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, last 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
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
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
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

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. Which of the following is an approximation?
   (A) 10 kWh = 34,120 Btus
   (B) 5 therms = 500,000 Btus
   (C) 3 tons of air conditioning = 36,000 Btu/hr
   (D) 1 MCF = 1 MMbtu

2. A factory has a kWh usage in August of 550,000 and a peak demand of 3,000 kW. Calculate the July 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. The lighting efficacy term is lumens per watt.
   (A) True
   (B) False

4. A chiller has a full load rating of 0.7 kW/ton. What is the full load kW if this unit has a 200 ton rating?
   (A) 286
   (B) 140
   (C) 900
   (D) 75

5. An office building replaced 20 W CFLs with 14W LEDs. The lights are on 3,000 hrs/yr. The average electricity cost is $0.10/kWh and the LEDs are $12 each. 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 a peak demand of 100 kW and has used 45,500 kWh for January (31 Days). Calculate the load factor.
   (A) 0.61
   (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 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 400,000 gallons of water per year just for showers. The showers have the old style showerheads that use 4.5 gpm. What is the annual amount of water saved if they replace the showerheads with new ones that used 2.0 gpm as a flow rate?
    (A) 200,000 gallons per year
    (B) 285,765 gallons per year
    (C) 222,222 gallons per year
    (D) 177,778 gallons 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 1 MMBtu/hr boiler with an efficiency of 70%. They want to replace it with a 90% efficient condensing boiler. The average fuel usage for the last five heating seasons was 20,000 therms. If a therm cost $0.60, calculate the annual savings per heating season.
    (A) $4,388
    (B) $2,667
    (C) $10,000
    (D) $3,185

13. The speed of a three phase induction motor is determined by the line voltage.
    (A) True
    (B) False

14. A 20 HP 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 20 HP 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) 1.33 years
    (D) 3.33 years

15. How many Btu/hr of cooling are supplied by a chiller with a 45°F chilled water supply temperature, a 57°F chilled water return temperature and a 2.5 gpm water pump?
    (A) 9,252 Btu/hr
    (B) 12,000 Btu/hr
    (C) 120,000 Btu/hr
    (D) 15,000 Btu/hr

16. A building wall is made up of the following material resistance's:
    Outside Air Film (7.5mph) - R = 0.25
    Concrete Block - R = 2.2
    Brick Facade - R = 3.1
    Drywall - R = 2
    Inside Air Film - R = 0.68

    What is the U value of this wall?
    (A) 8.23
    (B) 6.75
    (C) 0.12
    (D) 0.14

17. Motor slip is defined as:
    (A) Pulley 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 absorption chiller has a COP of 0.7. What is the EER?
    (A) 4.87
    (B) 13.2
    (C) 3.41
    (D) 2.39

19. A four-ton heat pump with a SEER of 14 and an HSPF of 8.0 operates 3,100 full load hours/yr in the cooling mode and 1,200 hours/yr in the heating mode. What is the annual operating cost if electricity is $0.15/kWh?
    (A) $2,675/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- C
11- C
12- B
13- B
14- C
15- D
16- C
17- C
18- D
19- A
20- A