The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	Master of Energy Management (MEM)
Name of the Examination	Final Examination
Course Code and Title	**DMX9201 Energy and Environment (E&E)**
Academic Year	2020
Date	14th August 2020 (Friday)
Time	14.00 h– 17.00 h (**IST**)
Duration	**03 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Five (5)** questions. **Answer all questions.**
3. All questions carry equal marks
4. **Answer for each question should commence from a new page.**
5. **Relevant data/ charts/ codes are provided.**
6. This is a Closed Book Test (CBT).
7. Answers should be in clear handwriting.
8. Do not use Red color pen.

QUESTION 01 (20 marks)

(a) Explain the evolution of energy from 15th century to 21st century by changing their form. (10 marks)

(b) Compare the use of renewable energy sources against fossil fuels considering economic, social, technological and environmental aspects in the Sri Lankan context. (10 marks)

QUESTION 02 (20 marks)

(a) What are the current trends in Renewable Energy? How does it help sustainable development? (6 marks)

(b) Sri Lanka is endowed with several types of renewable energy resources. Do you agree? Discuss your answer. (6 marks)

(c) Since World War II, there has been a huge ramp-up in energy consumption per capita. There are several reasons for this. Discuss two major reasons for it. (8 marks)

QUESTION 03 (20 marks)

(a) Briefly explain the key outcomes of the Paris Agreement. (5 marks)

(b) Sustainable development has 3 pillars: Social, Environmental, Economic. (5 marks)
Discuss the significance of each pillar in relation to sustainable development.

(c) Define Scope 01, 02 and 03 emissions in relation to the GHG Protocol. (5 marks)

(d) Discuss 3 adverse impacts of global warming. (5 marks)

QUESTION 04 (20 marks)

A river with the flow exceedance of 0.37 m³/s throughout the year passes near a village in Nepal. Assume that you have been hired as a consultant to help the village develop a hydropower project. There is a requirement to retain 15% of the volume of water in the river for downstream irrigation and other environmental reasons. The length of the penstock required is 300 m and gross head is 35m. (Assume the Head loss to be 2.404 m)

Assume that the turbine efficiency is 80% and generator efficiency is 90%. The average energy demand is 100W peak per household and average operating hours is 10 hours a day. The total number of households in the village is 600. Consider 10% power loss due to transmission and distribution. Assume the average velocity of water inside the penstock is 1.8 m/s and other losses viz. bend loss and contraction/expansion loss are negligible.

Power output (P) can be calculated from the equation below.

$$P = (Q_a - Q_l)(H_{gr} - H_l)\eta\rho g$$

Where,

$Q_a = Water\ flow\ available\ in\ the\ river\ (m^3s^{-1})$

$Q_l = Water\ to\ be\ left\ in\ the\ river\ (m^3s^{-1})$

$H_{gr} = Gross\ Head\ (m)$

$H_l = Hydraulic\ losses\ due\ to\ friction\ and\ velocity\ change\ (m)$

$\eta = efficiency\ in\ energy\ conversion\ in\ electromechanical\ equipment$

$\rho = Density\ of\ water\ (1000\ kgm^{-3})$

(a) Compare and contrast the differences between "reservoir type" and "run of river" type hydro power systems. (4 marks)

(b) What is the available flow of water for power generation? (2 marks)

(c) What is the diameter of the penstock pipe? (2 marks)

(d) Calculate the Net Head of the project (2 marks)

(e) What is the power output of the plant? Can the demand of the village be met with the available head and flow? (4 marks)

(f) The village was previously powered by a diesel generator, which is now to be replaced by the hydropower. Assume that the CO_2 tax is 360 USD/m³ diesel fuel. Diesel cost is $ 0.7 per liter and specific fuel consumption of the diesel engine is 0.5 liters per kWh and 1 liter of diesel produces 2.65 kg of CO_2.

    (i) Calculate the annual cost saving in terms of avoided fuel cost and CO_2 emission tax.   (4 marks)

    (ii) Calculate the quantity of CO_2 emissions avoided.   (2 marks)

QUESTION 05 (20 marks)

You have been hired as a consultant to help ABC Organization head office to become a NetZero Carbon building. Electricity and Diesel Consumption details of ABC Organization in 2019 are given in **Table 1**.

The WorldGreen Building Council's definition of a Net Zero Carbon building is a building that is highly energy efficient and fully powered through on-site and/or off-site renewable energy sources.

The building is equipped with a diesel generator as a backup source, and it is operated only when the utility power is unavailable. It was previously calculated that the diesel generator produces 3.5kWh per one liter of dieselon average, while serving as a backup source.

The organization does not report emissions under Scope 3, and it could be neglected from the study.

Building falls under GP-2 tariff category and is provided in **Annexure-01**

Table 1: Electricity and Diesel Consumption details of ABC Organization in 2019

Month	Total kWh in the Electricity Bill	Generator Diesel Consumption(l)
Jan	42,849	200
Feb	37,627	800
Mar	52,794	450
Apr	50,287	1,350
May	34,976	420
Jun	32,576	2,700
Jul	50,594	450
Aug	40,327	100
Sep	42,436	100
Oct	47,987	350
Nov	52,954	600
Dec	48,028	70
Total	533,435	7,590

(a) As the consultant, what is the first step that you would take before looking at the renewable energy alternatives? Justify your answer. (2 marks)

(b) Using the data in **Table 1**, calculate the is the annual total electricity consumption of ABC Organization in 2019? (4 marks)

(c) Calculate the Scope 1, Scope 2, and total emissions of the office building in 2019. (*Emission factors are provided in Annexure 2*) (4 marks)

(d) During the energy audit conducted as a part of this project, it was observed that there is a potential saving of 25% of the total electricity consumption if the recommendations in the audit are implemented.

Additionally, during a simulation conducted using PVSyst software package, it was noted that there is a potential of 1600 kWh/ kW/ year in the area the office is located.

(i) In order to become a NetZero Carbon building, what is the capacity of the roof top solar PV system you would propose? (4 marks)

(ii) Assuming a cost of LKR 110/ Watt for rooftop solar PV, what will be the total cost for the proposed roof top solar PV system? (2 marks)

(iii) The Government has introduced 3 schemes for roof top solar PV systems: Net Plus, Net Accounting and Net Metering. (See Annexure 03 for details)

ABC Organization has informed you that as a company policy they are going to allow flexible hours (from 8am to 10pm), where the employees will work for 8 hours a day. Further, during a survey conducted prior to this decision, it was identified that a large proportion of employees prefers to report to work late and finish work at night to avoid traffic congestion. (4 marks)

As the consultant, propose which scheme (out of Net Plus, Net Accounting, and Net Metering) best suits the organization from a financial perspective. Justify your answer.

Annexure-01

Electricity Tariff – General Purpose

Customer Category GP-2

This rate shall apply to supplies at each individual point of supply delivered and metered at 400/230 Volt nominal and where the contract demand exceeds 42 kVA.

Table 2- Tariff Applicable for Industrial-2 Customers

Table 2- Tariff Applicable for General Purpose- 2

Time Intervals	Energy Charge (LKR/kWh)	Fixed Charge (LKR/month)	Maximum Demand Charge per month (LKR/kVA)
Peak (18.30-22.30)	26.60	3,000.00	1,100.00
Day (5.30-18.30)	21.80		
Off-peak (22.30-05.30)	15.40		

Annexure-02

Type of Fuel	Stationary Combustion Units						
	Emissions factor						
	CO₂	CH₄	N₂O	HFC	PFC	SF6	Units
HFO	2.810	0.002	0.013	0	0	0	kg CO2e / l
Diesel	2.670	0.002	0.012	0	0	0	kg CO2e/ l
Kerosene	2.540	0.002	0.012	0	0	0	kg CO2e/ l
LPG	2.950	0.002	0.016	0	0	0	kg CO2e/ kg
Coal	2.150	0.001	0.007	0	0	0	kg CO2e/ kg
LNG	0.054	0.026	0.030	0	0	0	kg CO2e/ SCF
Wood	1.869	0.013	0.026	0	0	0	kg CO2e/ kg

Grid Emission Factor in Sri Lanka (2019) – 0.735 kg CO₂e /kWh

Annexure-03

Net Metering	The customer generates electricity using solar panels fixed on their houses/premises and connected to the grid through Net Metering system. The consumer pays only for the net amount of electricity that is consumed. In this system, if that customer's production exceeds consumption, they can bring forward the balance and consume it in the months forthcoming. No fee will be paid for the excess electricity produced. The customer will be given the choice of using the balance electricity within 10-year period.
Net Accounting	If the generated units of electricity using the solar panels fixed on their houses/premises are greater than the amount consumed, the customer will be paid Rs.22.00 per unit during the first 07 years and from the 8th year, be paid Rs. 15.50 per unit. If the consumption is greater than the amount generated, the consumer pays at the existing electricity tariff for the excess electricity consumed.
Net Plus	Getting paid for the quantity of electricity generated using the solar panels fixed on their houses/premises. Unlike Net Metering, there is no linkage between the electricity consumption of the customer and the electricity generation. The customer pays for the electricity consumed according to the existing tariff. The Electricity Board will pay for the total amount of electricity generated by the customer.