Energy Charting and Metrics Tool (ECAM) Part III: Creating and Analyzing Re-tuning Charts

Danny Taasevigen (PNNL)
Efthimios Vlachokostas (Student Intern, PNNL)
Manorge Joseph (Student Intern, PNNL)
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Part III: Webinar Outline

- Main tools and components of ECAM
  - Data Input (INPUT)
    - Select Data (user interaction)
    - Definition of Points (Mapping)
      - Mapping Air-Handling Units (user interaction)
      - Mapping Zones
      - Mapping Physical Plant
  - PNNL Re-tuning (OUTPUT)
    - AHU Charts (Scatter and Time-Series, user interaction)
    - Zone Charts (Time-Series)
      - Zones Common
    - Central Plant Charts
- Examples of good and bad operation
- Other ECAM capabilities
  - Future improvements and modifications

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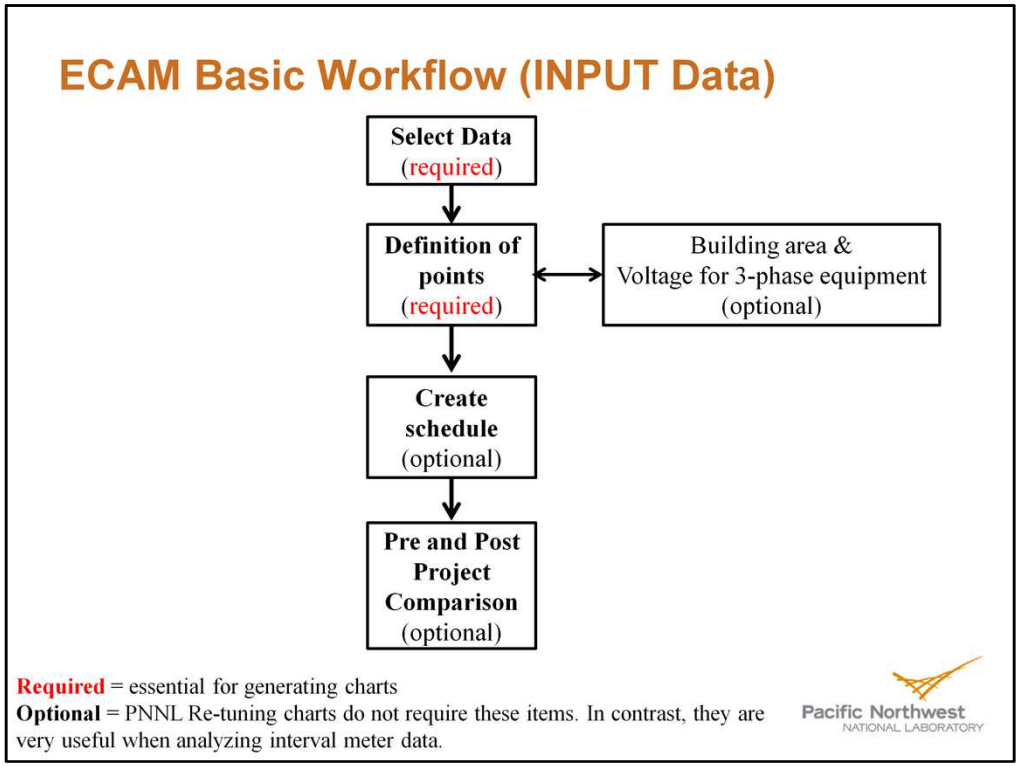

To create any charts (whether whole building or retuning), the first two items of ECAM must be completed.

User Interactive Walkthrough

- Please open pre-processed data file from Webinar number #1 (originally Air_Handlers.csv)
  - If correct, should look like the following slide
  - Questions before we continue?

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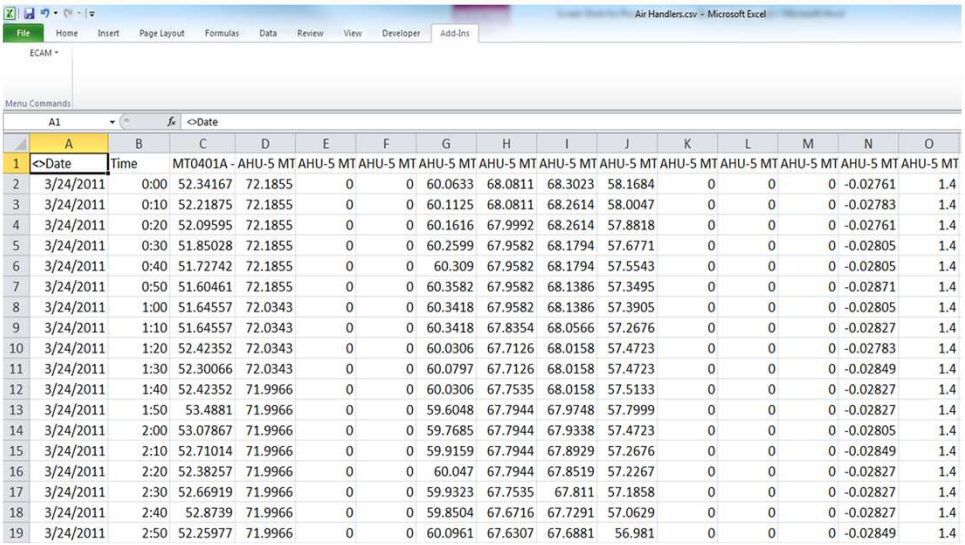
Resulting .csv file from Webinar #1



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	<>Date	Time	MT0401A -	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT
2	3/24/2011	0:00	52.34167	72.1855	0	0	60.0633	68.0811	68.3023	58.1684	0	0	0	-0.02761	1.4
3	3/24/2011	0:10	52.21875	72.1855	0	0	60.1125	68.0811	68.2614	58.0047	0	0	0	-0.02783	1.4
4	3/24/2011	0:20	52.09595	72.1855	0	0	60.1616	67.9992	68.2614	57.8818	0	0	0	-0.02761	1.4
5	3/24/2011	0:30	51.85028	72.1855	0	0	60.2599	67.9582	68.1794	57.6771	0	0	0	-0.02805	1.4
6	3/24/2011	0:40	51.72742	72.1855	0	0	60.309	67.9582	68.1794	57.5543	0	0	0	-0.02805	1.4
7	3/24/2011	0:50	51.60461	72.1855	0	0	60.3582	67.9582	68.1386	57.3495	0	0	0	-0.02871	1.4
8	3/24/2011	1:00	51.64557	72.0343	0	0	60.3418	67.9582	68.1386	57.3905	0	0	0	-0.02805	1.4
9	3/24/2011	1:10	51.64557	72.0343	0	0	60.3418	67.8354	68.0566	57.2676	0	0	0	-0.02827	1.4
10	3/24/2011	1:20	52.42352	72.0343	0	0	60.0306	67.7126	68.0158	57.4723	0	0	0	-0.02783	1.4
11	3/24/2011	1:30	52.30066	72.0343	0	0	60.0797	67.7126	68.0158	57.4723	0	0	0	-0.02849	1.4
12	3/24/2011	1:40	52.42352	71.9966	0	0	60.0306	67.7535	68.0158	57.5133	0	0	0	-0.02827	1.4
13	3/24/2011	1:50	53.4881	71.9966	0	0	59.6048	67.7944	67.9748	57.7999	0	0	0	-0.02827	1.4
14	3/24/2011	2:00	53.07867	71.9966	0	0	59.7685	67.7944	67.9338	57.4723	0	0	0	-0.02805	1.4
15	3/24/2011	2:10	52.71014	71.9966	0	0	59.9159	67.7944	67.8929	57.2676	0	0	0	-0.02849	1.4
16	3/24/2011	2:20	52.38257	71.9966	0	0	60.047	67.7944	67.8519	57.2267	0	0	0	-0.02827	1.4
17	3/24/2011	2:30	52.66919	71.9966	0	0	59.9323	67.7535	67.811	57.1858	0	0	0	-0.02827	1.4
18	3/24/2011	2:40	52.8739	71.9966	0	0	59.8504	67.6716	67.7291	57.0629	0	0	0	-0.02827	1.4
19	3/24/2011	2:50	52.25977	71.9966	0	0	60.0961	67.6307	67.6881	56.981	0	0	0	-0.02849	1.4

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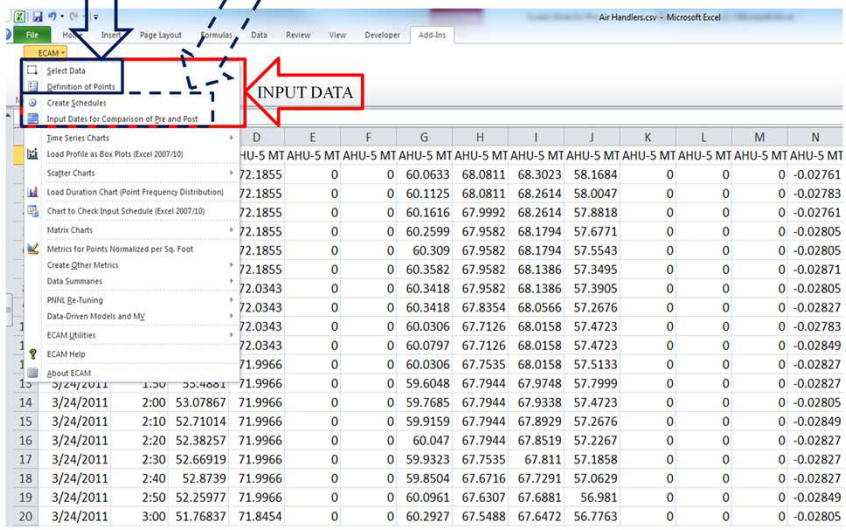
The header names will look different if the file was saved as an extension xlsx (the headers will have the wrap text function applied to them). If it was saved as an extension csv, then it will look like this.

ECAM Basic Workflow (INPUT Data)

Required for PNNL-retuning

Optional for generating additional charts and/or metrics



	D	E	F	G	H	I	J	K	L	M	N
	HU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT
	72.1855	0	0	60.0633	68.0811	68.3023	58.1684	0	0	0	-0.02761
	72.1855	0	0	60.1125	68.0811	68.2614	58.0047	0	0	0	-0.02783
	72.1855	0	0	60.1616	67.9992	68.2614	57.8818	0	0	0	-0.02761
	72.1855	0	0	60.2599	67.9582	68.1794	57.6771	0	0	0	-0.02805
	72.1855	0	0	60.309	67.9582	68.1794	57.5543	0	0	0	-0.02805
	72.1855	0	0	60.3582	67.9582	68.1386	57.3495	0	0	0	-0.02871
	72.0343	0	0	60.3418	67.9582	68.1386	57.3905	0	0	0	-0.02805
	72.0343	0	0	60.3418	67.8354	68.0566	57.2676	0	0	0	-0.02827
	72.0343	0	0	60.0306	67.7126	68.0158	57.4723	0	0	0	-0.02783
	72.0343	0	0	60.0797	67.7126	68.0158	57.4723	0	0	0	-0.02849
	71.9966	0	0	60.0306	67.7535	68.0158	57.5133	0	0	0	-0.02827
13	71.9966	0	0	59.6048	67.7944	67.9748	57.7999	0	0	0	-0.02827
14	3/24/2011	2:00	53.07867	71.9966	0	0	59.7685	67.7944	67.9338	57.4723	0	0	0	-0.02805
15	3/24/2011	2:10	52.71014	71.9966	0	0	59.9159	67.7944	67.8929	57.2676	0	0	0	-0.02849
16	3/24/2011	2:20	52.38257	71.9966	0	0	60.047	67.7944	67.8519	57.2267	0	0	0	-0.02827
17	3/24/2011	2:30	52.66919	71.9966	0	0	59.9323	67.7535	67.811	57.1858	0	0	0	-0.02827
18	3/24/2011	2:40	52.8739	71.9966	0	0	59.8504	67.6716	67.7291	57.0629	0	0	0	-0.02827
19	3/24/2011	2:50	52.25977	71.9966	0	0	60.0961	67.6307	67.6881	56.981	0	0	0	-0.02849
20	3/24/2011	3:00	51.76837	71.8454	0	0	60.2927	67.5488	67.6472	56.7763	0	0	0	-0.02805

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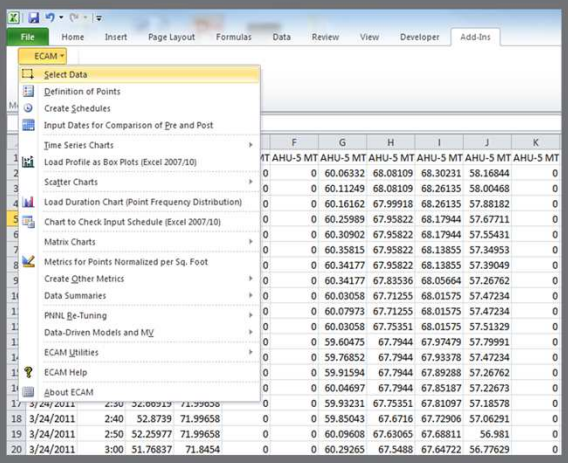
Menu Item Number 1: Select Data (Required)

Purpose: To import the raw data into an ECAM formatted workbook.



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

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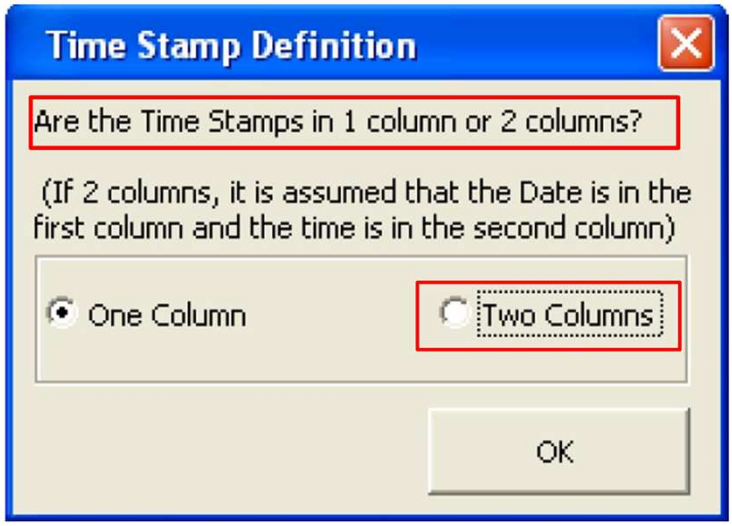
Note: The raw data file will not be modified. Rather, ECAM uses the data selection to create a new workbook that recognizes the timestamp, and creates multiple columns for Year, Month, Day, Hour, Date, Time, WeekdayNum (i.e., 1-7, with Monday being 1 and Sunday being 7), Daytype (i.e., Weekend, Weekday, Holiday), and several outdoor-air temperature categories (if outdoor-air temperature exists in the data) such as temperature bins and temperature range.

Data Input: Select Data cont.

- **Step 2: Select the correct timestamp format**



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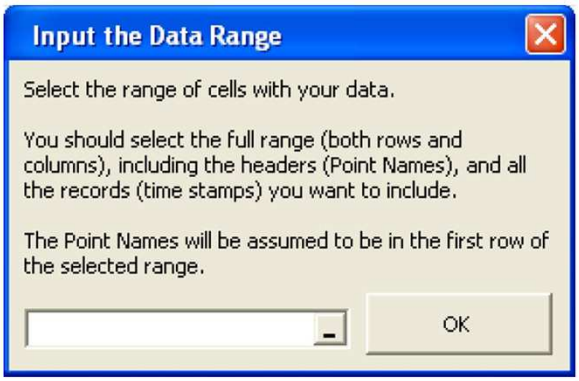
Note that for this file, the time stamps are in 2 columns instead of 1.

Data Input: Select Data cont.

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



Tip: Click the 1st cell on the upper left, hold Ctrl+Shift and press the right & down arrows on the keyboard to select all of the data.

Note: If the data contain empty cells, the above tip will not work. Thus, if you use the tip, be sure that all data is selected by scrolling to the end of the excel sheet.

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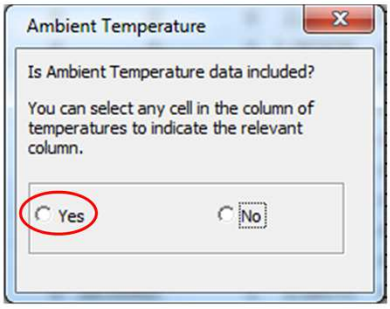
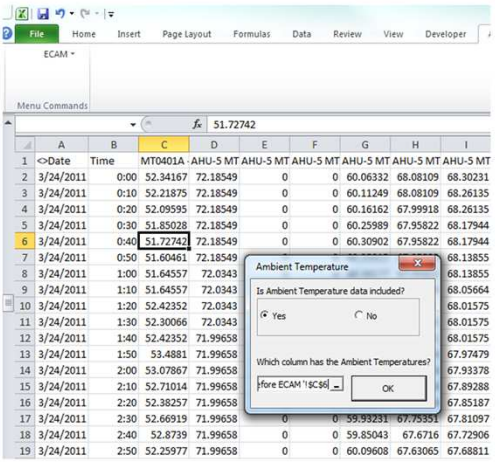
Note: The user should remove any empty cells or rows or columns before importing it into ECAM. This was handled in webinar #1 during our pre-processing steps.

Data Input: Select Data cont.

- **Step 4: Select whether ambient temperature data is included**





Tip: Click on any cell within the Ambient Temperature column to select it. The ambient temperature is the same as the outdoor-air temperature.

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Note: Having the outdoor-air temperature located at the first column after the timestamp makes it easy to remember for this step in ECAM.

Data Input: Select Data Result

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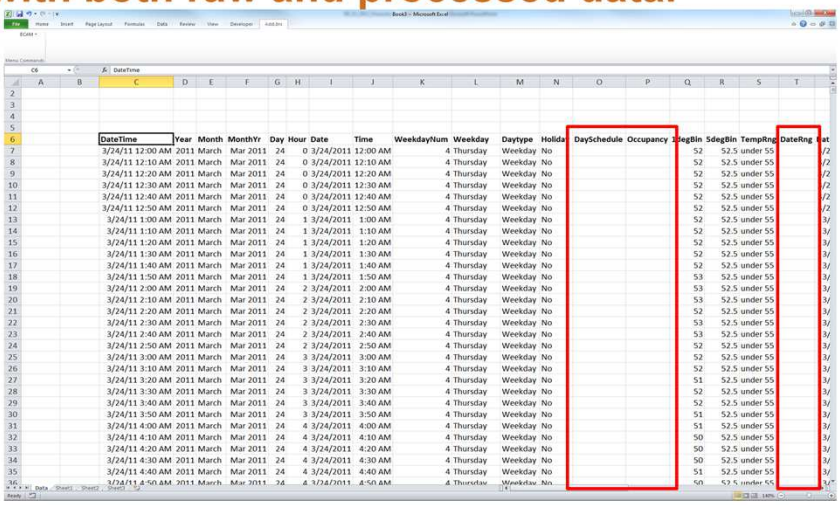
Result: ECAM generates a new workbook with both raw and processed data.



DateTime	Year	Month	MonthYr	Day	Hour	Date	Time	WeekdayNum	Weekday	Daytype	Holida	DaySchedule	Occupancy	SdegBin	SdegBin	TempRng	DateRng
3/24/11 12:00 AM	2011	March	Mar 2011	24	0	3/24/2011	12:00 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 12:10 AM	2011	March	Mar 2011	24	0	3/24/2011	12:10 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 12:20 AM	2011	March	Mar 2011	24	0	3/24/2011	12:20 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 12:30 AM	2011	March	Mar 2011	24	0	3/24/2011	12:30 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 12:40 AM	2011	March	Mar 2011	24	0	3/24/2011	12:40 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 12:50 AM	2011	March	Mar 2011	24	0	3/24/2011	12:50 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 1:00 AM	2011	March	Mar 2011	24	1	3/24/2011	1:00 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 1:10 AM	2011	March	Mar 2011	24	1	3/24/2011	1:10 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 1:20 AM	2011	March	Mar 2011	24	1	3/24/2011	1:20 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 1:30 AM	2011	March	Mar 2011	24	1	3/24/2011	1:30 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 1:40 AM	2011	March	Mar 2011	24	1	3/24/2011	1:40 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 1:50 AM	2011	March	Mar 2011	24	1	3/24/2011	1:50 AM	4	Thursday	Weekday	No			53	52.5 under 55		
3/24/11 2:00 AM	2011	March	Mar 2011	24	2	3/24/2011	2:00 AM	4	Thursday	Weekday	No			53	52.5 under 55		
3/24/11 2:10 AM	2011	March	Mar 2011	24	2	3/24/2011	2:10 AM	4	Thursday	Weekday	No			53	52.5 under 55		
3/24/11 2:20 AM	2011	March	Mar 2011	24	2	3/24/2011	2:20 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 2:30 AM	2011	March	Mar 2011	24	2	3/24/2011	2:30 AM	4	Thursday	Weekday	No			53	52.5 under 55		
3/24/11 2:40 AM	2011	March	Mar 2011	24	2	3/24/2011	2:40 AM	4	Thursday	Weekday	No			53	52.5 under 55		
3/24/11 2:50 AM	2011	March	Mar 2011	24	2	3/24/2011	2:50 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 3:00 AM	2011	March	Mar 2011	24	3	3/24/2011	3:00 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 3:10 AM	2011	March	Mar 2011	24	3	3/24/2011	3:10 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 3:20 AM	2011	March	Mar 2011	24	3	3/24/2011	3:20 AM	4	Thursday	Weekday	No			51	52.5 under 55		
3/24/11 3:30 AM	2011	March	Mar 2011	24	3	3/24/2011	3:30 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 3:40 AM	2011	March	Mar 2011	24	3	3/24/2011	3:40 AM	4	Thursday	Weekday	No			52	52.5 under 55		
3/24/11 3:50 AM	2011	March	Mar 2011	24	3	3/24/2011	3:50 AM	4	Thursday	Weekday	No			51	52.5 under 55		
3/24/11 4:00 AM	2011	March	Mar 2011	24	4	3/24/2011	4:00 AM	4	Thursday	Weekday	No			51	52.5 under 55		
3/24/11 4:10 AM	2011	March	Mar 2011	24	4	3/24/2011	4:10 AM	4	Thursday	Weekday	No			50	52.5 under 55		
3/24/11 4:20 AM	2011	March	Mar 2011	24	4	3/24/2011	4:20 AM	4	Thursday	Weekday	No			50	52.5 under 55		
3/24/11 4:30 AM	2011	March	Mar 2011	24	4	3/24/2011	4:30 AM	4	Thursday	Weekday	No			50	52.5 under 55		
3/24/11 4:40 AM	2011	March	Mar 2011	24	4	3/24/2011	4:40 AM	4	Thursday	Weekday	No			51	52.5 under 55		

Note: Some columns in the new workbook will be blank (i.e., DaySchedule, Occupancy, and DateRng). These can be filled by alternate ECAM menu items, but are not necessary for basic re-tuning functions, and will be omitted for this walkthrough.

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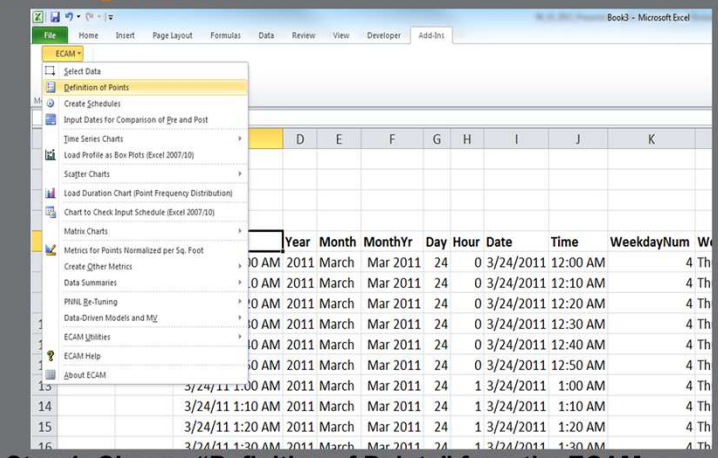
Note: It is a good idea for the user to save the new workbook before continuing so that the process does not have to be repeated if a mistake is made. Save the file as an extension xlsm (macro-enabled workbook). ECAM now recognizes the timestamp, and creates multiple columns for Year, Month, Day, Hour, Date, Time, WeekdayNum (i.e., 1-7, with Monday being 1 and Sunday being 7), Daytype (i.e., Weekend, Weekday, Holiday), and several outdoor-air temperature categories (if outdoor-air temperature exists in the data) such as temperature bins and temperature range.

Menu Item Number 2: Definition of Points (Required)

Purpose: To "map" the BAS trended points (columns of data) into ECAM so charts can be generated.



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

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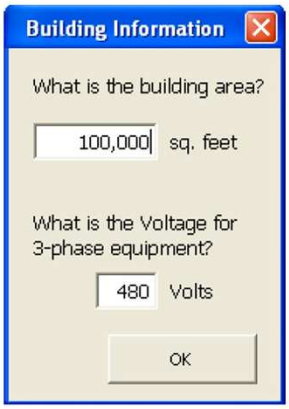
Note: The number of points trended and exported from the BAS can be very large (i.e., 2,000 points). However, only certain points are necessary for ECAM to generate useful charts to analyze. Thus, mapping the points of interest in ECAM allows the user to keep all data in the workbook, but only utilize that which is useful for generating charts to analyze.

Data Input: Definition of Points

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



Tip: ECAM needs this input to create metrics. However, PNNL re-tuning does not require this input and thus the default values (e.g, building area = 100,000 sq.feet and 3-phase voltage = 480 V are acceptable).

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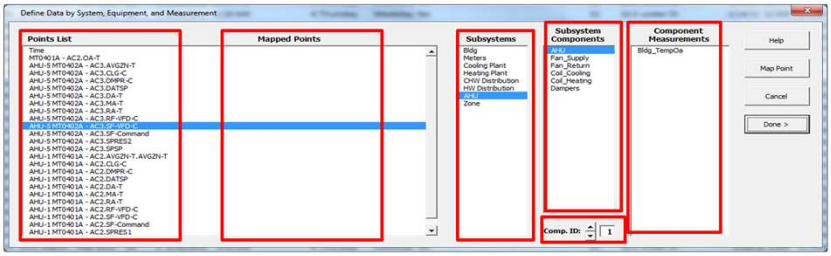
Tip: ECAM needs this input to create metrics. However, PNNL Re-tuning does not require this input and thus the default values (e.g, building area = 100,000sq.feet and 3-phase voltage = 480 V are acceptable).

Data Input: Definition of Points Cont.

- **Step 3: Define or "map" the points**



Points List: Consists of the header names in the "data" sheet

Subsystems: A list for different systems inside of the building for the user to cycle between when defining specific points.

Subsystem Components: The individual components for the subsystem chosen.

Component Measurements: Specific measurement (with units) for the subsystem and component chosen

Component ID: ECAM designation allowing for multiple components to be mapped, and generate charts for different components (i.e., air-handling unit 1 and air-handling unit 2). The user should map all components for a specific system with the proper Comp. ID.

Mapped Points: New name given by ECAM once the point has been mapped.

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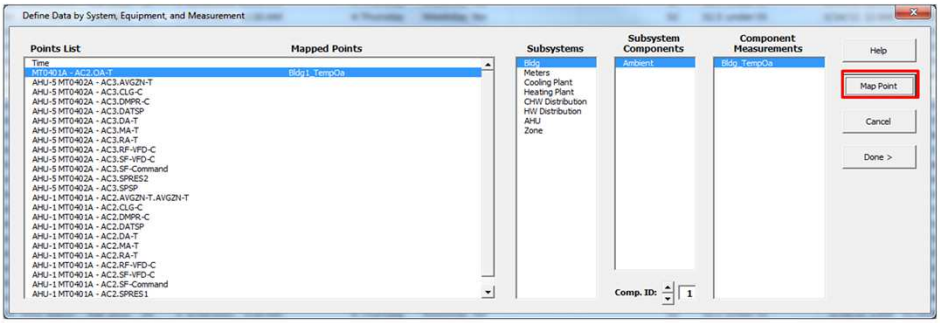
Note: The Definition of Points window needs to be refreshed before mapping any points. To do so simply click on any subsystem and everything else will refresh.

Data Input: Definition of Points Cont.

- Step 3 Detailed Example: Walkthrough



Click on MT0401A – AC2.OA-T under the "Points List"
Click on "Bldg" under "Subsystems"
Click on "Ambient" under "Subsystem Components"
Click on Bldg_TempOa under "Component Measurements"
Click on "Map Point"

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Note: Identifying what each point name from the BAS is can be confusing unless you are the one who set up the trends. Generally, the end of the point name will give a good indication of what the point that is trended corresponds to.

Live walkthrough to map all points in the Points List

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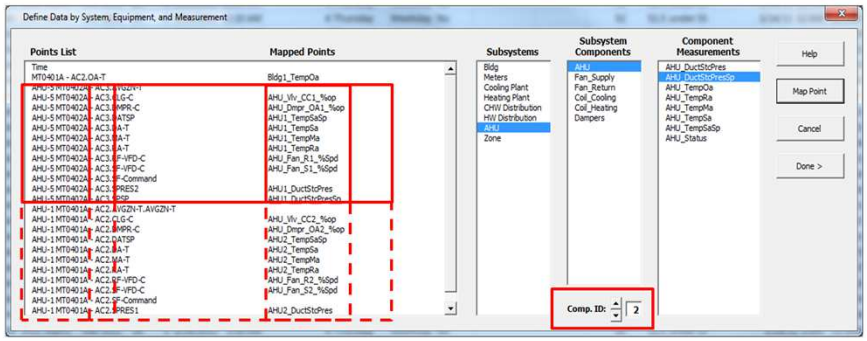
Data Input: Definition of Points Cont.

- All points defined correctly should look like this:



- Points for air-handler 1
- Points for air-handler 2

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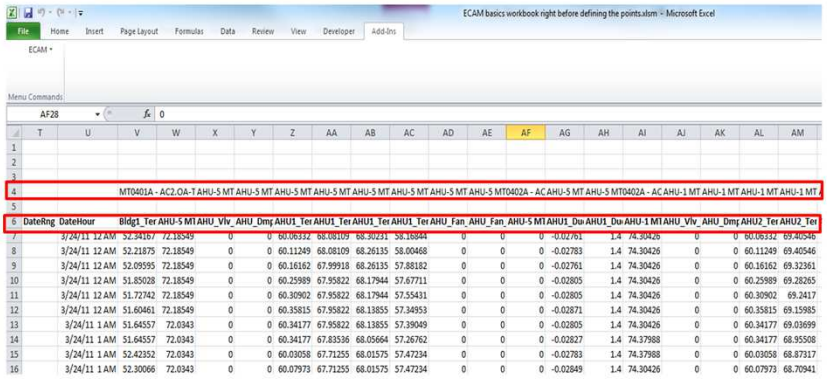
Note: Comp. ID changed to "2" to map second air-handling unit

Note: although it is clear (per the Points List) that the air-handlers for this building are AHU-5 and AHU-1, ECAM will label the air-handlers as AHU-1 and AHU-2. This is because of the ECAM naming convention, so the only way to identify which AHU is from the building is to label the corresponding charts that are created.

Definition of Points: Result

- ECAM defined point names show up in row 6, and BAS point names are moved up to row 4 as a reference for the user:



	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1																				
2																				
3																				
4			MT0401A - AC2,OA-T	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	AHU-5 MT	MT0402A - AC	AHU-5 MT	AHU-5 MT	MT0402A - AC	AHU-1 MT	AHU-1 MT	AHU-1 MT	AHU-1 MT	
5																				
6	DateRng	DateHour	Bldg1_Ter	AHU-5 MT	AHU_Vlv_	AHU_Dmp	AHU1_Ter	AHU1_Ter	AHU1_Ter	AHU1_Ter	AHU_Fan_	AHU_Fan_	AHU-5 MT	AHU1_Du	AHU1_Du	AHU-1 MT	AHU_Vlv_	AHU_Dmp	AHU2_Ter	AHU2_Ter
7		3/24/11 12 AM	52.34167	72.18549	0	0	60.06332	68.08109	68.30231	58.16844	0	0	0	-0.02761	1.4	74.30426	0	0	60.06332	69.40546
8		3/24/11 12 AM	52.21875	72.18549	0	0	60.11249	68.08109	68.26135	58.00468	0	0	0	-0.02783	1.4	74.30426	0	0	60.11249	69.40546
9		3/24/11 12 AM	52.09595	72.18549	0	0	60.16162	67.99918	68.26135	57.88182	0	0	0	-0.02761	1.4	74.30426	0	0	60.16162	69.32361
10		3/24/11 12 AM	51.85028	72.18549	0	0	60.25989	67.95822	68.17944	57.67711	0	0	0	-0.02805	1.4	74.30426	0	0	60.25989	69.28265
11		3/24/11 12 AM	51.72742	72.18549	0	0	60.30902	67.95822	68.17944	57.55431	0	0	0	-0.02805	1.4	74.30426	0	0	60.30902	69.2417
12		3/24/11 12 AM	51.60461	72.18549	0	0	60.35815	67.95822	68.13855	57.34953	0	0	0	-0.02871	1.4	74.30426	0	0	60.35815	69.15985
13		3/24/11 1 AM	51.64557	72.0343	0	0	60.34177	67.95822	68.13855	57.39049	0	0	0	-0.02805	1.4	74.30426	0	0	60.34177	69.03699
14		3/24/11 1 AM	51.64557	72.0343	0	0	60.34177	67.83536	68.05664	57.26762	0	0	0	-0.02827	1.4	74.37988	0	0	60.34177	68.95508
15		3/24/11 1 AM	52.42352	72.0343	0	0	60.03058	67.71255	68.01575	57.47234	0	0	0	-0.02783	1.4	74.37988	0	0	60.03058	68.87317
16		3/24/11 1 AM	52.30066	72.0343	0	0	60.07973	67.71255	68.01575	57.47234	0	0	0	-0.02849	1.4	74.30426	0	0	60.07973	68.70941

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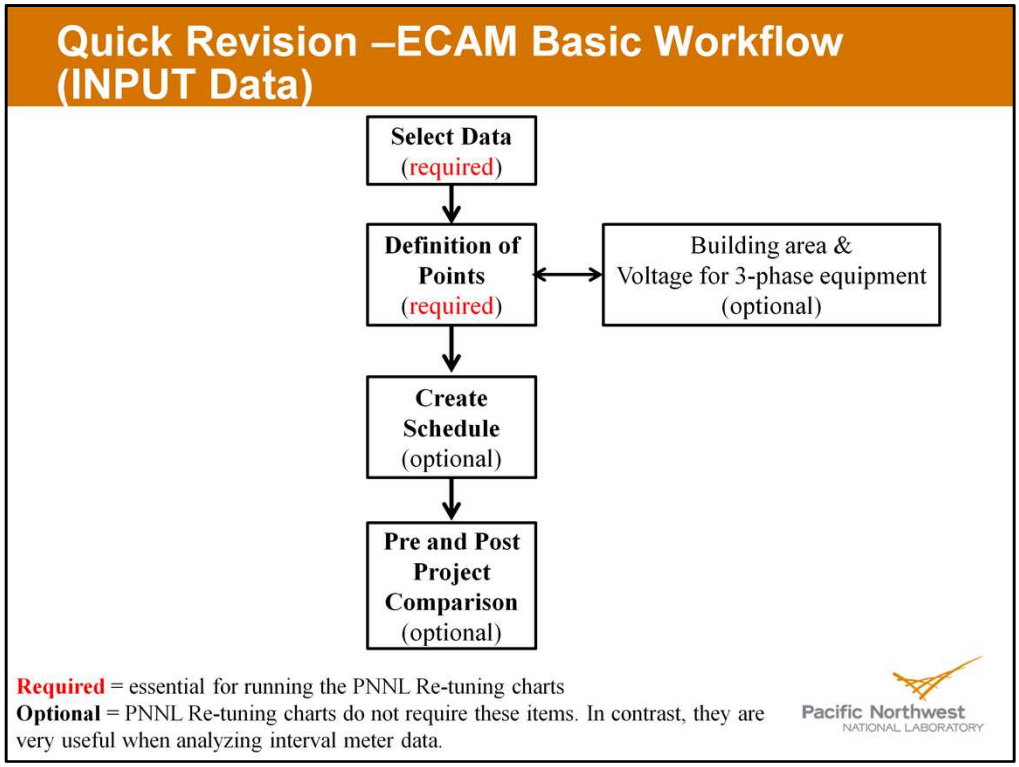
You can see the difference here, where the names at the top are AHU-5 and the bottom shows AHU-1



Required = essential for running the PNNL Re-tuning charts
Optional = PNNL Re-tuning charts don't use these items. In contrast, these are used for creating metrics (e.g., W/sq.ft, etc.) for interval meter data.

PNNL Re-tuning Charts

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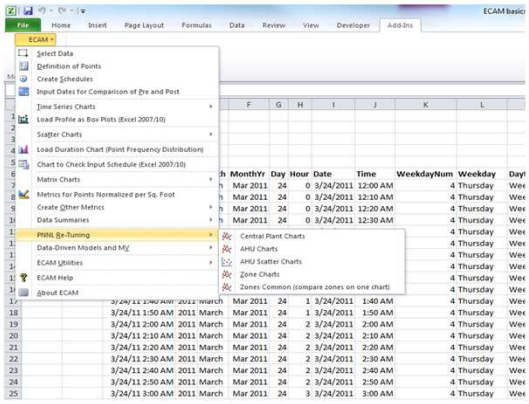
PNNL Building Re-tuning Charts

- The PNNL building re-tuning menu items are designed to automatically create charts for analysis, to aid in identifying and correcting HVAC problems. The output charts are the result of the data input in the previous steps.



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Notes

- Selection of each menu item creates a separate worksheet (with the related charts) for each relevant building re-tuning focus area. For example, if there are five air-handling units (AHUs), five worksheets will be created, one for each AHU. The data range for each chart is consistent.
- 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.
- Minimum of 2-weeks of data collection before analysis, to get a bigger picture of how the building is performing, at a collection frequency of 5-30 minutes.

Analyzing PNNL Building Re-tuning Charts

- Several guides to re-tuning measures have been created and posted on PNNL's website to help users identify opportunities for improvement to AHUs, chillers, boilers, etc. http://www.pnnl.gov/buildingretuning/retuning_measures.stm
- Specific guides posted include:
  - Air-Side Economizer Operation
  - AHU Static Pressure Control
  - AHU Discharge-Air Temperature Control
  - Occupancy Scheduling: Night and Weekend Temperature Set Back and Supply Fan Cycling during Unoccupied Hours
  - Zone Heating and Cooling Control
  - Central Utility Plant Cooling Control
  - Central Utility Plant Heating Control
  - AHU Minimum Outdoor-Air Operation
  - AHU Heating and Cooling Control

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Note: The goal is to have user's generate charts using ECAM, and then identifying opportunities by looking at these guides as aid in analysis. Each guide shows examples of good and bad operation, utilizing charts generated in ECAM. Future guides to be posted on the website include rooftop unit controls, and optimal start and night set back.

Air-Handling Unit (AHU) Trending Guidelines

- If there are fewer than 6 AHUs in the building, recommend trending all AHUs.
- If the building is less than 4-stories tall, pick at least one AHU from each floor.
- Trend a maximum of 10 AHUs.
- Don't pick an AHU that is operating the "best," rather take a random sample of AHU's to monitor.
- If possible, choose from AHUs that are most common throughout the building in configuration and layout.

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Air-Handling Unit (AHU) Charts (INPUT)

- To identify operational problems and make corrections for air-handling unit operations, the following points should be trended and collected from the BAS at 5-30 minute intervals:

- Outdoor-air temperature (OAT)
- Mixed-air temperature (MAT)
- Return-air temperature (RAT)
- Discharge-air (supply-air) temperature (DAT)
- Discharge-air temperature set point (DATSP)
- 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

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Note: The outdoor, exhaust, and return-air damper commands often will come as one command from the BAS (these three dampers work together to control how much air is being exhausted out of the building, returned into the mixed-air stream, and fresh air brought in from the outside). Also, humidity can be trended, but is not used in ECAM.

Air-Handling Unit (AHU) Charts (OUTPUT)

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

- Outdoor-air (OAT), return-air (RAT), mixed-air (MAT), and discharge-air (DAT) 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

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Air-Handling Unit (AHU) Charts (OUTPUT)

- The following scatter charts will be created by ECAM, depending on the availability of the relevant points mapped in ECAM:
  - Discharge-air temperature (DAT) vs. discharge-air temperature set point
  - Cooling-coil valve command vs. heating-coil valve command
  - Outdoor-air damper position (OAD) vs. outdoor-air temperature (OAT)
  - Mixed-air temperature (MAT) vs. outdoor-air temperature (OAT)

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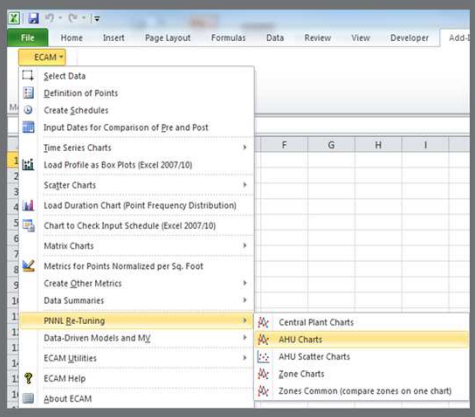
User Interaction: Generating AHU Charts

- Step 1: Under the ECAM menu, go to PNNL Re-tuning and click on “AHU Charts.”



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AHU Charts Result

- 2 new sheets are generated, “AHU1” and “AHU2.” Each sheet will have 10 charts. Below is a screenshot of AHU1

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Note: The legend on each chart will tell the user which points are shown on each chart, and on some charts both vertical axis are used for different points. Make sure the scale of the axis makes sense before analyzing the data, and make use of the Pivot Tables to analyze specific days within the data collection period. Also, this would be the time to rename the sheets to match that of the BAS AHU names. Demonstration of pivot table and axis in ECAM. The default ECAM axis label has “Avg” in the name. The user should note that the data is not averaged, but ECAM calls it an average because of other ECAM menu items that do use average values. This is a cosmetic feature that is being changed, but the user can change the axis name if it appears confusing.

Analyzing AHU Charts

- User Interaction: Click on “AHU2” in the ECAM workbook, and use the PivotTable to select Month>March, and Day>(24th and 25th). This will be demonstrated on screen now, and analysis will follow in the upcoming two slides.
- From the Air-Side Economizer Operations guide to re-tuning measures
  - “When the cooling coil is open, is the outdoor-air damper fully open, if the conditions are favorable for economizing?
    - How do I determine if the conditions are favorable for economizing?
      - See the control guide and reference the suggested action portions for recommendations, and examples of good and bad operations.
  - See the following slides for analysis

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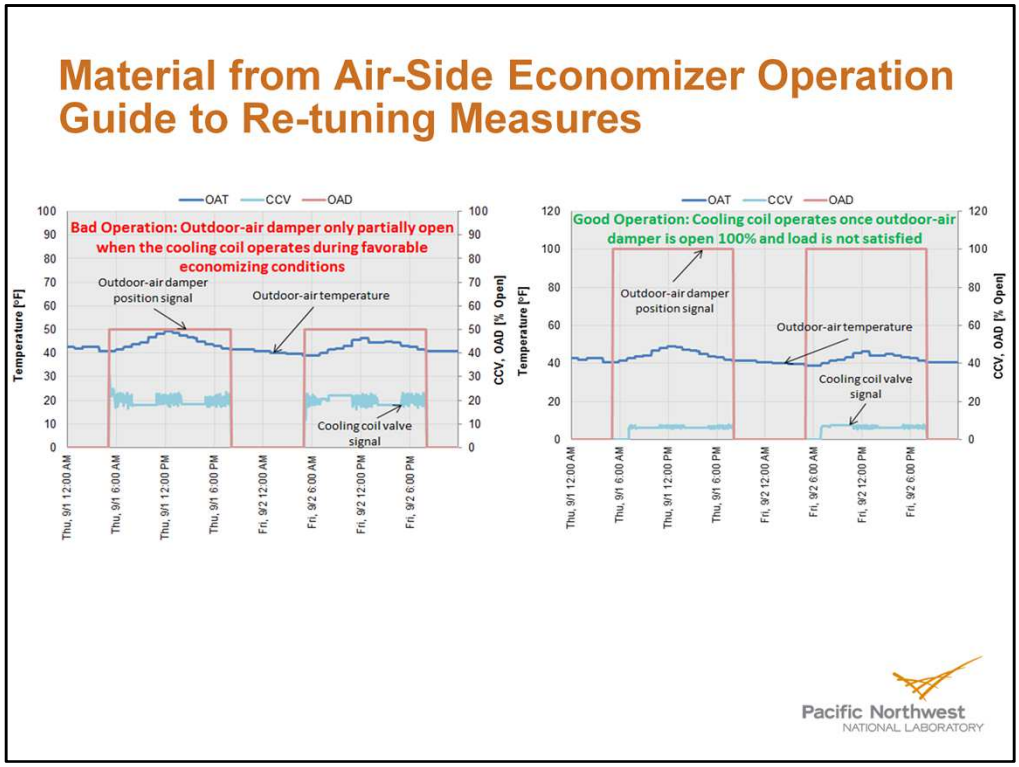
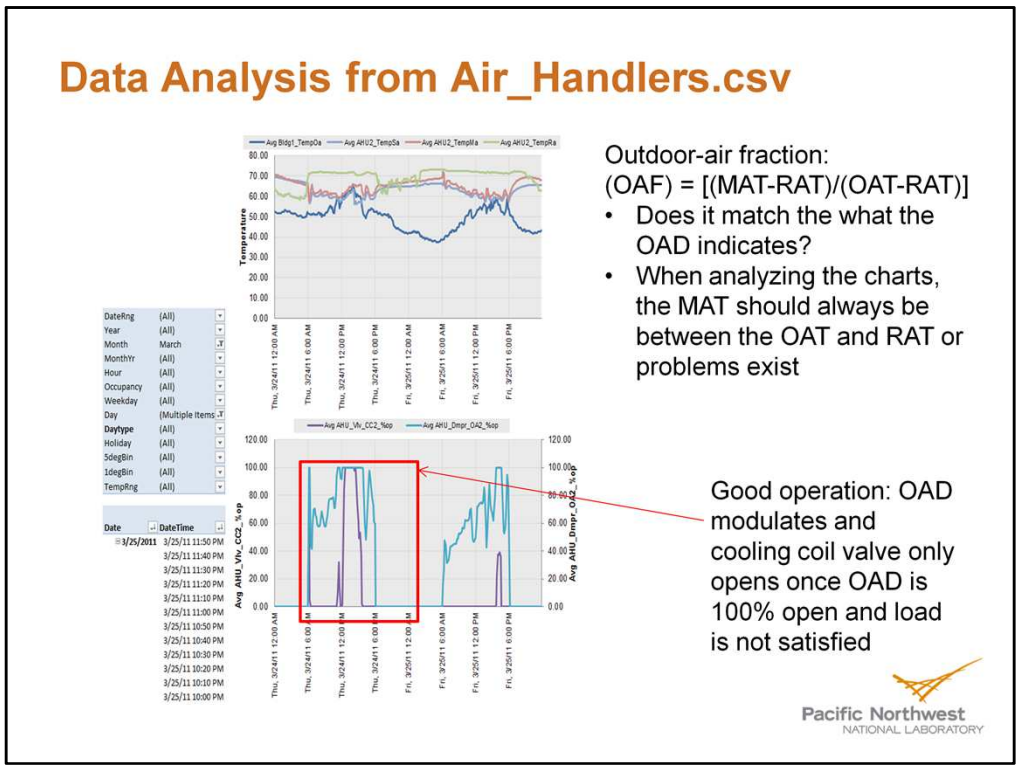


Note: As the user can see, an example of bad operation results when the outside-air damper (OAD) is partially open and the cooling-coil-valve (CCV) signal is also sending chilled water through the coil. If this occurs during conditions that are favorable for economizing (i.e., OAT<55), then the OAD should open up fully before the cooling coil opens up. The chart on the right shows an example of good operation, when the OAD is open 100% before the cooling-coil-valve is opened up.



Note: When the user modifies the charts with the pivot table, the specified selection will be saved if the user overwrites the previously saved workbook or creates a new file with the desired pivot table selection. However, if the user does not save, then the pivot table will revert back to the last time the file was saved and can be modified each time the user opens the workbook.

The outdoor-air fraction (OAF) is not something that is calculated by ECAM, but is going to be an added feature. The user can generate this manually, but the main takeaway is to look at the mixed-air temperature data and make sure that it is between the outdoor and return-air temperatures. As the MAT gets closer to the OAT, the OAF gets greater (closer to 1, or 100% outdoor air), and as the MAT gets closer to the RAT, the OAF gets smaller (OAF closer to 0, or no outdoor air). However, to accurately use the OAF, make sure that the OAT and RAT have at least 5°F difference between them.

AHU Static Pressure Operation

- Data from Air_Handlers.csv
  - Use this chart to identify when the AHU is turning on/off
  - Opportunities?
  - Let's go to the AHU Static Pressure Operation Control Guide:
    - Is there a reset schedule for the duct static pressure set point?
    - What are the scheduled On/Off times for the AHU?

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Note: You will notice that the static pressure (red line) is plotted on the primary y-axis (the left axis), and the static pressure set point (green line) is plotted on the secondary y-axis (the right axis). Make sure that the scales are the same on these axis before analyzing the charts. This goes for all charts that utilize multiple axis. If the units on the axis are the same, the user can either move them both to the primary axis, or match up the scaling on the axis. Some charts will plot sensors with different units and scales on different axis (e.g., the static pressure on the primary y-axis, and the fan speed on the secondary y-axis). In this case, they have different units and should not be scaled the same.

AHU Static Pressure Operation

- From static pressure chart on previous slide, it appears that this AHU is scheduled on from 6:00AM to 8:00PM Monday through Friday, 6:00AM-2:00PM on Saturday, and off on Sunday
  - Does this match the building occupancy schedule?
    - If not, can the AHU schedule be tightened to match the building occupancy schedule more closely
    - Can the static pressure set point be reset to a lower value during late afternoons when occupants begin to leave? What about early in the morning?
    - Can the AHU satisfy the load by reducing the static pressure set point on Saturdays if the building is "lightly" occupied?
    - How can I reset the static pressure?
      - See the suggested actions portion of the AHU Static Pressure Operation Control Guide to implement static pressure reset.

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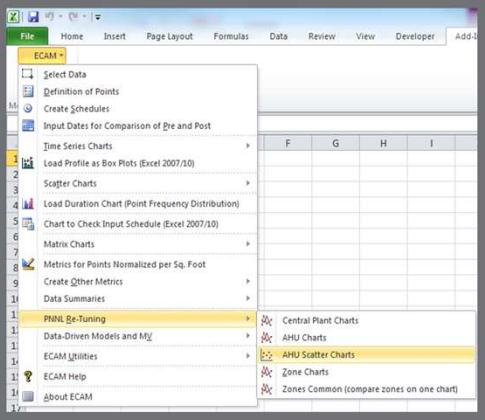
Note: In retuning, changing the set point for discharge static pressure or any temperature or command in the system is the focus when trying to save energy or identify corrective actions based on the performance of the system.

User Interaction: Generating AHU Scatter Charts

- Step 1: Under the ECAM menu, go to PNNL Re-tuning and click on “AHU Scatter Charts.”



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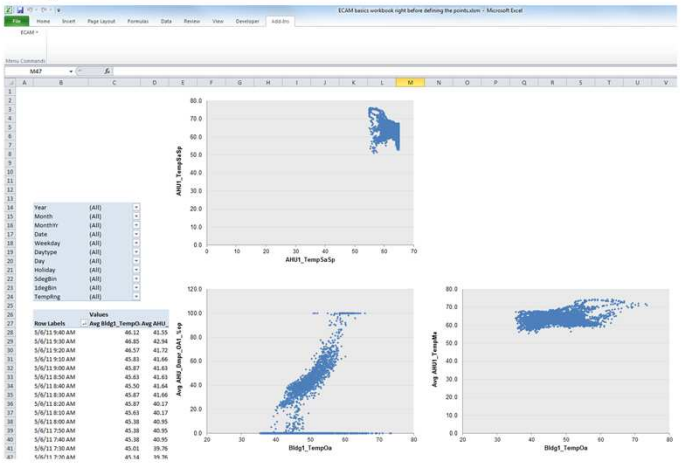
AHU Scatter Charts Result

- 2 new sheets are generated, “AHUxy1” and AHUxy2.” Each sheet will have 3 charts. Below is a screenshot of AHUxy1



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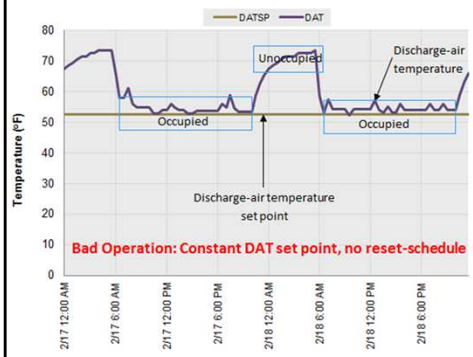
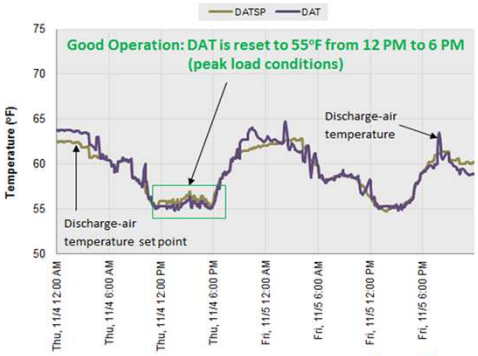
Note: There should be a second chart for the cooling coil valve command vs. the heating coil valve command. However, since there was no heating coil valve command data given by the BAS, this chart does not show up. Also, the top left chart should be the supply-air temperature vs. the supply-air temperature set point. ECAM shows the y-axis as the set point, but in reality it is the temperature and not the set point.

When analyzing the bottom left chart (OAD vs. OAT), there should be a positive linear trend between 40°F and 60°F. This is because these temperatures are optimal for economizing, and as the temperature gets closer to 60°F, the OAD should be closer to 100% open, and as the temperature gets closer to 40°F the OAD should start to close to the minimum position. This example appears to follow this guideline.

AHU Charts: Examples of Good and Bad Operation

- From AHU Discharge-Air Temperature Control Guide:
  - Is reset being used to control the discharge-air set point?
    - The chart on the left shows constant set point during occupied hours
    - The chart on the right shows the set point being reset
- See suggested actions portion of guide for implementation





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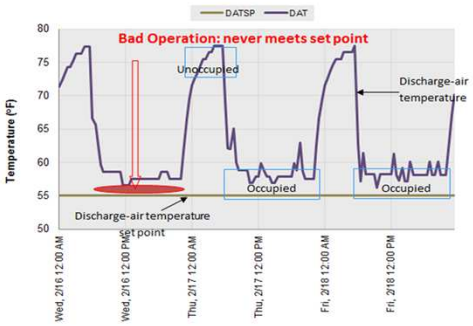
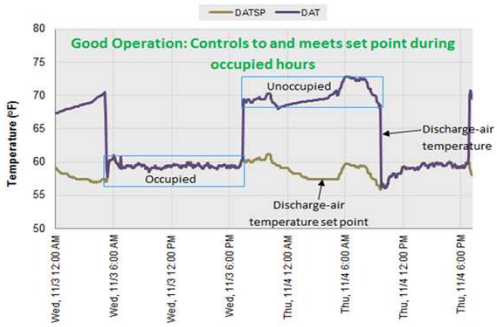
AHU Charts: Examples of Good and Bad Operation

- Does the discharge-air meet set point?
  - If not, this can indicate that the AHU cannot satisfy building's cooling requirements, bad proportional integral derivate (PID) loop control, a leaking heating coil valve, or a bad/failing economizer or control.





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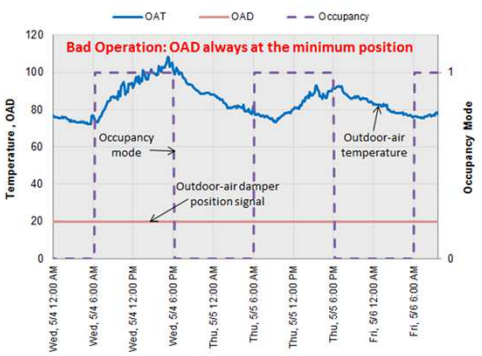
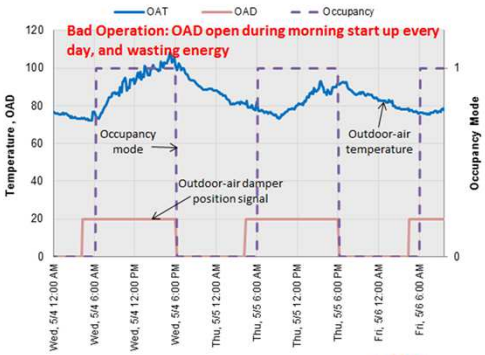
AHU Charts: Examples of Good and Bad Operation

- From AHU Minimum Outdoor-Air Operation
  - Does the outdoor-air damper close during unoccupied times?
    - The chart on the left shows the OAD command is constant
    - The chart on the right shows the OAD command opening before occupied times
    - Example of good operation on the following slide





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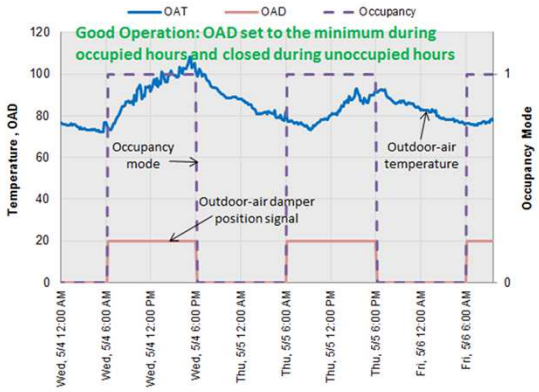
AHU Charts: Examples of Good and Bad Operation

- From AHU Minimum Outdoor-Air Operation
  - Does the outdoor-air damper close during unoccupied times?
    - Good operation below, where the OAD is closed except during occupied periods, and opens to the minimum position (no economizing) due to warm outdoor-air temperatures
  - See the control guide for further instruction regarding minimum outdoor-air operations.



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Zone Trending Guidelines

- If there are fewer than 8 zones per floor, trend all zones on the floor.
- For each floor, trend at least one zone on each of the four directions (north, south, east, and west) and at least four zones in the core of the floor.
- If the building is less than 4-stories tall, trend 8 zones on every floor, otherwise trend all 8 zones on every other floor
- Trend a maximum of 80 zones.

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Zone Charts (INPUT)

- To identify operational problems and make corrections for zone terminal unit/VAV unit operations, the following points should be trended and collected from the BAS for the zones:

- Zone temperature
- Zone temperature set point
- VAV box damper position
- Reheat valve position (if supply air is reheated at the zone)
- Zone occupancy mode (occupied/unoccupied)
- Re-cool valve position (if supply air is re-cooled at the zone)
- Zone CFM
- Zone CFM set point
- Zone discharge-air temperature
- Fan status, or fan command (for fan powered boxes only)

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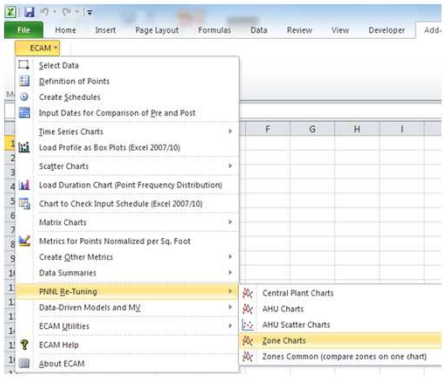
Note: Many VAV box BAS controllers will only have 5 to 6 of these data points configured. The zone discharge-air temperature and the fan status/fan command may not exist. This is ok, the user should trend all points from this list that are available.

Zone Charts (OUTPUT)

- 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



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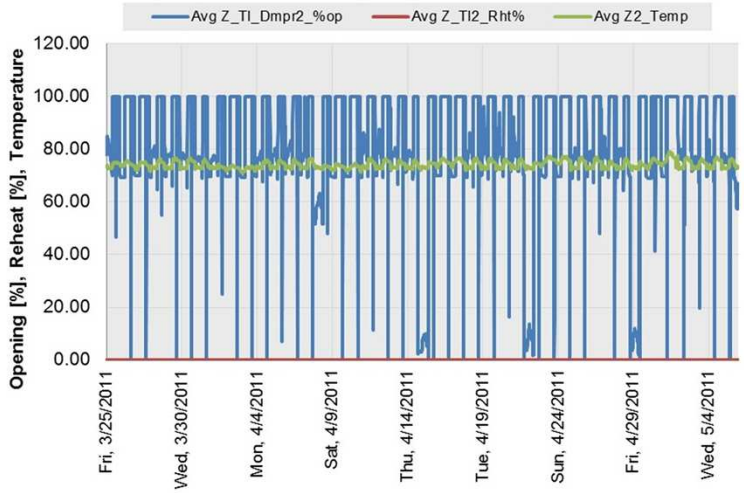
Zone Charts (OUTPUT)

- Example graph for Zone Charts output (this zone has reheat capability).



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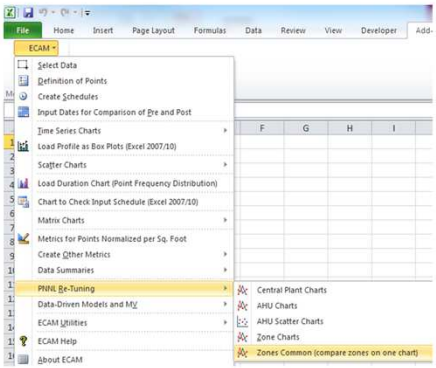
Note: The vertical axis here is shared by all three points, so it represents a percentage open on the valve and also a temperature. It is important for the user to remember this when analyzing the charts.

Zones Common (OUTPUT)

- The following time-series chart will be created by ECAM
  - VAV box damper position for all zones vs. time
  - Depending on the building size, hundreds of zones can be generating data, but a representative sample of interior and exterior zones for each air-handling unit should be trended and collected by the BAS for analysis.



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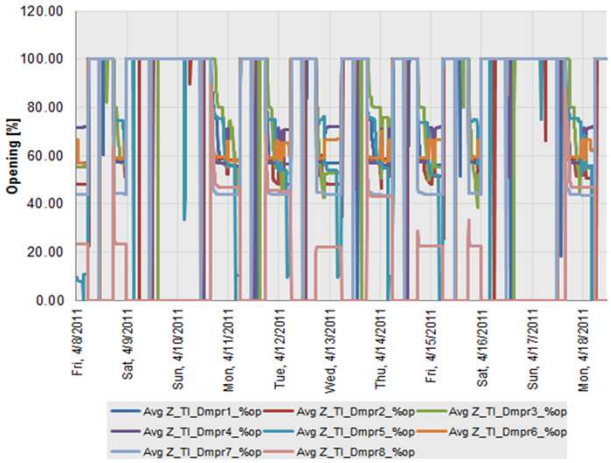
Note:

Zones Common (OUTPUT)

- Example graph for Zones Common Chart output (this AHU has 8 zones trended).



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Zone Analysis

- Make sure to map all zones related to a specific AHU in one workbook, do not mix zones from different AHUs into one spreadsheet
- See how many zones for that AHU have reheat commands active
- Use the zones common chart and the pivot table to see how the dampers are modulating during occupied hours for that AHU
- Opportunities?
  - Zone information is critical when analyzing the performance of the AHU. The zone loads drive the AHU, and information such as number of zones in reheat, and VAV box damper position can be used to aid in discharge-air temperature set point reset and discharge static pressure set point reset
  - Example to follow

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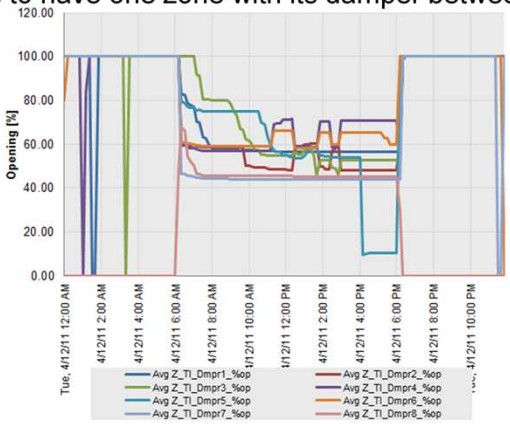
Zone Analysis

- Utilizing the pivot table to highlight one day, you can see that the damper positions are between 40% and 80% open during occupied hours. This tells us that these zones are more than adequately supplied with air from the AHU.
  - Goal is to have one zone with its damper between 95-100% open*



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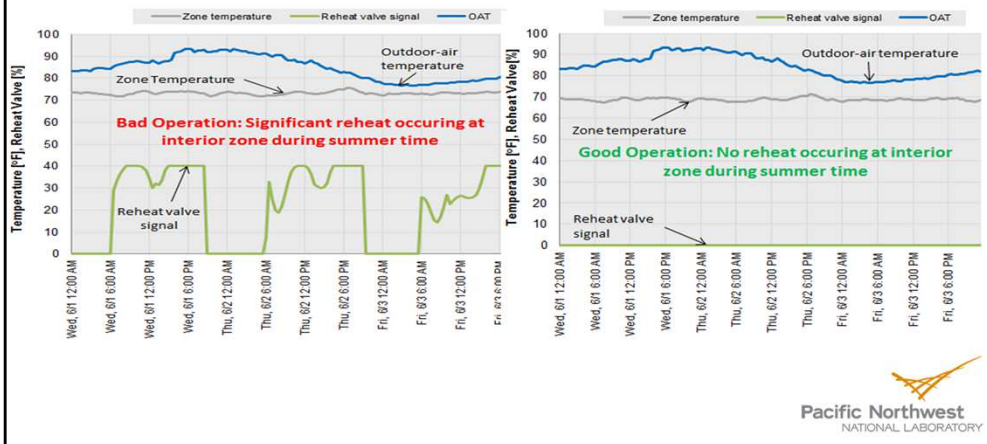
*Achieving this goal can be found in the suggested actions portions of the AHU Static Pressure Operation Control Guide.

Zone Examples of Good and Bad Operation

- Reheat at interior zones (if reheat is available at the interior zone)
  - Significant reheat at interior zones can indicate that the minimum air flow setting for the zone is too high, or the AHU discharge-air temperature is too low.



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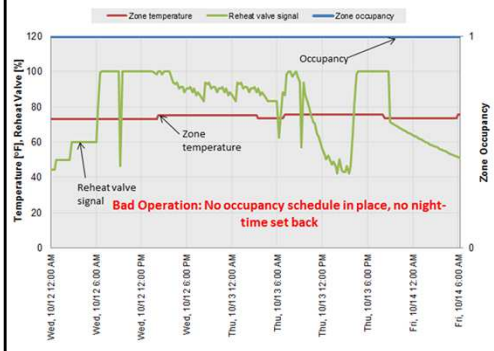
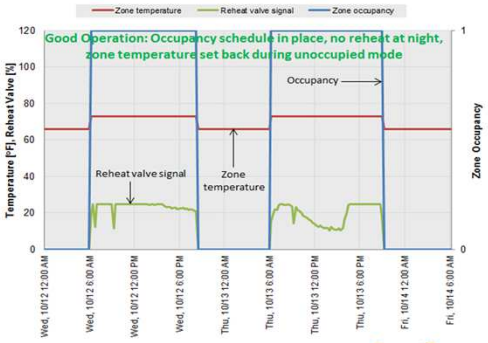
Note: Although discharge-air temperature is not included in these charts, future additions of ECAM are to add more charts and display them in a way that enable the user to analyze them more efficiently.

Zone Examples of Good and Bad Operation

- Is there night-time set back/unoccupied mode at the zone level?
  - The figure on the left does not have an occupancy schedule, or is occupied 24/7, and the reheat valve modulates at night
  - The figure on the right has an occupancy schedule, and no reheat during unoccupied periods





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Central Plant Charts (INPUT)

- To identify operational problems and make corrections for central plant operations, the following points should be trended and collected from the BAS for the central plant:

  - 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)
  - Each chiller status
  - Chilled water flow (gpm)
  - Chilled water differential pressure
  - Chilled water differential pressure SP
  - Cooling tower fan speed
  - Cooling tower fan speed set point
  - Cooling tower fan status
  - CHW and HW delta-T

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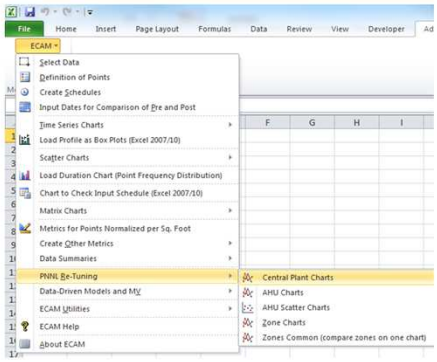
Central Plant Charts (OUTPUT)

- 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.



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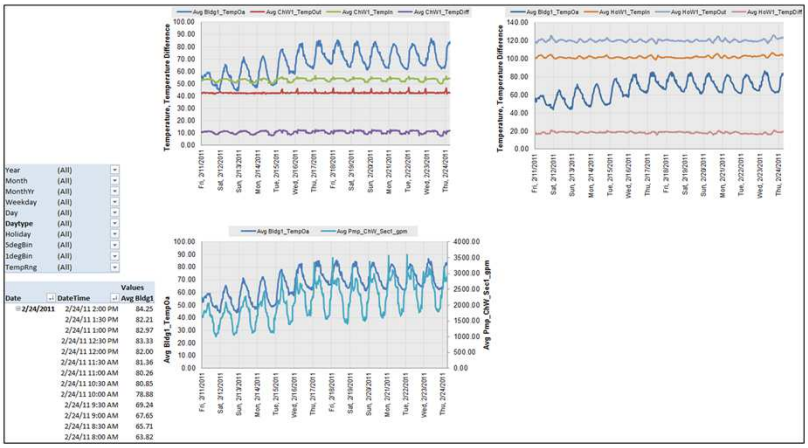
Central Plant Charts (OUTPUT)

- Example charts for the Central Plant.



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Note: The first chart (top left) is for the chilled water temperatures, the second chart (top right) is for the hot water temperatures, and the third chart (bottom left) is for the chilled water pump and outdoor-air temperature.

Analyzing Central Plant Charts

- Questions to ask when analyzing the charts
  - Is the chilled water/hot water supply temperature set point reset?
  - Is the loop delta-T low (less than 8°F for chilled water, less than 18°F for hot water)?
  - Is the loop differential pressure set point constant, and if so, can it be reset at partial load conditions?
- Examples of good and bad operation to follow

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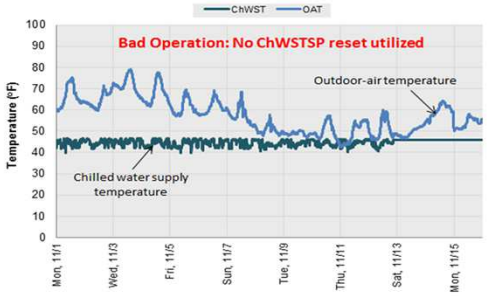
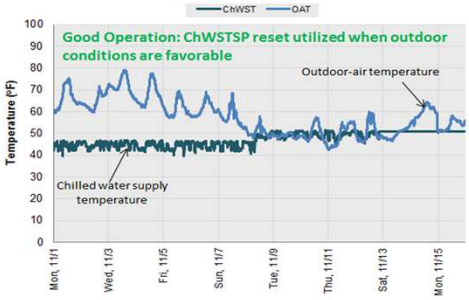
Central Utility Plant Examples of Good and Bad Operation

- From Central Utility Plant Cooling Control Guide
  - Is reset utilized on the chilled water supply temperature?
  - The chart on the left shows no reset
  - The chart on the right shows chilled water reset based on outdoor-air temperature
- Other actions and methods are discussed in the guide





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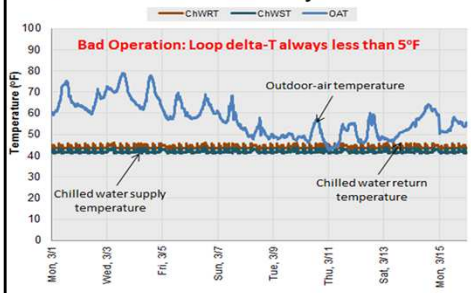
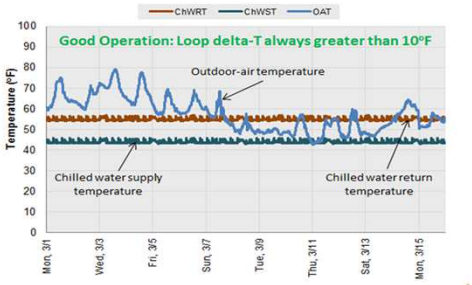
Central Utility Plant Examples of Good and Bad Operation

- From Central Utility Plant Cooling Control Guide
  - Is the loop delta-T low (less than 8°F)?
  - The chart on the left shows a delta-T always less than 5°F
  - The chart on the right shows a delta-T around 10°F
- The delta-T indicates the load in the building, and impacts consumption on chillers
- See Central Utility Control Guide for further instruction





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Note: low delta-T has a significant effect on consumption. Usually, this occurs when there is very little load in the building, and can be an indicator that there is no chilled water or hot water reset being utilized, or lack of a differential pressure set point reset. See the guide for further instruction.

ECAM Enhancements

- Recent addition of data-driven models and modeling and verification
  - Create baseline and post baseline models of interval meter data and look at savings for pre and post operations
  - This capability is in the latest version, but there is no documentation yet for its use (will be added in next version of the user guide)
- PNNL re-tuning changes
  - Cosmetic changes to aid in the analysis of the charts
    - Additional sheet in the workbook that describes the point definitions of ECAM
    - Consistent axis labels and specified colors for each sensor (i.e., outdoor-air temperature is always blue)

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ECAM Resources

- All material pertaining this webinar series will be posted at www.pnnl.gov/buildingretuning/resources.stm
  - Will be updating to latest version of ECAM
  - Guide to retuning measures can be found here: http://www.pnnl.gov/buildingretuning/retuning_measures.stm
  - Interval data analysis with ECAM document can be found here: http://www.pnnl.gov/buildingretuning/documents/pnnl_20495.pdf
  - ECAM user guide: http://www.pnnl.gov/buildingretuning/documents/pnnl_21160.pdf
  - ECAM webinar content: http://www.pnnl.gov/buildingretuning/webseries.stm
  - Online re-tuning training: http://retuningtraining.labworks.org

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Thank You

Danny Taasevigen
Advanced Power and Energy Systems Group
Pacific Northwest National Laboratory
902 Battelle Boulevard
P.O. Box 999, MSIN K6-68
Richland, WA 99354 USA
Tel: 509-375-6551
danny.taasevigen@pnnl.gov

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