Optimal network expansion

This article provides non-technical summaries of relevant publications[1][2][3] in the area of optimal network expansion.

Modelling and optimisation of marginal expansion[1]

Although district heating networks have a key role to play in tackling greenhouse gas emissions associated with urban energy systems, little work has been carried out on district heating networks expansion in the literature. The present article develops a methodology to find the best district heating network expansion strategy under a set of given constraints. Using a mixed-integer linear programming approach, the model developed optimises the future energy centre operation by selecting the best mix of technologies to achieve a given purpose (e.g. cost savings maximisation or greenhouse gas emissions minimisation). Spatial expansion features are also considered in the methodology. Applied to a case study, the model demonstrates that depending on the optimisation performed, some building connection strategies have to be prioritised. Outputs also prove that district heating schemes' financial viability may be affected by the connection scenario chosen, highlighting the necessity of planning strategies for district heating networks. The proposed approach is highly flexible as it can be adapted to other district heating network schemes and modified to integrate more aspects and constraints.

Optimal phasing of network expansion[2]

Most design optimization studies for district heating systems have focused on the optimal sizing of network assets and location of production units. One important aspect mentioned in UK schemes feasibility studies but almost always overlooked neglected in the literature is the strategic value of the flexibility in phasing of the inherently modular heat networks. The objective of this paper is to propose a model for the phasing of district heating network investments. The model is formulated as a multi-staged stochastic program to determine the annual capital outlay that maximizes the expected present value for the project. The It was shown that the approach is appropriate to simulate the growth of a network from a single heat source to separate islands of growth as well as the marginal expansion of an existing district heating network. The approach can be used as a template for district heating extension and phasing calculation and adapted to various situations by introducing additional constraints and parameters. The versatility of the base formulation also makes it relevant regardless of the size of the network and also potentially adaptable to cooling networks.

Optimal sequential decision under risk[3]

Although the value of complex and risky investment projects such as systemic low-carbon urban infrastructure investments is generally affected by both endogenous and exogenous uncertainties, most existing valuation approaches based on real options analysis consider only the latter and neglect the former; the few existing approaches that deal with both types are impractical and opaque. This paper presents an extension of a recently developed simple and powerful approach for modelling and valuing a portfolio of interdependent real options to allow for the consideration of both endogenous and exogenous uncertainties. Using influence diagrams to graphically model the real options' interdependencies, which are then mathematically translated into linear integer constraints, we directly model the dynamic of not only underlying exogenous uncertainties, but also of decision and state dependent uncertainties. These are then integrated in a portfolio optimization problem which is formulated as a multi-stage stochastic integer program. Approximating the valuation problem's value function by parametric regression and using Monte Carlo simulation, we present an efficient, backward-induction-based valuation algorithm which only determines the portfolio value of resource states that are actually reachable in any subset of simulation paths at any decision time. The approach is then illustrated by evaluating the real-case of a district heating network expansion investment in London, which contains the option to delay, expand, operate and abandon, whilst being exposed to decision dependent construction cost, a state dependent residual (salvage) value, and an exogenous revenue cash flow. This application demonstrates that our approach is powerful, flexible, compact and computationally efficient, and can be applied in a wide range of application domains including, but not limited to, investments into resilient, low-carbon infrastructure systems.

Read More

Introduction to investment appraisal

- Investment appraisal

Recordings

- CELSIUS Talk: New approaches to understanding and evaluating the risks in district heating investments

References

1. ↑ Jump up to:1.0 1.1 Delangle, A., Lambert, R.S., Shah, N., Acha, S. and Markides, C.N., 2017. Modelling and optimising the marginal expansion of an existing district heating network. Energy, 140, pp.209-223.
2. ↑ Jump up to:2.0 2.1 Lambert, R.S.C., Maier, S., Shah, N. and Polak, J.W., 2016. Optimal phasing of district heating network investments using multi-stage stochastic programming. International Journal of Sustainable Energy Planning and Management, 9, pp.57-74.
3. ↑ Jump up to:3.0 3.1 Maier, S. (2016). Risk-managing a portfolio of systemic low-carbon urban infrastructure investments using approximate dynamic programming with decision dependent uncertainties. YSSP Report, International Institute for Applied Systems Analysis (IIASA).