

PRACTICE PAPER — NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS

PAPER – 1: GENERAL ASPECTS OF ENERGY MANAGEMENT & ENERGY AUDIT

Question code: 1P1CEM001 – 1P1CEM064 | SOLUTIONS & MODEL ANSWERS

Duration: 3 HRS Max. Marks: 150 Pass: 50% marks in the paper

General instructions:

- Please check that this question paper contains 64 questions
- The question paper is divided into three sections
- All questions in all three sections are compulsory
- All parts of a question should be answered at one place
- Use of a non-programmable scientific calculator is permitted; show formula, substitution with units and result for every numerical

Disclaimer: Independent practice paper prepared by Beyond Smart Cities / Beyond Xlearn (learn.beyondsmartcities.in). Not affiliated with, endorsed by or issued by the Bureau of Energy Efficiency (BEE) or the National Productivity Council (NPC). All questions are original and written to the pattern of the National Certification Examination; the official BEE guidebook remains the authority.

Section – I: OBJECTIVE TYPE

Marks: 50 × 1 = 50

- (i) Answer all 50 questions
(ii) Each question carries one mark

1. A country consumes 950 Mtoe of primary energy a year and its GDP at constant prices is ₹ 260 lakh crore. What is its energy intensity expressed in kgoe per ₹1,000 of GDP?

[1P1CEM001 | Chapter 1: Energy Scenario | Energy intensity of GDP in rupee terms]

- a) 0.365 kgoe/₹1,000
- b) 0.274 kgoe/₹1,000
- c) 36.538 kgoe/₹1,000
- d) 3.654 kgoe/₹1,000

Correct answer: (d) 3.654 kgoe/₹1,000.

Given: primary energy = 950 Mtoe = 950×10^9 kgoe (≈ 39.8 EJ); GDP = ₹ 260 lakh crore = ₹ 260×10^{12} = 260×10^9 thousand rupees (1 lakh crore = 10^{12}).

Formula: Energy intensity = Energy consumption ÷ GDP (guidebook definition; GDP at constant prices so that inflation does not distort the trend).

Substitution: EI = 950×10^9 kgoe ÷ 260×10^9 (₹1,000 units) = 3.654 kgoe/₹1,000.

Result: **3.654 kgoe/₹1,000 (≈ 153 MJ/₹1,000) of GDP**, equivalent to 36.5 toe ($\approx 1,528$ GJ) per ₹ crore since ₹ 1 crore = $10^4 \times$ ₹1,000.

Why the other options are wrong: (a) 0.365 kgoe/₹1,000 – results from taking 1 Mtoe as 10^8 kgoe instead of 10^9 kgoe. (b) 0.274 kgoe/₹1,000 – is the inverse ratio (thousands of rupees of GDP per kgoe), which is energy productivity, not energy intensity. (c) 36.538 kgoe/₹1,000 – results from taking 1 lakh crore as 10^{11} instead of 10^{12} rupees (decimal slip of one place).

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 1 – Energy Scenario.

2. The proven coal reserves of a country at the end of a year are 36 billion tonnes and production in that year was 0.9 billion tonnes. Which interpretation of the resulting R/P ratio is technically correct?

[1P1CEM002 | Chapter 1: Energy Scenario | Reserves-to-production (R/P) ratio]

- a) Reserves last 0.025 years because R/P is production divided by reserves
- b) Reserves will certainly last 40 years even if output keeps growing

c) Reserves last 40 years only if new discoveries equal this year's output

d) Reserves last 40 years only if output stays at this year's level

Correct answer: (d) Reserves last 40 years only if output stays at this year's level.

Given: reserves remaining at end of year R = 36 billion t; production in that year P = 0.9 billion t/yr.

Formula: R/P ratio = Reserves remaining at end of year ÷ Production in that year (guidebook).

Substitution: $R/P = 36 \div 0.9 = 40$ years.

Result: **40 years, valid only if production continues at the present rate.** The ratio is a static indicator: it neither assumes growth in output nor new discoveries, so real life of the reserve will differ.

Why the other options are wrong: (a) This option inverts the ratio; R/P is reserves remaining ÷ annual production. (b) This option ignores that R/P assumes constant production; rising output shortens the life. (c) R/P is a static snapshot; it does not assume any new additions to reserves.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 1 – Energy Scenario.

3. Which of the following actions in a factory is an energy efficiency measure rather than a pure energy conservation (curtailment) measure?

[1P1CEM003 | Chapter 1: Energy Scenario | Energy conservation vs energy efficiency]

a) Running the compressor house for one shift less on weekly maintenance days

b) Replacing a standard motor with an IE3 motor giving the same shaft output

c) Raising the air-conditioning set point of offices from 22 °C to 26 °C

d) Switching off corridor lights in the canteen during the lunch break hours

Correct answer: (b) Replacing a standard motor with an IE3 motor giving the same shaft output.

Energy efficiency means using less energy to provide the same service or output (lower energy per unit of output), whereas energy conservation is the broader idea of reducing energy use, often by curtailing or changing the level of service. A higher-efficiency (IE3) motor delivers the identical shaft power with lower input kW because its losses are lower, so output is unchanged and energy per unit of output falls.

Why the other options are wrong: (a) This option is reduction of operating hours (curtailment), not an improvement in efficiency. (c) Reduces energy by accepting a lower level of service (comfort) - a conservation action. (d) This option is conservation by curtailment; it reduces service, not energy per unit of service.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 1 – Energy Scenario.

4. Over a decade, a country's GDP grew at 7% a year, primary energy use at 4.5% a year and population at 1.2% a year. Which statement is consistent with these trends?

[1P1CEM004 | Chapter 1: Energy Scenario | Energy intensity and economic growth]

a) Energy intensity rose while per capita energy use kept on falling

b) Energy intensity fell while per capita energy use still kept rising

c) Energy intensity and per capita energy use both kept falling

d) Energy intensity stayed constant while per capita energy use rose

Correct answer: (b) Energy intensity fell while per capita energy use still kept rising.

Given: GDP growth 7%/yr, energy growth 4.5%/yr, population growth 1.2%/yr.

Formula: Energy intensity = Energy ÷ GDP; per capita energy = Energy ÷ Population.

Substitution: change in intensity per year = $1.045/1.07 - 1 = -2.34\%$; change in per capita energy = $1.045/1.012 - 1 = +3.26\%$.

Result: **intensity falls (~2.3%/yr) while per capita energy rises (~3.3%/yr)** — the normal pattern of a growing, modernising economy.

Why the other options are wrong: (a) GDP grew faster than energy, so intensity (energy/GDP) must fall; energy grew faster than population, so per capita use rose. (c) Per capita use cannot fall when energy grows at 4.5% and population only at 1.2%. (d) Intensity is constant only if energy and GDP grow at the same rate.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 1 – Energy Scenario.

5. Under the PAT scheme a designated consumer had a baseline SEC of 0.80 toe/t and a notified target SEC of 0.75 toe/t. In the assessment year it achieved 0.72 toe/t at a production of 2,00,000 t. How many ESCerts (1 ESCert = 1 toe) is it entitled to?

[1P1CEM005 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | PAT scheme - Energy Saving Certificates]

- a) 16,000 ESCerts
- b) 10,000 ESCerts
- c) 6,000 ESCerts
- d) 600 ESCerts

Correct answer: (c) 6,000 ESCerts.

Given: target SEC = 0.75 toe/t (≈ 31.4 GJ/t); achieved SEC = 0.72 toe/t (≈ 30.1 GJ/t); assessment-year production = 2,00,000 t; 1 ESCert = 1 toe (≈ 41.9 GJ).

Formula: $\text{ESCert} = (\text{Target SEC} - \text{Achieved SEC}) \times \text{Production in assessment year}$.

Substitution: $(0.75 - 0.72) \times 2,00,000 = 0.03 \times 2,00,000 = 6,000$ toe.

Result: **6,000 ESCerts**, which the DC may trade on the power exchange; a DC that falls short must buy ESCerts or pay penalty.

Why the other options are wrong: (a) 16,000 ESCerts – uses baseline minus achieved SEC; only over-achievement beyond the target earns certificates. (b) 10,000 ESCerts – is the mandated saving (baseline – target), which the unit had to achieve anyway. (d) 600 ESCerts – drops a zero in the production figure.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 2 – Energy Conservation Act, 2001 and Related Policies.

6. Under the Energy Conservation Act, 2001, which of the following powers is vested in the State Government rather than the Central Government?

[1P1CEM006 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | EC Act 2001 - role of State Government]

- a) Specifying energy consumption norms for designated consumers
- b) Designating a State agency to enforce the Act locally
- c) Prohibiting sale of appliances not meeting notified standards
- d) Notifying energy-intensive industrial units as designated consumers

Correct answer: (b) Designating a State agency to enforce the Act locally.

Under Section 14 the Central Government notifies designated consumers, specifies their energy consumption norms and prohibits sale of equipment not meeting notified standards. Section 15 empowers the State Government to designate an agency (the State Designated Agency) to coordinate, regulate and enforce the Act within the State and to notify ECBC rules for local climatic conditions; Section 16 lets it constitute the State Energy Conservation Fund. Designating the SDA is therefore the State's power.

Why the other options are wrong: (a) Norms and standards for DCs are specified by the Central Government. (c) Standards and labelling enforcement is a Central Government power. (d) This option is a Central Government power under Section 14 of the Act.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 2 – Energy Conservation Act, 2001 and Related Policies.

7. Which combination correctly states the obligations of a designated consumer under the EC Act, 2001?

[1P1CEM007 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | Obligations of designated consumers]

- a) Appoint a certified energy manager; audits by an accredited energy auditor
- b) Appoint a certified energy auditor; send audit reports to the electricity regulator
- c) Appoint an accredited energy auditor as energy manager and self-certify audits
- d) Appoint a certified energy manager; audits by any in-house plant engineer

Correct answer: (a) Appoint a certified energy manager; audits by an accredited energy auditor.

A designated consumer must (i) designate or appoint a certified energy manager in charge of energy conservation activities, (ii) get an energy audit conducted by an accredited energy auditor at the intervals specified in the BEE energy

audit regulations, (iii) furnish information on energy consumed and action taken on audit recommendations to the designated agency/BEE and (iv) comply with notified norms.

Why the other options are wrong: (b) Reports go to BEE/SDA, not to the electricity regulatory commission. (c) The energy manager must be a certified energy manager, and mandatory audits are by an accredited auditor, not self-certified. (d) Mandatory energy audit must be conducted by an accredited energy auditor.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 2 – Energy Conservation Act, 2001 and Related Policies.

8. The Energy Conservation (Amendment) Act, 2010 strengthened the market mechanism of the EC Act. Which provision did it add?

[1P1CEM008 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | Energy Conservation (Amendment) Act, 2010]

- a) Standards and labelling of notified equipment and appliances with star ratings
- b) Mandatory energy audit of every designated consumer by an accredited energy auditor
- c) Issue and trading of energy savings certificates for DCs beating norms
- d) Creation of the Bureau of Energy Efficiency by merging the Energy Management Centre

Correct answer: (c) Issue and trading of energy savings certificates for DCs beating norms.

The 2010 amendment empowered the Central Government to issue energy savings certificates to designated consumers whose energy consumption is less than the prescribed norms, and allowed DCs that consume more than the norm to purchase such certificates to comply. This created the legal basis for the market-based Perform, Achieve and Trade (PAT) scheme under NMEEE.

Why the other options are wrong: (a) S&L powers date from the original 2001 Act; the amendment only tightened them. (b) The mandatory audit obligation already existed in the original 2001 Act. (d) BEE was created by the original 2001 Act (it took over the Energy Management Centre).

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 2 – Energy Conservation Act, 2001 and Related Policies.

9. Which statement about BEE's Standards & Labelling programme is correct?

[1P1CEM009 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | Standards & Labelling programme]

- a) The label is voluntary for every appliance and can never be made mandatory
- b) The label fixes the maximum retail price of each star-rated appliance
- c) The label certifies that the appliance runs only on renewable electricity
- d) The label lets buyers compare running cost, with ratings mandatory for notified items

Correct answer: (d) The label lets buyers compare running cost, with ratings mandatory for notified items.

The S&L programme provides consumers an informed choice about the energy and cost-saving potential of appliances: the star label (1 to 5 stars) indicates the relative energy efficiency and annual energy consumption so a buyer can compare running costs. Under the EC Act, the Central Government can make display of labels mandatory for notified equipment (for example frost-free refrigerators, room air conditioners, tubular fluorescent lamps and distribution transformers), while others remain voluntary.

Why the other options are wrong: (a) The EC Act allows the Centre to make labelling mandatory for notified equipment. (b) The S&L programme has no role in price regulation. (c) The label conveys energy performance, not the source of electricity.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 2 – Energy Conservation Act, 2001 and Related Policies.

10. A three-phase induction motor at 415 V draws 62 A at a power factor of 0.82. What is the active power drawn?

[1P1CEM010 | Chapter 3: Basics of Energy and its Various Forms | Three-phase power and power factor]

- a) 63.3 kW
- b) 21.1 kW
- c) 44.6 kW
- d) 36.5 kW

Correct answer: (d) 36.5 kW.

Given: $V(\text{line}) = 415 \text{ V}$; $I(\text{line}) = 62 \text{ A}$; $\cos \phi = 0.82$.

Formula: $P = \sqrt{3} \times V \times I \times \cos \phi$ (three-phase active power).

Substitution: $P = 1.732 \times 415 \times 62 \times 0.82 = 36,544 \text{ W}$.

Result: **36.5 kW** (apparent power = 44.6 kVA).

Why the other options are wrong: (a) 63.3 kW – multiplies by 3 instead of $\sqrt{3}$ with line voltage and line current. (b) 21.1 kW – uses the single-phase formula; the $\sqrt{3}$ factor for a three-phase supply is missing. (c) 44.6 kW – is the apparent power (kVA); power factor has been omitted.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 3 – Basics of Energy and its Various Forms.

11. Unsaturated air in a spinning department is measured with a sling psychrometer. Which relation between its temperatures must hold?

[1P1CEM011 | Chapter 3: Basics of Energy and its Various Forms | Psychrometry - DBT, WBT and dew point]

- a) Wet bulb > dry bulb > dew point temperature
- b) Dry bulb > wet bulb > dew point temperature
- c) Dry bulb > dew point > wet bulb temperature
- d) Dry bulb = wet bulb = dew point temperature

Correct answer: (b) Dry bulb > wet bulb > dew point temperature.

For unsaturated air, water evaporating from the wick cools the wet bulb, so $WBT < DBT$. The dew point is the temperature at which the existing vapour starts condensing when cooled at constant moisture content, and it lies below the wet bulb temperature. Thus $DBT > WBT > DPT$. All three coincide only when the air is saturated ($RH = 100\%$), when no evaporation from the wick occurs.

Why the other options are wrong: (a) Evaporative cooling always makes the wet bulb read lower than the dry bulb. (c) The dew point can never exceed the wet bulb temperature of the same air. (d) The three become equal only at 100% relative humidity (saturated air).

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 3 – Basics of Energy and its Various Forms.

12. A 22 kW (rated output) motor runs at 80% load with an efficiency of 90% for 20 h/day, 25 days a month. What is its monthly energy consumption?

[1P1CEM012 | Chapter 3: Basics of Energy and its Various Forms | Electrical energy from motor loading]

- a) 12,222 kWh
- b) 7,920 kWh
- c) 8,800 kWh
- d) 9,778 kWh

Correct answer: (d) 9,778 kWh.

Given: rated output = 22 kW; load = 0.8; $\eta = 0.9$; hours = $20 \times 25 = 500 \text{ h}$.

Formula: Input kW = (Rated output kW $\times$ % load) $\div \eta$; Energy = Input kW $\times$ hours.

Substitution: Input = $22 \times 0.8 \div 0.9 = 19.556 \text{ kW}$; Energy = $19.556 \times 500 = 9,778 \text{ kWh}$.

Result: **9,778 kWh per month** ($\approx 35.2 \text{ GJ}$).

Why the other options are wrong: (a) 12,222 kWh – assumes full load; the measured 80% loading is ignored. (b) 7,920 kWh – multiplies by efficiency instead of dividing, giving less than the output. (c) 8,800 kWh – is the shaft output energy; motor losses (efficiency) are ignored.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 3 – Basics of Energy and its Various Forms.

13. As the pressure of saturated steam generated in a boiler is increased, which statement about its properties is correct?

[1P1CEM013 | Chapter 3: Basics of Energy and its Various Forms | Latent heat and steam pressure]

- a) Latent heat rises while the sensible heat (enthalpy of water) falls
- b) Saturation temperature falls and so does the specific volume
- c) Latent heat falls while the total enthalpy changes only marginally

d) Latent heat and sensible heat both rise in exact proportion

Correct answer: (c) Latent heat falls while the total enthalpy changes only marginally.

Total enthalpy of dry saturated steam = sensible heat (enthalpy of water at saturation temperature) + latent heat. As pressure rises, saturation temperature rises, so sensible heat increases, but latent heat of evaporation decreases; the two effects largely offset, so total enthalpy changes only slightly. This is why steam is used at the lowest practicable pressure for heating, where more latent heat per kg is available, and why the guidebook stresses latent heat as the useful part for process heating.

Why the other options are wrong: (a) Sensible heat rises with saturation temperature; latent heat falls. (b) Saturation temperature rises with pressure; specific volume falls. (d) They move in opposite directions as pressure rises.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 3 – Basics of Energy and its Various Forms.

14. Wet steam at a certain pressure has sensible heat of 185 kcal/kg, latent heat of 480 kcal/kg and a dryness fraction of 0.92. What is the enthalpy of this steam?

[1P1CEM014 | Chapter 3: Basics of Energy and its Various Forms | Enthalpy of wet steam]

a) 665.0 kcal/kg

b) 441.6 kcal/kg

c) 626.6 kcal/kg

d) 611.8 kcal/kg

Correct answer: (c) 626.6 kcal/kg.

Given: $h_f = 185 \text{ kcal/kg}$ ($\approx 775 \text{ kJ/kg}$); $h_{fg} = 480 \text{ kcal/kg}$ ($\approx 2,010 \text{ kJ/kg}$); dryness fraction $x = 0.92$.

Formula: $h(\text{wet}) = h_f + x \times h_{fg}$.

Substitution: $h = 185 + 0.92 \times 480 = 185 + 441.6$.

Result: **626.6 kcal/kg** ($= 2623.4 \text{ kJ/kg}$). The 8% moisture carries no latent heat, so it reduces the useful heat available.

Why the other options are wrong: (a) 665.0 kcal/kg – is the enthalpy of dry saturated steam; dryness fraction is ignored. (b) 441.6 kcal/kg – counts only the latent heat portion and omits sensible heat. (d) 611.8 kcal/kg – applies the dryness fraction to the sensible heat as well.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 3 – Basics of Energy and its Various Forms.

15. A 2 kW resistive heater is rated for 230 V. If the supply voltage at site is only 210 V, what power will it draw (resistance constant)?

[1P1CEM015 | Chapter 3: Basics of Energy and its Various Forms | Resistive load and supply voltage]

a) 2.000 kW

b) 1.667 kW

c) 1.826 kW

d) 2.399 kW

Correct answer: (b) 1.667 kW.

Given: $P(\text{rated}) = 2.0 \text{ kW}$ at 230 V; actual $V = 210 \text{ V}$; R constant.

Formula: $P = V^2/R$, so $P_2 = P_1 \times (V_2/V_1)^2$.

Substitution: $P_2 = 2.0 \times (210/230)^2 = 2.0 \times 0.8336$.

Result: **1.667 kW** — about 16.6% less heat output, so heating time rises.

Why the other options are wrong: (a) 2.000 kW – assumes the rated power is drawn regardless of the supply voltage. (c) 1.826 kW – assumes power varies linearly with voltage; for constant R , $P = V^2/R$. (d) 2.399 kW – inverts the voltage ratio; lower voltage cannot increase resistive power.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 3 – Basics of Energy and its Various Forms.

16. Which of the following energy and pressure equivalences is INCORRECT?

[1P1CEM016 | Chapter 3: Basics of Energy and its Various Forms | Units and conversion factors]

a) 1 kWh = 860 kcal = 3,600 kJ

- b) 1 toe = 10^7 kcal = 41,868 MJ
- c) 1 bar = 10.33 m of water column
- d) 1 TR = 3,024 kcal/h of cooling

Correct answer: (c) 1 bar = 10.33 m of water column.

10.33 m of water column is the equivalent of one standard atmosphere (101.325 kPa), not of one bar. One bar = 100 kPa $\approx$ 10.2 m of water column ($100,000 \text{ Pa} \div (1,000 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2)$). The other equivalences are standard guidebook conversion factors: 1 kWh = 860 kcal = 3,600 kJ; 1 toe = 10^7 kcal = 41,868 MJ; 1 TR = 3,024 kcal/h. Confusing bar with atm is a common audit error.

Why the other options are wrong: (a) This option is correct (1 kWh = 3.6 MJ $\approx$ 860 kcal). (b) This option is correct by definition of tonne of oil equivalent. (d) This option is correct (1 ton of refrigeration $\approx$ 3,024 kcal/h $\approx$ 3.517 kW).

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 3 – Basics of Energy and its Various Forms.

17. In the reference year a plant used 48,000 GJ for 1,20,000 t of product. In the current year it produced 1,35,000 t and used 51,300 GJ. What is the plant energy performance (PEP), with a positive value meaning saving?

[1P1CEM017 | Chapter 4: Energy Management and Audit | Plant energy performance]

- a) +5.00%
- b) +12.50%
- c) +5.26%
- d) -6.88%

Correct answer: (a) +5.00%.

Given: reference energy = 48,000 GJ; reference production = 1,20,000 t; current production = 1,35,000 t; current energy = 51,300 GJ.

Formula: Production factor = current production $\div$ reference production; Reference year equivalent = reference energy $\times$ PF; PEP = (Ref. equivalent – Current energy) $\div$ Ref. equivalent $\times$ 100.

Substitution: PF = $1,35,000 / 1,20,000 = 1.125$; Ref. equivalent = $48,000 \times 1.125 = 54,000$ GJ; PEP = $(54,000 - 51,300) \div 54,000 \times 100$.

Result: **5.00% (positive = energy saving).**

Why the other options are wrong: (b) +12.50% – is merely the production increase, not an energy performance figure. (c) +5.26% – divides by current energy use; the guidebook divides by the reference year equivalent. (d) -6.88% – compares raw energy use without correcting for the change in production (production factor).

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 4 – Energy Management and Audit.

18. A boiler can fire furnace oil (₹48/kg, GCV 10,050 kcal/kg, efficiency 84%) or coal (₹7.5/kg, GCV 4,200 kcal/kg, efficiency 72%). What is the cost of 10 lakh kcal of useful heat when coal is fired?

[1P1CEM018 | Chapter 4: Energy Management and Audit | Fuel substitution - cost of useful heat]

- a) ₹ 2,480
- b) ₹ 1,786
- c) ₹ 5,686
- d) ₹ 1,286

Correct answer: (a) ₹ 2,480.

Given: coal price = ₹7.5/kg; GCV = 4,200 kcal/kg ($\approx$ 17,585 kJ/kg); boiler η = 0.72.

Formula: Cost of useful heat = Fuel price $\div$ (GCV $\times \eta$) $\times 10^6$ (₹ per 10 lakh kcal useful).

Substitution: $= 7.5 \div (4200 \times 0.72) \times 10^6 = 7.5 \div 3,024 \times 10^6$.

Result: **₹ 2,480 per 10 lakh kcal ($\approx$ 4,187 MJ) useful heat ($\approx$ ₹ 592 per GJ).** For oil it is ₹ 5,686, so coal costs about 44% of oil per useful kcal.

Why the other options are wrong: (b) ₹ 1,786 – is the cost of 10 lakh kcal of fuel input; boiler efficiency is ignored. (c) ₹ 5,686 – is the corresponding cost of useful heat with furnace oil, not coal. (d) ₹ 1,286 – multiplies by efficiency instead of dividing, understating the cost.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 4 – Energy Management and Audit.

19. Which of the following is NOT normally part of a preliminary energy audit of a textile process house?

[1P1CEM019 | Chapter 4: Energy Management and Audit | Types of energy audit - preliminary audit]

- a) Setting a reference point and the areas for a detailed study
- b) Identifying obvious low-cost and no-cost saving opportunities in the plant
- c) Establishing energy consumption and costs from bills and records
- d) 48-hour trials with flow and temperature logging on each stenter

Correct answer: (d) 48-hour trials with flow and temperature logging on each stenter.

A preliminary energy audit is a relatively quick exercise that uses existing or easily obtained data to establish energy consumption, estimate the scope for saving, identify the most likely and easiest areas for attention, identify immediate (especially no-cost/low-cost) improvements, set a reference point and identify areas for more detailed study and measurement. Extended trials with portable instruments on individual equipment belong to the detailed (comprehensive) energy audit, which evaluates energy balances and quantifies savings project by project.

Why the other options are wrong: (a) The preliminary audit identifies where a detailed audit is needed. (b) Spotting quick wins is a stated objective of the preliminary audit. (c) This option is a core preliminary audit activity using existing data.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 4 – Energy Management and Audit.

20. Which pairing of portable audit instrument and the parameter it measures is INCORRECT?

[1P1CEM020 | Chapter 4: Energy Management and Audit | Instruments for energy audit]

- a) Infrared pyrometer – non-contact surface temperature
- b) Fyrite kit – O₂ or CO₂ percentage in flue gas
- c) Ultrasonic flow meter – liquid flow by transit time
- d) Stroboscope – static pressure in an air duct

Correct answer: (d) Stroboscope – static pressure in an air duct.

A stroboscope measures the speed (rpm) of rotating equipment without contact, by matching its flash frequency to the rotation. Static pressure in ducts is measured with a Pitot tube and manometer. The other pairs are correct per the guidebook's list of audit instruments: ultrasonic (transit-time) flow meters for liquid flow, Fyrite for O₂/CO₂ in flue gas and infrared/contact thermometers for temperatures.

Why the other options are wrong: (a) This option is correct; it senses emitted infrared radiation from the surface. (b) This option is correct; Fyrite uses chemical absorption to read O₂ or CO₂. (c) This option is correct; it measures flow non-intrusively through the pipe wall.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 4 – Energy Management and Audit.

21. As per the Energy Conservation Act, 2001, 'energy audit' is best defined as:

[1P1CEM021 | Chapter 4: Energy Management and Audit | Definition of energy audit under EC Act]

- a) Measuring a plant's electricity use and reporting its power factor to the DISCOM
- b) Verification, monitoring and analysis of energy use, with costed recommendations and action plan
- c) Calculation of a plant's carbon footprint for disclosure in the annual report
- d) Inspection of boilers and pressure vessels for safety and for statutory certification

Correct answer: (b) Verification, monitoring and analysis of energy use, with costed recommendations and action plan.

The EC Act, 2001 defines energy audit as the verification, monitoring and analysis of use of energy including submission of a technical report containing recommendations for improving energy efficiency with cost-benefit analysis and an action plan to reduce energy consumption. The definition therefore has three essentials: analysis of energy use, recommendations with cost-benefit analysis, and an action plan.

Why the other options are wrong: (a) This option is only metering; the Act's definition covers all energy and a costed action plan. (c) This option is GHG accounting, not the EC Act definition of energy audit. (d) This option is a statutory safety inspection, not an energy audit.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 4 – Energy Management and Audit.

22. Plant A makes cement at 72 kWh/t with a clinker factor of 0.68 (blended cement); Plant B uses 80 kWh/t with a clinker factor of 0.92 (OPC). Which is the most valid benchmarking conclusion?

[1P1CEM022 | Chapter 4: Energy Management and Audit | Benchmarking]

- a) No efficiency verdict is possible until both are normalised for product mix
- b) The plants cannot be compared at all because their capacities may differ
- c) Plant A is clearly the more efficient plant because its kWh/t is lower
- d) Plant B is clearly the more efficient plant because it makes stronger cement

Correct answer: (a) No efficiency verdict is possible until both are normalised for product mix.

The guidebook cautions that benchmarking requires comparable parameters: scale of operation, vintage of technology, raw material quality and product specification/mix. Specific energy consumption of cement depends heavily on the clinker factor because clinker making and grinding dominate energy use. Comparing 72 kWh/t (68% clinker) with 80 kWh/t (92% clinker) is therefore misleading; the figures must first be normalised (e.g., kWh per tonne of clinker or equivalent cement) before any efficiency conclusion is drawn.

Why the other options are wrong: (b) Plants of different capacity can be compared once parameters are normalised. (c) This option ignores that product mix (clinker factor) strongly affects kWh per tonne. (d) Product strength alone does not establish energy efficiency.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 4 – Energy Management and Audit.

23. While preparing a material balance of a continuous rotary dryer, which quantity is the most convenient 'tie' (key) component?

[1P1CEM023 | Chapter 5: Material and Energy Balance | Choice of tie element in material balance]

- a) Bone-dry solids, which pass through the dryer unchanged in quantity
- b) Moisture in the feed, which is fully removed by hot air
- c) Hot air flow, which equals the evaporated water flow
- d) Total wet mass of feed, which equals the product mass

Correct answer: (a) Bone-dry solids, which pass through the dryer unchanged in quantity.

In material balance, a tie (key) component is one that passes from one stream to another without change in quantity, so it links the unknown streams. In drying, the bone-dry solids are conserved (input dry solids = output dry solids) while water leaves as vapour. Writing the balance on dry solids immediately gives product mass and hence water evaporated, as in: Dry solids = Feed $\times$ (1 – w₁) = Product $\times$ (1 – w₂).

Why the other options are wrong: (b) Moisture changes between inlet and outlet, so it cannot tie the streams. (c) Air and evaporated water are different quantities and not conserved together. (d) Total mass falls as water evaporates; inlet and outlet masses differ.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 5 – Material and Energy Balance.

24. A dryer receives 2,000 kg/h of wet cake at 70% moisture (wet basis) and discharges it at 8% moisture (wet basis). How much water is evaporated?

[1P1CEM024 | Chapter 5: Material and Energy Balance | Drying - water removed (wet basis)]

- a) 652.2 kg/h
- b) 1,400.0 kg/h
- c) 1,240.0 kg/h
- d) 1,347.8 kg/h

Correct answer: (d) 1,347.8 kg/h.

Given: feed = 2,000 kg/h; w₁ = 0.7; w₂ = 0.08 (wet basis).

Formula: Dry solids = F $\times$ (1 – w₁); Product = Dry solids $\div$ (1 – w₂); Water evaporated = F – Product.

Substitution: Dry solids = 2000 $\times$ 0.30 = 600 kg/h; Product = 600 $\div$ 0.92 = 652.2 kg/h; Water = 2000 – 652.2.

Result: **1,347.8 kg/h of water evaporated.**

Why the other options are wrong: (a) 652.2 kg/h – is the dried product flow, not the water evaporated. (b) 1,400.0 kg/h – assumes all moisture is removed (bone-dry product). (c) 1,240.0 kg/h – subtracts moisture percentages directly on feed mass; dry solids must be the tie element.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 5 – Material and Energy Balance.

25. Taking air as 23% oxygen by mass, what is the theoretical (stoichiometric) air needed to burn 1 kg of pure carbon completely to CO₂?

[1P1CEM025 | Chapter 5: Material and Energy Balance | Stoichiometric air requirement]

a) 11.59 kg air

b) 2.67 kg air

c) 12.70 kg air

d) 5.80 kg air

Correct answer: (a) 11.59 kg air.

Given: $C + O_2 \rightarrow CO_2$; 12 kg C needs 32 kg O₂; O₂ in air = 23% by mass.

Formula: Theoretical air = (O₂ required per kg fuel) ÷ 0.23.

Substitution: O₂ = 32/12 = 2.667 kg/kg C; Air = 2.667 ÷ 0.23.

Result: **11.59 kg of air per kg of carbon** (also giving 44/12 = 3.67 kg CO₂).

Why the other options are wrong: (b) 2.67 kg air – is the oxygen requirement only (32/12 kg O₂ per kg C), not air. (c) 12.70 kg air – divides by 21%, which is the volume (mole) fraction of O₂, not the mass fraction. (d) 5.80 kg air – is the air for burning carbon only to CO (half the oxygen).

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 5 – Material and Energy Balance.

26. Flue gas at 5,000 kg/h (specific heat 0.24 kcal/kg°C) is cooled from 320 °C to 180 °C in an economiser. What is the heat recovered expressed in kW?

[1P1CEM026 | Chapter 5: Material and Energy Balance | Waste heat recovery - energy balance]

a) 168.0 kW

b) 195.3 kW

c) 703.4 kW

d) 446.5 kW

Correct answer: (b) 195.3 kW.

Given: $m = 5,000 \text{ kg/h}$; $C_p = 0.24 \text{ kcal/kg}^\circ\text{C}$ ($\approx 1.00 \text{ kJ/kg}^\circ\text{C}$); $\Delta T = 320 - 180 = 140^\circ\text{C}$.

Formula: $Q = m \times C_p \times \Delta T$; 1 kW = 860 kcal/h.

Substitution: $Q = 5000 \times 0.24 \times 140 = 1,68,000 \text{ kcal/h}$ ($= 7,03,382 \text{ kJ/h}$); in kW = $1,68,000 \div 860$.

Result: **195.3 kW** of heat recovered.

Why the other options are wrong: (a) 168.0 kW – simply divides kcal/h by 1,000; 1 kW = 860 kcal/h. (c) 703.4 kW – converts to kJ/h and treats kJ/h ÷ 1,000 as kW (missing ÷ 3,600 s). (d) 446.5 kW – uses the inlet temperature instead of the temperature drop.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 5 – Material and Energy Balance.

27. In an ISO 50001 energy management system, establishing the energy baseline and energy performance indicators (EnPIs) belongs to which PDCA stage?

[1P1CEM027 | Chapter 6: Energy Action Planning | ISO 50001 - PDCA]

a) Do – implementation and operation of controls

b) Plan – energy review and energy planning

c) Act – management review and continual improvement

d) Check – monitoring, measurement and internal audit

Correct answer: (b) Plan – energy review and energy planning.

ISO 50001 follows the Plan-Do-Check-Act cycle. The Plan stage covers the energy review (analysis of energy use and consumption, significant energy uses, opportunities), setting the energy baseline, defining EnPIs, objectives, energy targets and action plans. Do = implement action plans and operational controls; Check = monitor, measure, analyse and audit performance against the baseline using EnPIs; Act = management review and actions for continual improvement.

Why the other options are wrong: (a) 'Do' implements the action plans; baseline and EnPIs are set before that. (c) 'Act' takes corrective actions after review, not initial baselining. (d) 'Check' uses the EnPIs and baseline to measure performance; it does not set them.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 6 – Energy Action Planning.

28. Which of the following is NOT a responsibility of the energy manager appointed by a designated consumer?

[1P1CEM028 | Chapter 6: Energy Action Planning | Duties of energy manager]

- a) Establishing an improved data recording and monitoring system
- b) Preparing an annual activity plan and progress report for the plant
- c) Certifying the mandatory energy audit as the accredited energy auditor
- d) Promoting staff awareness and training on energy efficiency

Correct answer: (c) Certifying the mandatory energy audit as the accredited energy auditor.

The guidebook lists the energy manager's responsibilities: preparing an annual activity plan and progress report, establishing an improved data recording, collection and analysis system, conducting internal audits, preparing information for the designated agency/BEE, promoting awareness and training, and initiating energy-saving projects. The mandatory energy audit of a DC must be conducted by an independent accredited energy auditor; the in-house energy manager cannot certify it, which preserves the independence of the audit.

Why the other options are wrong: (a) This option is a listed duty, needed for monitoring and targeting. (b) This option is a listed duty of the energy manager. (d) This option is a listed duty, part of creating an energy-conscious culture.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 6 – Energy Action Planning.

29. A paper mill's energy policy is being converted into targets. Which statement is a properly framed energy target?

[1P1CEM029 | Chapter 6: Energy Action Planning | Goals, objectives and targets]

- a) Reduce energy consumption wherever it is possible in all the plant sections
- b) Become a world-class energy-efficient paper mill in the shortest possible time
- c) Cut steam per tonne of paper 6% by March 2027 versus FY 2025-26
- d) Encourage all staff members to save steam and power during every single shift

Correct answer: (c) Cut steam per tonne of paper 6% by March 2027 versus FY 2025-26.

A target is a detailed, quantified performance requirement that follows from an objective and is measurable and time-bound (SMART: specific, measurable, achievable, realistic, time-bound). 'Cut steam per tonne of paper by 6% by March 2027 compared with FY 2025-26' states the indicator (steam per tonne), the magnitude (6%), the baseline (FY 2025-26) and the deadline, so progress can be monitored against it. The other options are goals or general intentions.

Why the other options are wrong: (a) This option has no quantity, baseline or deadline, so it cannot be tracked. (b) This option is a goal or vision; it is not specific, measurable or time-bound. (d) This option is an awareness intention, not a measurable target.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 6 – Energy Action Planning.

30. A waste-heat recovery project costs ₹24 lakh and saves ₹9 lakh a year in fuel, but adds ₹1.2 lakh a year of operation and maintenance cost. What is its return on investment (ROI)?

[1P1CEM030 | Chapter 7: Financial Management | Return on investment]

- a) 42.5%
- b) 3.1%
- c) 37.5%
- d) 32.5%

Correct answer: (d) 32.5%.

Given: investment = ₹24.0 lakh; gross saving = ₹9.0 lakh/yr; added O&M = ₹1.2 lakh/yr.

Formula: ROI = Net annual cash inflow ÷ Capital cost × 100 (guidebook); net inflow = savings – O&M.

Substitution: Net inflow = 9.0 – 1.2 = ₹7.8 lakh; ROI = 7.8 ÷ 24.0 × 100.

Result: **32.5%** (simple payback = 3.08 years). ROI should exceed the cost of capital.

Why the other options are wrong: (a) 42.5% – adds the O&M cost to the savings instead of subtracting it. (b) 3.1% – is the simple payback in years, wrongly expressed as a percentage. (c) 37.5% – uses gross savings; the added O&M cost must be deducted first.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 7 – Financial Management.

31. A VFD retrofit costs ₹5,00,000 and gives a net saving of ₹1,50,000 at the end of each year for 5 years. At a discount rate of 12%, what is its NPV?

[1P1CEM031 | Chapter 7: Financial Management | Net present value]

a) ₹ 40,716

b) ₹ 68,618

c) ₹ 2,50,000

d) ₹ -44,398

Correct answer: (a) ₹ 40,716.

Given: CF₀ = -₹5,00,000; CF₁...CF₅ = ₹1,50,000; i = 0.12.

Formula: NPV = $\sum CF_t \div (1 + i)^t$, t = 0...n.

Substitution: cumulative discount factor (12%, 5 yr) = 3.6048; PV of savings = 1,50,000 × 3.6048 = ₹5,40,716; NPV = 5,40,716 – 5,00,000.

Result: **NPV = ₹ 40,716** (positive, so the project earns more than 12%).

Why the other options are wrong: (b) ₹ 68,618 – discounts at 10% instead of the given 12%. (c) ₹ 2,50,000 – ignores the time value of money (undiscounted savings minus investment). (d) ₹ -44,398 – counts only 4 years of savings instead of 5.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 7 – Financial Management.

32. The NPV of an energy project is +₹2.1 lakh at a discount rate of 12% and -₹1.4 lakh at 16%. Estimate its IRR by linear interpolation.

[1P1CEM032 | Chapter 7: Financial Management | IRR by interpolation]

a) 13.6%

b) 14.0%

c) 14.4%

d) 24.0%

Correct answer: (c) 14.4%.

Given: NPV₁ = +2.1 lakh at r₁ = 12%; NPV₂ = -1.4 lakh at r₂ = 16%.

Formula: IRR = r₁ + (r₂ – r₁) × NPV₁ ÷ (NPV₁ – NPV₂).

Substitution: IRR = 12 + 4 × 2.1 ÷ (2.1 – (-1.4)) = 12 + 4 × 2.1/3.5.

Result: **IRR ≈ 14.4%** — the discount rate at which NPV = 0.

Why the other options are wrong: (a) 13.6% – weights the interval with the negative NPV instead of the positive NPV at the lower rate. (b) 14.0% – takes the simple mid-point and ignores the NPV magnitudes. (d) 24.0% – adds the signed NPVs (2.1 – 1.4) in the denominator instead of the spread 2.1 + 1.4.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 7 – Financial Management.

33. Which statement correctly contrasts 'shared savings' and 'guaranteed savings' performance contracts?

[1P1CEM033 | Chapter 7: Financial Management | ESCO performance contracting]

a) Shared savings: ESCO bears performance and credit risk; guaranteed: client bears credit risk

b) Both models place all performance and credit risk entirely on the financing bank

c) Shared savings: client bears performance and credit risk; guaranteed: ESCO bears both

d) Shared savings: ESCO bears credit risk only; guaranteed: client bears performance risk

Correct answer: (a) Shared savings: ESCO bears performance and credit risk; guaranteed: client bears credit risk.

In a shared-savings contract the ESCO finances the project (on its own balance sheet or through a lender) and recovers its investment from an agreed share of the measured savings; it therefore carries both performance risk and credit risk. In a guaranteed-savings contract the client (host) finances the project, typically borrowing from a bank, and so carries the credit risk, while the ESCO guarantees a minimum level of energy savings, carrying the performance risk.

Why the other options are wrong: (b) Lenders price credit risk but the contract allocates risk between ESCO and client. (c) This option reverses the risk allocation of both contract types. (d) In guaranteed savings the ESCO guarantees performance; the client finances.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 7 – Financial Management.

34. For an energy-saving project with a fixed annual kWh saving, which change will INCREASE its NPV, all else unchanged?

[1P1CEM034 | Chapter 7: Financial Management | Sensitivity of NPV]

- a) A rise in the annual operation and maintenance cost
- b) A steady rise in the electricity tariff over project life
- c) A rise in the discount rate used by the finance team
- d) A shorter economic life of the installed equipment

Correct answer: (b) A steady rise in the electricity tariff over project life.

$NPV = \sum (\text{net annual savings}) \div (1 + i)^t - \text{investment}$. With a fixed kWh saving, the rupee value of savings rises with the tariff, raising every future cash inflow and hence NPV. A higher discount rate, shorter life or higher O&M cost all reduce NPV. Sensitivity analysis in the guidebook examines exactly such variations (energy prices, discount rate, life, O&M costs) to test project robustness before investment.

Why the other options are wrong: (a) Higher O&M reduces net annual cash inflows and NPV. (c) A higher discount rate lowers the present value of future savings. (d) Fewer years of savings reduce the present value of inflows.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 7 – Financial Management.

35. A project saves ₹10 lakh a year (before tax). Annual depreciation is ₹4 lakh and the tax rate is 30%. What is the annual after-tax net operating cash inflow?

[1P1CEM035 | Chapter 7: Financial Management | Depreciation and after-tax cash flow]

- a) ₹ 8.8 lakh
- b) ₹ 8.2 lakh
- c) ₹ 4.2 lakh
- d) ₹ 7.0 lakh

Correct answer: (b) ₹ 8.2 lakh.

Given: saving = ₹10.0 lakh; depreciation $D = ₹4.0$ lakh; tax rate = 0.3.

Formula: After-tax cash inflow = (Savings – Depreciation) $\times$ (1 – tax) + Depreciation.

Substitution: $= (10.0 - 4.0) \times 0.70 + 4.0 = 4.2 + 4.0$.

Result: **₹ 8.2 lakh per year** — depreciation lowers taxable income and so increases cash inflow by $D \times t = ₹1.2$ lakh.

Why the other options are wrong: (a) ₹ 8.8 lakh — deducts tax on depreciation instead of tax on the taxable profit. (c) ₹ 4.2 lakh — forgets to add back depreciation, which is a non-cash expense. (d) ₹ 7.0 lakh — taxes the full saving and ignores the depreciation tax shield.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 7 – Financial Management.

36. Which statement correctly distinguishes a capital lease from a true (operating) lease for energy-efficient equipment?

[1P1CEM036 | Chapter 7: Financial Management | Financing options - leases]

- a) Capital lease: user owns asset, claims depreciation; true lease: payments expensed

- b) Capital lease: lessor claims depreciation; true lease: user owns the asset
- c) Capital lease: no asset on books; true lease: user claims depreciation
- d) Both leases transfer ownership and depreciation to the user at day one

Correct answer: (a) Capital lease: user owns asset, claims depreciation; true lease: payments expensed.

As described in the guidebook's financing options, a capital lease is essentially an instalment purchase: the lessee is treated as owner, carries the asset on its balance sheet and claims depreciation and interest deductions. In a true (operating) lease the lessor owns the equipment and claims depreciation, while the lessee's lease payments are treated as an operating expense, keeping the asset off the user's balance sheet.

Why the other options are wrong: (b) This option reverses the ownership and depreciation treatment of the two leases. (c) Under a capital lease the asset appears on the user's books. (d) A true lease keeps ownership with the lessor throughout.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 7 – Financial Management.

37. In PERT, the expected activity time is taken as $t_e = (t_o + 4t_m + t_p)/6$. This weighting is based on which assumed distribution of activity time?

[1P1CEM037 | Chapter 8: Project Management | PERT time estimates]

- a) Normal distribution
- b) Beta distribution
- c) Uniform distribution
- d) Poisson distribution

Correct answer: (b) Beta distribution.

PERT uses three time estimates (optimistic t_o , most likely t_m and pessimistic t_p) and assumes each activity time follows a beta distribution. The weighted mean $t_e = (t_o + 4t_m + t_p)/6$ and standard deviation $\sigma = (t_p - t_o)/6$ follow from that assumption. The sum of activity times along the critical path is then approximated as normally distributed to estimate the probability of meeting a deadline.

Why the other options are wrong: (a) Normal distribution – the normal distribution is used for the total project time along the critical path, not for an individual activity. (c) Uniform distribution – a uniform distribution would weight all times equally, with no extra weight on t_m . (d) Poisson distribution – the Poisson distribution describes counts of discrete events, not durations.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 8 – Project Management.

38. An activity has ES = 6 weeks, duration = 4 weeks and LF = 14 weeks. The earliest start of its only successor is week 11. What are its total float and free float?

[1P1CEM038 | Chapter 8: Project Management | Total float and free float]

- a) TF = 8 weeks; FF = 1 week
- b) TF = 4 weeks; FF = 4 weeks
- c) TF = 1 week; FF = 4 weeks
- d) TF = 4 weeks; FF = 1 week

Correct answer: (d) TF = 4 weeks; FF = 1 week.

Given: ES = 6; d = 4; LF = 14; ES(successor) = 11 (weeks).

Formula: EF = ES + d; Total float = LF – EF (= LS – ES); Free float = ES(successor) – EF.

Substitution: EF = 6 + 4 = 10; TF = 14 – 10 = 4; FF = 11 – 10 = 1.

Result: **Total float = 4 weeks; free float = 1 week.** The activity can slip 1 week without delaying its successor and 4 weeks without delaying the project.

Why the other options are wrong: (a) This option computes LF – ES without deducting the activity duration. (b) This option assumes free float equals total float; FF uses the successor's earliest start. (c) This option interchanges the definitions of total float and free float.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 8 – Project Management.

39. A project must be shortened by one week at minimum extra cost. Which activity should be crashed first?

[1P1CEM039 | Chapter 8: Project Management | Project crashing]

- a) The non-critical activity with the lowest crash cost per week
- b) The critical activity with the lowest crash cost per week
- c) The critical activity with the longest normal duration
- d) Any activity having the largest total float in the network

Correct answer: (b) The critical activity with the lowest crash cost per week.

Project duration is fixed by the critical path, so only critical activities can reduce it. Among them, the activity with the least cost slope, $(\text{crash cost} - \text{normal cost}) \div (\text{normal time} - \text{crash time})$, gives the required time reduction at the lowest extra cost. After each step the network is re-checked, because new critical paths may emerge and parallel critical paths must be crashed together.

Why the other options are wrong: (a) Shortening a non-critical activity does not reduce project duration. (c) Duration alone does not decide; the cost slope must be lowest. (d) Activities with float are non-critical; crashing them wastes money.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 8 – Project Management.

40. An activity has a normal time of 12 weeks at a cost of ₹1,80,000 and a crash time of 8 weeks at ₹2,60,000. What is its crash cost slope?

[1P1CEM040 | Chapter 8: Project Management | Crash cost slope]

- a) ₹ 20,000 per week
- b) ₹ 32,500 per week
- c) ₹ 15,000 per week
- d) ₹ 6,667 per week

Correct answer: (a) ₹ 20,000 per week.

Given: normal time = 12 wk, normal cost = ₹1,80,000; crash time = 8 wk, crash cost = ₹2,60,000.

Formula: Cost slope = $(\text{Crash cost} - \text{Normal cost}) \div (\text{Normal time} - \text{Crash time})$.

Substitution: $= (2,60,000 - 1,80,000) \div (12 - 8) = 80,000 \div 4$.

Result: **₹ 20,000 per week** of time saved.

Why the other options are wrong: (b) ₹ 32,500 per week – divides crash cost by crash time; the slope uses differences. (c) ₹ 15,000 per week – is the normal cost per week of duration, not the extra cost of crashing. (d) ₹ 6,667 per week – divides the extra cost by the normal time instead of the time saved.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 8 – Project Management.

41. For the activity network in the table, what is the project duration and the total float of activity D?

[1P1CEM041 | Chapter 8: Project Management | Critical path in a network]

Activity	A	B	C	D	E	F
Predecessor	—	—	A	A	B, C	D, E
Duration (weeks)	3	5	4	5	2	3

- a) 11 weeks; float of D = 0 weeks
- b) 12 weeks; float of D = 1 week
- c) 10 weeks; float of D = 1 week
- d) 12 weeks; float of D = 2 weeks

Correct answer: (b) 12 weeks; float of D = 1 week.

Given: A(3, start), B(5, start), C(4, after A), D(5, after A), E(2, after B and C), F(3, after D and E).

Formula: Forward pass $ES = \max(ES \text{ of predecessors})$; backward pass $LF = \min(LS \text{ of successors})$; Float = $LS - ES$.

Substitution: paths A-C-E-F = $3+4+2+3 = 12$; A-D-F = $3+5+3 = 11$; B-E-F = $5+2+3 = 10$. $ES(F) = \max(ES \text{ D} = 8, ES \text{ E} = 9) = 9$, so $LF(D) = 9$, $LS(D) = 4$, $ES(D) = 3$.

Result: **Duration = 12 weeks (critical path A-C-E-F); total float of D = 1 week.**

Why the other options are wrong: (a) This option takes path A-D-F (11 weeks) as critical; A-C-E-F is longer. (c) This option takes path B-E-F (10 weeks) as the project duration. (d) This option measures D's float against path B-E-F instead of the critical path.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 8 – Project Management.

42. A plant's monthly energy use plotted against production gives a very poor correlation ($R^2 = 0.35$). What is the most likely inference for the energy manager?

[1P1CEM042 | Chapter 9: Energy Monitoring and Targeting | Energy-production correlation]

- a) The meters are certainly faulty and all data should be discarded
- b) The plant's fixed energy consumption must be exactly equal to zero
- c) Energy use is driven by factors other than production or by poor control
- d) Energy use is fully explained by production and so no action is required

Correct answer: (c) Energy use is driven by factors other than production or by poor control.

In monitoring and targeting, energy (E) is plotted against production (P) and a line $E = mP + c$ is fitted. A good correlation means production is the main driver. Wide scatter (low R^2) indicates that energy use is influenced by other variables (weather, product mix, batch size, idling) or that the process is poorly controlled. The guidebook advises investigating the scatter, as reducing variability is itself a saving opportunity.

Why the other options are wrong: (a) Faulty meters are one possibility, but poor control or other drivers are more usual. (b) R^2 says nothing about the size of the intercept (fixed consumption). (d) A low R^2 means production explains little of the variation.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 9 – Energy Monitoring and Targeting.

43. After running downwards for six months following a retrofit, a plant's CUSUM line (actual – predicted) turns and rises steadily from month 7. What is the correct interpretation?

[1P1CEM043 | Chapter 9: Energy Monitoring and Targeting | Interpreting CUSUM chart]

- a) Savings are being eroded; consumption now exceeds the baseline model
- b) The baseline must be wrong because CUSUM can never change direction
- c) Savings are increasing faster than before; consumption is falling further
- d) Performance is exactly equal to the baseline model from month 7

Correct answer: (a) Savings are being eroded; consumption now exceeds the baseline model.

$CUSUM = \sum (Actual - Predicted)$. A falling line shows actual consumption below the baseline (savings accumulating); a horizontal line shows performance equal to the baseline; a rising line shows actual consumption higher than predicted. A turn upward after a downward run therefore signals that the earlier savings are being eroded, e.g., through loss of control, drifting set points or equipment deterioration, and calls for corrective action.

Why the other options are wrong: (b) CUSUM changes slope whenever performance changes; that is its purpose. (c) A rising CUSUM line means actual consumption is above predicted. (d) Equal performance gives a horizontal CUSUM line, not a rising one.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 9 – Energy Monitoring and Targeting.

44. A plant's baseline is $E = 1.8P + 5,000$ (E in kWh, P in tonnes). This month $P = 40,000$ t and actual $E = 74,500$ kWh. The CUSUM at the end of last month was -8,000 kWh. What is the new CUSUM value?

[1P1CEM044 | Chapter 9: Energy Monitoring and Targeting | CUSUM calculation]

- a) -2,500 kWh
- b) 2,500 kWh
- c) -5,500 kWh
- d) -10,500 kWh

Correct answer: (d) -10,500 kWh.

Given: $E(\text{pred}) = 1.8P + 5,000$; $P = 40,000$ t; $E(\text{act}) = 74,500$ kWh; previous CUSUM = -8,000 kWh.

Formula: Difference = $E(\text{act}) - E(\text{pred})$; $\text{CUSUM}(n) = \text{CUSUM}(n-1) + \text{Difference}$.

Substitution: $E(\text{pred}) = 1.8 \times 40,000 + 5,000 = 77,000$ kWh; Difference = $74,500 - 77,000 = -2,500$ kWh; CUSUM = $-8,000 + (-2,500)$.

Result: **-10,500 kWh** — cumulative saving continues to grow.

Why the other options are wrong: (a) -2,500 kWh — is only this month's difference; CUSUM is cumulative. (b) 2,500 kWh — reverses the sign and also ignores the cumulative total brought forward. (c) -5,500 kWh — uses predicted – actual, reversing the sign convention.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 9 – Energy Monitoring and Targeting.

45. An audit finds an annual leak of 50 kg of HFC-134a (GWP 1,430) and 2 tonnes of methane (GWP 21) from a plant. What are these emissions in tonnes of CO₂ equivalent?

[1P1CEM045 | Chapter 10: Energy Efficiency and Climate Change | Global warming potential - CO₂ equivalent]

a) 71.5 tCO₂e

b) 71,542.0 tCO₂e

c) 113.5 tCO₂e

d) 43.0 tCO₂e

Correct answer: (c) 113.5 tCO₂e.

Given: HFC-134a = 50 kg = 0.05 t, GWP 1430; CH₄ = 2 t, GWP 21.

Formula: CO₂e = $\Sigma (\text{mass of gas} \times \text{GWP})$.

Substitution: HFC: $0.05 \times 1430 = 71.5$ t; CH₄: $2 \times 21 = 42$ t; total = $71.5 + 42$.

Result: **113.5 tCO₂e per year**. Note that a small mass of a high-GWP refrigerant outweighs tonnes of methane.

Why the other options are wrong: (a) 71.5 tCO₂e — counts only the HFC leak and omits the methane. (b) 71,542.0 tCO₂e — mixes units: HFC in kg is added to methane in tonnes without conversion. (d) 43.0 tCO₂e — applies the methane GWP to both gases.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 10 – Energy Efficiency and Climate Change.

46. An energy efficiency project saves 2,400 MWh of grid electricity a year. With a grid emission factor of 0.82 tCO₂/MWh and a carbon credit price of ₹800 per tCO₂e, what is the annual credit revenue?

[1P1CEM046 | Chapter 10: Energy Efficiency and Climate Change | Emission reduction and carbon credits]

a) ₹ 19,20,000

b) ₹ 1,57,440

c) ₹ 15,74,400

d) ₹ 23,41,463

Correct answer: (c) ₹ 15,74,400.

Given: saving = 2,400 MWh/yr; EF = 0.82 tCO₂/MWh; price = ₹800/tCO₂e.

Formula: CO₂ avoided = Energy saved $\times$ EF; Revenue = CO₂ avoided $\times$ credit price.

Substitution: CO₂ = $2,400 \times 0.82 = 1,968$ tCO₂e; Revenue = $1,968 \times 800$.

Result: **₹ 15,74,400 per year** (≈ ₹15.74 lakh), subject to validation and verification of the reductions.

Why the other options are wrong: (a) ₹ 19,20,000 — treats 1 MWh as 1 tCO₂; the grid emission factor is ignored. (b) ₹ 1,57,440 — drops a zero when converting MWh to tCO₂e. (d) ₹ 23,41,463 — divides by the emission factor instead of multiplying.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 10 – Energy Efficiency and Climate Change.

47. A cold store replaces R-22 refrigerant with R-134a. Which statement best describes the environmental effect?

[1P1CEM047 | Chapter 10: Energy Efficiency and Climate Change | Ozone depletion vs global warming]

a) Ozone depletion is eliminated, but the gas still adds to global warming

b) There is no change because both refrigerants are classed as CFCs

- c) Both ozone depletion and global warming impacts are fully eliminated
 d) Ozone depletion increases because R-134a contains more chlorine atoms than R-22

Correct answer: (a) Ozone depletion is eliminated, but the gas still adds to global warming.

R-22 is an HCFC: it contains chlorine, has a non-zero ozone depletion potential and is being phased out under the Montreal Protocol. R-134a is an HFC: it has no chlorine and zero ODP, so ozone depletion is avoided, but it is a potent greenhouse gas (GWP about 1,430) included in the Kyoto basket of gases. Hence the switch addresses ozone depletion, while leakage control remains essential for climate impact.

Why the other options are wrong: (b) R-22 is an HCFC and R-134a is an HFC, neither is a CFC. (c) R-134a (HFC) has zero ODP but a high GWP. (d) R-134a contains no chlorine; R-22 (HCFC) does.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 10 – Energy Efficiency and Climate Change.

48. A wind turbine has a rotor diameter of 40 m. At a wind speed of 9 m/s, air density 1.225 kg/m³ and power coefficient 0.4, what power does the rotor extract?

[1P1CEM048 | Chapter 11: New and Renewable Energy Sources | Wind power]

- a) 561.1 kW
 b) 24.9 kW
 c) 224.4 kW
 d) 897.8 kW

Correct answer: (c) 224.4 kW.

Given: $D = 40 \text{ m}$; $v = 9 \text{ m/s}$; $\rho = 1.225 \text{ kg/m}^3$; $C_p = 0.4$.

Formula: $P = \frac{1}{2} \rho A v^3 \times C_p$, with $A = \pi D^2/4$.

Substitution: $A = \pi \times 40^2/4 = 1256.6 \text{ m}^2$; $P = 0.5 \times 1.225 \times 1256.6 \times 9^3 \times 0.4 = 224,442 \text{ W}$.

Result: **224.4 kW**. Doubling wind speed would raise power eight-fold.

Why the other options are wrong: (a) 561.1 kW – is the power available in the wind; the power coefficient is ignored. (b) 24.9 kW – uses the square of wind speed; wind power varies with v^3 . (d) 897.8 kW – takes the diameter as the radius when computing swept area.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 11 – New and Renewable Energy Sources.

49. A 100 kWp rooftop PV plant receives an average of 5.2 kWh/m²/day (peak sun hours) and has a performance ratio of 0.78. What is its expected annual generation?

[1P1CEM049 | Chapter 11: New and Renewable Energy Sources | Solar PV energy yield]

- a) 1,89,800 kWh
 b) 12,168 kWh
 c) 22,207 kWh
 d) 1,48,044 kWh

Correct answer: (d) 1,48,044 kWh.

Given: capacity = 100 kWp; insolation = 5.2 kWh/m²/day (= peak sun hours at 1 kW/m²); PR = 0.78.

Formula: Annual energy = kWp $\times$ peak sun hours $\times$ PR $\times$ 365.

Substitution: = $100 \times 5.2 \times 0.78 \times 365 = 405.6 \text{ kWh/day} \times 365$.

Result: **1,48,044 kWh per year** (specific yield $\approx 1,480 \text{ kWh/kWp}$).

Why the other options are wrong: (a) 1,89,800 kWh – ignores the performance ratio (system losses). (b) 12,168 kWh – is the generation of a 30-day month, not of a year. (c) 22,207 kWh – multiplies again by module efficiency, which is already reflected in kWp rating.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 11 – New and Renewable Energy Sources.

50. Which of the following is a thermochemical conversion route for biomass?

[1P1CEM050 | Chapter 11: New and Renewable Energy Sources | Biomass conversion routes]

- a) Gasification of wood chips to producer gas

- b) Composting of farm residues into manure
- c) Anaerobic digestion of cattle dung to biogas
- d) Fermentation of cane molasses to ethanol

Correct answer: (a) Gasification of wood chips to producer gas.

Biomass can be converted by thermochemical routes (direct combustion, gasification and pyrolysis), which use heat to break down the biomass, or by biochemical routes (anaerobic digestion to biogas and fermentation to ethanol), which use micro-organisms. Gasification partially oxidises biomass with limited air at high temperature to produce producer gas (CO, H₂, CH₄ with N₂) for engines or thermal use.

Why the other options are wrong: (b) This option is aerobic biological decomposition, not energy conversion by heat. (c) This option is a biochemical route using micro-organisms in the absence of air. (d) This option is a biochemical route using yeast.

Ref: BEE Guidebook Book 1 (Paper 1), Ch. 11 – New and Renewable Energy Sources.

..... End of Section I

Section – II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 × 5 = 40

- (i) Answer all Eight questions
- (ii) Each question carries Five marks

S-1 A chlor-alkali plant reports the following annual energy consumption. The notified threshold for the chlor-alkali sector to be a designated consumer is 12,000 tonnes of oil equivalent (toe) per year. Take 1 toe = 10⁷ kcal and, as directed for this question, convert grid electricity at 860 kcal/kWh.

[1P1CEM051 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | Designated consumer - annual energy consumption in toe]

Energy source	Annual consumption	Calorific value
Grid electricity	6.5 crore kWh	860 kcal/kWh (as directed)
Coal	12,000 tonnes	GCV 4,200 kcal/kg
Furnace oil	1,500 kL (density 0.93 kg/L)	GCV 10,200 kcal/kg

- (a) Convert the consumption of each energy source into toe. [3 Marks]
- (b) Find the total annual consumption and state whether the plant qualifies as a designated consumer. [1 Mark]
- (c) State any two obligations the plant must meet once it is notified as a designated consumer. [1 Mark]

S-1 Ans

(a) [3 marks]

Given: grid electricity = 6.5 crore kWh/yr; coal = 12,000 t/yr at GCV 4,200 kcal/kg ($\approx 17,585$ kJ/kg); furnace oil = 1,500 kL/yr at density 0.93 kg/L and GCV 10,200 kcal/kg ($\approx 42,705$ kJ/kg); 1 toe = 10⁷ kcal = 41.868 GJ.

Formula: toe = (quantity × calorific value in kcal) ÷ 10⁷.

Electricity: 6,50,00,000 kWh × 860 = 55,90,00,00,000 kcal (≈ 234 TJ) → ÷ 10⁷ = **5,590.0 toe (≈ 234 TJ)** (1 mark)

Coal: 12,000 × 1,000 kg × 4,200 = 50,40,00,00,000 kcal (≈ 211 TJ) → **5,040.0 toe (≈ 211 TJ)** (1 mark)

Furnace oil: 1,500 kL × 1,000 L × 0.93 = 13,95,000 kg; × 10,200 = 14,22,90,00,000 kcal (≈ 59.6 TJ) → **1,422.9 toe (≈ 59.6 TJ)** (1 mark)

(b) [1 mark]

Total = 5,590.0 + 5,040.0 + 1,422.9 = **12,052.9 toe/yr** (= 504.6 TJ).

Result: since 12,052.9 toe (≈ 505 TJ) > 12,000 toe (≈ 502 TJ) threshold, the plant **qualifies as a designated consumer**. (1 mark)

(c) [1 mark]

Any two (½ mark each): (i) designate/appoint a certified energy manager; (ii) get mandatory energy audit done by an accredited energy auditor at the notified interval; (iii) furnish annual energy consumption returns and action taken on audit

recommendations to BEE/SDA in the prescribed form; (iv) comply with the energy consumption norms and standards (SEC targets) notified for it.

Marking scheme (5 marks): a) 1 mark per source converted correctly (3). b) Total and correct conclusion (1). c) Any two valid obligations, ½ each (1).

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 2 – Energy Conservation Act, 2001 and Related Policies.

S-2 A plant has a contract demand of 1,000 kVA. Its maximum demand is steady at 720 kW at a power factor of 0.8. The tariff levies a demand charge of ₹450 per kVA per month on the billing demand, which is the higher of the recorded maximum demand (kVA) and 75% of the contract demand. The plant proposes to raise the power factor to 0.96 by installing capacitors.

[1P1CEM052 | Chapter 3: Basics of Energy and its Various Forms | Power factor improvement and kVA demand charges]

- Calculate the maximum demand in kVA before and after power factor improvement. [1 Mark]
- Calculate the capacitor rating (kVAr) required. [2 Marks]
- Calculate the monthly and annual saving in demand charges. [2 Marks]

S-2 Ans

(a) [1 mark]

Given: $P = 720 \text{ kW}$; $\cos \phi_1 = 0.8$; $\cos \phi_2 = 0.96$.

Formula: $\text{kVA} = \text{kW} \div \cos \phi$.

Substitution: $\text{kVA}_1 = 720 \div 0.8 = \mathbf{900 \text{ kVA}}$; $\text{kVA}_2 = 720 \div 0.96 = \mathbf{750 \text{ kVA}}$. (1 mark)

(b) [2 marks]

Formula: $\text{kVAr required} = \text{kW} \times (\tan \phi_1 - \tan \phi_2)$.

Substitution: $\tan \phi_1 = \tan(\cos^{-1} 0.8) = 0.7500$; $\tan \phi_2 = \tan(\cos^{-1} 0.96) = 0.2917$.

$\text{kVAr} = 720 \times (0.7500 - 0.2917) = 720 \times 0.4583$.

Result: **330.0 kVAr** (a standard 350 kVAr bank would be selected). (2 marks)

(c) [2 marks]

Minimum billing demand = $0.75 \times 1,000 = 750 \text{ kVA}$.

Billing demand before = higher of (900, 750) = 900 kVA; after = higher of (750, 750) = 750 kVA.

Monthly saving = $(900 - 750) \times ₹450 = \mathbf{₹ 67,500 \text{ per month}}$; annual = **₹ 8,10,000** ($\approx ₹8.1 \text{ lakh}$). (2 marks)

Note: improving PF beyond the point where the billing demand reaches the 75% floor brings no further demand-charge saving (only lower I^2R losses).

Marking scheme (5 marks): a) 1 mark. b) Formula ½, tan values ½, answer 1. c) Billing demand logic 1, monthly/annual saving 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 3 – Basics of Energy and its Various Forms.

S-3 In a boiler house, 4,000 kg/h of condensate at 90 °C and 6,000 kg/h of make-up water at 30 °C are mixed in the feed-water tank (total 10,000 kg/h). After repairing the condensate return lines, condensate recovery rises to 6,000 kg/h at 90 °C with make-up reduced to 4,000 kg/h at 30 °C. Boiler efficiency is 80% on GCV; fuel oil GCV is 10,000 kcal/kg and costs ₹45/kg; the boiler operates 8,000 h/yr. Take specific heat of water as 1 kcal/kg°C and neglect tank losses.

[1P1CEM053 | Chapter 5: Material and Energy Balance | Energy balance of feed-water mixing (condensate recovery)]

- Calculate the feed-water temperature before and after the improvement. [2 Marks]
- Calculate the fuel oil saving in kg/h. [2 Marks]
- Calculate the annual monetary saving. [1 Mark]

S-3 Ans**(a) [2 marks]**

Given: condensate = 4,000 kg/h $\rightarrow$ 6,000 kg/h at 90 °C; make-up = 6,000 kg/h $\rightarrow$ 4,000 kg/h at 30 °C; total feed water = 10,000 kg/h; $C_p = 1 \text{ kcal/kg}^\circ\text{C}$ ($\approx 4.19 \text{ kJ/kg}\cdot\text{K}$); $\eta = 80\%$; GCV = 10,000 kcal/kg ($\approx 41,868 \text{ kJ/kg}$); fuel oil = ₹45/kg; 8,000 h/yr.

Formula (energy balance, no losses): $\Sigma m \cdot C_p \cdot T \text{ (in)} = m \text{ (total)} \cdot C_p \cdot T \text{ (mix)} \rightarrow T \text{ (mix)} = \Sigma(m \cdot T) \div \Sigma m$.

Result (Before): $T_1 = (4,000 \times 90 + 6,000 \times 30) \div 10,000 = \mathbf{54^\circ\text{C}}$ (1 mark)

Result (After): $T_2 = (6,000 \times 90 + 4,000 \times 30) \div 10,000 = \mathbf{66^\circ\text{C}}$ (1 mark)

(b) [2 marks]

Additional sensible heat in feed water = $10,000 \times 1 \times (66 - 54) = 1,20,000 \text{ kcal/h}$ ($= 5,02,416 \text{ kJ/h} \approx 139.5 \text{ kW}$).

Formula: Fuel saving = Heat saved $\div$ ($\eta \times \text{GCV}$).

Substitution: $1,20,000 \div (0.8 \times 10,000) = \mathbf{15.0 \text{ kg/h of fuel oil}}$. (2 marks)

(c) [1 mark]

Annual fuel saving = $15.0 \times 8,000 = 1,20,000 \text{ kg} = 120 \text{ t}$.

Result: Annual saving = $1,20,000 \times ₹45 = ₹ \mathbf{54,00,000}$ (₹54 lakh per year). Water treatment and make-up water savings are additional. (1 mark)

Marking scheme (5 marks): a) 1 + 1. b) Heat saved 1, fuel 1. c) 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 5 – Material and Energy Balance.

S-4 The following macro-energy data are reported for a developing economy (GDP at constant 2011-12 prices).

[1P1CEM054 | Chapter 1: Energy Scenario | Energy intensity of GDP and per capita energy consumption]

Parameter	2015	2024
Primary energy consumption (Mtoe)	700	1,020
GDP at constant prices (₹ lakh crore)	115	190
Population (million)	1,310	1,440

(a) Calculate the energy intensity (kgoe per ₹1,000 of GDP) for both years and its percentage change. [2 Marks]

(b) Calculate the per capita primary energy consumption (kgoe/person) for both years and its percentage change. [1 Mark]

(c) Explain why the fall in energy intensity need not mean an equal gain in energy efficiency, and why GDP at constant prices (not current prices) is used for such trend comparisons. [2 Marks]

S-4 Ans**(a) [2 marks]**

Given: primary energy = 700 Mtoe ($\approx 29.3 \text{ EJ}$) (2015) and 1,020 Mtoe ($\approx 42.7 \text{ EJ}$) (2024); GDP at constant prices = ₹ 115 lakh crore and ₹ 190 lakh crore; population = 1,310 and 1,440 million; 1 Mtoe = 10^9 kgoe ; ₹ 1 lakh crore = $10^{12} \text{ rupees} = 10^9 \times ₹1,000$; 1 kgoe = 41.868 MJ.

Formula: Energy intensity = Primary energy consumption $\div$ GDP (constant prices).

Substitution: 2015: $700 \times 10^9 \text{ kgoe} \div 115 \times 10^9 = \mathbf{6.087 \text{ kgoe/₹1,000}}$; 2024: $1,020 \times 10^9 \text{ kgoe} \div 190 \times 10^9 = \mathbf{5.368 \text{ kgoe/₹1,000}}$.

Result: change = $(5.368 \div 6.087 - 1) \times 100 = \mathbf{-11.8\%}$ (a fall). (2 marks)

(b) [1 mark]

Formula: Per capita energy = Primary energy $\div$ Population.

Substitution: 2015: $700 \times 10^9 \text{ kgoe} \div 1,310 \times 10^6 = 534 \text{ kgoe/person}$; 2024: $1,020 \times 10^9 \text{ kgoe} \div 1,440 \times 10^6 = 708 \text{ kgoe/person}$.

Result: $\mathbf{534 \rightarrow 708 \text{ kgoe/person} (\approx 29.6 \text{ GJ/person})}$; change = $\mathbf{+32.6\%}$. (1 mark)

(c) [2 marks]

Energy intensity reflects both efficiency and the structure of the economy (any two points, ½ mark each): (i) a shift of GDP from energy-intensive industry to services lowers intensity without any efficiency gain; (ii) substitution of non-commercial fuels (firewood, dung) by commercial energy changes recorded energy use; (iii) climate, geography, lifestyle and import of energy-intensive goods also affect intensity; (iv) only part of the change comes from technical efficiency improvement. (1 mark)

Constant prices (any two points, ½ mark each): GDP at current prices rises with inflation even when real output does not; dividing energy by an inflated GDP would show a false fall in intensity; constant (base-year) prices measure the real volume of economic activity, so the trend reflects real change in energy use per unit of output. (1 mark)

Marking scheme (5 marks): a) EI for two years 1, % change 1. b) 1. c) Structural reasons 1, constant-price reasons 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 1 – Energy Scenario.

S-5 The installation of a waste-heat recovery system is planned using PERT. Optimistic (to), most likely (tm) and pessimistic (tp) times in weeks are given below.

[1P1CEM055 | Chapter 8: Project Management | PERT - expected time and variance]

Activity	Predecessor	to	tm	tp
A	—	2	4	6
B	—	3	5	13
C	A	4	6	8
D	B	1	2	3
E	C, D	2	3	10

(a) Calculate the expected time (te) and variance of each activity. [2 Marks]

(b) Identify the critical path and the expected project duration. [2 Marks]

(c) Calculate the standard deviation of the project duration. [1 Mark]

S-5 Ans

(a) [2 marks]

Given: (to, tm, tp) in weeks: A (2, 4, 6), B (3, 5, 13), C (4, 6, 8), D (1, 2, 3), E (2, 3, 10); C follows A, D follows B, E follows C and D.

Formula: $te = (to + 4tm + tp) \div 6$; $\sigma = (tp - to) \div 6$; variance = σ^2 .

A: $te = (2 + 4 \times 4 + 6)/6 = 4.0$, $\sigma^2 = ((6-2)/6)^2 = 0.444$; B: $te = (3 + 4 \times 5 + 13)/6 = 6.0$, $\sigma^2 = ((13-3)/6)^2 = 2.778$; C: $te = (4 + 4 \times 6 + 8)/6 = 6.0$, $\sigma^2 = ((8-4)/6)^2 = 0.444$; D: $te = (1 + 4 \times 2 + 3)/6 = 2.0$, $\sigma^2 = ((3-1)/6)^2 = 0.111$; E: $te = (2 + 4 \times 3 + 10)/6 = 4.0$, $\sigma^2 = ((10-2)/6)^2 = 1.778$ (2 marks)

(b) [2 marks]

Path A–C–E = 4 + 6 + 4 = 14 weeks; Path B–D–E = 6 + 2 + 4 = 12 weeks.

Result: **Critical path A–C–E; expected project duration = 14 weeks.** (2 marks)

(c) [1 mark]

Project variance = sum of variances on the critical path = 0.444 + 0.444 + 1.778 = 2.667.

Result: **$\sigma(\text{project}) = \sqrt{2.667} = 1.63$ weeks.** (1 mark)

Note: B–D–E has the larger variance on B, but only critical-path variances are summed in basic PERT.

Marking scheme (5 marks): a) te values 1, variances 1. b) Paths 1, CP and duration 1. c) 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 8 – Project Management.

S-6 A forging furnace uses 1,800 t/yr of furnace oil (carbon 85% by mass, GCV 10,200 kcal/kg). It is proposed to switch to natural gas (GCV 9,100 kcal/Sm³, density 0.78 kg/Sm³, carbon 74% by mass). Assume the furnace efficiency remains the same and combustion is complete.

[1P1CEM056 | Chapter 10: Energy Efficiency and Climate Change | CO₂ emission reduction by fuel switching]

- (a) Calculate the annual heat input in kcal and GJ. [1 Mark]
 (b) Calculate the annual natural gas requirement in Sm^3 . [1 Mark]
 (c) Calculate the annual CO_2 emissions with furnace oil and with natural gas. [2 Marks]
 (d) Calculate the annual CO_2 reduction and the percentage reduction. [1 Mark]

S-6 Ans**(a) [1 mark]**

Given: furnace oil = 1,800 t/yr (18,00,000 kg/yr), carbon 85%, GCV = 10,200 kcal/kg ($\approx 42,705 \text{ kJ/kg}$); natural gas GCV = 9,100 kcal/ Sm^3 ($\approx 38.1 \text{ MJ/Sm}^3$), density 0.78 kg/ Sm^3 , carbon 74%; same furnace efficiency; complete combustion; $\text{CO}_2/\text{C} = 44/12$.

Result: Heat input = $18,00,000 \text{ kg} \times 10,200 = \mathbf{18,36,00,00,000 \text{ kcal/yr}} = 76,870 \text{ GJ/yr}$. (1 mark)

(b) [1 mark]

Result: NG required = $18,36,00,00,000 \div 9,100 = \mathbf{20,17,582 \text{ Sm}^3/\text{yr}}$ (mass = $\times 0.78 = 15,73,714 \text{ kg}$). (1 mark)

(c) [2 marks]

Formula: $\text{CO}_2 = \text{mass of fuel} \times \text{carbon fraction} \times 44/12$.

Result (Furnace oil): $1,800 \text{ t} \times 0.85 \times 44/12 = \mathbf{5,610.0 \text{ t CO}_2/\text{yr}}$ (1 mark)

Result (Natural gas): $15,73,714 \text{ kg} \times 0.74 \times 44/12 \div 1,000 = \mathbf{4,270.0 \text{ t CO}_2/\text{yr}}$ (1 mark)

(d) [1 mark]

Result: Reduction = $5,610.0 - 4,270.0 = \mathbf{1,340.0 \text{ t CO}_2/\text{yr}}$, i.e. 23.9% lower, because natural gas has a higher hydrogen-to-carbon ratio. (1 mark)

Marking scheme (5 marks): a) 1. b) 1. c) 1 each. d) 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 10 – Energy Efficiency and Climate Change.

S-7 An engineering unit installs a 500 kWp grid-connected rooftop solar PV system. The site receives an average solar insolation of 4.8 kWh/m²/day and the system performance ratio is 0.77. The installed cost is ₹45,000 per kWp, and every kWh generated displaces grid power at ₹8.20/kWh. Grid emission factor is 0.79 kg CO_2/kWh .

[1P1CEM057 | Chapter 11: New and Renewable Energy Sources | Solar PV rooftop - generation, payback and CO_2]

- (a) Estimate the annual energy generation. [2 Marks]
 (b) Calculate the annual monetary saving and the simple payback period. [2 Marks]
 (c) Estimate the annual CO_2 emission avoided. [1 Mark]

S-7 Ans**(a) [2 marks]**

Given: capacity = 500 kWp; insolation = 4.8 kWh/m²/day (= 4.8 peak sun hours at 1 kW/m²); PR = 0.77.

Formula: Annual generation = kWp $\times$ peak sun hours $\times$ PR $\times$ 365.

Substitution: $500 \times 4.8 \times 0.77 \times 365 = 1,848.0 \text{ kWh/day} \times 365$.

Result: $\mathbf{6,74,520 \text{ kWh/yr}}$ ($\approx 6.75 \text{ lakh kWh}$; CUF = 15.4%). (2 marks)

(b) [2 marks]

Saving = $6,74,520 \times ₹8.20 = \mathbf{₹ 55,31,064 \text{ per year}}$.

Investment = $500 \times ₹45,000 = ₹2,25,00,000$ (₹2.250 crore).

Simple payback = $2,25,00,000 \div 55,31,064 = \mathbf{4.07 \text{ years}}$. (2 marks)

(c) [1 mark]

CO_2 avoided = $6,74,520 \times 0.79 \div 1,000 = \mathbf{532.9 \text{ t CO}_2/\text{yr}}$. (1 mark)

Marking scheme (5 marks): a) Formula 1, answer 1. b) Saving 1, payback 1. c) 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 11 – New and Renewable Energy Sources.

S-8 A steel re-rolling mill plans a programme to install VFDs on its blowers and a recuperator on its reheating furnace.

[1P1CEM058 | Chapter 6: Energy Action Planning | Force field analysis and energy policy]

- (a) Apply force field analysis to this programme: list three driving (positive) forces and three restraining (negative) forces, and state which approach is generally more effective for achieving the goal. [3 Marks]
 (b) List four essential elements that the mill's written energy policy should contain. [2 Marks]

S-8 Ans

(a) [3 marks]

Force field analysis (Kurt Lewin) identifies the forces supporting and opposing a change so that the plan can strengthen the former and weaken the latter.

Driving forces (any three, ½ mark each): rising fuel and power costs; top-management commitment to cost reduction; attractive payback of VFDs/recuperator; PAT/SEC compliance pressure; availability of BEE/financing schemes or ESCOs; improved product quality and furnace productivity.

Restraining forces (any three, ½ mark each): fear of production loss during installation shutdown; lack of capital or competing investment priorities; lack of in-house technical skills and data; resistance to change by operators; doubts about savings/vendor claims; scale and dust affecting recuperator life.

Approach: **Minimising (removing) the restraining forces is generally more effective** than merely increasing the driving forces, because pushing harder on driving forces tends to raise resistance. (Driving ½ × 3 = 1½; restraining ½ × 3 = 1½ — total 3 marks with the approach statement expected.)

(b) [2 marks]

Any four (½ mark each): (i) a declaration of top-management commitment to energy efficiency; (ii) energy-saving objectives/targets (e.g. % reduction in SEC) with time frame; (iii) assignment of responsibility — appointment of the energy manager/energy cell and accountability of line managers; (iv) commitment of resources/budget for energy projects and training; (v) monitoring, reporting and review mechanism; (vi) compliance with EC Act and other legal requirements; (vii) staff awareness, communication and continual improvement.

Marking scheme (5 marks): a) 3 driving + 3 restraining forces (½ each) with correct approach. b) Four valid elements, ½ each.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 6 – Energy Action Planning.

..... End of Section II

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 6 × 10 = 60

- (i) Answer all Six questions
 (ii) Each question carries Ten marks

L-1 The activities for commissioning a cogeneration plant, with their normal durations and crashing data, are given below.

[1P1CEM059 | Chapter 8: Project Management | CPM network, float and least-cost crashing]

Activity	Predecessor	Normal time (weeks)	Max. crash (weeks)	Crash cost (₹/week)
A	—	4	1	16,000
B	—	6	2	5,000
C	A	5	2	12,000
D	A	3	1	6,000
E	B, D	4	1	8,000
F	C	6	2	9,000
G	E	3	1	7,000

H	F, G	2	1	20,000
---	------	---	---	--------

- (a) Draw the activity-on-arrow (or activity-on-node) network. [2 Marks]
 (b) Compute ES, EF, LS, LF and total float for every activity. [4 Marks]
 (c) Identify the critical path and the project duration. [1 Mark]
 (d) The project must be completed 2 weeks earlier. Determine the least-cost crashing plan and the extra cost. [3 Marks]

L-1 Ans**(a) [2 marks]**

Given: normal times (weeks) A 4, B 6, C 5, D 3, E 4, F 6, G 3, H 2; predecessors as tabulated; crash cost (₹/week) A 16,000, B 5,000, C 12,000, D 6,000, E 8,000, F 9,000, G 7,000, H 20,000 with maximum crash 1–2 weeks each.

Network (activity on node): Start → A, B. A → C, D. B → E. D → E. C → F. E → G. F → H. G → H. H → Finish.

Paths: A–C–F–H = 17 weeks; A–D–E–G–H = 16 weeks; B–E–G–H = 15 weeks. (2 marks for a correct network with all dependencies)

(b) [4 marks]

Forward pass: ES = max(EF of predecessors), EF = ES + duration. Backward pass: LF = min(LS of successors), LS = LF – duration. Total float = LS – ES.

Activity	Duration	ES	EF	LS	LF	Total float
A	4	0	4	0	4	0
B	6	0	6	2	8	2
C	5	4	9	4	9	0
D	3	4	7	5	8	1
E	4	7	11	8	12	1
F	6	9	15	9	15	0
G	3	11	14	12	15	1
H	2	15	17	15	17	0

(4 marks: ½ per activity row)

(c) [1 mark]

Activities with zero float: A, C, F, H. **Critical path A–C–F–H; project duration = 17 weeks.** (1 mark)

(d) [3 marks]

Formula: crash only critical activities, cheapest cost slope first; re-check paths after each week.

Week 1: critical activities A (₹16,000), C (₹12,000), F (₹9,000), H (₹20,000) → crash **F by 1 week** at ₹9,000. Duration = 16 weeks; now A–C–F–H = A–D–E–G–H = 16 weeks (two critical paths). (1 mark)

Week 2: both critical paths must be shortened together. Options: common activity A (₹16,000) or H (₹20,000); or one activity on each path: F (₹9,000, 1 week left) + cheapest of D/E/G = D (₹6,000) → ₹15,000; C + D = ₹18,000. Cheapest = **F + D at ₹15,000.** (1 mark)

Result: **New duration = 15 weeks; extra cost = ₹9,000 + ₹15,000 = ₹ 24,000.** Path B–E–G–H (15 weeks) also becomes critical, so further crashing would need all three paths shortened. (1 mark)

Marking scheme (10 marks): a) 2. b) 4 (½ per activity). c) 1. d) Week-1 choice 1, week-2 choice with parallel paths 1, final cost 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 8 – Project Management.

L-2 A forging unit commissioned a set of energy-saving measures at the end of May. Its reference-period data (before any measure) and the monthly data after the reference period are given below.

[1P1CEM060 | Chapter 9: Energy Monitoring and Targeting | Regression baseline and CUSUM analysis]

Reference month	R1	R2	R3	R4
-----------------	----	----	----	----

Production P (t)	400	500	600	700
Energy E (kWh)	82,000	96,000	1,10,000	1,24,000

Month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Production (t)	520	610	480	560	650	590	500	620
Actual energy (kWh)	1,00,300	1,12,200	90,000	1,00,300	1,12,200	1,04,100	94,800	1,14,600

- (a) Using the method of least squares on the reference-period data, derive the baseline relation $E = mP + c$ and state the meaning of m and c . [3 Marks]
- (b) Prepare the CUSUM table for April to November. [5 Marks]
- (c) Find the net energy saved by the end of November in kWh, toe (1 kWh = 860 kcal) and rupees at ₹7.50/kWh, and comment on the trend in the last two months. [2 Marks]

L-2 Ans**(a) [3 marks]**

Given: reference data $P = 400, 500, 600, 700$ t and $E = 82,000, 96,000, 1,10,000, 1,24,000$ kWh ($n = 4$); monthly P and actual E for Apr–Nov as tabulated; 1 kWh = 860 kcal ($\approx 3,601$ kJ); 1 toe = 10^7 kcal; electricity at ₹7.50/kWh.

Formula: $m = (n\Sigma PE - \Sigma P\Sigma E) \div (n\Sigma P^2 - (\Sigma P)^2)$; $c = (\Sigma E - m\Sigma P) \div n$.

Substitution: $n = 4$; $\Sigma P = 2,200$; $\Sigma E = 4,12,000$; $\Sigma PE = 23,36,00,000$; $\Sigma P^2 = 12,60,000$.

Result: $m = (4 \times 23,36,00,000 - 2,200 \times 4,12,000) \div (4 \times 12,60,000 - 2,200^2) = \mathbf{140 \text{ kWh/t}}$; $c = (4,12,000 - 140 \times 2,200) \div 4 = \mathbf{26,000 \text{ kWh/month}}$.

Result (Baseline): $E = \mathbf{140P + 26,000}$. m = variable (production-related) energy per tonne; c = fixed energy consumed irrespective of production (lighting, idling, auxiliaries). (3 marks)

(b) [5 marks]

Month	Production P (t)	Actual E (kWh)	Predicted E = $140P + 26,000$ (kWh)	$E(\text{act}) - E(\text{pred})$	CUSUM (kWh)
Apr	520	1,00,300	98,800	1,500	1,500
May	610	1,12,200	1,11,400	800	2,300
Jun	480	90,000	93,200	-3,200	-900
Jul	560	1,00,300	1,04,400	-4,100	-5,000
Aug	650	1,12,200	1,17,000	-4,800	-9,800
Sep	590	1,04,100	1,08,600	-4,500	-14,300
Oct	500	94,800	96,000	-1,200	-15,500
Nov	620	1,14,600	1,12,800	1,800	-13,700

(Predicted values 2 marks, differences 1½ marks, CUSUM 1½ marks)

(c) [2 marks]

Result: Net saving by November = $-(\text{CUSUM}) = \mathbf{13,700 \text{ kWh}} = 13,700 \times 860 \div 10^7 = \mathbf{1.178 \text{ toe}}$ ($= 49.3 \text{ GJ}$); value = $13,700 \times 7.50 = \mathbf{₹ 1,02,750}$.

Comment: CUSUM was positive in Apr–May (before the measures), fell steeply from June to October (savings accumulating), but rose in November (difference +1,800 kWh) after a slower fall in October — savings are being eroded; check for loss of control (e.g. furnace door practice, air leaks, idle running). (2 marks)

Marking scheme (10 marks): a) Sums 1, m and c 1, interpretation 1. b) 5 as indicated. c) Saving in three units 1, trend interpretation 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 9 – Energy Monitoring and Targeting.

L-3 A process plant's cooling-water pumping system can be improved by either of two mutually exclusive options. Life of both options is 8 years and the discount rate is 12%.

[1P1CEM061 | Chapter 7: Financial Management | Mutually exclusive projects - payback, NPV and IRR]

Item	Option X: high-efficiency pump-set	Option Y: VFD on existing pump
Investment (₹ lakh)	18.0	9.0
Net annual saving (₹ lakh)	5.2	3.1
Salvage at end of year 8 (₹ lakh)	1.5	Nil

- Calculate the simple payback period of each option. [2 Marks]
- Calculate the NPV of each option. [4 Marks]
- Calculate the IRR of each option by interpolation (use 24% and 25% for X; 30% and 32% for Y). [3 Marks]
- Recommend the better option, giving the reason when NPV and IRR rankings conflict. [1 Mark]

L-3 Ans

(a) [2 marks]

Given: Option X: investment ₹18.0 lakh, net saving ₹5.2 lakh/yr, salvage ₹1.5 lakh; Option Y: investment ₹9.0 lakh, net saving ₹3.1 lakh/yr, no salvage; life = 8 years; discount rate = 12%.

Formula: Simple payback = Investment ÷ Net annual saving.

Result (X): $18 \div 5.2 = 3.46$ years; Y: $9 \div 3.1 = 2.90$ years. (1 + 1 marks)

(b) [4 marks]

Formula: NPV = -Investment + Annual saving × cumulative discount factor + Salvage × $1/(1.12)^8$.

Cumulative discount factor (12%, 8 years) = 4.9676; $1/(1.12)^8 = 0.4039$.

Result (X): $-18 + 5.2 \times 4.9676 + 1.5 \times 0.4039 = -18 + 25.832 + 0.606 = ₹ 8.44$ lakh (2 marks)

Result (Y): $-9 + 3.1 \times 4.9676 = -9 + 15.400 = ₹ 6.40$ lakh (2 marks)

(c) [3 marks]

Result (X): NPV(24%) = +0.059; NPV(25%) = -0.438 → IRR = $24 + 1 \times 0.059 / (0.059 + 0.438) = 24.12\%$ (exact 24.12%) (1½ marks)

Result (Y): NPV(30%) = +0.067; NPV(32%) = -0.364 → IRR = $30 + 2 \times 0.067 / (0.067 + 0.364) = 30.31\%$ (exact 30.30%) (1½ marks)

(d) [1 mark]

Y has the shorter payback and higher IRR, but X has the higher NPV (₹8.44 lakh vs ₹6.40 lakh). For mutually exclusive projects with no capital constraint, the NPV criterion is decisive because it measures the absolute increase in wealth at the firm's cost of capital; IRR ignores project scale. **Recommend Option X.** (1 mark)

Marking scheme (10 marks): a) 1 + 1. b) 2 + 2. c) 1½ + 1½. d) 1 with reasoning.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 7 – Financial Management.

L-4 An oil-fired reheating furnace in a rolling mill operates with the following data (steady state).

[1P1CEM062 | Chapter 5: Material and Energy Balance | Heat balance of an oil-fired reheating furnace]

Parameter	Value
Stock heated	25 t/h
Stock temperature (in / out)	35 °C / 1,150 °C
Mean specific heat of stock	0.12 kcal/kg°C
Furnace oil consumption	1,150 kg/h
GCV of furnace oil	10,000 kcal/kg
Actual air-fuel ratio	18 kg air/kg oil
Flue gas exit temperature	950 °C
Specific heat of flue gas	0.24 kcal/kg°C
Ambient temperature	35 °C

Wall and radiation loss	8% of heat input
Cooling water (skids, doors)	60 m ³ /h with 10 °C rise

- (a) Calculate the heat input to the furnace. [1 Mark]
- (b) Calculate the useful heat to stock and the thermal efficiency of the furnace. [2 Marks]
- (c) Calculate the flue gas loss, wall loss, cooling water loss and the unaccounted loss. [4 Marks]
- (d) Present the heat balance as a table (basis for a Sankey diagram) and state two measures to reduce the largest loss. [2 Marks]
- (e) Calculate the specific fuel consumption in kg of oil per tonne of stock. [1 Mark]

L-4 Ans**(a) [1 mark]**

Given: stock = 25 t/h (25,000 kg/h), 35 → 1,150 °C, $C_p = 0.12 \text{ kcal/kg}^\circ\text{C}$ ($\approx 0.502 \text{ kJ/kg}\cdot\text{K}$); oil = 1,150 kg/h, GCV = 10,000 kcal/kg ($\approx 41,868 \text{ kJ/kg}$); air-fuel ratio = 18 kg/kg; flue gas 950 °C, $C_p = 0.24 \text{ kcal/kg}^\circ\text{C}$ ($\approx 1.00 \text{ kJ/kg}\cdot\text{K}$); ambient = 35 °C; wall loss = 8% of input; cooling water = 60 m³/h with 10 °C rise ($C_p = 1 \text{ kcal/kg}^\circ\text{C}$ ($\approx 4.19 \text{ kJ/kg}\cdot\text{K}$)).

Result: Heat input = 1,150 kg/h $\times$ 10,000 kcal/kg ($\approx 41,868 \text{ kJ/kg}$) = **1,15,00,000 kcal/h** ($= 48.1 \text{ GJ/h} \approx 13.37 \text{ MW}$). (1 mark)

(b) [2 marks]

Formula: Useful heat = $m \times C_p \times (T(\text{out}) - T(\text{in}))$; Efficiency = Useful heat $\div$ Heat input $\times 100$.

Result: Useful heat = 25,000 $\times$ 0.12 $\times$ (1150 – 35) = **33,45,000 kcal/h** ($\approx 3,890 \text{ kW}$).

Result: Efficiency = 33,45,000 $\div$ 1,15,00,000 $\times 100 = 29.1\%$. (2 marks)

(c) [4 marks]

Flue gas mass = $(A/F + 1) \times \text{fuel} = (18 + 1) \times 1,150 = 21,850 \text{ kg/h}$.

Result: Flue gas loss = 21,850 $\times$ 0.24 $\times$ (950 – 35) = **47,98,260 kcal/h** ($\approx 5,579 \text{ kW}$) (**41.7%**) (1½ marks)

Result: Wall loss = 8% $\times$ 1,15,00,000 = **9,20,000 kcal/h** ($\approx 1,070 \text{ kW}$) (1 mark)

Result: Cooling water loss = 60 m³/h $\times$ 1,000 kg/m³ $\times$ 1 $\times$ 10 = **6,00,000 kcal/h** ($\approx 698 \text{ kW}$) (**5.2%**) (½ mark)

Result: Unaccounted = 1,15,00,000 – (33,45,000 + 47,98,260 + 9,20,000 + 6,00,000) = **18,36,740 kcal/h** ($\approx 2,136 \text{ kW}$) (**16.0%**) (1 mark)

(d) [2 marks]

Item	kcal/h	% of input
Heat input (fuel GCV)	1,15,00,000	100.0
Useful heat to stock	33,45,000	29.1
Dry flue gas loss	47,98,260	41.7
Wall/radiation loss	9,20,000	8.0
Cooling water loss	6,00,000	5.2
Unaccounted (openings, scale, unburnt)	18,36,740	16.0

Largest loss is the flue gas loss (~42%). Measures (any two, ½ mark each): install a recuperator to preheat combustion air; control excess air with O₂-trim/air-fuel ratio control; maintain furnace pressure slightly positive to avoid air ingress; use hot charging / longer preheating zone to cool the gases. (Table 1 mark, measures 1 mark)

(e) [1 mark]

Result: SFC = 1,150 kg/h $\div$ 25 t/h = **46 kg oil per tonne of stock**. (1 mark)

Marking scheme (10 marks): a) 1. b) Useful heat 1, efficiency 1. c) Flue 1½, wall 1, cooling water ½, unaccounted 1. d) Table 1, measures 1. e) 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 5 – Material and Energy Balance.

L-5 A cement plant is a designated consumer under the Perform, Achieve and Trade (PAT) scheme. Ignore normalisation factors and convert grid electricity at 860 kcal/kWh for this question (1 toe = 10⁷ kcal).

[1P1CEM063 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | PAT scheme - SEC, ESCerts and plant energy performance]

Parameter	Baseline year	Assessment year
Cement production (t)	20,00,000	22,00,000
Baseline SEC (toe/t)	0.078	—
Notified SEC reduction target	—	4.5% of baseline SEC
Coal consumed (t), GCV 4,800 kcal/kg	—	2,90,000
Grid electricity (kWh)	—	18 crore

- (a) Calculate the total energy consumption (toe) and the specific energy consumption (toe/t) in the assessment year. [4 Marks]
- (b) Calculate the target SEC and the number of ESCerts the plant will earn or must purchase. [3 Marks]
- (c) Calculate the plant energy performance (PEP) for the assessment year relative to the baseline year. [2 Marks]
- (d) Estimate the value of the ESCerts at ₹2,000 per ESCert. [1 Mark]

L-5 Ans**(a) [4 marks]**

Given: production = 20,00,000 t (baseline), 22,00,000 t (assessment); baseline SEC = 0.078 toe/t ($\approx 3,266$ MJ/t); target reduction = 4.5%; coal = 2,90,000 t at GCV 4,800 kcal/kg ($\approx 20,097$ kJ/kg); grid electricity = 18 crore kWh at 860 kcal/kWh ($\approx 3,601$ kJ/kWh); 1 toe = 10^7 kcal = 41.868 GJ; ESCert price = ₹2,000.

Formula: toe = quantity $\times$ calorific value (kcal) $\div 10^7$; SEC = total energy (toe) $\div$ production (t).

Result (Coal): $2,90,000 \text{ t} \times 4,800 \div 10^7 = \mathbf{1,39,200 \text{ toe} (\approx 5,828 \text{ TJ})}$ (1½ marks)

Result (Electricity): $18 \text{ crore kWh} \times 860 \div 10^7 = \mathbf{15,480 \text{ toe} (\approx 648 \text{ TJ})}$ (1½ marks)

Result: Total = 1,54,680 toe ($\approx 6,476$ TJ); SEC = $1,54,680 \div 22,00,000 \text{ t} = \mathbf{0.07031 \text{ toe/t} (\approx 2,944 \text{ MJ/t})}$ (1 mark)

(b) [3 marks]

Result: Target SEC = $0.078 \times (1 - 0.045) = \mathbf{0.07449 \text{ toe/t} (\approx 3,119 \text{ MJ/t})}$ (1 mark)

Formula: ESCerts = (Target SEC – Achieved SEC) $\times$ Assessment-year production.

Result: $= (0.07449 - 0.07031) \times 22,00,000 = \mathbf{9,198 \text{ ESCerts (earned)}}$ since achieved SEC is below target. (2 marks)

(c) [2 marks]

Reference energy = $0.078 \times 20,00,000 = 1,56,000$ toe; production factor = $22,00,000/20,00,000 = 1.10$; reference year equivalent = $1,56,000 \times 1.10 = 1,71,600$ toe.

Result: PEP = $(1,71,600 - 1,54,680) \div 1,71,600 \times 100 = \mathbf{9.86\% \text{ energy saving}}$. (2 marks)

(d) [1 mark]

Result: Value = $9,198 \times ₹2,000 = \mathbf{₹1,83,96,000 (\approx ₹1.84 \text{ crore})}$, tradable on the power exchanges. (1 mark)

Marking scheme (10 marks): a) 1½ + 1½ + 1. b) Target 1, ESCerts 2. c) 2. d) 1.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 2 – Energy Conservation Act, 2001 and Related Policies.

L-6 During a detailed energy audit of a textile process house, the auditor evaluates replacing the furnace-oil-fired thermic fluid heater with a new biomass-briquette-fired heater of the same duty.

[1P1CEM064 | Chapter 4: Energy Management and Audit | Fuel and energy substitution - thermic fluid heater]

Parameter	Furnace oil heater (existing)	Briquette heater (proposed)
Heat duty	15 lakh kcal/h	15 lakh kcal/h
Operating hours	7,200 h/yr	7,200 h/yr
GCV of fuel	10,200 kcal/kg	3,800 kcal/kg
Heater efficiency (on GCV)	82%	70%
Fuel price	₹46 per kg	₹7.20 per kg
Investment	—	₹1.10 crore
Additional O&M (ash, manpower)	—	₹12 lakh/yr

CO2 emission factor of FO	3.15 t CO2/t	—
---------------------------	--------------	---

- (a) Calculate the hourly and annual consumption of furnace oil and of briquettes. [3 Marks]
 (b) Calculate the annual fuel costs and the net annual saving. [3 Marks]
 (c) Calculate the simple payback period. [1 Mark]
 (d) Estimate the annual reduction in CO2 emissions (treat biomass as carbon neutral). [1 Mark]
 (e) List four practical issues the auditor must examine before recommending this substitution. [2 Marks]

L-6 Ans**(a) [3 marks]**

Given: heat duty = 15 lakh kcal/h ($\approx 1,744$ kW); 7,200 h/yr; GCV = 10,200 kcal/kg ($\approx 42,705$ kJ/kg) (FO) and 3,800 kcal/kg ($\approx 15,910$ kJ/kg) (briquettes); efficiency = 82% (FO) and 70% (briquettes); price = ₹46/kg (FO) and ₹7.20/kg (briquettes); investment = ₹1.10 crore; extra O&M = ₹12 lakh/yr; FO emission factor = 3.15 t CO2/t.

Formula: Fuel rate = Heat duty $\div$ (GCV $\times$ efficiency).

Result (FO): $15,00,000 \div (10,200 \times 0.82) = 179.3 \text{ kg/h} \rightarrow \times 7,200 \text{ h} = 1,291.2 \text{ t/yr}$ (1½ marks)

Result (Briquettes): $15,00,000 \div (3,800 \times 0.7) = 563.9 \text{ kg/h} \rightarrow 4,060.2 \text{ t/yr}$ (1½ marks)

(b) [3 marks]

FO cost = $12,91,248 \text{ kg} \times ₹46 = ₹5,93,97,418$ (₹5.94 crore) (1 mark)

Briquette cost = $40,60,150 \text{ kg} \times ₹7.2 = ₹2,92,33,083$ (₹2.92 crore) (1 mark)

Result: Net saving = $5,93,97,418 - 2,92,33,083 - 12,00,000$ (extra O&M) = ₹ 2,89,64,335 per year ($\approx$ ₹2.90 crore) (1 mark)

(c) [1 mark]

Result: Payback = $₹1,10,00,000 \div ₹2,89,64,335 = 0.38 \text{ years}$ ($\approx 4.6 \text{ months}$). (1 mark)

(d) [1 mark]

Result: CO2 reduction = $1,291.2 \text{ t FO} \times 3.15 \text{ t CO2/t} = 4,067 \text{ t CO2/yr}$. (1 mark)

(e) [2 marks]

Any four (½ mark each): assured year-round supply and price stability of briquettes; storage area and protection from rain (moisture lowers GCV and efficiency); ash handling and disposal, particulate emission control to meet pollution norms; heater response to load changes and thermic fluid temperature control; additional manpower/feeding system; quality testing of GCV and moisture on receipt; impact on process temperature stability.

Marking scheme (10 marks): a) 1½ + 1½. b) 1 + 1 + 1. c) 1. d) 1. e) four issues $\times$ ½.

Ref: BEE Guidebook Paper 1 (Book 1: General Aspects of Energy Management and Energy Audit), Ch. 4 – Energy Management and Audit.

..... End of Section III

Answer key — Section I

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	d	11	b	21	b	31	a	41	b
2	d	12	d	22	a	32	c	42	c
3	b	13	c	23	a	33	a	43	a
4	b	14	c	24	d	34	b	44	d
5	c	15	b	25	a	35	b	45	c
6	b	16	c	26	b	36	a	46	c
7	a	17	a	27	b	37	b	47	a
8	c	18	a	28	c	38	d	48	c
9	d	19	d	29	c	39	b	49	d
10	d	20	d	30	d	40	a	50	a