# IT Equipment Energy Assessment Tool - User's Manual

**Version 2.1**
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## Disclaimer

## DOE/Federal Energy Management Program (FEMP)

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**OVERVIEW**

**What does this Tool do?**

Information Technology (IT) equipment is at the core of energy consumption in data centers. Energy savings at the IT level will have an impact on essentially all energy use in these facilities. According to the Uptime Institute (2020), many energy efficiency opportunities involving IT equipment such as servers, network, and storage remain untapped.

The Department of Energy's (DOE) Microsoft® Excel® based IT Equipment Energy Assessment Tool (abbreviated: IT Tool or Tool) was developed to help accelerate the energy savings in data centers by identifying opportunities through IT equipment upgrades. The Tool is designed both as a learning aid and as a tool to assist the energy assessor to build a business case for energy efficiency improvements.

The IT Tool structure as well as user input forms and output data are described in this User's Manual. The output includes numerical information such as energy savings, energy cost savings, carbon savings, and simple payback periods as well as hands-on recommendations to help reinforce best practices. The Tool helps avoid tedious manual calculations.

The Tool not only provides the structure for organizing relevant information but it also provides key IT performance data. However, it does not directly aid in collecting the input data or how to implement various IT equipment energy-saving measures. We hope to add more guidance on these topics in the next version of the Tool.

Appendices at the back of this User's Manual provide in-depth information on a number of topics. These appendices are referenced throughout this document.

**Prerequisites**

The Tool is designed for simplicity both in content and presentation. Still, having some basic understanding of IT equipment and the physical data center environment makes this Tool easier to understand and use.

It is recommended to take the one-day Data Center Energy Practitioner (DCEP) IT Equipment training module (DCEP, 2020). This training reviews important terms and concepts implemented in the Tool. By attending the course, the user will have the context and familiarity with terms and applications for which the Tool is intended. This document does not attempt to explain that context or to introduce the terminology for the reader who has not been exposed to the course or who does not already have similar knowledge. See Appendix 1 for more information on the DCEP program.

### How is the Tool used?

First, the user fills in data and answers questions on up to six input Excel sheets. Each screen includes basic guidance for entering the data. 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.

In most data centers, servers dominate in number of IT devices, overall IT electric power draw, and to space cooling challenges in data centers. Servers typically account for more than 80% of the electricity use in all IT devices. Although this tool focuses on servers, it can also be used for other heat-generating electronic devices, such as network equipment and storage products.

### DOE Software Tool Suite

The IT Tool is part of the DOE Software Tool Suite (DOE, 2021) which also includes an online Profiling Tool (DC Pro), an Excel-based Air Management Tool, and an Excel-based Electrical Power Chain Tool. These tools are not a substitute for detailed "investment grade" audits. Rather, they provide estimates of savings for various energy efficiency measures, but actual savings may vary based onsite specific conditions that are not addressed in the tools.

Although the IT Tool is designed to be a stand-alone tool, it has the same look and feel as the DOE Air Management and Electrical Tools. Users familiar with those tools should find it easy to navigate the IT Tool. Besides being a part of the DOE Tool Suite, it is also part of the DCEP IT Equipment training module (DCEP, 2021).

### Tool Download

The IT Tool can be downloaded from the Center of Expertise for Energy Efficiency in Data Centers website: http://datacenters.lbl.gov/tools

Questions, comments, and/or suggestions on this User's Manual and/or the IT Tool can be directed to mkherrlin@lbl.gov

### High-Level Tool Structure and Input/Output

This User's Manual provides a description of the tool structure, input, and output. First, the user assembles an inventory consisting of all IT equipment in the data center and assigns Classes to all equipment. A Class is a group of IT equipment with similar characteristics. A Class could be made up of IT equipment that fits within a particular IT Equipment Energy-Saving Measure (described later). This may well be the most practical way of defining the Classes.

The complex IT equipment inventory discovery process is not included in the Tool but the inventory and associated equipment power consumption is assumed to be

known by the user. However, we do discuss various ways to establish the power consumption. The user will have several alternatives for collecting the data depending on what is available and what is possible, including clipboard (manual), IT management tools, SpecPower IT database, and Data Center Infrastructure Management (DCIM) software tools.

Second, the user selects energy-saving measures for each Class individually. For our purposes, an IT equipment measure is designed to reduce the equipment power draw and consequently also the heat output to the surrounding space (Figure 1). There is a hierarchy of what is easy to implement with biggest payoff down to what is more complicated to implement with less-certain payoff. Certain measures are rarely possible on existing IT equipment but could be introduced in future procurement (refresh) cycles.

Lastly, the user is provided with numerical output (energy savings, energy cost savings, and carbon savings) and recommended actions to improve the energy efficiency of the IT equipment.

More information on the tool structure can be found in Appendix 2: The Big Picture.
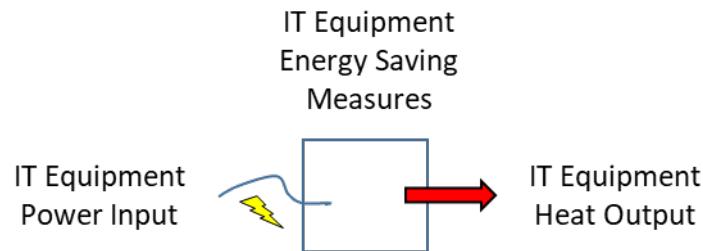


Figure 1. IT Equipment Anatomy.

**Tool Overview**

The Tool Overview screen (Figure 2a and 2b) provides an overview of the data flow and a one-sentence description of each individual screen.

All screens are color coded for improved clarity. The IT Tool has nine screens for input and output:

Overview   Provides an overview of data flow and screen descriptions
Inventory   User input: Collects the IT inventory and assigned Classes
Classes 1-4   User input: Collects Class specific energy savings measures
Questions   User input: Questions for crafting hands-on recommendations
Numerical Results Result output: Provides calculated numerical results
Recommendations Result output: Provides hands-on recommendations.

**OVERVIEW**

**Data Center IT Equipment Assessment Tool, Version 2.1, October 26, 2021**
*This tool was developed by Lawrence Berkeley National Laboratory (LBNL) for the US Department of Energy (DOE)*
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| Screen (tab) | Description |
|---|---|
| Overview | This Sheet: Provides an overview of data flow and screen descriptions. |
| Inventory | User input: Collects the IT inventory and assigned Classes. |
| Classes 1-4 | User input: Collects Class specific energy savings measures. |
| Questions | User input: Questions for crafting hands-on recommendations. |
| Numerical Results | Result output: Provides calculated numerical results. |
| Recommendations | Result output: Provides hands-on recommendations. |

**What does this Tool do?**
IT equipment is at the core of energy consumption in data centers. Energy savings at the IT level will have an impact on essentially all energy use in data centers. Based on user input, this Tool estimates overall energy savings by a number of saving measures. It is designed to help identify areas for energy savings improvements.

**How is the Tool used?**
First, the user fills in data and answers questions on up to six input screens. Each screen includes basic guidance for entering the data correctly. Second, based on this user input, numerical output and recommended actions are given on two result output screens.

**Tool suite**
This IT Equipment Tool is part of a tool suite, which includes HVAC, electrical, and IT tools. Currently, the individual tools are designed as "stand-alone" modules. More information at http://datacenters.lbl.gov/tools

**Questions, comments, and/or suggestions?**
Please contact mkherrlin@lbl.gov

Figure 2a: Overview Screen.

| Screen (tab) | Description |
|---|---|
| Overview | This Sheet: Provides an overview of data flow and screen descriptions. |
| Inventory | User input: Collects the IT inventory and assigned Classes. |
| Classes 1-4 | User input: Collects Class specific energy savings measures. |
| Questions | User input: Questions for crafting hands-on recommendations. |
| Numerical Results | Result output: Provides calculated numerical results. |
| Recommendations | Result output: Provides hands-on recommendations. |

Figure 2b: Overview Screen (detail).

**INPUT/OUTPUT SCREENS**

This section describes the input and output screens (tabs) in the order they appear in the Tool. This section can be read "from cover to cover" or used as a reference manual for finding particular information on any of the nine screens.

General Information applicable to all six input screens includes:

- The screen shots included in this Manual can be difficult to read at the 100% zoom level. Use the zoom capability of your software to enlarge the figures.
- Yellow cells identify cells where to input data. All other cells are permanently locked with no user access.
- Some input cells accept typed data whereas other cells have fixed options selected from drop-down menus. Activate the menu by selecting the cell.
- For some input cells, a pop-up tooltip is shown when the cell is selected. You can temporarily remove the pop-up by using the Esc key on your keyboard.
- All input cells have input-range checking to help avoid data-entry errors.
- Error messages are organized under Error Message headings. On the Class screens, cells to the right of cells with a letter-number code are reserved for Informational or Error (e.g., E5) messages. Messages on the Inventory screen have no letter-number identifiers.
- Cell data in faint gray is for internal use only, generally showing intermediate calculation steps.
- Note that the screen shots may differ slightly from the latest IT Tool version.

The IT Tool comes preloaded with data for demonstration purposes. The Excel screen shots in this User's Manual reflect that data.

**Inventory Input**

The Inventory Input is the first of six input screens (tabs). This screen allows the user to create an inventory of the IT equipment, and group the equipment into four user-defined Classes. In this way, the Tool provides the structure for organizing the information but does not directly assist in the collection of the data. The collection methods can be varied and are usually dictated by the level of sophistication of asset management in the data center. For details, please see Appendix 3: Establish Inventory and Power Draw.

Input data (yellow cells) in Table 1 (Figure 3):
- IT Equipment Class Description
- Power Performance Level

First, provide a concise description of each IT Equipment Class and assign a Power Performance level (High, Mid, or Low) in Table 1. A unique set of energy saving measures will be applied to each Class on the next four screens (tabs). Although the Descriptions are not required, the Power Performance levels are. The drop-down menu for the Power Performance Level is activated by clicking on the yellow cell.

The Power Performance is the relationship between Power Utilization and Computational Utilization. For this report, we analyzed the comprehensive SpecPower (2020) server data and we created three levels of generalized power performance curves for equipment commonly found in data centers. In this User's Manual and in the IT Tool itself, they are called High-Range Power Performance, Mid-Range Power Performance, and Low-Range Power Performance servers. Going from Low to Mid to High, the power performance increases and the power savings increase. These generalized performance curves are shown and discussed in more detail in Appendix 7.

If a server has known power performance, the matching with one of the three curves should be straight forward. If no information is available, select High-Range for most servers. Although low-powered servers are not common in data centers, they usually have power characteristics near the Low-Range Power Performance level.

The generalized performance curves do not go below 10% Computational Utilization since the data is uncertain below that utilization. The idling state does not follow the overall trend of actual performance curves (three typical examples are shown in Appendix 7). Based on this limit of 10% Computational Utilization, the Tool uses the following lower limits for Power Utilization for the three Performance levels: 26% (High-Range), 36% (Mid-Range), and 48% (Low-Range).

**Inventory**

This screen allows the user to create an inventory of the IT equipment, and group the equipment into four user-defined Classes.

**First**, provide a description of each "IT Equipment Class" and assign a Power Performance level (Table 1). A unique set of energy saving measures will be applied to each Class on the next four screens (tabs).

**Second**, each Class is populated with IT equipment (Table 2a). An "IT Equipment Type" is equipment with similar power draw. Actual and Max Power are per equipment unit.

**Third**, the Tool compiles the user input into Tables 2b and 3.

**Table 1: IT Equipment Class Descriptions**

| IT Equip Class | Description | Power Performance |
|---|---|---|
| Class 1 | X Servers | High |
| Class 2 | Y Servers | High |
| Class 3 | Z Servers | Mid |
| Class 4 | Mixed Servers | Mid |

**Table 3: IT Equipment Inventory by Class and total**

| IT Equip Class | Actual Power | Max Power | Power Util [%] |
|---|---|---|---|
| Class 1 | 7,800 | 18,000 | 43.3 |
| Class 2 | 7,000 | 13,200 | 53.0 |
| Class 3 | 11,200 | 13,800 | 81.2 |
| Class 4 | 4,000 | 5,000 | 80.0 |
| Sum | 30,000 | 50,000 | 60.0 |

ERROR Messages

**Table 2a: IT Equipment Inventory**

| # | IT Equip Type | Number of Units | Actual Power [W] | Max Power [W] | IT Equip Class |
|---|---|---|---|---|---|
| 1 | A | 20 | 350 | 700 | 1 |
| 2 | B | 4 | 400 | 500 | 4 |
| 3 | C | 5 | 800 | 2,000 | 2 |
| 4 | D | 1 | 1,200 | 1,800 | 3 |
| 5 | E | 8 | 100 | 500 | 1 |
| 6 | F | 10 | 300 | 320 | 2 |
| 7 | G | 6 | 400 | 500 | 4 |
| 8 | H | 20 | 500 | 600 | 3 |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
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| 28 | | | | | |
| 29 | | | | | |
| 30 | | | | | |

ERROR Messages

**Table 2b: Utilization**

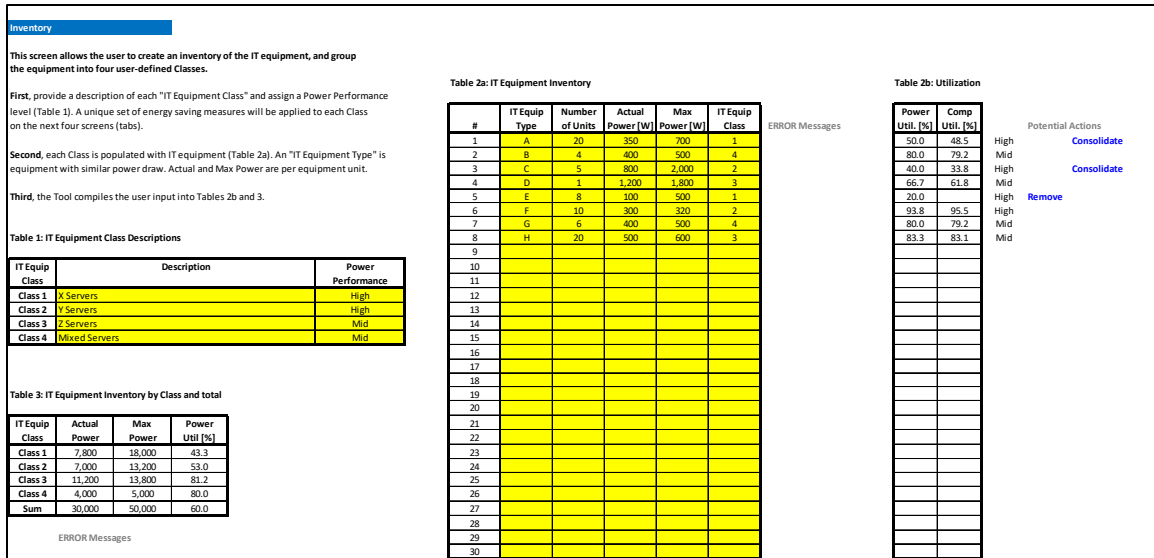| Power Util. [%] | Comp Util. [%] | | Potential Actions |
|---|---|---|---|
| 50.0 | 48.5 | High | Consolidate |
| 80.0 | 79.2 | Mid | |
| 40.0 | 33.8 | High | Consolidate |
| 66.7 | 61.8 | Mid | |
| 20.0 | | High | Remove |
| 93.8 | 95.5 | High | |
| 80.0 | 79.2 | Mid | |
| 83.3 | 83.1 | Mid | |

Figure 3. Inventory Screen (truncated).

Second, each IT Equipment Class is populated with IT equipment (Table 2a). The user enters IT equipment data (yellow cells) for up to 50 IT Equipment Types. An Equipment Type is simply IT equipment with similar power requirements, both for Actual Power and Max Power. Then, the user matches each IT Equipment Type with one of four IT Equipment Classes.

The IT Equipment Types and the IT Equipment Classes are a way of organizing maybe hundreds (or even thousands) of pieces of IT equipment. The Class input screens (beginning on Page 13) allow applying energy-saving measures individually to each Class.

If data is exceptionally scant, the user could define just four "IT equipment", one for each Class. This would be the most extreme simplification. This approach is not recommended besides maybe for educational purposes.

Input data (yellow cells) in Table 2a (Figure 3):
- IT Equipment Type
- Number of Units (multiplier)
- Actual Power [W]
- Max Power [W]
- IT Equipment Class (1-4).

Specifically, the user assigns an identifier (max six characters) to each IT Equipment Type followed by the Number of Units, which serves as a multiplier. Actual Power refers to the current actual operating power and the Max Power refers to the maximum operating power as configured. Actual Power [W] and Max Power [W] are per unit. Lastly, the user assigns a Class (1, 2, 3, or 4) to each IT Equipment Type.

Although not required, it is recommended for clarity to enter the table data from the top down.

If an input cell for Number of Units, Actual Power, or Max Power is left blank, this will be interpreted as a zero value. If an input cell for IT Equipment Class is left blank, the corresponding row will not be included in the calculation. Space immediately to the right of Table 2a is reserved for input error messages. Each message refers to the row where they appear. If the entire Table 2a is left blank, an error message will appear below Table 3. An inventory is always required.

Third, the Tool compiles the user input into Tables 2b and 3. The Tool scans the inventory to identify opportunities for equipment removal or consolidation. Table 2b calculates the Power Utilization and Computational Utilization for each IT Equipment Type. Immediately to the right of the table, the corresponding Power Performance level is copied from Table 1.

One Equipment Type (E) has been flagged for potential Removal, and two Types (A and C) have been flagged for potential Consolidation. These equipment Types can be entered on the corresponding Class sheets under the Removing or Consolidating measures.

A Computational Utilization below 10% may be a Removal opportunity and between 10-50% may be a Consolidation opportunity. When the utilization is in these ranges, full or partial Removal or Consolidation could be considered. Note that the Computational Utilization cell is blank when Removal is recommended since no meaningful data is available (outside the curve fits in Appendix 7).

Calculated data in Table 3 (Figure 3):
- Actual Power and Max Power for each Class and Total for all Classes
- Power Utilization for each Class and Total for all Classes.

In Table 3, the Tool consolidates the data in Table 2a by Classes. Finally, the Power Utilization is calculated for each Class and total for all Classes. This table provides insight into which Class potentially is best suited for IT energy-saving measures to improve the efficiency.

The example in Figure 3 shows that each of the four IT Equipment Classes has been given a Descriptive name and a Power Performance Level (Table 1). Next, eight IT Equipment Types, named A through H, have individually been given the total Number of Units, Actual Power per unit, and Max Power per unit (Table 2a). Each IT Type is then assigned an IT Class. Finally, the total power is summed up for each Class. For example, Class 1 has a total Current Actual Power of 7,800 W and a total Current Max Power of 18,000 W (Table 3).

## Class Input

When the IT inventory has been completed, we can move on to introducing IT equipment energy-savings measures. This input consists of up to four input screens (tabs), one for each Class. Figure 4a shows the Class 1 screen.

Input data (yellow cells):
- Current Actual Power [W]
- Current Max Power [W]
- Target Actual Power [W]
- Target Max Power [W]
- Power Reduction Factor
- Power Performance
- Include this Form?

The last input determines whether the Form will be included in the calculations [select Yes from the drop-down menu] or not [select No]. The drop-down menu is activated by clicking on the yellow cell.

Calculated data:
- All white cells in the table contain calculated data. Key data includes Power Save for each IT equipment energy-saving measure and Total for all IT equipment measures.



**Table 4: Energy Saving Measures for IT Equipment Class 1**

This screen allows the user to provide a description of changes to IT Inventory (yellow cells) for Class 1. "Current" refers to current conditions and "Target" refers to the conditions after changes.

| | Current Power | | | | Target Power | | | | Power Reduction Factor | Power Save [W] | ERROR Message # |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | | | |
| Adding | | | | | 490 | 1,000 | 49.0 | 47.1 | | -490 | E12 |
| Removing | 800 | 4,000 | 20.0 | | | | | | | 800 | E13 |
| Replacing | | | | | | | | | 0.00 | | E14 |
| Modifying | | | | | | | | | | | Reserved for future use. |
| Consolidating | 7,000 | 14,000 | 50.0 | 48.5 | 5,000 | 8,000 | 62.5 | 64.6 | | 2,000 | E15 |
| Clouding | | | | | | | | | | | E16 |
| Unchanged | | | | | | | | | | | E17 |
| Universal | | | | | | | | | | | E18 |
| Total | 7,800 | 18,000 | 43.3 | 38.9 | 5,490 | 9,000 | 61.0 | 62.8 | | 2,310 | |

Power Performance: High — 5
High — 5

| Table 3 Total | 7,800 | 18,000 | | | | | | | Save Total | 2,310 |

Include this form? If Yes, IT Tool will check for Errors.   Yes   ERRORS Found

INFO and ERROR Message #
I1   INFO: Total Power Save ≠ Waste Recovery since IT equipment added
E1
E2
E3
E4
E5
E6
E7   ERROR (Multiple): Current Power Utilization must not be <26.
E8
E9
E10
E11

Figure 4a: Class 1 Screen with Table 4.

Table 4 in Figure 4a includes Current IT Equipment Power (before changes) and Target IT Equipment Power (after changes). For both of these main groups we have: Actual Power (calculated, estimated, or measured), Max Power (calculated, estimated, or measured), Power Utilization (calculated), and Computational Utilization (calculated or selected). Again, Actual Power refers to the actual operating power and the Max Power refers to the maximum power. The Power Reduction Factor is valid for only one of the energy-saving measures (Replacing). This Factor allows improving the equipment energy efficiency. Specifically, a Power Reduction Factor of 0.0 means 0% power reduction and 1.0 means 100% power reduction. Finally, the Power Save (savings) is calculated.

The following terminology for the energy-saving measures is designed so that users can relate to their own situation. Although each measure represents one well-defined case, significant overlap exists between the measures.

a. Adding IT equipment to increase computational capacity. This is not an energy-saving measure but is included for completeness.
b. Removing long-term idling IT equipment (decommission). Could also include turning equipment off, put in sleep mode, or put in stand-by mode although the gear will still use a small amount of energy.
c. Replacing (refresh) IT equipment with new energy-efficient gear which generally also has better power management and virtualization potential.
d. Modifying IT equipment with high-efficiency Power Supply Units (PSUs). This measure may be included in a future version of the IT Tool.
e. Consolidating sub-utilized IT equipment onto fewer servers, leading to increased computational utilization.
f. Cloud Service Providers generally operate at very high energy efficiency. However, relevant Cloud information may be difficult to find.
g. Unchanged. No changes made to the IT equipment. This is not an energy-saving measure but is included for completeness.
h. Universal. Universal input – user defined.

Measures b, c, d, e, f, and g do not involve changing the computational output (work). We are simply trying to make our work more energy efficient, not increasing or decreasing the computational output. If more (less) computational output is desired, the Adding (Removing) measure needs to be used. Measure h is fully user defined – it might or might not involve changing the computational output.

Each Equipment Class can have one or several of the IT equipment energy-saving measures a-h. The data will be used by the Tool to determine the Power Save (savings).

The Power Performance cell to the right of Table 4 in Figure 4a is copied directly from the Power Performance level selected in Table 1 (Figure 3). The options High, Mid, and Low correspond to the performance curves in Appendix 7.

Computational underutilization results in "IT waste". The Power Save (Current Actual Power – Target Actual Power) is identical to recovered IT Waste as long as the computational capacity is unchanged. The IT waste is determined by what better process that can be put in place. If there is no better process, there cannot be any IT waste - maybe theoretically but not from a practical stand point. The maximum recoverable IT waste would be with the best available process.

The Tool can be used for two purposes depending how the energy-saving measures are selected. First, it can estimate the recovered IT waste, but this requires that the computational capacity is the same before and after the IT equipment changes. Second, the tool can be used to calculate the total power change. In this case, any combination of the input options a-h can be used.

There are a number of error messages listed under ERROR Message headings to the right of Table 4 and below the table. All messages have a letter-number code. Each message to the right of the table refers to the row where they appear. Messages below the table include references to which row(s) they refer to.

Below the table, select Yes to "Include this Form?" to include all Class 1 measures in the calculations. The drop-down menu is activated by clicking on the yellow cell. The Tool will also perform a comprehensive error check. Otherwise, select No which means that the IT equipment is unchanged for Class 1, i.e., it retains all Current values. It is recommended to initially select Yes to capture all errors and clear the errors before proceeding (see next page for the recommended two-step strategy of entering data).

By selectively using this feature, different permutations can be evaluated quickly across the four Classes. Selecting No is a quicker way of doing the same as entering all equipment power in the yellow cells for measure Unchanged.

The Tool will check that the Class 1 totals for Current Actual Power and Current Max Power in Table 4 are equal to those for Class 1 in Table 3 on the Inventory screen (tab). The values on the Inventory screen are copied immediately below Table 4 in the "Table 3 Total" cells. No match will result in one or two error messages below Table 4.

Finally, the "Save Total" cell under the Power Save column adds all values in this column. This value [2,310 W] should be the same as the Total in the same column, which is calculated as the difference between Total Current Actual Power [7,800 W] minus the Total Target Actual Power [5,490 W].

There may be small rounding errors in the calculated cells of the spreadsheet. Under some rare circumstances this may lead to error messages with no relevance. If a change is made to the inventory *after* the Class entries, please ensure that the Class entries are still valid.

The recommended two-step strategy of entering data is as follows:

1) Under the Current Power section (tan heading), fill out yellow cells and clear error messages (if any) row-by-row. Adjust your input as needed. Complete entire section before proceeding. *No error messages should remain* (except those that may originate from small rounding errors in the table).

   At this point, the Save Total cell under the Power Save column will normally not show the same number as in the Total cell. When Step 2 below has been completed, however, the numbers should be the same.

2) Under the Target Power section (green heading), fill out yellow cells and clear error messages (if any) row-by-row. Adjust your input as needed. *No error messages should remain* (except those that may originate from small rounding errors in the table). This section must be filled out for each and every row that has an input under the Current Power section.

Specifically,

- First, determine the Current Actual Power by measurements or estimation. Measurements would be best, but are not always possible. The user could use various methods to estimate the power (see Appendix 3).

- Second, determine the Current Max Power, usually by estimation from available performance data. This represents the power at maximum computational utilization and output.

- The Tool then calculates the Current Power Utilization (Current Actual Power / Current Max Power) as well as the Current Computational Utilization from the Power Performance Curves in Appendix 7.

- The required input under the Target Power section varies with each energy-saving measure as indicated by the yellow input cells (see below for details).

- Finally, the Tool calculates the Power Save (Current Actual Power – Target Actual Power). The power savings can be due to more energy efficient electronics (hardware) and/or higher utilization (software).

If the Inventory is modified, please revisit the two-step strategy above to ensure that the entries reflect the modified inventory.

If the data is already available, the table can be filled out directly by the user. The Tool then calculates Utilization and Power Save. A second scenario could be that the

user does not know the required information but wants to apply different ways of finding the data. A third scenario could be to let the Tool find/estimate the information after the user specifies the IT equipment makes and models. Please see Appendix 3 for details on the two latter scenarios.

Next, the energy-saving measures will be described one by one. The numbers within brackets refer to the numbers in Tables 4, 5, 6, and 7.

Adding (see Figure 4b)
Adding IT equipment to *increase computational capacity* results in negative Power Save since it requires additional power. If this measure is used, the Total Power Save is not equal to IT waste recovery.

First, enter Target Actual Power [490 W] and Target Max Power [1,000 W]. The Target Power Utilization [49.0%] is then computed as (Target Actual Power) / (Target Max Power). The Target Power Utilization is entered into the High-Range performance curve in Appendix 7 (since High was selected in Table 1 for Class 1), and the result is the Target Computational Utilization [47.1%]. Finally, the Power Save is the same as negative Target Actual Power [-490 W].

| | Current Power | | | | Target Power | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Power Reduction Factor | Power Save [W] |
| **Adding** | | | | | 490 | 1,000 | 49.0 | 47.1 | | -490 |
| **Removing** | 800 | 4,000 | 20.0 | | | | | | | 800 |
| **Replacing** | | | | | | | | | 0.00 | |
| **Modifying** | | | | | | | | | | |
| **Consolidating** | 7,000 | 14,000 | 50.0 | 48.5 | 5,000 | 8,000 | 62.5 | 64.6 | | 2,000 |
| **Clouding** | | | | | | | | | | |
| **Unchanged** | | | | | | | | | | |
| **Universal** | | | | | | | | | | |
| **Total** | 7,800 | 18,000 | 43.3 | 38.9 | 5,490 | 9,000 | 61.0 | 62.8 | | 2,310 |

| Table 3 Total | 7,800 | 18,000 | | | | | | | Save Total | 2,310 |
|---|---|---|---|---|---|---|---|---|---|---|

Include this form? If Yes, IT Tool will check for Errors.   | Yes |   **ERRORS Found**

Figure 4b: Class 1 Screen with Table 4 (detail).

The Power Reduction Factor cell is grayed out since it is not applicable for this measure. The Current Power cells are also grayed out since we are only adding IT equipment.

Removing (decommissioning) (see Figure 4b)
This involves removing *long-term idling IT equipment* (no computational output). This option could also include turning IT equipment off or put in sleep mode or stand-by mode, although the gear will still use a small amount of energy. A secondary use of this measure could be to remove non-idling equipment. But in such

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a case it would mean that we remove computational output (work). Make sure that this is considered when evaluating waste recovery (see page 14).

Even if there is no computational output, it does not mean that the power usage is zero. This is evident by studying the Power Performance curves in Appendix 7. We established the following "Active Idle" Power Utilization for the three Power Performance levels: 11% (High-Range), 18% (Mid-Range), and 30% (Low-Range).

The Inventory flagged Equipment Type E as a candidate for removal due to very low computational utilization. Enter Current Actual Power [800 W] and Current Max Power [4,000 W]. The Current Power Utilization [20.0%] is calculated as (Current Actual Power) / (Current Max Power) and the Current Computational Utilization is computed from the Power Performance curve [High] with the Current Power Utilization. Note that the latter cell will be empty if the value is below 10%. Finally, the Power Save is the same as Current Actual Power [800 W]. The Target Power cells in Table 4 are grayed out since we are only removing equipment for this measure.

The entered values cause an error message (E7): Current Power Utilization must not be <26 (see Figure 4a). Class 1 has been assigned a Power Performance of High, which do not allow lower utilization than 26 (see Page 11). Normally, the error should be cleared before proceeding. We left it in here to demonstrate the error functionality.

Note that the Power Performance level is the same for Current and Target equipment. Though, there may be situations where we want to increase the Power Performance. Such scenarios can be handled by specifying a new Class with higher performance. Then we simply remove the current equipment and add equipment to the new Class.

Replacing (refresh) (see Figures 5 and 6)
*Replacing equipment with more energy-efficient gear* often results in other benefits such as better power management and virtualization potential.

Equipment Type H was selected for a refresh with more energy-efficient equipment. In Figure 5, enter Current Actual Power [10,000 W] and Current Max Power [12,000 W]. The Current Power Utilization [83.3%] is calculated as (Current Actual Power) / (Current Max Power) and the Current Computational Utilization [83.1%] is computed from the Power Performance curve [Mid] with the Current Power Utilization.

The Tool now makes a correction for the Power Reduction Factor. This is the sole input under the Target Power section. This Factor allows increasing the IT efficiency. In this case, the Factor is 0.5 which means a 50% reduction of the Current Actual Power and the Current Max Power. If the input cell is left blank, it will be interpreted as a zero value.

| | Current Power | | | | Target Power | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Power Reduction Factor | Power Save [W] |
| Adding | | | | | | | | | | |
| Removing | | | | | | | | | | |
| Replacing | 10,000 | 12,000 | 83.33 | 83.07 | 5,000 | 6,000 | 83.33 | 83.07 | 0.50 | 5,000 |
| Modifying | | | | | | | | | | |
| Consolidating | | | | | | | | | | |
| Clouding | | | | | | | | | | |
| Unchanged | 1,200 | 1,800 | 66.67 | 61.76 | 1,200 | 1,800 | 66.67 | 61.76 | | 0 |
| Universal | | | | | | | | | | |
| Total | 11,200 | 13,800 | 81.16 | 80.55 | 6,200 | 7,800 | 79.49 | 78.57 | | 5,000 |

| Table 3 Total | 11,200 | 13,800 | | | | | | | Save Total | 5,000 |
|---|---|---|---|---|---|---|---|---|---|---|

Include this form? If Yes, IT Tool will check for Errors.　　Yes　　No ERRORS Found

Figure 5: Class 3 Screen with Table 6 (detail).

The Target Power Utilization and the Target Computational Utilization are copied directly from the Current Power section since the utilization will not change with equipment energy efficiency (Power Reduction Factor).

Finally, the Tool calculates the Power Savings [5,000 W] as Current Actual Power [10,000 W] minus Target Actual Power [5,000 W]. The calculations for the Replacing measure in Figure 6 are done in an analogous way to above (Equipment Type B).

| | Current Power | | | | Target Power | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Power Reduction Factor | Power Save [W] |
| Adding | | | | | | | | | | |
| Removing | | | | | | | | | | 0 |
| Replacing | 1,600 | 2,000 | 80.00 | 79.18 | 1,200 | 1,500 | 80.00 | 79.18 | 0.25 | 400 |
| Modifying | | | | | | | | | | |
| Consolidating | | | | | | | | | | |
| Clouding | | | | | | | | | | |
| Unchanged | 2,400 | 3,000 | 80.00 | 79.18 | 2,400 | 3,000 | 80.00 | 79.18 | | 0 |
| Universal | | | | | | | | | | |
| Total | 4,000 | 5,000 | 80.00 | 79.18 | 3,600 | 4,500 | 80.00 | 79.18 | | 400 |

| Table 3 Total | 4,000 | 5,000 | | | | | | | Save Total | 400 |
|---|---|---|---|---|---|---|---|---|---|---|

Include this form? If Yes, IT Tool will check for Errors.　　Yes　　No ERRORS Found

Figure 6: Class 4 Screen with Table 7 (detail).

Modifying

*Modifying IT equipment with energy-efficient Power Supply Units* (PSUs) may not be important for the assessment project as it is generally not an actionable activity for the current equipment. This energy-saving measure is more likely to be applied to

new equipment purchases. Nevertheless, this option could be worthwhile for educational (training) purposes to help students understand the impact of high-efficient PSUs. There is only a placeholder for this measure - it may be developed in a future version of the IT Tool.

Consolidating (see Figures 4b and 7)
*Consolidating sub-utilized servers* onto fewer servers results in better computational utilization through virtualization. In other words, consolidation allows a reduction in server power.

The Inventory flagged Equipment Type C as a candidate for consolidation due to low computational utilization. In Figure 7, enter Current Actual Power [4,000 W] and Current Max Power [10,000 W]. The Current Power Utilization [40.0%] is then computed as (Current Actual Power) / (Current Max Power) and the Current Computational Utilization [33.8%] is computed from the Current Power Performance curve [High] with the Current Power Utilization.

| | Current Power | | | | Target Power | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Actual Power [W] | Max Power [W] | Power Util. [%] | Comp Util. [%] | Power Reduction Factor | Power Save [W] |
| Adding | | | | | | | | | | |
| Removing | | | | | | | | | | |
| Replacing | | | | | | | | | | 0.00 | |
| Modifying | | | | | | | | | | |
| Consolidating | 4,000 | 10,000 | 40.0 | 33.8 | 3,500 | 6,000 | 58.3 | 59.5 | | 500 |
| Clouding | | | | | | | | | | |
| Unchanged | 3,000 | 3,200 | 93.8 | 95.5 | 3,000 | 3,200 | 93.8 | 95.5 | | 0 |
| Universal | | | | | | | | | | |
| Total | 7,000 | 13,200 | 53.0 | 52.6 | 6,500 | 9,200 | 70.7 | 74.0 | | 500 |

| Table 3 Total | 7,000 | 13,200 | | | | | | | Save Total | 500 |

Include this form? If Yes, IT Tool will check for Errors.     Yes     No ERRORS Found

Figure 7: Class 2 Screen with Table 5 (detail).

The Target Power may need to originate from an integrator/vendor, since these numbers are equipment specific. Specify to the integrator/vendor a desired Computational Utilization at the current computational (work) output. With these numbers at hand, enter the Target Actual Power [3,500 W] and Target Max Power [6,000 W]. The Target Power Utilization [58.3%] and Target Computational Utilization [59.5%] will then be calculated. Finally, the Tool calculates the Power Savings [500 W] as Current Actual Power [4,000 W] minus Target Actual Power [3,500 W]. The calculations for the Consolidation measure in Figure 4b are done in a similar way to above (Equipment Type A).

The entered Target Actual Power and Target Max Power reflect the consolidated equipment including the effect of more energy efficiency hardware (if any). During

consolidation efforts it is common to select more efficient IT equipment. Note that the Power Utilization and Computational Utilization will not change with equipment energy efficiency.

The spreadsheet may report a different Computational Utilization compared to that you specified to the integrator or vendor. Remember that the calculated Target Computational Utilization is based on the Power Performance curves in Appendix 7. In this case the High-Range curve since it was selected in Table 1 for Class 2. This power performance may not reflect that of the equipment the integrator or vendor selected so there may be a discrepancy between their utilization number and the reported number. However, most IT equipment for data centers tends to follow the High-Range curve so the discrepancy (if any) should be small.

Note that server consolidation is different from server virtualization. Server consolidation is about reducing server counts and server virtualization is about hosting multiple workloads on a single machine. Virtualization enables physical equipment consolidation by providing the technology to accommodate multiple workloads on a single machine.

Both the computational utilization and the composition of computational utilization (useful work vs. overhead work) also need to be considered. High utilization does not necessarily mean "good" if we don't do any useful work; this would be hidden under-utilization. See Appendix 4 for additional information on useful work.

Clouding
From a calculation stand point, "Clouding" (i.e., moving to the Cloud) is not much different than Consolidation. Consequently, the input process is identical for these two measures. Please review the description under Consolidating above.

It is unlikely that an energy assessor will be able to get accurate energy information from a Cloud Service Provider (CSP).  The technologies in play vary from CSP to CSP, and there is no way for the assessor to know the state of devices at the CSP at any moment in time.  Therefore, this is an action that is subject to an educated guess – at best. But, if Cloud credits are desired, the information is needed.

Unchanged (see Figures 5, 6, and 7)
In this measure, *no changes are made to the IT equipment*. Equipment Type F was selected for making no changes due to high utilization. In Figure 7, enter Current Actual Power [3,000 W] and Current Max Power [3,200 W]. The Current Power Utilization [93.8%] is then computed as (Current Actual Power) / (Current Max Power) and the Current Computational Utilization [95.5%] is computed from the Current Power Performance curve [High] with the Current Power Utilization.

Since no changes are made to the equipment, the Current Power section data will simply be copied to the Target Power section, resulting in no Power Savings [0 W]. The Power Reduction Factor cell is grayed out since it is not applicable. The

calculations for the Consolidation measure in Figure 5 and 6 are done in an analogous way to above (Equipment Types D and G, respectively).

<u>Universal</u>
This is a user-defined, universal input. The user can here *name and define his/her own energy-saving measure*. The Universal measure can simulate (duplicate) any other of the measures - and more.

First, input a concise name for the measure in the far-left yellow cell. Second, enter the Current Actual Power and Current Max Power. The Current Power Utilization and Current Computational Utilization will then be calculated. Third, enter the Target Actual Power and Target Max Power. The Target Power Utilization and Target Computational Utilization will be calculated. Finally, the Power Savings are calculated. The Power Reduction Factor cell is grayed out.

## Questions Input

The Questions Input screen is the last of the six input screens (tabs) although some input data should be entered on the Numerical Output screen. The Questions Input screen collects information that generates hands-on recommendations to help reinforce best practices.

Input data (yellow cells):
- Answer each question with a Yes or No.

The table in Figure 8 lists a number of questions. Select Yes or No from the drop-down menus. The menus are activated by clicking on the yellow cells. A No answer to any question will result in a recommendation on the Recommendations Output screen (tab). A Yes answer will not trigger a recommendation (blank field).

If you are unsure, enter No. A recommendation will then be provided that may help determine whether the No answer was the best choice.

| # | Question | Yes/No |
|---|---|---|
| 1 | Have you defined "Critical Values" (hot-button issues that are top-of-mind of executives) for the IT project? | No |
| 2 | Have you identified the organizational stakeholders for the IT project? | No |
| 3 | Are you keeping an IT equipment inventory? | Yes |
| 4 | Do you track IT asset utilization? | No |
| 5 | Is there an Information Technology Asset Management (ITAM) system present to monitor IT utilization and status? | No |
| 6 | Are unused or obsolete IT equipment systematically removed from the data center space? | Yes |
| 7 | Do you require Energy Star certification on purchase of new IT equipment? | No |
| 8 | Do you have a way of discerning business-application processes from overhead processes? | No |
| 9 | Are you able to observe utilization of virtual assets? | No |
| 10 | Is your method of tracking IT utilization able to produce reports timely to enable Operations to manage inventory? | No |
| 11 | Do you have tools and processes for assessing IT asset utilization? | No |
| 12 | Do you have a clear decommissioning process for IT equipment? | Yes |
| 13 | Does the IT equipment refresh plan consider the age of the equipment? | Yes |
| 14 | Are "80+" power supply units (PSUs) required in equipment procurement? 80+ is a specification for PSU efficiency. | No |
| 15 | Have you considered the impact of your public cloud providers in your energy and carbon estimates? | No |
| 16 | Are power management features enabled in IT equipment that is in service? | Yes |
| 17 | Have you established an Energy Activity Policy? | No |
| 18 | Does the IT Provisioning Policy include energy-related rules and conditions? | No |

This screen allows the user to answer a number of IT equipment assessment questions. A "No" answer will result in a recommendation on the Recommendations screen (tab).

If unsure, enter "No".

Figure 8: Questions Screen for Recommendations Output.

**Numerical Output**

The Numerical Output screen (tab) is the first of two output screens. It has two main sections: Results (white cells) and "Scalers" (yellow input cells).

The screen is shown in Figure 9. It lists numerical output based on the user input on the previous screens. In addition, a number of input cells (yellow) is located directly on this Numerical Output screen so that the user can quickly evaluate a change on a particular output. We call this input data "scalers".

Input data (yellow cells):
- PUE [-]
- Energy Price ($/kWh)
- State or Custom Carbon Emission Rate (lbs/kWh)
- Cost to Implement ($).

The Power Usage Effectiveness (PUE) is a widely accepted metric for data center infrastructure energy efficiency. It is the ratio of total energy used by a data center to the energy used by the IT equipment. The PUE cannot be lower than 1.0.

Calculated data:
- Power Utilization (%)
- IT Power Savings (W)
- Infrastructure Power Savings (W)
- Total Energy Savings (kWh/year)
- Total Energy Cost Savings ($/year)
- Emission Rate (lbs/kWh)
- Total Carbon Savings (lbs $CO_2$/year)
- Simple Payback (years)
- IT Power Pre-Implementation (W)
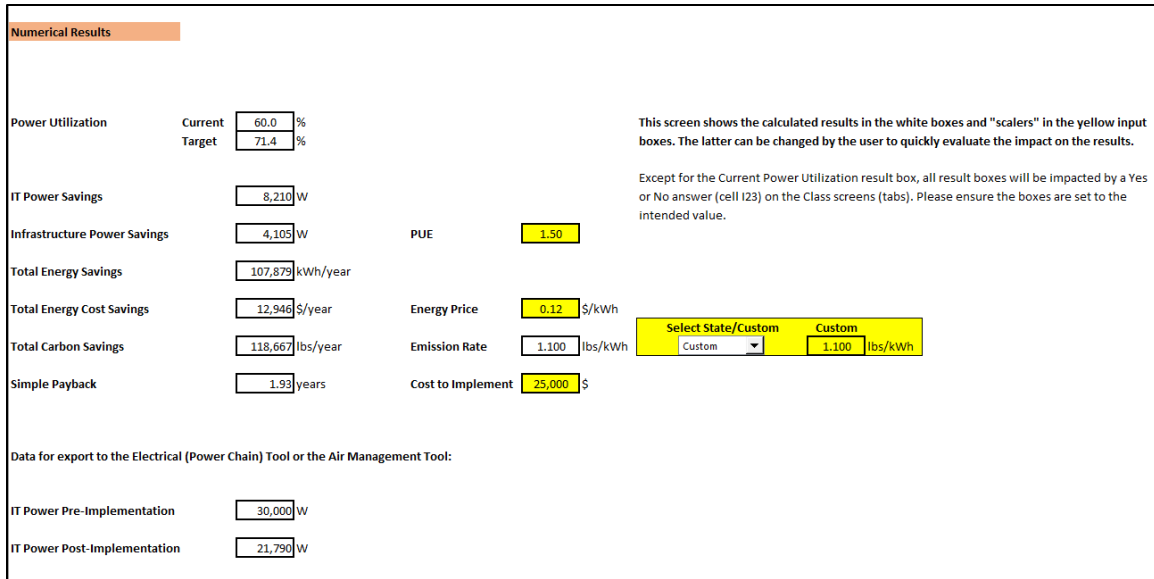- IT Power Post-Implementation (W).

Figure 9: Numerical Output Screen.

Each of the output items and the yellow scalers will now be described in the order they appear on the screen. Total Savings refer to data from all four Classes as well as for both IT and infrastructure.

Calculated Power Utilization (%)

Both the Current Actual (before changes) and the Target Actual (after changes) power utilization are shown on this screen. The Current Actual Utilization [60.0%] is simply copied from Table 3 in Figure 3. The Target Actual Utilization [71.4%] is compiled from the Class screens, but only those that are included in the calculations (i.e., a Yes answer to the "Include this form?" question).

No additional input required by user.

The following power numbers are assumed to be annual averages and the energy savings are based on that assumption.

Calculated IT Power Savings (W)

The savings (Power Save) going from Current Actual to Target Actual conditions are compiled from the Class screens that are included in the calculations (i.e., a Yes answer to the "Include this form?" question). In Figures 9a and 9b, the IT savings are 8,210 W.

No additional input required by user.

Calculated Infrastructure Power Savings (W)

This is estimated by using the average PUE factor provided by the user in the top yellow cell. The savings are calculated by multiplying the IT Power Savings by (PUE-1), since (PUE-1) is the infrastructure overhead power saved per unit of IT power savings. The Infrastructure Power Savings are 4,105 W using a PUE of 1.50.

Input required by user (yellow cell): PUE.

Calculated Total Energy Savings (kWh/year)

The total power savings are the sum of the IT Power Savings (W) and the Infrastructure Power Savings (W). The total power savings are then multiplied by 8,760 hours (hours in one year) and lastly divided by 1,000 to estimate the Total Energy Savings in kWh/year. The Total Energy Savings are 107,879 kWh/year.

No additional input required by user.


Calculated Total Energy Cost Savings ($/year)

The energy cost is based on the average price of energy for the whole year, which is consistent with the power assumptions above.

The total energy cost savings are calculated as Total Energy Savings multiplied by the energy price ($/kWh). In Figures 9a and 9b, the Total Energy Cost Savings are 12,946 $/year using an Energy Price of 0.12 $/kWh (middle yellow cell).

Input required by user (yellow cell): Energy Price.

Calculated Total Carbon Savings (lbs. $CO_2$/year)

The total carbon savings are calculated by multiplying the Total Energy Savings (kWh/year) by the $CO_2$ Emission Rate (lbs/kWh). The Total Carbon Savings are 118,667 lbs/year using an Emission Rate of 1.100 lbs/kWh (bottom white cell).

Input required by user (yellow cells): State or Custom carbon emission rate.

Select a state from the drop-down list and the average emission rate per eGRID (2021) for that state will be shown in the bottom white Emission Rate box. Alternatively, you can specify any emission rate by selecting Custom from the same drop-down list (first item) and then input the custom emission rate in the yellow Custom box.

The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive source of data on the environmental characteristics of almost all

electric power generated in the United States. The map on the next page from eGRID (2021) provides an overview of the $CO_2$ emission rates across the United States.

The correlation with type of generation fuel is strong. States with a high percentage of coal are generally colored dark blue or >1,300 lbs. $CO_2$/MWh electric generation (e.g., Wyoming and West Virginia), and states with a high percentage of clean power are colored light blue or <540 lbs. $CO_2$/MWh. If more current and/or detailed information is needed for a specific location, please contact your energy provider.

Please note that the map uses lbs/MWh whereas the input on the Numerical Output screen requires lbs/kWh. In addition, Appendix 5 provides some general information about carbon footprints of servers.

Except for Current Power Utilization, all results will be impacted by a Yes or No answer (Excel spreadsheet cell I23) on the Class screens (tabs). Please ensure these switches are set to the intended values.
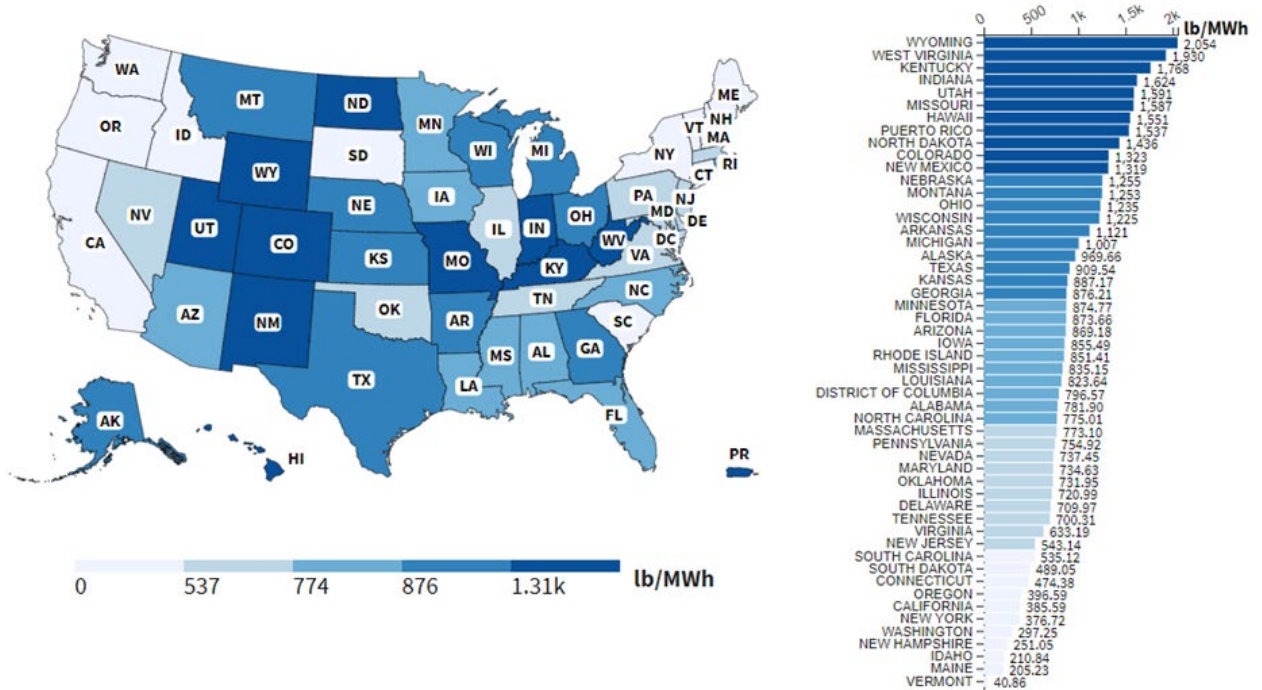


Figure 10. $CO_2$ Emission Rates (lbs/MWh) (eGRID, 2021).

Simple Payback (years)
Enter the total implementation cost for all selected measures. The Simple Payback period will be calculated based on this input.

Input required by user (yellow cell): Cost to Implement.

The following two output items contain information intended for export to the DOE Electrical (Power Chain) Tool or the DOE Air Management Tool (DOE, 2021).

IT Power Pre-Implementation (W)

IT Power Pre-Implementation of IT measures is copied from the Inventory sheet, Cell B36 (Sum of Actual Power). No input required by user.

IT Power Post-Implementation (W)

IT Power Post-Implementation of IT measures is calculated as IT Power Pre-Implementation minus the value in Cell E11 (IT Power Savings) on the Numerical Results sheet. No input required by user.


There are two principal ways of exporting this information to the DOE Electrical (Power Chain) Tool or the DOE Air Management Tool (DOE, 2021).

A)      From the IT Equipment Tool to the Electrical (Power Chain) Tool

The IT Power (Savings) calculated by the IT Tool does not take into account the power chain (e.g., UPS, PDU). However, the power data can be exported to the Electrical (Power Chain) Tool for that purpose.

IT power pre- and post-implementation of IT measures can be exported to the Electrical (Power Chain) Tool as an input to Cell C28 (IT Equipment Power Demand) on sheet User Inputs A. Other input data may need to be adjusted accordingly.

B)      From the IT Equipment Tool to the Air Management Tool

The Air Management Tool does not take into account improvements in the IT equipment efficiency. However, the IT Power data can be exported from the IT Equipment Tool to the Air Management Tool for that purpose.

IT power pre- and post-implementation of IT measures can be exported to the Air Management Tool as input to Cells C26-C35 (Measured Power) on sheet Step 2: Equipment. Note that this requires selecting Class Option "Similar DT(P)" on the same sheet. To maintain an energy balance in the data center, the data on sheet Step1: AHU may need to be adjusted.

## Recommendations Output

Figure 11 lists hands-on recommendations based on user responses to the questions on the Questions Input screen (tab). Fields that are blank are those that were answered Yes on the Questions Input screen.

**Recommendations**

This screen shows recommendations based on user responses on the Questions screen (tab). A blank field means that the corresponding question was answered "Yes".

| # | Recommendation |
|---|---|
| 1 | CRITICAL VALUE: Since energy savings alone are likely not an important justification for energy assessment projects, it is critical that the assessor articulates both the total value and the critical value (hot buttons) to the business. |
| 2 | STAKEHOLDERS: There are many stakeholders. The obvious ones are Facilities and IT, but that's far from all. You have to crawl each thread of this web to identify those who may benefit from the project or potentially be harmed. |
| 3 | |
| 4 | UTILIZATION: Tracking IT utilization plays a central role in making the IT (and infrastructure) estate energy efficient. Methods should be in place to continuously monitor the utilization. Energy Star equipment requires direct access to CPU utilization. |
| 5 | ITAM: An Information Technology Asset Management system is the best way to manage IT gear. ITAM can also be programmed to automatically alarm or report on conditions that will be favorable for waste harvesting and consolidation. |
| 6 | |
| 7 | ENERGY STAR: Energy Star certified IT equipment ensure certain levels of energy efficiency and control of energy-related operation. Energy Star requires direct access to power, intake temperatures, and processor utilization. Strongly recommended. |
| 8 | OVERHEAD WORK: The ability to determine the level of data processing due to execution of business applications versus overhead functions can provide additional opportunities for consolidation of workloads and reducing IT gear count. |
| 9 | VIRTUAL IT EQUIPMENT: IT equipment waste occurs to virtual as well as physical assets. Because of the high level of virtualization in enterprise data centers, it is necessary to apply the same analytical rigor to virtual assets. |

Figure 11: Recommendations Output Screen (truncated)

**Appendix 1: DCEP Program**

IT equipment is at the core of energy consumption in data centers. Not only does the IT equipment consume energy but its heat must typically be removed from the data hall by mechanical equipment, which, in turn, consumes additional energy. Therefore, energy savings at the IT equipment level will have an impact on essentially all energy use in the data center, including cooling and the electrical power chain.

The Data Center Energy Practitioner (DCEP) IT training module was created to train energy assessors in approaches and methods of reducing the energy demand at the IT equipment level. A primary action in that regard is to identify and remove wasteful energy consumption by the IT equipment. The one-day IT training module provides a solid foundation for better understanding the IT Tool and how to reduce IT waste in general.

The DCEP IT module is complemented by two other training modules: The Generalist module and the HVAC module. The high-level Generalist module is a one-day training course aimed at giving a general overview of the major energy consuming systems in data centers (electrical, cooling, air management, and IT equipment). The HVAC module, on the other hand, is a two-day training course addressing the cooling and air management systems in significant detail. For more information on the DCEP program, please visit http://datacenters.lbl.gov/dcep

**Appendix 2: The Big Picture**

The energy demand of the IT gear is the root of overall data center energy consumption. As the IT energy load increases, so does that of the facility support systems. A primary action should be to identify and remove wasteful energy consumption by the IT equipment. Since wasteful energy consumption often is rampant in data centers, removal of this waste can be one the most significant energy efficiency improvement steps available to an energy assessor.

An IT energy assessment should never be looked at in isolation. Data centers are complex environments with numerous interconnected energy consuming systems (IT, electrical, cooling, air management). Consequently, the data center should be viewed in a holistic way. However, this may be difficult considering the common disconnect between the facilities staff and the IT staff in data centers.

In discussions with Ben Radhakrishnan (see Appendix 6) he shared a conceptual, non-published model for a predictive Total Cost of Ownership (TCO) model for IT equipment. The model tracks Key Performance Indicators (KPI) against a set of IT Cost Drivers. The KPIs include metrics such as TCO, energy cost ($), and $CO_2$ emissions. Cost Drivers include energy price ($/kWh), number of IT devices, and utilization of the devices.

The IT Cost Drivers are part of the input parameters, whereas the computed KPIs are the output of the model. The connections between the two are governed by straightforward computations. We take a similar approach with the IT Tool (see figure below), which allows the user to apply improvement steps to achieve a before/after comparison of any of several key metrics.

The Figure depicts a computational flowchart of the IT Tool implementation. In the first step, we establish an Inventory of IT equipment that will be the subject of the analysis including the associated power draw of each piece of equipment. See also Appendix 3.

With this inventory in hand, the user segregates equipment into Classes (we implemented four Classes although only three are shown in the figure). These Classes can be defined in whatever way makes the best sense to the user, with some key exceptions. There will be some group association that is evident to the user, and we allow this to be a use-case decision to maximize the applicability of the tool.
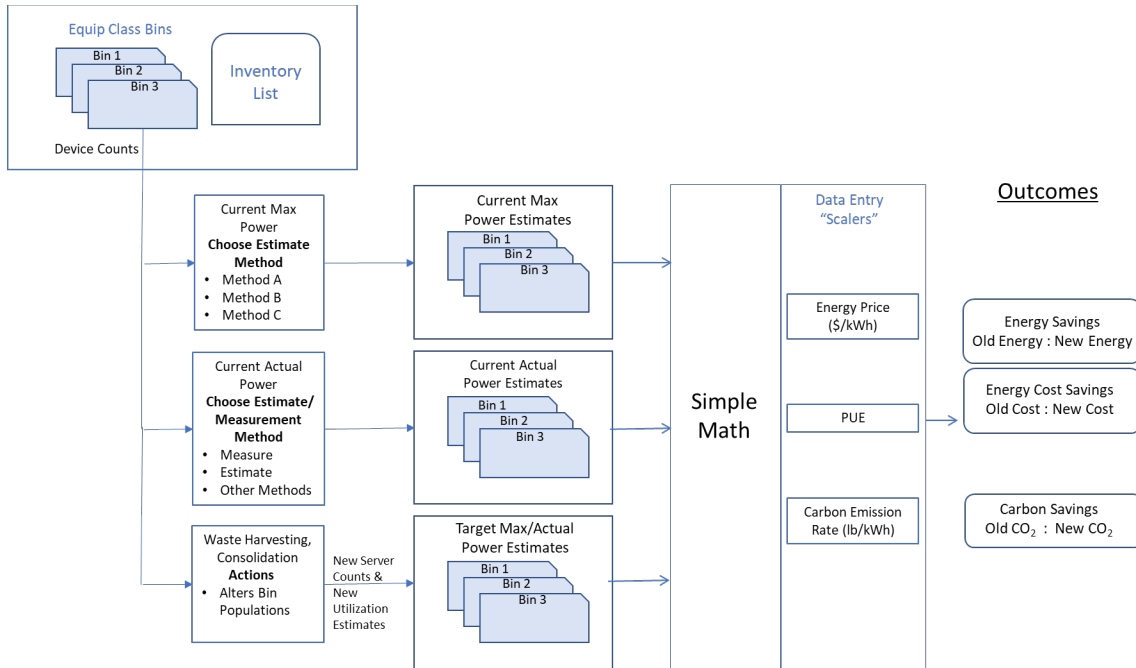
Overview of Analysis Implemented by the Tool.

In the next step, each individual Bin or Class is processed through an analysis step. Three examples are shown in the figure. One is a Max Power calculation, which can be estimated using one of eight energy-saving measures. A second is an Actual Power calculation, again derived using one of eight measures. The third is a power savings (IT waste harvesting) and consolidation activity. Note that this is about reducing the energy consumed by the IT equipment upfront, not to recover the heat when it is out in the IT equipment room.

The resulting before and after state of these measures can then be run through computations to produce the outcomes or the Key Performance Indicators (KPIs). Energy price, PUE, and carbon emission rate are entered by the user in this final step. These input variables or "scalers" are used to complete the calculations. The result (outcomes) is a set of business-relevant KPIs that support the IT equipment energy efficiency improvement project.

**Appendix 3: Establish Inventory and Power Draw**

The methods for collecting the IT inventory can be varied and is usually dictated by the level of sophistication of the asset management system. Some organizations have software tools (e.g., IT Asset Management - ITAM) that facilitate receipt, deployment, application, operation, and retirement of IT assets. That is, they have electronic documentation of the full IT lifecycle. Other organizations on the other hand, may have nothing to assist with this effort, and thus necessitate a manual discovery on the part of the assessor.

Data Center Management Solutions can be divided into Data Center Networking tools and Data Center Infrastructure Management (DCIM) tools. Such tools are used to manage the daily operations of the data center, and can be leveraged by the assessor to quickly identify removal and consolidation opportunities. LBNL (2021) provides a discussion how to access onboard server sensors, such as power draw and CPU utilization.

Unfortunately, it is common that the data center lacks these types of operational resources. The assessor is left to assemble the data using whatever resources are at hand. Options include Domain Name System (DNS) records and various methods of discovery. These are all subject to various levels of accuracy and restrictions on access with electronic tools. In the most labor-intensive option, the assessor may resort to clipboards and spreadsheets to assemble the information. Although this method is primitive, it is not uncommon.

The Tool not only provides the structure for organizing relevant information but it also provides key generalized IT power performance data based on SpecPower (2020). This power performance data is useful for consolidation efforts. However, the Tool does not directly aid in collecting other data or how to implement various IT energy-saving measures. For example, the Tool does not discuss the means of server virtualization.

The assessor must use his/her expertise to collect the data. However, we do provide high-level guidance on finding IT power data. The quality of the data will strongly depend on the source selected by the user. Measuring and estimating equipment power often require substantial expertise. The DCEP (2020) training program provides such know-how.

There are a number of techniques for measuring and estimating IT power and energy use, but they are mostly less than ideal. In the end, it takes a pragmatic strategy to most effectively collect the necessary information.

If the IT power data is already available, the Tool input screens can be filled out without too much trouble. The Tool then calculates Power Utilization and Power Savings. A second scenario could be that the user does not know the power data but wants to apply different techniques to find them. A third scenario could be to let the

Tool estimate the power data after the user specifies the IT equipment manufacturers and models.

For the second scenario, there are several ways to determine the IT equipment power data:

• De-rated name plate values. Use the raw nameplate values, but de-rate them by some purposeful percentage (50% is common). This is a blunt instrument for estimating IT power.
• ASHRAE Thermal Reports (ASHRAE, 2015) provide an effective way of estimating key operating data such as power draw. This method results in more realistic values than de-rated name plate values.
• SpecPower (2020) has compiled a very useful up-to-date server database with power data for a number of server makes and models. This method results in still better data quality.
• Many IT manufacturers have developed calculator apps to help estimate IT power. These apps can become cumbersome since they often require significant input. Done correctly, however, they provide quality results.
• Another method is to use temporary IT equipment power cord measurements. This method can provide high quality data but could become very labor intensive in larger environments.
• Permanent meters (measuring devices) can be installed to measure power, e.g., intelligent power strips. This method provides benefit of real-time, high-quality power data especially if combined with a power management system.
• Towards the high end on the quality scale are real-time data from internal IT equipment measurements. This is typically the best option for collecting accurate power data. For example, ENERGY STAR servers must provide such information. The data must be made available in a user-accessible format to be readable by third-party, non-proprietary management systems. Management tools and Data Center Infrastructure Management (DCIM) software can further automate the process.

For the Target Power sections on the Class sheets (tabs), similar methods to above can be used. In addition, implementors/vendors of consolidation equipment and software should be able to help estimate the power draw after consolidation.

For the third scenario, the SpecPower (2020) database with server power performance (full and part utilization) could potentially be used by the IT Tool to automatically harvest current and target power for different server brands and models. This scenario has not been implemented in the Tool.

**Appendix 4: Useful Work**

Server computational utilization is a metric commonly used to determine whether a server is "useful" or not. If the server is showing high utilization, the general assumption is that it is doing something purposeful. We could monitor a server and determine, for example, that it is running at 50% utilization. But of that 50%, what is really being processed?

There are plenty of overhead processes running on a server. There are activities like virus scans, software updates, and backups. One can argue that these processes are necessary activities. However, the business did not invest in server hardware, maintenance, license fees, and data center resources to run virus scans. Such overhead work is not the business purpose (primary service) of the server.

The designation of which processes are "useful" and which are not can often be subjective. The utilization comprising the overhead (secondary services) activity is another opportunity for consolidation and subsequent energy savings.

Utilization analysis can yield significant consolidation opportunities, but it requires an additional level of investigation. We have to know, for example, the names of the processes comprising and related to the business applications we want to see operating on the server. Next, we need a way to observe the processes so that we can determine the proportion of useful work.

In order to do this, software discovery daemons may need to be installed to classify processes into "useful" or "non-useful" work, or we need System Administrator access to manually inspect the processes running. In 2010, the Green Grid proposed two metrics for assisting in this work: Data Center Compute Efficiency (DCcE) and its underlying sub-metric Server Compute Efficiency (ScE) (TGG, 2010).

If this level of server access is known to be impossible, then the assessor should put aside this analysis. On the other hand, if such access is indeed possible, the assessor could consider the opportunity for further energy savings along with the level of effort that will be required to assemble the necessary data.

**Appendix 5: Carbon Footprint of Servers**

What is the carbon footprint of an IT server? The answer can vary by a factor of 10 (or even more), depending on three key factors.

- The power consumption of the server
- The energy efficiency of the support systems (PUE)
- The carbon footprint of the electricity.

Two representative high-low data points for each factor is shown in the table below, grouping together all the highs and all the lows to illustrate the range of server carbon footprint.

Range of Annual Server Carbon Footprint (Vertatique, 2009).

| Server (W) | PUE (-) | Annual kWh | Power Source | Source Carbon (kg/kWh) | Annual Carbon (metric tons) |
|---|---|---|---|---|---|
| 450 | 2.2 | 8,678 | Brown Coal | 1.20 | **10.4** |
| 150 | 1.8 | 2,367 | Natural Gas | 0.45 | **1.1** |

Note: Multiply the Source Carbon column by 2.2 to convert to lbs/kWh.

**Appendix 6: Industry Focus Group**

The purpose of the assembled Industry Focus Group was to review the development of the IT Tool and suggest changes, additions, and deletions. The authors are grateful for the important contributions of this Group.

The Group consisted of the following industry subject matter experts:

- Dennis O'Brian (Dennis O'Brien Consulting, LLC)
- Ben Radhakrishnan (National University, San Diego)
- Gerald Riso (DOE)
- David Rogers (BC Hydro, Canada)
- Henry Wong (E3HS IT Consulting, LLC).

Dennis works with the Department of Defense (DoD) on data center energy issues, while Ben and Henry have been involved in developments of related IT tools. Gerald has been busy with the Federal Data Center Optimization Initiative (DCOI), and David is presently heading up a related standard development project in Canada.

**Appendix 7: Server Performance Curves**

For the development of the IT Tool, we analyzed the comprehensive SpecPower (2020) server data base dated July 2, 2020 and created three levels of server power performance curves based on commonly found servers in data centers. In this User's Manual and in the IT Tool itself, they are called High-Range Power Performance, Mid-Range Power Performance, and Low-Range Power Performance servers. Going from Low to Mid to High, the power performance increases and the power requirements decrease.

The next page shows three actual 2U servers representing the three levels of power performance (blue curves), and on the following page are the generalized performance curves implemented in the IT Tool. In all six figures, the x-axis represents Power Utilization and the y-axis represents Computational Utilization.

The generalized curves do not go below 10% Computational Utilization since the available data is ambiguous below that level. The Active Idle state (no throughput) is addressed separately. The idling state does not follow the overall trend of the performance curves. The IT Tool uses the following Active Idle Power Utilization for the three performance levels: 11% (High-Range Power Utilization), 18% (Mid-Range Power Utilization), and 30% (Low-Range Power Utilization).

If a server has known power performance characteristics, the matching with one of the three generalized curves should be straight forward. If little is known about the server, we recommend using the High-Range curve since it represents a majority of servers in data centers. Low-powered servers are not common in data centers. On average, this server type has power characteristics near the Low-Range Power Performance equipment.
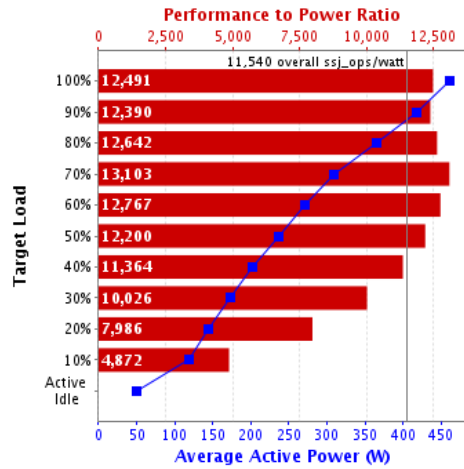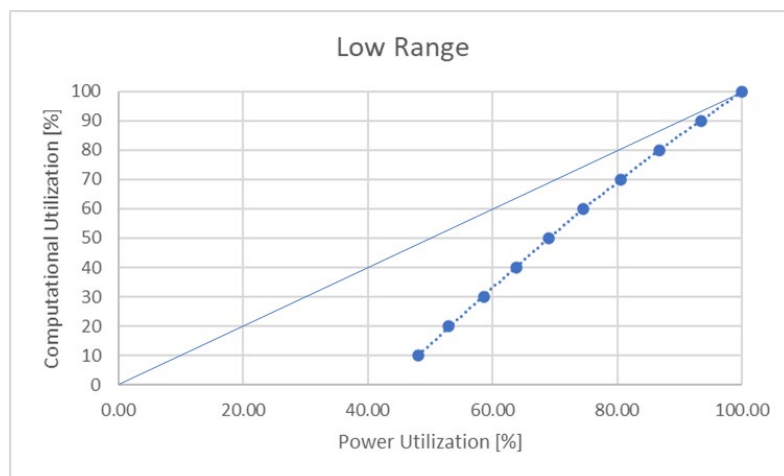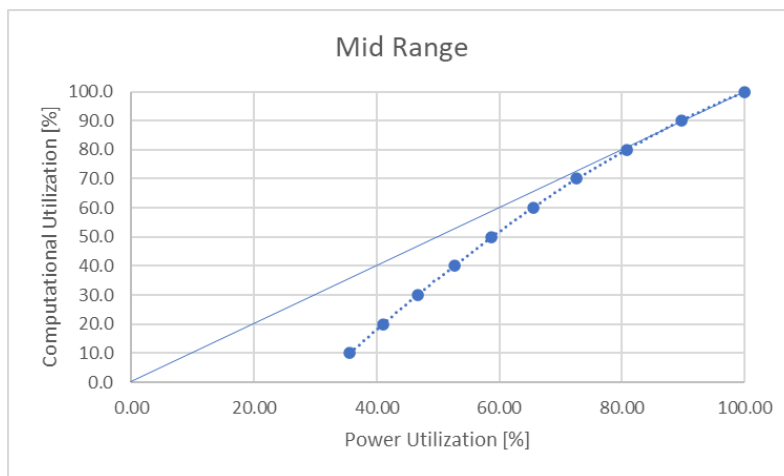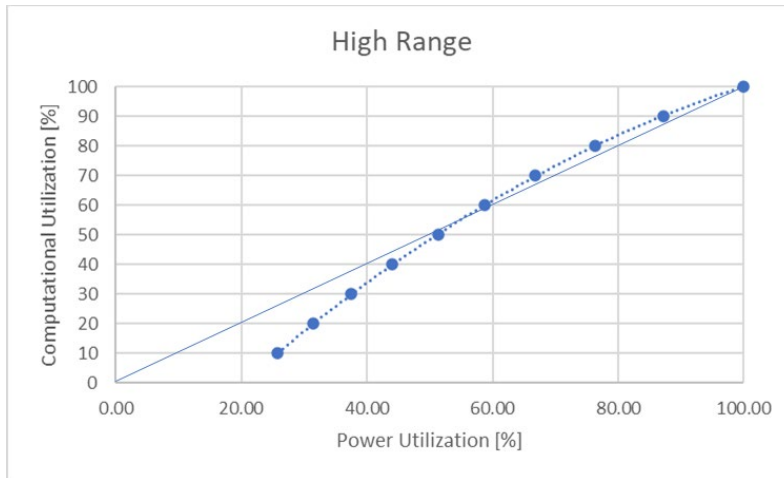
High-Range Server – Actual 2U Server
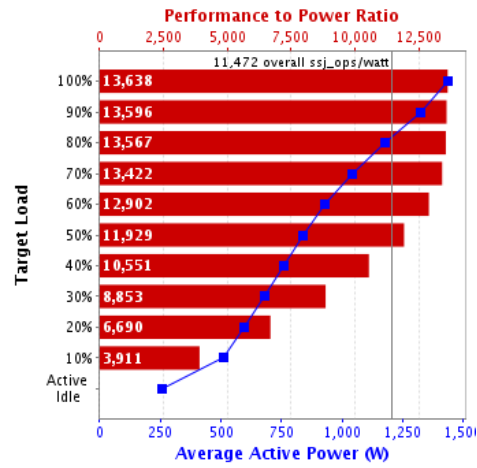

Mid-Range Server – Actual 2U Server
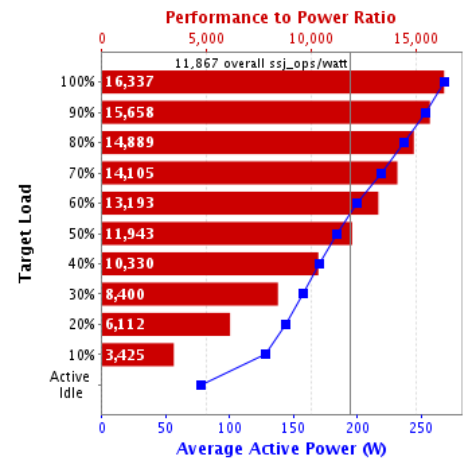

Low-Range Server – Actual 2U Server

Generalized Performance Curves: High, Mid, Low.

**DEFINITIONS** (in the order they appear in IT Tool)

**Equipment Type**
The user groups the IT Equipment into IT Equipment Types, having similar power requirements both for Actual Power and Max Power.

**Equipment Class**
The user groups the IT Equipment Types into Classes. At a minimum, all equipment in a Class must have the same Power Performance. There will usually be some additional group associations that are important to the user.

**IT Equipment Energy-Saving Measures**
Measures that help save energy at the IT level, such as consolidation.

**Current/Target Actual Power**
Current Actual Power is the operating power before IT changes and Target Actual Power is the operating power after IT changes. Actual Power is the actual operating power as configured.

**Current/Target Max Power**
Current Max Power is the maximum power before IT changes and Target Max Power is the maximum power after IT changes. Max power is the maximum operating power as configured.

**Power Utilization**
Power Utilization = Actual Power / Max Power

**Current/Target Power Utilization**
Current Power Utilization is the power utilization before IT changes and Target Power Utilization is the power utilization after IT changes.

**Computational Utilization**
Computational Utilization = Actual Computation / Max Computation

**Current/Target Computational Utilization**
Current Computational Utilization is the computational utilization before IT changes and Target Computational Utilization is the computational utilization after IT changes.

**Target Power Reduction Factor**
Selects more energy efficient IT equipment. Power Reduction of 0.0 means 0% power reduction, Power Reduction of 0.5 means 50% power reduction, and Power Reduction of 1.0 means 100% power reduction.

**Power Save (savings)**
Current Actual Power minus Target Actual Power.

**Power Performance**
The Power Performance is the relationship between Power Utilization and
Computational Utilization.

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