Design of a Compact Heat Pump System for Optimal Space Heating in a 42 sqm Apartment

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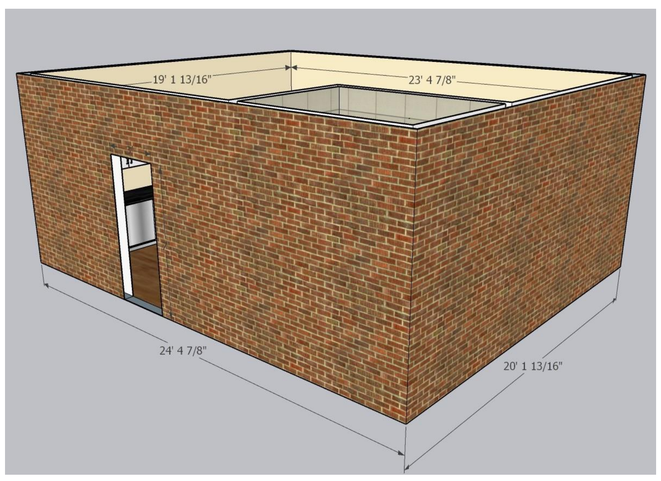
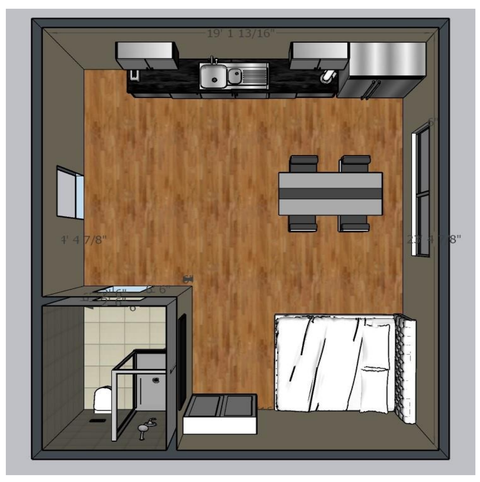
Introduction and Motivation

In response to the growing need for efficient heating in small living spaces, our project focuses on designing a Compact Heat Pump System for optimal space heating in a 42 sqm apartment. As urban living becomes more compact, our goal is to introduce a space-saving, energy-efficient solution that prioritizes both comfort and sustainability. This project aims to create a solution that not only meets the heating needs of a 42 sqm apartment but sets new benchmarks for energy conservation and eco-friendly living.

Location and Description

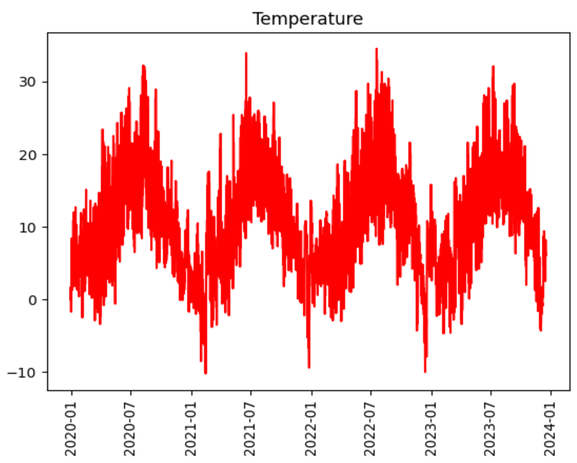
The apartment is located in Oldenburg, Germany. It is a studio apartment with an area of 42 sqm. The coordinates of the apartment are Latitude: 53.134613°N Longitude: 8.171513°E. The walls are made of concrete and has a thickness of 6 inches and the outer area of the apartment is 24.4*20.15 ft. The detailed layout of the studio apartment is shown below.





Analysis

Heating Degree Days (HDD) play a pivotal role in our heat pump design. HDD is a metric used to gauge the amount of heating needed in a specific location during a given period. By analyzing the HDD for our target area, we can precisely tailor the Compact Heat Pump System to meet the heating demands of the 42 sqm apartment. For calculating HDD, the temperature datasets from ERA-5 Reanalysis data are used. The datasets are taken for the location of Latitude: 53.25°N Longitude: 8.25°E and are shown below along with the calculated HDD.

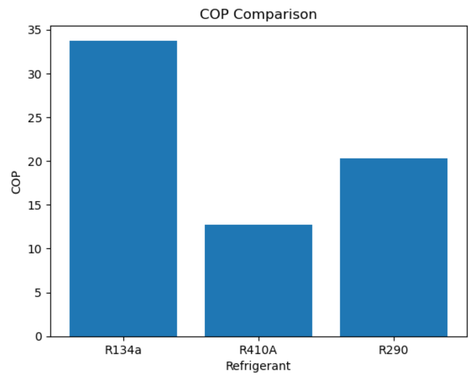


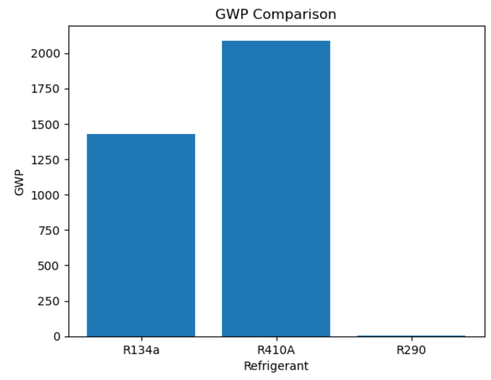
Year	Annual Mean Temp (°C)	Annual HDD
2020	10.89	2602.67
2021	9.88	2965.00
2022	10.78	2634.70
2023	11.06	2423.34

The total Heat transfer coefficient of the apartment is calculated based on the thermal resistance, size and thickness of the material. U defines how properly the apartment is insulated.

$U_T = 19.012\ W/m^2K$

Comparative study of Refrigerants





R290 is used as a refrigerant which has a COP of 4. The seasonal coefficient of performance (SCOP) is 4.52. This implies that the heat pump is relatively efficient, providing four times the amount of heating or cooling compared to the energy it consumes. Considering this, the heat demand is calculated to be 23955.12 Watts. The heat pump capacity is calculated to be 5.98KW. The efficiency of the heat pump is 80%.

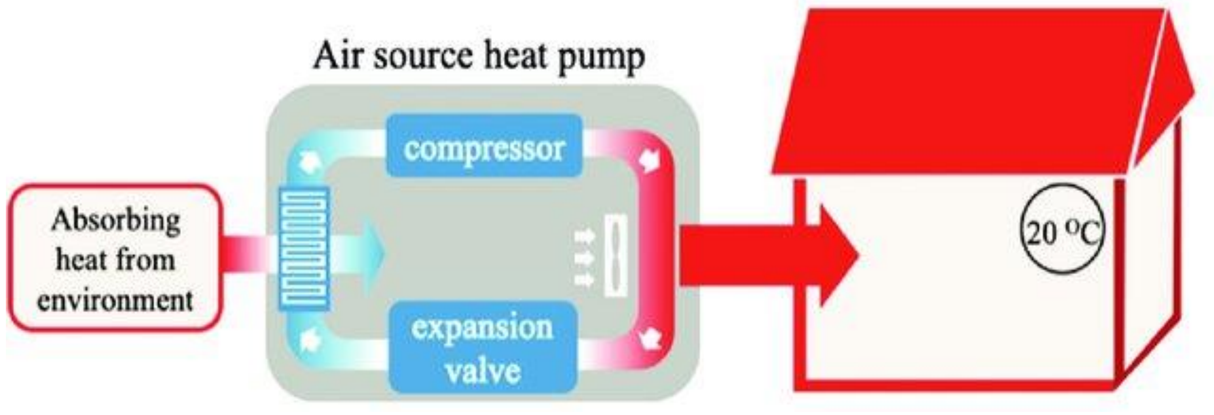
Assumptions

1. The desired input temperature is 22°C and the minimum possible ambient temperature will be -10°C.
2. Comparing Different Refrigerants such as R134, R32, R290 and R410. Among these refrigerants, we picked the one having best COP and SCOP. Also which has the least Global Warming Potential (GWP) and the least power consumption.
3. The heat transfer coefficients 'U' of the walls of the apartment building are obtained from the research paper[1].

Discussion

Relying solely on Heating Degree Days (HDD) is inadequate for assessing Heating demand. It is imperative to calculate thermal conductance, thermal resistance, overall heat transfer coefficient, outdoor temperature, and ambient temperature. All these variables play a critical role in improving the accuracy of the calculations.

System Layout



References

[1]. Sizing a collective heat pump system in an apartment building: impact of occupancy profiles - Matthias Criel, Maarten Sourbron & Hilde Breesch. DOI: https://doi.org/10.34641/clima.2022.269

[2]. Solar seasonal thermal energy storage for space heating in residential buildings: Optimization and comparison with an air-source heat pump - Jie Lu & Guoqing he. DOI:10.1080/15567249.2020.1786192

Conclusion: The determined capacity is well-suited for the specified apartment. Taking into account abrupt climatic fluctuations and the heat pump's adaptability, it is advisable to incorporate a safety margin of 20%. The operational capacity of the heat pump falls within the range of 5.98 to 7.176 kW, with the compressor consuming power in the range of 1.45 to 1.8 kW.