

INSTITUTE OF ACTUARIES OF INDIA

EXAMINATIONS

May 2026

CP2B- Actuarial Modelling

Time allowed: 3 Hours 15 Minutes

Total Marks: 100

Exam Requirements

Read the background document, which describes the scenario that has been modelled and documented for this project and the work that remains outstanding.

Read the audit trail, which has been written by your junior team member, another actuarial student, for the calculations they performed. This will assist you in following and understanding the calculations in the Excel model provided.

Expand the spreadsheet model to produce the following additional calculations. You should ensure that the additional work contains appropriate self-checks and you should not overwrite the existing calculations.

You are not required to add to or amend the audit trail.

You should assume that your colleague's calculations have been checked and are correct.

Q. 1) Additional Modelling – Scenarios and Carbon Reduction Options

Vidyut Bharat Manufacturing Ltd's management wants to evaluate three strategies to reduce its carbon footprint and the associated financial costs over the 10-year projection period. Recalculate carbon emissions, energy costs and nature-based carbon offsetting under each of the following scenarios. Each scenario must be treated independently - all changes are to be made relative to the base case projection completed by your junior colleague.

i) Carbon Reduction Scenarios:

a) Scenario A: Green Energy Transition

Vidyut Bharat's operations team has proposed a phased transition away from diesel. The proposed transition parameters are summarised below:

Parameter	Value	Applies from	Note
CNG substitution (% of diesel replaced)	30% of total diesel volume	Year 3 onwards	CNG burns cleaner in particulates but produces slightly more CO ₂ per litre than diesel
Solar/electric substitution (% of diesel replaced)	20% of total diesel volume	Year 6 onwards	Combined with CNG: 50% of diesel replaced from Year 6. Solar produces zero direct emissions
CNG emission factor	2.74 kg CO ₂ per litre-equivalent	All years	Marginally higher than diesel (2.68 kg/L). Savings come from lower energy cost, not lower emissions per unit
CNG price (Year 1)	INR 65 per litre-equivalent	Year 1	Escalates at 4% p.a. (same rate as diesel).
Solar energy cost	INR 40 per kWh-equivalent	Year 6 onwards	Solar cost is flat (no escalation assumed)
CBAM exported emissions (Scenario A only)	35% of total emissions from all sources	All years	Simplifying assumption: 35% of combined diesel + CNG + grid emissions are attributable to exported goods

Why use CNG if it produces slightly more CO₂ per litre than diesel? CNG burns more completely and generates far fewer particulate pollutants, making it easier to comply with air quality regulations. More importantly, CNG costs significantly less per litre-equivalent (INR 65 vs INR 92 for diesel), so replacing diesel with CNG reduces energy bills even though it does not immediately reduce CO₂ emissions. The CO₂ benefit comes later when solar power displaces diesel entirely from Year 6, producing zero direct emissions.

Recalculate the following under Scenario A:

- Total energy cost (separating diesel, CNG and solar costs).
- Total carbon emissions (separating diesel, CNG and grid electricity emissions).
- India carbon tax and CBAM penalty on the revised emission figures.
- Net present value (NPV) of total costs under Scenario A.

[9]

b) Scenario B: Carbon Credit Purchase

Instead of changing its energy mix, Vidyut Bharat considers purchasing carbon credits to offset its India carbon tax liability. Carbon credits are tradeable certificates representing the reduction of one tonne of CO₂ emissions elsewhere. The company would purchase enough credits each year to fully offset its India carbon tax bill. The CBAM penalty is unaffected - the EU does not currently recognise Indian domestic carbon credits as a qualifying offset under CBAM rules.

Credit prices: INR 800 per tonne CO₂ for Years 1–5; INR 1,100 per tonne CO₂ for Years 6–10 (reflecting expected growth in the domestic carbon credit market as India's carbon trading scheme matures).

Recalculate the following under Scenario B:

- Annual carbon credit purchase cost.
- Net saving (or additional cost) versus simply paying the India carbon tax.
- Total annual cost and its NPV.

[4]

c) Scenario C: Nature-Based Carbon Offsetting

Vidyut Bharat invests in a certified afforestation and wetland restoration programme across degraded land near its three facilities. The programme is registered under India's Green Credit Programme (GCP) and generates carbon removal certificates recognised for both India carbon tax and CBAM offset purposes. All parameters are provided in the 'Other Inputs' sheet.

The programme has the following structure:

- Investment cost: INR 400 lacs per year in Years 1–3 (phased capital expenditure for land acquisition, planting and restoration), then INR 80 lacs per year from Year 4 onwards (annual maintenance).
- Sequestration capacity: The programme offsets a maximum of 50% of Vidyut Bharat's total annual CO₂ emissions at full capacity. Sequestration ramps up linearly - the effective offset as a percentage of total annual emissions is shown in the 'Other Inputs' sheet (10% in Year 1, rising to 50% from Year 5 and held flat thereafter).
- The certified offsets reduce both India carbon tax and CBAM liability proportionally. The CBAM saving in each year is calculated as the offset tCO₂ multiplied by the proportion of total emissions that is exported.

Recalculate the following under Scenario C:

- Annual offset volume (tCO₂e) for each year, using the effective offset percentages from the 'Other Inputs' sheet.
- Annual India carbon tax saving and CBAM saving arising from the offsets.
- Net annual carbon cost and its NPV over the 10-year period.

[6]

d) Scenario Summary

In a separate 'Scenario Summary' sheet, present a comparison of the base case and all three scenarios (A, B and C). Your summary should include:

- A table showing the NPV of energy cost, and total cost (including India carbon tax / credit cost, CBAM penalty) for the base case and each scenario.
- A table showing total CO₂ released for all scenarios, and separately the net CO₂ after sequestration offset for Scenario C.
- The absolute difference in NPV total cost versus the base case for each scenario.
- An appropriate graph summarising the results.

[4]

e) Charts

For each of the scenarios above (a) to (c), create appropriate charts to illustrate the key results.

[3]

You should ensure that the additional work you undertake on the spreadsheet contains appropriate self-checks.

[26 marks]

Q. 2) Management Summary

Prepare a summary in the specified 'Summary' worksheet within the same spreadsheet, capturing the main features and results of the work completed by you and your junior team member. You can assume that the summary is being prepared for the Chief Sustainability Officer (CSO) and Finance Director of Vidyut Bharat Manufacturing Ltd, who will use it to decide on the company's carbon reduction strategy and to seek Board approval for capital investment in green energy.

Your summary should include the following:

- Purpose of the exercise, data inputs used, methodology and assumptions used by you and your junior team member.
- Results: including (i) year-wise total carbon emissions, energy cost and carbon penalties; (ii) facility-wise contribution to total emissions.
- Charts on how total carbon emissions and costs vary by year.
- Summary results (NPV of total costs - by cost component and in total) on how the results change under the different scenarios, along with relevant rationale.
- Chart summarising the financial impact of the different scenarios.
- Key conclusions.
- Suggested next steps.

The summary should cover the full scope of the project, including the additional scenarios modelled in the spreadsheet.

You are not required to add to or amend the audit trail.

Marks available for the summary:

i) Purpose, data inputs and assumptions

[10]

ii) Methodology

[12]

iii) Input checks and reasonableness checks	[5]
iv) Results, including tables and charts with commentary	[10]
v) Commentary on results and conclusions	[12]
vi) Next steps (specific, justified steps)	[15]
vii) Drafting quality	[10]
	[74 Marks]

Overview of the Project

Vidyut Bharat Manufacturing Ltd ('Vidyut Bharat') is a large Indian manufacturing company with three production facilities across India. The company manufactures heavy industrial components - including steel castings, precision-machined engine parts, hydraulic assemblies and industrial fasteners - primarily for the automotive, heavy engineering and infrastructure sectors. Its European parent company, EuroPower Components GmbH ('EuroPower'), is headquartered in Frankfurt, Germany, and distributes Vidyut Bharat's components to original equipment manufacturers (OEMs) across the EU. EuroPower is subject to the EU Carbon Border Adjustment Mechanism (CBAM) on goods it imports from India.

Vidyut Bharat's manufacturing processes are energy-intensive: steel casting requires sustained high temperatures, precision machining requires uninterrupted electrical power, and hydraulic assembly lines operate continuously. The company relies on diesel generators for backup power and in areas where grid supply is unreliable, and on coal-powered grid electricity for its base load. As a result, Vidyut Bharat produces significant carbon dioxide (CO₂) emissions across all three facilities. These emissions expose the company to two carbon cost regimes: India's domestic carbon tax (paid by Vidyut Bharat on all its emissions) and the EU's Carbon Border Adjustment Mechanism (CBAM - a levy charged on the carbon embedded in goods imported into Europe, effectively paid by EuroPower on the components it receives from Vidyut Bharat). Together, these two costs make carbon management a strategic financial priority for the group.

Vidyut Bharat operates three facilities as shown below. 'Diesel use (litres per tonne produced)' means the litres of diesel consumed for every tonne of finished product; 'grid electricity use (kWh per tonne produced)' means the grid electricity drawn for every tonne of finished product:

Facility	Year 1 Output (tonnes/year)	Diesel Use (litres per tonne produced)	Grid Electricity Use (kWh per tonne produced)	% Output Exported to Europe	Primary Energy Source
Facility 1 – Pune (Heavy Manufacturing)	1,20,000	8.5	120	35%	Diesel generators + coal-grid
Facility 2 – Chennai (Assembly)	75,000	6	95	50%	Mix of diesel and grid electricity
Facility 3 – Jaipur (Light Processing)	40,000	10	60	20%	Primarily diesel-powered

***Note:** Jaipur's higher diesel use per tonne reflects its more remote location and greater dependence on diesel-powered equipment. Chennai's 50% export proportion makes it the single largest source of CBAM exposure despite its lower diesel intensity.*

Vidyut Bharat's finance team has commissioned this analysis to understand the total financial cost of its carbon footprint and to evaluate whether proactive measures - switching to cleaner fuels, buying carbon credits, or nature-based carbon offsetting - offer a better financial outcome than the status quo. The junior team member has already built the base model, which projects production, energy costs and carbon penalty costs for all three facilities over a 10-year period assuming no change in energy mix or regulatory rates. You, as the senior actuary, are now asked to extend that work by modelling three alternative scenarios and preparing a management summary that the CSO and Finance Director can present to the Board.

The key parameters used in the base model are listed below:

Parameter	Value	Description
Production growth rate	8% per annum	Output at each facility grows by 8% every year
Diesel emission factor	2.68 kg CO ₂ per litre	Burning 1 litre of diesel releases 2.68 kg of CO ₂ into the atmosphere
Grid electricity emission factor	0.82 kg CO ₂ per kWh	Consuming 1 kWh from India's grid releases 0.82 kg of CO ₂ (because the grid is mainly coal-powered)
Diesel price (Year 1)	INR 92 per litre	Rises by 4% every year from Year 2 onwards
Grid electricity tariff (Year 1)	INR 7.50 per kWh	Rises by 3% every year from Year 2 onwards
India carbon tax (base)	INR 200 per tonne CO ₂	Vidyut Bharat pays this on every tonne of CO ₂ it releases from all three facilities
EU CBAM penalty (base)	EUR 50 per tonne CO ₂	Vidyut Bharat pays this (via EuroPower, its EU parent) on the CO ₂ embedded in goods exported to Europe
INR / EUR exchange rate	INR 90 per EUR	Used to convert CBAM costs from EUR into INR for comparison; held constant throughout
Discount rate for NPV	9% per annum	Used to calculate today's value of future costs; higher discount rate makes future costs appear smaller
Projection period	10 years	All calculations cover Years 1 through 10

What is CO₂ and why is it measured in 'tonnes'? Carbon dioxide (CO₂) is the main greenhouse gas released when fuel is burned. We measure it in tonnes because the quantities involved in industrial operations are very large - one tonne equals 1,000 kg. Both the India carbon tax and the EU CBAM are charged per tonne of CO₂ released.

Audit Trail

Background

Vidyut Bharat Manufacturing Ltd operates three production facilities in India and exports a significant proportion of finished industrial components to Europe through its parent, EuroPower Components GmbH. This model projects total carbon emissions and the associated financial costs over 10 years under India's domestic carbon tax regime and the EU Carbon Border Adjustment Mechanism (CBAM).

Objective

The objective of this work is to:

- Project annual production output for each facility over a 10-year period based on a base growth rate applied to Year 1 actuals.
- Calculate annual diesel and grid electricity consumption based on production output and facility-specific energy intensity ratios.
- Calculate annual carbon emissions (tonnes CO₂) from diesel and grid electricity consumption using standard emission factors.
- Calculate the annual India carbon tax liability at the prescribed base rate.
- Calculate the annual EU CBAM penalty on the embedded carbon in goods exported to Europe, using facility-specific export proportions.
- Calculate the present value (NPV) of total carbon costs over the projection period.

Data

All inputs are contained in the 'Inputs' sheet. The following data is used:

- Production Inputs: Year 1 production output (tonnes) for each of the three facilities; base production growth rate (% p.a.); proportion of output exported to Europe (facility-wise). Check: the sum of export proportions across facilities is calculated for information.
- Energy Inputs: Diesel consumption intensity (litres per tonne of production, facility-wise); grid electricity consumption intensity (kWh per tonne of production, facility-wise); diesel price in Year 1 and annual escalation rate; grid electricity tariff in Year 1 and annual escalation rate.
- Emission Factor Inputs: Diesel emission factor - 2.68 kg CO₂ per litre; Grid electricity emission factor - 0.82 kg CO₂ per kWh (reflecting the Indian average grid carbon intensity). Check: an automatic check confirms both emission factors are positive. A zero or negative factor would indicate a data error.
- Carbon Cost and NPV Inputs: India carbon tax base rate (INR per tonne CO₂); CBAM base rate (EUR per tonne CO₂); INR/EUR exchange rate; discount rate for NPV calculation.
- Scenario parameters for Scenarios A, B and C are provided in the 'Other Inputs' sheet.

Assumptions

Besides the data above, the following assumptions have been made:

- All production, energy consumption, emissions and cost amounts are assumed to occur at the end of each year for simplicity of discounting purposes.
- Grid electricity emission factors are assumed to remain constant over the projection period, reflecting the average Indian grid carbon intensity. No improvement in the grid mix is assumed in the base case.
- Diesel prices and electricity tariffs are escalated annually from Year 2 onwards at their respective escalation rates.
- The CBAM penalty is assessed on the embedded carbon in exported goods. This is calculated as (facility total emissions × facility export proportion), summed across all three facilities.
- There are no taxes or surcharges on the carbon tax or CBAM liability beyond the stated rates.
- There are no other costs associated with the production of goods beyond energy costs.
- The model is deterministic - all future values for production, energy prices and carbon rates are treated as known with certainty.

Cashflow Projections – Base Model

The calculations are done in the 'Projection – Base' worksheet. The calculation is divided into the following parts:

Production Output (Columns C–F): The projection is done for 10 years. Year 1 production for each facility is taken directly from the Inputs sheet. For subsequent years, it is grown at the base growth rate - $\text{Production}(t) = \text{Production}(t-1) \times (1 + \text{growth rate})$. Total production across all three facilities is summed in Column F.

Energy Consumption (Columns H–P): Facility-wise diesel consumption is calculated by multiplying production by the diesel intensity for that facility - $\text{Diesel consumption} = \text{Production} \times \text{Diesel intensity (litres per tonne)}$. Grid electricity consumption is calculated similarly - $\text{Grid electricity} = \text{Production} \times \text{Electricity intensity (kWh per tonne)}$ - and summed across all three facilities in Column K & P for Diesel and Grid electricity respectively.

Energy Cost (Columns R–S, AO): Diesel cost is calculated as total diesel volume multiplied by the diesel price, escalated annually from Year 2 - $\text{Diesel cost} = \text{Diesel volume} \times \text{Diesel price} \times (1 + \text{escalation rate})^{(\text{year}-1)}$. Electricity cost is calculated in the same way using the grid tariff and its escalation rate. Total energy cost (AO) = diesel cost + electricity cost. All amounts are expressed in INR lacs (1 lac = INR 100,000).

Carbon Emissions (Columns U–AC, AE): Diesel emissions (tonnes CO₂) = total diesel volume (litres) $\times 2.68 \div 1,000$. Grid electricity emissions (tonnes CO₂) = total electricity volume (kWh) $\times 0.82 \div 1,000$. Total emissions (AE) = diesel emissions + grid emissions. Exported emissions are calculated for each facility as total facility emissions $\times$ export proportion, then summed across all three facilities. A check was done to confirm that total emissions equal the sum of diesel and grid emission components.

India Carbon Tax (Column AP): India carbon tax = total annual emissions $\times$ base rate (INR 200 per tonne CO₂). Expressed in INR lacs. India carbon tax = Total emissions $\times$ Tax rate. A check was done to confirm the calculated tax equals total emissions $\times$ rate in each projection year.

CBAM Penalty (Columns AQ): CBAM penalty = exported emissions $\times$ CBAM rate (EUR 50 per tonne CO₂) $\times$ INR/EUR exchange rate (90). Expressed in INR lacs.

Total Carbon Costs and NPV (Columns AO–AR): Total annual cost = energy cost + India carbon tax + CBAM penalty. The NPV of each cost component is calculated using the Excel NPV function at the prescribed discount rate of 9% per annum, with cashflows assumed to occur at year-end. A check was done to confirm the NPV of the total cost equals the sum of the NPV of each individual component.

Year-on-Year Growth Analysis (Rows 20–29): Year-on-year percentage growth rates are shown for production volumes, diesel consumption volumes and energy costs. These are included to facilitate reasonableness checking of the projection. Rows 31–40 show the real growth in energy cost net of volume growth - this isolates the price escalation effect from volume growth.
