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BERKELEY NATIONAL LABORATORY

Department of Energy (DOE)
Energy Assessment
Process Manual

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1 INTRODUCTION

1.1 Energy in Data Centers

Data centers are dynamic and energy-intensive facilities. However, the rapid rate of growth in data center electricity use that prevailed from 2000 to 2006 slowed significantly from 2006 to 2016, yielding total electricity use by data centers in 2016 of about 2% of all electricity used in the US. Figure 1 below shows the historic (black curve) and in 2006 projected (colored curves) electric energy use in data centers.

The slower growth was driven by energy efficiency improvements and a lower server installed base (Great Recession). Nevertheless, the total energy savings potential in data centers is large, and energy assessments are an effective way to realize those savings.

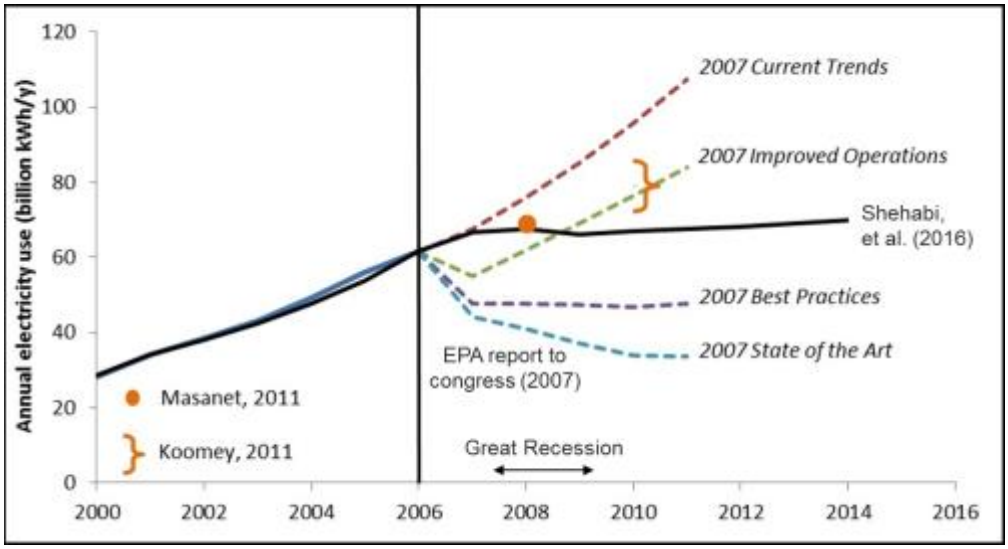

Figure 1: Historical energy use (black curve) and future energy-use projections in 2006.

1.2 Role of DOE Energy Assessments in the Process to Implement Efficiency

Although the DOE Energy Assessment is not meant to be a traditional investment-grade audit, the assessment is designed to provide the data center industry with immediate, tangible, and sustainable results such as energy, economic, and environmental savings. For best results, it is recommended that the individual conducting the Energy Assessment (Assessor) is a trained Data Center Energy Practitioner (DCEP): datacenters.lbl.gov/dcep.

A key outcome of the DOE assessment is the development of an action plan for progress. There are two main objectives with the DOE Energy Assessment strategy.

First, accelerate energy savings through assessments by developing an energy profile with the internal data center team, performing reviews of select data center systems, identifying a list of potential energy saving measures, estimating associated cost and energy savings, and documenting cost and energy savings from measures implemented.

Second, multiply savings through replication by building internal awareness and expertise. Specifically help the organization form an energy management program, create internal champions to lead energy savings efforts, and train the Site Lead in the DOE Energy Assessment Process and the use of the DOE Tool Suite.

The role of the DOE Energy Assessments in the overall energy-efficiency process and how the private sector consultants fit in are depicted in Figure 2. The top two (blue) blocks represent the DOE Energy Assessments (high-level profiling and in-depth system assessments). The next three (brown) blocks describe work by private sector consultants. Lastly, the last two (green) blocks represent savings validation and documentation by site personnel and engineering firms.

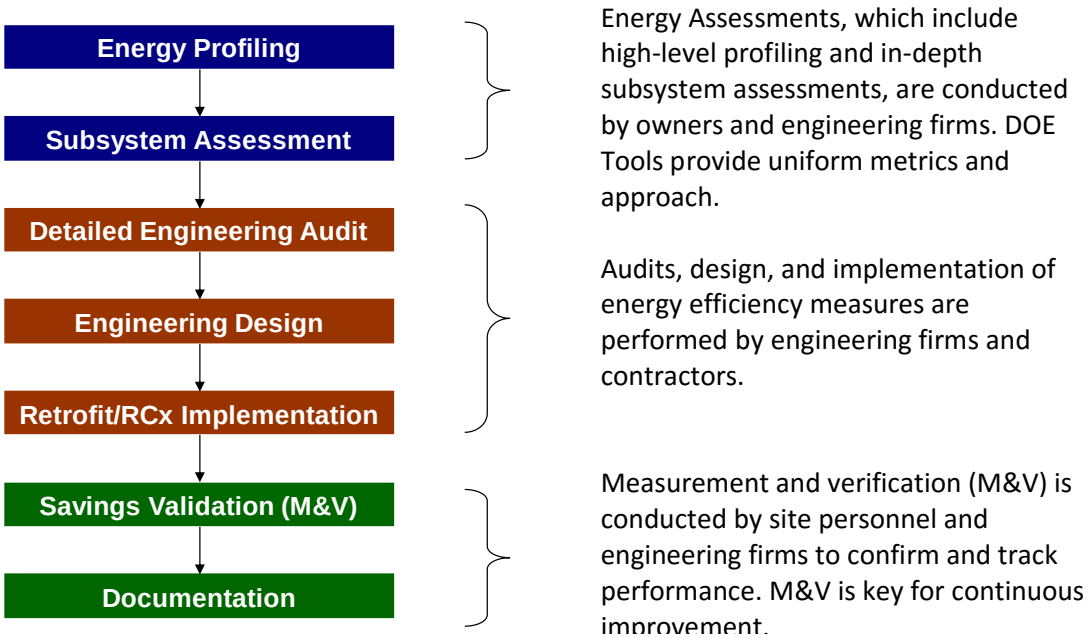

Figure 2: Overall Process for Saving Energy in Data Centers

1.3 Purpose of this Process Manual and Other Resources

This Process Manual provides administrative step-by-step instructions for conducting a DOE Energy Assessment before, during, and after the onsite assessment. Multiple appendices include useful templates for the assessments. Assessment resources and their descriptions are listed in Table 1. In addition, Appendix A provides useful terminology.

Table 1: Assessment Resources

Documents and Tools	Description
DOE Energy Assessment Process Manual (this document)	Administrative step-by-step instructions for conducting an Energy Assessment before, during, and after the onsite assessment.
DCEP Training PDF Slides (if DCEP)	Program training curriculum
Data Center Profiler (DC Pro) Tools • DC Pro and the PUE Estimator – Full Lists of Questions – User's Manuals – Calculation Reference Guide – Training Presentation https://datacenters.lbl.gov/dcpro	Two "early stage" scoping tools to estimate Power Usage Effectiveness (PUE) without sub-metering. The DC Pro Tools, which include DC Pro and the simplified PUE Estimator, are free, web-based, and confidential. DC Pro provides potential PUE and tailored recommendations for improvement while the PUE Estimator only asks questions required to estimate PUE.
Air Management Tool • User's Manual • Data Collection Guide • Engineering Reference https://datacenters.lbl.gov/tools/5-data-center-air-management-tool-featured	Excel-based tool that provides air management recommendations including reducing the supply airflow rate and increasing the supply air temperature without affecting the thermal environment. The Air Management Tool also estimates % energy reduction, kWh reduction, and associated $ savings for fans and chillers.
Data Center Master List of Energy Efficiency Actions https://datacenters.lbl.gov/resources/data-center-master-list-energy	Comprehensive list of recommended efficiency actions. The Master List also provides DC Pro with its tailored recommendations for improvement.
Assessment Worksheets https://datacenters.lbl.gov/tools/3-energy-assessment-worksheets	Excel template that can be used to collect data as well as document measurements, metrics, and actions from the Assessment. The Worksheets follow the same structure as the Assessment Report Template.
Energy Efficiency Assessment Report Template and Example Report https://datacenters.lbl.gov/tools/7-energy-efficiency-assessment-report	Word template to report Assessment findings as well as a real-word example. The Report Template can easily be filled in with actual site data.

2 PROCESS FOR DOE ENERGY ASSESSMENTS

Table 2 provides an overview of the ten assessment process steps outlined in this document as well as the available resources. The assessment process is broken down into four phases: Assessment Initiation (faint red), Pre-Onsite Preparation (faint blue), Onsite Activities (faint green), and Post-Onsite Activities (faint orange). The text sections following the table provide details on each of these process steps. Table 2 is written for a third-party assessor. For an in-house assessor, the difference between on-site and off-site becomes moot.

Table 2: Overview of Process Steps

#	Process Step Description	Available Resources
1	**Phase 1: Assessment Initiation** Introduce the DOE Assessment process. Identify preliminary goals, scope, onsite activities, and key personnel. Arrange for onsite logistics.	
2	**Preliminary assessment** by Site Lead using DC Pro or the PUE Estimator.	* DC Pro Tools
3	**Phase 2: Pre-Onsite Preparation** **Kick-off conference call** - Review scope, onsite activities, team, and logistics - Identify target systems, tools, and data to collect - Identify safety issues.	* DC Pro Tools results * Target System List (App. E) * Air Management Tool
4	**Off-site compilation of information** - Collect technical info from drawings, logs, etc. - Collect Site Description Survey - Collect Energy Management Practices Survey - Review required measurement equipment - Ensure functioning of the DOE Tools onsite - Review Safety, Health, and Environmental Training - Review confidentiality agreements.	* Assessment Worksheets * Site Survey (App. C) * Energy Management Practices Survey (App. D)
5	**Phase 3: Onsite Activities** (2-3 days per System) **Initiation onsite meeting** with all stakeholders: - Collect participant list - Overview presentation by the Assessor - Safety, health, and environmental training - Site tour of data center - Develop detailed work plan (measurements) - Assign roles and responsibilities	* Assessment Participants Template (App. I)
6	**Training to allow replication (mainly part of Step 7)** - Training on DOE Tools - Energy management best practices	* DC Pro Tools * Air Management Tool
7	**Fundamental investigations** - Field measurements - System modeling with the Air Management Tool - Assessment Worksheets - Results compilation and presentation	* Air Management Tool * Assessment Worksheets
8	**Preliminary Findings Meeting** **-** Directed to Site Management - Complete Assessment Evaluation	* Evaluation Template (App. J)
9	**Phase 4: Post-Onsite Activities** **Compilation of Assessment Report** - Observations and opportunities - Estimated energy savings for each opportunity - Estimated costs for implementing each opportunity	* Process Manual (this doc) * Assessment Report Template and Example Report * Assessment Worksheets * Air Management Tool * DC Pro Tools * Master List of Actions * Any complete surveys and templates (App. B-J)
10	**Finalize reporting requirements + Follow up** - Draft to site for review, document savings	Same as above

2.1 Phase 1: Assessment Initiation (Process Steps 1-2)

The Assessor contacts the Initial Site Contact to identify preliminary scope, onsite activities, key personnel, and onsite logistics including approximate timing of the Energy Assessment. The Initial Site Contact may not be the Site Lead, who is the onsite technical representative who will be the primary person participating in the Assessment.

Step 1: Establish Preliminary Scope and Onsite Activities

The preliminary scope of the Energy Assessment should be established in this initiation phase and be refined in the preparation phase (the next phase). Sharing this Process Manual with the Site Lead may not only help communicate the overall Assessment process but also establish the scope and onsite activities. The ultimate goal of Energy Assessments is to provide the site with trained staff that can effectively apply the DOE Tool Suite and energy management principles to investigate systems in other data centers.

Identify Site Lead

A primary point of the assessment initiation is to identify the Site Lead. This person must:

- understand the nature of the Energy Assessment
- be knowledgeable about the data center systems
- have contact with system operations and maintenance personnel
- be fully devoted to the Energy Assessment during the onsite period
- be responsible for learning the DOE Tool Suite
- be able to replicate identified system analyses.

Identify Assessment Team

The personnel who will be participating in the Energy Assessment need to be identified:

- Devoted Onsite Assessment Personnel (Assessment Lead Team)
  - Assessor
  - Site Lead (the primary person participating in the assessment)
  - Other core personnel participating in the assessment.
- As-needed Personnel
  - System Operations/Maintenance Staff
  - Technical Support Staff
  - Management must participate in the Initiation Onsite Meeting (Step 5) and the Preliminary Findings Meeting (Step 8).

Arrange for Logistics

The onsite logistics tasks include the following:

- Solidify energy assessment timing; the total number of days on site depends on the number of system analyses (typically 2-3 days per Primary System)
- Arrange gate-pass for the Assessor
- Identify a conference room that can serve as an uninterrupted base
- Identify lodging issues
- Consider food services onsite to minimize lost time.

Step 2: Preliminary Assessment

The Site Lead should do a preliminary online assessment using one of the DC Pro Tools, based on available data. The Assessor will be available (off site) to assist. Besides providing an energy profile of the data center, this preliminary assessment will help with the Target Systems identification in the next assessment phase (Step 3).

2.2 Phase 2: Pre-Onsite Preparation (Process Steps 3-4)

Step 3: Kick-off Conference Call

The kick off conference call serves the purpose to ensure that scope, onsite activities, key personnel, and onsite logistics have been identified. Other purposes are to identify the data center systems to be included in the energy assessment, technical information to be collected prior to the site visit (Step 4), and safety issues.

Target System Identification (see Appendix E)

- The activities are driven from the Target System List; data center systems targeted for the Assessment. Do not allow one system to dominate the Assessment. The preliminary offsite assessment with one of the DC Pro Tools (Step 2) should provide guidance.
- The Primary Systems consist of the following three systems:
  - IT-Equipment
  - HVAC Systems (Cooling and Air Management)
  - Electrical Systems.

Step 4: Off-Site Compilation of Information

Collect technical information and data from surveys, drawings, logs, etc. Enter the information into the Air Management Tool or Assessment Worksheets. The Worksheets can later be used to document measurements, metrics, and actions from the Assessment (Step 7).

Site Description Survey (see Appendix C)

If one of the DC Pro Tools has not been used or more information is needed, request the Site Lead to complete the Site Description Survey to identify the *general* characteristics of the data center. See Appendix C.

- Principal data center description
  - Size
  - Type of data center (enterprise, collocation, telecom, etc.)
  - Geographic location
  - Fuel, fuel costs, and fuel unit cost.
- Primary System description
  - Type and number of equipment/systems
  - Redundancy
  - Control strategies
  - Power requirements and fuel types
  - Operating characteristics, normal operating conditions.

Energy Management Practices Survey (see Appendix D)

If one of the DC Pro Tools has not been used or more information is needed, also request the Site Lead to complete the Energy Management Practices Survey, see Appendix D. This survey provides high-level information on energy policies implemented at the data center.

Required Measurement Equipment

The Assessor should review the collected data and determine the existence of any data gaps for which onsite measurements or other collection methods may be necessary. Identify the measurement equipment the Assessor must bring to the site. Examples include equipment for measuring:

- Fluid temperature
- Air Humidity
- Fluid flow
- Electrical power.

Questions to ask the Site Lead include the following:

- Are there needs for special measurement equipment?
- Are there stationary sensors?
- What does the control system report?

Functioning Onsite DOE Tools

Ensure the DOE Tools are working on a computer available to the Site Lead:

- The Site Lead should explore the DOE Tools as a preparatory exercise
- The Air Management Tool should also be downloaded and brought to the Energy Assessment by the Assessor in a form that allows easy access by the team (e.g., memory stick).

Review Safety, Health, and Environmental Issues and Training

Identify site-specific safety, health, and environmental issues/training:

- Identify personal protective equipment the Assessor will be required to bring
- Identify personal protective equipment the Site Lead will provide
- Identify any "special requirements"—if any
- Determine the safety, health, and environmental training requirements
- Establish a tentative schedule for safety, health, and environmental training
- Perform the training the first day of the onsite activities
- Training must be completed *and* documented before onsite activities.

Agreements

The Site Lead must provide the Assessor with the appropriate confidentiality agreements:

- Ensure the agreements are understood
- They must be reviewed, signed, and returned prior to entering the site
- The Assessor is the entity entering the agreements.

2.3 Phase 3: Assessment Onsite Activities (Process Steps 5-8)

Typically, the onsite activities take about 2-3 days per Primary System.

Step 5: Initiation Onsite Meeting

Begin the onsite activities with an initiation meeting with all stakeholders to review the assessment scope and onsite activities and to introduce the Assessor to the Lead Team.

Collect Participant List (see Appendix I)

Document the following participant information:

- Name and title
- Company
- Address
- Phone number and email address.

Overview Presentation by the Assessor

The event is an Energy *Training*-Assessment in that the Assessment Lead Team should be active participant in the Assessment. Creating the ability for replication is a key goal of the Energy Assessment.

- The general framework of the Energy Assessment should be established.
    - Assessment scope
    - Onsite activities
    - Role of the Assessor
    - DOE Tools
    - Field measurement
    - Roadmap development
    - Preliminary Findings Meeting
    - Post-assessment activities.

- The Energy Assessment is not a fault-finding activity but an activity that is designed to:
    - Share knowledge
    - Provide tools
    - Teach energy management best practices
    - Identify opportunities for improvement
    - Identify opportunities for replication.

Safety, Health, and Environmental Training

Perform the safety, health, and environmental training identified in Step 4.

Site Tour

Conduct a brief site tour to familiarize the Assessor with the data center facility. This is an excellent opportunity to ask and answer questions.

Develop Detailed Work Plan

Develop a detailed work plan by agreeing on potential energy efficiency opportunities to investigate, metrics to be analyzed, and Measurement Plan to be implemented. The off-site compilation of information (Step 4) should provide an excellent starting point for establishing required field measurements. The actual measurements are taking place during the Fundamental Investigations (Step 7).

Assign Roles and Responsibilities

With the Site Lead, assign roles and responsibilities among the members of the Assessment Team according to the Detailed Work Plan.

Step 6: Training of Lead Team to Allow Replication

DOE Tool Suite (DC Pro Tools and the Air Management Tool)

While performing the onsite assessment (Step 7), the Assessor should train the Assessment Lead Team so that they sufficiently understand the DOE Tools, including the associated data collection of required input data. It is beneficial for the Site Lead to complete some of the analysis with the Assessor. At the end of the onsite assessment, the Site Lead should be able to replicate the investigations.

Energy Management Best Practices

Identification of energy management best practices is an important part of a successful Assessment. While performing the onsite assessment (Step 7), the Assessor should highlight and transfer energy management best practice knowledge to the Lead Team. Understanding the overall energy assessment process as well as energy management best practices is an excellent replication vehicle.

Step 7: Fundamental Investigations

This Step is where the rubber hits the road. First, the Lead Team collects the missing information based on the data gaps identified in Steps 4 and 5. Second, Air Management Tool modeling is performed to quantify potential energy opportunities. The Assessment Worksheets can be useful if a particular system tool is not available. Finally, the results are compiled into a presentation directed to the Site Management.

Some missing information (data) will be readily available, including data that can be collected from building management systems, equipment read-outs (e.g., UPS), operating information, and design data. Other data collection may require measurements and temporary metering. The assessment team could decide to use a design value in lieu of a measured value, or decide to use estimates rather than actual data.

Field Measurements

Field measurements provide key input data to the Air Management Tool. The detailed Measurement Plan developed in Step 5 should be applied. Ensure that all measurements required for determining critical data are performed while on site. Measurement Plan modifications are likely as the fundamental investigations proceed.

Air Management Tool Modeling

When the measurements are completed and other data have been collected, the system modeling with the Air Management Tool should be performed to quantify potential energy opportunities. At this point, there should be no surprises regarding required Tool input data if the process outlined above was followed.

Assessment Worksheets

The Assessment Worksheets can be useful if a particular system tool is not available. The Worksheets cannot only be used for collecting data (Step 4) but also for documenting measurements, metrics, and actions from the assessment. Data from the one of the DC Pro Tools (Step 2) can be used as a starting point for the more detailed assessment.

Results Compilation and Presentation

The assessment results are compiled into a brief PowerPoint presentation. Preparation for the Preliminary Findings Meeting should also include discussions of presentation points with the Assessment Lead Team.

- Preliminary findings must be accepted by the Site Lead before the Meeting
  - Opportunities
  - Best practices
  - Roadmap (action plan).
- Provide a presentation with no surprises
- This should not be a fault finding presentation.

Step 8: Preliminary Findings Meeting

The Preliminary Findings Meeting is directed to Site Management, the personnel to whom the Site Lead wishes to communicate the findings.

- Present real and tangible energy-efficiency opportunities
- Identify and promote energy management best practices
- Assessment Lead Team presents the Roadmap
- Modify recommendations based on information attained during the Meeting.

Assessment Evaluation Summary (see Appendix J)

The Site Lead and other participants should complete an Assessment Evaluation prior to the conclusion of the onsite activities.

2.4 Phase 4: Post-Onsite Activities (Process Steps 9-10)

The post-onsite activities are initiated by compiling the Assessment Report and the Attendance and Evaluation Report. The Assessment Report is submitted to the Site Lead. The Assessor revises the draft to the satisfaction of the Site Lead. The result is the final Assessment Report.

Step 9: Compilation of Assessment and Attendance Reports

Compilation of Assessment Report (see Assessment Report Template and Example Report).

If collected, the following documents should be included in the Appendix of the Assessment Report:

- Site Description Survey (see Appendix C)
- Energy Management Practices Survey (see Appendix D)
- Target Systems List (see Appendix E)
- Attendance Report (see Appendix I)
- Evaluation Report (see Appendix J).

Potential Case Study

The Assessment Report should also discuss whether developing a case study from activities at the site is a possibility. Case studies are generally widely applicable, straightforward, and generally focus on an aspect of areas such as fundamental systems, energy management best practices, innovative solutions, and comprehensive management activities.

Step 10: Finalize Reporting Requirements

- Submit the draft Assessment Report to the Site Lead ten business days after completion of the onsite work
- The Site Lead provides review comments on the draft to the Assessor
- The Assessor revises the draft to the satisfaction of the Site Lead. The result is the final Assessment Report.

Follow Up

Follow up with the site to document implemented solutions and savings.

Appendix A: Terminology

Assessor

The energy expert assigned to complete the DOE Assessment; the expert serves as the facilitator for all activities and is usually a Data Center Energy Practitioner (DCEP).

DCOI

Data Center Optimization Initiative (DCOI) states that all tiered Federal data centers shall have at least one certified DCEP assigned to manage data center performance and continued optimization.

DC Pro Tools

DC Pro Tools include the DC Pro and the PUE Estimator

DOE

U.S. Department of Energy

DOE Tool Suite

DOE Tool Suite includes the DC Pro, the PUE Estimator, and the Air Management Tool

Initial Site Contact

Data center representative that serves as the initial contact

Lead Team

Core personnel participating in the Assessment, including Assessor and Site Lead

Preliminary Findings Meeting

This meeting is directed to Site Management

Primary Systems

- IT-Equipment
- HVAC Systems (Cooling and Air Management)
- Electrical Systems.

Site Lead

Data center technical representative that will be the primary person participating in the Assessment

Site Management

Data center personnel to whom the Site Lead wishes to communicate the findings

Target Systems List

Listing of data center systems targeted for the Assessment.

Appendix B: General Information

Data Center Owner		**Assessment Dates**	
Facility Name		**Assessment Type**	
Location		**Assessor Name**	
Data Center Contact Information			
Name			
Address			
City/State			
Phone			
Email			

Appendix C: Site Description Survey

Request the Site Lead to complete the Site Description Survey to identify the *general* characteristics of the data center.

Principal Data Center Description			
Total data center area			
Electrically active area			
Type (enterprise, collocation, telecom, etc.)			
Geographic location			
Annual fuel cost ($) and fuel unit cost ($/kWh)	Electricity		
	Gas		
	Oil		
Primary Systems Description			
General description of key IT-equipment ▪ Type and number of equipment ▪ Power requirements ▪ Operating characteristics ▪ Nominal operating conditions.			
General description of key HVAC systems ▪ Type and number of systems ▪ Redundancy ▪ Control strategies ▪ Power requirements and fuel types ▪ Operating characteristics ▪ Nominal operating conditions.			
General description of key electrical systems ▪ Type and number of systems ▪ Redundancy ▪ Control strategies ▪ Power requirements and fuel types ▪ Operating characteristics ▪ Nominal operating conditions.			

Appendix D: Energy Management Practices Survey

Request the Site Lead to complete the following Energy Management Practices Survey to identify energy policies implemented at the data center.

- Does your organization have a written CEO- or Board-approved policy that includes reducing energy consumption?
  □ No □ Yes □ Unknown or no answer

- Does your company/agency have a formal written energy management plan that is updated at least every two years?
  □ No □ Yes □ Unknown or no answer

- Does your company/agency have a corporate or facility energy manager position?
  □ No □ Yes

- Do the duties of manager include finding and implementing ways of reducing the energy consumption?
  □ No □ Yes

- In the last two years, have there been any corporate/agency or facility mandates to reduce energy consumption by a targeted percentage or amount?
  □ No □ Yes □ What was the percentage? _____%

- How many employees does the data center employ? _____

- Does the annual performance rating for the data center manager include a component with energy reduction goals that influence bonuses?
  □ No □ Yes □ Unknown

- In the last two years, have there been any projects in your data center to reduce energy consumption or projects that included a component aimed at reducing or managing energy?
  □ No □ Yes

- Were those projects a result of (check all that apply):
  □ New construction
  □ As a consequence of updating the data center
  □ A project focusing almost entirely on energy use
  On what systems were those projects focused?_____

- When you purchase new or replace equipment at the data center, does the life cycle cost, including energy use, affect what is purchased?
  - □ Always
  - □ Usually
  - □ Sometimes
  - □ Occasionally
  - □ Never
  - □ Unknown

- In managing operations and maintenance, do you analyze energy use trends to identify needed changes to operations or maintenance practices to reduce energy use?
  - □ No □ Yes

- Which financial methods does your firm typically use to evaluate energy efficiency improvements?
  - □ Initial Cost
  - □ Simple payback
  - □ Internal rate of return
  - □ Life cycle cost
  - □ Other (please explain) _____
  - □ Unknown

- What payback *(length of time)* do you normally require in order to consider an energy investment cost effective?
  - □_____ (Years*)*

- What rate of return do you normally require in order to consider an energy investment cost effective?
  - □ _____%

- What discount rate do you normally use in determining the life-cycle costs of various equipment options?
  - □ _____%

Appendix E: Target System List (Assessment Scope)

The three Primary Systems are IT-Equipment, HVAC Systems, and Electrical Systems. Each Primary System, in turn, consists of key sub-systems as shown below. Check the selected subsystems for the Assessment.

Systems	**Target System(s)**
IT-Equipment	
Servers	
Storage	
Networking	
HVAC Systems	
Air Management	
Cooling Systems	
Chilled-Water Plant	
Electrical Systems	
UPS	
PDU	
Lighting	
Onsite generation	

Appendix F: Summary Energy Savings

Energy Savings Opportunity Summary				
	Impact			
Primary System Opportunity	$/yr	kWh/yr	Cost	Payback yrs
IT-Equipment				
HVAC Systems				
Electrical Systems				
Total				

Appendix G: Detailed Energy Savings

Energy Savings Opportunity for Primary System: _____ **(One table for each Primary System: IT-Equipment, HVAC Systems, and Electrical Systems)**						
		Impact				
#	Opportunity	$/yr	kWh/yr	Cost	Payback yrs	N,M,L[1]
1						
2						
3						
4						
5						
:						
	Total					

Footnote 1:
N = Near-Term
M = Medium-Term
L = Long-Term

Appendix H: Identified Actions

Identified Actions for Primary System: _____ **(One table for each Primary System: IT-Equipment, HVAC Systems, and Electrical Systems)**		
#	Opportunity	Action(s)
1		
2		
3		
4		
5		
:		

Appendix I: Assessment Participants (attendance)

Data Center Owner		**Location**	
Facility Name		**Assessment Date(s)**	
Name	**Address**	**Phone**	**email**

Appendix J: Assessment Evaluation

Data Center Owner		**Location**	
Facility Name		**Assessment Date(s)**	
Individual Evaluation Summary (5 highest/likely/good, 1 Lowest/unlikely/poor)			
The program increased my understanding of my data center systems. **Comments:**			
The program and information learned will be useful to me. **Comments:**			
Will you use the DOE Tool Suite? **Comments:**			
The agenda was appropriate. **Comments:**			
The Assessor was knowledgeable and added value. **Comments:**			
Overall Comments and Suggestions:			

Resources

Air Management Tool: https://datacenters.lbl.gov/tools/5-data-center-air-management-tool-featured

Assessment Report Template and Example Report: https://datacenters.lbl.gov/tools/7-energy-efficiency-assessment-report

Assessment Worksheets: https://datacenters.lbl.gov/tools/3-energy-assessment-worksheets

Center of Expertise for Energy Efficiency in Data Centers: http://datacenters.lbl.gov

Data Center Optimization Initiative (DCOI) https://datacenters.cio.gov/

DC Pro Tools: https://datacenters.lbl.gov/dcpro

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

DCEP Training Program: http://datacenters.lbl.gov/dcep

Koomey, J, 2010, Growth in Data Center Electricity Use 2005 to 2010: http://www.missioncriticalmagazine.com/ext/resources/MC/Home/Files/PDFs/Koomey_Data_Center.pdf

Shehabi et al., 2016, United States Data Center Energy Usage Report: https://datacenters.lbl.gov/sites/all/files/DataCenterEnergyReport2016_0.pdf