# CEA BODY OF KNOWLEDGE AND STUDY GUIDE
## Preparation for the CEA Certification Exam

The CEA 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 and background and experience of Energy Auditors, the examination has 12 different subject sections, all of which are included in the exam. You must bring a hand-held calculator to the exam as the CEA 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 20 Exam Review questions included in the Study Guide to determine your readiness for the exam.

**The CEA Examination contains the following subjects:**

| Body of Knowledge | | Percent of Exam |
|---|---|---|
| 1 | Developing an Energy Audit Strategy & Plan | 9% - 13% |
| 2 | Energy Use Analysis | 7% - 11% |
| 3 | Data Collection & Analysis | 8% - 12% |
| 4 | Economic Analysis | 7% - 11% |
| 5 | Lighting Systems | 6% - 8% |
| 6 | Heating, Ventilation & Air Conditioning Systems | 12% - 18% |
| 7 | Domestic Hot Water Systems | 5% - 7% |
| 8 | Motors & Drives & Compressed Air Systems | 8% - 12% |
| 9 | Building Envelope | 6% - 8% |
| 10 | BAS, PAS and EMCS | 6% - 8% |
| 11 | Alternative Generation & Storage | 4% - 6% |
| 12 | Transport | 3% - 5% |

# CERTIFIED ENERGY AUDITOR® (CEA®) EXAM

The following is a list of the subjects for the CEA exam. Each subject covers several topics. Following the list of topics are suggested references with chapter numbers. The primary references are the Handbook of Energy Audits, 9th Edition, by Albert Thumann, Terry Niehus, and William J. Younger, the Commercial Energy Auditing Reference Handbook, 3rd Edition by Steve Doty, Energy Management Handbook, 9th Edition by Stephen Roosa, Steve Doty and Wayne C. Turner and the Certified Energy Auditor Training Workbook, 2021.

The exam will: be open book, four hours, and have 120 multiple choice questions to answer. Of the 120 questions, 100 are scored and 20 randomly located questions are trial questions being prepared for possible use on future exams. The 20 trial questions do not count toward the examinee's score. The trial questions are randomly located and are not identified. Therefore, all 120 questions should be answered. There are 12 sections listed below from which questions mainly are drawn.

## BODY OF KNOWLEDGE: STUDY GUIDE TOPICS & REFERENCES

| 1 | **Developing an Energy Audit Strategy & Plan** |
|---|---|
| 101 | Plan an energy audit |
| 102 | Define required audit procedures |
| 103 | Define the project team |
| 104 | Determine appropriate audit level |
| 105 | Define pre-audit tasks |
| 106 | Define data & instrumentation required for energy analysis |
| 107 | Communicate procedures and data gathering |
| 108 | Identify operations and maintenance team and create pre-audit O&M interview questions |
| 109 | Define audit report format and requirements |
| 110 | Draft audit report / final audit report |
| 111 | Conduct audit follow-up |
| 112 | Support ISO 50001 Energy Management Systems |
| 113 | Understand industry standards (ASHRAE 211, ISO 50002) |
| 114 | Awareness of code, legal, industry-specific energy requirements |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapters 2 and 3
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapter 1
REF: **Certified Energy Auditor Training Workbook**, Section 1

| 2 | **Energy Use Analysis** |
|---|---|
| 201 | Define required energy usage & other information |
| 202 | Review rate classifications |
| 203 | Establish utility / costs baseline |
| 204 | Establish utility / energy usage baseline |
| 205 | Establish relevant variables, regression analysis, energy performance indicators |
| 206 | Analyze Energy Use Graphs |
| 207 | Facility benchmarking, targets, EUI, ECI, load factor & savings potential |
| 208 | Analyze & breakdown energy end use |

| | |
|---|---|
| 209 | Utilize balance point temperature |
| 210 | Perform analysis of fleet information |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 4 and 23
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapters 2 and 3
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapters 1 and 6
REF: **Certified Energy Auditor Training Workbook**, Section 2

| 3 | **Data Collection & Analysis** |
|---|---|
| 301 | Define pre-site data collection |
| 302 | Collect pre-site data |
| 303 | Define on-site data collection |
| 304 | Collect on-site data |
| 305 | Determine EEMs to be evaluated/considered |
| 306 | Account for interactive effects of measures |
| 307 | Understand energy modelling methods (Ordinary Least Square = regression) |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 27
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapters 2 and 4
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapter 6
REF: **Certified Energy Auditor Training Workbook**, Section 3

| 4 | **Economic Analysis** |
|---|---|
| 401 | Review client financial decision-making criteria (Investment projects, The Need for Life Cycle Cost Analysis (LCCA), Capital Investment Characteristics) |
| 402 | Costing both O&M and capital EEMs |
| 403 | Understand financial calculations and results (Simple Payback Period (SPP), Net Present Value (NPV), Internal Rate of Return (IRR), Life Cycle Cost (LCC), Free Cash Flow (FCF), Saving to Investment Ratio (SIR) – Benefit cost Ratio (BCR), Analysis of projects with different life spans: Annual Value (AV), Replacement Chain Approach (RCA), Equivalent Annual Annuity (EAA) |
| 404 | Conduct economic analysis of transport options |
| 405 | Conduct What-if Analysis (Break-even Analysis, Sensitivity Analysis, Scenario Analysis) |
| 406 | Perform detailed financial analysis |
| 407 | Present results of analysis (Cash Flow Diagram, Revenues and Costs, Indirect Effects on Incremental Earnings) |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 4
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapters 2 and 4
REF: **Certified Energy Auditor Training Workbook**, Section 4

| 5 | **Lighting Systems** |
|---|---|
| 501 | Determine efficiency/efficacy of light source |
| 502 | Calculate replacement period given lamp lumen depreciation |
| 503 | Determine lamp & fixture types and characteristics |
| 504 | Evaluate lamp types & characteristics for replacement |
| 505 | Audit lighting control system |
| 506 | Calculate Lighting power density |

| | |
|---|---|
| 507 | Evaluate illumination levels |
| 508 | Evaluate daylight harvesting opportunities |
| 509 | Identify energy efficiency measures (EEMs) |
| 510 | Evaluate O&M characteristics and opportunities |
| 511 | Calculate energy savings |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 13
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapter 7
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapter 16
REF: **Certified Energy Auditor Training Workbook**, Section 5

| 6 | **Heating, Ventilation & Air Conditioning Systems** |
|---|---|
| | ***HVAC*** |
| 601 | Evaluate and identify HVAC terminal units |
| 602 | Audit & determine types of HVAC systems |
| 603 | Determine existing HVAC efficiencies |
| 604 | Identify existing control strategies including locations of thermostats, scheduling of loads and occupants |
| 605 | Identify HVAC system components |
| 606 | Audit & determine types of chillers: electric, gas driven, absorbers |
| 607 | Identify piping arrangements for chilled water and or refrigerant systems |
| 608 | Audit & determine types of heat pump, chillers, or split system units |
| 609 | Examine filter performance and maintenance |
| 610 | Identify energy efficiency measures (EEMs) |
| 611 | Evaluate O&M characteristics and opportunities |
| 612 | Calculate energy savings |
| | ***Heating Systems*** |
| 613 | Audit & determine types of boilers: fire tube, water tube, cast iron & burners (atmospheric, power burners, modulating …) |
| 614 | Audit & determine types of furnaces: electric, gas, pulse, condensing |
| 615 | Determine existing boiler efficiencies |
| 616 | Evaluate distribution systems, (ductwork and/or piping), for insulation, pressure drop, leaks and steam traps |
| 617 | Identify terminal units |
| 618 | Identify energy efficiency measures (EEMs) |
| 619 | Evaluate O&M characteristics and opportunities |
| 620 | Calculate energy savings |
| | ***Ventilation Systems*** |
| 621 | Audit & determine types of ventilation systems |
| 622 | Examine filters types classification and energy impacts |
| 623 | Determine ventilation requirements (code related) |
| 624 | Evaluate ventilation control options |
| 625 | Identify energy efficiency measures (EEMs) |
| 626 | Evaluate O&M characteristics and opportunities |

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|---|---|
| 627 | Calculate energy savings |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 10
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapter 8 and 9
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapter 11 and 14
REF: **Certified Energy Auditor Training Workbook**, Section 6

| **7** | **Domestic Hot Water Systems** |
|---|---|
| 701 | Audit & determine types of hot water systems |
| 702 | Calculate efficiencies |
| 703 | Identify temperature set points |
| 704 | Evaluate circulating systems |
| 705 | Identify energy efficiency measures (EEMs) |
| 706 | Evaluate O&M characteristics and opportunities |
| 707 | Calculate energy savings |
| | ***Water Conservation*** |
| 708 | Evaluate irrigation and landscaping installation and efficiency |
| 709 | Audit water use |
| 710 | Identify water efficiency measures |
| 711 | Evaluate O&M characteristics and opportunities |
| 712 | Calculate water savings |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapters 5 and 21
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapter 13
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapters 18 and 22
REF: **Certified Energy Auditor Training Workbook**, Section 7

| **8** | **Motors and Drives & Compressed Air Systems** |
|---|---|
| | ***Motors and Drives*** |
| 801 | Understand electrical fundamentals (inductive & resistive loads, power factor) |
| 802 | Audit & determine types and sizes of motors |
| 803 | Evaluate appropriate types of motors |
| 804 | Determine operating characteristics of motors and drives |
| 805 | Calculate efficiencies of motors and drives |
| 806 | Review potential energy savings of variable frequency drives |
| 807 | Identify energy efficiency measures (EEMs) |
| 808 | Evaluate O&M characteristics and opportunities |
| 809 | Calculate energy savings |
| | ***Compressed Air Systems*** |
| 810 | Analyze existing conditions for improvement opportunities |
| 811 | Identify supply (Compressor types, operation, control, application, heat recovery) |
| 812 | Evaluate treatment & distribution (condensate, drying, filtering, storage, distribution) |
| 813 | Characterize demand (leaks, inappropriate use, artificial demand) |
| 814 | Identify energy efficiency measures (EEMs) |
| 815 | Evaluate O&M characteristics and opportunities |

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|---|---|
| 816 | Calculate energy savings |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapters 11 and 22
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapters 7 and 10
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapter 12 and 14
REF: **Certified Energy Auditor Training Workbook**, Section 8

| **9** | **Building Envelope** |
|---|---|
| 901 | Determine R and U values |
| 902 | Evaluate efficiency of walls, roofs, windows |
| 903 | Evaluate replacement with alternative glass types |
| 904 | Audit building envelope infiltration |
| 905 | Determine thermal weight |
| 906 | Identify energy efficiency measures (EEMs) |
| 907 | Evaluate O&M characteristics and opportunities |
| 908 | Understand different energy estimating and modelling methods |
| 909 | Calculate energy savings |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 9
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits**, Chapter 6
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapter 17
REF: **Certified Energy Auditor Training Workbook**, Section 9

| **10** | **Building Automation Systems, Process Automation Systems, & Energy Management and Control Systems** |
|---|---|
| 1001 | Understand energy saving control strategies |
| 1002 | Identify controls issues from EMS evaluation |
| 1003 | Understand which points exist and which should be added for particular EEMs |
| 1004 | Evaluate operator understanding and usage of systems |
| 1005 | Understand how to read trend logs and identify opportunities |
| 1006 | Understand accuracy of sensors and how to identify and handle questionable data before use |
| 1007 | Identify energy efficiency measures (EEMs) |
| 1008 | Evaluate O&M characteristics and opportunities |
| 1009 | Calculate energy savings |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 12
REF: Thumann, Niehus, and Younger, **Handbook of Energy Audits,** Chapter 2
REF: Doty, **Commercial Energy Auditing Reference Handbook**, Chapter 7
REF: **Certified Energy Auditor Training Workbook**, Section 10

| **11** | **Alternative Generation & Storage** |
|---|---|
| 1101 | Know the different alternative energy technologies |
| 1102 | Understand the different renewable and storage energy technologies, sites, and their costs |
| 1103 | Determine technical and economic implications of integrating renewable and energy storage |
| 1104 | Identify subsidies and incentives associated with alt generation or energy storage |

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|---|---|
| 1105 | Evaluate opportunities (first cut potential) in energy storage, thermal and electrical storage, and demand response |
| 1106 | Evaluate opportunities (first cut potential) for use of alternative generation, cogeneration, and renewable energy source |

REF: Roosa, Doty and Turner, **Energy Management Handbook**, Chapter 16 and 19
REF: **Certified Energy Auditor Training Workbook**, Section 11

| **12** | **Transport** |
|---|---|
| 1201 | Understand types/modes of transport (road, rail, ship, air), public transport vs. private transport |
| 1202 | Understand type of vehicles, transport sectors - options available and fuel costs (Primarily Road) |
| 1203 | Understand vehicle operation, impacts on fuel consumption, training & awareness (All modes) |
| 1204 | Understand maintenance & cost of vehicle maintenance - for different fuels (Road transport only) |
| 1205 | Understand planning and logistics, route management, fleet management, getting most benefit from the journey |
| 1206 | Evaluate data collection, energy performance Indicators, benchmarking for transport |
| 1207 | Utilize energy estimating and modelling methods, vehicle specification data vs. real life figures |
| 1208 | Understand vehicle improvements opportunities (under vehicle dampers, remove roof racks etc.) |
| 1209 | Understand information management, vehicle monitoring systems (The M&T of transport), monitoring driver performance |

REF: **Certified Energy Auditor Training Workbook**, Section 12

# 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. Which of the following is **not** correct?
   (A) 1 kWh = 3,600 kJ
   (B) 1 litre diesel = 39,000 kJ
   (C) 1 litre gasoline = 35,000 kJ
   (D) 1 cubic meter natural gas = 3,700 kJ

2. A factory has a kWh usage in August of 550,000 and a peak demand of 3,000 kW. Calculate the August energy and demand charges if the utility costs for this rate class are $0.06/kWh and $15/kW-month for demand.
   (A) $33,000
   (B) $60,000
   (C) $78,000
   (D) $45,000

3. Lighting efficacy is measured in lumens per watt.
   (A) True
   (B) False

4. A chiller has a COP of 5.02. What is the full load kW if this unit has a thermal load of 703.37 kW?
   (A) 286
   (B) 140
   (C) 900
   (D) 75

5. An office building replaced 20W CFLs with 14W LEDs. The lights are on 3,000 hrs/yr. The average electricity cost is $0.10/kWh. The cost of each LED lamp is $12. Calculate the simple payback.
   (A) 6.67 years
   (B) 8.67 years
   (C) 0.15 years
   (D) 4.25 years

6. A customer wants to install an occupancy sensor in the break room. A data logger has shown that, on average, the lights can be turned off 5 hrs/week. The lights in this room have a combined wattage of 3 kW. Electricity is $0.09/kWh and an occupancy sensor cost $150 installed. What is the simple payback?
   (A) 0.47 years
   (B) 3.63 years
   (C) 0.90 years
   (D) 2.14 years

7. A commercial customer has set a peak demand of 100 kW and has used 45,500 kWh during the 30-day billing period month of April. Calculate the load factor for the April billing period.
   (A) 0.63
   (B) 0.42
   (C) 0.81
   (D) 1.63

8. The terms load factor and power factor can be used interchangeably.
   (A) True
   (B) False

9. A three-phase AC induction motor draws 13 amps at 240 volts. The power factor is 0.9. Determine the kW.
   (A) 5.54
   (B) 5.16
   (C) 4.86
   (D) 6.32

10. A hospital uses 1,520,000 litres of water per year just for showers. The showers have recently been replaced from an old style showerheads that used 17.1 litres per minute with showerheads that meet the July 2018 WaterSense specification. What is the annual amount of water (in litres) that will be saved by replacing these showerheads with the WaterSense showerheads (assuming the same number of showers will be taken each year)?
    (A) 285,770 litres per year
    (B) 385,580 litres per year
    (C) 675,560 litres per year
    (D) 844,440 litres per year

11. An office building has the following:
    Existing: 100 T-12 fixtures @ 164 watt/fixture
    Proposed: 100 T-8 fixtures @ 106 watts/fixture
    4,000 hrs/yr operation
    Utility costs: $.10/kWh and $13/kW-month
    Installation cost: $100/fixture
    Determine the simple payback.
    (A) 0.32 years
    (B) 1.86 years
    (C) 3.10 years
    (D) 2.46 years

12. A company has a 300 kW natural gas boiler with an efficiency of 70%. They want to replace it with a 90% efficient condensing boiler. The average fuel usage at the meter for the last five heating seasons was 2,111 GJ. If natural gas costs 0.035 €/kWh, calculate the annual savings per heating season for switching to a condensing boiler.
    (A) 1,670 €
    (B) 2,660 €
    (C) 4,170 €
    (D) 4,560 €

13. A two-pole pair three-phase AC induction motor is installed in Madrid. What is the synchronous speed of this motor?
    (A) 1,500 RPM
    (B) 1,800 RPM
    (C) 3,000 RPM
    (D) 3,600 RPM

14. A 15 kW standard fan motor runs 8,760 hours per year has an efficiency of 86.5%. What will the simple payback be for replacing this motor with a 15 kW premium one with an efficiency of 93.5%? The premium motor cost $725 installed. The utility charges are $0.05/kWh and $14.00/kW-month. Motor loading is 0.7.
    (A) 0.75 years
    (B) 2.65 years
    (C) 1.32 years
    (D) 3.33 years

15. How many kW of cooling are supplied by a chiller with a 10°C chilled water supply temperature, a 15°C chilled water return temperature with a chilled water flow rate of 15 litres per second?
    (A) 116 kW
    (B) 315 kW
    (C) 488 kW
    (D) 562 kW

16. A building wall is made up of the following materials:

| | |
|---|---|
| Concrete block | R = 2.2 |
| Brick façade | R = 3.1 |
| Drywall | U= 0.5 |

What is the total R value of this wall?
    (A) 5.8
    (B) 7.3
    (C) 6.4
    (D) 1.9

17. True motor slip is defined as:
    (A) Pulley (sheave) displacement
    (B) Percentage of winding drift
    (C) The difference between the synchronous speed and actual speed
    (D) The difference between nominal efficiency and actual efficiency

18. An energy efficient chiller has a cooling COP of 7.8. What is the equivalent cooling EER?
    (A) 2.2 kJ/Wh
    (B) 3.2 kJ/Wh
    (C) 4.2 kJ/Wh
    (D) 28.1 kJ/Wh

19. A 14 kW heat pump with a SEER of 14 kJ/Wh and an HSPF of 8.0 kJ/Wh operates 3,100 full load hours/yr in the cooling mode and 1,200 hours/yr in the heating mode. What are the annual operating cost if the electricity costs $0.15/kWh?
    (A) $2,808/yr
    (B) $3,200/yr
    (C) $4,878/yr
    (D) $1,320/yr

20. Motor slip is proportional to loading.
    (A) True
    (B) False

Answer Key:

1- D
2- C
3- A
4- B
5- A
6- D
7- A
8- B
9- C
10- D
11- C
12- D
13- A
14- C
15- B
16- B
17- C
18- D
19- A
20- A