



School of Computing and Engineering Sciences
Master of Science in Sustainable Energy Transitions
End of Semester Examination

MSSET 8204: Energy Systems Analysis and Decision-making

Date: 11th December 2024

Exam Duration: 18:00-20:30 Hours

Instructions

1. Question 1 (ONE) is compulsory.
2. Select any other TWO questions from the remaining questions.

Question ONE (20 Marks). Compulsory

- a) You are tasked with advising a government on how to reduce national carbon emissions. Would you recommend using a top-down macroeconomic model or a bottom-up engineering model? Explain your choice based on the strengths of each model. [4 marks]
- b) A solar energy developer wants to optimize the location of a new solar farm. Describe the data-oriented decision-making process they should follow, from data collection to model analysis. [3 marks]
- c) Write an R script to optimize the cost of generating 800 MWh using two types of power plants:
 - Plant A: Cost = \$60 per MWh, Max Capacity = 500 MWh
 - Plant B: Cost = \$80 per MWh, Max Capacity = 500 MWh[3 marks]
- d) You are given historical data on crude oil prices, GDP growth rates, inflation rates, and interest rates for the past few years as shown in the table below. Your task is to predict the crude oil prices for the next year based on the current economic indicators.

Year	Crude Oil Price (USD)	GDP Growth Rate (%)	Inflation Rate (%)	Interest Rate (%)
2018	65.2	2.3	1.8	3.0
2019	58.3	2.9	2.1	2.8
2020	41.2	-3.5	1.4	0.5
2021	68.7	5.9	2.5	0.8
2022	88.1	3.5	3.0	2.2

Create a model to predict the crude oil price for **2023** given the economic indicators:

- GDP growth rate = 2.5%
 - Inflation rate = 3.2%
 - Interest rate = 2.5%
- [10 marks]

Question TWO (15 Marks)

- a) You are evaluating a wind farm project. Explain how sensitivity analysis can help assess risks related to variations in wind speed and maintenance costs. [3 marks]
- b) A non-profit is planning off-grid solutions for rural communities. Conduct a scenario analysis comparing solar microgrids versus diesel generators, focusing on cost, sustainability, and reliability. [4 marks]
- c) Historical efficiency data on a solar panel suggests that has the decay constant is 0.05 per year. The panel had an initial efficiency of 20%. Using the Exponential Decay Model predict the decline in efficiency of solar panels over 5 years based on the historical efficiency data. Show all the calculations. [8 marks]

Question THREE (15 Marks)

- a) A country wants to understand how GDP, population, and oil prices affect national electricity consumption. Which econometric model would you use, and how would you structure it? [4 marks]
- b) Describe how you would apply time-series analysis to forecast seasonal energy demand for a utility company. [3 marks]

c) A solar farm is considering the installation of a battery storage system to enhance its energy management and increase its revenue. The following data is available for the project:

- Initial Investment for Battery Storage System (Capital Cost): \$1,000,000
- Annual Operating Costs (Maintenance, Insurance, etc.): \$50,000 per year

Energy Storage Revenue:

- The battery system can store 500 MWh per year, and it is expected to generate \$120 per MWh of energy stored and discharged.
- The energy storage system will be operational for 5 years.
- Discount Rate (Cost of Capital): 7%
- Expected Life Span of the Battery System: 5 years
- Salvage Value (End of Life Value): \$100,000 (after 5 years)

Using the available data, calculate the Net Present Value (NPV) of the project over its expected 5-year life span. Based on the NPV, assess whether the installation of the battery storage system is economically feasible. [8 marks]

Question FOUR (15 Marks)

a) You are given wind speed data and energy output from a wind farm. Explain the steps you would follow to model the relationship between wind speed and energy output.

[2 marks]

b) Using weather data (solar radiation, temperature, humidity), identify a machine learning mode to be used to predict the daily energy output of a solar farm. Explain the steps to be followed when applying the model to predict the daily energy using the weather data. [3 marks]

c) An off-grid community is exploring ways to minimize energy costs by optimizing the use of **solar panels** and **diesel generators**. The community needs to meet its energy demand while minimizing fuel costs and taking advantage of solar energy when possible. The following data is provided:

1. **Daily Energy Demand:** The community requires a total of **1,000 kWh** of energy each day.
2. **Solar Panels:**

- Maximum daily energy production: **500 kWh**
 - Cost of solar energy (maintenance and amortized cost): **\$0.05 per kWh**
3. **Diesel Generators:**
- Diesel fuel cost: **\$0.20 per kWh** produced
 - Generator can run for a maximum of **15 hours per day** with a capacity of **50 kW**
 - Fixed operating cost: **\$50 per day** when used
4. **Battery Storage System:**
- Capacity: **200 kWh**
 - Charging/Discharging efficiency: **90%**
 - Cost of battery wear and tear: **\$0.03 per kWh** cycled
5. **System Constraints:**
- The solar panels can only generate electricity during the daytime (8 hours per day).
 - The battery can store excess solar energy to be used during non-daylight hours.
 - The diesel generators can be used any time but are more expensive than solar energy.
 - The community prefers to maximize the use of solar energy to minimize costs.
- i. Define the decision variables for the amount of energy generated by solar panels, diesel generators, and battery usage. [3 marks]
- ii. Define the objective function to minimize total energy costs, including fuel, maintenance, and battery cycling costs. [3 marks]
- iii. Set-up the constraints for energy balance, battery capacity, generator capacity, and solar production limits. [4 marks]