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Externalities Analysis on Heat Pump System (EU)

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Abstract: This paper analysis the positive externalities of using heat pumps in European society to solve the high-temperature problem. Through the paper, heat pump as a potential solution to the climate problem, contemplating how it is done, why it is the best solution, and what are the positive externalities specifically to the City of London. The heat pump is renewable and can reduce carbon dioxide and sulfur emissions. In order to better introduce the benefits of heat pumps in those high-temperature cities, the author thus chooses to create a hypothetical city which is called M&M City. In the stimulating process, we predict the specific circum-stances of heat pumps that may be needed in the simulated city and associated packages, analyze the value and feasibility, as well as present the shortcomings and look to the future.

Keywords: climate change, geothermal energy, heat pump, three sectors, renewable energy, New England London

1. Introduction

1.1. New England Environmental Problem

The recent Temperature trend has been fickle in New England. The vicious circle of environmental problems is reflected in the existing climate change. Not only is there an increased frequency of extreme weather in those regions, but it is also a cause of a wide range of impacts on the environment, the economy, and society. “Antonio Gasparrini at the London School of Hygiene & Tropical Medicine estimates that 948 people died in England and Wales because of the sweltering conditions between 17 and 19 July” [1]. Data has shown that nearly a thousand people were killed specifically by the heat wave this year, within only 3 days. Furthermore, New England lacks substantial improvement even though climate change has become a broader problem in recent centuries. According to our study, London has been significantly impacted by the current heat waves generated by extreme environmental situations. Moreover, when we narrowed down the causation of the problem, we also came across interesting facts that affected the severity of the problem. In the past, due to the location of London on the high latitude and cold weather, the architectural design emphasized the important purpose for thermal insulation. As a result, few buildings have air con-

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ditioning, so efficiency has been low for people in London. People can't work without air conditioning after being attacked by heat waves. Therefore, dedicated air conditioning units are a weakness to the city. Traditional air conditioning will enter a vicious cycle without energy saving.

1.2. Proposing a Plan and Explain How and Why the Government can Intervene

To get a grip on solving the problem, we looked at different energy-saving strategies and selected the most reasonable one. Some examples of the strategies can be manipulated through micro perspectives, such as the widespread adoption of ENERGY STAR products, or promoting ENERGY STAR certification labels on energy-efficient products. Or large advocacy on civilians, workspace, and buildings on Installing heating control systems, such as thermostats, to adjust your heating to thermal requirements. Furthermore, for example, from a macro perspective, there are solutions such as decreasing the consumption of fossil fuels, and protecting forests and oceans. However, from all the solutions proposed prior, all of them have little to none chance of large adoption. In today's world, where many countries are entering developing or developed status, industrialization is undeniably a part of the process of their living conditions. In other words, it is a fond dream for countries to decrease their consumption to a level to reduce climate change problems. To find a practical and feasible solution, we looked at the solution from a different perspective, geothermal energy. Geothermal energy is renewable and can reduce carbon dioxide and sulfur emissions. The 'closed cycle' allows the water to be recycled and reused for later uses and purposes. Therefore, it is very environmentally friendly and clean. Public goods, such as electricity and water, are primarily delivered and controlled by the government. How-ever, Heat pump system is an undeveloped public good, waiting for further exploration by the world. It will be a reasonable proposal for situating government incentives and subsidies. Furthermore, the government can bring up the advocacy to get a community to collectively work together because the most efficient systems are on the neighborhood scale rather than the individual scale. We just need to access it with heat. Geothermal heat pump systems essentially deliver that public good.

1.3. Paper’s Purpose

The purpose of this paper is to address the problem of current climate change happening in New England and propose a practical solution that can largely ameliorate it. Our solution is proposing a built-in heat pump system within the city on a large scale to completely cool down the weather. It may be presented through potential positive externalities on the regional, economic, and environments by having a heat pump system as a solution, and how it will positively affect the community. In addition, we will present some limitations of Heat pumps and where there are some negative problems about it. Lastly, construct an imaginary city having a similar climate-related problem to London and calculate to what extent a wide adoption of the heat pump system for residential buildings in London would benefit, in data.

2. Literature Review

2.1. Recent Temperature Trends in Europe

Last year was the warmest on record across Europe, considering breaking the previous high mark. According to a report from new scientist, “About a thousand extra people are estimated to have died during the recent three-day UK heatwave, in the first snap analysis of the human toll of record-breaking temperatures.” [2]. “For the first time on record, temperatures in the UK have exceeded 40°C. A provisional temperature of 40.3°C was recorded at Coningsby at 15:12 yesterday (19 July)” [3]. According to BBC, “Temperatures over land reached worrying new heights, reaching 2.1C above

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the 1981-2010 average, which was the highest since the series of records began 121 years ago." Temperatures across the region were more than 1.9C above the long-term average between 1981 and 2010. (BBC) "The temperature over land there was the highest since records began in 1900. Despite the global pandemic that slowed economic activity, the major atmospheric greenhouse gas concentrations, including carbon dioxide (CO2), methane and nitrous oxide rose to a new record high in 2020" (BBC).

2.2. The Health Effects of Extreme Heat

When exposure to heat is high enough to raise the body's core temperature, heat stress illness—which encompasses heat cramps, heat exhaustion, and heat stroke—can occur [4]. According to the article from ECDC, "statements are pointed out that Vector-borne diseases are transmitted by arthropods such as ticks, mosquitoes, or sandflies." Meanwhile, food-borne diseases like salmonella are highly temperature sensitive, meaning increased annual average temperatures could affect food safety.

2.3. Economic

Under high temperatures, the demand for electricity surges. Europe is already facing a natural gas supply crisis. The high temperature and drought have led to a decline in electricity generation from renewable sources such as hydro and wind power, adding to Europe's energy problems (NDRC, para 3). According to PNAS, the consequences of climate change on the four market impact categories-agriculture, river floods, coastal systems, and tourism-can be valued in monetary terms because they directly affect sectoral markets and—via the cross-sector linkages—the overall economy. They also influence the consumption behavior of households and, therefore, house-hold welfare. Data indicates the GDP loss for the European total. Suppose the climate of the 2080s occurred today. The annual damage of climate change to the EU's GDP loss is estimated to be between €20 billion for the 2.5 °C scenarios and €65 billion for the 5.4 °C scenarios with high SLR. (PNAS).

2.4. Heat Pump

A heat pump can utilize electricity to transfer heat from one place to another. Heat pumps are more environmentally friendly than traditional air conditioners. A report from the US Department of Energy shows heat pumps can have the same functions as air conditioners, but the price is lower. Using a heat pump to deal with the hot cli-mate can save money [5]. Compared to the Indirect evaporative cooling systems, invented in the early 20th century and requiring lower energy, the heat pump seems to be the ideal machine to replace heat pumps to reduce the high temperature in Eu-rope. Still, the complex system makes them difficult and expensive to manufacture and spread in Europe. But the new technology, an improved version of heat pump, called cold-SNAP, can have an effective heat transfer unit. It uses the evaporative cooling method, which requires low energy to lower the ample space's temperature. According to the research done by scientists, the efficiency of cold-SNAP is four times higher than those of traditional air conditioning units, and the whole energy require-ment is lower by about 75 percent without compromising its cooling ability [6]. Ac-cording to EHPA (European Heat Pump Association), the total sale of heat pumps is about 1.4 million units in Norway. The reason for choosing heat pumps is that they are cheaper and don't require extensive maintenance. Besides, the cold-SNAP system requires water instead of those poisonous or harmful refrigerants, reducing the environmental impact. It can also function as heating and cooling at the same time.

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3. Positive Externalities

According to the “Carbonomics Re-Imagining Europe’s Energy System” from Gold-man Sachs, natural gas will remain the dominant source of energy in Europe for the next two decades. Meanwhile, the investment for the heat pump is 0.6 trillion euros, whose trend will also be steady in the future half-decade [7].

The current research demonstrated that, based on the previously mentioned heat pump properties, the benefits of heat pump are not only at the surface level. This technology can bring significant positive benefits to environments that do not directly benefit from it (general environment, including people, communities, ecosystems, etc.). Due to the special characteristics of the heat pump, it is not necessary to consider whether the building has a duct system when installing it.

It is well known that the normal installation will not only cost more and also pro-duce physical pollution. Under the condition of the current environment and considering the overall neighborhood surrounding, it is a good choice to install heat pumps because of short installation time and there is no need to worry about contamination (heat pumps are wall-mounted). Furthermore, heat pump installation will be expensive at first but afterward it will be much cheaper in the long run than a normal cooling system because of the reduction in power consumption [8]. In the case of retrofit-ting a heat pump, the installation will be simpler and result in less potential for environmental contamination, as the heat pump can even be used directly with existing ductwork [9].

At the same time, according to the report, Europe's investment in renewable energy accounts for one-third [7]. The current dilemma of renewable energy is the limited amount generated to supply urban needs. In this situation, Europe's main energy supply for the next two decades will only be predicted as natural gas. However, heat pumps are characterized by low energy consumption and operate partly through geothermal energy itself. What can be seen is that the widespread use of heat pumps will indirectly lead to a shift away from traditional energy sources in Europe.

As mentioned, heat pump systems can use geothermal energy to heat or cool a single room or an entire business. In addition, heat pump systems have a high level of comfort, with all activities done in one system. These properties determine that heat pumps cause extremely tiny damage to the environment and greatly reduce the waste of pollution from building layouts and the loss of heat from the building itself, creating a significant positive value for the local environment.

In terms of the pro-environmental nature of heat pumps, there is no doubt that it is an excellent choice to replace the usual noisy and energy-consuming air-conditioner. However, it would be irresponsible to judge by intuition alone that it is not harmful to the environment. The current greenhouse gas equivalent calculator paired with the European digital platform can largely promote this technology and communicate environmental lessons to the community in everyday language from an educational perspective. Since heat pump systems are currently not fully accepted, the positive externalities — education can bring (classic example) are immeasurable.

4. Hypothetical City

This paper has a hypothetical city named M&M near London that is affected by heat waves due to climate change. The temperature in the town rises to about 40 degrees. High temperatures led to several social problems. For example, some schools and hospitals have to close, and flights should be canceled. Unfortunately, people who live in this M&M city do not have air conditioning in their homes. There are no such cooling centers to deal with heat waves. Public facilities cannot be used without high-temperature prerequisite preparation. Houses in the city are designed to retain heat. High temperature promotes an upward trend of public health risks such as dis-ease dissemination. Such things already affect the usual life of humans. In this situation, the local government must find a path to solve the high-temperature problems and help repair the M&M city.

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Fortunately, they found a team who could adopt a heat pump to deal with the heat waves and help improve people's lives in M&M city. This team asked the government to construct the geothermal heat pump system. The system will have a capacity of about 5000 tons and service heating and cooling purposes for 47 buildings over 731 acres. It also consists of 3600 heat exchangers underground, which help handle the high temperature. It takes about depths ranging from 400-500 ft and 5-6 inches diameters. They also built two energy stations to hold the large heat pump chillers and two water supply lines. One is a hot water loop with a constant temperature of 150º F, and another is a cold-water loop with a continuous temperature of 42ºF.

The whole construction of this heat pump system costs about 70 million dollars. The local government predicts that it can save about 20 million dollars every year. Even though the capital costs are upward of $70 million, the price is only $15 million more than that for traditional air conditioning. In this way, the payback period is about 7.5 years. Furthermore, the system will reduce the city's CO2 emissions by roughly 50% and provide about 2300 direct and indirect jobs to deal with unemployment. On the one hand, it can successfully decrease the temperature in the whole city, and on the other hand, it can also help the government save a large amount of energy and save money for future constructions [10].

5. Reasons for Three Sectors to Provide Investment and Subsidies for Heat Pump

According to the report from United Union, A rising number of nations, towns, companies, and other organizations have committed to achieving net-zero emissions more significantly than 70 nations. Also, because of global warming, different countries are continuing the cool Earth as a suitable public need. The necessary power from the various sectors is critical for a heat pump because we can't access it without all sectors of society taking part in changing how to cool our homes. Heat pumps are suitable investing options because they are crucial for improving energy efficiency. They can significantly reduce energy costs and emissions and are the most energy-efficient way of heating and cooling. The heat pump has the most considerable up-front cost, but that's what investors have to invest in, and everybody is willing to pay their share of the taxes to do so. But it's the most expensive upfront, which is why it needs community-level buy-in; The government, private sector, and non-profit organizations can invest heat pumps and finally contribute to reducing carbon emissions and figure out the warming problem in Europe.

For the government, Policies need to address barriers to adoption, including high upfront purchase prices, operational costs, and the legacy of the existing building stock.

It can provide subsidies for heat pump installation fees. The government subsidy's purpose is to fulfill worthy public objectives that improve citizens' welfare or address the market. Heat pumps provide public goods that provide a cooling place in de-carbon dioxide. The government could pay for part of the cost of producing a good or service by offering tax credits or reimbursements. For example, Air, water, and ground-source heat pumps are all eligible for subsidies in Austria. However, hybrid heat pumps are not. Depending on the energy produced and the heating capability of their system, homeowners may get a fixed monthly payment. For single-family structures, the government offers subsidies up to €5000, and for multi-story buildings, awards up to €1000 [11]. Additionally, scholarships and loans are offered locally.

For non-profit organizations, there is a non-profit, member-driven organization established in 1987- The International Ground Source Heat Pump Association (IGSHPA) - to advance ground source heat pump (GSHP) technology on local, state, national, and international levels [12]. The geothermal heat pump industry aims to foster a coordinated effort to encourage the use of geothermal energy by raising knowledge of and interest in the technology. This non-profit organization can write some action Plan to expand the ground source heat pump market in different areas, such as London. That promotion taken by this non-profit organization can finally encourage community and civic's

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awareness of using heat-pump. It is profitable for a private business to invest in heat pumps. According to the evaluation of the financial benefits of a ground-source heat pump pool with demand side management, it states “in the future, low-carbon energy systems, the real estate owners are not interested in only cost savings but also environmental implications as well as increasing self-sufficiency, which can protect the property from rising electricity prices” [13]. Also, there will be a financial gain when the company makes some green while investing in green.

6. Conclusion

This paper is dedicated to the solution to European warming. First, compare the externalities generated by using conventional air conditioners and heat pumps. It is concluded that using heat pumps saves energy, reduces greenhouse gas emissions, and is less expensive in the long run. Second, this paper will install more heat pumps in the future to solve the temperature rise in a fictional city for simulation, and it can be seen that the positive externality of heat pumps can solve the problem of temperature rise, and heat pumps will solve the vicious circle brought by traditional air conditioners. Therefore, in response to the rising temperatures that mid-Europe is now facing, heat pumps should be given to conventional and new buildings as much as possible. However, the upfront cost of heat pumps and the environmental impact on heat pumps require more institutional effort. Therefore, this paper suggests that three sectors, including government, non-profit organizations, and the private sector, make subsidized investments and raise awareness about the use of heat pumps. Although heat pumps are flawed to some extent, their intensive use is the key to reducing car-bon emissions. This paper's solution to rising temperatures in Europe - heat pumps - can be applied not only to European regions but also to more cities facing global warming in the United States and Asia.

6.1. Limitations and Future Expectations

First, the available ground energy conditions limit the heat pump's efficiency. Air energy heat pumps are highly susceptible to the influence of ambient temperature. Because all heat is obtained from the environment, the heat pump's heating capacity decreases significantly when the ambient temperature is below -35 C, which can easily lead to insufficient indoor heating [14]. Secondly, a ground source heat pump can theoretically use the soil and water resources together; the cost difference between different soil and water resource utilization is quite significant in the actual process. The availability of suitable soil and water resources in other areas is key to applying ground source heat pumps. Therefore, the heat pump's efficiency is limited by the environmental impact of the surrounding environment.

Second, the disadvantages of installing a heat pump include the high upfront cost of the system. In terms of initial cost, heat pump systems cost more than conventional air conditioning systems. The high price is mainly due to the many nodes of the system. Ground source heat pumps require drilling wells, and this part of the equipment, material, and labor costs are unavailable in other systems. According to Muther B. Luther, a professor of Michigan University in architecture, “There is a con-cern regarding the high initial costs of GSHPs and whether they are economically justified.” [15]. The difficulty of the system, the cost of processing, and the configuration of equipment correspondingly more than other systems. Thus, It is more ex-pensive in the short term, the installation needs to ensure the scale effect, and the return on investment time is extended.

High-efficiency heat pump technology is the cornerstone of sustainable buildings. Highly energy-efficient buildings equipped with heat pumps can reduce CO2 emissions, cut energy bills, and improve home comfort. In 2020, almost 180 million heat pumps were utilized for heating, with the worldwide stock has grown by about 10% annually during the previous five years. Although heat pumps are now the most popular technology in newly constructed homes in many nations, they still

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only provide 7% of the world's demand for building heating [16]. Government, non-profit organizations, and private organizations are necessary to contribute to the scaling of heat pumps. According to Thibaut Abergel, a Clean Energy Technology Analyst, they need 600 million installed heat pumps by 2030 if mid-European countries want Net Zero Emissions by 2050 Scenario (As shown in the form).[16] Suppose mid-Europe does not intend to increase heat pumps but insists on using traditional air conditioners in the future. In that case, traditional air conditioners for cooling will lead to a vicious circle. Conventional air conditioners work through electricity to produce large amounts of greenhouse gases, ultimately leading to global warming. The increase in temperature will be similar to the need for air conditioning to cool places in Europe that do not need artificial cooling. Using energy-saving heat pumps will reduce green-house gas emissions and provide both cooling in summer and heating in winter. In the future, using many heat pumps in traditional and new buildings will bring the region into a virtuous circle. While many heat pump technology designs are ready to be deployed, the diversity of more building types and climatic conditions need to be understood before deployment to accommodate a variety of operating environments.

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