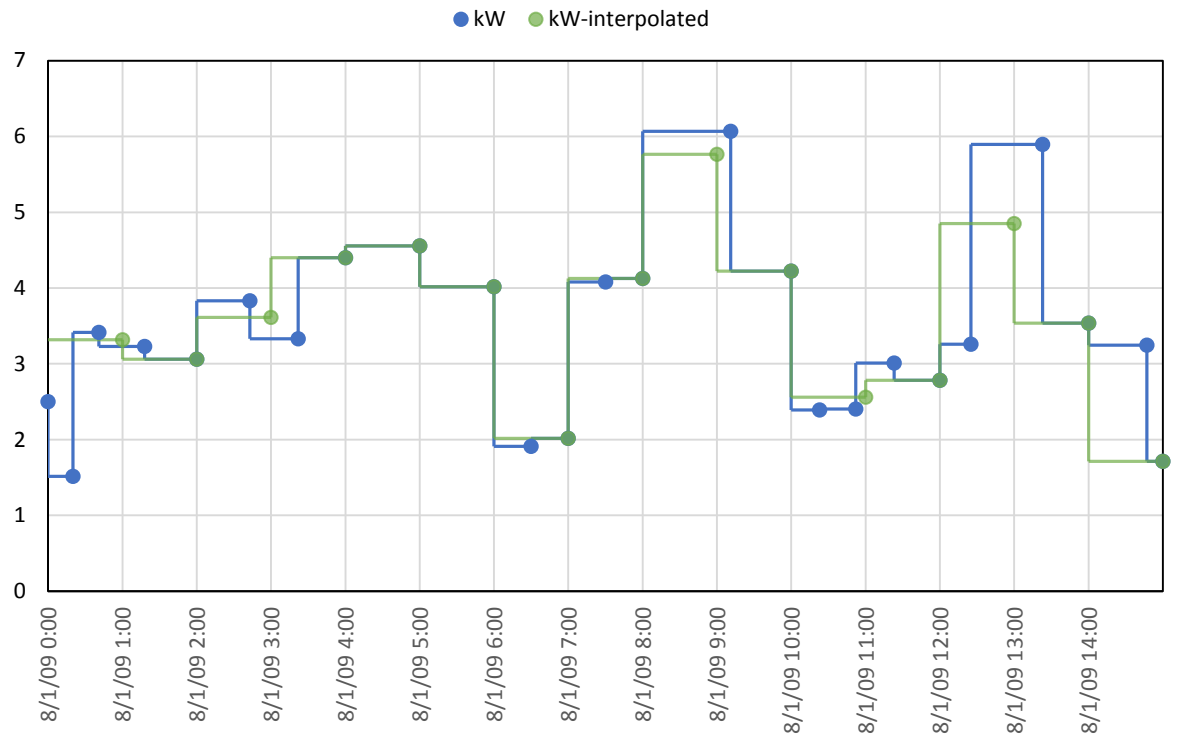


Figure 102: Stairstep Chart of Actual Data and Data Resampled Using Interpolation

13.1.2 Resample by Time Weighted Average

The Time Weighted Average is typically used when, for example, the integrated total of the resampled kW*time needs to equal the same integrated total as the kW* time from the original data.

Values in the resampled data will often not exactly match values for the same timestamp, if it exists, in the original data. Therefore, when the data is plotted as a scatter chart with lines, the points may not appear to fall correctly. This is because the resampled data is not interpolated, but filled to give the same total energy. The two charts below show a normal scatter chart, with lines, and a stairstep chart. (Note that ECAM does not presently create stairstep charts.)

In Figure 103, it appears that some points don't fall correctly. For example, at 4am, 10am, and 2pm the time-weighted point is clearly not the same as the original data. An examination of the stairstep chart shows why this is so. The resampling assumes that the value measured was the same, going back in time to the last known value, as shown in Figure 104. Other assumptions could be made, but this approach ensures that the area under the curves is the same for both the original and resampled data.

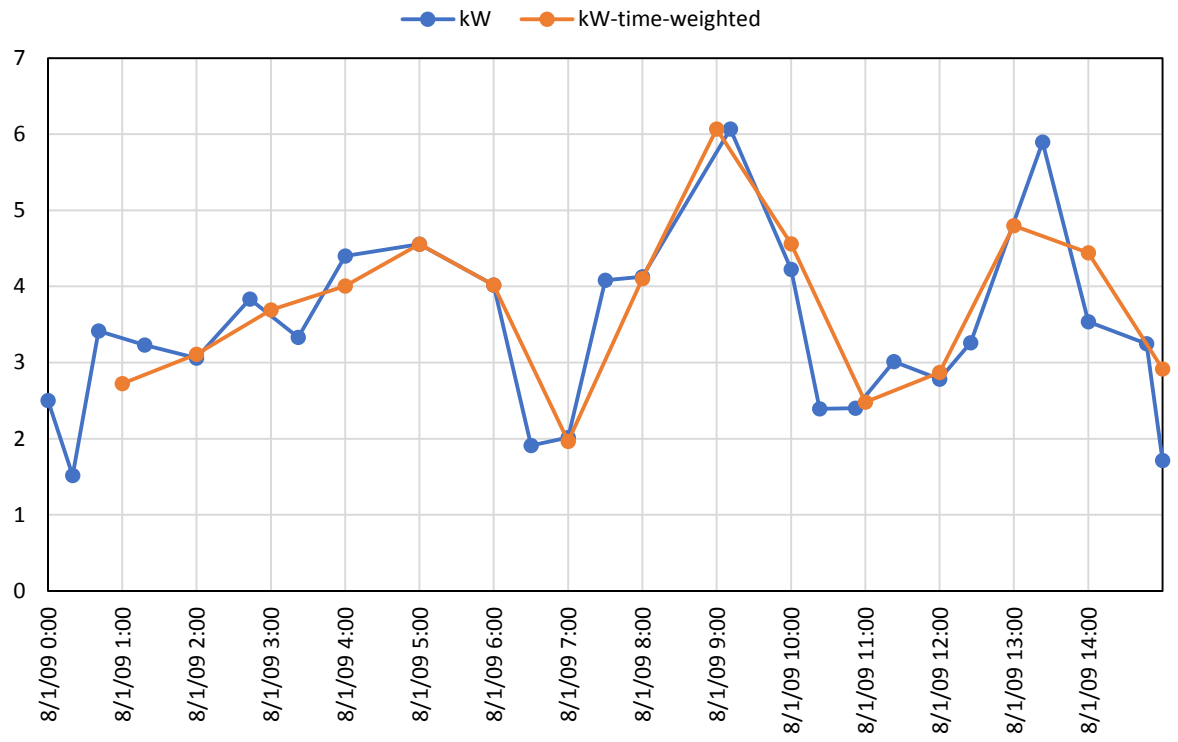


Figure 103: Scatter Chart of Actual Data and Data Resampled Using Time-Weighted Average

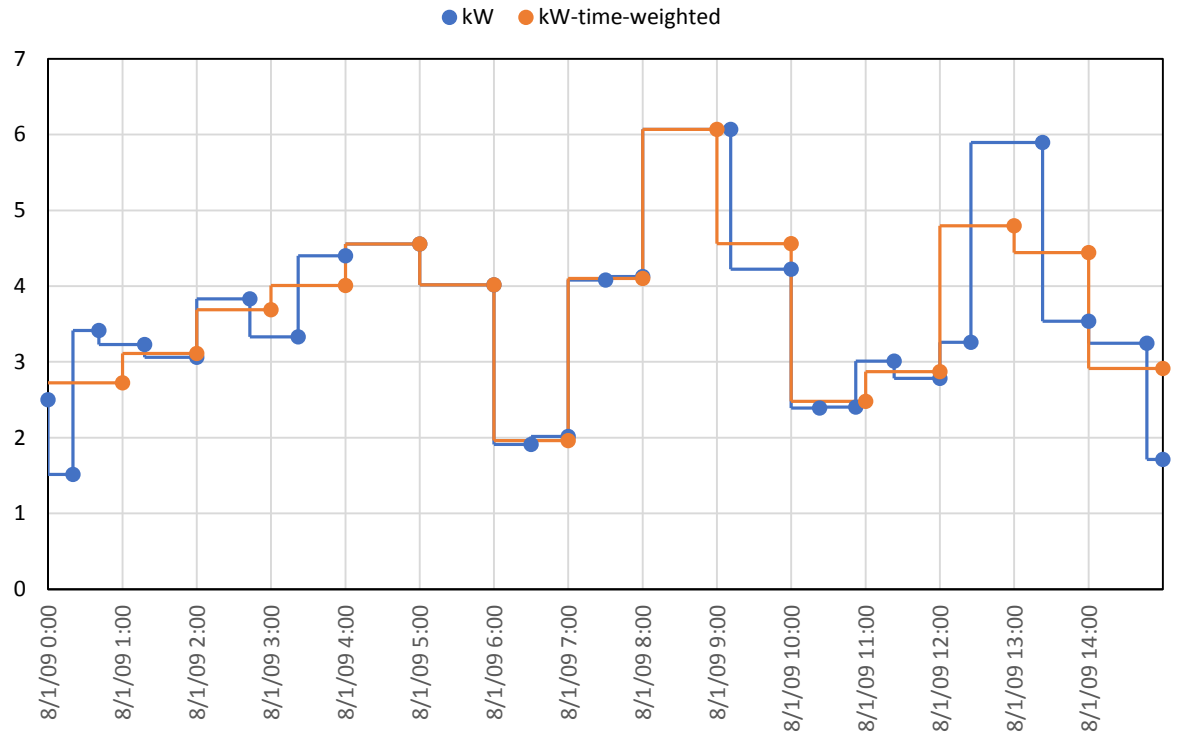


Figure 104: Stairstep Chart of Actual Data and Data Resampled Using Time-Weighted Average

A comparison of Figure 104 with Figure 102 shows the change in values when using a time-weighted average in comparison to simple interpolation. For the data in this example, covering 15 hours (midnight to 3 PM), the area under the curve for the actual data, using a straight line between points as in Figure 103, was 55.5 kWh. For the actual data using a stairstep chart as in Figure 104, the area under the curve was was 56.3 kWh. For the interpolated data, the area under the curve was 54.5 kWh. Using the time-weighted resampling the area under the curve was the same as for the actual data assuming stairsteps, 56.3 kWh.

13.1.3 Resample by Time Weighted Sum

The Time Weighted Sum is typically used for values that are totals over time, such as kWh, cubic feet of gas, or pounds of steam.

Values in resampled data will usually not match values for the same timestamp, if it exists, in the actual data. They will only match if the timestamp interval is the same for the actual and downsampled data.

13.1.4 Resample with Value from Nearest Prior Time

Nearest Prior Value is typically used for change-of-value (COV) data or data that can only have a small number of unique values, such as equipment status data. The resampled value is assumed to be exactly the same as the value from the closest earlier timestamp in the original data.

13.1.5 Do not Resample, but Leave Blank/Set to Null

There may be circumstances where it is not appropriate to assume a value is known for timestamps that are not in the original data. This menu item only includes values for the resampled timestamps when the same timestamp occurs in the original data. Otherwise, no value is included; the cell is left blank.

13.2 Resample to Get Avg Temp for Billing Data

This utility makes it easier to create energy models based on monthly billing data by calculating the average temperature over the billing period. Before using this utility, the data should be sorted in ascending order, with the oldest data first, and in the format shown in Figure 105 and Figure 106.

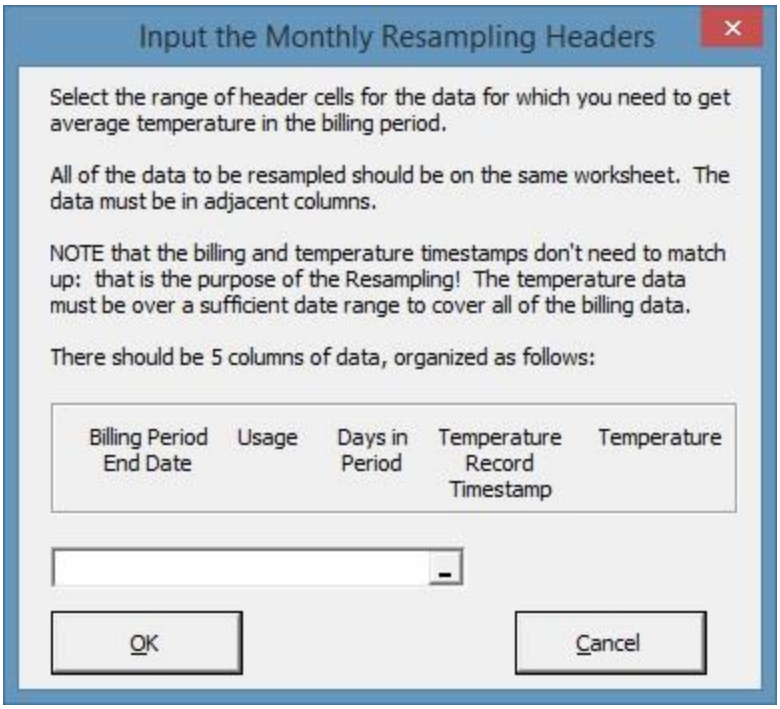


Figure 105: Form for Resampling Temperature Data to Billing Periods

The top of data sets, prior to resampling, might look like Figure 106:

Date_BillingPeriodEnd	kWh	DaysInPeriod	Date_Temperature	Temp ºF
2009/2/24	423	30	2009/1/1	35
2009/3/24	518	28	2009/1/2	35
2009/4/23	403	30	2009/1/3	10
2009/5/26	490	33	2009/1/4	-2
2009/6/24	565	29	2009/1/5	5
2009/7/29	583	35	2009/1/6	17
2009/8/26	524	28	2009/1/7	29

Figure 106: Billing Period Energy Data and Daily Temperature Data Prior to Resampling

The resampling can also use the original temperature data at hourly or non-uniform intervals.

The resampled data would look like this:

Period End Date	Avg Temp in Period	Usage	Days in Period
2009/2/24	17.4	423	30
2009/3/24	32.1	518	28
2009/4/23	42.8	403	30
2009/5/26	50.1	490	33
2009/6/24	58.6	565	29
2009/7/29	67.1	583	35
2009/8/26	66.0	524	28

Figure 107: Monthly Energy Data and Temperature Data After Resampling

This is the form of the data needed for the billing period energy models as described in Section 11.3.

13.2.1 Quality Control for Data With Monthly Billing Models

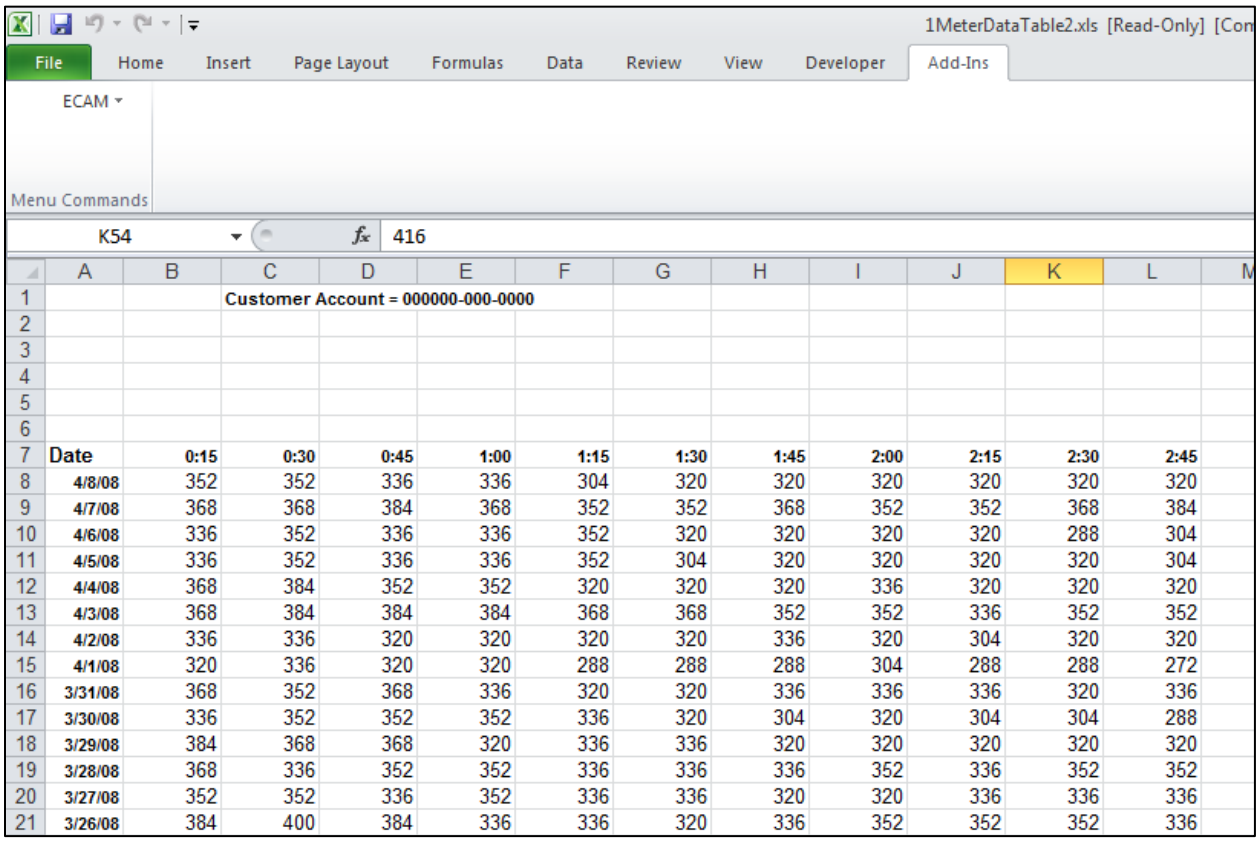
ECAM makes multiple checks to better ensure that the required data is available prior to starting the modeling. The following checks are performed:

- Is there weather data available for at least as early as the first day of the billing data?
- Is there weather data available for at least as late as the last day of the billing data?
- Is the weather data daily?
- Are there at least as many total days of weather data as there are of billing data?

If any of these checks fail, a worksheet “MonthlyBillingQC” will be added with an explanation of the shortcomings in the weather data.

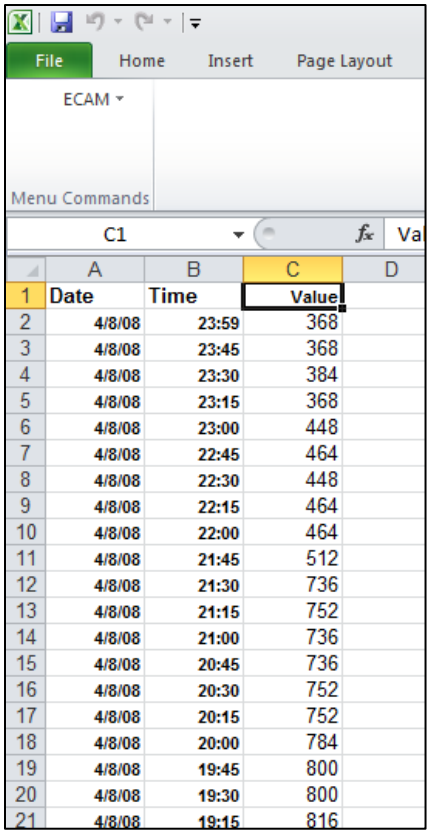
13.3 Convert Table format to ECAM List format

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 timestamp. 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 below in Figure 108. 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 109. 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.



	A	B	C	D	E	F	G	H	I	J	K	L
1			Customer Account = 000000-000-0000									
2												
3												
4												
5												
6												
7	Date	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45
8	4/8/08	352	352	336	336	304	320	320	320	320	320	320
9	4/7/08	368	368	384	368	352	352	368	352	352	368	384
10	4/6/08	336	352	336	336	352	320	320	320	320	288	304
11	4/5/08	336	352	336	336	352	304	320	320	320	320	304
12	4/4/08	368	384	352	352	320	320	320	336	320	320	320
13	4/3/08	368	384	384	384	368	368	352	352	336	352	352
14	4/2/08	336	336	320	320	320	320	336	320	304	320	320
15	4/1/08	320	336	320	320	288	288	288	304	288	288	272
16	3/31/08	368	352	368	336	320	320	336	336	336	320	336
17	3/30/08	336	352	352	352	336	320	304	320	304	304	288
18	3/29/08	384	368	368	320	336	336	320	320	320	320	320
19	3/28/08	368	336	352	352	336	336	336	352	336	352	352
20	3/27/08	352	352	336	352	336	336	320	320	336	336	336
21	3/26/08	384	400	384	336	336	320	336	352	352	352	336

Figure 108: Utility company data example



	A	B	C	D
1	Date	Time	Value	
2	4/8/08	23:59	368	
3	4/8/08	23:45	368	
4	4/8/08	23:30	384	
5	4/8/08	23:15	368	
6	4/8/08	23:00	448	
7	4/8/08	22:45	464	
8	4/8/08	22:30	448	
9	4/8/08	22:15	464	
10	4/8/08	22:00	464	
11	4/8/08	21:45	512	
12	4/8/08	21:30	736	
13	4/8/08	21:15	752	
14	4/8/08	21:00	736	
15	4/8/08	20:45	736	
16	4/8/08	20:30	752	
17	4/8/08	20:15	752	
18	4/8/08	20:00	784	
19	4/8/08	19:45	800	
20	4/8/08	19:30	800	
21	4/8/08	19:15	816	

Figure 109: Utility company data after ECAM has converted it

13.4 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 later. When adding the temperature data to the file, make sure the timestamps 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 (outdoor) 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.

13.5 "Data" Worksheet was Changed

This option in ECAM allows the user to add additional data, or change existing data to an ECAM file and the program will update to include the data when this feature is selected. If additional trend data is gathered, i.e. more timestamps 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.

Some charts may need to be re-created after this option is used. For example, any custom daytypes created will be lost.

13.6 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 one month and create a second chart for a second month, the user needs to simply click on this feature in ECAM while on the worksheet 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 that 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.

14.0 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 (http://www.cacx.org/PIER/ecam/) that cover some common ECAM features and functions.

15.0 Known Issues and Reminders

15.1 The following list summarizes known issues of this tool:

- 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.
- 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.
- For most metrics and charts, number of digits displayed is not adjusted for the number of significant digits.
- 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.
- "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.
- Most features will be unaffected, but some charts may need to be re-created after the menu item for "New Data was added to "Data worksheet" is used. For example, any custom daytypes created will be lost.
- Data-driven (M&V) models created by occupancy period or using hourly data may have bias issues if any building schedules don't end on an even hour, e.g. if occupancy starts at 7:30 AM instead of 8:00 AM.

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

- One important note regarding the automated charting is that 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, since 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."

- Prior to using the utility to “Convert Table format to ECAM List format,” make sure that the times are recognized as times by Excel.
- Also, when using the “Convert Table format to ECAM List format,” if the last time is exactly 12:00 AM (12 midnight), change it to just slightly less, such as 11:59:55 PM. Otherwise Excel will think the time is at the start of the day instead of the end.