Optimisation in Modern Power Systems - Phase 2 Assignment 2
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1 Client problem definition

The client is a generation company operating a portfolio of power plants. They must procure fuel for these power plants every week. They would like a short-term inventory and procurement optimisation model for their fuel procurement. They would like to include price and demand uncertainty within their modelling. They are limited by storage capacity and a weekly budget. They are subject to shortage penalties for unmet demand.
Optimisation will allow them to determine the optimal quantity and timing for fuel purchases and storage. Given the complexity of the problem, an optimisation model is well placed to provide detailed and efficient solutions to minimise their costs.

1.1 Client proposals that have been changed/placed out of scope or identified as ambiguous

Due to time constraints in the project, it has been decided to place some of the topics mentioned in the client brief out of scope. Some subjects have also been altered/added to be more realistic and improve the model.
We have decided to model only one power plant with one fuel resource. For each additional power plant and fuel resource the number of decision variables doubles, majorly increasing the complexity of the model. This still allows in depth insights into the procurement strategy of one power plant and associated fuel resource. Furthermore, the proposed decision model can be applied to the other plants individually to gain insights into the individual optimised procurement trends in a limited capacity without cross-plant effects.
Additionally, it was decided to model a direct cost for storing the fuel instead of relying on "unspent capital" to account for this. It was felt that this better represents the real-world problem and does not significantly increase computational complexity.
It was decided not to consider hedging as a potential pricing structure. This additional group of decision variables related to the potential pricing structures adds a high level of model complexity and is not possible within the scope of this project.
It was unclear from the client brief exactly the time horizon of the model. Further clarification on the time horizon is needed in order to implement the model effectively.

2 Preliminary consultant project proposal

We would like to propose a decision making model that will manage fuel procurement and storage for one power plant under uncertain future prices and demand. It will aim to minimise the total cost to the client, incurred from purchases, storage and shortage penalites.
We propose three models with growing complexity and increased realism. The first model will act as a baseline with no intertemporal considerations, and the last with high complexity intertemporal considerations and accounting for uncertainty.

3 Model Roadmap

3.1 Evaluation metric

In order to evaluate each of the models proposed below we propose to use an evaluation metric comprised of total procurement cost and total unmet demand over the desired time period. These metrics were specifically expressed by the client as being important considerations in their power plant operation. Therefore, we believe they will provide the most valuable understanding to the client of model effectiveness.

Model 1 – Deterministic Baseline Finds the minimum procurement cost given fuel prices, demand and unmet demand cost.

- **Decision Variables:** Bought fuel, unmet demand.
- **Data and parameters:** Fuel prices in the time period of study, demand in the time period of study, minimum demand needed to be covered for plant operation, available expenditure in time period.
- **Assumptions:** Unmet demand has an associated cost. Demand is the market demand, which does not include the minimum demand needed to be covered for plant operation.
- **Limitations of the model:** One period, no uncertainty.
- **Expected Outcome:** Minimum procurement cost
- **Trade-offs:** Meeting demand will depend on the fuel prices and available expenditure, unmet demand is possible but comes at a cost.

Model 2 – Multi-period model Find the minimum procurement cost over time, given the fact that now there is an option to store fuel, but a cost associated to it.

- **Additional Decision Variables:** Stored fuel.
- **Additional Data and Parameters:** Storage cost and available expenditure budget accumulated from last period. Maximum storage capacity.
- **Additional Key Assumptions:** Fuel can be stored and the available expenditure from last period can be used in the next time period.
- **Model Boundaries:** Lack of uncertainty in future prices and demand make it easy for the model to optimise the expenditure with full foresight.
- **Expected Outcome:** Minimum procurement cost taking into account storage and intertemporal for inventory and budget.
- **Additional Trade-offs and Insights:** Storage can be used to help meet more demand and take advantage of temporal price differences, but also comes at an additional cost.

Model 3 – Stochastic model Find the minimum procurement cost over time taking into account the uncertainty about future prices and demand.

- **Additional Decision Variables:** First-stage decisions for the current period such as bought fuel, unmet demand, storage and available budget; scenario-dependent decisions for future periods for each scenario of prices and demand.
- **Additional Data and Parameters:** Set of scenarios for fuel prices and demand over the planning horizon and scenario probabilities.
- **Assumptions:** Uncertainty is captured by a discrete set of scenarios; probabilities are known; all scenarios share the same first-period decisions.
- **Model Boundaries:** Quality of the solution depends on the quality and number of scenarios.
- **Expected Outcome:** Minimum procurement cost across all scenarios, while respecting storage and budget carryover in every possible future.
- **Trade-offs and Insights:** Model is more realistic than the deterministic versions because it hedges against several possible futures, but it is also more computationally demanding and sensitive to scenario design; it can show the value of early procurement and storage under price/demand uncertainty.