U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

System-Level Tools for Identifying and Quantifying Carbon Reduction Opportunities In Data Centers

March 29, 2022

FEMP Federal Energy Management Program

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- Enter any questions in the Question Box throughout the webinar.
- Instructions to take the quiz will be provided at the end of webinar.
- Slides will be sent out afterwards to those who attend the entire webinar.

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Today's Speakers

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CENTER OF EXPERTISE
FOR ENERGY EFFICIENCY IN DATA CENTERS

Webinar Agenda

Agenda	
I.	Introduction
II.	Context of Energy Efficiency and Decarbonization
III.	New Carbon Saving Functionality in the DOE System Tools
IV.	Resources and Q&A

Learning Objectives

- Recognize the DOE Data Center Energy Assessment System Tools, what they do and how they can be used to increase energy efficiency and decarbonization
- Understand newly added functionality for carbon savings associated with different energy-efficiency measures
- Understand newly added functionality for simple payback associated with different energy-efficiency measures
- Gain an understanding of how data can be passed between the tools (high-level integration) to make them work together.

Purpose of Webinar

The objective of this webinar is to make the DOE Data Center Energy Assessment System Tools better known in general and the new functionality in particular to be in a better position to reduce IT and facility energy use and carbon footprint.

A “System Tool” focuses on a single energy consuming system (e.g., IT, HVAC, Electrical) in the data center to produce a more accurate estimate of potential energy saving from energy-saving measures.

Context of Energy Efficiency and Decarbonization In Data Centers

Importance of Energy Efficiency

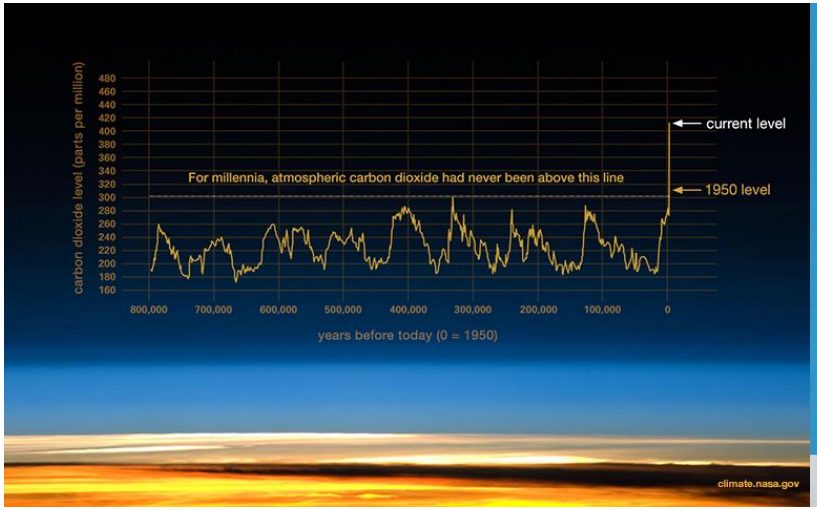
During 2014, energy consumed by data centers was around 1.8%* of the total electric energy consumed in the US. This is a large amount of energy for a single type of facility.

Energy is a cost to the data center and energy efficiency is an important business consideration. There are also growing regulatory, compliance, and market pressures to reduce the energy usage to demonstrate leadership in energy efficiency and environmental stewardship.

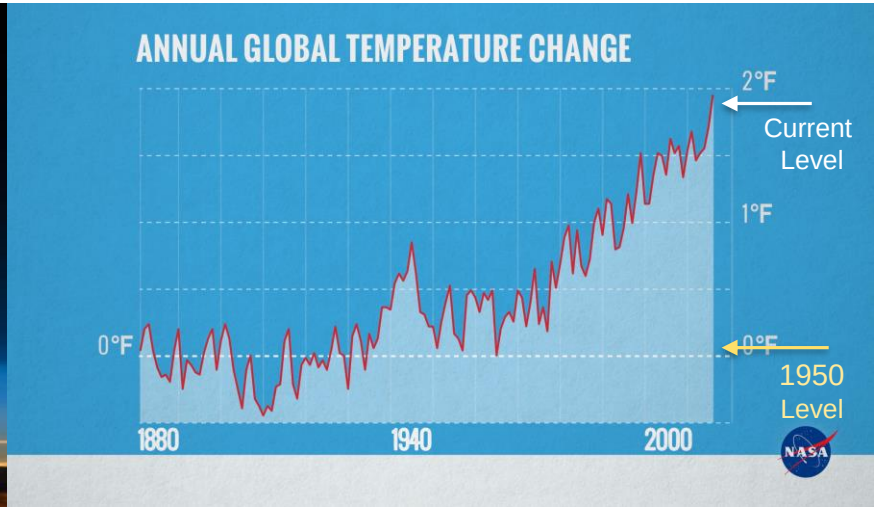
* https://datacenters.lbl.gov/sites/default/files/DataCenterEnergyReport2016_0.pdf

Importance of Decarbonization

Climate change is a concern to all of us, and CO_2 emissions are at the center of increased global temperatures. It is undeniable that human activity has caused higher CO_2 levels, and higher levels trap more heat.



CO_2 Concentration



Temperature

http://climate.nasa.gov

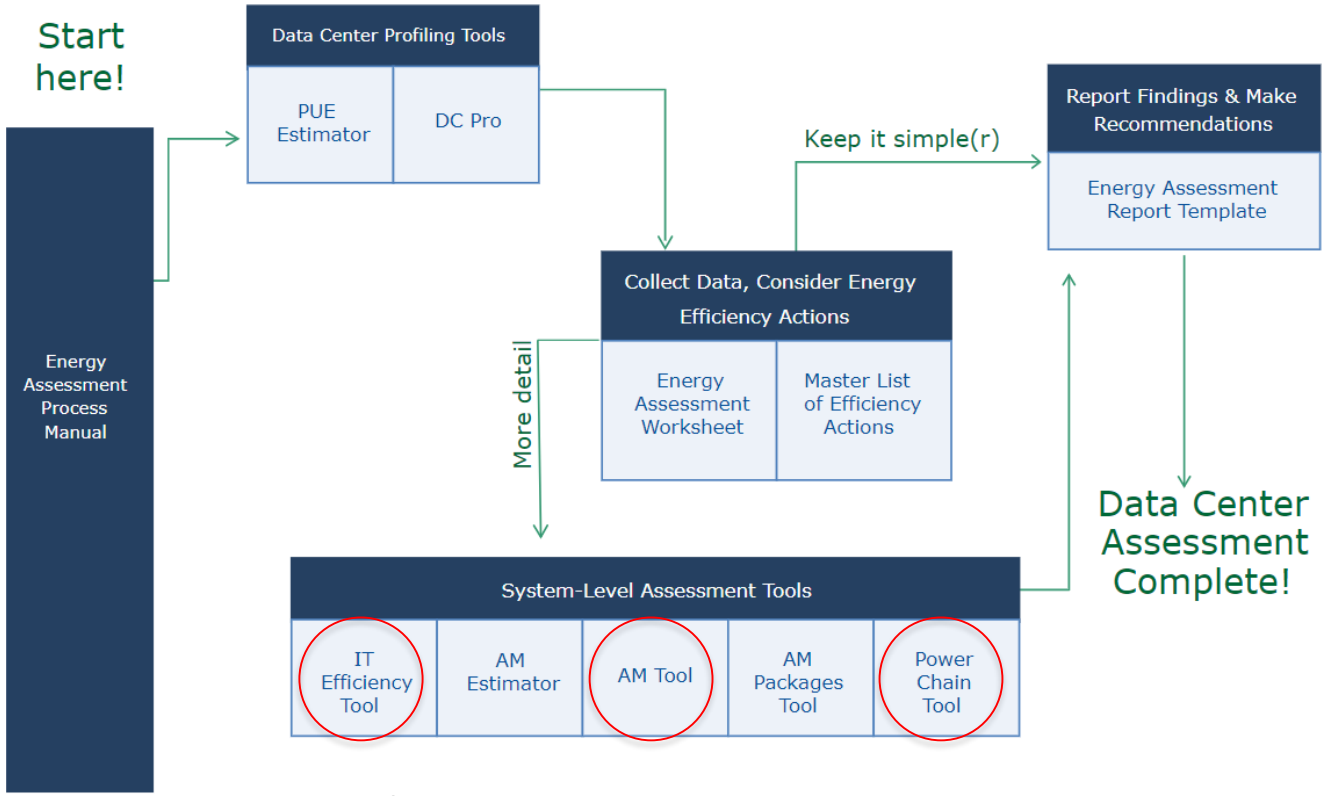
Estimating Carbon Reductions in Data Centers

Energy consumption and carbon (CO_2) are linked – higher energy consumption will lead to higher release of carbon assuming the utility emission rate stays the same.

How can we estimate energy and carbon savings with specific implemented energy-saving measures?

- The DOE Energy Assessment System Tools already estimate the energy savings
- A new feature extends the Tools' capabilities to include carbon savings
- We have also included simple payback and high-level interoperability between the tools.

CoE* Data Center Energy Efficiency Toolkit



AM = Air Management

*CoE = Center of Expertise for Energy Efficiency in Data Centers at Berkeley Lab

http://datacenters.lbl.gov

DOE Energy Assessment System Tools

There are three DOE Data Center Energy Assessment System Tools:

- The IT Equipment Tool
- The Air Management (AM) Tool
- The Electrical Power Chain Tool

Now, let's take a closer look at each of the these Excel-based tools before discussing the new features.

http://datacenters.lbl.gov/Tools

First, the IT Equipment Tool

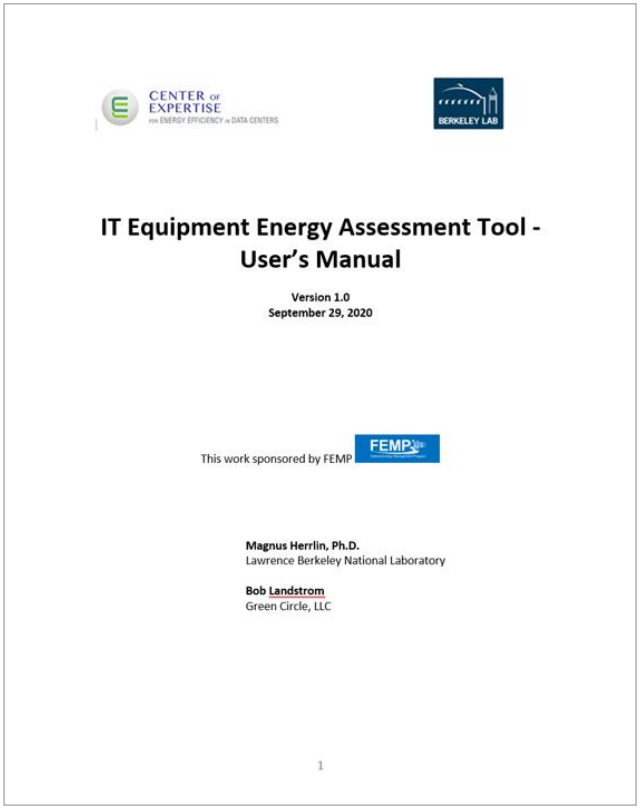
The DOE IT Equipment Tool was developed to help understand energy savings associated with improved IT equipment design and operation. It contains numerous energy-saving measures, allowing for various what-if scenarios. It provides:

- Hands-on recommendations (actions)
- Power Utilization (%)
- IT and Infrastructure Power Savings (W)
- Energy (kWh/year) and Energy Cost ($/year) savings
- State average Emission Rates (lb/kWh) NEW
- Carbon Dioxide (CO_2) reductions NEW
- Simple Payback for energy-saving measures NEW
- Export of power data to other System Tools NEW

Tool Documentation

Tool structure as well as user input forms and output data are described in the User's Manual.

Appendices provide in-depth information on a number of useful topics.



CENTER OF EXPERTISE for ENERGY EFFICIENCY in DATA CENTERS

BERKELEY LAB

IT Equipment Energy Assessment Tool - User's Manual

Version 1.0
September 29, 2020

This work sponsored by FEMP

Magnus Herrlin, Ph.D.
Lawrence Berkeley National Laboratory

Bob Landstrom
Green Circle, LLC

1

This document is the official resource in using the DOE IT Equipment Tool

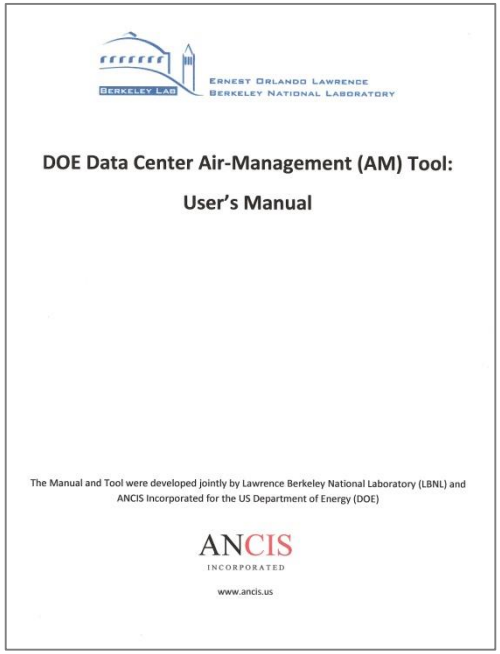
http://datacenters.lbl.gov/Tools

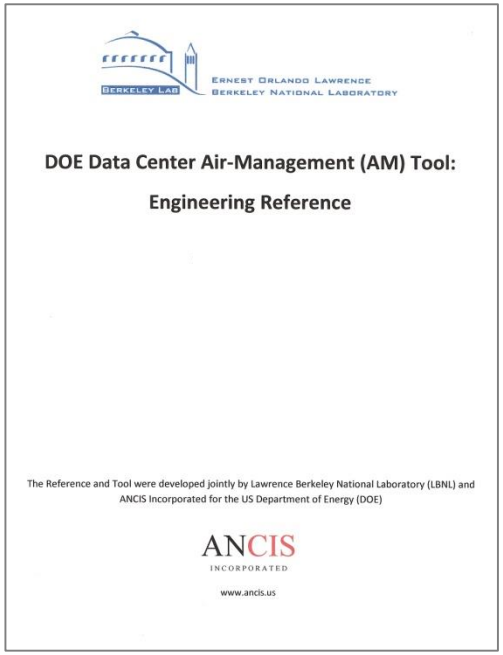
Second, the Air Management Tool

The DOE Air Management Tool was developed to help accelerate the energy savings related to improved air management without negatively affecting the thermal IT equipment environment. It includes many energy-saving measures, allowing for what-if analyses. The Tool provides:

- Hands-on recommendations (actions)
- RCI and RTI air management metrics
- Energy savings (kWh/year) for fans and chillers
- Energy cost savings ($/year) for fans and chillers
- State average Emission Rates (lb/kWh) NEW
- Carbon Dioxide (CO_2) reductions NEW
- Simple Payback for energy-saving measures NEW
- Import of power data from the IT Equipment Tool NEW

Tool Documentation





These documents are the official resources in using the DOE Air Management Tool

http://datacenters.lbl.gov/Tools

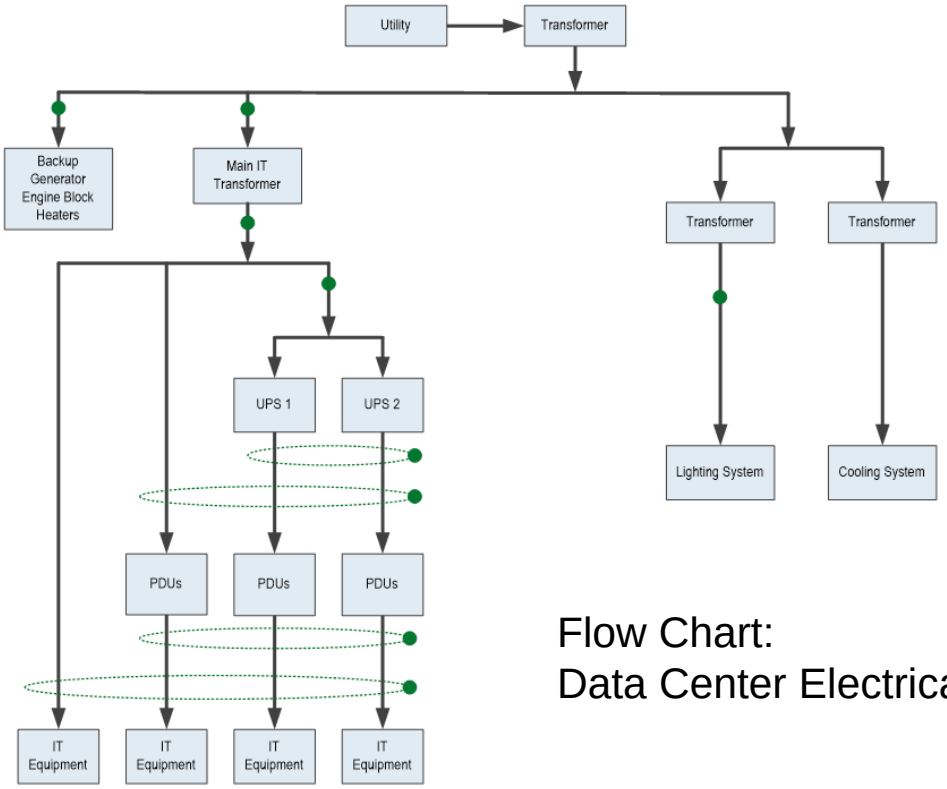
Third, the Electrical Power Chain Tool

The Electrical Power Chain Tool was developed to help reduce electrical losses. It takes into account transformers, generators, UPSs, PDUs, and lighting. It contains numerous energy-saving measures – allows various what-if scenarios. The Tool provides:

- Hands-on recommends (actions)
- Energy savings (kWh/year)
- Energy cost savings ($/year)
- Peer comparison to LBNL database
- State average Emission Rates (lb/kWh) NEW
- Carbon Dioxide (CO_2) reductions NEW
- Simple Payback for energy-saving measures
- Import of power data from the IT Equipment Tool NEW

Tool Documentation

The Electrical Power Chain Tool does not have a separate User's Manual. Brief guidance is provided in the tool itself (example below). A manual may be forthcoming.



Flow Chart:
Data Center Electrical Power Chain

Understanding the Carbon Emission Rate

The carbon emission rates vary with the way electricity is produced. Coal fired power plants have high emission rates whereas hydro, geothermal, wind, solar, and nuclear power plants have low emissions. Nuclear has other challenges, though.

The Carbon Emission Rate is measured in pounds of carbon dioxide (CO_2) released into the atmosphere per kWh electricity produced at the plant.

Knowing the plant's Carbon Emission Rate, the transmission and distribution losses, and the data center energy consumption allows the estimation of the data center's carbon dioxide emission (footprint).

The EPA eGRID* Data Explorer

The eGRID Data Explorer helps consumers (e.g., data centers) understand the environmental impact of their electricity usage. It shows the average annual carbon dioxide emission rate.

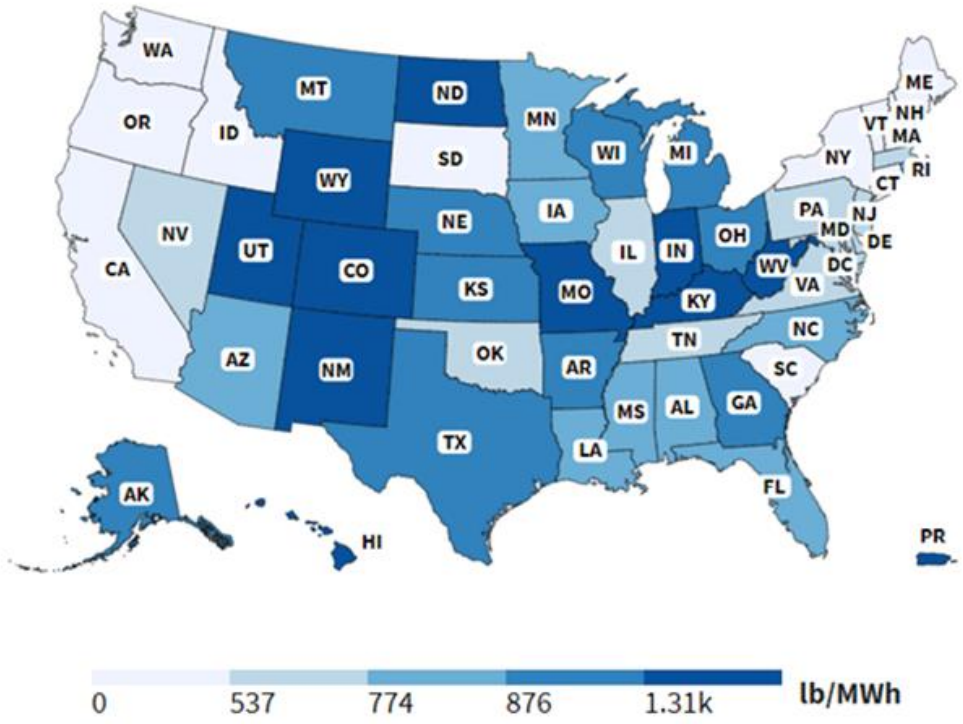
The eGRID Data Explorer can be used from the state level down to the plant level (if the user knows where their electric power is generated).

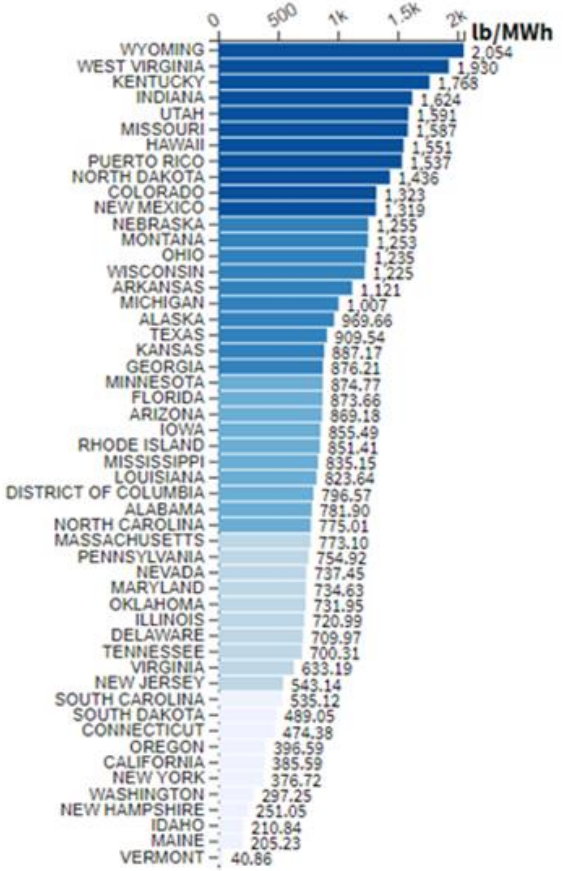
The average annual state data in eGRID is incorporated in the System Tools.

www.epa.gov/egrid/data-explorer

* eGRID = Emissions and Generation Resource Integrated Database

State Average Carbon Dioxide Emission Rates





CO_2 emission rate (lb/MWh – average annual) by state, 2019 (eGRID, 2021)

Another EPA Tool…

The Avoided Emissions and Generation Tool (AVERT) is only intended for analyzing the power sector emission impact of energy efficiency (EE) and renewable energy (RE) policies and programs. AVERT can be used as a screening tool to understand the emission impact of different policies and programs.

The tool not only calculates avoided CO_2 emissions but also $PM_{2.5}$, NO_x, and SO_2 emissions.

www.epa.gov/avert

New Carbon Saving Functionality in the DOE System Tools

Implementation of the New Features

Each System Tool has implemented the new features slightly differently but the principle is the same.

Again, the new features include the following:

- Carbon dioxide (CO_2) saving estimates
- Simple payback estimates for energy-saving measures
- Guidance on interoperability

We will now step through these new features and see how they have been implemented in the System Tools.

Carbon Savings

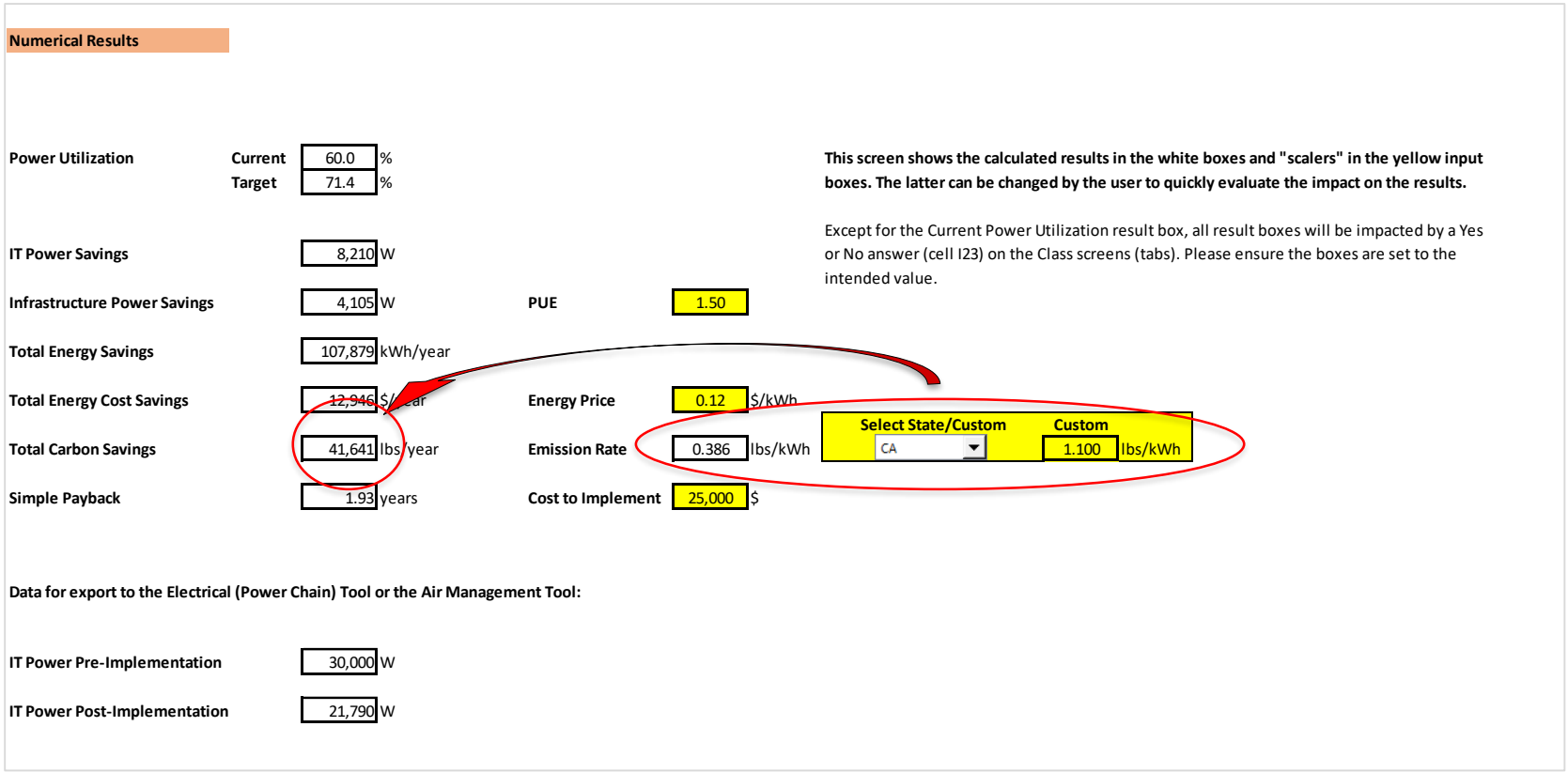
The carbon dioxide (CO_2) savings (lb/year) are simply calculated as Energy Savings (kWh/year) times the Emission Rate (lb/kWh).

Social Cost of Carbon (SCC)* is not included in the System Tools but may be added in future versions. The current focus on the System Tools is at the data center level.

*In 2021, the Biden administration set an interim value of around $50 a ton CO_2 (One Metric Ton is equal to 1.10231 US Ton)

Carbon Savings In the IT Equipment Tool

The carbon (CO_2) savings implementation in the IT Equipment Tool looks like this for a state-level selection.



Numerical Results

Power Utilization	**Current**	60.0	%			
	Target	71.4	%			
IT Power Savings		8,210	W			
Infrastructure Power Savings		4,105	W	**PUE**	1.50	
Total Energy Savings		107,879	kWh/year			
Total Energy Cost Savings		12,946	$/year	**Energy Price**	0.12	$/kWh
Total Carbon Savings		41,641	lbs/year	**Emission Rate**	0.386	lbs/kWh
Simple Payback		1.93	years	**Cost to Implement**	25,000	$

Select State/Custom CA **Custom** 1.100 lbs/kWh

This screen shows the calculated results in the white boxes and "scalers" in the yellow input boxes. The latter can be changed by the user to quickly evaluate the impact on the results.

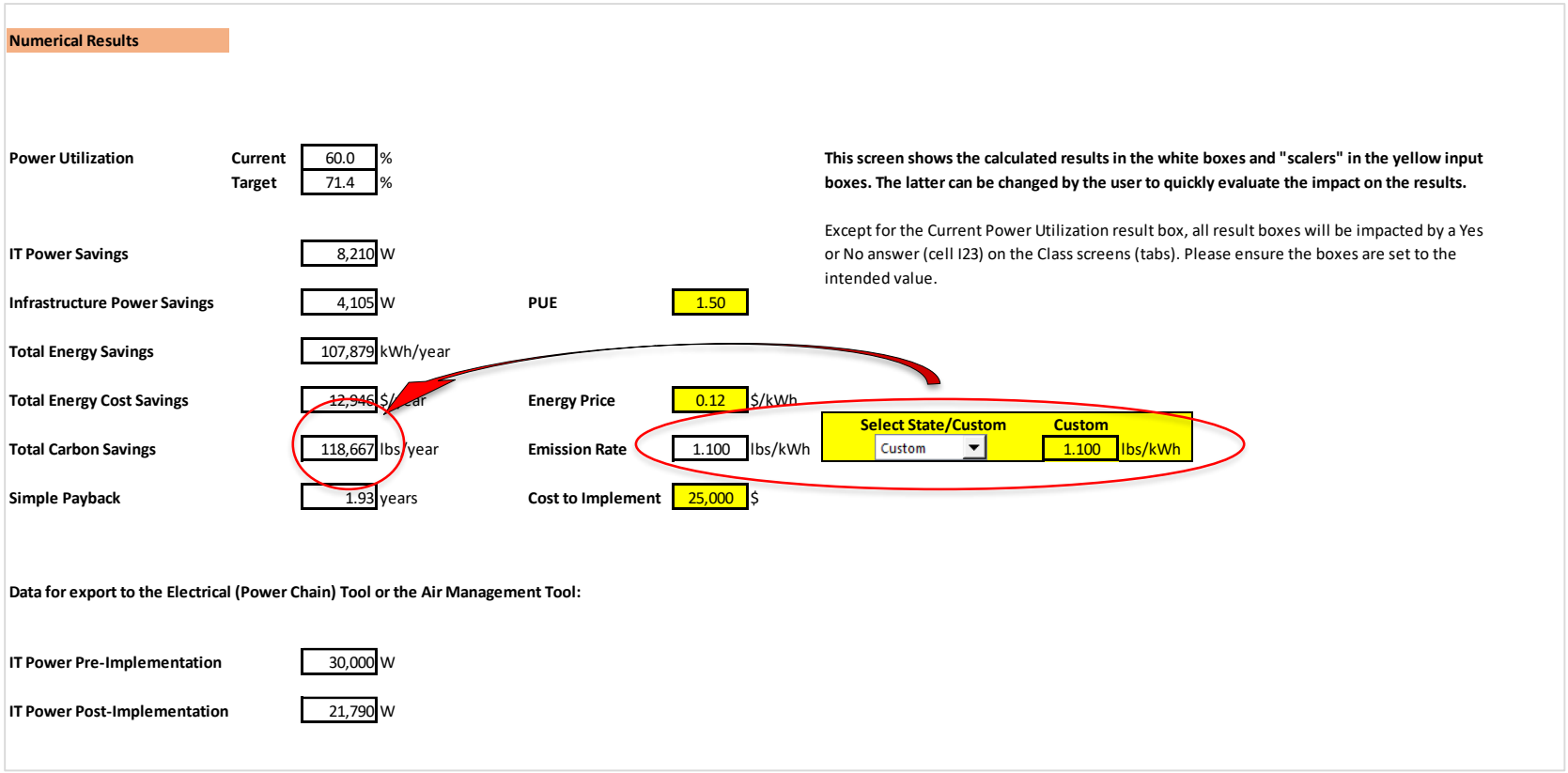
Except for the Current Power Utilization result box, all result boxes will be impacted by a Yes or No answer (cell I23) on the Class screens (tabs). Please ensure the boxes are set to the intended value.

Data for export to the Electrical (Power Chain) Tool or the Air Management Tool:

IT Power Pre-Implementation	30,000	W
IT Power Post-Implementation	21,790	W

Carbon Savings In the IT Equipment Tool

The carbon savings implementation in the IT Equipment Tool looks like this for a custom selection, e.g., plant level.



Numerical Results

Power Utilization	**Current**	60.0	%			
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IT Power Savings		8,210	W			
Infrastructure Power Savings		4,105	W	**PUE**	1.50	
Total Energy Savings		107,879	kWh/year			
Total Energy Cost Savings		12,946	$/year	**Energy Price**	0.12	$/kWh
Total Carbon Savings		118,667	lbs/year	**Emission Rate**	1.100	lbs/kWh
Simple Payback		1.93	years	**Cost to Implement**	25,000	$

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Select State/Custom	**Custom**	
Custom	1.100	lbs/kWh

Data for export to the Electrical (Power Chain) Tool or the Air Management Tool:

IT Power Pre-Implementation	30,000	W
IT Power Post-Implementation	21,790	W

Simple Payback

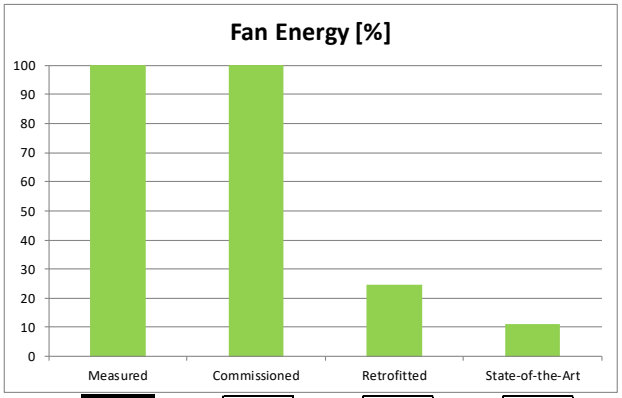
Simple Payback is a simple but powerful metric to understand how long time it would take to pay off an investment, in our case an energy-saving measure.

The Simple Payback (in years) is calculated as implementation cost (capital cost plus installation cost) divided by the yearly cost savings.

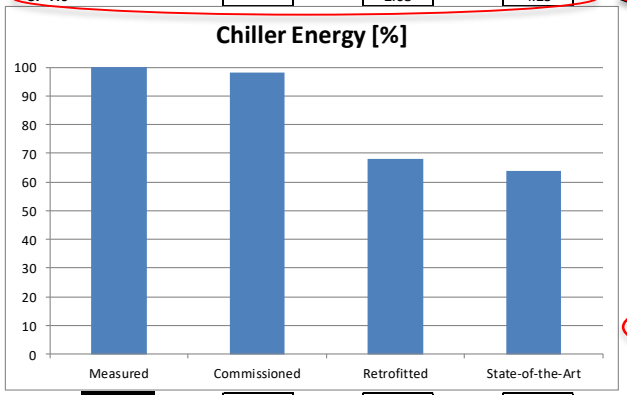
Other more comprehensive metrics such as Total Cost of Ownership (TCO) may be included in the tools in future versions.

Simple Payback In the Air Management Tool

Step 6: ENERGY Results (last sheet)



	Measured	Commissioned	Retrofitted	State-of-the-Art
kWh/yr	80,000	80,000	19,839	9,030
$/yr	16,000	16,000	3,968	1,806
CO2/yr	88,000	88,000	21,823	9,933
SP Yrs			2.08	4.23



	Measured	Commissioned	Retrofitted	State-of-the-Art
kWh/yr	350,000	343,000	238,000	224,000
$/yr	70,000	68,600	47,600	44,800
CO2/yr	385,000	377,300	261,800	246,400
SP Yrs		2.14	4.24	6.35

This sheet includes fan and chiller energy, energy costs, carbon emissions, and simple payback periods, which can be controlled by twelve yellow input boxes. (All other results can be found on the Main Results sheet, Step 5).

Note 1: "Measured" bar is the reference (100%) and values above 100% for other bars will not be displayed.
Note 2: The "Commissioned" and "Retrofitted" bars valid for raised-floor cooling only.

Electric Cost: 0.2 [$/kWh]

Fan Exponent: 3 [-] (Range: 2 - 3)

For fully turbulent flow there is a cubical (3) relationship between fan energy and airflow; for fully laminar flow there is a quadratic (2) relationship. For data centers, an exponent of 2.8 is common.

kWh/yr (yellow cell far left) = Enter measured annual fan energy.

Emission Rate: 1.1 [lbs/kWh] (Range: 0.1-5.0)

Select State/Custom	Custom	
Custom	1.1	[lbs/kWh]

To the right, select a State or "Custom" from the drop down menu.
If "Custom" is slected, enter CO2 emission rate in yellow box.

Chiller Factor: 2 [%/F] or [%/C] (Range: 1-3 %/F or 2-5 %/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.

Com	Retro	State	
2,000	25,000	60,000	$ - Fan
3,000	95,000	160,000	$ - Chiller

Com: Commissioned
Retro: Retrofitted
State: State-of-the-Art

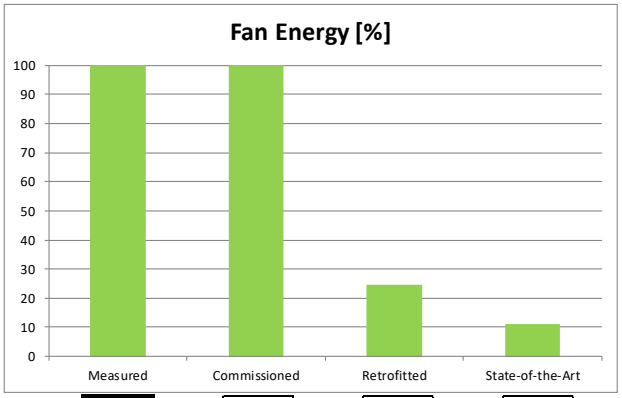
Implementation Cost

Implementation Costs attributable to fan and chiller savings, respectively.
Simple Payback (SP) will be calculated based on this input.

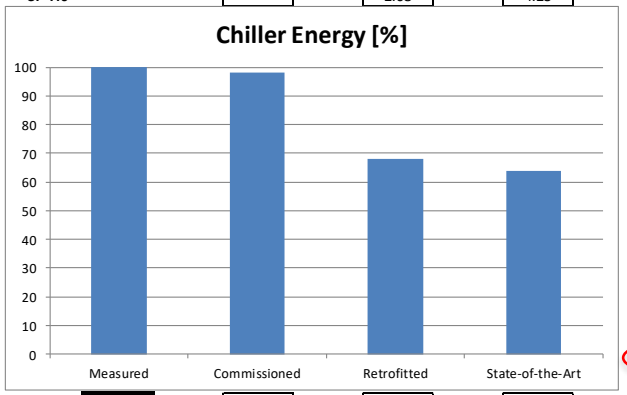
kWh/yr (yellow cell far left) = Enter measured annual chiller energy.

Simple Payback In the Air Management Tool

Step 6: ENERGY Results (last sheet)



	Measured	Commissioned	Retrofitted	State-of-the-Art
kWh/yr	80,000	80,000	19,839	9,030
$/yr	16,000	16,000	3,968	1,806
CO2/yr	88,000	88,000	21,823	9,933
SP Yrs			2.08	4.23



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kWh/yr (yellow cell far left) = Enter measured annual fan energy.

Emission Rate: 1.1 [lbs/kWh] (Range: 0.1-5.0)

To the right, select a State or "Custom" from the drop down menu.
If "Custom" is slected, enter CO2 emission rate in yellow box.

Select State/Custom	Custom
Custom	1.1 [lbs/kWh]

Chiller Factor: 2 [%/F] or [%/C] (Range: 1-3 %/F or 2-5 %/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.

Com	Retro	State	
2,000	25,000	60,000	$ - Fan
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Com: Commissioned
Retro: Retrofitted
State: State-of-the-Art

Implementation Cost

Implementation Costs attributable to fan and chiller savings, respectively.
Simple Payback (SP) will be calculated based on this input.

kWh/yr (yellow cell far left) = Enter measured annual chiller energy.

Guidance On Interoperability

First we need to understand the allowed data exchanges between the tools.

- Data can only be exported in one direction:
  IT Tool → Air Management Tool
  IT Tool → Electrical Power Chain Tool

- The IT tool can export data to the Air Management Tool as well as directly to the Electrical Power Chain Tool.

- But, the Air Management tool cannot export data to the Power Chain Tool because that tool does not include the infrastructure power chain (we may add this in the future).

Guidance In IT Equipment Tool

The export guidance in the IT Equipment Tool looks like this…

Numerical Results

Power Utilization	**Current**	60.0 %			
	Target	71.4 %			
IT Power Savings		8,210 W			
Infrastructure Power Savings		4,105 W	**PUE**	1.50	
Total Energy Savings		107,879 kWh/year			
Total Energy Cost Savings		12,946 $/year	**Energy Price**	0.12	$/kWh
Total Carbon Savings		118,667 lbs/year	**Emission Rate**	1.100	lbs/kWh
Simple Payback		1.93 years	**Cost to Implement**	25,000	$

This screen shows the calculated results in the white boxes and "scalers" in the yellow input boxes. The latter can be changed by the user to quickly evaluate the impact on the results.

Except for the Current Power Utilization result box, all result boxes will be impacted by a Yes or No answer (cell I23) on the Class screens (tabs). Please ensure the boxes are set to the intended value.

Select State/Custom	**Custom**	
Custom	1.100	lbs/kWh

Data for export to the Electrical (Power Chain) Tool or the Air Management Tool:

IT Power Pre-Implementation	30,000	W
IT Power Post-Implementation	21,790	W

⇨ Export

User's Guide Language

There are two ways of exporting IT power pre- and post-implementation data from the IT Equipment Tool:

A) 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 and operation. However, the IT Power data can be exported from the IT Equipment Tool to the Air Management Tool for that purpose.

B) From the IT Equipment Tool to the Electrical Tool

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

Accessing the System Tools/Manuals

The DOE Energy Assessment System Tools and their manuals can be accessed at the following link to the Center of Expertise's website:

http://datacenters.lbl.gov/Tools

Summary

- The objective of this webinar was to make the DOE Energy Assessment System Tools better known in general and the new decarbonization functionality in particular
- CO_2 emissions are at the center of global warming. It is clear that human activity has caused higher CO_2 levels, and higher levels trap more heat in the atmosphere
- The DOE System Tools already included estimates of energy savings due to various energy efficiency measures. A new feature extends the capabilities to include carbon savings
- Simple payback and interoperability were also added to the updated System Tools. Simple payback is a simple yet powerful metric to understand how long it takes to pay off an investment.

References

DOE Tool Suite
http://datacenters.lbl.gov/tools

eGRID, 2021. Emissions & Generation Resource Integrated Database (eGRID)
www.epa.gov/egrid/data-explorer

Resources and Q&A

FEMP's Data Center Program

FEMP's Data Center program assists federal agencies and other organizations with optimizing the design and operation of data centers. design and operation of energy and water systems in data centers to enhance agency's mission.

Assistance

- Project and technical assistance from the Center of Expertise including identifying and evaluating ECMs, M&V plan review, and project design review.
- Support agencies in meeting OMB's Data Center Optimization Initiative requirements

Tools

- Data Center Profiler (DC Pro) Tools (x2)
- Air Management Tools (x3)
- IT Equipment Tool
- Electrical Power Chain Tool
- Energy Assessment Worksheets
- The Energy Assessment Process Manual

Key Resources

- Better Buildings Data Center Challenge and Accelerator
- Small Data Centers, Big Energy Savings: An Introduction for Owners and Operators
- Data Center Master List of Energy Efficiency Actions

Training

- Better Buildings webinar series
- Nine on-demand FEMP data center trainings
- Center of Expertise Webinars
- Data Center Energy Practitioner (DCEP) Trainings

LBNL's Center of Expertise (CoE)

Use CoE's Energy Efficiency Toolkit

Filter CoE's many resources by type and topic.

Choose from upcoming live webinars, pre-recorded trainings, and in-person Data Center Energy Practitioner (DCEP) trainings.

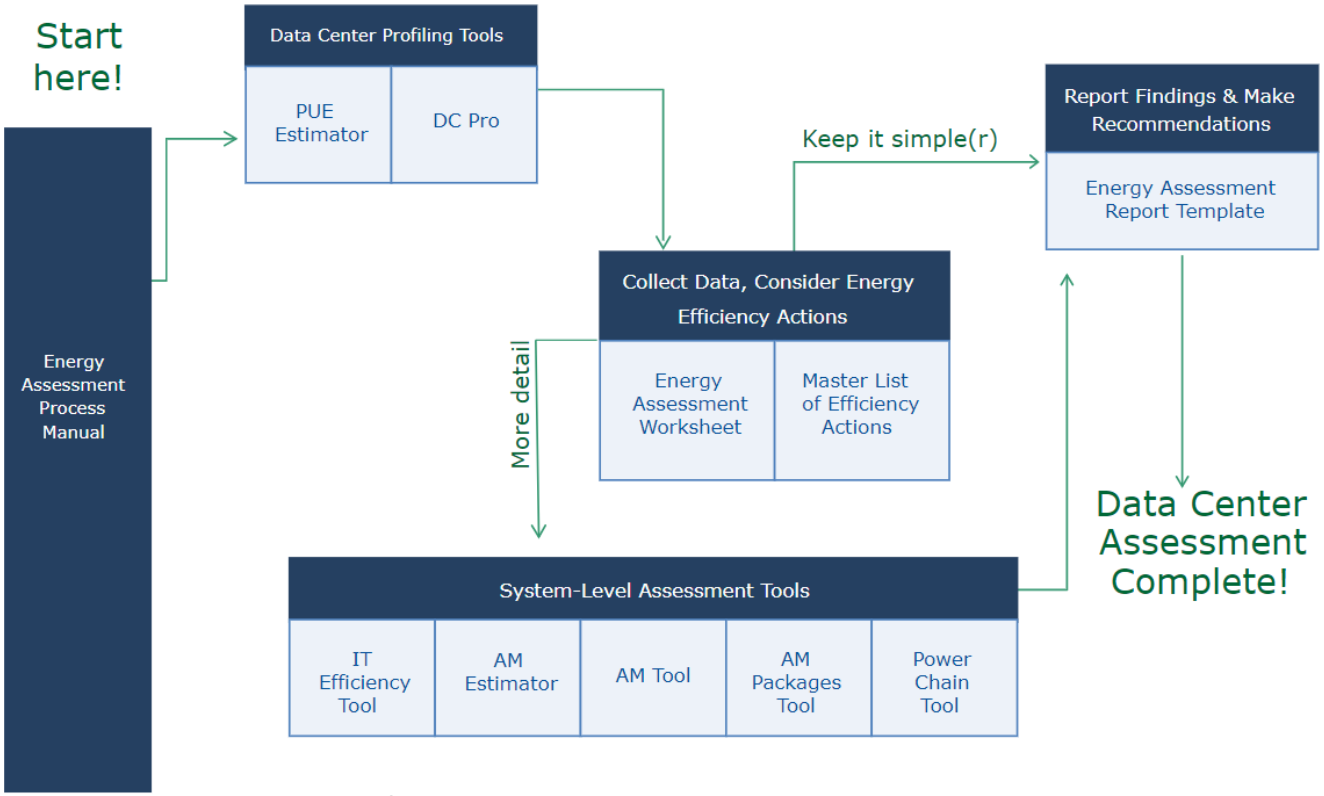
Search resources by topics of interest.

Explore the diverse activities that CoE is engaged in.

Follow us on Twitter @DataCenterCoE

Visit us at datacenters.lbl.gov

CoE* Data Center Energy Efficiency Toolkit



AM = Air Management

*CoE = Center of Expertise for Energy Efficiency in Data Centers at Berkeley Lab
http://datacenters.lbl.gov

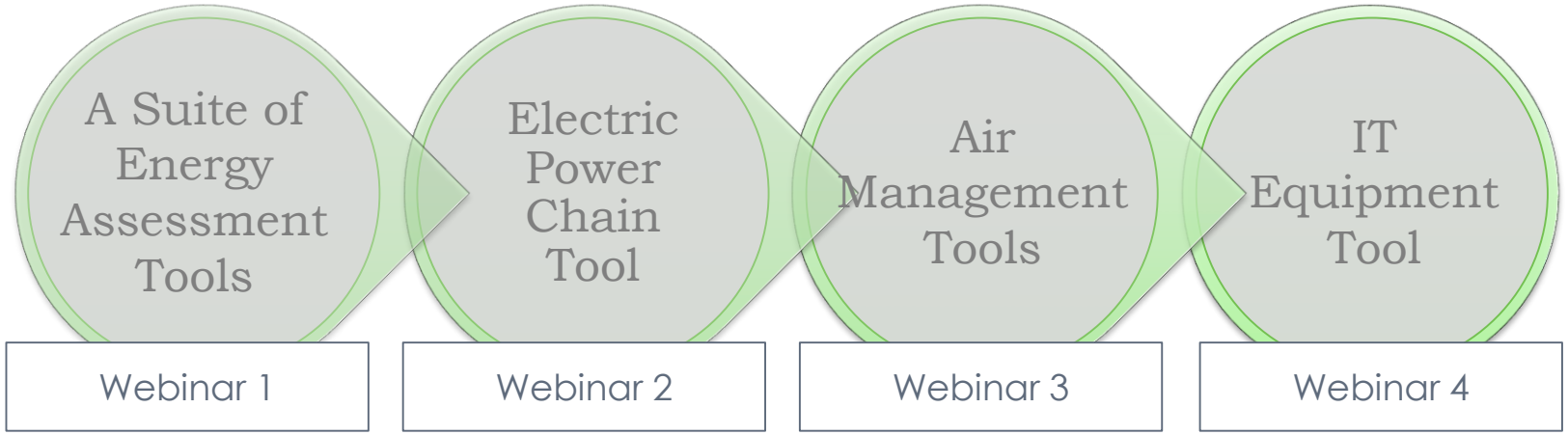
DOE Tool Suite

- Data Center Profiler ("DC Pro"), online
- PUE Estimator, online
- Air Management Tool, Excel
- Air Management Estimator, Excel
- Electrical Power Chain Tool, Excel
- IT Equipment Tool, Excel.

http://datacenters.lbl.gov/tools

Previous Four-Part Webinar Series

This training series introduced a broad toolkit for identifying energy-saving opportunities in data centers.

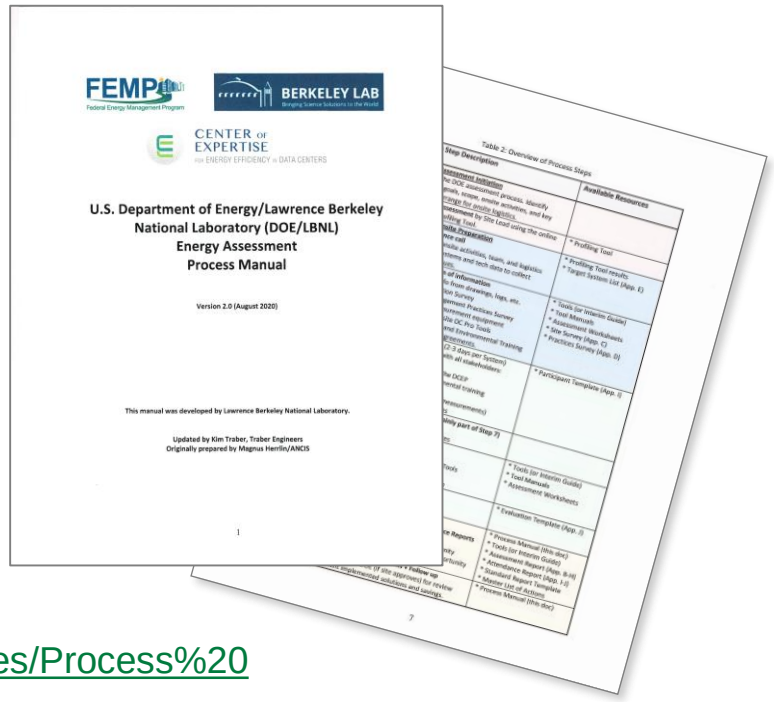


https://www.wbdg.org/continuing-education/femp-courses/fempodw049

Slides from Webinars 2, 3, and 4 at
http://datacenters.lbl.gov/resources/energy-efficiency-toolkit-series
http://datacenters.lbl.gov/resources/energy-efficiency-toolkit-series-air
http://datacenters.lbl.gov/resources/energy-efficiency-toolkit-series-it

Energy Assessment Process Manual

- The Process Manual provides administrative step-by-step instructions for conducting an energy assessment before, during, and after the onsite assessment.
- Multiple appendices include useful templates for the assessments.



https://datacenters.lbl.gov/sites/default/files/Process%20Manual%20DOE%20v2_080320_0.pdf

Master List of DC Energy Efficiency Measures

- Living encyclopedia of all data center EEMs
  - Recognized as an essential desk reference for data center energy efficiency – top download for CoE
  - >250 energy-saving changes in components, operations or other actions
- Several tools recommend common EEMs:
  - DC Pro, Air Management Tool, Electric Power Chain Tool
- The Master List contains all common EEMs, plus many others that do not appear elsewhere in the toolkit.
- For each EEM, the list explains the principles involved and how energy cost savings are generated, plus tips on implementation and more in-depth references.

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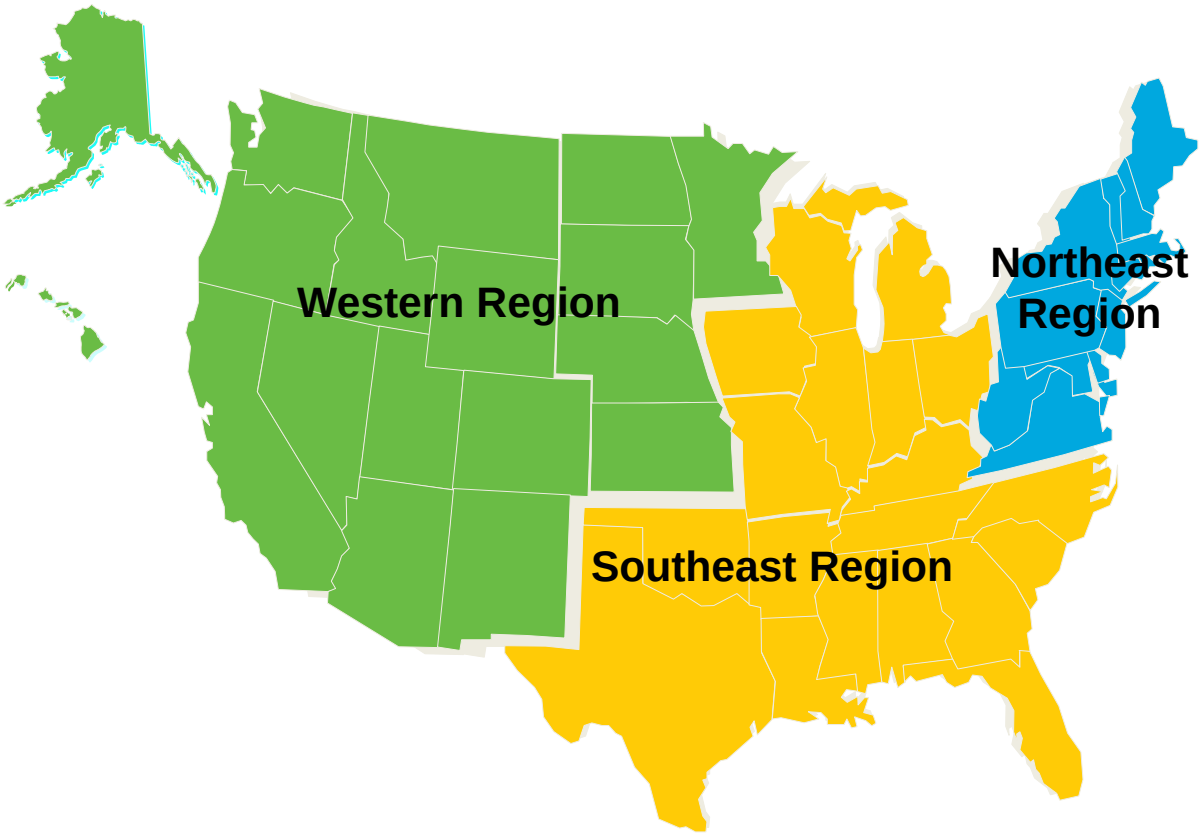

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FOR ENERGY EFFICIENCY IN DATA CENTERS

Questions?