Technical University of Denmark

46750 - Optimization in Modern Power Systems

Assignment 2 – From Board Game to Real-World Decision-Making Challenges

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Phase I	25%	25%	25%	25%
Phase II	25%	25%	25%	25%
Phase III	25%	25%	25%	25%
Phase IV	25%	25%	25%	25%

Table 1: Individual participation in % (each row must sum up to 100%)

1 Phase 1 – Problem Identification (Client Discovery)

Stage 2 – Buying Energy Resources: Short-Term Procurement and Portfolio Optimization under Price and Supply Uncertainty

Actor / Scope: We adopt the perspective of a power generation company owning a portfolio of thermal and renewable units. The company must procure fuels and pay environmental fees to ensure continuous operation while participating in centralized fuel and allowance markets.
Link to *Power Grid* Stage 2: As in the board game, where players buy limited resources and prices increase with scarcity, our company faces similar real-world challenges when purchasing fuels under uncertain demand and policy-driven costs.
Main Concern: The main concern of the company is to *minimize the long-run expected cost of fueling its power plants (including environmental fees on coal) while avoiding fuel shortages*, in a market where resource prices increase with aggregate demand and may rise further due to environmental policy.

Decision Variables and Constraints

Decision variables: The main decision variables include the amount of each fuel to purchase in every period, the level of inventory to maintain or store for future use, and the timing of purchases (buying early versus waiting for later periods).

Constraints: The company faces several key constraints. **Storage capacity** limits the ability to store fuels, and excess storage implies additional cost. **Capital and budget limits** mean that early purchases tie up working capital and reduce liquidity. **Operational alignment** requires that the fuel bought must match expected plant utilization. Finally, **supply reliability** ensures that fuel availability must cover required generation without shortages.

Input Data and Sources of Uncertainty

Input data: Relevant input data include current and expected fuel prices (coal, gas, oil, uranium), forecasts for environmental fees or CO_2 prices, and information on storage costs, capacity, and handling constraints.

Uncertainties/Assumptions: The problem involves multiple uncertainties, including future price evolution and supply conditions, environmental policy changes affecting coal or emission costs, and market demand along with competitors' aggregate fuel consumption. To make modeling less challenging, we assume that the company is a price taker, so its procurement decisions do not influence fuel market prices. Additionally, fuel can be stored up to a fixed capacity, with linear inventory holding costs and no consideration of quality degradation over time. Finally, instead of modeling electricity prices and profit directly, we represent operations through a fixed yearly power production target for the plant portfolio.

Challenges

Key challenges include the following. **Buying early vs. waiting:** Early purchase secures supply and low prices but increases storage and capital costs, while waiting maintains flexibility but risks higher prices or scarcity. **Fuel mix:** Coal is cheaper but environmentally risky, whereas gas or other fuels are cleaner but more expensive. **Storage vs. market exposure:** Higher storage buffers against price spikes but increases holding costs; buying less implies reduced participation in the fuel market (not modeled directly here).

Expected Deliverables

A Python-based decision-support tool will be developed, which will use price and policy scenarios, plant utilization data, and cost parameters as inputs. It will suggest procurement quantities and timing for each fuel type and provide visualizations of purchase schedules, storage levels, and total costs under different policy and market assumptions.

Summary

In summary, we are seeking an optimization-based analysis to help us evaluate procurement strategies under uncertainty, quantify the trade-offs between cost, risk, and reliability, and support transparent decision-making. The required tool will allow us to explore different fuel purchasing policies under varying price and policy scenarios, and enable us to plan ahead rather than react to market volatility. Ultimately, this will strengthen our ability to secure reliable and cost-effective fuel supply while maintaining financial and strategic resilience in an evolving regulatory and market environment.