Abstract

Throughout much of the United States, there is a need to heat homes up in colder weather. Monthly energy bills typically fall in the hundreds of dollars range, especially during the winter season, speaking to how much energy is required to keep homes comfortable. As global warming worsens, our reliance on fossil fuels for energy becomes increasingly prominent and problematic. This brief analysis will examine different types of heating systems to evaluate them based on energy efficiency. Maximizing energy efficiency in homes across America would be a step in the right direction to reduce our dependence on fossil fuels.

Statistics

According to the United States Energy Information Administration, 98.4% of U.S. homes have heating equipment [1]. Of these homes, 61.4% use central furnaces, 13.3% use heat pumps, and 7.5% use hot water heating systems [1]. Note that this is strictly residential data and does not include commercial data. This analysis will examine furnaces and heat pumps in particular, and evaluate them on effectiveness as well as efficiency to determine if this current distribution is justified or if large amounts of energy are wasted every year heating residential homes in the U.S.

Assumptions

It is difficult to gather data on efficiencies of current household heating systems, therefore this analysis will use the newest, cutting-edge models available online as baselines. It is reasonable to assume that people are buying the latest technology and not replacing their systems with older, less efficient systems, regardless.

Thermodynamic Analysis

Lennox's standard, efficient furnace has an AFUE rating of 99 [2]. Thus, using 1 watt-hour of energy will yield 0.99 watt-hours of heat. This efficiency is almost the maximum possible efficiency a furnace can have, according to the first law of thermodynamics. Lennox's standard, efficient heat pump has a HSPF2 rating of 10.3, thus 10.3 BTU of heat is produced for each watt-hour consumed [3]. Converting units, for every watt-hour consumed, approximately 3 watt-hours of heat are produced. Heat pumps are able to surpass 100% efficiency as heat is simply being moved around rather than being produced from energy, as furnaces do. Thus, from a strict energy usage to heat-output standpoint, heat pumps are significantly better than furnaces, about three times better. However, with their operation comes difficulty, as heat pump function depends on temperature ranges.

In colder climates, more powerful heat pumps are necessary. Let's use Goodman's GVZC20 [4] as a baseline. From the electrical data, this heat pump has a maximum power output of around 8800 W. In kilowatts, we have $W_{max} \approx 8.8\ kW$. Using a standard heat transfer coefficient of $U = 8 \frac{W}{m^2 * K}$ [5], and a typical house square footage of $A = 550 m^2$, we have that heat lost constant per K, $C_{lost} = UA = 4.4 \frac{kW}{K}$. Let inside temperature be constant at room temperature: $T_{inside} = 20℃,\ or\ 293K$.

$Q_{lost} = C_{lost}(T_{inside} - T_{outside}) = 4.4 \frac{kW}{K} (293K - T_{outside})$ {1}

Efficiency of heat pump in the ideal (Carnot) case: $\eta = \frac{T_H}{T_H - T_C} = \frac{293K}{(293 - T_{outside})K}$.

Supplying 8.8 kW, heat supplied, $Q_{supplied} = W_{max} * \eta = \frac{2578.4 kW*K}{(293 - T_{outside})K}$ {2}

Setting {1} and {2} equal, we find the lowest possible temperature for this scenario to work:

$4.4\frac{kW}{K}(293K - T_{outside}) = \frac{2578.4kW*K}{(293-T_{outside})K}$ yields $T_{outside} = 268.79256K = \boxed{-4.36°C}$

Discussion

The result of $-4.36°C$ is a relatively high temperature for this heat pump system to break down. Of course, heat pumps can still heat homes at lower temperatures, but at the cost of efficiency. Therefore, when considering the choice between heat pumps and furnaces, the extent of geographical coldness should be considered. In fahrenheit, $-4.36°C \approx 24°F$, a temperature quite uncommon even in the peak of winter for many coastal and mid-to-southern states. Considering 98.4% of U.S. homes use heating equipment and only 13.3% use heat pumps, there is a large gap in energy efficiency lost. One reason for this result is simply that alternative fuels such as oil are potentially more cost effective for home owners, therefore the difference in energy expenditure between an oil furnace and an electric heat pump may not be apparent on the energy bill alone. As we move further into the twenty first century, raising awareness to everyday energy efficiency is more relevant than ever. The result from this brief dissertation highlights the fact that heat pumps are far more efficient than the furnaces that over 60% of the American population currently uses, with the exception being consistently below-freezing climates. Further action will be necessary for actual change to occur.

References

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