Project Reinforcement Learning (2025)

6th of January 2025 - 31st of January 2025

One of the main applications of reinforcement learning is in operations research. Among the many domains of operations research, one of increasing importance is in the energy management sector.

Flexible energy systems, combining production and consumption, are a growing focus as datacenters aim to optimize their energy use while managing operational demands and incorporating renewable sources. A significant challenge for such systems is defining an operational strategy that balances energy consumption, generation, and limited storage efficiently.

In this project, you are part of the data science team tasked with developing a control strategy for a new datacenter with flexible energy consumption and limited storage capabilities.

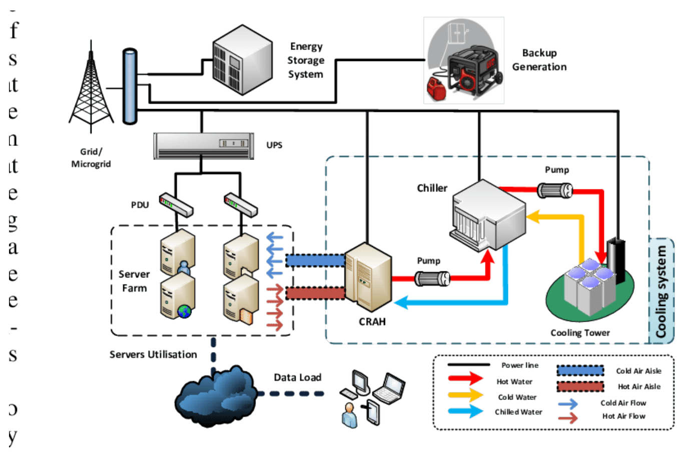

Figure 1: Illustration of a datacenter

This datacenter can dynamically adjust its energy consumption patterns based on workload and electricity availability. It can also store a limited amount of energy for future use. These capabilities allow the datacenter to act as a responsive energy consumer while contributing to grid stability by aligning its energy demand with supply fluctuations and market conditions.

Consider a datacenter that requires 120 MWh of energy everyday that it needs to buy from the grid at a maximum power rate of 10MW. There is no constraint on when these 120MWh of energy are bought but they need to be bought every day of the year (from midnight to midnight). If the 120MWh are not met, the datacenter will automatically start buying early enough such that it meets its energy requirements (e.g. if at 8pm, it has only bought 80MWh, it will buy for the next 4 hours). An excess of energy supplied to the datacenter of 50MWh can counts as a heads up for the next day. Anything above that is considered as wasted.

The datacenter can also act as a storage system by selling to the grid at a maximum power rate of 10MW as long as it is compensated by buying electricity at other time steps. It should however never fall below 0 MWh and reach at least 120MWh of positive energy supply by the end of the day. Selling electricity to the grid only provides 80% compensation of the grid price due to the electricity losses and financial agreements with the grid.

You need to suggest a control strategy for the operation (with unseen time series, i.e. next years of electricity prices) of the datacenter given 3 years of past electricity prices on the grid. These electricity prices (euros/MWh) are given on Canvas in the file *'spotmarket_data_train.xls'* that you can use to train/validate your model. You can assume that the price of electricity on the market is independent of the quantity of electricity that you trade with the market.

One important element is that the operation algorithm of your datacenter can only access the data up to the current time step. The future price is stochastic and unknown at the time of taking a decision because it depends on the offer and demand at the later time steps. This is also why RL is useful (otherwise an optimization formalization of the problem could solve this).

Presentation 1 (17th of January)

You need to make a presentation where

- you have completed the environment,
- you have implemented at least one baseline algorithm (not necessarily RL),
- you can provide visualization of the operation of the datacenter as well as estimated performance (with the validation time series),
- you explain the key next steps to improve the model.

You need to make a presentation (5-8 minutes presentation + 5-8 minutes feedback/questions).

Report (30th of January) and presentation 2 (31st of January)

The final report and presentation need to show

- an RL solution that you have developed for the problem at hand,
- how you have validated the RL algorithm and what the estimated performance are,
- the code with a pre-trained model that can be run on new time series that will be provided. The additional data will be provided in the same format but possibly less days (e.g. with 1 year of data). The code should also have a README file that explains how to run the code for training the model and how one can use the pre-trained model.

You need to hand in a report (max 8 pages, appendix allowed) along with source code. You also need to make a presentation (5-8 minutes presentation + 5-8 minutes questions).

Additional research questions

As part of your final report and final presentation, you can also add variants to this problem and/or perform ablation analysis to highlight the key parts of your algorithm.

Additional avenues that you can investigate:

- Make the problem even more realistic by simulating variations in energy demand or renewable energy production over time and investigate how you need to adapt the initial algorithm.
- Run the same algorithm with fewer/more features (e.g., energy price, workload predictions, weather data) and analyze how the performance is impacted.
- Explain different validation strategies and evaluate the pros and cons of each technique. For instance, you can estimate the confidence in your algorithm's performance by calculating the variance using techniques like cross-validation.

Other

- Report and presentation (7 points)
  - Formalization (clarity)
  - Description of the results
  - Additional more open research questions that is investigated
- Code and its performance (3 points)
  - Details on how the required API that your code will need to have will be provided on Canvas such that your code can be tested with new unseen time series.