

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

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

Question code: 5P1CEM001 – 5P1CEM064 | 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

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Section – I: OBJECTIVE TYPE

Marks: 50 × 1 = 50

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

1. A 2×660 MW coal station generated 8,900 GWh (gross) last year and its auxiliary consumption was 6.5%. What was its plant load factor (PLF)?

[5P1CEM001 | Chapter 1: Energy Scenario | Plant load factor of a thermal station from annual generation]

- a) 82.3%
- b) 84.3%
- c) 77.0%
- d) 72.0%

Correct answer: (c) 77.0%.

Given: installed capacity = $2 \times 660 = 1,320$ MW; gross generation = 8,900 GWh; hours in the year = 8,760.

Formula: $\text{PLF} = \text{gross energy generated} \div (\text{installed capacity} \times 8,760 \text{ h}) \times 100$.

Substitution: $8,900 \times 10^6 \text{ kWh} \div (13,20,000 \text{ kW} \times 8,760 \text{ h}) = 8,900 \div 11,563.2 \text{ GWh}$.

Result: **PLF = 77.0%.**

PLF measures how fully installed coal capacity is used. Auxiliary consumption reduces the energy sent out, not the PLF.

Why the other options are wrong: (a) 82.3% – grosses the energy up again for auxiliary use, counting it twice. (b) 84.3% – divides by 8,000 operating hours instead of the 8,760 hours in the year. (d) 72.0% – uses the net (sent-out) energy, whereas PLF is defined on gross generation.

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

2. India imported 232 million tonnes of crude oil in a year at an average landed price of ₹6,500 per barrel. Taking 7.33 barrels per tonne of crude, what was the import bill?

[5P1CEM002 | Chapter 1: Energy Scenario | Crude oil import bill from tonnage and barrel price]

- a) ₹11.05 lakh crore
- b) ₹13.00 lakh crore
- c) ₹9.49 lakh crore
- d) ₹9.40 lakh crore

Correct answer: (a) ₹11.05 lakh crore.

Given: imports = 232 Mt; 7.33 bbl/t; price = ₹6,500/bbl.

Formula: import bill = tonnes × barrels per tonne × price per barrel.

Substitution: $232 \times 10^6 \times 7.33 = 1,700.6$ million barrels; $\times ₹6,500 = ₹11,053,640,000,000$.

Result: $\approx ₹11.05$ lakh crore (1 lakh crore = 10^{12} rupees).

This is why the guidebook links oil imports to energy security and the trade balance: each 1% cut in crude use saves roughly ₹11,000 crore a year.

Why the other options are wrong: (b) ₹13.00 lakh crore – divides by 85% import dependence although the tonnage is already the imported quantity. (c) ₹9.49 lakh crore – uses 6.29 barrels, which is the number of barrels in one cubic metre, not in one tonne. (d) ₹9.40 lakh crore – multiplies by the 85% import share, wrongly treating the tonnage as total consumption.

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

3. Domestic gas is priced at ₹900 per MMBtu on GCV basis. The gas has a GCV of 9,500 kcal/Sm³ (≈ 39.8 MJ/Sm³) and 1 MMBtu = 2,52,000 kcal ($\approx 1,055$ MJ). What does one Sm³ of this gas cost?

[SP1CEM003 | Chapter 1: Energy Scenario | Natural gas pricing - converting a price per MMBtu into rupees per standard cubic metre]

a) ₹35.71 per Sm³

b) ₹33.93 per Sm³

c) ₹29.18 per Sm³

d) ₹30.54 per Sm³

Correct answer: (b) ₹33.93 per Sm³.

Given: price = ₹900/MMBtu (GCV); GCV = 9,500 kcal/Sm³ (≈ 39.8 MJ/Sm³); 1 MMBtu = 2,52,000 kcal ($\approx 1,055$ MJ).

Formula: ₹ per Sm³ = price per MMBtu × GCV per Sm³ ÷ kcal per MMBtu.

Substitution: $900 \times 9,500 \div 2,52,000 = 85,50,000 \div 2,52,000$.

Result: **₹33.93 per Sm³**, i.e. about 37.7 Sm³ of gas per MMBtu.

Gas prices in India are set per MMBtu, so the GCV basis must match. Using NCV makes gas look cheaper than it is.

Why the other options are wrong: (a) ₹35.71 per Sm³ – rounds the GCV up to 10,000 kcal/Sm³ instead of using the stated value. (c) ₹29.18 per Sm³ – uses 2,93,000 as kcal per MMBtu, mixing up kWh (293 kWh per MMBtu) with kcal. (d) ₹30.54 per Sm³ – uses the net calorific value of 8,550 kcal/Sm³ although the price is on GCV basis.

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

4. India's strategic petroleum reserve caverns hold 5.33 million tonnes of crude. Crude processed by refineries is 232 Mt a year, of which 85% is imported. For how many days of total crude processing does the reserve provide cover?

[SP1CEM004 | Chapter 1: Energy Scenario | Energy security - cover provided by strategic petroleum reserves]

a) 9.87 days

b) 6.89 days

c) 7.13 days

d) 8.39 days

Correct answer: (d) 8.39 days.

Given: reserve = 5.33 Mt; crude processed = 232 Mt/year; 365 days.

Formula: days of cover = reserve ÷ daily crude processing = reserve ÷ (annual crude ÷ 365).

Substitution: $232 \div 365 = 0.6356$ Mt/day; $5.33 \div 0.6356$.

Result: ≈ 8.39 days of total crude processing.

Strategic stocks are one of the energy security strategies in Chapter 1, along with diversifying suppliers and fuels.

Commercial refinery stocks add further cover.

Why the other options are wrong: (a) 9.87 days – measures cover against imports only, whereas the question asks for total crude processing. (b) 6.89 days – uses 300 working days, but refineries run all 365 days of the year. (c) 7.13 days – multiplies by the import share, which has no place in a days-of-processing cover.

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

5. A country's coal reserves are 1,50,000 Mt and this year's production is 1,000 Mt, so the static reserves-to-production ratio is 150 years. If production grows 5% a year, after how many years will the reserves be exhausted?

[SP1CEM005 | Chapter 1: Energy Scenario | Life of fossil reserves when production keeps growing]

- a) 60.0 years
- b) 41.3 years
- c) 43.9 years
- d) 42.8 years

Correct answer: (c) 43.9 years.

Given: reserves $R = 1,50,000$ Mt; production $P_0 = 1,000$ Mt/year; growth $g = 5\%$; static $R/P = 150$ years.

Formula: $\sum P_0(1+g)^t$ over n years $= P_0[(1+g)^n - 1] \div g = R$, so $n = \ln(1+g \cdot R/P_0) \div \ln(1+g)$.

Substitution: $\ln(1 + 0.05 \times 150) \div \ln(1.05) = \ln 8.5 \div 0.04879 = 2.1401 \div 0.04879$.

Result: ≈ 43.9 years, less than a third of the static R/P .

The guidebook quotes R/P ratios at current production. Growth in demand shortens reserve life sharply, which is the energy-security case for efficiency.

Why the other options are wrong: (a) 60.0 years – assumes production grows by a constant 50 Mt a year, i.e. linear rather than compound growth. (b) 41.3 years – drops the '1 +' inside the logarithm of the exponential-life formula. (d) 42.8 years – uses continuous growth, dividing by 0.05 instead of $\ln(1.05)$.

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

6. Under the Carbon Credit Trading Scheme, 2023 notified using the EC (Amendment) Act, 2022, which pairing of body and role is NOT correct?

[SP1CEM006 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | Carbon Credit Trading Scheme, 2023 - institutional roles]

- a) Grid Controller of India – registry that holds and tracks the certificates
- b) Central Electricity Regulatory Commission – regulator of credit trading
- c) Bureau of Energy Efficiency – administrator that proposes targets and trajectories
- d) Bureau of Energy Efficiency – registry for the carbon credit certificates

Correct answer: (d) Bureau of Energy Efficiency – registry for the carbon credit certificates.

The EC (Amendment) Act, 2022 inserted Section 14(w), letting the Central Government specify a carbon credit trading scheme. The CCTS, 2023 then divided the work.

BEE is the administrator: it develops the trading procedures, proposes GHG emission intensity targets for obligated entities and accredits verifiers.

Grid Controller of India Ltd is the registry, holding the accounts in which certificates are issued, transferred and surrendered. CERC regulates trading.

A National Steering Committee for the Indian Carbon Market oversees the whole scheme. One certificate equals one tonne of CO_2 equivalent. Calling BEE the registry is therefore wrong.

Why the other options are wrong: (a) This option is correct; Grid-India is the registry. (b) This option is correct; CERC regulates trading on power exchanges. (c) This option is correct; BEE is the scheme administrator.

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

7. An obligated aluminium-sheet plant under the CCTS has a baseline GEI of 2.10 $\text{tCO}_2\text{e/t}$ and a target GEI of 1.95 $\text{tCO}_2\text{e/t}$ for the compliance year. It produced 8,00,000 t at an achieved GEI of 2.02 $\text{tCO}_2\text{e/t}$. How many carbon credit certificates must it buy and surrender?

[SP1CEM007 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | CCTS compliance - certificates to surrender for missing the GHG emission intensity target]

- a) 1,20,000 certificates
- b) 56,000 certificates

c) 64,000 certificates

d) 49,000 certificates

Correct answer: (b) 56,000 certificates.

Given: target GEI = 1.95 tCO₂e/t; achieved = 2.02 tCO₂e/t; production = 8,00,000 t; 1 certificate = 1 tCO₂e.

Formula: shortfall = (achieved GEI – target GEI) × compliance-year production.

Substitution: $(2.02 - 1.95) \times 8,00,000 = 0.07 \times 8,00,000$.

Result: **56,000 certificates** must be surrendered.

This mirrors the way PAT counted ESCerts in toe, but CCTS targets are emission intensities. An entity that beats its target is issued certificates it can sell.

Why the other options are wrong: (a) 1,20,000 certificates – takes baseline minus target, which is the required improvement, not the shortfall. (c) 64,000 certificates – takes baseline minus achieved, which is the improvement made, not the shortfall against target. (d) 49,000 certificates – uses an assumed baseline output of 7,00,000 t instead of the compliance-year output.

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

8. Which change was NOT made by the Energy Conservation (Amendment) Act, 2022?

[SP1CEM008 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | EC (Amendment) Act, 2022 - changes to the scope of the Act]

a) Designated consumers can be required to meet a minimum non-fossil energy share

b) Vehicles and vessels were added to the equipment for which norms can be set

c) Large residential buildings were brought within the building energy code

d) Designated consumers were relieved of their duty to appoint certified energy managers

Correct answer: (d) Designated consumers were relieved of their duty to appoint certified energy managers.

The 2022 amendment widened the Act in four main ways. It enabled a carbon credit trading scheme (Section 14(w)). It let the Centre require designated consumers to meet a minimum share of their energy from non-fossil sources (Section 14(x)). It renamed the building code the Energy Conservation and Sustainable Building Code and extended it to large residential buildings. It also brought vehicles and vessels within the Act.

Designated consumers' duties to appoint certified energy managers, file returns and get mandatory audits were not touched. The statement claiming they were relaxed is the incorrect one.

Why the other options are wrong: (a) This option is a real change under the new Section 14(x). (b) This option is a real change; ships and vehicles can now be given norms. (c) This option is a real change; the code now covers large residential buildings too.

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

9. Which statement about the Energy Conservation and Sustainable Building Code (ECSBC) 2024 for commercial buildings is wrong?

[SP1CEM009 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | ECSBC 2024 - compliance approaches and performance levels]

a) Three performance levels give progressively lower energy use than the base level

b) The Super level needs only the mandatory provisions, nothing more

c) Whole-building performance compares a proposed design with a standard design

d) Mandatory provisions apply under every compliance approach and level

Correct answer: (b) The Super level needs only the mandatory provisions, nothing more.

ECSBC keeps the structure of ECBC 2017 and adds sustainability requirements. A building can comply through the prescriptive method, the building-envelope trade-off method or the whole-building performance method.

Under the whole-building route the proposed design is simulated and its annual energy is compared with a standard design built to code. Each route has three performance levels: the base code level, the 'plus' level and the 'super' level, each needing deeper savings.

The mandatory provisions cover the envelope, comfort systems, lighting and electrical systems and apply at every level. The super level demands the most, so saying it needs only the mandatory provisions is wrong.

Why the other options are wrong: (a) This option is correct; the levels are base, plus and super. (c) This option is correct; this is the simulation route. (d) This option is correct; mandatory provisions are always required.

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

10. Section 14(x), inserted by the EC (Amendment) Act, 2022, lets the Centre require designated consumers to meet a minimum share of energy from non-fossil sources. A steel plant uses 1,20,000 MWh of electricity a year: 18,000 MWh from captive rooftop solar, 12,000 MWh bought under green energy open access and the rest from the grid.

What non-fossil share of its electricity has it achieved?

[SP1CEM010 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | Non-fossil energy share of a designated consumer under Section 14(x)]

a) 10.0%

b) 33.3%

c) 25.0%

d) 15.0%

Correct answer: (c) 25.0%.

Given: total electricity = 1,20,000 MWh; captive solar = 18,000 MWh; green open access = 12,000 MWh.

Formula: non-fossil share = (captive renewable + contracted renewable) ÷ total consumption × 100.

Substitution: $(18,000 + 12,000) \div 1,20,000 = 30,000 \div 1,20,000$.

Result: **non-fossil share = 25.0%.**

If the notified minimum were 30%, the plant would need 6,000 MWh more from renewable sources. Before the amendment the Act had no such power. Renewable purchase obligations applied only to DISCOMs and captive users under the Electricity Act.

Why the other options are wrong: (a) 10.0% – counts only the open-access power and leaves out the captive solar. (b) 33.3% – divides the non-fossil MWh by the fossil MWh instead of total consumption. (d) 15.0% – counts only the captive solar and leaves out green open-access power.

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

11. A 10 m^3 hydrogen buffer vessel at an electrolyser plant is at 30 bar(g) and 30 °C. Taking the gas constant for hydrogen as 4,124 J/kg·K, atmospheric pressure as 1.013 bar and ideal-gas behaviour, what mass of hydrogen does it hold?

[SP1CEM011 | Chapter 3: Basics of Energy and its Various Forms | Ideal gas law - mass of hydrogen in a buffer vessel]

a) 24.0 kg

b) 27.5 kg

c) 26.6 kg

d) 24.8 kg

Correct answer: (d) 24.8 kg.

Given: $V = 10 \text{ m}^3$; $p = 30 + 1.013 = 31.013 \text{ bar(a)} = 31,01,300 \text{ Pa}$; $T = 303.15 \text{ K}$; $R(\text{H}_2) = 4,124 \text{ J/kg·K}$.

Formula: $m = pV \div (RT)$.

Substitution: $31,01,300 \times 10 \div (4,124 \times 303.15) = 3,10,13,000 \div 1,250,191$.

Result: **$m \approx 24.8 \text{ kg}$** of hydrogen, about 977 kWh on HHV.

Gas-law calculations always use absolute pressure and temperature. Hydrogen's low density is why its storage is bulky even at 30 bar.

Why the other options are wrong: (a) 24.0 kg – uses gauge pressure in $pV = mRT$, which needs absolute pressure. (b) 27.5 kg – uses 273.15 K, i.e. 0 °C, instead of the actual 303.15 K. (c) 26.6 kg – uses gauge pressure and also takes the temperature as 0 °C.

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

12. An auditor tests an 18 kW electric flow heater. With a measured input of 18.0 kW it heats 6.0 litres per minute of water from 25 °C to 60 °C. Taking $c_p = 4.187 \text{ kJ/kg}\cdot\text{K}$ and $1 \text{ L} = 1 \text{ kg}$, what is the heater's efficiency?

[5P1CEM012 | Chapter 3: Basics of Energy and its Various Forms | Efficiency of an electric water heater from a measured flow test]

- a) 98.9%
- b) 73.3%
- c) 81.4%
- d) 47.0%

Correct answer: (c) 81.4%.

Given: flow = 6.0 L/min = 0.10 kg/s; $\Delta T = 60 - 25 = 35 \text{ K}$; input = 18.0 kW.

Formula: useful heat = $m \times c_p \times \Delta T$; efficiency = useful heat $\div$ electrical input $\times 100$.

Substitution: $0.10 \times 4.187 \times 35 = 14.65 \text{ kW}$; $14.65 \div 18.0$.

Result: **efficiency $\approx 81.4\%$.**

Measured flow and temperatures give the direct (input-output) efficiency. The shortfall from 100% is surface and pipe loss, which insulation can recover.

Why the other options are wrong: (a) 98.9% – uses the mean water temperature of 42.5 °C as the temperature rise. (b) 73.3% – applies an extra 0.9 power factor to an almost purely resistive heater. (d) 47.0% – multiplies the measured 18.0 kW by $\sqrt{3}$, a three-phase slip that applies to $V \times I$, not to measured kW.

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

13. A sealed 5 m³ steel tank holds air at 1.01325 bar and 27 °C. It is heated to 127 °C. Taking $R = 287 \text{ J/kg}\cdot\text{K}$, $c_v = 0.718 \text{ kJ/kg}\cdot\text{K}$ and $c_p = 1.005 \text{ kJ/kg}\cdot\text{K}$, how much heat does the air absorb?

[5P1CEM013 | Chapter 3: Basics of Energy and its Various Forms | Heating a gas at constant volume - specific heat c_v versus c_p]

- a) 422 kJ
- b) 591 kJ
- c) 650 kJ
- d) 464 kJ

Correct answer: (a) 422 kJ.

Given: $V = 5 \text{ m}^3$; $p = 1,01,325 \text{ Pa}$; $T_1 = 300.15 \text{ K}$; $\Delta T = 100 \text{ K}$; $c_v = 0.718 \text{ kJ/kg}\cdot\text{K}$.

Formula: $m = pV \div (RT_1)$; $Q = m \times c_v \times \Delta T$ (no work is done at constant volume).

Substitution: $m = 1,01,325 \times 5 \div (287 \times 300.15) = 5.881 \text{ kg}$; $Q = 5.881 \times 0.718 \times 100$.

Result: **$Q \approx 422 \text{ kJ}$.**

In a closed rigid vessel all the heat raises internal energy, so c_v applies. In an open, constant-pressure heater c_p applies because the gas also does expansion work.

Why the other options are wrong: (b) 591 kJ – uses c_p , which applies to heating at constant pressure, not in a sealed tank. (c) 650 kJ – uses the 0 °C density and also uses c_p instead of c_v . (d) 464 kJ – takes the air density as 1.293 kg/m^3 , the value at 0 °C, instead of using the gas law.

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

14. An air-handling unit cools 10,000 m³/h of air (density 1.2 kg/m³) and lowers its humidity ratio from 0.018 to 0.010 kg/kg dry air. Taking the latent heat as 2,450 kJ/kg, what is the latent cooling load?

[5P1CEM014 | Chapter 3: Basics of Energy and its Various Forms | Latent load of dehumidification from humidity ratios]

- a) 54.4 kW
- b) 147.0 kW
- c) 65.3 kW
- d) 60.2 kW

Correct answer: (c) 65.3 kW.

Given: air = 10,000 m³/h $\times 1.2 = 12,000 \text{ kg/h}$; $\Delta \omega = 0.018 - 0.010 = 0.008 \text{ kg/kg}$; $h_{fg} = 2,450 \text{ kJ/kg}$.

Formula: water condensed = $m(\text{air}) \times \Delta \omega$; latent load = water condensed $\times h_{fg} \div 3,600$.

Substitution: $12,000 \times 0.008 = 96 \text{ kg/h}$; $96 \times 2,450 \div 3,600$.

Result: **latent load $\approx 65.3 \text{ kW}$** (about 18.6 TR ($\approx 65.4 \text{ kW}$)).

Psychrometric balances always use the mass of dry air, because humidity ratio is defined per kg of dry air.

Why the other options are wrong: (a) 54.4 kW – multiplies the humidity ratio by m^3/h instead of by kg/h of air. (b) 147.0 kW – uses the whole inlet humidity ratio, as if the coil removed all the moisture. (d) 60.2 kW – uses $2,257 \text{ kJ/kg}$, the latent heat at 100°C , not at coil conditions.

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

15. A flywheel UPS has a moment of inertia of $25 \text{ kg}\cdot\text{m}^2$ and runs at 3,600 rpm. It can deliver energy until its speed falls to 1,800 rpm. How much energy can it deliver per discharge?

[5P1CEM015 | Chapter 3: Basics of Energy and its Various Forms | Kinetic energy stored in a flywheel UPS]

a) 0.247 kWh

b) 0.370 kWh

c) 0.493 kWh

d) 0.740 kWh

Correct answer: (b) 0.370 kWh.

Given: $I = 25 \text{ kg}\cdot\text{m}^2$; $N_1 = 3,600 \text{ rpm}$; $N_2 = 1,800 \text{ rpm}$.

Formula: $\omega = 2\pi N \div 60$; usable $E = \frac{1}{2} I (\omega_1^2 - \omega_2^2)$.

Substitution: $\omega_1 = 377.0 \text{ rad/s}$; $\omega_2 = 188.5 \text{ rad/s}$; $\frac{1}{2} \times 25 \times (377.0^2 - 188.5^2) = 1,332,397 \text{ J}$; $\div 3.6 \times 10^6$.

Result: **usable energy $\approx 0.370 \text{ kWh}$** (75% of the stored energy).

Kinetic energy rises with the square of speed, so halving speed releases three-quarters of it. Flywheels suit short ride-through, not long backup.

Why the other options are wrong: (a) 0.247 kWh – assumes energy falls in proportion to speed, but it varies with speed squared. (c) 0.493 kWh – counts all the stored energy, as if the flywheel could be run down to standstill. (d) 0.740 kWh – leaves out the $\frac{1}{2}$ in $E = \frac{1}{2} I \omega^2$.

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

16. A 30 kWh electric-vehicle battery is charged from 20% to 80% state of charge by a 7.4 kW AC charger whose overall charging efficiency is 92%. How long does the charge take at full charger output?

[5P1CEM016 | Chapter 3: Basics of Energy and its Various Forms | Charging time of an electric vehicle battery with charger losses]

a) 2.43 hours

b) 4.41 hours

c) 2.64 hours

d) 2.24 hours

Correct answer: (c) 2.64 hours.

Given: battery = 30 kWh; SoC window = $80\% - 20\% = 60\%$; charger = 7.4 kW; efficiency = 0.92.

Formula: time = energy into battery $\div$ (charger power $\times$ efficiency).

Substitution: $30 \times 0.60 = 18 \text{ kWh}$; $7.4 \times 0.92 = 6.808 \text{ kW}$ reaching the battery; $18 \div 6.808$.

Result: **$\approx 2.64 \text{ hours}$** ; grid energy drawn = $18 \div 0.92 = 19.57 \text{ kWh}$.

Energy conversion losses appear as extra input. That is why grid kWh per km of an EV is higher than battery kWh per km.

Why the other options are wrong: (a) 2.43 hours – ignores charging losses and assumes all 7.4 kW reaches the battery. (b) 4.41 hours – charges the full 30 kWh instead of the 60% window. (d) 2.24 hours – multiplies by the efficiency instead of dividing by it.

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

17. Hydrogen has a higher heating value of 141.8 MJ/kg and a molar mass of 2.016 kg/kmol . Taking the molar volume at NTP as $22.414 \text{ m}^3/\text{kmol}$, what is its higher heating value per Nm^3 ?

[5P1CEM017 | Chapter 3: Basics of Energy and its Various Forms | Volumetric heating value of hydrogen at NTP]

- a) 12.75 MJ/Nm³
- b) 6.38 MJ/Nm³
- c) 11.68 MJ/Nm³
- d) 10.79 MJ/Nm³

Correct answer: (a) 12.75 MJ/Nm³.

Given: HHV = 141.8 MJ/kg; M = 2.016 kg/kmol; V(m) = 22.414 m³/kmol at 0 °C and 1 atm.

Formula: density at NTP = $M \div V(m)$; HHV per Nm³ = HHV per kg × density.

Substitution: $2.016 \div 22.414 = 0.08994$ kg/Nm³; 141.8×0.08994 .

Result: **≈ 12.75 MJ/Nm³**, about a third of natural gas.

Hydrogen has the highest energy per kg of any fuel but one of the lowest per unit volume, which drives its storage and pipeline costs.

Why the other options are wrong: (b) 6.38 MJ/Nm³ – takes hydrogen as atomic, 1.008 kg/kmol, instead of H₂. (c) 11.68 MJ/Nm³ – uses 24.465 m³/kmol, the molar volume at 25 °C, not at NTP. (d) 10.79 MJ/Nm³ – uses the lower heating value of 120 MJ/kg instead of the higher value.

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

18. A cement plant makes 20 lakh t of cement a year at a clinker factor of 0.70. Its thermal SEC is 720 kcal/kg clinker (≈ 3,014 kJ/kg clinker) against a best practice of 680, and its electrical SEC is 78 kWh/t cement against 70. Taking 1 kWh = 860 kcal (≈ 3,601 kJ) and 1 toe = 10⁷ kcal, what total saving in toe would closing both gaps give?

[SP1CEM018 | Chapter 4: Energy Management and Audit | Benchmarking - saving potential of a cement plant expressed in toe]

- a) 9,376 toe
- b) 5,600 toe
- c) 9,947 toe
- d) 6,976 toe

Correct answer: (d) 6,976 toe.

Given: cement = 20 lakh t; clinker = $0.70 \times 20 = 14$ lakh t; thermal gap = 40 kcal/kg clinker (≈ 167 kJ/kg clinker); electrical gap = 8 kWh/t cement.

Formula: thermal saving = gap × clinker mass; electrical saving = gap × cement × 860 kcal/kWh; toe = kcal ÷ 10⁷.

Substitution: $40 \times 14 \times 10^8$ kg = 5.6×10^{10} kcal = 5,600 toe; $8 \times 20,00,000 = 1,60,00,000$ kWh × 860 = 1,376 toe.

Result: **≈ 6,976 toe (≈ 292 TJ) a year.**

Benchmarking shows the size of the prize before detailed audits.

Why the other options are wrong: (a) 9,376 toe – applies the thermal gap to cement tonnage, ignoring the clinker factor.

(b) 5,600 toe – counts only the thermal gap and leaves out electricity. (c) 9,947 toe – converts electricity at a 2,717 kcal/kWh heat rate, which is not the 860 kcal/kWh convention stated.

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

19. A plant's coal yard had an opening stock of 1,200 t on 1 April. During the year 8,500 t were received and the closing stock on 31 March was 1,500 t. The coal's GCV is 4,200 kcal/kg (≈ 17,585 kJ/kg). What was the year's coal consumption in toe (1 toe = 10⁷ kcal)?

[SP1CEM019 | Chapter 4: Energy Management and Audit | Energy accounting - fuel consumed from a stock reconciliation, in toe]

- a) 3,444 toe
- b) 4,704 toe
- c) 3,696 toe
- d) 3,570 toe

Correct answer: (a) 3,444 toe.

Given: opening 1,200 t; receipts 8,500 t; closing 1,500 t; GCV 4,200 kcal/kg (≈ 17,585 kJ/kg).

Formula: consumption = opening stock + receipts – closing stock; toe = mass (kg) × GCV ÷ 10⁷.

Substitution: $1,200 + 8,500 - 1,500 = 8,200$ t; $82,00,000$ kg × $4,200 \div 10^7$.

Result: $\approx 3,444 \text{ toe}$ ($\approx 144 \text{ TJ}$) of coal consumed.

Energy accounts in an audit and in designated-consumer returns must use consumption, not purchases. Stock changes, and moisture differences between receipt and firing, are common reconciliation errors.

Why the other options are wrong: (b) 4,704 toe – adds the closing stock instead of deducting it. (c) 3,696 toe – adds the 300 t stock change instead of subtracting it. (d) 3,570 toe – takes the coal received as the coal consumed, ignoring the stock build-up.

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

20. Energy is ₹30 crore of a plant's ₹200 crore manufacturing cost. Next year energy prices rise 20% and all other costs rise 5%, with output unchanged. What will energy's share of manufacturing cost be?

[5P1CEM020 | Chapter 4: Energy Management and Audit | Need for energy audit - share of energy in manufacturing cost after a price rise]

- a) 17.1%
- b) 15.3%
- c) 16.8%
- d) 18.0%

Correct answer: (c) 16.8%.

Given: energy = ₹30 crore; other costs = ₹170 crore; energy +20%; others +5%.

Formula: new share = new energy cost ÷ (new energy cost + new other costs) × 100.

Substitution: energy = $30 \times 1.20 = ₹36$ crore; others = $170 \times 1.05 = ₹178.5$ crore; $36 \div 214.5$.

Result: $\approx 16.8\%$ of manufacturing cost.

The guidebook lists energy among the top operating expenses. When energy prices outpace other costs its share grows, making the audit more valuable.

Why the other options are wrong: (a) 17.1% – scales the old 15% share by $1.20 \div 1.05$, which ignores the cost mix. (b) 15.3% – adds the new energy cost to the old total, counting energy twice. (d) 18.0% – divides the new energy cost by last year's total cost.

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

21. An audit report groups its recommendations into no-cost, low-cost and high-investment measures. Which classification is NOT appropriate?

[5P1CEM021 | Chapter 4: Energy Management and Audit | Classifying energy conservation measures by investment need]

- a) Cutting excess air in a furnace by retuning burners – no-cost measure
- b) Replacing a coal-fired boiler with a new FBC boiler – low-cost measure
- c) Installing a waste-heat recovery boiler on a kiln – high-investment measure
- d) Adding timers to switch off idle conveyors – low-cost measure

Correct answer: (b) Replacing a coal-fired boiler with a new FBC boiler – low-cost measure.

The guidebook's audit approach sorts energy conservation opportunities by what they cost. No-cost measures change operating or housekeeping practice, such as tuning combustion, switching off idle equipment and fixing set points. Low-cost measures need modest hardware with paybacks of months, such as timers, insulation repairs and traps.

High-investment measures need capital budgeting and detailed engineering, such as cogeneration, waste-heat boilers or new boilers. These go through financial appraisal with NPV and IRR.

Replacing a boiler with a new FBC unit costs crores and needs detailed appraisal, so calling it low-cost is wrong.

Why the other options are wrong: (a) This option is appropriate; only operating practice changes. (c) This option is appropriate; it needs major capital and engineering. (d) This option is appropriate; the hardware is cheap and pays back fast.

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

22. 1,000 kg of a 40% (by mass) potassium nitrate solution is cooled. At the final temperature the solubility is 20 kg per 100 kg of water. What mass of crystals (no water of crystallisation) separates?

[SP1CEM022 | Chapter 5: Material and Energy Balance | Material balance - crystals formed on cooling a saturated solution]

- a) 280 kg
- b) 233 kg
- c) 250 kg
- d) 200 kg

Correct answer: (a) 280 kg.

Given: feed = 1,000 kg with 400 kg salt and 600 kg water; solubility = 20 kg salt per 100 kg water.

Formula: water is the tie element, since it all stays in the mother liquor; salt in liquor = $0.20 \times \text{water}$; crystals = salt in feed – salt in liquor.

Substitution: salt held in liquor = $0.20 \times 600 = 120$ kg; crystals = $400 - 120$.

Result: **280 kg of crystals**; mother liquor = 720 kg.

The guidebook's method is to pick a component that passes through unchanged. Water does here, which avoids solving simultaneous equations.

Why the other options are wrong: (b) 233 kg – takes the solubility as 16.7% of the original solution mass. (c) 250 kg – takes 20% as the salt fraction of the remaining solution instead of 20 kg per 100 kg water. (d) 200 kg – deducts 20% of the original 1,000 kg of solution from the salt.

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

23. A continuous dryer removes 300 kg/h of water from a product. Inlet air has a humidity ratio of 0.012 kg/kg dry air and the exhaust 0.042 kg/kg dry air. What flow of dry air is needed?

[SP1CEM023 | Chapter 5: Material and Energy Balance | Dryer material balance - dry air needed to carry away the evaporated water]

- a) 7,143 kg/h
- b) 5,556 kg/h
- c) 10,000 kg/h
- d) 25,000 kg/h

Correct answer: (c) 10,000 kg/h.

Given: water evaporated = 300 kg/h; $\omega(\text{in}) = 0.012$; $\omega(\text{out}) = 0.042$ kg/kg dry air.

Formula: water balance on the air: $m(\text{dry air}) \times (\omega(\text{out}) - \omega(\text{in})) = \text{water evaporated}$.

Substitution: $m = 300 \div (0.042 - 0.012) = 300 \div 0.030$.

Result: **10,000 kg/h of dry air** (about 10,120 kg/h of moist inlet air).

The pick-up per kg of air fixes air flow and therefore fan power and heater load. Raising exhaust humidity is a classic dryer saving.

Why the other options are wrong: (a) 7,143 kg/h – divides by the exhaust humidity alone, ignoring the moisture the air brings in. (b) 5,556 kg/h – adds the two humidity ratios instead of subtracting. (d) 25,000 kg/h – divides by the inlet humidity, which is the wrong end of the dryer.

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

24. A recuperative air preheater cools 25,000 kg/h of flue gas (cp 0.25 kcal/kg°C (≈ 1.05 kJ/kg·K)) from 360 °C to 200 °C. It heats 22,000 kg/h of combustion air (cp 0.24 kcal/kg°C (≈ 1.00 kJ/kg·K)) entering at 35 °C. Ignoring losses, at what temperature does the air leave?

[SP1CEM024 | Chapter 5: Material and Energy Balance | Energy balance - air outlet temperature of a flue-gas air preheater]

- a) 216.8 °C
- b) 209.5 °C
- c) 189.4 °C
- d) 224.4 °C

Correct answer: (d) 224.4 °C.

Given: flue gas 25,000 kg/h, cp 0.25 kcal/kg°C (≈ 1.05 kJ/kg·K), ΔT 160 °C; air 22,000 kg/h, cp 0.24 kcal/kg°C (≈ 1.00 kJ/kg·K), in at 35 °C.

Formula: heat lost by gas = heat gained by air: $m(g) \cdot cp(g) \cdot \Delta T(g) = m(a) \cdot cp(a) \cdot \Delta T(a)$.

Substitution: $25,000 \times 0.25 \times 160 = 10,00,000$ kcal/h; $\Delta T(a) = 10,00,000 \div (22,000 \times 0.24) = 189.4$ °C.

Result: **air leaves at ≈ 224.4 °C**; heat transferred 10,00,000 kcal/h ($\approx 1,163$ kW).

Each stream must carry its own cp. Getting cp wrong distorts outlet temperatures even when the heat duty is right.

Why the other options are wrong: (a) 216.8 °C – assumes equal specific heats for both streams. (b) 209.5 °C – swaps the specific heats of flue gas and air. (c) 189.4 °C – gives the air temperature rise and forgets to add the 35 °C inlet temperature.

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

25. A coal with 30% ash is burnt on a grate. All the ash leaves as refuse, which analyses 5% unburnt carbon. How much carbon is lost in the refuse per tonne of coal fired?

[5P1CEM025 | Chapter 5: Material and Energy Balance | Ash balance - carbon lost in the ash of a coal-fired unit]

- a) 15.0 kg
- b) 14.3 kg
- c) 15.8 kg
- d) 35.0 kg

Correct answer: (c) 15.8 kg.

Given: ash in coal = 30% = 300 kg per tonne; refuse = ash + unburnt carbon, with carbon 5% of refuse.

Formula: ash is the tie element: refuse = ash $\div$ (1 – carbon fraction); carbon = refuse – ash.

Substitution: refuse = $300 \div 0.95 = 315.8$ kg; carbon = $315.8 - 300$.

Result: **≈ 15.8 kg of carbon per tonne of coal**, about 1,27,642 kcal (≈ 534 MJ) of heat at 8,084 kcal/kg ($\approx 33,846$ kJ/kg).

Ash passes through unchanged, which makes it the natural tie element. Unburnt carbon in refuse is a direct fuel loss.

Why the other options are wrong: (a) 15.0 kg – takes 5% of the ash itself, but the refuse is ash plus carbon. (b) 14.3 kg – divides by 1.05 instead of 0.95, adding carbon to the refuse. (d) 35.0 kg – applies 5% to the combustible part of the coal instead of to the refuse.

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

26. Top management of a steel plant holds its periodic EnMS meeting under ISO 50001:2018. Which item belongs among the decisions recorded as a result of that meeting, rather than the information presented to it?

[5P1CEM026 | Chapter 6: Energy Action Planning | ISO 50001 - inputs to and outputs of the management review]

- a) Status of actions from the previous management review
- b) Decisions on changes to the EnPIs or the energy baselines
- c) Results of internal audits and the status of corrective actions
- d) Energy performance and improvement measured by the EnPIs

Correct answer: (b) Decisions on changes to the EnPIs or the energy baselines.

ISO 50001 makes top management review the EnMS at planned intervals, so energy performance becomes a business decision rather than a technical report.

Inputs are the evidence the review examines: action status from previous reviews, the energy policy, EnPI results compared with the baselines, compliance with legal requirements, internal audit findings, nonconformities and corrective actions, and projected performance.

Outputs are the decisions taken: opportunities to improve energy performance, changes to the policy, EnPIs or baselines, objectives and targets, and allocation of resources. A decision to change EnPIs or baselines is therefore an output.

Why the other options are wrong: (a) This option is an input; past actions are reviewed. (c) This option is an input; audit results feed the review. (d) This option is an input; the review examines performance data.

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

27. A plant set a target to cut its SEC by 8% from 420 kWh/t over three years. After two years the SEC is 395 kWh/t. What percentage of the required reduction has been achieved so far?

[SP1CEM027 | Chapter 6: Energy Action Planning | Tracking progress against a SMART energy target]

- a) 25.6%
- b) 66.7%
- c) 79.1%
- d) 74.4%

Correct answer: (d) 74.4%.

Given: baseline SEC = 420 kWh/t; target cut = 8%, so target SEC = 386.4 kWh/t; current SEC = 395 kWh/t.

Formula: progress = (baseline – current) ÷ (baseline – target) × 100.

Substitution: $(420 - 395) \div (420 - 386.4) = 25 \div 33.6$.

Result: **≈ 74.4% of the required reduction achieved**, with 8.6 kWh/t still to go.

A target is SMART only if progress can be measured like this. Here the third year must deliver a quarter of the cut.

Why the other options are wrong: (a) 25.6% – measures the gap still remaining rather than the progress made. (b) 66.7% – assumes progress equals elapsed time, two years out of three. (c) 79.1% – divides the reduction by the current SEC instead of the baseline.

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

28. An energy team scores three projects from 1 to 10 against weighted criteria: saving potential (weight 0.5), ease of implementation (0.3) and low risk (0.2). Scores are A: 8, 6, 7; B: 6, 9, 8; C: 9, 4, 6. Which project ranks first, and with what score?

[SP1CEM028 | Chapter 6: Energy Action Planning | Prioritising energy projects with a weighted scoring matrix]

- a) Project B, with a weighted score of 7.3
- b) Project C, with a weighted score of 6.9
- c) Project B, with an unweighted score of 7.7
- d) Project A, with a weighted score of 7.2

Correct answer: (d) Project A, with a weighted score of 7.2.

Given: weights 0.5, 0.3 and 0.2.

Formula: weighted score = $\sum(\text{weight} \times \text{score})$.

Substitution: $A = 0.5 \times 8 + 0.3 \times 6 + 0.2 \times 7 = 7.2$; $B = 3.0 + 2.7 + 1.6 = 7.3$; $C = 4.5 + 1.2 + 1.2 = 6.9$.

Result: **Project A ranks first (7.2)**, just ahead of B (7.3).

Action planning ranks opportunities on more than savings alone. A close result like this one should be tested by varying the weights.

Why the other options are wrong: (a) This option is the runner-up; its weighted score is below A's. (b) Picks the project with the highest saving score, ignoring the other criteria. (c) Averages the raw scores and drops the weights altogether.

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

29. A VFD costing ₹6,00,000 saves 12 kW whenever the fan runs. The energy charge is ₹8.00/kWh plus 5% electricity duty. For the VFD to pay back within 2 years, how many hours a year must the fan run at least?

[SP1CEM029 | Chapter 7: Financial Management | Break-even operating hours for a required payback]

- a) 2,976 hours
- b) 5,952 hours
- c) 3,125 hours
- d) 3,307 hours

Correct answer: (a) 2,976 hours.

Given: cost = ₹6,00,000; saving = 12 kW; tariff = $8.00 \times 1.05 = ₹8.40/\text{kWh}$; payback = 2 years.

Formula: required annual saving = cost ÷ payback; hours = annual saving ÷ (kW saved × tariff).

Substitution: $6,00,000 \div 2 = ₹3,00,000$ a year; $3,00,000 \div (12 \times 8.40) = 3,00,000 \div 100.8$.

Result: **≈ 2,976 hours a year.**

Break-even analysis turns a payback criterion into an operating condition the auditor can check against the plant's real running hours.

Why the other options are wrong: (b) 5,952 hours – solves for a one-year payback instead of two years. (c) 3,125 hours – leaves out the 5% electricity duty, which the saving also avoids. (d) 3,307 hours – multiplies the kW saving by a 0.9 power factor, which does not apply to kW.

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

30. An energy project costs ₹10 lakh and saves ₹4 lakh at the end of each of 4 years. Savings are reinvested at the firm's 10% cost of capital. What is the modified internal rate of return (MIRR)?

[5P1CEM030 | Chapter 7: Financial Management | Modified internal rate of return with a reinvestment rate]

- a) 16.7%
- b) 12.5%
- c) 13.2%
- d) 21.9%

Correct answer: (a) 16.7%.

Given: outlay = ₹10 lakh; savings ₹4 lakh × 4 years; reinvestment rate 10%.

Formula: terminal value = $\sum CF \times (1.1)^{(4-t)}$; MIRR = $(\text{terminal value} \div \text{outlay})^{(1/4)} - 1$.

Substitution: $4 \times (1.331 + 1.21 + 1.1 + 1) = ₹18.564$ lakh; $(18.564 \div 10)^{0.25}$.

Result: **MIRR ≈ 16.7%**, against an IRR of 21.9%.

MIRR corrects IRR's optimistic reinvestment assumption, so it gives a more realistic return for short, high-yield projects.

Why the other options are wrong: (b) 12.5% – compounds the undiscounted savings total of ₹16 lakh without reinvestment. (c) 13.2% – takes the root over five periods instead of four years. (d) 21.9% – is the ordinary IRR, which assumes reinvestment at the IRR itself.

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

31. A process redesign permanently removes a heating duty, saving ₹6 lakh in the first year. The saving will grow 2% a year with fuel prices, effectively for ever. At a 12% discount rate, what is the most the plant should invest?

[5P1CEM031 | Chapter 7: Financial Management | Present value of a growing perpetuity - maximum justified investment]

- a) ₹42.9 lakh
- b) ₹60.0 lakh
- c) ₹50.0 lakh
- d) ₹47.1 lakh

Correct answer: (b) ₹60.0 lakh.

Given: first-year saving = ₹6 lakh; growth $g = 2\%$ a year; discount rate $r = 12\%$; life unlimited.

Formula: PV of a growing perpetuity = first-year cash flow $\div (r - g)$, valid when $r > g$.

Substitution: $6 \div (0.12 - 0.02) = 6 \div 0.10$.

Result: **maximum justified investment ≈ ₹60.0 lakh.**

Measures that remove a need altogether, rather than serve it more efficiently, have very long lives. Escalating energy prices add value that a level-annuity calculation misses.

Why the other options are wrong: (a) ₹42.9 lakh – adds the growth rate to the discount rate instead of subtracting it. (c) ₹50.0 lakh – values a level perpetuity and ignores the 2% growth. (d) ₹47.1 lakh – limits the saving to 25 years and ignores growth.

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

32. An energy-efficiency loan of ₹50 lakh is repaid in 5 equal annual principal instalments, with 10% interest charged each year on the balance outstanding at the start of that year. What is the total payment due in year 3?

[5P1CEM032 | Chapter 7: Financial Management | Debt financing - instalment in a given year with equal principal repayment]

- a) ₹13.2 lakh
- b) ₹15.0 lakh
- c) ₹13.0 lakh
- d) ₹12.0 lakh

Correct answer: (c) ₹13.0 lakh.

Given: loan = ₹50 lakh; principal ₹10 lakh a year for 5 years; interest 10% on opening balance.

Formula: $\text{payment}(t) = \text{principal instalment} + \text{rate} \times \text{opening balance}(t)$.

Substitution: opening balance in year 3 = $50 - 2 \times 10 = ₹30$ lakh; $\text{payment} = 10 + 0.10 \times 30$.

Result: **year-3 payment = ₹13.0 lakh** (₹10 lakh principal + ₹3 lakh interest).

With equal principal repayment the debt service falls each year, so the early years strain the project's cash flow most.

Lenders check this against the savings.

Why the other options are wrong: (a) ₹13.2 lakh – uses the equated (EMI-type) instalment, which is a different repayment scheme. (b) ₹15.0 lakh – charges interest on the original ₹50 lakh every year. (d) ₹12.0 lakh – charges interest on the balance at the end of year 3 instead of the start.

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

33. Project P costs ₹20 lakh, saves ₹10 lakh a year and lasts 3 years. Project Q costs ₹30 lakh, saves ₹10 lakh a year and lasts 10 years. Which conclusion is correct?

[SP1CEM033 | Chapter 7: Financial Management | Limitations of payback when ranking projects of different lives]

- a) Q is better on NPV at 10%, though P has the shorter payback
- b) Q has the shorter payback and also the higher NPV at 10%
- c) P is better on every measure because its payback is shorter
- d) Both are equally attractive as both save ₹10 lakh a year

Correct answer: (a) Q is better on NPV at 10%, though P has the shorter payback.

Given: P: -20, +10 for 3 years; Q: -30, +10 for 10 years; rate 10%.

Formula: $\text{payback} = \text{cost} \div \text{annual saving}$; $\text{NPV} = \text{saving} \times \text{PVA} - \text{cost}$.

Substitution: payback P = 2 years, Q = 3 years; $\text{NPV P} = 10 \times 2.4869 - 20 = ₹4.87$ lakh; $\text{NPV Q} = 10 \times 6.1446 - 30 = ₹31.45$ lakh.

Result: **Q creates far more value even though P pays back sooner.**

The guidebook warns that payback ignores cash flows after the payback date and the time value of money.

Why the other options are wrong: (b) This option is wrong because Q's payback is 3 years, P's only 2 years. (c) This option is wrong because payback ignores Q's savings after year 3. (d) This option is wrong because the costs and lives differ widely.

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

34. Installing a waste-heat recovery unit costs ₹18 lakh and needs a 3-day shutdown, during which the plant loses ₹2.5 lakh of contribution per day. Savings are ₹1 lakh a month. What is the payback period?

[SP1CEM034 | Chapter 7: Financial Management | Payback including production lost during installation]

- a) 48.0 months
- b) 25.5 months
- c) 18.0 months
- d) 20.5 months

Correct answer: (b) 25.5 months.

Given: capital = ₹18 lakh; lost contribution = $3 \times ₹2.5$ lakh = ₹7.5 lakh; saving = ₹1 lakh/month.

Formula: $\text{payback} = (\text{capital} + \text{one-time lost contribution}) \div \text{monthly saving}$.

Substitution: $(18 + 7.5) \div 1.0 = 25.5$.

Result: **payback ≈ 25.5 months** (about 2.1 years).

Lost production is a real cost of the project and belongs in the investment. Scheduling the work in a planned shutdown removes it.

Why the other options are wrong: (a) 48.0 months – deducts the ₹7.5 lakh loss from every year's savings as if recurring. (c) 18.0 months – ignores the contribution lost during the shutdown. (d) 20.5 months – counts only one day of lost contribution.

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

35. A boiler retrofit risk register lists: delivery delay (probability 30%, impact –₹40 lakh), tariff fall cutting savings (20%, –₹25 lakh) and a state subsidy (25%, +₹20 lakh). What is the net expected monetary value of these items?

[5P1CEM035 | Chapter 8: Project Management | Expected monetary value of project risks and opportunities]

- a) –₹7.0 lakh
- b) –₹22.0 lakh
- c) –₹12.0 lakh
- d) –₹17.0 lakh

Correct answer: (c) –₹12.0 lakh.

Given: threats 0.30×40 and 0.20×25 ; opportunity 0.25×20 (in ₹ lakh).

Formula: $EMV = \Sigma(\text{probability} \times \text{impact})$, with threats negative and opportunities positive.

Substitution: $-(0.30 \times 40) - (0.20 \times 25) + (0.25 \times 20) = -12 - 5 + 5$.

Result: **net EMV = –₹12.0 lakh**, a sensible size for the contingency reserve.

Risk analysis in project planning quantifies the contingency. Opportunities offset threats only by their expected value.

Why the other options are wrong: (a) –₹7.0 lakh – omits the tariff-fall risk, treating it as outside the project. (b) –₹22.0 lakh – adds the subsidy as a threat instead of subtracting it. (d) –₹17.0 lakh – includes the two threats but leaves out the subsidy opportunity.

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

36. Insulating 4,800 m² of steam piping is planned with 3 crews. Each crew's standard output is 50 m² per day, and site conditions give a productivity factor of 0.8. What duration should the schedule use for this activity?

[5P1CEM036 | Chapter 8: Project Management | Activity duration from work quantity, crew output and productivity factor]

- a) 32.0 working days
- b) 25.6 working days
- c) 38.4 working days
- d) 40.0 working days

Correct answer: (d) 40.0 working days.

Given: quantity = 4,800 m²; 3 crews $\times$ 50 m²/day; productivity factor 0.8.

Formula: $\text{duration} = \text{quantity} \div (\text{crews} \times \text{standard output} \times \text{productivity factor})$.

Substitution: $3 \times 50 \times 0.8 = 120 \text{ m}^2/\text{day}$; $4,800 \div 120$.

Result: **40.0 working days.**

Network durations are only as good as these estimates. Optimistic outputs make every downstream float and finish date wrong.

Why the other options are wrong: (a) 32.0 working days – uses the standard output and ignores the productivity factor. (b) 25.6 working days – divides the output by 0.8 instead of multiplying, raising it. (c) 38.4 working days – treats 0.8 as a 20% increase in time, using $1 \div 1.2$.

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

37. An EPC contract worth ₹3.2 crore for a cogeneration plant carries liquidated damages of 0.5% of contract value per week of delay, capped at 10%. The plant is commissioned 26 weeks late. What LD can the owner recover?

[5P1CEM037 | Chapter 8: Project Management | Liquidated damages for late completion with a contractual cap]

- a) ₹32.0 lakh
- b) ₹41.6 lakh
- c) ₹16.0 lakh

d) ₹20.8 lakh

Correct answer: (a) ₹32.0 lakh.

Given: contract = ₹3.2 crore = ₹320 lakh; LD = 0.5% per week; delay = 26 weeks; cap = 10%.

Formula: $LD = \min(\text{rate} \times \text{weeks}, \text{cap}) \times \text{contract value}$.

Substitution: $0.5\% \times 26 = 13\%$, above the 10% cap; $10\% \times 320$.

Result: **LD = ₹32.0 lakh.**

LD clauses are a contractual tool for keeping energy projects on schedule. The cap limits the owner's recovery, so a long delay can cost more in lost savings than LD repays.

Why the other options are wrong: (b) ₹41.6 lakh – applies 0.5% for all 26 weeks without the 10% cap. (c) ₹16.0 lakh – reads the cap as 5% of contract value. (d) ₹20.8 lakh – applies the uncapped LD to only half the contract value.

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

38. Match the response to the risk correctly. Which pairing of risk and response is wrongly classified?

[5P1CEM038 | Chapter 8: Project Management | Risk response strategies for an energy project]

- a) Buying a performance bond from the contractor – risk avoidance
- b) Changing the design to remove an untested technology – risk avoidance
- c) Adding a second supplier for a critical heat exchanger – risk mitigation
- d) Keeping a contingency reserve for minor overruns – risk acceptance

Correct answer: (a) Buying a performance bond from the contractor – risk avoidance.

Project risk management offers four responses. Avoidance removes the cause, for example by dropping an unproven design. Transfer shifts the financial consequence to another party through insurance, bonds, guarantees or fixed-price contracts. Mitigation lowers the probability or impact, for example with a second supplier or extra testing. Acceptance keeps the risk, often with a contingency reserve.

A performance bond does not remove the chance that the contractor under-performs. It moves the financial loss to the surety, so it is transfer, not avoidance.

Why the other options are wrong: (b) This option is correctly classified. (c) This option is correctly classified. (d) This option is correctly classified as active acceptance.

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

39. A plant must implement twelve energy projects while running normal production. Which statement about project organisation is NOT correct?

[5P1CEM039 | Chapter 8: Project Management | Project organisation structures for implementing energy projects]

- a) In a matrix structure, staff report to both functional and project managers
- b) A projectised structure suits a large, long project with a dedicated team
- c) A functional structure keeps experts in departments and suits small projects
- d) A functional structure gives the project manager the strongest authority over resources

Correct answer: (d) A functional structure gives the project manager the strongest authority over resources.

In a functional organisation the project is run inside the line departments. Department heads control people and budgets, so the project coordinator has little authority. This suits small projects within one discipline.

A projectised organisation gives a dedicated team to a full-time project manager, which suits large projects. A matrix organisation lets staff remain in their departments while working on projects, so a plant running many projects alongside production usually chooses it.

Authority over resources is weakest, not strongest, in a functional structure.

Why the other options are wrong: (a) This option is correct; this dual reporting defines a matrix. (b) This option is correct; the team reports only to the project manager. (c) This option is correct; work is coordinated through department heads.

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

40. A plant's daily SEC over a stable reference period averages 410 kWh/t with a standard deviation of 12 kWh/t. Using conventional three-sigma limits, what are the upper and lower control limits?

[5P1CEM040 | Chapter 9: Energy Monitoring and Targeting | Control limits for daily specific energy consumption]

- a) 434 and 386 kWh/t
- b) 422 and 398 kWh/t
- c) 482 and 338 kWh/t
- d) 446 and 374 kWh/t

Correct answer: (d) 446 and 374 kWh/t.

Given: mean = 410 kWh/t; σ = 12 kWh/t.

Formula: $UCL = \text{mean} + 3\sigma$; $LCL = \text{mean} - 3\sigma$.

Substitution: $410 + 3 \times 12 = 446$; $410 - 3 \times 12 = 374$.

Result: **UCL = 446 kWh/t; LCL = 374 kWh/t.** A day at 452 kWh/t is outside the limits and needs investigation.

Monitoring and targeting separates random variation from real change. Points outside three-sigma limits, or runs on one side of the mean, signal a cause worth finding.

Why the other options are wrong: (a) 434 and 386 kWh/t – uses two-sigma limits, which are warning limits, not control limits. (b) 422 and 398 kWh/t – uses one-sigma limits, which normal variation crosses about a third of the time. (c) 482 and 338 kWh/t – uses six sigma on each side, confusing control limits with the six-sigma quality target.

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

41. Monthly data give $E = 180 + 0.62 P$ (E in MWh, P in tonnes) with $R^2 = 0.93$. Which interpretation is NOT correct?

[5P1CEM041 | Chapter 9: Energy Monitoring and Targeting | Interpreting a regression model of energy against production]

- a) About 180 MWh a month is used regardless of production level
- b) If production doubles, energy use will exactly double as well
- c) About 93% of the variation in energy is explained by production
- d) Each extra tonne needs about 0.62 MWh of additional energy

Correct answer: (b) If production doubles, energy use will exactly double as well.

The guidebook's energy–production line splits consumption into a fixed part (the intercept, for lighting, idle running and utilities) and a variable part (the slope, energy per unit of output).

R^2 of 0.93 means 93% of the month-to-month variation in energy is explained by production, so the model is good enough for targeting.

Because of the fixed 180 MWh, energy does not rise in proportion to output: doubling production from 500 t to 1,000 t raises energy from 490 to 800 MWh, only 63% more. SEC therefore falls as output rises, which is why SEC must be compared at similar production levels.

Why the other options are wrong: (a) This option is correct; the intercept is the fixed energy. (c) This option is correct; that is the meaning of R^2 . (d) This option is correct; the slope is the marginal energy.

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

42. A cold store's monthly energy model is $E = 120 + 0.6 P + 2.5 CDD$ (E in MWh, P in tonnes handled, CDD in degree-days). In June $P = 500$ t, $CDD = 40$ (the long-term June average is 30) and the meter shows 545 MWh. By what percentage did June exceed the expected energy?

[5P1CEM042 | Chapter 9: Energy Monitoring and Targeting | Expected energy from a two-variable model with production and degree-days]

- a) 6.0%
- b) 4.8%
- c) 4.6%
- d) 10.1%

Correct answer: (b) 4.8%.

Given: $P = 500$ t; $CDD = 40$; actual = 545 MWh.

Formula: expected $E = 120 + 0.6 P + 2.5 CDD$; excess = $(\text{actual} - \text{expected}) \div \text{expected} \times 100$.

Substitution: $120 + 300 + 100 = 520$ MWh; $(545 - 520) \div 520$.

Result: $\approx$ **4.8% above expected** (25 MWh).

Including every significant driver stops weather or volume being mistaken for poor performance, the main purpose of normalising in M&T.

Why the other options are wrong: (a) 6.0% – divides the 25 MWh excess by the expected energy without the weather term. (c) 4.6% – divides the excess by actual instead of expected energy. (d) 10.1% – uses the long-term average of 30 CDD instead of June's actual 40.

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

43. Which statement about India's climate commitments is NOT correct?

[5P1CEM043 | Chapter 10: Energy Efficiency and Climate Change | India's updated Nationally Determined Contribution and long-term goal]

- a) India's long-term goal, announced at COP26, is net-zero emissions by the year 2050
- b) The NDC promotes LiFE, a mass movement for environment-friendly sustainable lifestyles
- c) The updated NDC targets a 45% cut in emission intensity of GDP from 2005
- d) The NDC targets about half of installed power capacity from non-fossil sources by 2030

Correct answer: (a) India's long-term goal, announced at COP26, is net-zero emissions by the year 2050.

India submitted its updated NDC under the Paris Agreement in August 2022. It commits to reducing the emission intensity of GDP by 45% from the 2005 level by 2030. It also aims for about 50% of cumulative installed electric power capacity from non-fossil sources by 2030, and it promotes LiFE (Lifestyle for Environment).

At COP26 in Glasgow, India announced its long-term goal of net-zero emissions by 2070, not 2050. Energy efficiency measures under the EC Act, such as PAT, S&L and building codes, are among the main tools for meeting the intensity target.

Why the other options are wrong: (b) This option is correct; LiFE is part of the update. (c) This option is correct; this is in the 2022 update. (d) This option is correct; this is in the 2022 update.

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

44. Coal-based power emits 0.95 tCO₂/MWh and combined-cycle gas power 0.37 tCO₂/MWh. If a carbon price of ₹1,500 per tCO₂ were applied to generators, by how much would it narrow the generation-cost gap in favour of gas?

[5P1CEM044 | Chapter 10: Energy Efficiency and Climate Change | Effect of a carbon price on the cost gap between coal and gas power]

- a) ₹1.98/kWh
- b) ₹0.56/kWh
- c) ₹0.87/kWh
- d) ₹1.43/kWh

Correct answer: (c) ₹0.87/kWh.

Given: EF(coal) = 0.95 t/MWh; EF(gas) = 0.37 t/MWh; carbon price = ₹1,500/t.

Formula: change in cost gap per kWh = (EF(coal) – EF(gas)) × price ÷ 1,000 kWh per MWh.

Substitution: $(0.95 - 0.37) \times 1,500 \div 1,000 = 0.58 \times 1.5$.

Result: $\approx$ **₹0.87 per kWh** in favour of gas.

Carbon pricing works by changing relative costs. A credit price under the CCTS has the same effect on choices between fuels, efficiency projects and renewables.

Why the other options are wrong: (a) ₹1.98/kWh – adds the two emission factors instead of taking the difference. (b) ₹0.56/kWh – gives the carbon cost of gas power alone. (d) ₹1.43/kWh – gives the carbon cost of coal power alone, not the change in the gap.

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

45. Which statement about Article 6 of the Paris Agreement is wrong?

[5P1CEM045 | Chapter 10: Energy Efficiency and Climate Change | Paris Agreement Article 6 - international cooperation mechanisms]

- a) Article 6.4 credits are issued under the Kyoto Protocol's CDM rules

- b) Article 6.2 allows countries to transfer mitigation outcomes bilaterally
- c) Corresponding adjustments prevent the same reduction being counted twice
- d) Article 6.8 covers non-market approaches such as capacity building

Correct answer: (a) Article 6.4 credits are issued under the Kyoto Protocol's CDM rules.

Article 6 lets countries cooperate on their NDCs. Article 6.2 covers cooperative approaches, in which countries transfer internationally transferred mitigation outcomes (ITMOs) under bilateral agreements. Corresponding adjustments make the seller add back what the buyer counts.

Article 6.4 sets up a new mechanism under a Supervisory Body of the Paris Agreement, the successor to the Kyoto Protocol's CDM; CDM activities can transition only if they meet its new rules. Article 6.8 covers non-market approaches. India's CCTS offset mechanism is domestic but follows similar principles. Saying 6.4 runs under Kyoto CDM rules is wrong. Why the other options are wrong: (b) This option is correct; these are ITMOs. (c) This option is correct; they avoid double counting. (d) This option is correct; it covers non-market cooperation.

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

46. A country's emission intensity of GDP fell 33% between 2005 and 2019. Its NDC requires a 45% cut from 2005 by 2030. By what percentage must intensity fall from the 2019 level to meet the target?

[5P1CEM046 | Chapter 10: Energy Efficiency and Climate Change | Further cut in emission intensity needed to meet the 2030 NDC target]

- a) 12.0%
- b) 17.9%
- c) 21.8%
- d) 26.7%

Correct answer: (b) 17.9%.

Given: intensity index 2005 = 1.00; 2019 = $1 - 0.33 = 0.67$; target 2030 = $1 - 0.45 = 0.55$.

Formula: further cut = $(I(2019) - I(2030)) \div I(2019) \times 100$.

Substitution: $(0.67 - 0.55) \div 0.67 = 0.12 \div 0.67$.

Result: $\approx 17.9\%$ further reduction from the 2019 level.

Percentage cuts compound on a shrinking base, so remaining effort must be measured from the latest level, not by subtracting percentages.

Why the other options are wrong: (a) 12.0% – subtracts the percentages, which are of different bases. (c) 21.8% – divides the 12-point gap by the target level instead of the 2019 level. (d) 26.7% – divides the 12-point gap by the 45% target cut.

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

47. A 545 Wp module (temperature coefficient of power $-0.35\%/^{\circ}\text{C}$, NOCT 45°C) operates at 900 W/m^2 irradiance and 38°C ambient. Estimate cell temperature with $T_c = T_a + (\text{NOCT} - 20) \times G \div 800$. What is the expected module output?

[5P1CEM047 | Chapter 11: New and Renewable Energy Sources | Solar PV output corrected for cell temperature using NOCT]

- a) 419.9 W
- b) 377.0 W
- c) 490.5 W
- d) 468.2 W

Correct answer: (a) 419.9 W.

Given: $P_{\text{stc}} = 545\text{ W}$; $G = 900\text{ W/m}^2$; $T_a = 38^{\circ}\text{C}$; NOCT = 45°C ; $\gamma = -0.35\%/^{\circ}\text{C}$.

Formula: $T_c = T_a + (\text{NOCT} - 20) \times G \div 800$; $P = P_{\text{stc}} \times (G \div 1,000) \times [1 + \gamma(T_c - 25)]$.

Substitution: $T_c = 38 + 25 \times 900 \div 800 = 66.1^{\circ}\text{C}$; $P = 545 \times 0.9 \times [1 - 0.0035 \times 41.1]$.

Result: $P \approx 419.9\text{ W}$, about 14% below the irradiance-scaled value.

Hot Indian summers cut crystalline PV output noticeably, so yield estimates must include temperature losses.

Why the other options are wrong: (b) 377.0 W – applies the coefficient to the full cell temperature instead of the rise above 25 °C. (c) 490.5 W – scales for irradiance but ignores the temperature loss. (d) 468.2 W – uses the ambient temperature as the cell temperature.

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

48. Diesel has an energy content of 36.0 MJ/L and biodiesel 33.0 MJ/L. A fleet switches from diesel to B20 (20% biodiesel by volume). By what percentage must fuel volume rise to deliver the same energy?

[5P1CEM048 | Chapter 11: New and Renewable Energy Sources | Biodiesel blend - extra fuel volume for the same energy]

- a) 1.67%
- b) 1.69%
- c) 1.45%
- d) 1.82%

Correct answer: (b) 1.69%.

Given: diesel 36.0 MJ/L; biodiesel 33.0 MJ/L; B20 = 0.8 diesel + 0.2 biodiesel.

Formula: blend energy = $0.8 \times 36.0 + 0.2 \times 33.0$; extra volume = $36.0 \div \text{blend energy} - 1$.

Substitution: $28.8 + 6.6 = 35.4$ MJ/L; $36.0 \div 35.4 = 1.0169$.

Result: **≈ 1.69% more fuel by volume.**

Biofuels cut fossil carbon, but their lower energy density must be allowed for when comparing fuel economy and cost per km.

Why the other options are wrong: (a) 1.67% – gives the drop in energy per litre, not the extra volume needed. (c) 1.45% – multiplies the pure biodiesel penalty by both 0.2 and 0.8. (d) 1.82% – takes 20% of the pure-biodiesel volume penalty of 9.09%, which overstates it.

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

49. A 2.1 MW wind turbine runs 2,500 h at 300 kW, 3,000 h at 1,200 kW and 1,500 h at 2,000 kW in a year (rest of the year below cut-in). Machine availability is 97%. What is its capacity utilisation factor (CUF)?

[5P1CEM049 | Chapter 11: New and Renewable Energy Sources | Wind turbine annual energy and capacity utilisation factor from a power-curve table]

- a) 40.0%
- b) 38.8%
- c) 42.0%
- d) 48.5%

Correct answer: (b) 38.8%.

Given: energy bins $2,500 \times 300 + 3,000 \times 1,200 + 1,500 \times 2,000$ kWh; availability 0.97; rating 2,100 kW.

Formula: $\text{CUF} = \text{annual energy} \div (\text{rated capacity} \times 8,760) \times 100$.

Substitution: $7,50,000 + 36,00,000 + 30,00,000 = 73,50,000$ kWh; $\times 0.97 = 71,29,500$ kWh; $\div (2,100 \times 8,760)$.

Result: **CUF ≈ 38.8%.**

Indian wind sites usually show CUFs of 25–40%. CUF always uses calendar hours, so it is comparable across sites and with thermal PLF.

Why the other options are wrong: (a) 40.0% – leaves out the 97% availability. (c) 42.0% – uses 2,000 kW and also ignores availability. (d) 48.5% – divides by the 7,000 generating hours instead of all 8,760 hours.

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

50. A pumped-storage plant draws 1,000 MWh to pump water uphill. Pumping efficiency is 88%, turbine-generator efficiency 90% and the penstock passes 97% of the energy in each direction. How much electricity is returned to the grid?

[5P1CEM050 | Chapter 11: New and Renewable Energy Sources | Round-trip efficiency of pumped-storage hydro]

- a) 720.0 MWh
- b) 768.2 MWh

c) 792.0 MWh

d) 745.2 MWh

Correct answer: (d) 745.2 MWh.

Given: input = 1,000 MWh; $\eta(\text{pump}) = 0.88$; $\eta(\text{turbine-generator}) = 0.90$; $\eta(\text{penstock}) = 0.97$ each way.

Formula: energy returned = input $\times \eta(\text{pump}) \times \eta(\text{penstock})^2 \times \eta(\text{turbine})$.

Substitution: $1,000 \times 0.88 \times 0.97 \times 0.97 \times 0.90$.

Result: $\approx$ **745.2 MWh returned**, a round-trip efficiency of 74.5%.

Pumped storage loses about a quarter of the energy, but moving solar power from noon to the evening peak often justifies it.

Why the other options are wrong: (a) 720.0 MWh – adds the percentage losses instead of multiplying the efficiencies. (b)

768.2 MWh – applies the penstock loss in only one direction. (c) 792.0 MWh – ignores the penstock losses altogether.

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 cement plant is an obligated entity under the Carbon Credit Trading Scheme (CCTS), 2023, notified under the EC (Amendment) Act, 2022. Its baseline GHG emission intensity (GEI) is 0.720 tCO₂e per tonne of cement. Its notified targets are 0.705 tCO₂e/t in year 1 and 0.69 tCO₂e/t in year 2. Verified data: year 1 – production 24 lakh t, emissions 16.68 lakh tCO₂e; year 2 – production 26 lakh t, emissions 18.20 lakh tCO₂e. Certificates (1 per tCO₂e) trade at ₹1,200 each, and certificates earned in year 1 may be banked.

[SP1CEM051 | Chapter 2: Energy Conservation Act, 2001 and Related Policies | Carbon Credit Trading Scheme - compliance position of an obligated cement plant over two years]

(a) Calculate the achieved GEI in each year and state whether the target was met. [2 Marks]

(b) Calculate the certificates issued or to be surrendered in each year, and the net cost of compliance if year-1 certificates are banked. [2 Marks]

(c) State True or False with reason: (i) CCTS targets are set in toe per tonne of product. (ii) The registry under CCTS is Grid Controller of India. [1 Mark]

S-1 Ans

(a) [2 marks]

Given: year 1: 24 lakh t, 16.68 lakh tCO₂e; year 2: 26 lakh t, 18.20 lakh tCO₂e.

Formula: GEI = verified emissions ÷ production.

Substitution: $16.68 \div 24$ and $18.20 \div 26$.

Result: **GEI(year 1) = 0.695 tCO₂e/t**, better than the 0.705 target; **GEI(year 2) = 0.700 tCO₂e/t**, worse than the 0.69 target. (1 mark each)

(b) [2 marks]

Formula: certificates = (target – achieved GEI) $\times$ production; positive means issued, negative means surrendered.

Substitution: year 1: $(0.705 - 0.695) \times 24,00,000$; year 2: $(0.69 - 0.700) \times 26,00,000$.

Result: **year-1 certificates issued = 24,000; year-2 certificates to surrender = 26,000**. Banking the year-1 certificates leaves **net purchase = 2,000 certificates**, so **net compliance cost = ₹24,00,000**. (1 mark each)

(c) [1 mark]

Result: (i) **False** – CCTS targets are GHG emission intensities in tCO₂e per tonne of product; PAT used toe per tonne. (ii)

True – Grid Controller of India Ltd is the registry; BEE is the administrator and CERC the trading regulator. (½ mark each)

Marking scheme (5 marks): a) GEI each year with status, 1 + 1. b) Certificates each year 1, net position and cost 1. c) ½ per statement with reason.

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 hostel's heat pump charges an 8 m³ hot-water tank to 80 °C each evening. Water is usable down to 50 °C. The tank's overall heat-loss coefficient (UA) is 20 W/K and it stands in a plant room at 30 °C. Take $c_p = 4.187$ kJ/kg·K and 1 m³ of water = 1,000 kg.

[SP1CEM052 | Chapter 3: Basics of Energy and its Various Forms | Hot-water thermal store - usable energy, overnight standing loss and the value of better insulation]

- Calculate the usable energy stored when the tank is fully charged. [1 Mark]
- If no water is drawn for 14 hours overnight, calculate the tank temperature next morning (use $T(t) = T(\text{amb}) + (T_o - T(\text{amb})) e^{-(t/\tau)}$, with $\tau = m c_p \div UA$) and the energy lost. [2 Marks]
- Extra insulation would halve UA to 10 W/K. Calculate the new overnight loss and the annual electricity saved, if the heat pump has a COP of 3.5 and power costs ₹8.00/kWh. [2 Marks]

S-2 Ans

(a) [1 mark]

Given: $m = 8,000$ kg; usable $\Delta T = 80 - 50 = 30$ K.

Formula: $E = m c_p \Delta T \div 3,600$ (kWh).

Substitution: $8,000 \times 4.187 \times 30 \div 3,600$.

Result: **usable energy = 279.1 kWh.** (1 mark)

(b) [2 marks]

Formula: $\tau = m c_p \div UA$; $T(t) = T(\text{amb}) + (T_o - T(\text{amb})) e^{-(t/\tau)}$; loss = $m c_p (T_o - T(t))$.

Substitution: $\tau = 8,000 \times 4,187 \div 20 = 16,74,800$ s = 465.2 h; $T = 30 + 50 \times e^{(-14/465.2)} = 30 + 50 \times 0.97036$.

Result: **morning temperature = 78.52 °C; overnight loss = 13.79 kWh** (4.9% of the usable energy). (1 + 1 marks)

(c) [2 marks]

Substitution: $\tau = 930.4$ h; $T = 30 + 50 \times e^{(-14/930.4)} = 79.25$ °C; saving = $(13.79 - 6.95) \div 3.5 \times 365 \times ₹8.00$.

Result: **new overnight loss = 6.95 kWh; electricity saved = 714 kWh a year, worth ≈ ₹5,710 a year.** Because the loss is small relative to the store, the insulation upgrade is justified only if it is cheap; shortening the standing time (charging just before use) helps too. (1 + 1 marks)

Marking scheme (5 marks): a) 1. b) Temperature 1, loss 1. c) New loss 1, 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 A plant buys 14,40,000 kWh a year at LT, with an energy charge of ₹9.20/kWh and a demand charge of ₹350/kVA/month on 450 kVA. Taking supply at 11 kV would cost ₹42 lakh for its own transformer and switchgear. The HT tariff is ₹7.60/kWh and ₹450/kVA/month on the same 450 kVA, metered on the HT side. Transformer losses are 2.5% of the energy used and the new substation adds ₹1.5 lakh a year of maintenance.

[SP1CEM053 | Chapter 4: Energy Management and Audit | Understanding energy costs - techno-economics of converting from LT to HT supply]

- Calculate the present annual LT bill. [1 Mark]
- Calculate the annual cost after HT conversion, including transformer losses and maintenance. [2 Marks]
- Calculate the annual saving and simple payback, and give two non-financial benefits of HT supply. [2 Marks]

S-3 Ans

(a) [1 mark]

Given: 14,40,000 kWh; ₹9.20/kWh; 450 kVA $\times$ ₹350 $\times$ 12.

Formula: annual bill = kWh × energy rate + kVA × demand rate × 12.

Substitution: $14,40,000 \times 9.20 + 450 \times 350 \times 12 = 1,32,48,000 + 18,90,000$.

Result: **LT bill = ₹1,51,38,000 a year.** (1 mark)

(b) [2 marks]

Formula: HT kWh = kWh used × (1 + loss fraction); HT cost = HT kWh × rate + demand charges + maintenance.

Substitution: $14,40,000 \times 1.025 = 14,76,000$ kWh; $14,76,000 \times 7.60 + 450 \times 450 \times 12 + 1,50,000 = 1,12,17,600 + 24,30,000 + 1,50,000$.

Result: **annual cost at HT = ₹1,37,97,600.** (2 marks)

(c) [2 marks]

Substitution: saving = $1,51,38,000 - 1,37,97,600$; payback = $42,00,000 \div \text{saving}$.

Result: **annual saving = ₹13,40,400; simple payback = 3.13 years.** Non-financial benefits: better voltage regulation and supply reliability, freedom to choose transformer tap and loading for minimum losses, and eligibility for HT tariff options such as TOD rebates and open access. (1 + 1 marks)

Marking scheme (5 marks): a) 1. b) HT kWh 1, total cost 1. c) Saving and payback 1, benefits 1.

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

S-4 A pit-head washery treats 1,000 t/day of raw coal with 40% ash (GCV 3,400 kcal/kg ($\approx 14,235$ kJ/kg)). Washed coal leaves with 30% ash (GCV 4,100 kcal/kg ($\approx 17,166$ kJ/kg)) and rejects with 65% ash. A power station 1,000 km away now receives 10,000 t/day of raw coal by rail at ₹1.60 per tonne-km.

[SP1CEM054 | Chapter 5: Material and Energy Balance | Coal washery - yield from an ash balance and the freight saved by shipping washed coal]

(a) Using total and ash balances, calculate the yield of washed coal and the rejects per day. [2 Marks]

(b) Check the ash balance. [1 Mark]

(c) If the station switches to washed coal for the same heat input, calculate the daily tonnage and the daily freight saving. [2 Marks]

S-4 Ans

(a) [2 marks]

Given: raw 1,000 t/day at 40% ash; washed 30% ash; rejects 65% ash.

Formula: total: $R = W + J$; ash: $R \cdot a(r) = W \cdot a(w) + J \cdot a(j)$, so yield $W/R = (a(j) - a(r)) \div (a(j) - a(w))$.

Substitution: $(65 - 40) \div (65 - 30) = 25 \div 35$.

Result: **yield = 71.4%; washed coal = 714.3 t/day; rejects = 285.7 t/day.** (2 marks)

(b) [1 mark]

Substitution: ash in = $1,000 \times 0.40 = 400$ t; ash out = $714.3 \times 0.30 + 285.7 \times 0.65 = 214.3 + 185.7$.

Result: **ash out = 400.0 t/day = ash in**, so the balance closes. (1 mark)

(c) [2 marks]

Formula: heat needed = raw tonnage × GCV(raw); washed tonnage = heat ÷ GCV(washed); saving = $\Delta \text{tonnage} \times \text{distance} \times \text{freight rate}$.

Substitution: heat = $10,000 \text{ t} \times 3,400 \text{ kcal/kg} = 34,000 \text{ Gcal/day}$; washed = $34,000 \div 4.1$; saving = $(10,000 - 8,293) \times 1,000 \times 1.60$.

Result: **washed coal = 8,293 t/day; freight saving = ₹27,31,707 per day ($\approx$ ₹99.7 crore a year)**, besides lower ash handling and better boiler performance. (2 marks)

Marking scheme (5 marks): a) Balance equations 1, yield and tonnages 1. b) Ash check 1. c) Washed tonnage 1, freight saving 1.

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

S-5 A dairy plans a heat pump costing ₹40 lakh that will save 2,00,000 kWh a year of electric heating at ₹7.50/kWh. Extra maintenance is ₹1.0 lakh a year. The life is 8 years and the discount rate 12%.

[SP1CEM055 | Chapter 7: Financial Management | Switching values - break-even tariff, energy saving and capital cost of a heat pump project]

- Calculate the NPV of the project. [1 Mark]
- Calculate the switching value (the value that makes NPV zero) of (i) the electricity tariff, (ii) the annual kWh saved and (iii) the capital cost, each as a percentage change from the base value. [3 Marks]
- Which variable is the project most sensitive to, and what does that mean for the audit report? [1 Mark]

S-5 Ans

(a) [1 mark]

Given: capital ₹40 lakh; saving 2,00,000 kWh × ₹7.50 = ₹15.0 lakh; O&M ₹1.0 lakh; PVAF(12%, 8) = 4.9676.

Formula: NPV = (annual saving – O&M) × PVAF – capital.

Substitution: (15.0 – 1.0) × 4.9676 – 40.

Result: **NPV = ₹29.55 lakh.** (1 mark)

(b) [3 marks]

Formula: at NPV = 0, required net annual saving = capital ÷ PVAF = 40 ÷ 4.9676 = ₹8.052 lakh.

Substitution: (i) tariff = (8.052 + 1.0) × 10⁵ ÷ 2,00,000; (ii) kWh = (8.052 + 1.0) × 10⁵ ÷ 7.50; (iii) capital = 14.0 × 4.9676.

Result: **(i) break-even tariff = ₹4.53/kWh (-39.7%); (ii) break-even saving = 1,20,695 kWh/year (-39.7%); (iii) break-even capital = ₹69.55 lakh (+73.9%).** (1 mark each)

(c) [1 mark]

Result: **the project is equally and most sensitive to tariff and kWh saved** (a 40% fall in either wipes out the NPV), and much less sensitive to capital cost. The audit report should therefore verify the measured heating load and running hours, and test the savings against tariff scenarios, before quoting the NPV. (1 mark)

Marking scheme (5 marks): a) NPV 1. b) Each switching value with % change 1. c) Most sensitive variable and implication 1.

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

S-6 In 2025 a tyre plant used 50,000 MWh of grid electricity (emission factor 0.71 tCO₂/MWh) and 8 million Sm³ of natural gas (2.0 kg CO₂/Sm³) to produce 1,00,000 t. By 2030 output will rise 30%. Efficiency projects will cut specific electricity use by 10% and specific gas use by 15%. The company has committed to cut its emission intensity (tCO₂/t) by 45% from 2025 by 2030, the same percentage as India's NDC.

[SP1CEM056 | Chapter 10: Energy Efficiency and Climate Change | Decarbonisation pathway - renewable electricity share needed to meet a 2030 emission-intensity target]

- Calculate the 2025 emissions and emission intensity. [1 Mark]
- Calculate the 2030 emissions and intensity with the efficiency projects but no renewable power. [2 Marks]
- Calculate the renewable electricity (MWh) and its share needed to meet the target, and the solar capacity required at a CUF of 19%. [2 Marks]

S-6 Ans

(a) [1 mark]

Given: 50,000 MWh × 0.71; 8 million Sm³ × 2.0 kg/Sm³; 1,00,000 t.

Formula: emissions = Σ activity × emission factor; intensity = emissions ÷ production.

Substitution: 35,500 + 16,000 = 51,500 tCO₂; ÷ 1,00,000.

Result: **2025 emissions = 51,500 tCO₂; intensity = 0.515 tCO₂/t.** (1 mark)

(b) [2 marks]

Substitution: electricity = 50,000 × 1.3 × 0.9 = 58,500 MWh; gas = 8 × 1.3 × 0.85 = 8.84 million Sm³; emissions = 41,535 + 17,680.

Result: **2030 emissions = 59,215 tCO₂; intensity = 0.456 tCO₂/t** – only 11.6% below 2025, well short of 45%. (2 marks)

(c) [2 marks]

Formula: allowed emissions = $0.515 \times (1 - 0.45) \times 1,30,000$ t; grid MWh allowed = (allowed – gas emissions) $\div$ 0.71; RE = total electricity – grid.

Substitution: allowed = 36,823 tCO₂; grid = $(36,823 - 17,680) \div 0.71 = 26,961$ MWh; RE = 58,500 – 26,961.

Result: **RE = 31,539 MWh a year, i.e. 53.9% of 2030 electricity; solar capacity $\approx$ 18.9 MW** at 19% CUF. (2 marks)

Marking scheme (5 marks): a) Emissions and intensity 1. b) 2030 activity $\frac{1}{2} + \frac{1}{2}$, emissions and intensity 1. c) RE MWh 1, share and MW 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 A farmer needs 60 m³ of water a day at a total head of 40 m. A solar pump-set (motor, pump and controller) has an overall efficiency of 45%. The site's PV yield is 5.0 kWh per kWp per day before losses, and temperature, dust and wiring losses are 20%. The present diesel pump-set has an overall fuel-to-water efficiency of 15%; diesel gives 10 kWh of heat per litre and costs ₹92/L. Pumping is needed 300 days a year.

[SP1CEM057 | Chapter 11: New and Renewable Energy Sources | Solar photovoltaic water pump replacing a diesel pump-set on a farm]

(a) Calculate the daily hydraulic energy needed. [1 Mark]

(b) Size the PV array in kWp. [2 Marks]

(c) Calculate the diesel and money saved each year, and the CO₂ avoided at 2.68 kg CO₂ per litre. [2 Marks]

S-7 Ans**(a) [1 mark]**

Given: V = 60 m³/day; H = 40 m.

Formula: hydraulic energy = $\rho g H V \div 3.6 \times 10^6$ (kWh).

Substitution: $1,000 \times 9.81 \times 40 \times 60 \div 3.6 \times 10^6$.

Result: **hydraulic energy = 6.54 kWh/day.** (1 mark)

(b) [2 marks]

Formula: DC energy needed = hydraulic energy $\div$ η (pump-set); net yield = $5.0 \times (1 - 0.2)$; array = DC energy $\div$ net yield.

Substitution: $6.54 \div 0.45 = 14.53$ kWh/day; net yield = 4.0 kWh/kWp/day; $14.53 \div 4.0$.

Result: **array $\approx$ 3.63 kWp**; a 3.75 kWp array (or the nearest standard size above) would be installed. (2 marks)

(c) [2 marks]

Formula: diesel = hydraulic energy $\div$ (η (diesel set) $\times$ kWh per litre).

Substitution: $6.54 \div (0.15 \times 10) = 4.36$ L/day; $\times 300$ days; $\times ₹92$; $\times 2.68$.

Result: **diesel saved = 1,308 L a year; saving = ₹1,20,336 a year; CO₂ avoided $\approx$ 3.51 t a year.** (2 marks)

Marking scheme (5 marks): a) Hydraulic energy 1. b) DC energy 1, array size 1. c) Diesel 1, money and CO₂ 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 state utility compares the fuel cost of power from three sources: (i) a pit-head plant on domestic coal (heat rate 2,400 kcal/kWh ($\approx$ 10,048 kJ/kWh), coal GCV 3,800 kcal/kg, landed price ₹4,200/t, auxiliary use 8%); (ii) a coastal plant on imported coal (heat rate 2,300 kcal/kWh ($\approx$ 9,630 kJ/kWh), GCV 5,800 kcal/kg, ₹9,500/t, auxiliary 8%); (iii) a combined-cycle gas plant on LNG (heat rate 1,750 kcal/kWh ($\approx$ 7,327 kJ/kWh) on GCV, LNG ₹1,100 per MMBtu, 1 MMBtu = 2,52,000 kcal, auxiliary 3%).

[SP1CEM058 | Chapter 1: Energy Scenario | Energy security and pricing - fuel cost of power from domestic coal, imported coal and LNG]

(a) Calculate the fuel cost per kWh generated for each source. [2 Marks]

(b) Calculate the fuel cost per kWh sent out for each source. [2 Marks]

(c) Match each source to its best duty (base load, mid-merit, peaking/balancing) and give one energy-security point. [1 Mark]

S-8 Ans

(a) [2 marks]

Given: heat rates, GCVs and fuel prices above.

Formula: fuel cost per kWh = heat rate ÷ GCV × price per kg (coal); = heat rate ÷ kcal per MMBtu × price per MMBtu (LNG).

Substitution: (i) $2,400 \div 3,800 \times 4.20 = 2.653$; (ii) $2,300 \div 5,800 \times 9.50 = 3.767$; (iii) $1,750 \div 2,52,000 \times 1,100 = 7.639$.

Result: (i) ₹2.65/kWh; (ii) ₹3.77/kWh; (iii) ₹7.64/kWh generated. (2 marks)

(b) [2 marks]

Formula: cost per kWh sent out = cost per kWh generated ÷ (1 – auxiliary fraction).

Substitution: $2.653 \div 0.92$; $3.767 \div 0.92$; $7.639 \div 0.97$.

Result: (i) ₹2.88/kWh; (ii) ₹4.09/kWh; (iii) ₹7.88/kWh sent out. (2 marks)

(c) [1 mark]

Result: **domestic coal – base load; imported coal – mid-merit; LNG combined cycle – peaking and balancing renewables**, as it ramps quickly and has low capital cost but the dearest fuel. Energy security: imported coal and LNG expose the state to exchange-rate and world price risk, so domestic coal and renewables reduce import dependence. (1 mark)

Marking scheme (5 marks): a) $\frac{3}{5}$ mark per source. b) $\frac{3}{5}$ mark per source. c) Matching $\frac{1}{2}$, security point $\frac{1}{2}$.

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

..... End of Section II

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: $6 \times 10 = 60$

(i) Answer all Six questions

(ii) Each question carries Ten marks

L-1 A spray dryer is fed 4,000 kg/h of milk concentrate with 48% solids and produces powder with 3.5% moisture. Drying air is drawn in at 30 °C, heated in a gas-fired heater (efficiency 90%, natural gas GCV 9,000 kcal/Sm³ (≈ 37.7 MJ/Sm³)) to 190 °C and leaves the chamber at 90 °C. Take the heat needed per kg of water evaporated (from feed temperature to vapour at exhaust temperature) as 2,600 kJ/kg, air specific heat as 1.01 kJ/kg·K, and chamber surface losses as 150 kW. Ignore the heat taken by the solids. The dryer runs 6,000 h/year and gas costs ₹40/Sm³.

[SP1CEM059 | Chapter 5: Material and Energy Balance | Mass and energy balance of a milk-powder spray dryer and the effect of a lower outlet air temperature]

(a) Calculate the powder output and the water evaporated per hour. [2 Marks]

(b) From an energy balance on the chamber, calculate the air flow required. [3 Marks]

(c) Calculate the air-heater duty, the gas consumption, the specific heat consumption per kg of water evaporated and the share of heater duty leaving with the exhaust air. [2 Marks]

(d) Better atomisation lets the outlet air temperature be lowered to 80 °C with the same inlet temperature and product moisture. Calculate the new air flow and heater duty, and the gas saved per year and its value. [3 Marks]

L-1 Ans

(a) [2 marks]

Given: feed 4,000 kg/h at 48% solids; powder at 3.5% moisture.

Formula: solids are the tie element: powder = solids ÷ (1 – moisture fraction); water evaporated = feed – powder.

Substitution: solids = $4,000 \times 0.48 = 1,920$ kg/h; powder = $1,920 \div 0.965$; water = $4,000 - 1,989.6$.

Result: **powder = 1,989.6 kg/h; water evaporated = 2,010.4 kg/h.** (1 + 1 marks)

(b) [3 marks]

Formula: heat given up by air in the chamber = heat to evaporate water + surface losses; $m(\text{air}) \times c_p \times (T(\text{in}) - T(\text{out})) = W \times h(v) + Q(\text{loss})$.

Substitution: evaporation heat = $2,010.4 \times 2,600 \div 3,600 = 1,451.9 \text{ kW}$; $m(\text{air}) = (1,451.9 + 150) \times 3,600 \div (1.01 \times 100)$.

Result: **evaporation heat = 1,451.9 kW; air flow = 57,098 kg/h.** (1 + 2 marks)

(c) [2 marks]

Formula: heater duty = $m(\text{air}) \times c_p \times (T(\text{in}) - T(\text{ambient}))$; gas = $\text{duty} \times 860 \div (\eta \times \text{GCV})$; specific heat = $\text{duty} \div \text{water evaporated}$; exhaust share = $m(\text{air}) \times c_p \times (T(\text{out}) - T(\text{ambient})) \div \text{duty}$.

Substitution: $57,098 \times 1.01 \times 160 \div 3,600$; gas = $\text{duty} \times 860 \div (0.9 \times 9,000)$; exhaust = $57,098 \times 1.01 \times 60 \div 3,600$.

Result: **heater duty = 2,563.1 kW; gas = 272.1 Sm³/h; specific heat = 4,590 kJ/kg water; exhaust heat = 961.2 kW = 37.5% of heater duty.** The exhaust is the largest single loss. (2 marks)

(d) [3 marks]

Formula: new $m(\text{air}) = (\text{evaporation heat} + \text{losses}) \times 3,600 \div (c_p \times (T(\text{in}) - 80))$; new duty = $\text{new } m(\text{air}) \times c_p \times (T(\text{in}) - T(\text{ambient}))$; gas saved = $\Delta \text{duty} \times 860 \div (\eta \times \text{GCV}) \times \text{hours}$.

Substitution: $(1,451.9 + 150) \times 3,600 \div (1.01 \times 110)$; duty = $\text{new } m(\text{air}) \times 1.01 \times 160 \div 3,600$; $\Delta \text{duty} = 2,563.1 - 2,330.1$.

Result: **new air flow = 51,908 kg/h; new duty = 2,330.1 kW (saving 233.0 kW); gas saved = 24.7 Sm³/h = 1,48,435 Sm³/year; value $\approx$ ₹0.59 crore a year.** Outlet temperature must stay high enough to keep powder moisture and avoid sticky deposits. (1 + 1 + 1 marks)

Marking scheme (10 marks): a) Powder 1, water 1. b) Evaporation heat 1, air balance and flow 2. c) Duty, gas, specific heat, exhaust share ½ each. d) New air flow and duty 1, gas 1, value 1.

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

L-2 A plant will replace its old compressors with a VFD screw compressor package costing ₹60 lakh, saving ₹22 lakh a year in electricity for 5 years (no salvage value). It can either buy the package with its own funds, claiming straight-line tax depreciation over 5 years, or take it on an operating lease at ₹15 lakh a year paid at each year end, with the rentals fully tax-deductible. The tax rate is 25% and the after-tax discount rate is 9%. Assume tax effects occur at the end of each year.

[5P1CEM060 | Chapter 7: Financial Management | Lease or buy - after-tax present-value comparison for an energy-efficient compressor package]

(a) Calculate the present value of the after-tax cost of (i) buying and (ii) leasing. Which is cheaper and by how much? [4 Marks]

(b) Find the annual lease rental at which the plant would be indifferent between the two options. [2 Marks]

(c) If the package is leased, calculate the after-tax NPV of the project including the energy savings. [2 Marks]

(d) Give two non-financial factors that should influence the lease-or-buy decision. [2 Marks]

L-2 Ans

(a) [4 marks]

Given: cost ₹60 lakh; depreciation ₹12 lakh/year; tax 25%; rental ₹15 lakh; $PVAF(9\%, 5) = 3.8897$.

Formula: $PV(\text{buy}) = \text{capital} - PV \text{ of depreciation tax shield}$; $PV(\text{lease}) = \text{rental} \times (1 - \text{tax rate}) \times PVAF$.

Substitution: tax shield = $12 \times 0.25 = ₹3.0 \text{ lakh/year}$; $PV(\text{buy}) = 60 - 3.0 \times 3.8897$; $PV(\text{lease}) = 15 \times 0.75 \times 3.8897$.

Result: **PV(buy) = ₹48.33 lakh; PV(lease) = ₹43.76 lakh; leasing is cheaper by ₹4.57 lakh.** (2 + 2 marks)

(b) [2 marks]

Formula: indifference rental $L: L \times (1 - \text{tax}) \times PVAF = PV(\text{buy})$.

Substitution: $L = 48.33 \div (0.75 \times 3.8897)$.

Result: **indifference rental = ₹16.57 lakh a year;** any rental below this favours leasing. (2 marks)

(c) [2 marks]

Formula: $NPV = (\text{after-tax saving} - \text{after-tax rental}) \times PVAF$, with no capital outlay.

Substitution: $(22 \times 0.75 - 15 \times 0.75) \times 3.8897 = (16.50 - 11.25) \times 3.8897$.

Result: **after-tax NPV with leasing = ₹20.42 lakh**, positive from year 1 with no capital tied up. (2 marks)

(d) [2 marks]

Result: **any two**: who bears performance and maintenance risk (a lessor or ESCO lease often includes service and guarantees); flexibility to upgrade technology at the end of the lease; impact on borrowing limits and balance sheet; ownership and residual value after the term; availability of capital for higher-return core projects. (1 mark each)

Marking scheme (10 marks): a) Tax shield and PV(buy) 2, PV(lease) and comparison 2. b) 2. c) 2. d) 1 per factor.

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

L-3 A forging shop's energy baseline, fitted on last year's data, is $E = 140 + 0.58 P$ (E in MWh, P in tonnes), and the standard deviation of last year's residuals was 6.0 MWh. The table gives this year's production and electricity use for eight months. The plant flags any month whose residual lies outside ± 2 standard deviations. Electricity costs ₹7.00/kWh.

[SP1CEM061 | Chapter 9: Energy Monitoring and Targeting | Monitoring against an energy baseline model - EnPI ratio, control limits and exception reporting]

Month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
P, t	420	480	510	450	560	600	530	470
E, MWh	384	413	435	398	482	477	441	409

- (a) Calculate the expected energy and the residual (actual – expected) for each month. [3 Marks]
- (b) Calculate the EnPI ratio (total actual ÷ total expected) for the eight months and the net energy saved against the baseline. [2 Marks]
- (c) State the control limits and identify the month(s) to be flagged, with the deviation. [2 Marks]
- (d) Calculate the saving the plant would have reported if the flagged high month had performed to the baseline, its value, and state what the energy manager should do about the flagged month(s). [3 Marks]

L-3 Ans

(a) [3 marks]

Given: $E = 140 + 0.58 P$; monthly P and E in the table.

Formula: expected E = $a + bP$; residual = actual – expected.

Substitution: Apr: $140 + 0.58 \times 420 = 383.6$; May: $140 + 0.58 \times 480 = 418.4$; Jun: $140 + 0.58 \times 510 = 435.8$; Jul: $140 + 0.58 \times 450 = 401.0$; Aug: $140 + 0.58 \times 560 = 464.8$; Sep: $140 + 0.58 \times 600 = 488.0$; Oct: $140 + 0.58 \times 530 = 447.4$; Nov: $140 + 0.58 \times 470 = 412.6$.

Result: **residuals (MWh): Apr +0.4, May -5.4, Jun -0.8, Jul -3.0, Aug +17.2, Sep -11.0, Oct -6.4, Nov -3.6.** (3 marks)

(b) [2 marks]

Formula: EnPI ratio = $\Sigma \text{ actual} \div \Sigma \text{ expected}$; net saving = $\Sigma \text{ expected} - \Sigma \text{ actual}$.

Substitution: $\Sigma \text{ actual} = 3,439 \text{ MWh}$; $\Sigma \text{ expected} = 3,451.6 \text{ MWh}$; $3,439 \div 3,451.6$.

Result: **EnPI ratio = 0.9963; net saving = 12.6 MWh** (0.37% better than baseline). (2 marks)

(c) [2 marks]

Formula: limits = $0 \pm 2\sigma = \pm 12.0 \text{ MWh}$ on the residual.

Result: **flagged: Aug (+17.2 MWh)**. All other months lie within $\pm 12.0 \text{ MWh}$; Sep (-11.0 MWh) is close to the lower limit and is worth watching as possible genuine improvement. (2 marks)

(d) [3 marks]

Substitution: potential saving = $12.6 + 17.2$; value = $29.8 \times 1,000 \times ₹7.00$.

Result: **saving would have been 29.8 MWh, worth $\approx ₹2,08,600$** ; the flagged month alone cost $\approx ₹1,20,400$. The energy manager should investigate the flagged month (furnace idling, door-open losses, compressed-air leaks, a metering fault or a product-mix change), record the cause and corrective action in the exception report, and check whether a non-routine adjustment to the baseline is justified. (1 + 1 + 1 marks)

Marking scheme (10 marks): a) Expected values 1½, residuals 1½. b) EnPI 1, net saving 1. c) Limits 1, flagged month 1. d) Potential saving 1, value 1, action 1.

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

L-4 A waste-heat recovery project is awarded at a fixed contract price of ₹2.40 crore. The contractor received an interest-free mobilisation advance of 10% of the contract price, which is recovered at 10% of the work value of each bill. A retention of 5% of each bill's gross amount (work value plus price variation) is held until the defect liability period ends. Price variation is paid on each bill's work value using $P = P_0 \times (0.15 + 0.55 M/M_0 + 0.30 L/L_0)$, where M/M_0 and L/L_0 are the material and labour index ratios for the billing period, given below.

[5P1CEM062 | Chapter 8: Project Management | Implementing an energy project - running bills with price variation, advance recovery and retention]

Bill	Work value, ₹ lakh	M/M ₀	L/L ₀
RA-1	80.0	1.04	1.02
RA-2	100.0	1.08	1.05
Final	60.0	1.12	1.06

- (a) Calculate the price variation factor and the price variation amount for each bill. [4 Marks]
 (b) Calculate the advance recovery, retention and net amount payable for each bill. [4 Marks]
 (c) Calculate the total cost of the project to the owner and the escalation as a percentage of the contract price, and comment on why a fixed (non-variable) element is kept in the formula. [2 Marks]

L-4 Ans

(a) [4 marks]

Given: bills and index ratios in the table; fixed element 0.15.

Formula: PV factor $k = 0.15 + 0.55 (M/M_0) + 0.30 (L/L_0)$; PV amount = work value $\times (k - 1)$.

Substitution: RA-1: $0.15 + 0.55 \times 1.04 + 0.30 \times 1.02 = 1.0280$, PV = 80.0×0.0280 ; RA-2: $0.15 + 0.55 \times 1.08 + 0.30 \times 1.05 = 1.0590$, PV = 100.0×0.0590 ; Final: $0.15 + 0.55 \times 1.12 + 0.30 \times 1.06 = 1.0840$, PV = 60.0×0.0840 .

Result: **RA-1 PV = ₹2.24 lakh; RA-2 PV = ₹5.90 lakh; Final PV = ₹5.04 lakh; total PV = ₹13.18 lakh.** (4 marks)

(b) [4 marks]

Formula: advance recovery = 10% of work value; retention = 5% $\times$ (work value + PV); net = work value + PV – recovery – retention.

Substitution: RA-1: recovery 8.00, retention $0.05 \times 82.24 = 4.112$; RA-2: recovery 10.00, retention $0.05 \times 105.90 = 5.295$; Final: recovery 6.00, retention $0.05 \times 65.04 = 3.252$.

Result: **RA-1 net payable = ₹70.13 lakh; RA-2 net payable = ₹90.61 lakh; Final net payable = ₹55.79 lakh.** Total retention held = ₹12.66 lakh; the full advance of ₹24.00 lakh is recovered by the final bill. (4 marks)

(c) [2 marks]

Formula: total cost = contract price + total PV; escalation = total PV $\div$ contract price.

Substitution: $240 + 13.18$; $13.18 \div 240$.

Result: **total cost = ₹253.18 lakh; escalation = 5.49%.** The fixed element (15%) covers overheads and profit that do not move with indices, and gives the contractor a reason to control costs; without it the owner would carry all inflation risk. (1 + 1 marks)

Marking scheme (10 marks): a) Factors 2, PV amounts 2. b) Recovery 1, retention 1, net amounts 2. c) Total and % 1, comment 1.

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

L-5 A refinery makes 20,000 t/year of hydrogen by steam-methane reforming, emitting 10 kg CO₂ per kg H₂. It plans to switch fully to green hydrogen. The electrolyser plant uses 52 kWh per kg H₂ (system level) and 10 litres of demineralised water per kg H₂; the water plant recovers 50% of the raw water it takes. The electrolyzers will follow a solar-wind hybrid supply with a CUF of 32% and no storage, and transmission losses between the RE plant and electrolyzers are 5%.

[SP1CEM063 | Chapter 11: New and Renewable Energy Sources | Green hydrogen - electrolyser and renewable capacity, water and CO₂ for replacing grey hydrogen]

- Calculate the annual electricity needed by the electrolyzers. [2 Marks]
- Calculate the electrolyser capacity and the renewable capacity needed. [2 Marks]
- Calculate the demineralised water and raw water needed per year. [2 Marks]
- Calculate the CO₂ avoided per year and its value at ₹1,500 per carbon credit certificate. [2 Marks]
- Calculate the electricity cost component of green hydrogen at ₹3.00/kWh and state two other factors that decide its cost. [2 Marks]

L-5 Ans

(a) [2 marks]

Given: H₂ = 20,000 t/year; specific consumption = 52 kWh/kg.

Formula: electricity = H₂ (kg) × kWh per kg.

Substitution: 20,000 × 1,000 × 52 = 1,04,00,00,000 kWh.

Result: **electricity = 10,40,000 MWh/year (≈ 1.04 TWh).** (2 marks)

(b) [2 marks]

Formula: electrolyser MW = MWh ÷ (8,760 × CUF); RE MW = electrolyser MW ÷ (1 – loss).

Substitution: 10,40,000 ÷ (8,760 × 0.32); ÷ 0.95.

Result: **electrolyser capacity ≈ 371.0 MW; renewable capacity ≈ 390.5 MW.** (1 + 1 marks)

(c) [2 marks]

Formula: DM water = H₂ × litres per kg; raw water = DM water ÷ recovery.

Substitution: 2,00,00,000 kg × 10 L = 20,00,00,000 L; ÷ 0.5.

Result: **DM water = 2,00,000 m³/year; raw water = 4,00,000 m³/year.** (1 + 1 marks)

(d) [2 marks]

Formula: CO₂ avoided = H₂ × emission factor of grey H₂; value = CO₂ × price per certificate.

Substitution: 2,00,00,000 kg × 10 kg = 2,00,00,000 t; × ₹1,500.

Result: **CO₂ avoided = 2,00,000 t/year; value ≈ ₹30 crore a year,** if the scheme allows it to be credited. (1 + 1 marks)

(e) [2 marks]

Substitution: 52 kWh/kg × ₹3.00.

Result: **electricity cost ≈ ₹156 per kg H₂.** Other factors: electrolyser capital cost and its utilisation (a low CUF raises capital cost per kg), stack replacement and efficiency decline, storage and compression, water treatment and the cost of firming RE. (1 + 1 marks)

Marking scheme (10 marks): a) 2. b) Electrolyser 1, RE 1. c) DM 1, raw 1. d) CO₂ 1, value 1. e) Cost 1, factors 1.

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

L-6 A city transport undertaking will replace 50 diesel buses, each running 200 km a day for 330 days a year. A diesel bus does 3.0 km per litre; diesel costs ₹90/L, has an energy content of 36 MJ/L and emits 2.68 kg CO₂/L. An electric bus uses 1.2 kWh/km at the battery. Charger efficiency is 92% and battery charging efficiency 96%. Grid power costs ₹8.00/kWh with an emission factor of 0.71 tCO₂/MWh. All buses charge overnight at the depot within 6 hours.

[SP1CEM064 | Chapter 3: Basics of Energy and its Various Forms | Energy conversion chain - electric buses compared with diesel buses for a city fleet]

- (a) Calculate the annual diesel use, its energy content in GJ and the diesel bus energy use per km in kWh. [2 Marks]
- (b) Calculate the grid electricity per km and per year for the electric fleet, and the ratio of diesel to electric final energy per km. [2 Marks]
- (c) Calculate the annual energy cost of each fleet and the saving. [2 Marks]
- (d) Calculate the annual CO₂ of each fleet. Comment on the result, and find the renewable share of charging electricity at which the electric fleet emits half as much CO₂ as the diesel fleet. [2 Marks]
- (e) Calculate the average depot charging demand in kW and kVA (PF 0.95) and state one way to reduce its impact on the contract demand. [2 Marks]

L-6 Ans**(a) [2 marks]**

Given: fleet km = $50 \times 200 \times 330 = 33,00,000$ km/year; 3.0 km/L; 36 MJ/L.

Formula: diesel = km ÷ km per litre; energy = litres × MJ/L; energy per km = MJ/L ÷ km/L ÷ 3.6.

Substitution: $33,00,000 \div 3.0 \times 36 \div 1,000$; $36 \div 3.0 \div 3.6$.

Result: **diesel = 11,00,000 L/year; energy = 39,600 GJ/year; diesel bus = 3.333 kWh/km.** (2 marks)

(b) [2 marks]

Formula: grid kWh/km = battery kWh/km ÷ (η(charger) × η(battery)); annual = per km × fleet km.

Substitution: $1.2 \div (0.92 \times 0.96) = 1.3587$ kWh/km; $\times 33,00,000$; ratio = $3.333 \div 1.3587$.

Result: **grid energy = 1.3587 kWh/km = 44,83,696 kWh/year; diesel uses 2.45 times as much final energy per km.** (2 marks)

(c) [2 marks]

Substitution: diesel = $11,00,000 \times ₹90$; electricity = $44,83,696 \times ₹8.00$.

Result: **diesel fleet = ₹9.90 crore; electric fleet = ₹3.59 crore; saving = ₹6.31 crore a year.** (2 marks)

(d) [2 marks]

Substitution: diesel = $11,00,000 \times 2.68 \div 1,000$; electric = $44,83,696 \times 0.71 \div 1,000$; RE share x from $3,183 \times (1 - x) = 0.5 \times 2,948$.

Result: **diesel fleet = 2,948 tCO₂; electric fleet on grid power = 3,183 tCO₂**, i.e. 8.0% MORE than diesel, because the grid is coal-heavy and charging losses add 13.2% to the battery energy. **Renewable share needed for half the diesel CO₂ = 53.7%** (green tariff, open access or depot rooftop solar). (1 + 1 marks)

(e) [2 marks]

Substitution: daily grid energy = $1.3587 \times 200 \times 50 = 13,587$ kWh; ÷ 6 h; ÷ 0.95.

Result: **average charging demand = 2,264 kW = 2,384 kVA.** Smart charging that staggers buses across the night (or uses daytime opportunity charging on solar) flattens the peak so the depot needs a smaller contract demand. (1 + 1 marks)

Marking scheme (10 marks): a) Diesel and GJ 1, kWh/km 1. b) Grid kWh/km and annual 1, ratio 1. c) Costs 1, saving 1. d) CO₂ and comment 1, RE share 1. e) kW and kVA 1, measure 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.

..... End of Section III

Answer key — Section I

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	c	11	d	21	b	31	b	41	b
2	a	12	c	22	a	32	c	42	b
3	b	13	a	23	c	33	a	43	a
4	d	14	c	24	d	34	b	44	c
5	c	15	b	25	c	35	c	45	a
6	d	16	c	26	b	36	d	46	b

7	b	17	a	27	d	37	a	47	a
8	d	18	d	28	d	38	a	48	b
9	b	19	a	29	a	39	d	49	b
10	c	20	c	30	a	40	d	50	d