Assignment: Monte Carlo Modelling

# Teachers

Dr Jonathan Chambers, Xiang Li

# Introduction

This exercise presents a Monte Carlo simulation of cooling energy demand in Swiss office building stock and the projected change in energy demand caused by climate change.

This exercise will be done inside a “Jupyter Notebook” using the Python programming language. You will access a pre-prepared notebook that contains explanations, code, and results for the simulation. You will be able to get an overview of how using Python in a notebook works, but you will **not** need to learn Python programming to complete the exercise.

# Assignment Goals

* Learn how to implement and run a Monte Carlo simulation and interpret the results
* Learn how derive probability distributions from data samples
* Gain experience using Python to perform modelling an analysis.

# Answers Guidelines

Please reply to the questions by filling in answers to the exercise questions in the Microsoft Word document template, including plots where necessary, using the information and results found in the Notebook. Include figures saved from the notebook in the results and add a caption. You only have to answer the questions asked in each section, you are **not** expected to prepare a full report – it is normally possible to complete this during the Friday session.

*Note: When reporting numerical results with uncertainty, you should round the numbers precision of the uncertainty value. For example, if the calculation produces a mean value of 512.123123 and an uncertainty value of 2.123122, you should present the result as 512±2. If the value was 0.1234 and the uncertainty was 0.04345, you would write 0.12±0.4.*

# Submission date and debriefing

The report must be handed in on 24 April 2024

# Access Instructions

The online teaching tool can be found at: <https://iselab.unige.ch>

Log in using the first part of your university email address (before the ‘@’) and the password as provided in the lesson.

# Questions

**The assignment is graded out of 60 points.**

**General questions**

## How does a Monte Carlo model relate to a deterministic model? (4pt)

## List one advantage and one disadvantage of the Monte Carlo method. (3pt)

## Why is it important to perform uncertainty calculations? (3pt)

**Notebook Part 1 – Building the Monte Carlo model**

## From the results in the notebook, do the test statistics indicate that the distribution of the thermal power Pth,m2 is normal? (2pt)

## Present the plot of the approximated log-normal distribution of thermal power, including title and figure caption. (2pt)

## What other information about the thermal power demand is important in understanding the suitability of the normal distribution? Hint: can normally distributed values be less than zero? (2pt)

##

## For the number of operating hours *NH*, we had to fit a log-normal distribution to the log of the data in order to get a reasonable result.

## Do you think the result is a good approximation of the data? (2pt)

##  What alternative approach could we use to define a probability distribution instead of fitting a log-normal distribution? (2pt)

## Run the calculation of the total energy demand manually 5 times.

## Record each value in a table. (3pt)

##  Calculate the mean, standard deviation, and confidence interval of the values. (3pt)

## With reference to the central limit theorem, explain why we analyse the sums of total energy demand. (4pt)

|  |  |
| --- | --- |
|  | Result [GWh] |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |

## Run the MC simulation for 10, 100, 1000 iterations.

## For each value of N Iterations, calculate the mean and confidence interval and fill in the table. (3pt)

## What is the impact of having too few iterations? (2pt)

## Present the plot showing the results distribution where there are sufficient iterations (3pt)

## What might be a limiting factor on the maximum number of iterations? (2pt)

|  |  |  |
| --- | --- | --- |
| Number of Iterations | Cooling demand [GWh] | 95% confidence interval |
| 10 |  |  |
| 100 |  |  |
| 1000 |  |  |

**Notebook Part 2 – Climate change scenarios**

## Investigate the effect of climate change on cooling demand.

## Run the Monte Carlo model with the different values for CDD and cooling probability and fill the table below. (3pt)

## Create a chart showing the cooling demand and the error bars to compare the present day with the two climate scenarios. (4pt)

## Calculate the change, percentage change, and uncertainty in the change in cooling demand between present day and climate scenarios. (3pt)

Note: You can create the chart in Word, Excel, or in the Python notebook.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| scenario | CDD | Cooling Probability | Cooling demand [GWh] | 95% confidence interval |
| present day | 213.7 | 0.225 |  |  |
| RCP 2.6 | 276.7 | 0.5455 |  |  |
| RCP 8.5 | 365.2 | 0.5677 |  |  |

## Now investigate the impact of improving the COP.

## Calculate the value of a 50% improvement in mean COP compared to the present day data. (1pt)

## Run the model increasing the COP by 50% for the two climate scenarios and fill the table. (4pt)

## What policy conclusions with respect to cooling demand and cooling system efficiency can you draw from these results? (5pt)

|  |  |  |
| --- | --- | --- |
| Cooling demand in 2050 | COP +50% | 95% confidence interval |
| RCP 2.6 |   |  |
| RCP 8.5 |   |  |