System Dynamics
Practical Assignment

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Introduction

The objective at hand as an investment analyst was to figure out how to use our friends' parents' home's Systems Dynamics Model and then design an energy renovation to the heating system.

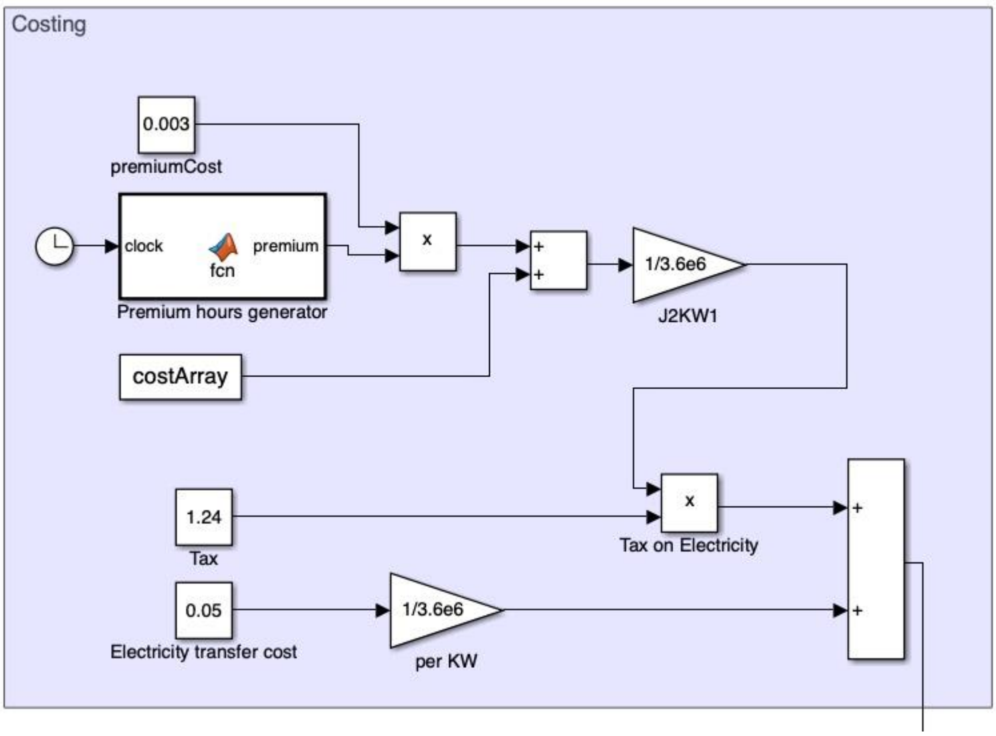
According to the current home model, the house has one electric heating system with a Co-efficient of performance of 1 (that is, 1 kW of electricity power converted to 1 KW of heat energy). The maximum heating power of the current heating system is 10kW. We have 3 different investment opportunities in the form of a heating solution. The heating systems have different parameters in the form of coefficient of performance and heating power. Before we explore the investment opportunities let's look at the model.

House heating model

Thermal model of a house was customized to fit our requirements. Firstly, we changed the model setting from a continuous time model to a fixed step discrete solver with step size 1. We will be running a single simulation for a period of 6 months (4380 months). We chose this length in order to ensure our analysis takes a wide range of data in different weathers in order to make a sensible decision. Another reason for choosing this period is to ensure that the GBM used for the cost does not deviate far from the starting point.

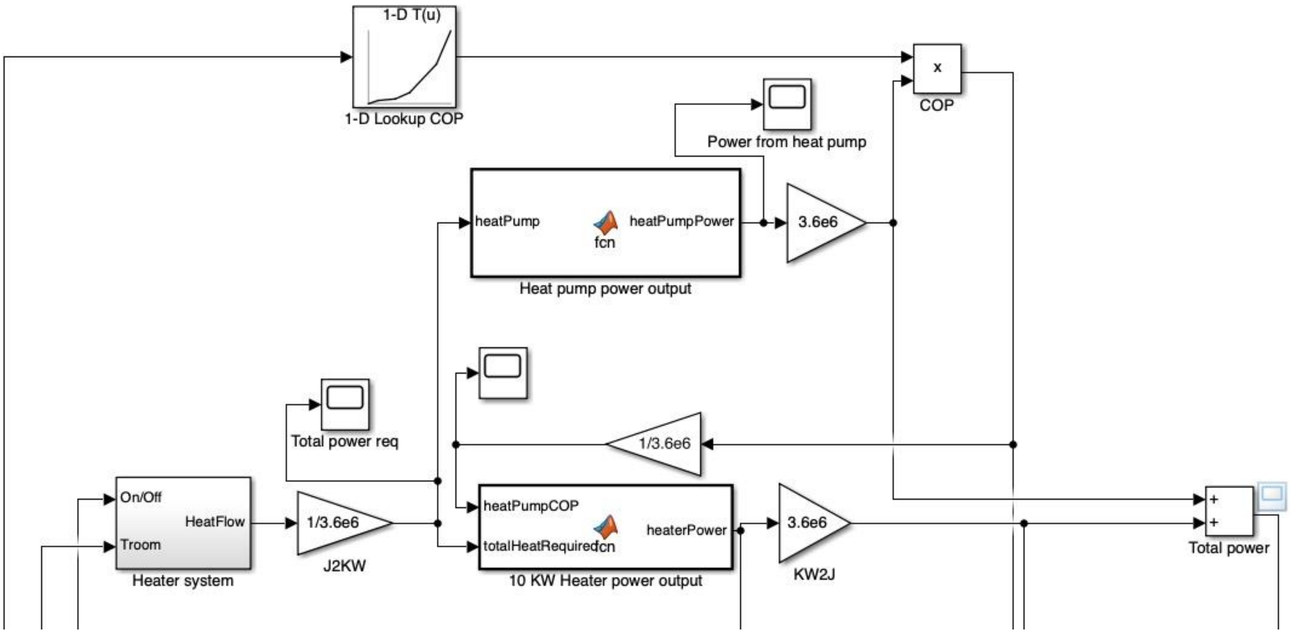
Moving on, in order to utilize the historic temperature data, we import the hourly temperature data that is provided and save it as a MATLAB object so we can use it later. For the purpose of analysis, the temperature data used ranges from 1st January 2020 to 30th June 2020. A custom costing model is also implemented. Geometric Brownian motion is used to model the per hour electricity cost. The parameters of the geometric Brownian motion are decided using the historic price data. We calculated volatility using excel and it amounted to 0.4. Then we calculated the mean of the price during this period which amounted to 16 Eur. Therefore, the starting point of the GBM is 16, volatility is 0.4 and the drift is set to 0.001.

Once the cost array with uncertainty is determined using GBM we implement the pricing model mentioned in the assignment in Simulink. The output of this costing model gives the cost of electricity/kW:



The Premium hours are determined in the MATLAB function block. We assume that every other hour is Premium hour (12 hours out of 24). Hence the premium charges only apply to 12 hours in a day.

Moving on to the heating system. The air flow inside the heater is set to 0.75m3/h (540 kg/h). We can now assess the part of the model that allows us to analyze different investment opportunities. In order to implement different heat pumps and geothermal heating option we introduce MATLAB function blocks that do not allow the heater and heat pumps to exceed the maximum heating capacity. In order to implement the COP property for heat pumps and geothermal heating we implement a 1D lookup table taking outdoor temperature as input and outputting COP.



The MATLAB function block ensures in this case that the heaters do not exceed the respective maximum heating power. The COP multiplication increases efficiency of the heat pumps and geothermal heating only.

In order to perform Monte Carlo Sensitivity Analysis, we use the above-described model and run simulations for 100 rounds. After the simulations we take the average value of the money spent on the specific heating system.
We want to maintain temperature of 40 Fahrenheit. The analysis is presented below:

	Cost after 6 months (Eur)	**Savings (Eur)**	**ROI**
10KW Heater	1.4361e+05		
5.5KW Heat Pump	7.5211e+04	68399	9.7 x 100%
3.5KW Heat Pump	5.4845e+04	88765	17.75 x 100%
12KW Geothermal heating	8.2161e+04	61449	2.92 x 100%

The highest return on investment is calculated against the 3.5 kW heat pump while keeping the initial investment in mind. It can also be seen that the 12kW geothermal heating option has the lowest savings while the 3.5 kW heat pump produces the highest savings compared to the initial 10kW heating option.