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Uncertainty analysis for industries investing in energy equipment and renewable energy sources

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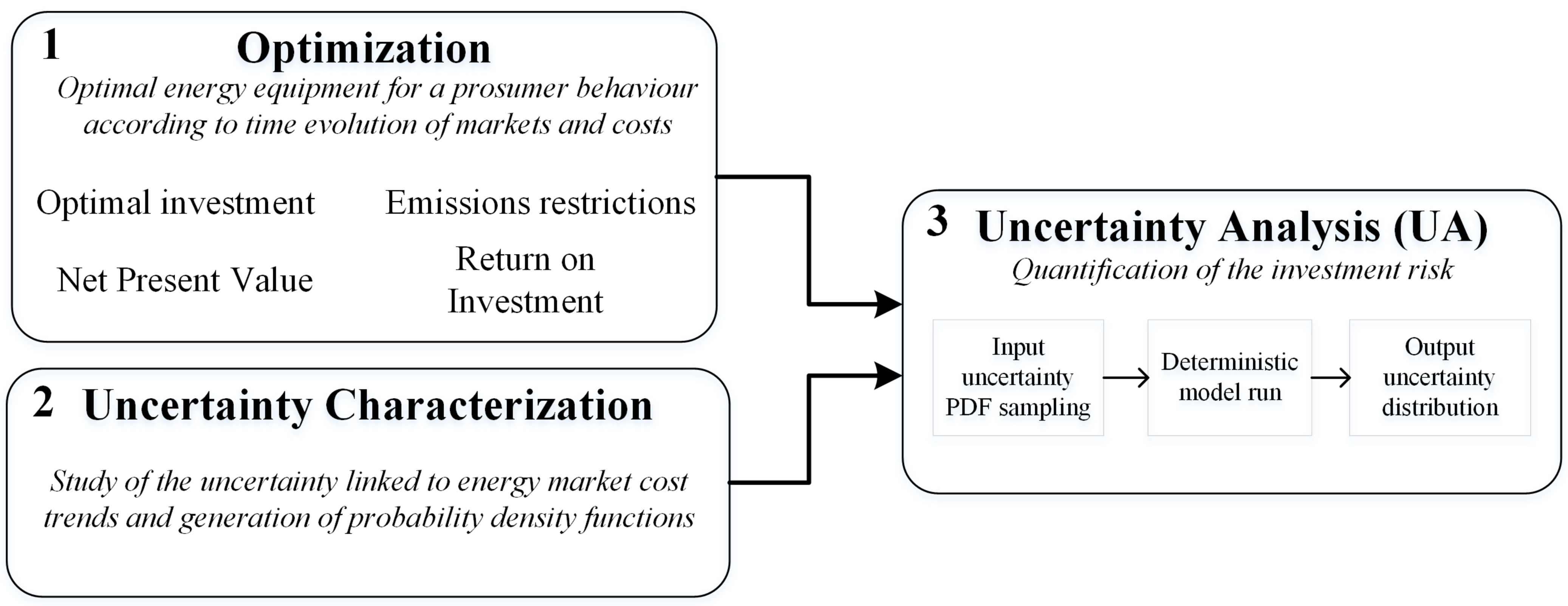
Abstract This paper studies the **optimal design and operation of new energy equipment including renewable energy sources for prosumer industries**. In order to augment the interest of industries in performing energy actions, **the economic parameters of the investment are analysed and the risk related to it considering the uncertainty in energy markets is evaluated**. A two-stage optimization approach is proposed considering the whole lifetime of the energy equipment and an uncertainty analysis performed through the evaluation of the deterministic model under Latin Hypercube Samples of uncertain parameters. A case study based on a real industry is presented, whose results expose the **robustness of the optimization methodology and the acceptable risk of investing in renewable energy sources and energy equipment for prosumer purposes**.

Research problem

- The energy use in industrial enterprises is under-researched [1], and the existing studies focus primarily on energy efficiency measures [2], not studying the possibility to adopt a prosumer model.
- The literature published up to date do not reflect the investment reality in the industrial sector due to two main reasons: uncertainty is not considered and/or time evolution is omitted.

Methodology



1. **Optimization:** Design and operation optimization of energy. The optimization is carried out in a two-stage approach. In the first stage, the energy equipment is selected and, in the second stage, their operation is obtained to compute the net present value (NPV) of the investment, the payback period and the emissions produced. The equipment which generates the higher NPV while fulfilling payback and emissions constraints is chosen.
2. **Uncertainty characterization:** Energy carrier costs strongly affect the performance of the energy infrastructure of the industrial plant. Therefore, the uncertainty linked to them has to be evaluated to assess the investment risk. Uncertain energy carrier costs increase is considered through probability density function (PDF).
3. **Uncertainty Analysis:** Risk acknowledgement through UA of investment NPV. A robust strategy considering PDFs and repeatedly sampling and evaluating the model is chosen [3]. In this paper, the quasi-random Latin Hypercube Sampling (LHS) strategy is selected to obtain the samples, improving the performance of common Monte Carlo approaches [4].

Results

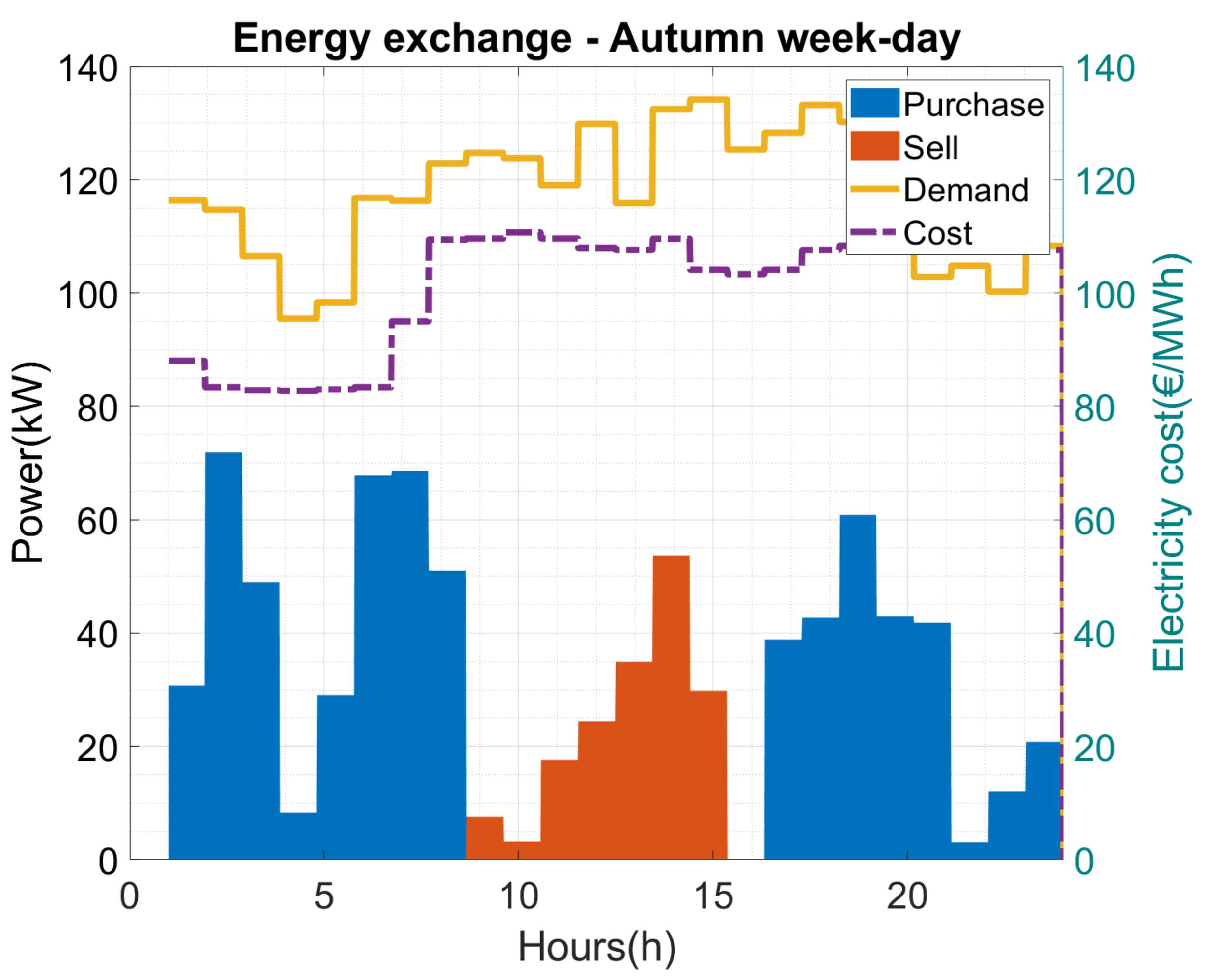
Analysis done for a case based on a real manufacturing industrial plant with yearly electrical and thermal consumption of 679 240 MWh and 1 127 600 MWh.

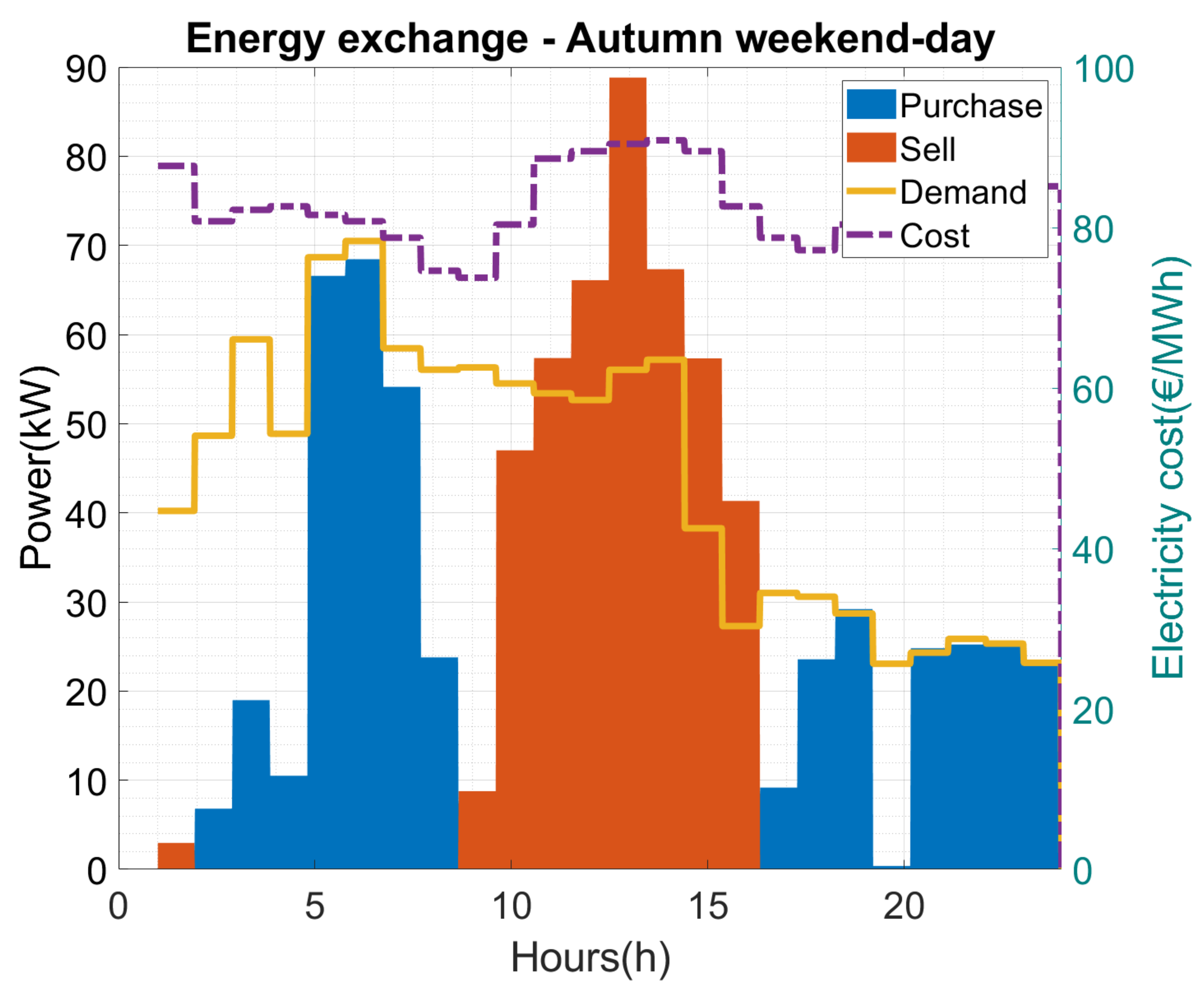
Results of the deterministic optimization

Energy equipment selected	Size
Photovoltaic (PV) Area	12 000 m^2
Cogeneration	200 We

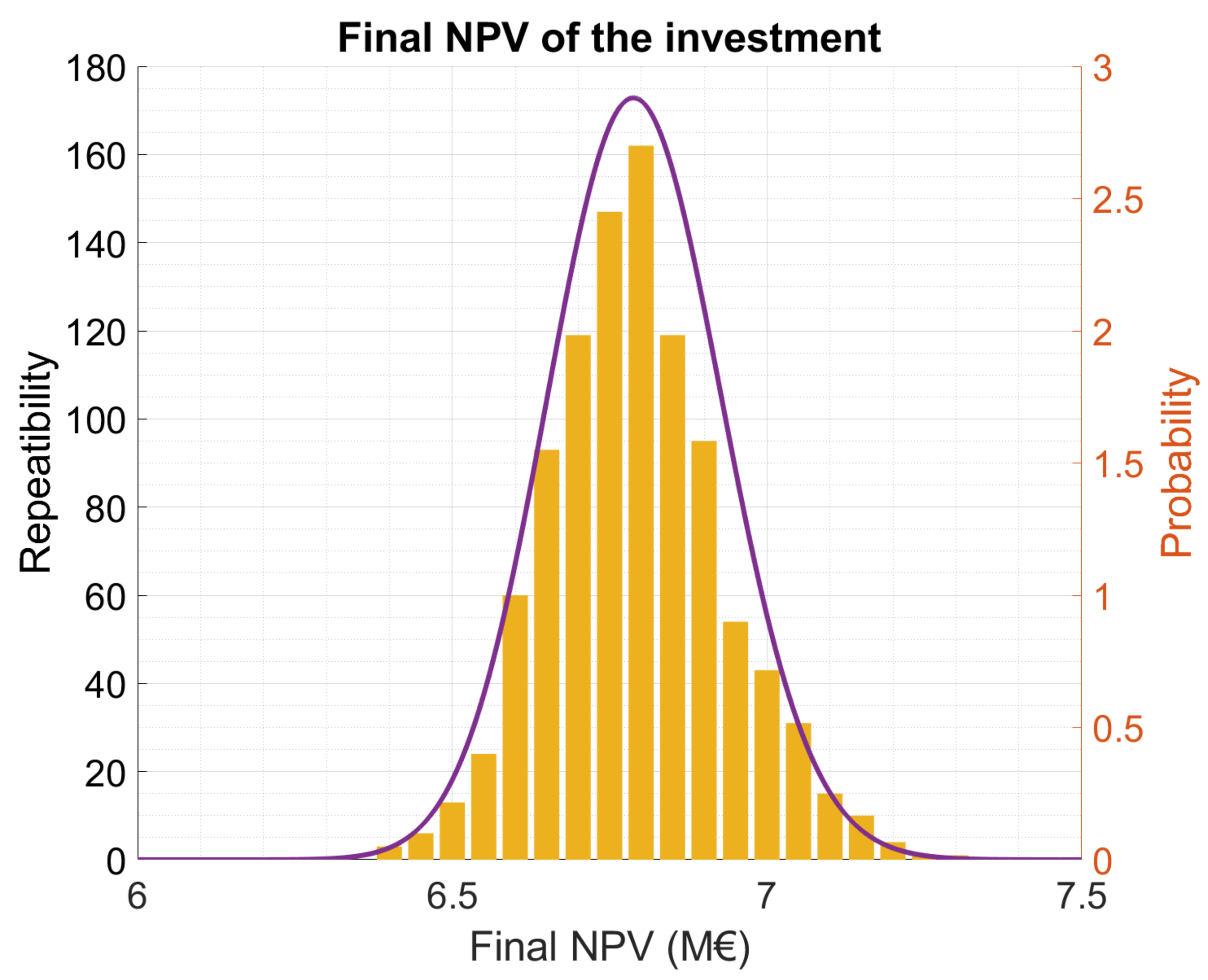
Optimization parameter	Value
Initial investment	913 630 €
Payback	5 years
NPV	6 788 400 €

Energy infrastructure operation – Prosumer electricity exchange





Risk analysis



- The **PV system** is sized to cover the completely area available. As a consequence, it is possible to **inject surplus energy to the utility grid**.
- A **cogeneration** system is included to **profit from the differences in energy carriers' cost**, partly covering electrical demand through it.

- The NPV standard deviation is 138 500 €, meaning that the deterministic obtained NPV is probable to **vary 2%** due to energy carrier price uncertainty.
- The results expose the **robustness of the proposed methodology** for energy investment selection for industrial enterprises.

Conclusions

In this study, a **methodology to properly address the energy upgrade problem of industrial entities** has been proposed. To adjust the energy investment problem to industrial requirements, the operation of the energy solution has been analyzed over its lifetime considering a prosumer behavior and the risk arising from the uncertainty in the evolution of energy carrier prices evaluated. The presented framework, together with the obtained results, are of **high utility for the industrial sector,** enhancing them to perform energy actions and providing a methodological procedure to evaluate their energy investment decisions.

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