U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

An Electric Power Chain Tool for Data Centers:

Assessing Energy Use and Options for Better Performance

September 10, 2020

FEMP
Federal Energy Management Program

Today's Speakers

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BERKELEY LAB

CENTER OF EXPERTISE
FOR ENERGY EFFICIENCY IN DATA CENTERS

Webinar Agenda

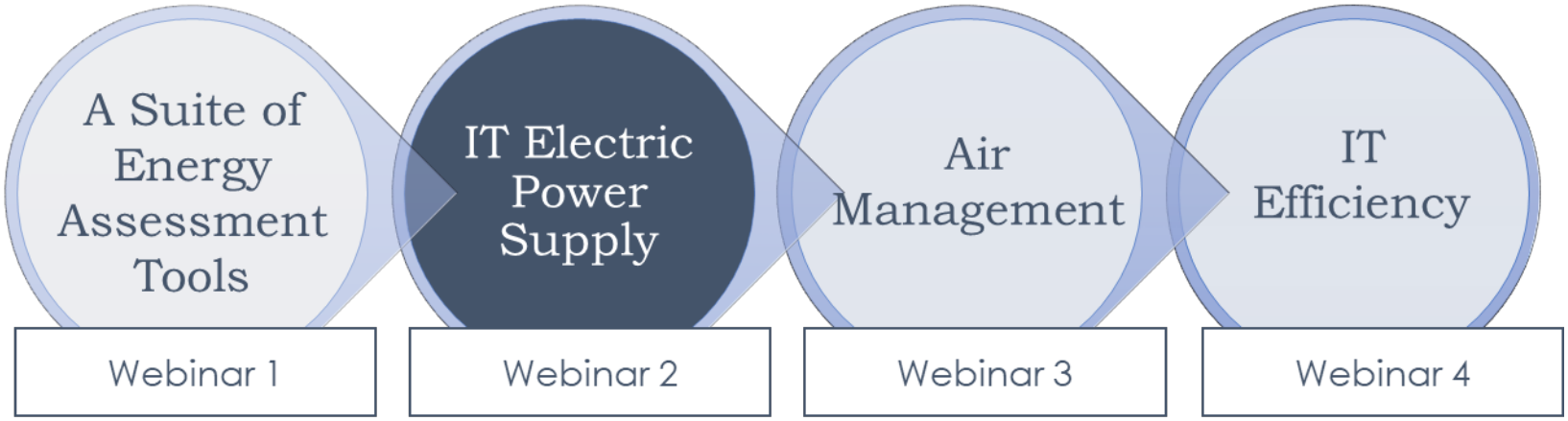
Agenda	
I.	Introduction
II.	IT Power Chain Tool is Critical to Energy Assessment
III.	Demo of Functions, Outputs, Limitations
IV.	Resources and Q&A

Learning Objectives

- Educate data center stakeholders in the DOE energy assessment process and about the IT power chain and this tool;
- Acquaint stakeholders with some energy conservation measure examples in the power chain and key tool inputs and outputs (e.g., energy and cost savings and payback periods);
- Illustrate synergies and trade offs between energy efficiency and redundancy--analyses that are helpful in deciding when and how to consolidate or move workloads to the cloud;
- Educate data center stakeholders about ways that the tool can contribute to a comprehensive energy assessment and creation of concrete plans of action and help engender institutional support for retrofits and energy-efficient procurements.

Second in a Four-Webinar Series

The next two webinars will take deeper dives into air management and IT efficiency tools and use cases.



Webinar 3: Air Management
Wednesday, October 7 from 2:30 – 4:00 pm EDT
Register Here

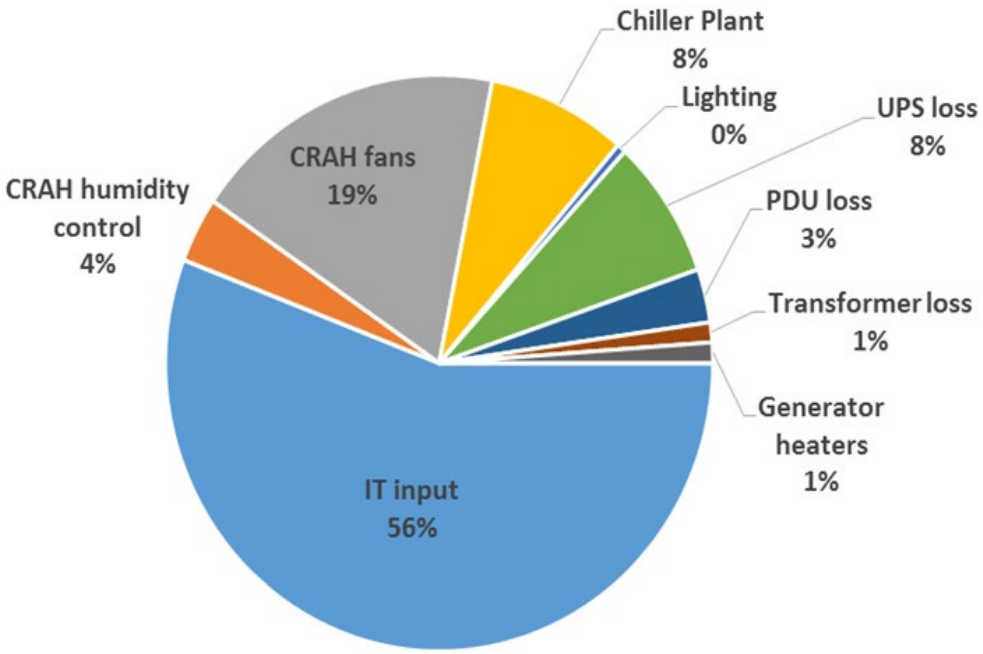
Webinar 4: IT Efficiency
Wednesday, November 18, 2020

The IT Power Chain and Why a Tool Is Needed

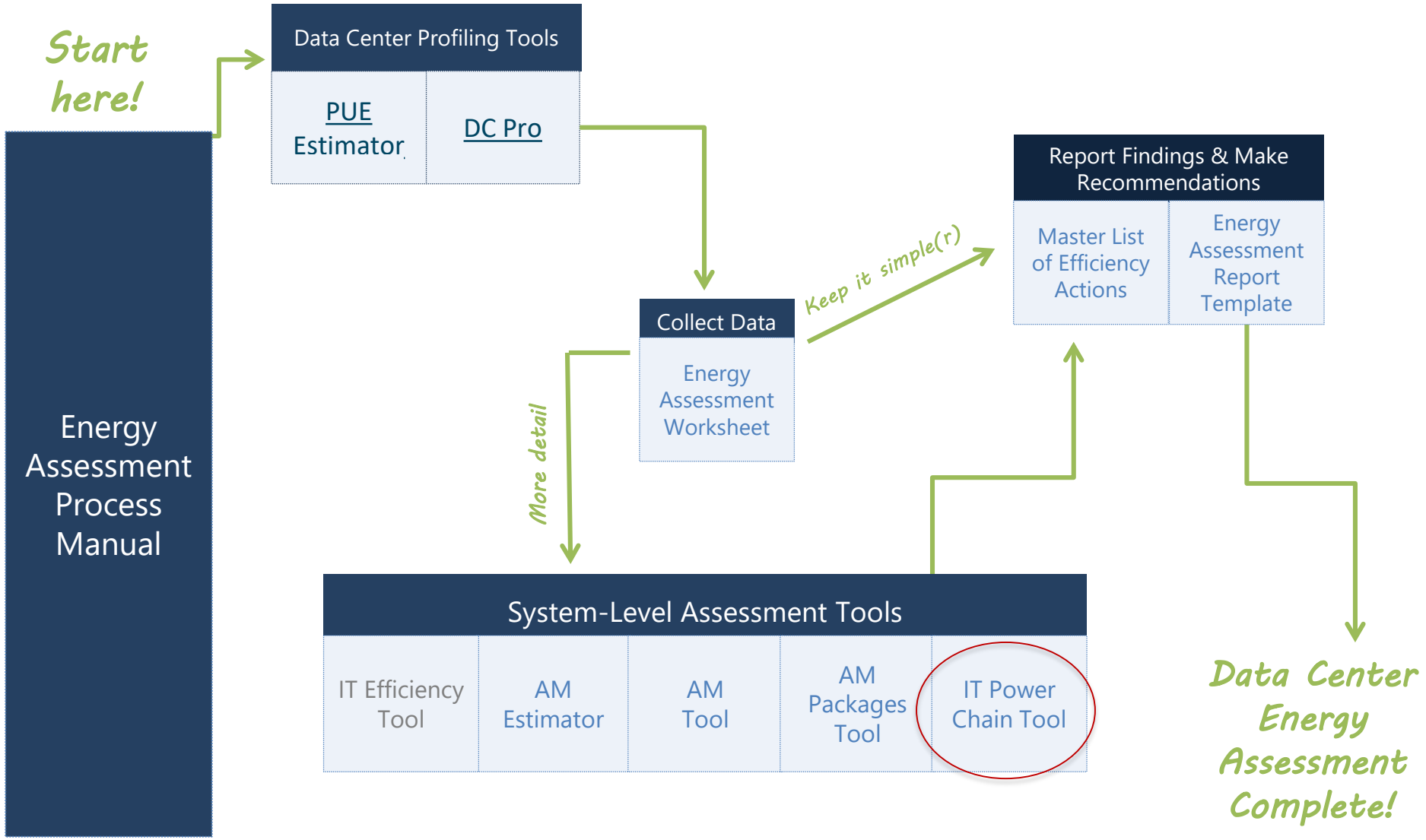
Why the Power Chain and Lighting?

- The IT power chain and lighting are typically the third largest power demand (after IT equipment and cooling infrastructure)

- Potential energy-saving actions number in the dozens
  - Absolute kWh and $ saved can be substantial.
  - Paybacks for many measures can be a few years or less.



CoE Data Center Energy Efficiency Toolkit



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6. Data Center Electrical Power Chain Tool

Updated September 2020

This Excel-based tool helps data center owners identify energy efficiency opportunities in the electrical power chain of a data center (transformers, generators, UPSs, power distribution units). The tool quantifies the energy and cost savings of the selected measures and calculates the payback periods for each measure. This new version, released in March 2020, offers a cleaner interface, a wider array of UPS load factors and control options (includes "ecomode"), and updated efficiency curves.

Note that this tool offers more energy efficiency options than Data Center Profiler (DC Pro) but is not a detailed 'investment-grade' audit tool. The savings estimates are driven by user inputs but based on typical practice and do not account for interactive effects. Actual savings will vary based on site-specific conditions and operations.

We welcome user feedback on how to improve our suite of tools. Email us at CoE@lbl.gov

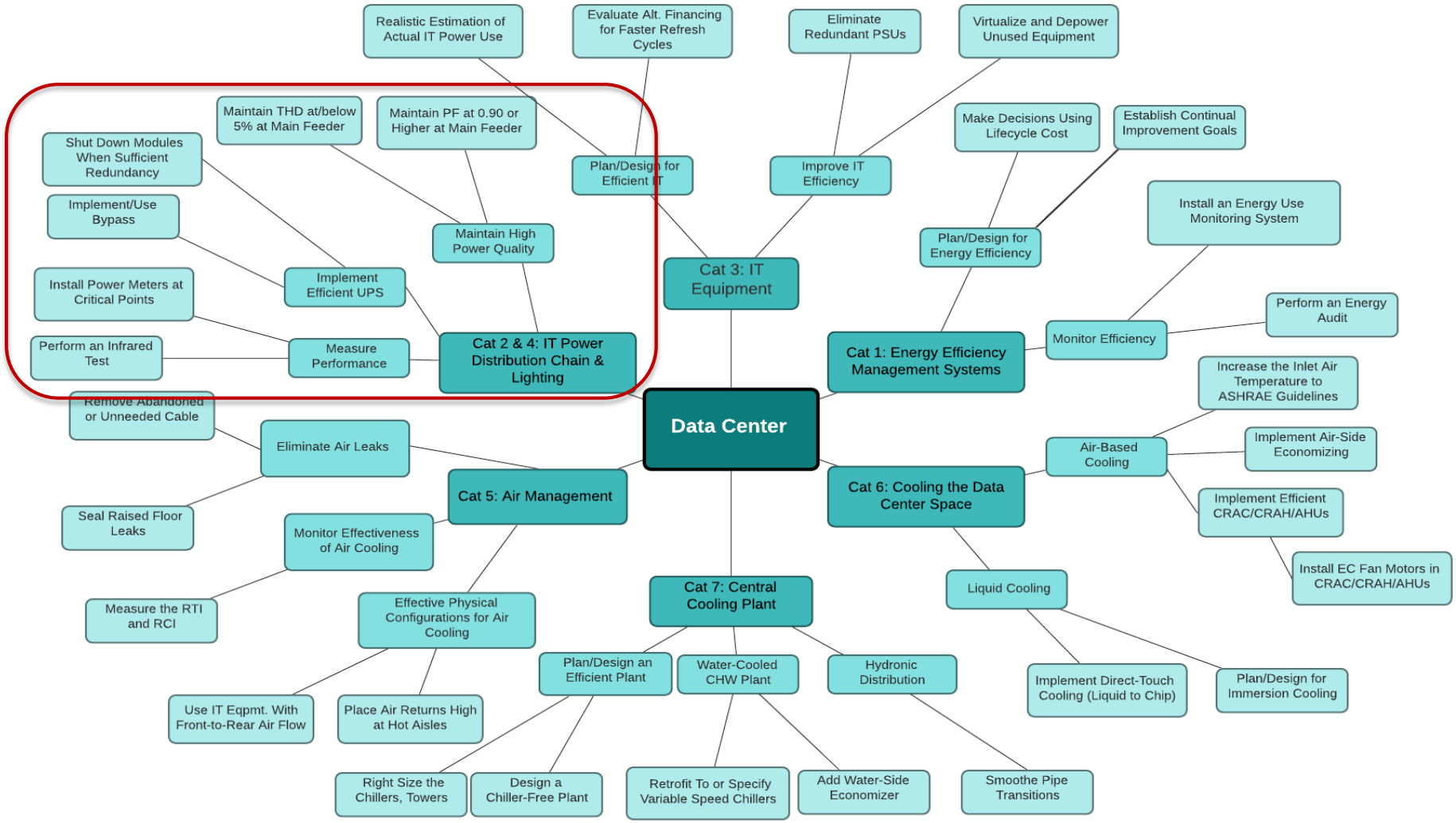
Files:

Power Chain Tool_v2.21.xlsx

CoE Data Center Electrical Power Chain Tool

- **Addresses the IT Power Chain and Data Center Lighting**
  - Transformers, generators, UPSs, and power distribution units
- **Asks 32 questions to diagnose likely energy losses and recommend solutions**
- **Compares among peers in the LBNL Data Center Database**
- **Calculates energy and cost savings and payback periods**
- ***Not* an investment-grade tool. The tool provides potential energy and cost savings as estimates only.**
- **Transparent – all data, assumptions and calculations unlocked**
- **Contains 25 different energy-saving measures – allows exploration**
  - The Master List of Data Center Energy Efficiency Measures contains all of these and more

Master List: Many More Power Chain and Lighting Measures*



*Measure map is illustrative only. Full taxonomy covers **more than 250 ECMs.***

Upgrades and Updates

- Cleaner, more streamlined user inputs
- Version 1 (2009) estimated savings for each efficiency action as a percent of total IT power chain energy loss. Version 2.22 now estimates savings independently for each element of the electric system.
- UPS efficiency curves updated to typical double-conversion units of recent vintage (2016, 2017).
- Broad updates for clarity, including diagrams, descriptions, and instructions.

Functional Structure of the Power Chain Tool

Tool Documentation and Color Coding

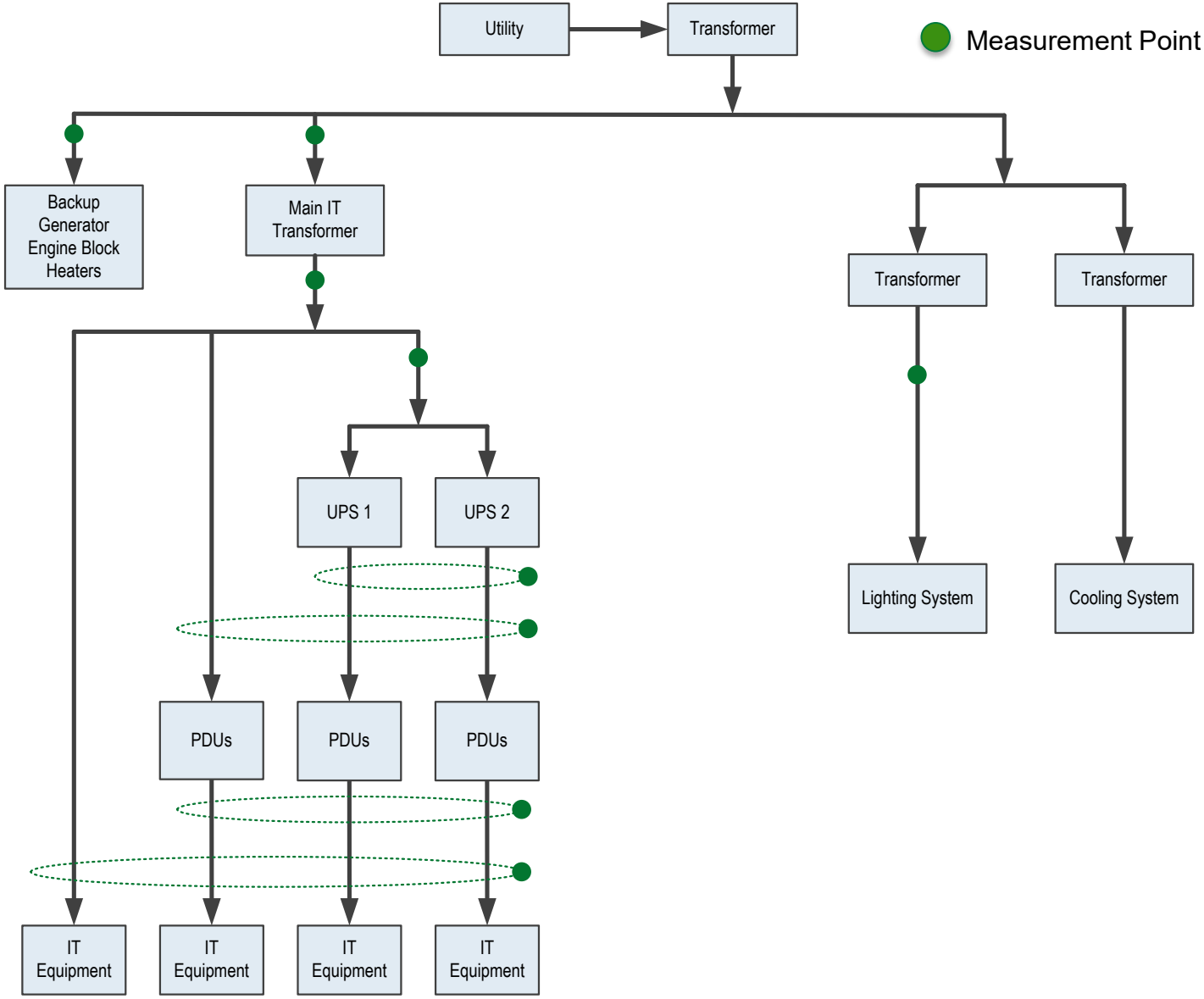
Seven visible tabs:

Worksheet	Description
Overview	This tab.
User Inputs A	Numeric questions about your data center's IT electric power chain and lighting systems.
User Inputs B	Multiple-choice questions about your data center's IT electric power chain and lighting systems. Suggested energy-saving actions.
Action Results	Estimated savings and simple payback for pursued actions.
Savings Summary	Estimated total savings for pursued actions.
Peer Comparison	Benchmarks for UPS load factor and IT power density.
UPS Efficiency	Lookup table for the operating efficiency of double-conversion UPSs of recent manufacture.

And six hidden tabs:

Table AA	Support for User Inputs Table A.
Table BB	Support for User Inputs Table B.
Table DD	Support for the Estimated Savings table.
DC_BM_data	Benchmark data from 25 measured, anonymous data centers.
UPS_data	Data that defines a modern, double-conversion, relatively efficient, 500 kW UPS.
Developer	Developer's notes.

Data Center Power Chain



Flexing the Tool: A Medium-Sized Data Center

Tool Demo Scenario: A Medium-Sized Data Center

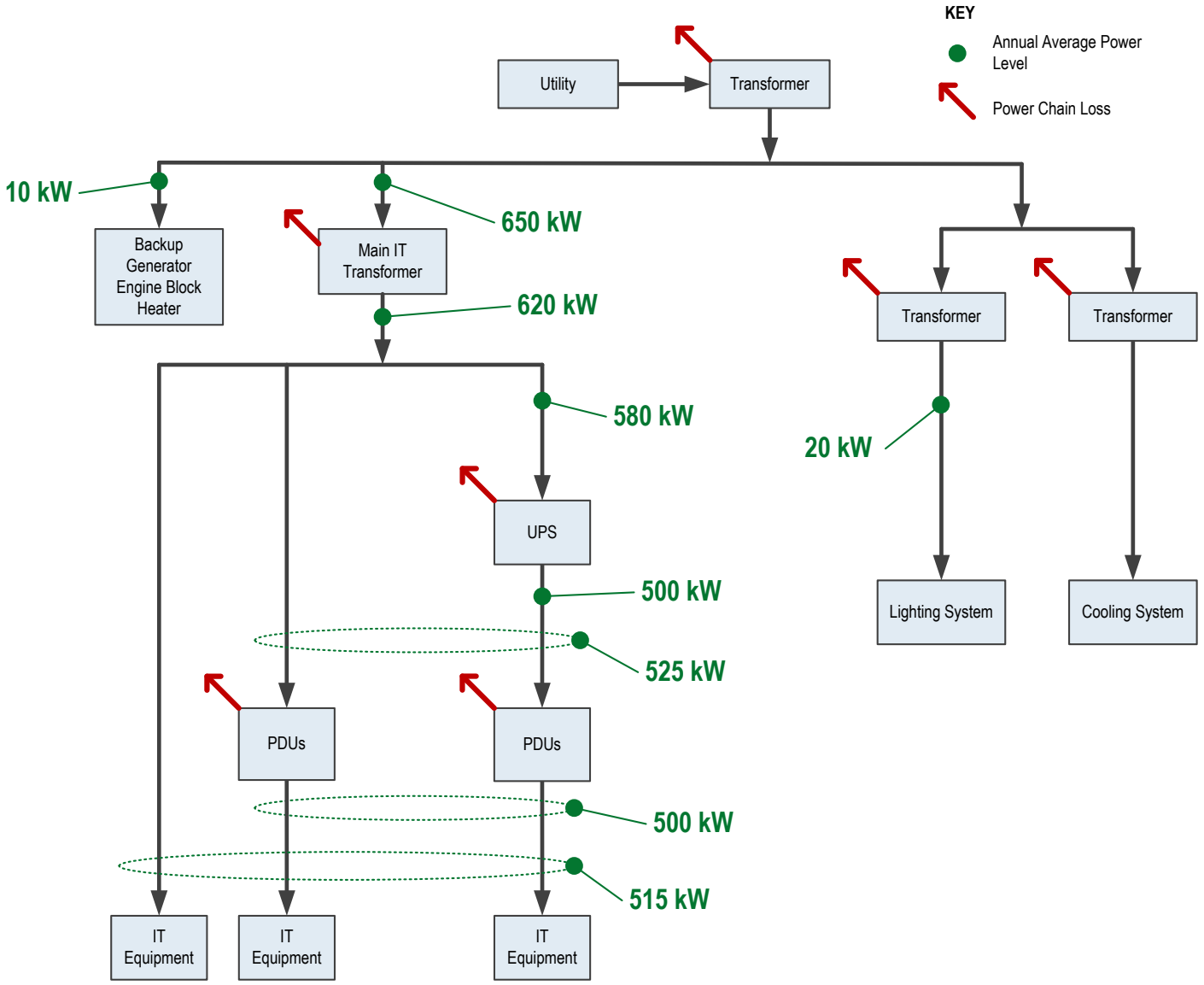
A simple, medium-sized data center tends to have a full complement of power chain components and often features a number of energy-saving opportunities.

Let's work through an example with the following equipment:

- One 850 kVA main transformer at the head of the IT power chain
- One 750 kVA UPS module feeding most of the PDUs
- PDUs containing transformers feeding most of the IT equipment
- A diesel backup generator with an electrically-heated engine block
- Data center lights are on 24/7.

Tool Demo Scenario, Continued

Assumed annual average power demands at these points in the system:



User Inputs Tab A: System Characteristics

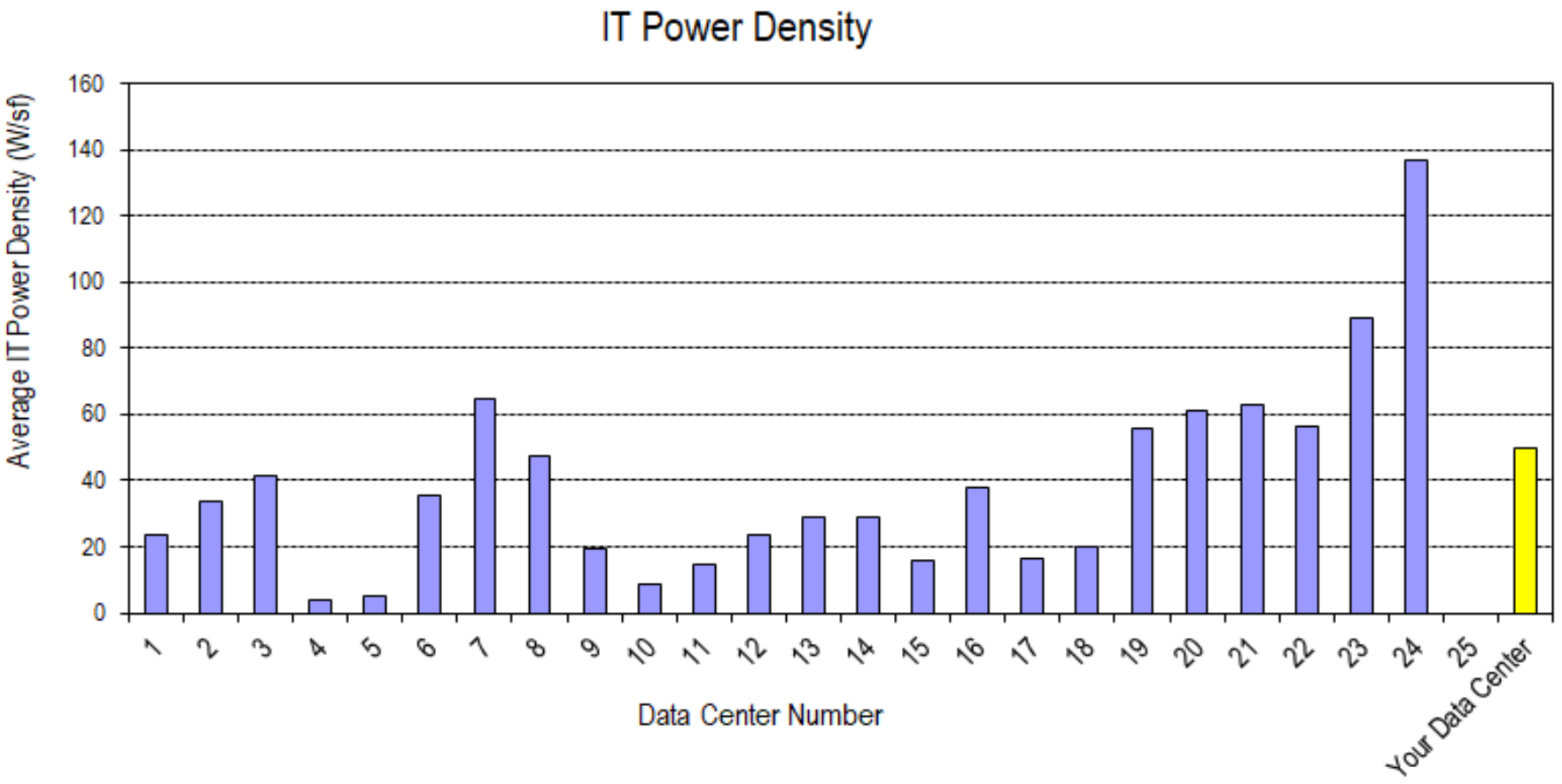
Table A: Basic Information

A1	A2	A3
Question Number	Question	Input
Q1	What is the annual average input power of the main IT transformer in kW?	**650.0**
Q2	What is the annual average output power of the main IT transformer in kW?	**620.0**
Q3	What is the nominal load capacity of the main IT transformer in kW?	850
Q4	What is the annual average input power of the UPS system in kW?	**580.0**
Q5	What is the annual average output power of the UPS system in kW?	**500.0**
Q6	What is the total load capacity of all active UPS modules in kW?	750
Q7	What is the UPS manufacturer's claimed efficiency at the calculated load factor shown at right?	0.0%
Q8	What is the annual average total PDU input power in kW?	**525.0**
Q9	What is the annual average total PDU output power in kW?	**500.0**
Q10	What is the total load capacity of all active PDUs in kW?	600
Q11	What is the annual average backup generator engine block heater power demand in kW?	**10.0**
Q12	What is the data center floor area in sq. ft.?	10,000
Q13	What is the annual average IT equipment power demand in kW?	**515.0**
Q14	What is the annual average lighting power demand in kW for the data center?	**20.0**
Q15	What is the annual average unit cost of electricity in ¢/kWh?	15.0

If you answered Question 4 with a number greater than zero, your input in this cell will be ignored. Otherwise, the efficiency value you enter here will be used to calculate the UPS input load.

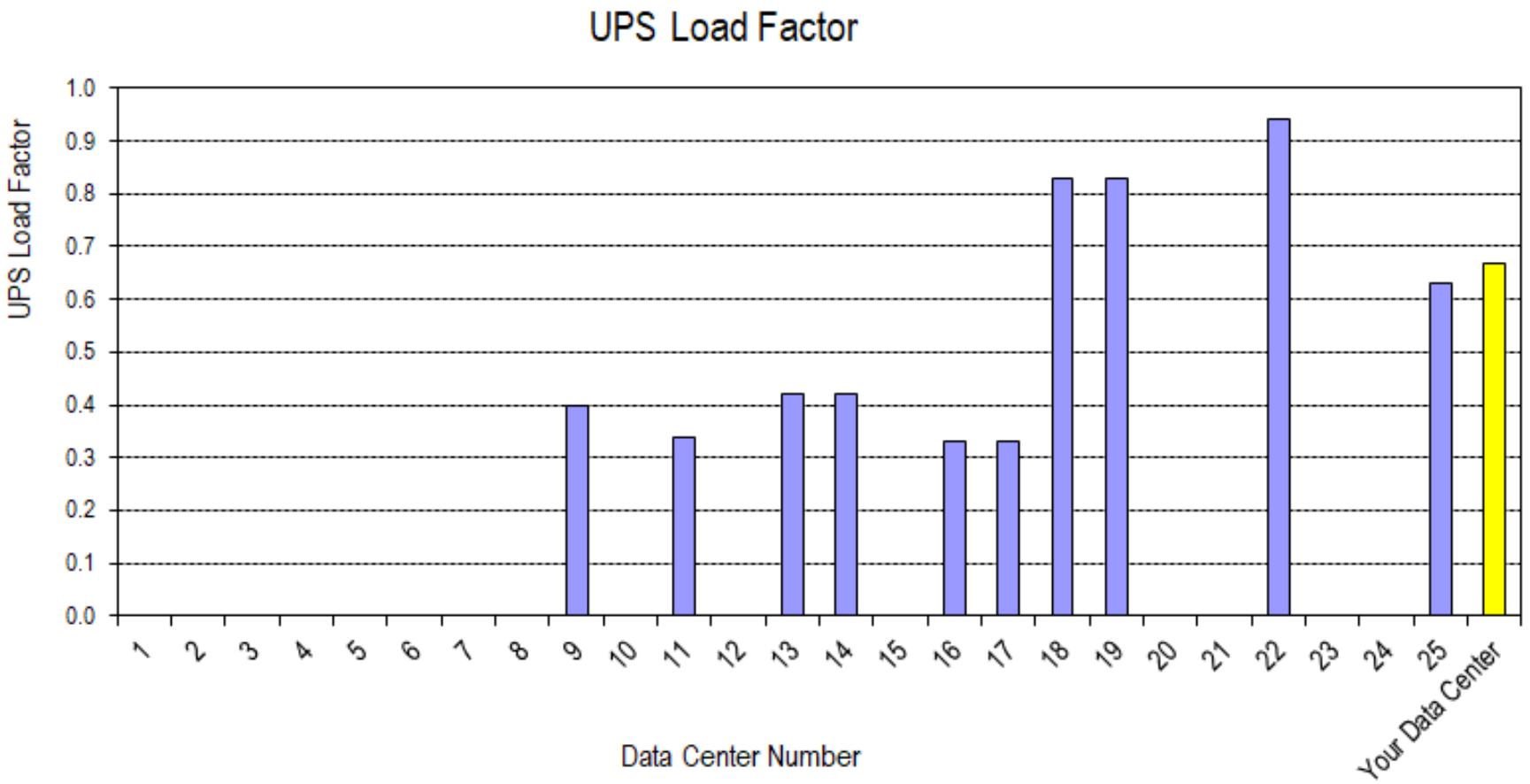
Peer Comparisons: Power Density

Compares your pre-implementation IT Power Density (UPS output divided by data center floor area) to other data centers.



Peer Comparisons: UPS Load Factor

Compares your pre-implementation UPS Load Factor (UPS output divided by UPS capacity) to other data centers.



User Inputs Tab A: Savings Calculations

Calc1	Calc2	Calc3	Calc4	Calc5	Calc6	Calc7	Calc8	Calc9	Calc10	Calc11	Calc12	Calc13	Calc14
				Power Demand		Losses			Annual Totals		Performance		
					Annual Average Power Demand	Annual Average Power Loss	Annual Energy Loss	Percent of Total Loss	Total Annual Energy Use	Annual Energy Cost	Nominal Capacity	Load Factor	Operating Efficiency
					kW	kW	kWh/yr	%	kWh/yr	$/yr	kW	%	%
IT Systems	IT Power Chain	Power Transformation Equipment	Main Transformer Serving IT Power Chain	Input	650.0								
						30.0	262,800	22%		$39,420	850	73%	95%
				Output	620.0								
			UPS System	Input	580.0								
						80.0	700,800	59%		$105,120	750	67%	86%
				Output	500.0								
			PDUs	Input	525.0								
						25.0	219,000	19%		$32,850	600	83%	95%
				Output	500.0								
			Total IT Power Chain Loss			135.0	1,182,600	100%		$177,390			
		IT Equipment			515.0				4,511,400	$676,710			
		Total IT Power Chain							5,694,000	$854,100			
	Backup Generator Engine Block Heaters				10.0				87,600	$13,140			
	Total IT Systems								5,781,600	$867,240			
Data Center Lighting System					20.0				175,200	$26,280			
Totals									5,956,800	$893,520			

User Inputs Tab B: Performance and Measures

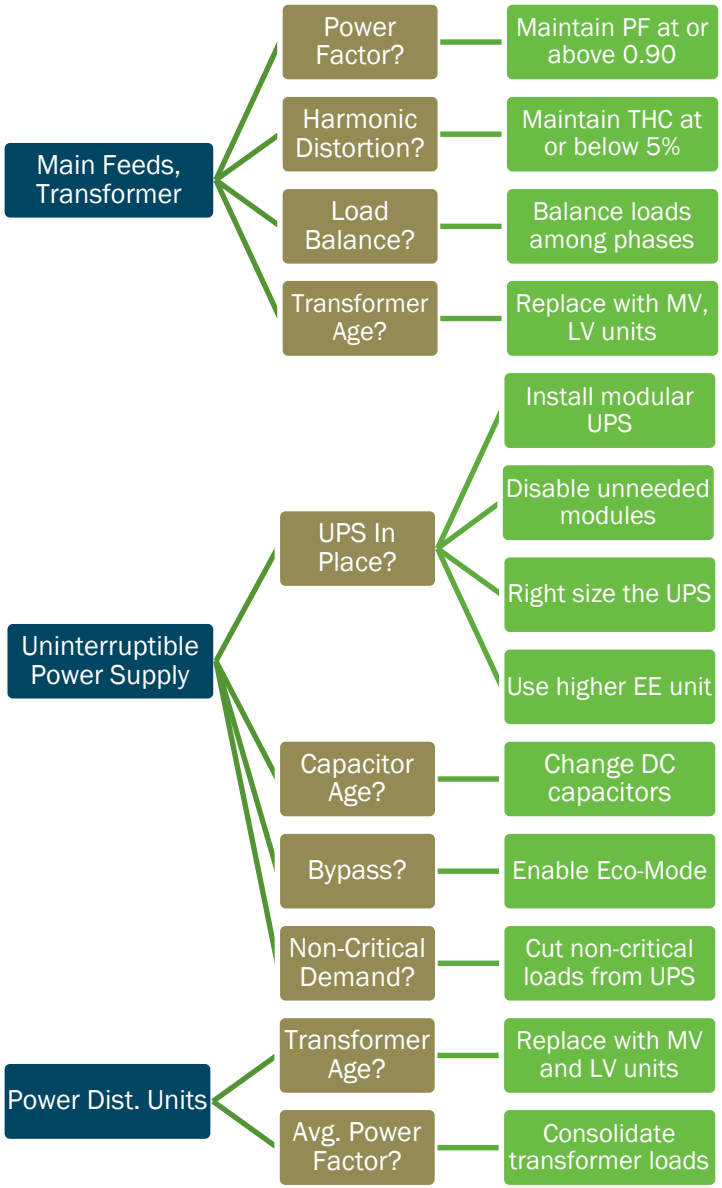
Table B: Efficiency Information and Potential Actions does four things:

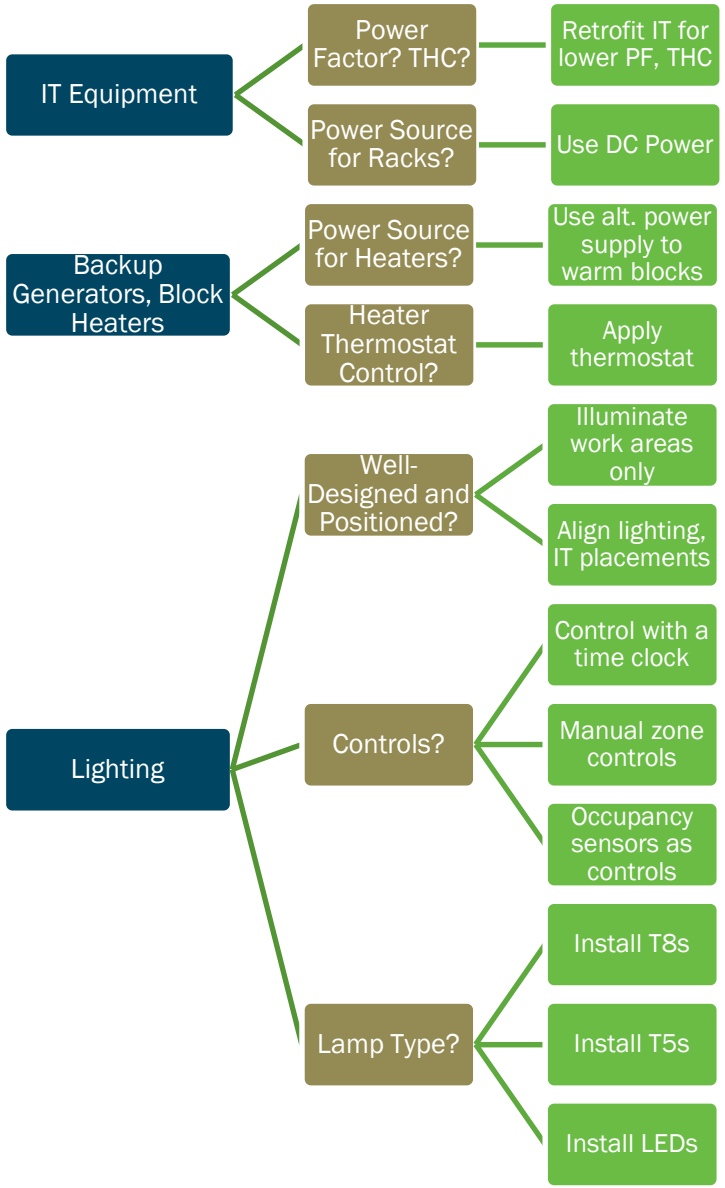
1. It asks questions about your data center. You don't have to answer all of them at once; it's OK to skip.
2. If you don't currently know an answer, it provides guidance.
3. If your answer indicates an opportunity for savings, it presents one or more potential actions to consider.
4. It asks which of the potential actions you wish to pursue.

User Inputs Tab B: Potential Actions

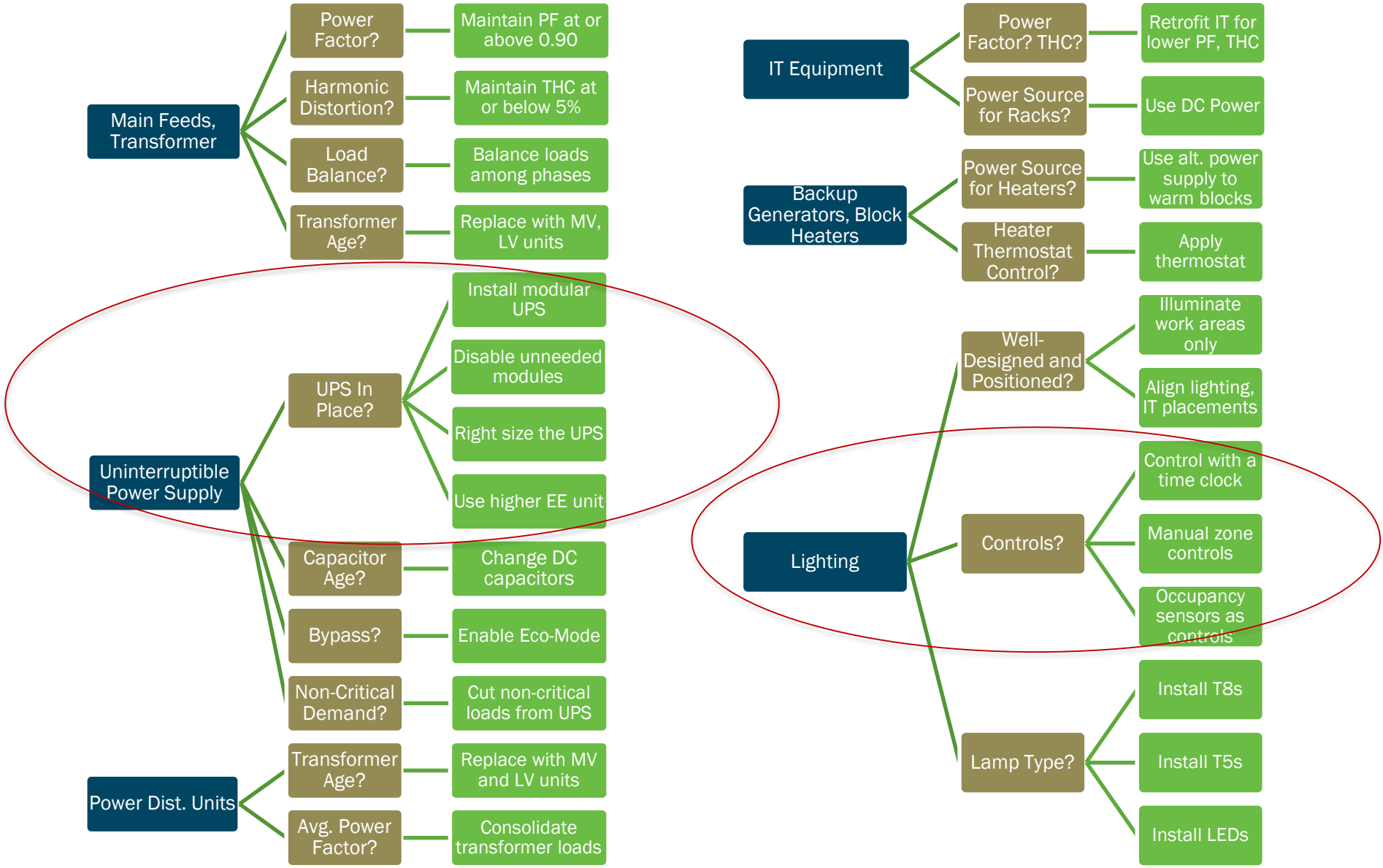
B1	B2	B6	B7
Question Number	Question	Potential Actions	
Q16	What is the building power factor?	1	Maintain Power Factor at Main Feeder Panel at 0.90 or Higher.
Q17	What is the building total harmonic current distortion (THD) at main feeder panel?	1	Maintain Total Harmonic Distortion at Main Feeder Panel at 5% or Less.
Q18	Are the loads balanced between all phases for the transformers, UPSs, and PDUs?	1	Maintain Balanced Loads Between Phases.
Q19	What is the age and type of the main transformer serving the IT power chain?	1	Use High Efficiency MV and LV Transformers.
Q20	Is there an active UPS?	1	Shut Down UPS Modules when Redundancy Level is High Enough.
		2	Install a Modular UPS.
		3	Right-Size the UPS.
		4	Replace the UPS with a More Efficient Unit.
Q21	Is the UPS operating in eco-mode?	1	Implement a Switching UPS
Q22	Are the UPS DC capacitors >5 years old?	1	Change UPS DC Capacitors.
Q23	What is the power source for non-critical loads?	1	Ensure Non-Critical Loads are Not Connected to the UPS.
Q24	What is the age and type of the transformers in the PDUs?	1	Use High Efficiency MV and LV Transformers.
Q25	What is the average load factor for the active PDUs that contain transformers?	1	Consolidate Transformer Loads
Q26	What is the IT equipment power factor?	1	Retrofit IT Equipment to Maintain High Power Factor and Low Total Harmonic Distortion.
Q27	What is the power source for the IT racks?	1	Supply DC Voltage to IT Rack.
Q28	What is the power source for the emergency generator block heater(s)?	1	Use Alternate Power Source to Warm Generator Blocks.
Q29	Does the block heater(s)/heater water jacket for emergency generator(s) operate with thermostat control?	1	Apply Thermostat Control to Generator Block Heaters.
Q30	Is the data center lighting well-designed?	1	Illuminate Work Areas Only.
		2	Coordinate Light Fixture Placement with IT Equipment Placement.
Q31	How are the lights controlled in the data center?	1	Control Lighting with a Timeclock.
		2	Implement Manually Controlled Zone Lighting Control.
		3	Install Occupancy Sensors to Control Lights.
Q32	What type of lamps are installed in the data center?	1	Install Linear Fluorescent T8 Fixtures.
		2	Install Linear Fluorescent T5 Fixtures.
		3	Install LED Fixtures.

Performance Questions and Measure Options





Performance Questions and Measure Options



User Inputs Tab B: Potential Actions

For our example, let's answer Questions 20 and 31:

B1	B2	B3
Question Number	Question	Input
Q20	Is there an active UPS?	Yes.
Q31	How are the lights controlled in the data center?	No control (always on).

User Inputs Tab B: Potential Actions

In our example, the tool recommends:

- Four potential ECMs for the UPS
- Three potential ECMs for lighting control

B5	B6	B7
Is Action Recommended?	Potential Actions	
Yes	1	Shut Down UPS Modules when Redundancy Level is High Enough.
	2	Install a Modular UPS.
	3	Right-Size the UPS.
	4	Replace the UPS with a More Efficient Unit.
Yes	1	Control Lighting with a Timeclock.
	2	Implement Manually Controlled Zone Lighting Control.
	3	Install Occupancy Sensors to Control Lights.

User Inputs Tab B: Potential Actions

Let's pursue Actions 2 and 3 for the UPS, and Action 3 for the lighting.

B6	B7	B8
Potential Actions		Pursue Action?
1	Shut Down UPS Modules when Redundancy Level is High Enough.	No
2	Install a Modular UPS.	Yes
3	Right-Size the UPS.	Yes
4	Replace the UPS with a More Efficient Unit.	No
1	Control Lighting with a Timeclock.	No
2	Implement Manually Controlled Zone Lighting Control.	No
3	Install Occupancy Sensors to Control Lights.	Yes

Action Results Tab

Table C: Estimated Results for Pursued Actions

Provides three things with each of the selected actions:

1. It states the assumed post-implementation performance level. (In some cases, it asks the user to specify.)
2. It asks for the estimated implementation cost.
3. It calculates the savings and simple payback.

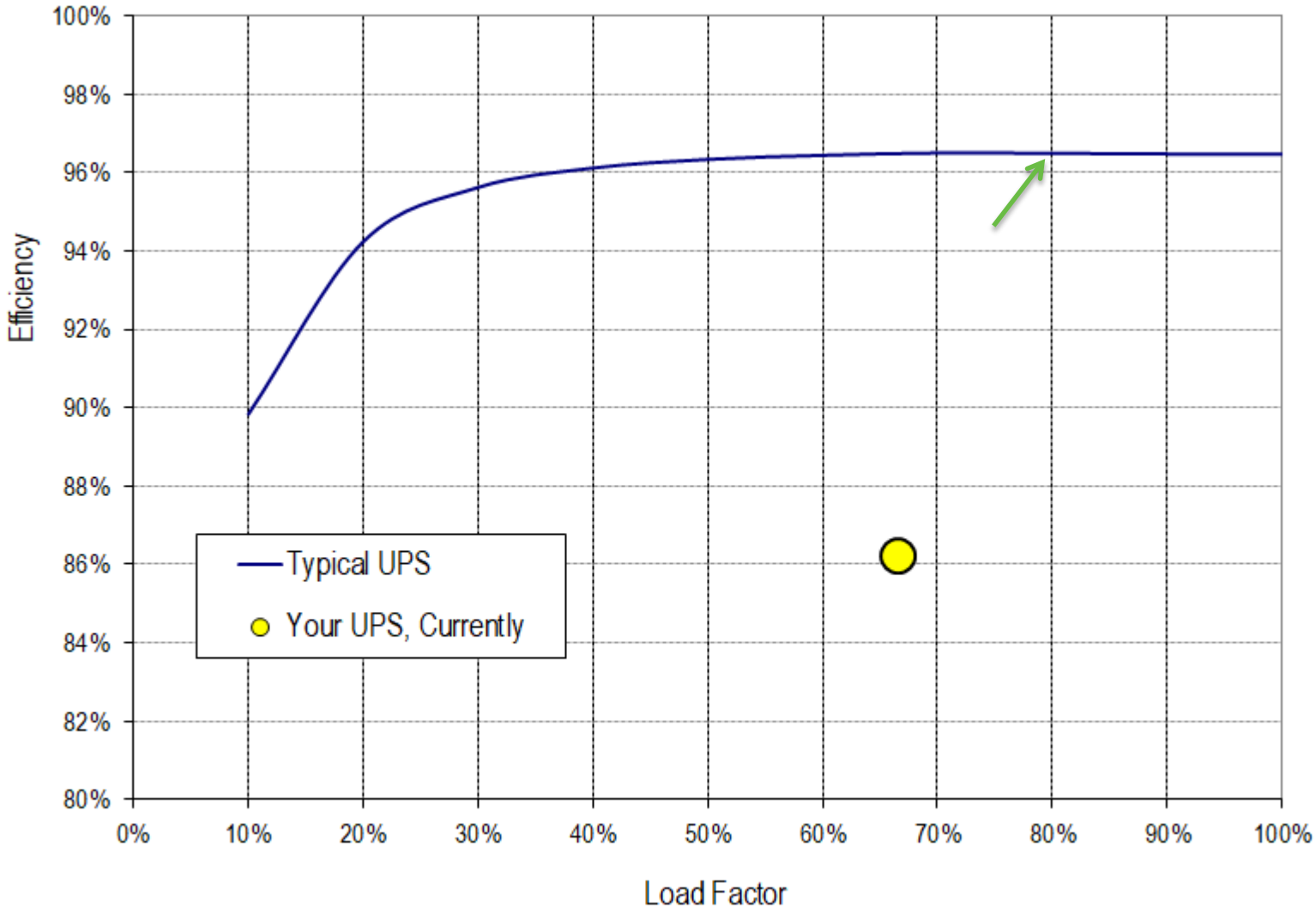
Action Results Tab

For the UPS, Table C requires the expected new operating load factor will be. Let's select 80%.

For the lighting system, Table C simply repeats the choice we made in Table B.

C1	C2	C3	C4	C5
Question Number	Actions Pursued		Post-Implementation Performance	
Q20	1	N/A	What will the new UPS load factor be?	80%
	2	Install a Modular UPS.		
	3	Right-Size the UPS.		
	4	N/A		
Q31	1	N/A	The lights will be controlled in the data center by:	Occupancy Sensor.
	2	N/A		
	3	Install Occupancy Sensors to Control Lights.		

Tool Plots Your UPS Efficiency vs. Average Unit



Action Results Tab

- The tool estimates the actions can save 77% of UPS loss.
- At $0.15/kWh, annual cost savings are $81,220.
- If implementing the UPS actions will cost $300,000, the simple payback is 3.7 years.

C6	C7	C8	C9	C10	C11
Estimated Savings				Cost to Implement	Simple Payback
%	Of	kWh/yr	$/yr	$	years
77.3	UPS System Loss	541,469	$81,220	$300,000	3.7

Action Results Tab

- The tool estimates 70% of lighting energy use can be saved by installing occupancy sensors.
- At $0.15/kWh, annual cost savings are $18,400.
- If installing occupancy sensors will cost $15,000, the simple payback is 0.8 years.

C6	C7	C8	C9	C10	C11
Estimated Savings				Cost to Implement	Simple Payback
%	Of	kWh/yr	$/yr	$	years
70.0	Data Center Total Lighting Energy Use	122,640	$18,396	$15,000	0.8

Savings Summary Tab

Users can limit savings for the UPS and the lighting system.

Cap the total UPS System Loss savings at:	80%
Cap the total Data Center Lighting energy use savings at:	80%

Why?

The tool does not account for interactive effects between actions.

If multiple ECMs are selected for the UPS system or the lighting system, the tool may tally unreasonably high savings percentages.

These fields are provided as a means of capping the total savings for those two elements of the power chain.

Savings Summary Tab

Table D: Estimated Savings

- Applies the savings caps, if needed
- Estimates the composite savings and payback period for the IT Power Chain and the Lighting System

D1	D2	D3	D4	D5	D6	D7	D8
Item	Annual Energy Use, Pre-Implementation	Estimated Savings			Estimated Annual Energy Use, Post-Implementation	Implementation Cost	Simple Payback
	kWh/yr	%	kWh/yr	$/yr	kWh/yr	$	years
Total IT Systems	5,781,600	9.4	541,469	$81,220	5,240,131	$300,000	3.7
Data Center Lighting System	175,200	70.0	122,640	$18,396	52,560	$15,000	0.8
Total	5,956,800	11.1	664,109	$99,616	5,292,691	$315,000	3.2

From Assessment to Action Plan: Path to DCOI Compliance

Data Center Optimization Initiative:

- Urges agencies to consider investments in long-term energy savings
- Recommends owners characterize their data centers and make performance assessments.
- Lifts PUE targets, but agencies are still expected to report PUE improvements over time
- Requires agencies to develop year-by-year targets for cost savings and report realized cost savings in their strategic plans

The Data Center Energy Assessment Report Template

A framework for presenting the results of your assessment

- Word document is designed to present as much – or as little – as you need
- Instructions (*blue italics)* and entire report subsections can be hidden, revealed or deleted through keyboard shortcuts
- Results from the Electric Power Chain Tool can be pasted in, along with results from other components of the Data Center Energy Efficiency Toolkit

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 energy and water systems in data centers to enhance the organization'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, including PUE Estimator
- Air Management Tools
- 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 Trainings

LBNL's Center of Expertise (CoE)

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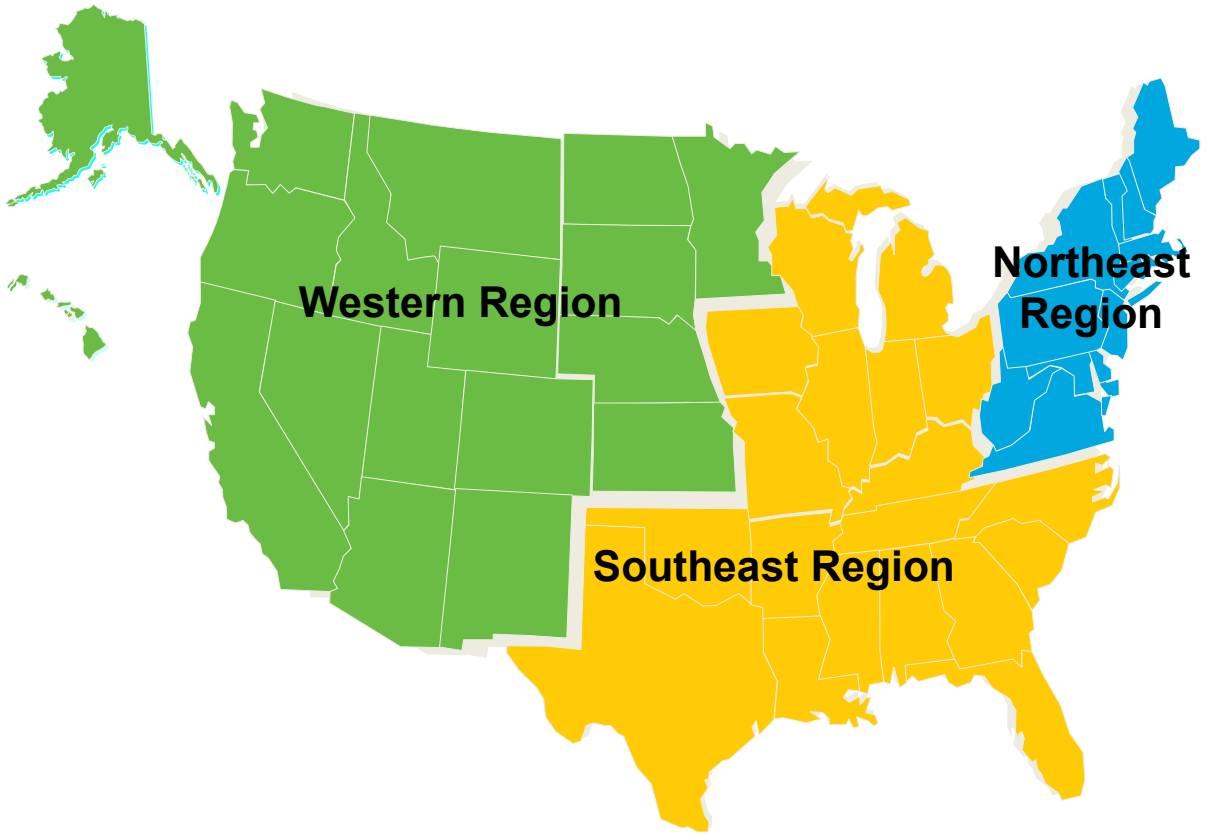

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