ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

DOE Data Center Air-Management (AM) Tool:

User's Manual

Version 1.16 (May 10, 2011)

ANCIS
INCORPORATED

www.ancis.us

DISCLAIMER

TABLE OF CONTENTS

FIGURES

TABLES

OVERVIEW

What does this Tool do?

Air management in data centers is essentially about keeping cold and hot air from mixing. Cold supply air from the air handler should enter the heat-generating IT-equipment without mixing with ambient air and the hot exhaust air should return to the air handler without mixing. Managing the cold and hot air streams in data centers is important for cooling infrastructure energy management and IT-equipment thermal management.

The DOE Data Center Air-Management Tool was developed to help accelerate the energy savings in data centers without affecting the thermal IT-equipment environment. Based on user input, the Tool provides air management recommendations (actions) and the potential for reducing the supply airflow rate and increasing the supply air temperature, both having an impact on energy use. Finally, the Tool estimates the percentage energy reduction for supply fans and chillers.

The underlying assumption for this Tool is sufficiently stable environmental conditions, for example, the air handlers may well have variable air volume (VAV) fans but they are assumed operating at a stable constant reduced airflow. Since the majority of conventional data centers has raised-floor cooling with hot and cold equipment aisles, this Tool is intended mainly for such environments. Having some basic understanding of the physical data center environment makes this Tool easier to understand and use.

How is the Tool used?

First, the user fills in data and answers questions on four input Excel sheets (Steps 1-4). Each sheet includes basic guidance for entering the data correctly. This User's Manual provides additional information. Second, based on this user input, numerical output and recommended actions are given on two result output Excel sheets (Steps 5 and 6). An Engineering Reference (DOE 2011a) and a Data Collection Guide (DOE 2011b) complete the support documentation.

"DC Pro" Software Tool Suite

This Air-Management Tool is part of the DC Pro software tool suite, which includes a web-based profiling tool as well as separate Excel-based assessment tools for HVAC, electrical, and IT-equipment (DOE 2011c). These tools are not a substitute for a detailed "investment grade" audit. They provide estimates of savings for various measures, but actual savings may vary based on site-specific conditions that are not addressed in the tools. Future versions of DC Pro will integrate the profiling and assessment tools with a common web-based interface and database.

Tool Download and Documentation

The Air Management Tool can be downloaded from the DOE Industrial Technologies Program website: http://www1.eere.energy.gov/industry/saveenergynow/dc_pro.html After downloading the Tool, there are three complementary documents on the same website for facilitating the use of the Tool:

- The *User's Manual* (this document) provides information on using the Tool.

- The *Engineering Reference* provides detailed information on the calculations, equations, metrics, and limitations.

- The *Data Collection Guide* provides information on collecting the necessary input data.

Questions, comments, and/or suggestions on these documents can be directed to mherrlin@ancis.us

Tool Structure

The Air-Management Tool has seven color coded Excel sheets for input and output plus three hidden sheets (see Figure 1):

Overview	Provides an overview of the data flow through the Excel sheets
Step 1: AHU	User input: Air-handler unit (AHU) data for calculating the RTI metric
Step 2: Equip	User input: Electronic equipment data for calculating the RTI metric
Step 3: RCI	User input: Equipment intake temperatures for calculating the RCI metric
Step 4: Main Input	User input: Main user input, including metrics from Steps 1-3
Step 5: Main Results	Result output: Main results but excluding energy estimates
Step 6: Energy Results	Result output: Energy estimates for supply fans and chillers
Lookup	Lookup tables for internal use (hidden)
Action Rules	Rules for triggering actions or recommendations (hidden)
Export	Output for post-processing (hidden).

The Overview sheet also allows the selection of either I-P (American) or SI (International) units. Please note that selecting I-P or SI units will not change the numerical values already entered into the Tool. Therefore, the selection of units should be done <u>before</u> any data are entered on subsequent sheets.
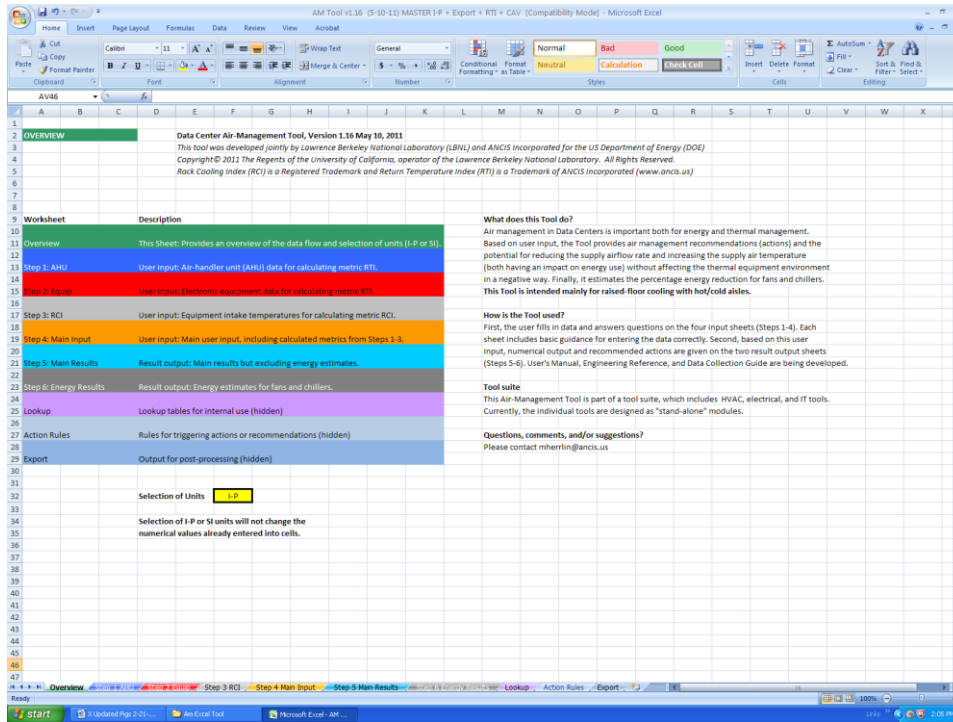
Figure 1: Overview sheet.

INPUT/OUTPUT SHEETS

This section describes the input and output sheets in the order they appear in the Excel Tool. This section can be read "from cover to cover" or as a reference manual for finding particular information on any of the sheets. General Information applicable to all four input sheets includes:

- Yellow cells indicate cells where to input data. All other cells are permanently locked.

- Dual units are shown next to each yellow input cell (e.g., °F or °C). The first unit represents I-P units and the second unit represents SI units. I-P or SI units are selected on the Overview sheet.

- Colored cells (besides yellow) indicate data that are exported to or imported from other sheets. The cells are color coded per the receiving or originating sheet (tab) color.

- Grayed out data are for internal use only, generally showing intermediate calculation steps.

- All input cells have input-range checking to avoid data-entry errors. If an input is Out of Range, check the accuracy of the input.

- Some input cells accept typed data whereas other cells have fixed options selected from drop-down boxes. The drop-down boxes are activated by simply selecting the cell.

- The screen shots included in this User's Manual can be difficult to read at the conventional 100% zoom level. Use the zoom capability of your software to enlarge the figures. Note that the screen shots may differ slightly from the latest version of the Tool.

- The Tool comes preloaded with data for a simple case.

Step 1 AHU

"Step 1 AHU" is the first of four input sheets. It is imperative to enter (accurate) data on this sheet.

By entering the requested air-handling unit (AHU) data (yellow cells) for up to 40 operating units, this sheet will calculate five pieces of data (orange boxes) and export them to the Main Input (Step 4) sheet.

The principal purpose of the data transfer to the Main Input sheet is to help calculate the Return Temperature Index (RTI)^{TM} on the Main Input sheet. This index plays an important role in understanding whether the data center is over-ventilated (by-pass air) or under-ventilated (recirculation air) (Herrlin 2008). For more information on RTI, please see section Step 4 Main Input.

Input data (yellow cells) (Figure 2):
- AHU Airflow [cfm or m^3/s]
- Supply Air Temperature [°F or °C]
- Return Air Temperature [°F or °C].

Although not required, it is recommended to enter the AHU units from the top (AHU 1) down in the yellow input table. At least one AHU must be entered. Note that high supply air temperatures save energy at the chiller level but may increase the energy usage at the server level. Generally, the server fans speeds up at high intake temperatures to ensure adequate cooling. For guidance on determining (measuring) the input data, see the *Data Collection Guide*.

Calculated data exported to the Main Input sheet (orange cells) (Figure 3):
- Total AHU Airflow [cfm or m^3/s] and AHU Count [-]
- Max-Min AHU supply temperature [°F or °C]
- Typical (airflow weighted) AHU supply air temperature [°F or °C]
- Typical (airflow weighted) AHU temperature drop [°F or °C].

Other calculated data (white cells):
- AHU kW Cooling
- AHU Ton Cooling

Resulting AHU kW cooling and AHU Ton Cooling (the heat extraction from the room by mechanical means and/or by free cooling) are calculated based on Total AHU Airflow and Typical (airflow weighted) AHU temperature drop. Note that AHU data are considered more robust than Equipment data (Step 2); Equipment Power (heat) is set equal to Resulting AHU Cooling (heat balance in room).

If there is a separate air-side economizer (one that provides cooling and airflow in addition to the AHUs) it could be specified as another "AHU". The Other Calculated Data listed above will then include the associated cooling effect. However, disregard separate fresh-air systems that generally have limited airflows. For built-in economizers, no additional entries are necessary.

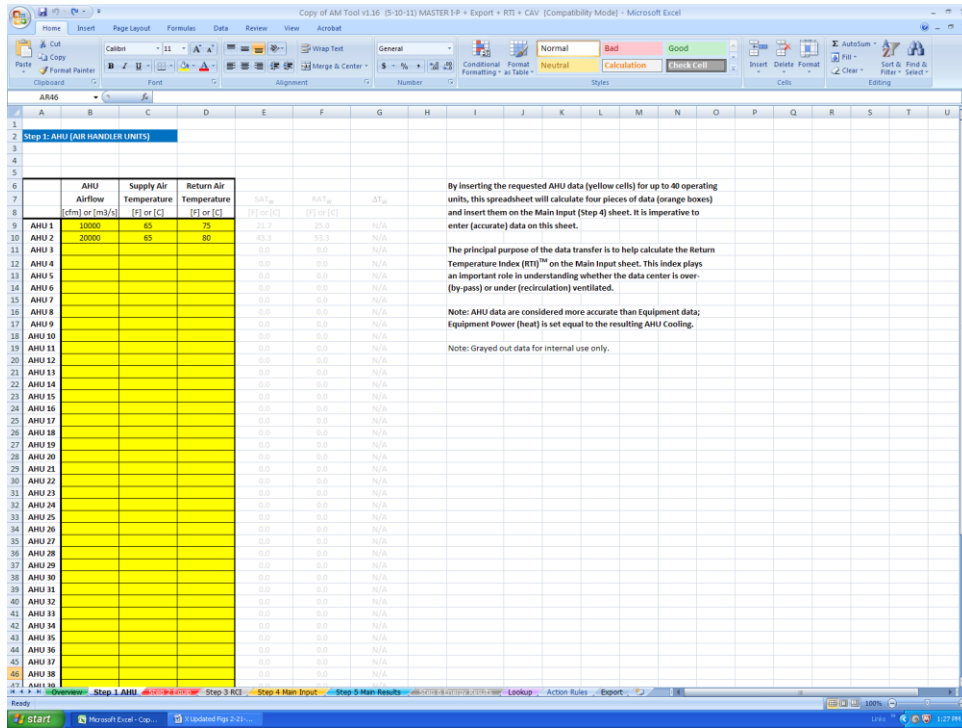For calculation details, see the *Engineering Reference*.
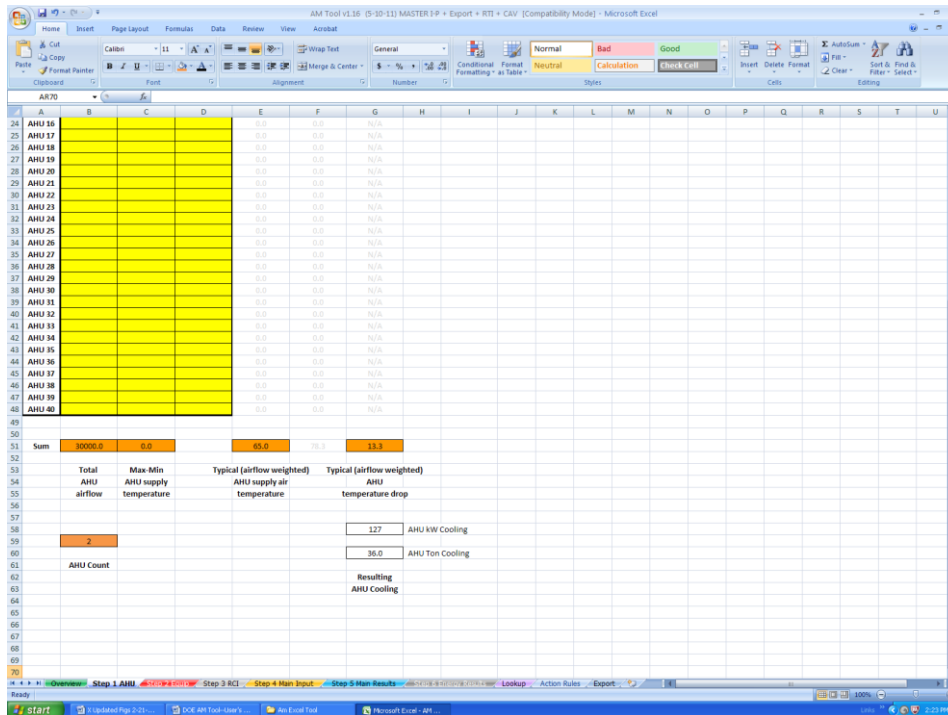
Figure 2: Step 1 AHU sheet, upper part.

Figure 3: Step 1 AHU sheet, lower part.

Step 2 Equipment

"Step 2 Equipment" is the second of four input sheets.

By inserting the requested equipment data (yellow cells), this spreadsheet will calculate two pieces of data (orange boxes) and export them to the Main Input (Step 4) sheet. "Equipment" includes heat-generating electronic equipment (IT) as well as electric equipment such as PDU and UPS.

The principal purpose of the data transfer is to help calculate the Return Temperature Index (RTI)^{TM} on the Main Input sheet. This index plays an important role in understanding whether the data center is over-ventilated (by-pass air) or under-ventilated (recirculation air) (Herrlin 2008). For more information on RTI, please see section Step 4 Main Input.

Since determining the equipment input data may be a challenging task, three options are available through the "Select Class Option" cell in the upper left corner of the spreadsheet. Select the cell to activate the drop-down box. Selection will display relevant table headings and yellow input cells. The option to select depends on which data are available and the quality of the data.

Depending on the selection, group the equipment into Classes with similar temperature rise (DT) or airflow rates (V) and fill in the remaining yellow input cells. Note that a "Class" can be on server, rack, or any spatial level defined by the user. Unique inputs for every piece of equipment, rather than consolidation into equipment Classes, are not allowed. Furthermore, only one Class Option can be selected for all input.

One of the following Class Options can be selected:

- Similar DT: "Class" refers here to equipment with similar Measured Temperature Rise (DT); used with corresponding fair estimates of Airflow (V). The manufacturers' published thermal reports or their online thermal calculators can also be used for estimating the equipment airflow and temperature rise.

  Input data (yellow cells):
  o Measured Temperature Rise arranged in Classes (DT) [°F or °C]
  o Estimated (low quality) Airflow per Class (V) [cfm or m^3/s].

- Similar V: "Class" refers here to equipment with similar Estimated Airflow (V); used with corresponding Number of Units (U). Use the manufacturers' published thermal reports or their online thermal calculators for estimating the equipment airflow.

  Input data (yellow cells):
  o Estimated (high quality) Airflow (V) [cfm or m^3/s]
  o Number of Units (U) [-].

- Similar DT(P): "Class" refers here to equipment with similar Measured Temperature Rise (DT); used with corresponding Measured Power (P) (Figure 4). Do not use nameplate power as a replacement for lack of measured power data. Instead, use the manufacturers' published thermal reports or their online thermal calculators for estimating the equipment power and temperature rise.

    Input data (yellow cells):
    o Measured Temperature Rise (DT) [°F or °C]
    o Measured Power (P) [W].

Although not required, it is recommended to enter the Classes from the top (Class 1) down in the yellow input tables. For more guidance on determining the input data for all three options, see the *Data Collection Guide*.

If no data are available, select "Similar DT" and fill in one row only. Estimate DT (table below may help) and set Airflow to any positive number. The trend is towards higher temperature rise across the electronic equipment.

Table 1: Typical Temperature Rise across IT-Equipment

Equipment Mix	ΔT [°F]	ΔT [°C]
Mainly traditional equipment	10 to 20	6 to 11
Mainly modern equipment	20 to 30	11 to 17
Mainly blade equipment	30 to 50	17 to 28

Calculated data exported to the Main Input sheet (orange cells):
- Typical (airflow weighted) equipment temperature rise [°F or °C]
    o "Similar DT": Based on yellow cells
    o "Similar V" or "Similar DT(P)": Based on Total Equipment Airflow and AHU data.
- Total Equipment Airflow
    o "Similar V" or "Similar DT(P)": Based on yellow cells
    o "Similar DT": Based on Typical (airflow weighted) equipment temperature rise and AHU data.

Other calculated data (white cells):
- Equipment Power (= AHU cooling) [kW].
  Compare with UPS readings—if available. If the UPS equipment is located outside the data center room, use the delivered UPS power. If poor agreement, revisit Steps 1 and 2, looking for potential errors. Note that the AHU data (Step 1) are considered more robust than the Equipment data; Equipment Power (heat) is set equal to Resulting AHU Cooling (heat balance in room).

- Total Measured Power (Similar DT(P) option only) [kW].
  Compare with the Equipment Power (white box). If poor agreement, revisit Steps 1 and 2 to avoid large errors in the Total Equipment Airflow and Typical (airflow weighted) Equipment Temperature Rise. Poor agreement will not affect the Equipment Power (white box).

For calculation details, see the *Engineering Reference*.
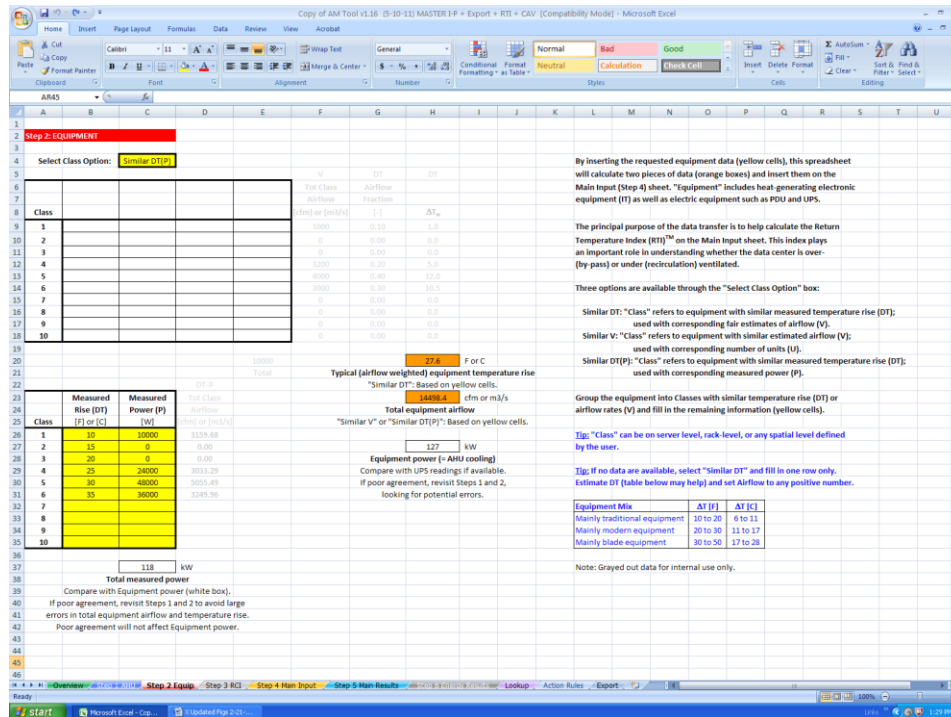
Figure 4: Step 2 Equipment sheet (Class Option DT(P) is selected in this screen shot).

Step 3 RCI

"Step 3 RCI" is the third of four input sheets.

The Rack Cooling Index (RCI)® plays an important role in understanding whether the data center is complying with the recommended and allowable intake temperature ranges (Herrlin 2005). These ranges are specified in Step 4 Main Input under "Current" for Questions 1 and 2 in Table B. The selected ranges are echoed next to the Intake Temperature plot.

The RCI is a performance metric explicitly designed to gauge compliance with the thermal guidelines of ASHRAE and NEBS for a given data center. The RCI is often used to make sure that no degradation of the thermal environment occurs when air-management measures are introduced for the purpose of saving energy. This index compresses the equipment intake

13

temperatures into two numbers: RCI_{HI} and RCI_{LO}. The RCI is a measure of how effectively equipment racks are cooled within a given thermal guideline, both at the high end and at the low end of the temperature range.

Specifically, the RCI_{HI} is a measure of the absence of over-temperatures, and 100% means no over-temperatures. Over-temperature conditions exist once one or more intake temperatures exceed the maximum recommended temperature. The lower the percentage, the greater probability (risk) that equipment experiences temperatures above the max allowable temperature. Indication of such potentially harmful thermal conditions is provided by a warning flag "*" appended to the index, generally indicating localized overheating. A value below 90% is often characterized as "poor." An analogous index is defined for temperature conditions at the low end of the temperature range. An RCI_{LO} of 100% mean no under-temperatures. Both RCI numbers at 100% mean that all intake temperatures are within the recommended temperature range; i.e., absolute compliance.

Input data (yellow cells):
- Intake Temperature [°F or °C].
  A maximum of 999 intake temperatures is allowed (Figure 6). The data must be inserted from the top down. If no data are available, leave all yellow input cells blank.

Calculated data exported to the Main Input sheet (orange cells):
- RCI_{HI} [%]   ("*" appended to the index means at least one intake > max allowable)
- RCI_{LO} [%]   ("*" appended to the index means at least one intake < min allowable)
  By inserting the IT-equipment intake temperatures, the spreadsheet will calculate the Rack Cooling Index (RCI) and export RCI_{HI} and RCI_{LO} (orange cells) to the Main Input (Step 4) sheet.

Other calculated data (white cells):
- Intake Temperature Plot (Figure 5).
  The Intake Temperature plot shows a graphical representation of the entered intake temperatures. The plot will dynamically update and scale with changes made to the intake temperatures and number of intake temperatures, respectively. The corresponding RCI values are shown immediately to the right of the plot in the orange boxes.

For RCI definitions, equations, and calculations, see the *Engineering Reference*. For guidance on determining the intake temperatures, see the *Data Collection Guide*.
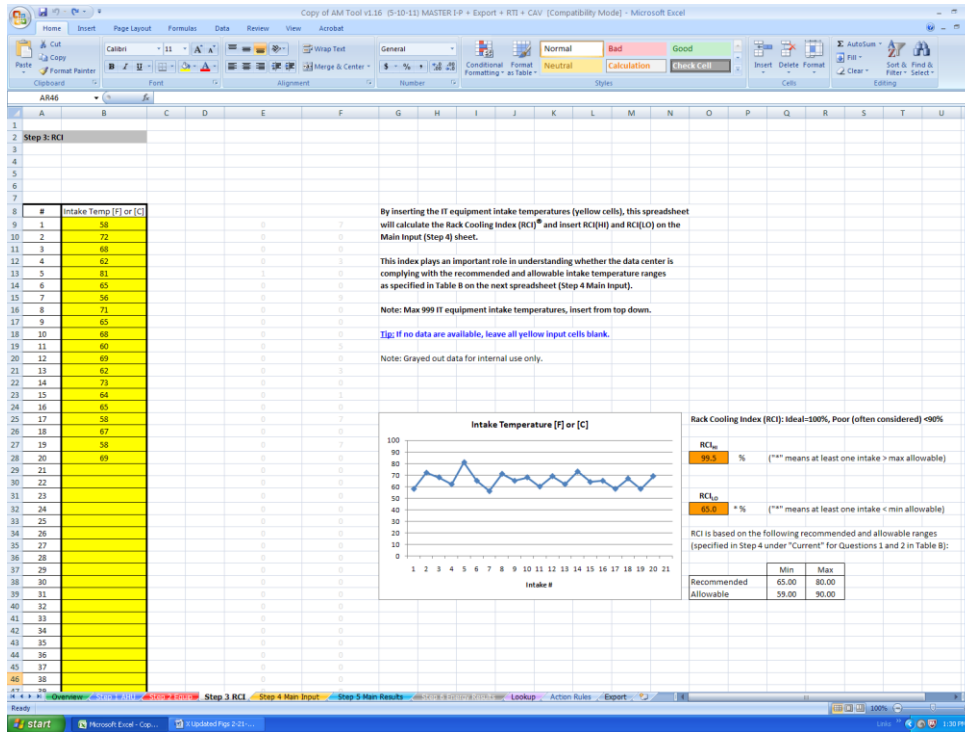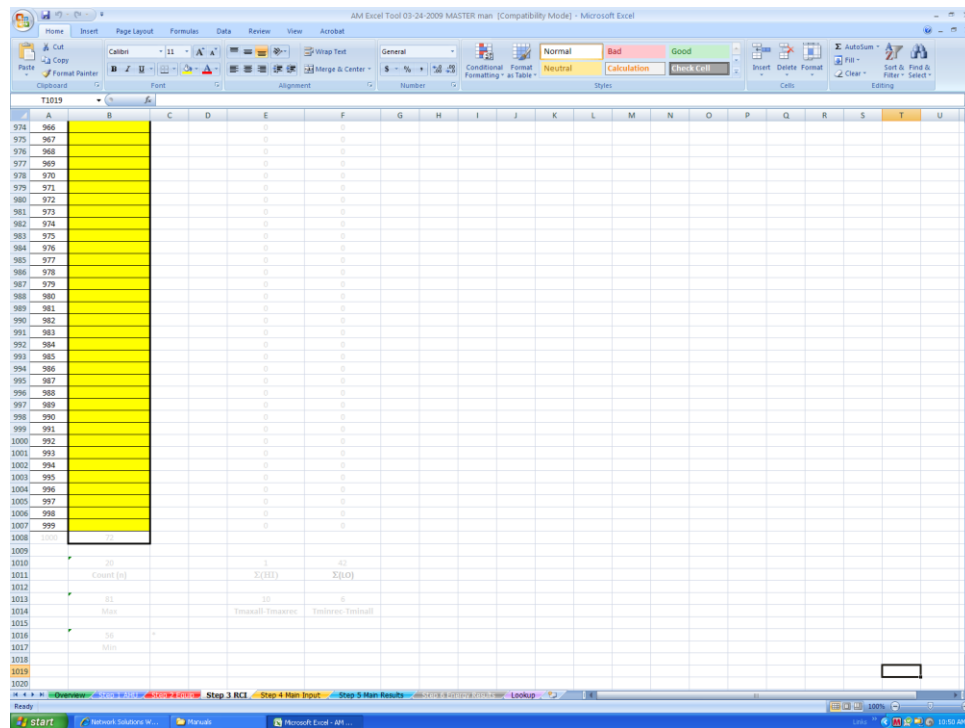
Figure 5: Step 3 RCI sheet, upper part.

Figure 6: Step 3 RCI sheet, lower part.

Step 4 Main Input

"Step 4 Main Input" is the last of four input sheets.

Table A shows air-management metrics (Figure 7):
- Yellow cells: Enter data
- Remaining metrics: Calculated or echoed from the AHU, Equip, and RCI sheets (color coded).

The Return Temperature Index (RTI)^{TM} is a high-level measure for by-pass air and recirculation air (Herrlin 2008). For the RTI definitions, equations, and calculations, see the *Engineering Reference*. However, the interpretation is straight forward:

- Balanced airflows (total equipment airflow = total air-handler airflow); RTI=100%
- Net by-pass air (air bypasses the equipment and not contributing to cooling); RTI<100%
- Net recirculation air (air re-circulates from equipment exhaust to equipment intake); RTI>100%.

If no data or insufficient data were entered in Step 1 (AHU) and Step 2 (Equip), multiple cells in Table A will be empty. If this happens, more likely than not, no energy estimates will be calculated in Step 6. Therefore, it is imperative that data are entered in both Step 1 and Step 2.

Rack Cooling Index (RCI)$^{®}$ is a measure of absence of over- and under-temperatures (Herrlin 2005). For the RCI definitions, equations, and calculations, see the *Engineering Reference*. However, the interpretation is again straight forward:

- Ideal (max)=100%
- Poor (often considered) <90%.

If no data was entered in Step 3 (RCI), the two RCI metric cells in Table A will be empty (Alt. 1). Typical (not extreme) maximum and minimum IT-equipment intake temperatures can then be entered in the yellow cells immediately below (Alt. 2). Note that Alt. 1 has priority over Alt. 2 should all four cells have values.

Table B lists air-management questions (Figure 8):
- Yellow cells: Enter data for Current and Target conditions.

The table has two columns:

- "Current" refers to existing data center architecture/controls.

- "Target" refers to realistic target data center architecture/controls. For Questions 3-10, this column is valid for raised-floor cooling only (Question 18 = Floor Plenum).

The table has three sections:

- Primary Input (impact on Energy estimates, Table 1 on Step 5 Main Results—if raised-floor cooling—and recommended Actions, Table 2 on Step 5 Main Results).

    o Questions 1 and 2: Recommended IT-equipment intake temperature range (this is a statement of equipment reliability) and Allowable IT-equipment intake temperature range (this is a statement of equipment functionality). These Current ranges will impact the numerical value of the RCI values calculated in Step 3 RCI. The drop-down boxes with the fixed options are activated by simply selecting the cells.

    o Questions 3-10 are considered the key factors for air management. These questions have three options: LOW, MID, and HIGH quality/implementation of the measure. (Question 15 has two options only: LOW and HIGH.) The drop-down boxes with the fixed options are activated by simply selecting the cells. A brief guidance on each option is also included. Note that only air-management measures can be rated for Current and Target conditions. For example, air-side economizers are not part of these measures.

    o Note that there is no input for the location of the temperature sensors for the control system. The AM-Tool assumes the preferred location; namely, at the electronic equipment intakes. The commonly used location at the air return is less accurate and the level of accuracy depends on the calibration with the intake temperatures. Return Air Temperature (RAT) sensing may require post-processing.

- Secondary Input (impact on Recommended Actions only, Table 2 on Step 5 Main Results).

    o Questions 11-28 are mostly about physical characteristics of the data center. Most of the questions have drop-down boxes with fixed options. Activate the drop-down boxes simply by selecting the cells. Depending on the answers, downstream questions may appear or disappear. Question 15 imports data from Step 1.

- Management Practices Input (impact on recommended Management Actions only, Table 2 on Step 5 Main Results, Actions 38-44).

    o Questions 29-35 covers management practices with Yes or No answers. The drop-down boxes are activated by simply selecting the cells.
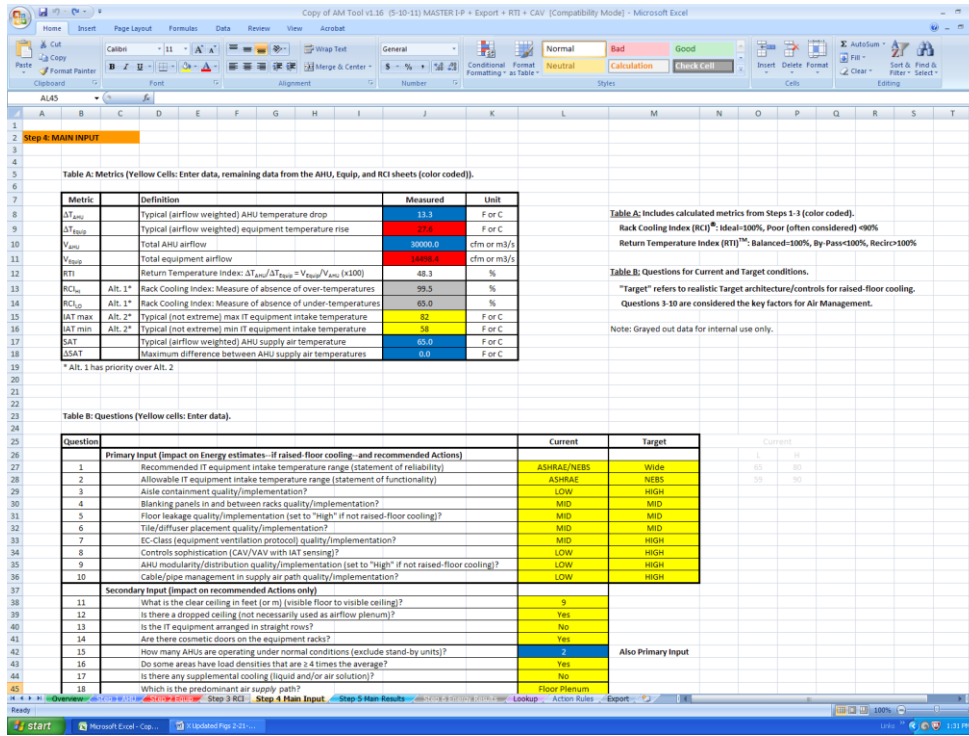
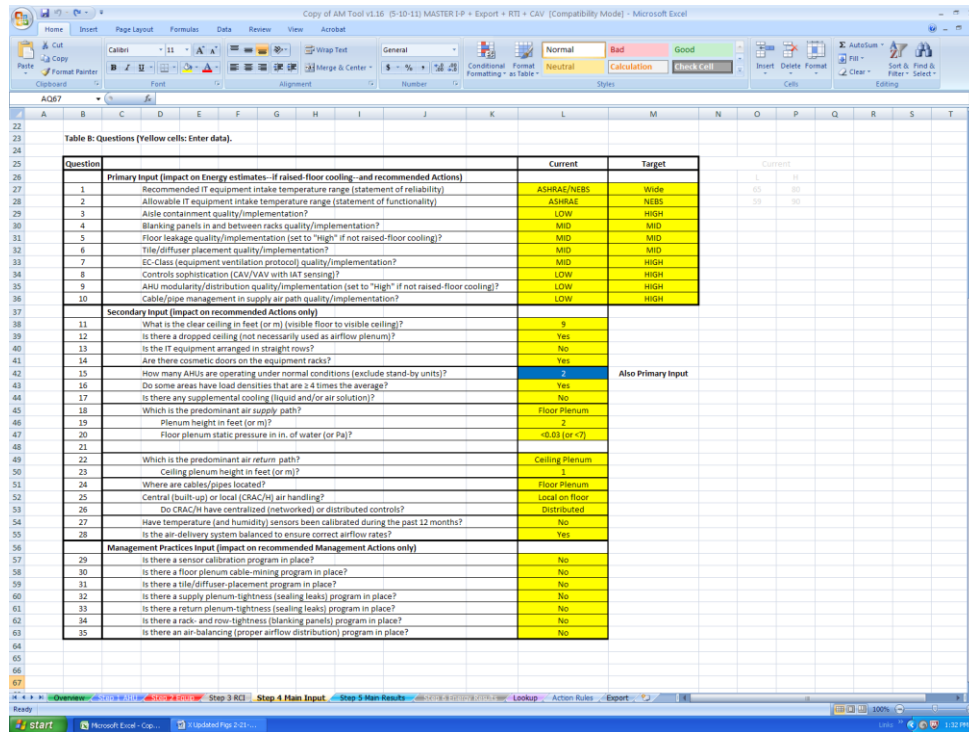*Figure 7: Step 4 Main Input sheet, upper part.*

Figure 8: Step 4 Main Input sheet, lower part.

Step 5 Main Results

"Step 5 Main Results" is the first of two output sheets.

Table 1 lists numerical output based on user input (Figure 9).

There are four columns:
- Measured: Measured data (Step 4, Table A) with <u>Current</u> architecture/controls (Step 4, Table B, Questions #1-10)
- Commissioned: Achievable through commissioning with <u>Current</u> architecture/controls (Step 4, Table B, Questions #1 and 3-10) and Intake Air Temperature (IAT) sensing
- Retrofitted: Achievable through retrofit with <u>Target</u> architecture/controls (Step 4, Table B, Questions #1 and 3-10) and Intake Air Temperature (IAT) sensing
- State-of-the-Art: Achievable with State-of-the-Art architecture/controls (SAT based on Target recommended range).

The "Commissioned" and "Retrofitted" columns are valid for raised-floor cooling only (Step 4, Table B, Question 18 = Floor Plenum). Multiple cells may be empty if insufficient data have been provided in Steps 1-3.

There are six rows:
- $100/RTI$ = Total AHU Airflow/Total Equipment Airflow (V_{AHU}/V_{Equip}) [-]
- SAT = Typical (airflow weighted) AHU Supply Air Temperature [°F or °C]
- RAT = Typical (airflow weighted) AHU Return Air Temperature [°F or °C]
- RCI_{HI} = Rack Cooling Index (RCI)$^{®}$ "HI" [%]; measure of absence of over-temperatures
- RCI_{LO} = Rack Cooling Index(RCI)$^{®}$ "LO" [%]; measure of absence of under-temperatures
- V_{AHU} = Total Air-Handler Unit Airflow [cfm or m^3/s].

By reading across the columns for the three first rows, the achievable improvements for three levels of air-management measures can quickly be evaluated. If CAV fans were selected on Step 4 Main Input (Question 8), see the *Engineering Reference*. The data are used for estimating the percentage savings for fan energy and chiller energy in Step 6 Energy Results. Since the Tool is using discrete look-up tables for calculating the numerical output, the results may not change if the input is only marginally changed.

Table 2 lists recommended Actions based on user input (figure 10).

The table has three sections:
- Actions for realizing Commissioned conditions in Table 1 (Actions 1-10)
- Actions for realizing Retrofitted or State-of-the-Art conditions in Table 1 (Actions 11-37)
- Management Practices (Actions 38-44).

Not applicable Actions are indicated by "N/A". By implementing recommended Actions (by revisiting user data input and/or question responses) further Actions may be provided.
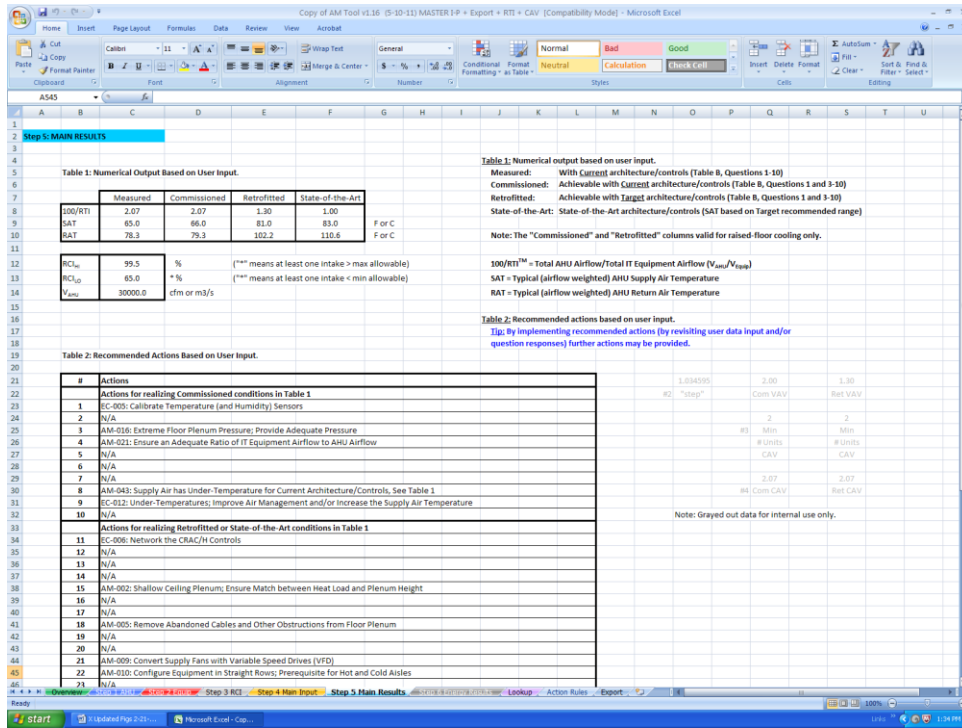
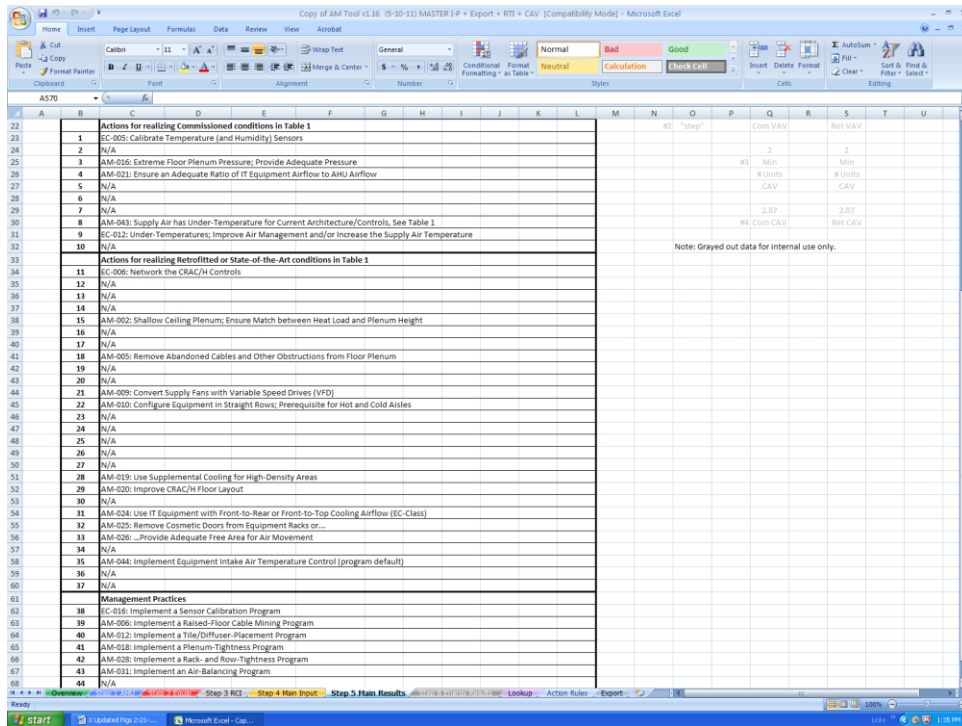*Figure 9: Step 5 Main Results sheet, upper part.*

Figure 10: Step 5 Main Results sheet, lower part.

20

Step 6 Energy Results

"Step 6 Energy Results" is the second of two output sheets.

This sheet contains percentage energy-savings estimates for supply fans and chillers; all other results can be found in Step 5 Main Results.

The two bar charts shown here are based on Table 1 in Step 5 Main Results. Since the Tool is using discrete look-up tables for calculating the numerical output, the percentage savings may not change if the input is only marginally changed.

The "Measured" bars are the reference (100%) and values above 100% for the other bars will not be displayed. Obviously, this is a situation that should be avoided—the goal is to decrease the energy demand, not increase it. The "Commissioned" and "Retrofitted" bars are valid for raised-floor cooling only (Step 4, Table B, Question 18 = Floor Plenum).

With adequate air management, the reduction in fan energy is often very large due to the fact that the fan energy varies close to the cube of the airflow. It is not uncommon to be in the 70-80% range.
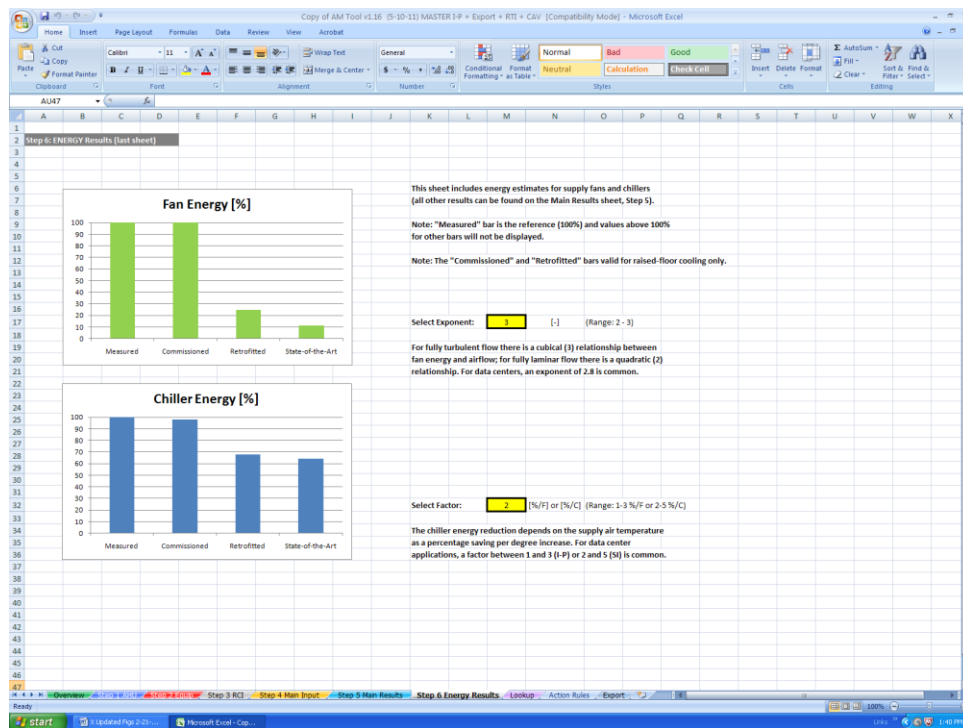

Figure 11: Step 6 Energy Results sheet.

Input data (yellow cells):
The calculations of the fan and chiller energy savings can be controlled by two input boxes.

- Select Exponent [-].
  For fully turbulent airflow, there is a cubical (^3) relationship between fan energy and airflow whereas for fully laminar airflow there is a quadratic (^2) relationship. For data centers, the majority of the flow resistance is turbulent. Therefore, an exponent of 2.8 can often be used.

- Select Factor [%/°F or %/°C].
  The chiller energy reduction depends on the supply air temperature as a percentage saving per degree increase. For data center applications, a factor between 1 and 3 (I-P) or 2 and 5 (SI) is common.

For calculation details, see the *Engineering Reference*.

Lookup

This sheet is initially a hidden since there are no user inputs or user outputs. If the sheet is made visible, please do not enter or change data. The screen shot below has been included for completeness only.

For calculation details and the significance of the lookup tables, see the *Engineering Reference*.
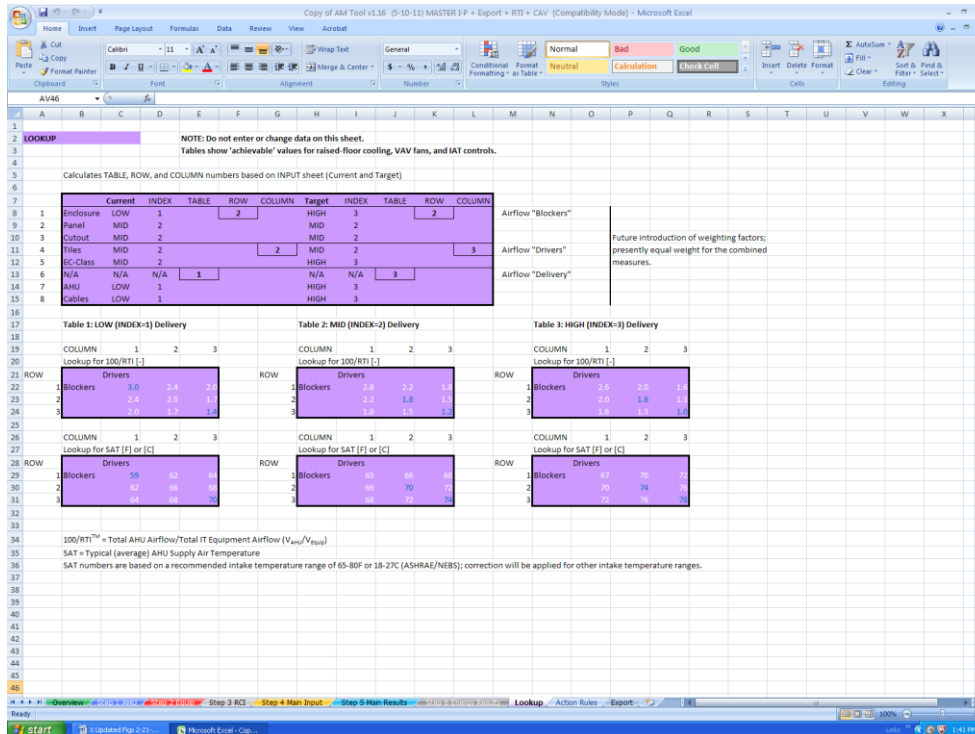

Figure 12: Lookup sheet.

Action Rules

This sheet is initially hidden since it does not contain any user inputs or user outputs. No screen shot is included for this sheet. Instead, please open the Tool and then select tab Action Rules (after making it visible) for viewing the sheet.

The Action Rules are rule-sets for triggering certain Actions or recommendations in Step 5 Main Results, Table 2 based on user input, mainly Table B in Step 4 Main Input, and the rather self-explanatory rule-sets on this sheet. Across the top of the spreadsheet, the Questions from Step 4 Main Input are listed as table columns. The rows in the table represent the resulting Actions or recommendations. In the body of the table are the actual rules or the conditions that trigger Actions.

See also the *Engineering Reference*.

Export

This last sheet is also initially hidden. The purpose of this sheet is to summarize output that may be used for post-processing, for example in whole-building simulation packages. The table cells are color coded per the originating sheet (tab) color.

Figure 13: Export sheet.

25

SUMMARY OF REQUIRED NUMERICAL INPUT DATA

This table provides a quick reference for all Tool input data. For details, see the associated Program Step(s) in this User's Manual.

Table 2: Required Numerical Input Data

	Unit	Program Step
AHU Airflow	cfm or m^3/s	Step 1 AHU
AHU Supply Air Temperature	°F or °C	Step 1 AHU
AHU Return Air Temperature	°F or °C	Step 1 AHU
Equipment Temperature Rise	°F or °C	Step 2 Equip
Equipment Airflow	cfm or m^3/s	Step 2 Equip
Number of Equipment Units	-	Step 2 Equip
1) IT-Equipment Heat Release: P_{in} 2) UPS Heat Release: P_{in}-P_{out}	W W	Step 2 Equip
IT-Equipment Intake Temperature	°F or °C	Step 3 RCI
Typical Max IT-Equipment Intake Temperature	°F or °C	Step 4 Main Input
Typical Min IT-Equipment Intake Temperature	°F or °C	Step 4 Main Input
Recommended IT-Equipment Intake Temperature Range	°F or °C	Step 4 Main Input
Allowable IT-Equipment Intake Temperature Range	°F or °C	Step 4 Main Input

ABBREVIATIONS AND ACRONYMS

ΔT_{AHU} ....Typical (airflow weighted) AHU temperature drop [°F or °C]

ΔT_{Equip} .... Typical (airflow weighted) equipment temperature rise [°F or °C]

AHU ....Air-Handler Unit

AM ....Air Management

By-pass..............Cool air that by passes the electronic equipment

Commissioned...Achievable with Current architecture/controls

CRAC................Computer Room Air Conditioner

CRAH ....Computer Room Air Handlers

Current ....Current architecture/controls in data center

DC Pro ....DOE Data Center Suite of Software Tools (Profiler Tool + Assessment Tools)

DT ....Temperature differential across Equipment [°F or °C]

Equip ....Equipment (IT and Electrical)

HVAC ....Heating, Ventilating, and Air-Conditioning

IAT max ....Typical (not extreme) maximum IT-equipment intake temperature [°F or °C]

IAT min.............Typical (not extreme) minimum IT-equipment intake temperature [°F or °C]

Measured...........Measured data with Current architecture/controls

P ....Power [W] or [kW]

RAT..................Return air temperature [°F or °C]

RCI....................Rack Cooling Index (RCI)® [%]

RCI_{HI} ....Rack Cooling Index (RCI)® "HI" [%]; Measure of absence of over-temperatures

RCI_{LO} ....Rack Cooling Index (RCI)® "LO" [%]; Measure of absence of under-temperatures

Recirculation .....Hot equipment exhaust re-circulated back to the equipment intakes

Retrofitted ....Achievable with Target architecture/controls

RTI ....Return Temperature Index (RTI)^{TM} [%]; $\Delta T_{AHU}/\Delta T_{Equip} = V_{Equip}/V_{AHU}$

SAT ....Typical (airflow weighted) AHU supply air temperature [°F or °C]

ΔSAT...................Maximum difference between AHU supply air temperatures [°F or °C]

State-of-the-Art ....State-of-the-Art architecture/controls

Target ....Realistic target architecture/controls for raised-floor cooling

Ton ....Ton Cooling = 3.52 kW

U..........................Number of Equipment Units [-]

V_{AHU}.....................Total Air-Handler Unit airflow [cfm or m^3/s]

V_{Equip} ....Total equipment airflow [cfm or m^3/s]

REFERENCES

DOE. 2011a. Engineering Reference.
http://www1.eere.energy.gov/industry/saveenergynow/dc_pro.html

DOE. 2011b. Data Collection Guide.
http://www1.eere.energy.gov/industry/saveenergynow/dc_pro.html

DOE. 2011c. DC Pro Software Tool Suite.
http://www1.eere.energy.gov/industry/saveenergynow/dc_pro.html

Herrlin, M. K. 2005. Rack Cooling Effectiveness in Data Centers and Telecom Central Offices: The Rack Cooling Index (RCI). ASHRAE Transactions, Volume 111, Part 2, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA (free download at www.ancis.us)

Herrlin, M. K. 2008. Airflow and Cooling Performance of Data Centers: Two Performance Metrics. ASHRAE Transactions, Volume 114, Part 2, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA (free download at www.ancis.us)