THE CEM BODY OF KNOWLEDGE AND STUDY GUIDE
Preparation for the CEM Certification Exam

CEM®

The CEM Certification Exam is a four-hour open book exam. The examination questions are based on the Body of Knowledge listed below. Because of the diversity of background and experience of Energy Managers, the examination has 14 different subject sections, all of which are included in the exam. You must bring a hand calculator to the exam as the CEM exam does not allow computers, tablets, or cell phones to be used during the test.

It is highly recommended that you review the complete Study Guide and answer the Exam Review questions included in the Study Guide to determine your readiness for the exam.

The CEM Examination contains the following mandatory subjects:

Body of Knowledge 2.0	Percent of Exam
1. Energy and Sustainability Policies, Codes and Standards	6%-8%
2. Energy Rates, Tariffs and Supply Options	5%-7%
3. Energy Audits and Instrumentation	7%-11%
4. Energy Accounting and Economics	6%-10%
5. Electrical Power Systems and Motors	7%-11%
6. Lighting Systems	5% -7%
7. HVAC Systems and Building Envelope	10%-16%
8. Building Automation, Controls and Artificial Intelligence Systems	6%-10%
9. Energy Storage Systems	3%-5%
10. Boiler and Steam Systems	4%-6%
11. Distributed Generation & Renewable Energy Systems	4%-6%
12. Industrial Systems	6%-8%
13. Operations, Maintenance and Commissioning	7%-11%
14. Energy Savings Performance Contracting and Measurement & Verification	3%-5%

STUDY GUIDE

CERTIFIED ENERGY MANAGERS (CEM® EXAM)

Online Self-Evaluation Exam Also Available

CEM Applicants have access to an online version self-evaluation CEM exam. The 65-question multiple choice self-evaluation exam simulates half the certification test, contains a two hour time limit, and covers seventeen sections. There is a **$50 fee** to take this online test and you may access the full details at:

Direct Link: www.aeecenter.org/cem/selfevaluation

Get a sense of how to time questions. The actual exam time allotted is 4 hours for 130 questions. You will need to complete the 65-question self-evaluation exam in 2 hours. At the end of the exam, you will receive a sections report that lets you know what sections you passed and failed. You will not be able to see the specific questions that you answered wrong/right or the answers.

The following is a list of the subjects for the CEM exam. Each subject covers a number of topics.

The primary references include:

Handbook of Energy Engineering, 8th by D. Paul Mehta and Albert Thumann

Energy Management Handbook, 9th Edition by Stephen Roosa, Steve Doty, and Wayne C. Turner

Guide to Energy Management, 8th Edition by Barney L. Capehart, Wayne C. Turner and William J. Kennedy

Certified Energy Manager (CEM) Training Workbook (available to AEE training attendees)

The primary textbook resources are available through the AEE eLibrary, which is a great source for accessing searchable content as well as highlighting and taking notes. *Digital books cannot be accessed during the certification exam.*

The study guide will not lead you to answers to all of the questions, but it will certainly lead you to a very large number of correct answers. A person with the necessary experience who reviews the study guide should not have any problem passing the exam.

The exam will: be open book, last four hours, and have 130 questions to answer. Of the 130 questions, 120 are scored and 10 randomly located questions are trial questions being prepared for possible use on future exams. The 10 trial questions do not count toward the examinee's score. The trial questions are randomly located and are not identified. Therefore, all 130 questions should be answered. There are 14 sections listed below from which questions mainly are drawn.

BODY OF KNOWLEDGE: STUDY GUIDE TOPICS & REFERENCES

1. Energy and Sustainability Policies, Codes and Standards   *20XX stands for current year of standard
Climate Change & Decarbonization Policies
Sustainable Development Goals & Policies
United Nations Sustainable Development Goals (SDGs)
Electrification Policies
Nuclear Policies & Approaches
Local and National Tax Incentives

GHG Accounting & Reporting (including Carbon Footprint Calculations)
ESG (Environmental, social and governance), CSR (Corporate Social Responsibility) Reporting
Net Zero Buildings
Smart Cities
Transition to Clean Energy
Climate Change Risk, Resiliency and Adaptation
Green Hydrogen Approaches
Circular Economy in Energy
ASHRAE/IESNA Standard 90.1-20XX
ASHRAE Standard 90.2-20XX
ASHRAE Standard 62.1 -20XX
Indoor Environmental Quality
ASHRAE Standard 135-20XX
ASHRAE Standard 189.1- 20XX
ASHRAE Guideline 14-20XX
ASHRAE Standard 211-20XX
IEEE PQ Standard 519
International Energy Conservation Code (IECC)
ISO 50001
Sustainable Design
International Green Building Rating Systems
LEED Certifications & Accreditations
ENERGY STAR Ratings & Tools
Cyber-Security Issues

2. Energy Rates, Tariffs and Supply Options

Basic Energy Units and Conversions
Fuel & Electricity Procurement
Point of Use Costs
Supply and Demand Impact on Pricing
Fuel Price Risks
Rate Structure & Analysis (energy, water and sewer)
Ratchet and Contract Clauses
Peak Demand Reduction
Evaluating Supply Options
Trends in Deregulation
Selection of Energy Supplier in a Deregulated Market
Primary and Secondary Power
Demand Side Management
Energy Efficiency in Transportation

3. Energy Audits and Instrumentation
Role of Audits
ASHRAE Level 1, 2, 3 Audit
Audit Equipment
Energy and Power Measurement
Power Factor Measurement
Flow Measurement
Air Velocity Measurement
Temperature Measurement
Humidity Measurement
Pressure Measurement
Combustion Analysis
Light Level Measurement
Heat Measurement
Infrared Equipment
Fuel Choices
Key Performance Indicators, Energy Use Index & Energy Cost Index
Facility Load Factor
HHV and LHV
ASHRAE Standard 211-20XX
Energy Management Measures
Energy Simulation / Models
Digital Tools / Apps

4. Energy Accounting and Economics
Time Value of Money
Impact of Escalation Rates
Financial Evaluation Methods: Present Worth, Net Present Value, Annual Worth, Savings to Investment Ratio, Internal Rate of Return, Life Cycle Cost, Simple Payback Interest Formulas and Tables
Depreciation Methods

5. Electrical Power Systems and Motors
Demand and Energy
Power Factor
Real Power and Reactive Power
Three Phase Systems
Power Quality, Harmonics and Grounding
Motor Types
Motor Selection Criteria
High Efficiency Motors
Motor Load Factor
Motor Slip

New vs. Rewound Motors
Affinity Laws (Pump and Fan Laws)
Motor Speed Control
Variable Frequency Drives / Variable Speed Drives
Variable Flow Systems

6. Lighting Systems

Color Rendering Index
Color Temperature
Visual Comfort Factor
Human Centric Lighting, Pupil Lumens
Spectral Power Distribution
Efficiency and Efficacy
Light Sources
Ballasts, Ballast Factors and Lighting Drivers
Strike and Restrike
Lamp Life
Lumens
Dimming
Glare Control with Reflectors, Diffusers and Uplighting
Footcandles
Inverse Square Law
Zonal Cavity Design Method
IES Lighting Standard
Coefficient of Utilization
Lamp Lumen Depreciation
Light Loss Factors
Lighting Retrofits
Lighting Controls
Luminaire Specific Lighting Controls
Natural Lighting (Skylights, Solar Tubes, Light Shelfs, etc.)

7. HVAC Systems and Building Envelope

Vapor Compression Cycle
HVAC Equipment Types
Refrigerants and Global Warming Potential Factors
Performance Ratings (COP, EER, kW/ton)
Cooling Towers
Variable Refrigerant Flow
HVAC Economizers
Air Distribution Systems (Reheat, Multizone, VAV)
Chillers

Absorption Cycle
Chilled Beam Systems
Heat Pumps
Energy Consumption Estimates
Enthalpy
Heat Transfer Equations
Psychrometric Chart
Building Envelope
Thermally Light and Heavy Facilities
Thermal Resistance, Conductance and Conductivity
Insulation
Degree Days
Seasonal Heat Transfer Estimation
Instantaneous Heat Transfer Estimation
Solar Heat Gain
Solar Shading
Passive Design

8. Building Automation, Controls and Artificial Intelligence Systems

Basic Controls
Terminology
Signal Communication Options (Analog vs Digital)
Power Line Carriers
Self-Tuning Control Loops
P, PI, and PID Controls
Hardware: Pneumatic, Electric and Direct Digital Control
Central and Distributed Control
Communication Protocols and Integrating Systems
Open Protocol Systems
Energy Information Systems
Control Strategies (Set-Back, Reset, Optimized Start/Stop, and others)
Building Automation & Energy Management Systems
Energy Management Strategies, Optimization and Sequencing
Internet Of Things (IOT)
Web or Cloud Based Systems
Artificial Intelligence
Expert Systems
Cyber-Security and Information Technology Issues

9. Energy Storage Systems

Design Strategies
Chilled Water Storage

Partial Storage Systems
Full Storage Systems
Operating Strategies
Advantages and Limitations
Storage Media
Sizing
Ice Storage
Phase Change Materials (PCM)
Thermal Storage for Heating
Electric Energy Storage

10. Boiler and Steam Systems

Combustion Efficiency (as it relates to: Oxygen to Fuel Ratio, Fouling and Heat Recovery)
HHV and LHV
Boiler Economizers & Waste Heat Recovery
Condensing Boilers
Enthalpy from Saturated and Superheated Steam Tables
Steam Traps
Condensate Return
Boiler Blowdown
Flash Steam
Turbulators

11. Distributed Generation & Renewable Energy Systems

CHP Regulations, Enablers and Barriers to Entry
District Energy Systems
Prime Movers
Fuel Selection
Operating Strategies
Thermal Efficiencies
Heat Recovery Steam Generators
Topping, Bottoming, and Combined Cycle Generation
Wind, Biomass, Geothermal and Hydropower
Solar Photovoltaic Systems & Batteries
Solar Thermal Systems
Micro-Grids
Building to Grid Integration
Waste to Energy

12. Industrial Systems

Industrial Energy Management
Pumps, System and Performance Curves

Compressed Air Systems
Compressed Air Equipment, Supply, Control, Treatment and Distribution
Compressed Air Demand
Industrial Process Steam Systems
Turbines
Industrial Fan Types and Applications
Industrial Refrigeration
Waste Heat Recovery
Heat Exchanger Types

13. Operations, Maintenance and Commissioning
Maintenance Strategies: Reactive, Preventive and Predictive
Computerized Maintenance Management System
Quantifying Losses from Compressed Air Leaks
Quantifying Losses from Uninsulated Pipes
Quantifying Steam Leaks
Quantifying Losses from Steam Trap Malfunction
Quantifying Losses from Boiler Scale or Soot
Water Treatment
Group Relamping
Human Behavior in Energy Management
Purpose and Benefits of Commissioning
Commissioning New Buildings
Re-Commissioning
Retro-Commissioning
Real Time and Continuous Commissioning
Phases of Commissioning
Commissioning Agent/Authority
Need for Commissioning
Facility Design Intent
Commissioning Documentation
Measurement in Support of Commissioning

14. Energy Savings Performance Contracting and Measurement & Verification
Loans, Stocks and Bonds
Capital and Operating Leases
Utility Financing
Energy Service Companies
Energy Savings Performance Contracting (ESPC)
Project Development Agreements
Shared Savings as well as Guaranteed Savings Contracts
Utility Energy Services Contract (UESC)

Measurement and Verification Protocols
Savings and/or Avoided Cost Calculations and/or Verification
Risk Assessment

EXAM REVIEW QUESTIONS (Sample Only)

Some of these review questions may be more complex or difficult than the exam but will be good practice problems.

1. What is the basis for Commercial Building Codes by most states?
   A. ASHRAE 90.2
   B. ASHRAE 90.1
   C. ASHRAE 62.2
   D. ASHRAE 60.1

2. ASHRAE Standard 55 has rules for:
   A. Ventilation for acceptable indoor air quality
   B. Energy standard for buildings except low rise residential buildings
   C. Thermal environmental conditions for human occupancy
   D. All the above

3. If electricity is selling for $0.06 per kilowatt-hour and is used for electric heating with an efficiency of 90%, what is the equivalent price of natural gas per therm if it can be burned with an efficiency of 80%?
   A. $1.33/therm
   B. $1.47/therm
   C. $1.56/therm
   D. $1.65/therm
   E. $1.780/therm

4. An energy saving device will save $25,000 per year for 8 years. How much can a company pay for this device if the interest rate (discount rate) is 15%?
   A. $10,000
   B. $77,000
   C. $112,000
   D. $173,000

5. What would be used to find hot spots or phase imbalances in an AC circuit?
   A. Ohmmeter
   B. Infrared Camera
   C. Wattmeter
   D. All of the above

6. An audit for one firm showed that the power factor is almost always 70% and that the demand is 1000kW. What capacitor size is needed to correct power factor to 90%?
   A. 266 kVAR
   B. 536 kVAR
   C. 618 kVAR
   D. 1000 kVAR

7. The amount of reactive power that must be supplied by capacitors to correct a power factor of 84% to 95% in a 400 HP motor at 75% load and 98% efficiency is
   A. 72.4 kVAR
   B. 82.5 kVAR
   C. 90.04 kVAR
   D. 92.4 kVAR
   E. 123.5 kVAR

8. Power factor correcting capacitors may be located
   A. At the inductive load
   B. At load control centers
   C. At the customer side of the service transformer
   D. All of the above

9. You find that you can replace a 50 HP motor with a 5 HP motor by cutting the total air flow requirements. Both motors operate at full load. Calculate the total dollar savings, given the information below: {Hint: savings of 45 HP}

Runtime:	8,760 hours/year
Motor Efficiency:	90% (both motors)
Electrical Rate:	$9.00/kW/mo
	$0.05/kWh
Fuel Cost Adjustment:	$0.005/kWh

   A. $22,000
   B. $18,798
   C. $15,650
   D. $12,710
   E. $9,874

10. An absorption system with a COP of 0.8 is powered by hot water that enters at 200 F and exits at 180 F at a rate of 25 gpm. The chilled water operates on a 10 F temperature difference. Calculate the Chilled water flow. You do not need to know how an absorption chiller works to solve this problem.
    Use COP = qout/qin.
    A. 10 gpm
    B. 20 gpm
    C. 40 gpm
    D. 45 gpm
    E. 50 gpm

11. 10,000 cfm of air leaves an air handler at 50 F; it is delivered to a room at 65 F. No air was lost in the duct. No water was added or taken away from the air in the duct. How many BTU/hr was lost in the ductwork due to conduction?
    A. 162,000 BTU/hr
    B. 126,550 BTU/hr
    C. 75,000 BTU/hr
    D. 42,550 BTU/hr
    E. 10,000 BTU/hr

12. An investment tax credit of 10% for a **single project** (Not the company) at a large company:
    A. Reduces the company's overall taxes by 10%
    B. Increases depreciation rate by 10%
    C. Effectively reduces first cost of the project by 10%
    D. A and C

13. Air at 69 F dry bulb and 50% relative humidity flows at 6750 cubic feet per minute and is heated to 90 F dry bulb. How many BTU/hr is required in this process?
    A. 50,000 BTU/hr
    B. 75,000 BTU/hr
    C. 152,000 BTU/hr
    D. 310,000 BTU/hr

14. Estimate the seasonal energy consumption for a building if its design-heating load has been determined to be 350,000 BTU/hr for a design temperature difference of 70 F. This means that the Building Load Coefficient, U x A, equals 5000. The heating season has 3,500-degree days. The heating unit efficiency is 80%. Assume 1 MCF = 10^6 BTU.
    A. 625 MCF/year
    B. 525 MCF/year
    C. 420 MCF/year
    D. 356 MCF/year
    E. 225 MCF/year

15. A wall has a total R-value of 15. Determine the annual cost of the heat loss per square foot in a climate having 5,000 heating degree-days. The heating unit efficiency is 70% and the fuel cost is $5.00/million BTUs.
    A. \$0.057/yr/ft^2
    B. \$0.040/yr/ft^2
    C. \$0.0312/yr/ft^2
    D. \$0.0201/yr/ft^2

16. A 10,000 square foot building consumed the following amounts of energy last year. What is the Energy Use Index of the building in BTU per square foot per year?
    - Natural Gas 5,000 therms/year
    - Electricity 60,000 kWh/year

    A. 7,500 BTU/square foot/yr
    B. 18,000 BTU/square foot/yr
    C. 31,500 BTU/square foot/yr
    D. 70,500 BTU/square foot/yr
    E. 700,000 BTU/square foot/yr

17. Assuming that adding 2 inches of fiberglass insulation drops the U-value of a building from 0.24 to 0.098, calculate the annual cooling savings per square foot from the data given below:
    - 2,000 cooling degree days; Cooling COP = 2.5; Electrical cost $0.05/kWh

    A. $0.010/ft^2-yr
    B. $0.025/ft^2-yr
    C. $0.040/ft^2-yr
    D. $0.195/ft^2-yr
    E. $0.202/ft^2-yr

18. How much fuel is wasted if 100 pounds per hour of condensate at 30 psia saturated liquid is drained to the sewer and is made up with water at 60 F. Assume the boiler is 80% efficient and ignore blowdown effects.
    A. 12,090 BTU/hr
    B. 15,200 BTU/hr
    C. 18,000 BTU/hr
    D. 23,850 BTU/hr
    E. 29,800 BTU/hr

19. Select the equipment best suited to efficient **air-to-air heat exchange and humidity** control in the HVAC system of a large office building:
    A. Heat pipe
    B. Radiation recuperator
    C. Rotary sensible heat wheel
    D. Shell and tube heat exchanger
    E. Run around heat exchanger loop

20. Chilled water reset increases chiller efficiency and succeeds because it ________ .
    A. Restarts the system.
    B. Raises the water temperature leaving the chiller.
    C. Lowers the water flowrate through the chiller.
    D. Stops water flow to zones with no occupancy.

21. The difference between the setting at which the controller operates to one position and the setting at which it changes to the other is known as the:
    A. Throttling range
    B. Offset
    C. Differential
    D. Control Point

22. An all-electric facility pays $100,000 annually for energy. The compressed air system has energy costs of $20,000 per year. The system air pressure can be lowered by 10 psi. Approximately how much will be saved annually?
    A. $20,000
    B. $10,000
    C. $5,000
    D. $2,000
    E. $1,000

23. With a load leveling TES strategy, a building manager will
    A. Not operate the chiller during peak hours
    B. Essentially base load the chiller (i.e., operate at high load most of the time)
    C. Operate only during the peaking times
    D. Operate in the “off” season

24. In retrofitting a large commercial building with a TES, which of these considerations would be least important?
    A. System efficiency
    B. Space issues
    C. Demand cost
    D. Equipment cost

25. A building presently has the following lighting system:

    Present System
    Type: 196 mercury vapor light fixtures
    Size: 250 watt/lamp (285 watt/fixture, including ballast)

    You have chosen to replace the existing system with the following:

    Proposed System
    Type: 140 high pressure sodium fixtures
    Size: 150 watt/lamp (185 watt/fixture)

    The facility operates 24 hours/day. Approximate the **heating effect** if the heating system efficiency is 80%, fuel costs $5.00 per million BTUs and there are 200 heating days (not heating degree days) per year. That is, find the increased heating cost for the heating system when the lights are more efficient, and produce less heat.
    A. $6,986/year
    B. $5,289/year
    C. $4,485/year
    D. $3,070/year
    E. $2,548/year

26. A program available at no-cost from a US Department of Energy website that displays cost and efficiency data on electric motors is:
    A. Freeware
    B. Building Life Cycle Cost
    C. MotorMaster
    D. 3EPlus
    E. QuickPEP

27. Given the same amount of excess air and the same flue gas stack temperature rise (look at 50% excess air and 500 degrees F stack temperature rise, for example), which fuel provides the highest boiler combustion efficiency?
    A. Natural Gas
    B. No. 2 Fuel Oil
    C. No. 6 Fuel Oil

28. A boiler is rated at 30 boiler horsepower and 80% efficient. What is the input rating?
    A. 1,255,000 BTU/hr
    B. 1,005,000 BTU/hr
    C. 2,502, 500 BTU/hr
    D. 3,628,750 BTU/hr
    E. 13,400,000 BTU/hr

29. In a steam system, several things can happen to the condensate. Which of these is the best from the standpoint of energy expense?
    A. Drain condensate to sewer
    B. Recover condensate in an insulated system at atmospheric pressure
    C. Recover condensate in an un-insulated system at boiler pressure
    D. Recover condensate in an insulated system at or near boiler pressure

30. Which of the following projects, or ECOs, would likely reduce boiler and steam system costs?
    A. Adding boiler endplate insulation
    B. Installing condensate return system
    C. Repairing steam leaks
    D. Installing combustion air preheater
    E. All the above

31. Estimate the waste heat available in Btu/minute from a refinery flare gas leaving a process unit at 800 deg F if it is flowing at 1,000 cfm and weighs 0.08 lb/cubic foot. Its specific heat or heat content over the temperature range is 0.3 Btu/lb·°F and you should assume the waste gas could be reduced in temperature to 250 deg F.
    A. 178,000 Btu/min
    B. 165,000 Btu/min
    C. 44,000 Btu/min
    D. 19,200 Btu/min
    E. 13,200 Btu/min

32. Water at 70 deg F is supplied to a 100 psia boiler. 1000 lb/hr of steam from the boiler is supplied to a process. How much heat was required to be added in the boiler to create the 1000 lb/hr of steam?
    A. 1000 Btu/hr
    B. 234,500 Btu/hr
    C. 729,250 Btu/hr
    D. 1,150,000 Btu/hr
    E. 3,759,000 Btu/hr

33. A 100 HP rotary screw air-compressor generates heat equivalent to about:
    A. 1000 Btu/hr
    B. 12,000 Btu/hr
    C. 100,000 Btu/hr
    D. 250,000 Btu/hr

34. An optimum start is a control function that**:**
    A. shuts off the outside ventilation air during start up of the building
    B. shuts off equipment for duty cycling purpose
    C. senses outdoor and indoor temperatures to determine the start time needed to heat or cool down a building to desired temperatures
    D. starts randomly

35. Which of the following could be used to detect failed steam traps?
    A. Ultrasonic equipment to listen to the steam trap operation
    B. Infrared camera to detect the change in temperature
    C. Real time MMS using conductance probes
    D. All of the above

36. Calculate the group re-lamping interval for T8 lamp fixtures with instant start ballasts that annually operate for 4,160 hrs with rated life of 15,000 hrs (assuming replacements at 70% of rated life)
    A. 1.0 year
    B. 2.5 years
    C. 3.5 years
    D. 4.5 years

CEM Exam questions Key

Questions	Answers
1	(B)
2	(C)
3	(C)
4	(C)
5	(B)
6	(B)
7	(A)
8	(D)
9	(A)
10	(C)
11	(A)
12	(C)
13	(C)
14	(B)
15	(A)
16	(D)
17	(C)
18	(D)

Questions	Answers
19	(A)
20	(B)
21	(C)
22	(E)
23	(B)
24	(A)
25	(D)
26	(C)
27	(C)
28	(A)
29	(D)
30	(E)
31	(E)
32	(D)
33	(D)
34	(C)
35	(D)
36	(B)

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CEM application, procedures, requirements, and eligibility are subject to change.