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# Hydraulic Modeling of Thermal Grid Systems for Minimizing Pumping Energy Consumption


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## Introduction

In thermal grid studies, the significance of hydraulic considerations is often underestimated. Failure to account for hydraulics can result in adverse consequences, ranging from pipe fouling due to insufficient flow velocity to water hammer caused by excessive velocity. Moreover, optimizing energy consumption is paramount in these systems: Selecting the appropriate pumps and pipe sizes is essential not only for meeting hydraulic and thermodynamic constraints but also for minimizing energy consumption by reducing head losses. Hence, this research addresses these crucial aspects to enhance the efficiency and reliability of thermal grid systems in different configurations.

## Problem

1. What are the optimal sizes of pipes and pumps needed to meet both hydraulic and thermodynamic constraints within the thermal grid system?
2. Which hydraulic approach for sizing pipes and pumps within the thermal grid is more effective: the pressure drop approach or the velocity limit approach?
3. What constitutes the best thermal grid configuration to optimize performance and minimize energy consumption and costs?
4. What are the implications if only a limited number of buildings are initially connected to the grid, with additional buildings joining later? How does this affect system performance?

## Goals

- Perform hydraulic modeling to analyze the thermal grid's performance under various configurations, considering factors such as flow rates, pressure drops, and temperature distribution.
- Optimize pipe and pump sizing to ensure efficient operation and mass balances throughout the thermal grid network, taking into account thermodynamic requirements and hydraulic constraints.
- Quantify the energy consumption of the pump systems to identify the opportunities for energy savings through design optimization.
- Compare and evaluate different hydraulic modeling approaches (i.e., the pressure drop approach and the velocity limit approach) for sizing pipes and pumps within the thermal grid.
- Conduct cost analysis to assess the economic feasibility of different pump options, considering purchase and bare module costs.
- Investigate the system's sensitivity to variations in pipe sizes and the number of buildings connected to the grid, allowing the identification of critical parameters in system design and scalability.

## Method

**Data Gathering**: Utilizing TESSA tool and ISO 6708 standards, relevant data, including heat demand of buildings, building topology, and pipe diameters, are collected to inform the design and analysis of the grid.

**Thermodynamics Calculations**: Applying principles of thermodynamics, flow properties and mass flow rates within the thermal grid are computed, providing essential parameters for system modeling.

**Grid Configuration**: Two grid configurations, such as single-pipe or double-pipe arrangements, are considered and implemented within the modeling framework.

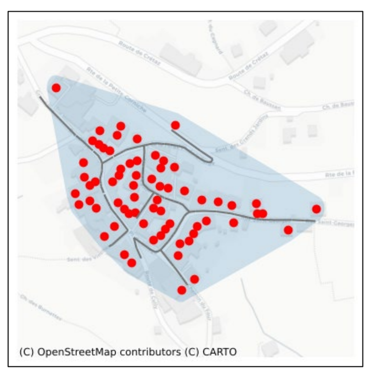
**Limitation Approach**: Employing the limitation approach, pipe sizes are determined based on two criteria, pressure drop or velocity limits, ensuring hydraulic and thermodynamic constraints are met effectively.

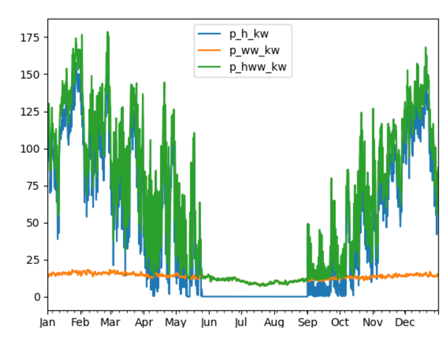
**Hydraulics Calculations**: Head losses within the thermal grid are assessed using the Darcy–Weisbach equation and Colebrook–White equation.

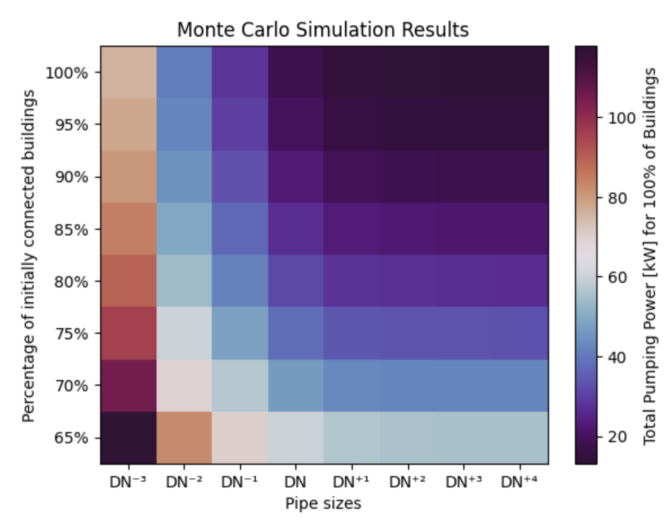
**Costs Estimation**: Pumping power and associated costs are calculated by considering the incurred head losses, providing insights into the economic implications of different design choices.

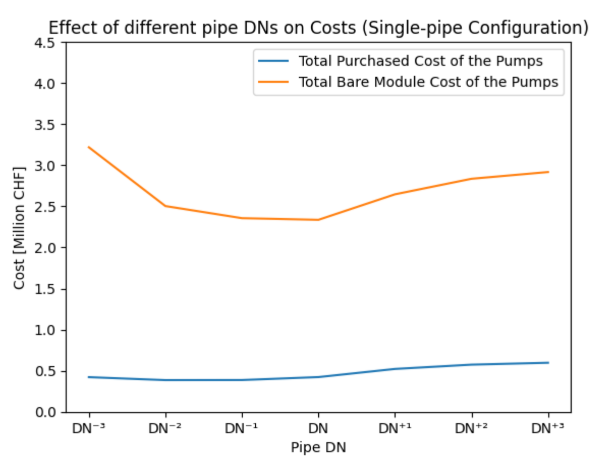
**Sensitivity Analyses**: Leveraging Monte Carlo simulation and sensitivity analysis techniques, the responsiveness of the thermal grid system to variations in key parameters is evaluated.

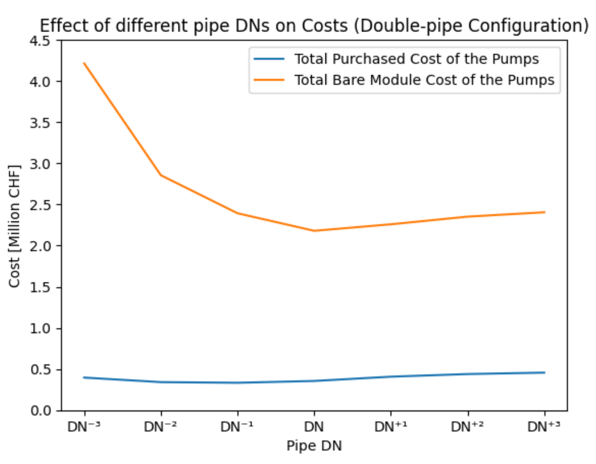
## Results

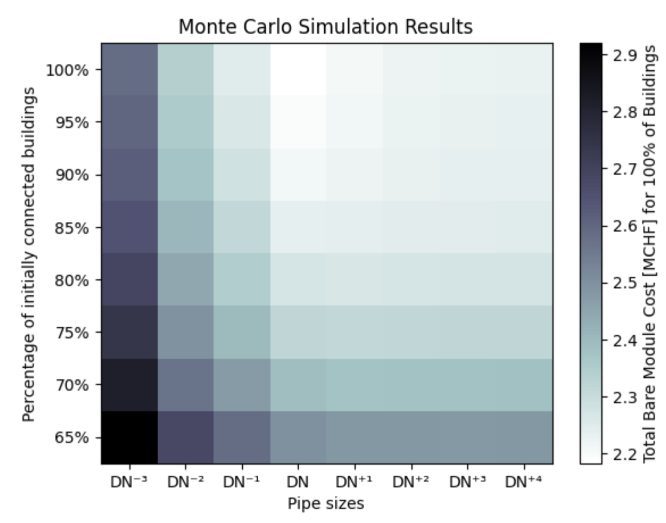


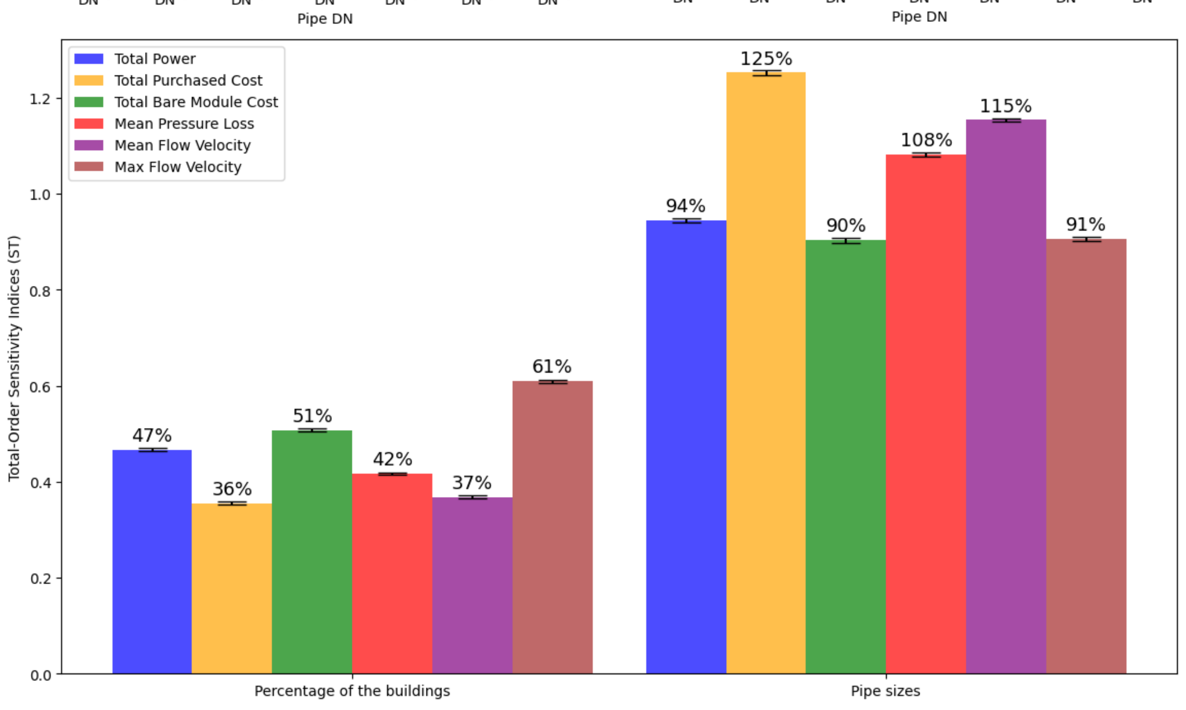



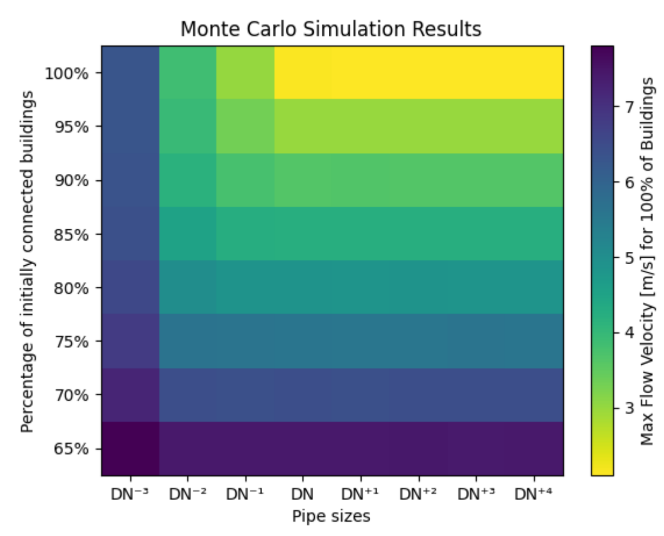



## Conclusions

- While the costs of the single-pipe and double-pipe configurations are comparable, the double-pipe configuration is a preferable choice because of better thermal performance.
- The thermal grid system is less sensitive to variations in the percentage of buildings than to pipe sizes. However, If the proportion of initially connected buildings falls below 90%, constraints related to velocity will arise.
- As pipe size increases, there is a corresponding decrease in total pumping power consumption.
- If the grid is initially designed for a lower percentage of buildings and if, eventually, all buildings connect to the grid, total pumping power consumption will be higher compared to a grid that was initially designed for all buildings (This work serves as the basis for more detailed sensitivity analysis).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