21st NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS

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

Date : 25.09.2021 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

General instructions :

- *Please check that this question paper contains **8** printed pages*
- *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*

Section -I: OBJECTIVE TYPE **Marks: 50x1 = 50**

1.	A factory has a fixed energy consumption of 2,000 kWh/month and it consumes a total of 38,000 kWh/month for manufacturing 90,000 units of the product. The variable energy consumption in kWh/unit is_____. **a) 0.4** b) 2.4 c) 2.5 d) none of the above	a
2.	If wet bulb and dry bulb temperatures read the same, the relative humidity is_____. a) 0% b) 50% **c) 100%** d) none of the above	c
3.	1 kWh is equivalent to a) 86000 cal b) 10000 Wh **c) 3.6 MJ** d) none of the above	c
4.	Which of the following data is not used for calculating Plant Energy Performance? a) Reference year energy use b) Production factor c) Current year energy use **d) Maximum electrical demand**	d
5.	Non-contact flow measurement can be carried out by _____. a) Orifice meter b) Turbine flow meter **c) Ultrasonic flow meter** d) Magnetic flow meter	c
6.	Which of the following means 'continuous improvement'? a) Seiton **b) Kaizen** c) Seiso d) Kanban	b
7.	54 kg of water is mixed with 0.34 moles of salt to make a solution. The mole fraction of the solution is _____. **a) 0.1** b) 18.36 c) 158.8 d) none of the above	a
8.	What is the future value of a cash flow at the end of the 6th year, if the Present Value is Rs. 2 Lakhs and the interest rate is 9%? a) 3,28,540 **b) 3,35,420**	b

	c) 2,84,980	d) none of the above	
9.	A temperature of -40°F will be _____°C?		
	a) 0	b) -10	c
	c) -40	d) none of the above	
10.	Unit of maximum demand is_____.		
	a) kVAh	**b) kVA**	b
	c) kVAr	d) kWh	
11.	The ISO standard for energy management system is_____.		
	a) ISO 9001	**b) ISO 50001**	b
	c) ISO 14000	d) ISO 14001	
12.	The depletion of ozone layer is caused mainly by _____.		
	a) Nitrous oxide	b) Carbon dioxide	c
	c) Chlorofluorocarbon	d) Methane	
13.	The presure of 1 atm is equal to _____.		
	a) 10.1325 bar	**b) 101.3 kpa**	b
	c) 1.033 mH_2O	d) none of the above	
14.	For the purpose of calculating TOE for a designated consumer the calorific value of oil is taken as		
	a) 10500 kcal/kg	**b) 10000 kcal/kg**	b
	c) 5000 kcal/kg	d) 8700 kcal/kg	
15.	1 BTU is equal to		
	a) 252 Joule	**b) 252 cal**	b
	c) 3600 kcal	d) 3.5 W	
16.	When the current leads the voltage in an AC electrical circuit, it is caused mainly due to		
	a) Inductive load	b) Resistive load	c
	c) Capacitive load	d) none of the above	
17.	The power indicated in the name plate of a motor denotes _____.		
	a) minimum kW drawn by the motor	b) maximum kW drawn by the motor	d
	c) maximum kVA drawn by the motor	**d) none of the above**	
18.	The law of conservation of energy is related with		
	a) third law of thermodynamics	b) second law of thermodynamics	c
	c) first law of thermodynamics	d) none of the above	
19.	The producer gas is basically _____.		
	a) only CH_4	b) only CO and CH_4	c
	c) CO, H_2 and CH_4	d) only CO and H_2	
20.	Return on investment (ROI) is _____.		
	a) initial investment/annual return	b) annual cost/capital cost	c
	c) annual net cash flow/capital cost	d) none of the above	
21.	The process of capturing CO_2 from point sources and storing them is called _____		
	a) carbon sequestration	b) carbon sink	a
	c) carbon capture	d) carbon adsorption	

22.	The typical efficiency of a solar cell in the field is **a) 12-15%** b) 25-30% c) 45-50% d) 80-85%	a
23.	Capacity utilization factor of a solar PV power plant is in the range of _____. a) 80-85% b) 60-65% **c) 18-20%** d) less than 10%	c
24.	Contact type speed measurement can be carried out by _____ **a) Tachometer** b) Stroboscope c) Oscilloscope d) Odometer	a
25.	The "superheat" of steam is expressed as_____. **a) degrees centigrade above saturation temperature** b) degrees centigrade above critical temperature of the steam c) degrees centigrade below the boiling point of water d) all of the above	a
26.	The electrical power unit GigaWatt (GW) may be expressed as a) 1,000,000,000 MW **b) 1,000 MW** c) 1,000 kW d) 10,000 W	b
27.	Which of the following is not true of liquid fuels? a) the viscosity of a liquid fuel is a measure of its internal resistance to flow b) the viscosity of all liquid fuels decreases with increase in its temperature **c) higher the viscosity of liquid fuels, higher will be its heating value** d) viscous fuels need heat tracing	c
28.	Which one of the following is not the duty of an energy manager under EC Act ? a) Report to BEE and state level designated agency once a year b) Prepare an annual activity plan **c) Conduct energy audit** d) Prepare a scheme for efficient use of energy	c
29.	Which one is not an energy consumption benchmark parameter? a) kcal/kWh of electricity generated **b) kg/deg. C** c) kW/ton of refrigeration d) kWh/kg of yarn	b
30.	300 liters of water in a tank is heated from 30°C to 70°C by using a direct steam with an enthalpy of 600 kcal/kg. The mass in kg of steam used is_____. a) 10 b) 200 c) 40 **d) none of the above**	d
31.	Which of the following is not a unit of energy? a) Joule b) Calorie **c) Watt** d) BTU	c
32.	What is the heat content of the 200 liters of water at 50°C in terms of the basic unit of energy in kilo Joules (kJ) a) 3000 b) 4187 c) 1000 **d) 41870**	d
33.	$C_2H_4 + xO_2$ ------> $2CO_2 + yH_2O$, what is the value of x + y? a) 2 b) 3 **c) 5** d) 8	c

34.	What is the "TOE" of 125 Ton of coal which has GCV of 4000 kcal/kg a) 40 **b) 50** c) 400 d) 500	b
35.	Infrared thermometer is commonly used to measure: **a) Surface temperature** b) Flue gas temperature c) Steam Temperature d) Hot water temperature	a
36.	Power in a 3 phase AC system is a) 3 x Voltage x Current b) Voltage x Current c) 1.73 x Voltage x Current **d) None of the above**	d
37.	Which industry among the following is not a designated consumer as per EC Act-2001? a) fertilizers b) chlor alkali c) cement **d) nuclear power stations**	d
38.	Star rating is a _____ program of BEE a) Demand Side Management b) Integrated Energy Policy **c) Standards & Labeling** d) National Mission for enhanced energy efficiency	c
39.	Energy consumption per unit of GDP is called as: a) energy elasticity **b) energy intensity** c) energy per capita d) none of above	b
40.	To maximize the combustion efficiency, it is required to _____ in the flue gas? a) maximize O_2 **b) maximize CO_2** c) minimize CO_2 d) maximize NO_x	b
41.	An electric heater of 230 V, 10 kW rating is installed for hot water generation in a hospital. The consumption per hour at 200 V is a) 10 kWh b) 8.7 kWh c) 13.23 kWh **d) 7.56 kWh**	d
42.	A sensitivity analysis is carried out for an energy saving project to make an assessment of a) cash flows **b) risks due to assumptions** c) capital investment d) best financing source	b
43.	The specific gravity of water is expressed as_____. **a) 1** b) 1 kg/m^3 c) 1 g/cc d) 1000 kg/m^3	a
44.	An activity in a project is having an optimistic time of 8 days, a most likely time of 15 days and a pessimistic time of 16 days. Its expected time of completion is **a) 14 days** b) 13 days c) 12 days d) none of the above	a
45.	From an activity in a project, latest start time is 8 weeks; latest finish time is 12 weeks. The slack time for the activity is_____. a) 1 week b) 5 weeks c) 4 weeks **d) none of the above**	d
46.	Which of the following is not a greenhouse gas? a) Water Vapour **b) SO_2**	b

	c) CO_2 d) CH_4	
47.	The period when maximum sunlight is available is called? a) Solar constant b) Solar insolation **c) Solar window** d) none of the above	c
48.	If wind speed increases by three times, energy output from windmill will be _____. a) 3 times higher **b) 27 times higher** c) 8 times higher d) none of the above	b
49.	A solution of common salt is prepared by adding 25 kg of salt to 100 kg of water. The weight fraction of solution is_____. **a) 20%** b) 25% c) 4% d) none of the above	a
50.	The number of moles in 90 kg of water is _____. **a) 5** b) 18 c) 2 d) none of the above	a

..... End of Section I .....

Section – II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

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

S-1 a) **List at least two factors affecting external energy bench marking of energy intensive processes. 2 Marks**

The factors affecting external benchmark could be:
- Scale of operation
- Vintage of technology
- Raw material specifications
- Product specifications

S-1 b) **Compute the plant energy performance of a brewery unit for the current year based on the following data 3 Marks**

Time frame	Production Level	Gross energy for the production level
Reference year	1,00,000 Barrels	35 Trillion Joules
Current year	1,10,000 Barrels	38 Trillion Joules

Production Factor = $\frac{\text{Current year production}}{\text{Reference year production}}$

$= \frac{110000}{100000}$

= 1.1

Reference year Energy Use = 35 Trillion Joules
Current year Energy Use = 38 Trillion Joules
Reference year Equivalent energy Use = (Reference year energy use) x (production factor)
= 35 x 1.1
= 38.5 Trillion Joules

Plant Energy Performance =

$$\frac{\text{(Reference year Equivalent energy use- Current year Energy use) x100}}{\text{Reference year Equivalent energy use}}$$

	= (38.5-38) x100 38.5 = 1.31% (improvement)
S-2	**A furnace shell has to be cooled from 95°C to 45°C. The mass of the furnace shell is 4 tonnes. The specific heat of the furnace shell is 0.122 kcal/kg.°C. Water is available at 30°C. The maximum permissible increase in water temperature is 5°C. Ignoring the heat loss, compute the quantity of water required to cool the furnace. 5 Marks**
	Mass of furnace shell (m) = 4000kg Specific heat of furnace shell (Cp) = 0.122 kcal/kg °C Temperature of shell before cooling (T1) = 95 °C Desired temp of shell after cooling (T2) = 45 °C Total heat that has to be removed from the furnace = m x Cp x (T1-T2) = 4000*0.122*(95-45) = 24400 kcal Quantity of water required (Q) =? Specific heat of water = 1 kcal/kg °C Inlet cooling water outlet temperature = 30 °C Maximum cooling water outlet temperature = 35 °C Heat removed by water = Qx1x(35-30) = 5Q 5 Q = 24400 Q = 24400/5 Q= 4880 kg
S-3	**A University is interested in installing a Solar Roof Top PV (SPV) system under net metering system. It has a total roof top area of 1200 Sq. meters, where the shading effect is 20% of the total area.** **Assuming 1 kWp SPV panel requires 10 sq meter area and the peak output is for 5 hours per day, calculate the following.**
S-3 a)	**How much kWp of Solar PV system can you suggest? 2 Marks**
	(1200x (1- 0.2)) / 10 = 96 kWp
S-3 b)	**How much would be the daily generation in kWh/day/kWp? 2 Marks**
	(96 x 5)/96 = 5 kWh/day/kWp
S-3 c)	**How many kg of CO_2/ year is avoided for 250 days operation, if the CO_2 emission factor is 0.82 kg/kWh. 1 Mark**
	96 kWp x 5 x 250 x 0.82 = 98,400 kg CO_2/year
S-4 a)	**List three types of performance contracting offered by ESCO and state the differences of each type. 3 Marks**
	Refer Guidebook 1, Page 178
S-4 b)	**What is the need for normalizing data, while establishing baseline energy use? 2 Marks**
	Refer Guidebook 1, Page 142
S-5 a)	**Why is an evacuated tube collector more efficient than a flat plate collector for solar water heating system? 2 Marks**
	Refer Guidebook 1, Page 264-265
S-5 b)	**Explain the term Betz limit related to wind turbines 2 Marks**
	Refer Guidebook 1, Page 273
S-5 c)	**Define capacity factor of a wind turbine 1 Mark**
	Refer Guidebook 1, Page 274
S-6	**Explain the concept of fuel substitution with three examples. 5 Marks**
	Fuel substitution is basically substituting existing fossil fuel with, less cost/less polluting fuel, such as, natural gas, biogas and locally available agro-residues. Fuel substitution is applicable in all sectors of the Indian economy.

	(2 marks) Few examples of fuel substitution Natural gas for cooking and industrial use in place of LPG. Replacement of coal by coconut shells, rice husk etc. Replacement of diesel/petrol by CNG, in automobiles Replacement of LDO by LSHS Replacement of electrical heaters by steam heaters Replacement of steam based hot water by solar systems (3 marks)
S-7	**A 10 HP rated induction motor having name plate details of 415 V, 12 amps and 0.9 PF is being tested for an audit. Input measuring instrument display was showing 2 kVAr and PF of 0.758. Determine the percentage loading of the motor during the test.** **5 Marks**
	$kW = KVA * PF$ (1) $(KVA)^2 = (kVAr)^2 + (kW)^2$ (2) Given kVAr = 2 and PF=0.758 Solve for kW in eqn (2) using eqn (1) we get, $kVA = kW/PF$; $PF = kW/kVA$; $(KVA)^2 = (kVAr)^2 + (kW)^2$; $(kW/pf)^2 = (kVAr)^2 + (kW)^2$ $(kW)^2 = pf^2 (kVAr)^2 + pf^2 (kW)^2$ $(kW)^2 - pf^2 (kW)^2 = pf^2 (kVAr)^2$ $(kW)^2 (1- pf^2) = pf^2 (kVAr)^2$ $(kW)^2 = (pf^2 *(kVAr)^2)/ ((1- pf^2))$ $kW = \sqrt{ (pf^2 *(kVAr)^2)/ ((1- pf^2))}$ $= ((pf *(kVAr))/ ((1- pf^2))^{0.5}$ $=(0.758*2)/((1-0.758^2))^{0.5}$ = 2.32 kW **(Or)** Cos θ = 0.758 Tan θ = 0.86 kW = kVAr / Tan θ = 2/0.86 = 2.32 kW **kW = 2.32 kW** Motor rated input kW= $\sqrt{3}*V*I*\cos\theta$ = 1.732*0.415*12*0.9=7.76 kW Percentage loading of motor= kW measured /rated input kW * 100 = 2.32/7.76 * 100 **=29.88%**
S-8 a)	**Calculate the Net Present Value of a project at a discount rate of 16% with an investment of Rs. 50,000 at the beginning of the first year and savings of Rs. 15,000, Rs. 18,000 and Rs. 20,000 respectively at the end of the first, second and third year.** **3 Marks**
	NPV = -50,000+(15000/1.16)+18000/(1.16x1.16)+(20000/(1.16x1.16x1.16)) = -50,000 + 12931 + 13377 + 12813 = (- **10879)**
S-8 b)	**State whether the project is viable or not?** **2 Marks**
	As NPV is negative the project is not viable.

..... End of Section II .....

Section – III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

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

L-1 **A company invests Rs.12 lakhs and completes an energy efficiency project at the beginning of year 1. The firm is investing its own reserve money and expects an internal rate of return (IRR) of at least 12% on constant positive annual net cash flow of Rs. 3 lakhs, over a period of 5 years, starting with year 1.**

L-1 a) **Will the project meet the firm's expectations?** **3 Marks**

Use the NPV formula with d = 0.12 and check to what extent NPV > 0 at n = 5 years.

	Cash out flow	Cash in flow
Year 0	-1200000	0
Year 1		300000
Year 2		300000
Year 3		300000
Year 4		300000
Year 5		300000

NPV for 12% discount rate

$$= -1{,}200{,}000 + \frac{300{,}000}{1.12^1} + \frac{300{,}000}{(1.12)^2} + \ldots\ldots\frac{300{,}000}{(1.12)5}$$

= - 1,200,000 + 267857.1+239158.2+213534.1+190655.4+170228.1= (-) 118567

From the table above it is seen that, NPV is negative at 12%, and the project will not meet the firm's expectations.

L-1 b) **What is the IRR of this measure? (Use the interpolation formula for obtaining the nearest IRR value, interpolation formulae is**

$$= (\textbf{\textit{lower discount rate}}\ \%) + \left\{\frac{(\textbf{\textit{NPV at Lower discount rate}}) \times (\textbf{\textit{Higher discount rate}}\ \% - \textbf{\textit{Lower discount rate}}\ \%)}{(\textbf{\textit{NPV at Lower discount rate}} - \textbf{\textit{NPV at Higher discount rate}})}\right\}$$

7 Marks

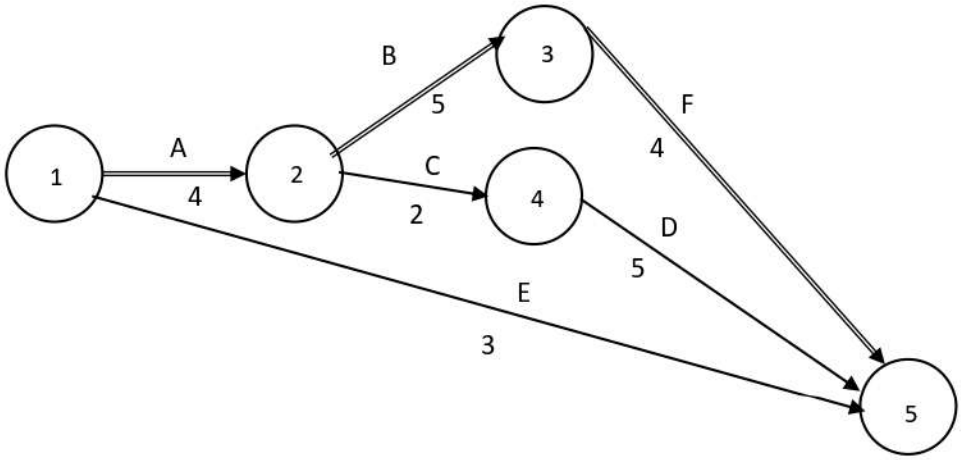
This means that the IRR of 12% must be selected smaller in order to have NPV = 0
The iterations for NPV at discount rates of 8%, 7% and 7.929% is given below:

Discount Rate							
12%		8%		7%		7.929%	
0.12		0.08		0.07		0.07929	
Cash Flow	Year Ref	Cash Flow	Year Ref	Cash Flow	Year Ref	Cash Flow	Year Ref
-1200000	0	-1200000	0	-1200000	0	-1200000	0
267857.1	1	277777.8	1	280373.8	1	277960.5	1
239158.2	2	257201.6	2	262031.6	2	257540.2	2
213534.1	3	238149.7	3	244889.4	3	238620	3
190655.4	4	220509	4	228868.6	4	221089.8	4
170228.1	5	204175	5	213895.9	5	204847.4	5
-118567		-2186.99		30059.23		57.82047	

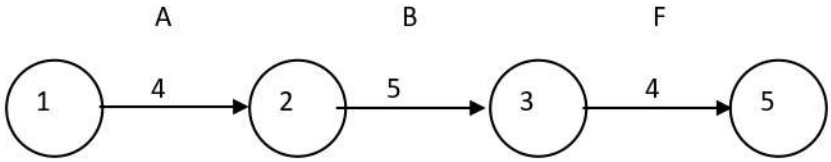
By iterations for total NPV at 12%, 8%,7% & 7.9%, the NPV is tending towards zero between 7.5 to 7.9% discount rate.

L-2 a) **Construct a CPM diagram for the data given below** **4 Marks**

Activity	Precedent	Time, weeks
A	Start	4
B	A	5
C	A	2
D	C	5
E	Start	3
F	B	4
Finish	D, E, F	--



L-2 b) **Identify the critical path** **2 Marks**



Total time on critical path: 13 weeks

L-2 c) **Also compute the earliest start, earliest finish, latest start & latest finish of all activities** **4 Marks**

Early start (ES), Early Finish (EF), Latest start (LS), Latest finish (LF) are:

S.no	Activity	Duration	ES	EF	LS	LF
1	A	4	0	4	0	4
2	B	5	4	9	4	9
3	C	2	4	6	6	8
4	D	5	6	11	8	13
5	E	3	0	3	10	13
6	F	4	9	13	9	13

L-3 a) **What is the relevance of molten salt tanks in a typical solar power tower?** **2 Marks**

Molten salt tanks provide an efficient low-cost medium to store thermal energy. Molten salt from the cold salt tank is pumped through the central receiver where it is heated to 566 °C. The heated salt from the receiver is stored in the hot salt thermal storage tank. Cold salt at 288 °C flows back to the cold salt thermal storage tank and is re-used.

L-3 b) **Explain how parabolic trough collectors work?** **4 Marks**

Refer Guidebook 1, Page 267

L-3 c) **Explain the difference between on grid and off grid solar PV systems? 4 Marks**

Refer Guidebook 1, Page 268 & 269

L-6 a) **Explain how Ozone layer is beneficial to life on earth and how it is getting destroyed? 5 Marks**

Refer Guidebook 1, Page 238 & 239

L-6 b) **What are the adverse effects of the melting of mountain glaciers on the eco system? 3 Marks**

It disturbs the ocean eco-system. Fresh water from melting ice caps desalinates the oceans besides raising the sea levels and flooding the low-lying areas near to coast/river beds. This will disturb the ocean currents which regulate the temperature. Also, the cooling property of white ice caps which reflect heat back into space is curtailed, thus contributing to further warming of the earth.
Refer Guidebook 1, **Page 247**

L-6 c) **State the advantages and limitations of IRR as a tool for project financial analysis 2 Marks**

Refer Guidebook 1, Page 172, Chapter 7

L-5 a) **In a cement plant the various forms of energy consumed are mentioned in the table below:**

Source of Energy	Qty	Heat Value
Pet Coke consumed in kiln	200 TPD	6500 kcal/kg
HSD consumed in the plant	5 kL/day	10200 kcal/kg
Electricity purchased from Grid	80000 kWh/day	860 kcal/kWh
Electricity "generated" from CPP	2 MW	
Heat rate of CPP		3770 kcal/kWh
Load factor of CPP	90 %	
GCV of Coal		4000 kCal/kg
Density of HSD	0.9 kg/L	
Annual operating days of the plant	330 Days/yr	

Calculate the following:

i. **Total energy input in kcal per day 2 Marks**

Source of Energy	Qty		Heat Value		Formula
Pet Coke consumed in kiln	200	TPD	6500	kcal/kg	= 200*1000*6500 = 1300000000 kcals/day
HSD consumed by earth moving equipment	5	kL/day	10200	kcal/kg	= 5*1000*0.9*10200 = 45900000 kcals/day
Electricity purchased from Grid	80000	kWh/day	860	kcal/kWh	= 80000*860 = 68800000 kcals/day
Electricity generated from CPP	2	MW			
Heat rate of CPP			3770	kcal/kWh	
Load factor of CPP	90	%			
Density of HSD	0.9	kg/L			
Annual operating days	330	Days/yr			

		of the plant					
		Heat input to CPP	= (2 MW*1000) *Load Factor, 0.9* CPP Heat Rate 3770* 24 hrs/d				= 162864000 kcals/day
		Total heat input per day	= 1300000000 +45900000+68800000+162864000				= 1577564000 kcals/day
ii.	**Annual energy input in TOE (Tonnes of Oil Equivalent)** **3 Marks**						
	$$Annual\ TOE = \frac{1577564000}{10^7} \times 330 = 52060\ TOE/annum$$						
iii.	**Coal consumption per day for CPP in TPD** **4 Marks**						
	$$Coal\ requirement\ for\ CPP = \frac{CPP, MW\ \times 1000\ \times CPP\ Load\ factor\ \times CPP\ Heat\ Rate}{GCV\ of\ Coal\ \times 1000}$$ $$= \frac{2\ \times 1000\ \times 0.9\ \times 3770}{4000\ \times 1000} = 1.697\ TPH$$ $$Coal\ Requirement\ for\ CPP\ per\ day = Coal\ requirement\ for\ CPP\ per\ hour\ \times 24$$ $$= 1.697 \times 24 = 40.716\ TPD$$						
iv.	**Whether the unit qualifies as a designated consumer or not?** **1 Mark**						
	As the annual consumption is greater than 30,000 TOE for a cement plant, this unit will be considered as a Designated consumer.						

L-6 a) **In a food processing plant, the monthly production related variable energy consumption was 1.9 times the production and the non-production related fixed energy consumption was 14,000 kWh per month upto December of the previous year. In the month of January, a series of energy conservation measures were implemented. Using CUSUM technique, develop a table and calculate the energy savings for the subsequent 6 months period upto the month of June from the data given below:** **7 Marks**

Month	Production (kg)	Actual Energy Consumption (kWh)
Jan	62000	113600
Feb	71000	139000
Mar	75000	158000
Apr	59000	119300
May	62000	123700
Jun	73000	143600

Month	Production (P)	Actual energy consumption (Ea)	Predicted energy Consumption (Ep) =1.9*P+14000	Ea-Ep	CUSUM
Jan	62000	113600	131800	-18200	-18200
Feb	71000	139000	148900	-9900	-28100
Mar	75000	158000	156500	1500	-26600
Apr	59000	119300	126100	-6800	-33400
May	62000	123700	131800	-8100	-41500
Jun	73000	143600	152700	-9100	-50600

L-6 b) **Mention three commonly used financial tools for evaluating economic viability of an energy conservation measure?** **3 Marks**

3 main tools used are:

- Pay-back period

	• Return on Investment • Present value method

..... End of Section III .....