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RISING DANGER OF AIR CONDITIONERS: A NECESSITY OR A LUXURY?

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Abstract: *Air conditioners have become an indispensable part of modern life, providing a comfortable indoor climate, especially during the hot summer months. However, their use comes with environmental consequences. The increased electricity consumption required to power air conditioners significantly contributes to greenhouse gas emissions and further exacerbates climate change. This research focuses on the use of air conditioners and addresses the question of whether they are used rationally. Methods for reducing air conditioner usage and promoting their proper use are presented. The study analyzes the relationship between air conditioner electricity consumption, GDP, and temperature, highlighting the significant correlation between air conditioner usage and economic prosperity rather than climate conditions. A discussion on policy measures, energy efficiency improvements, and behavioral adaptations is also included.*

Keywords: *Air conditioner; Greenhouse gases; GDP; Electricity consumption; Cooling, international standard*

1. Introduction

The mass use of air conditioners began in the 20th century, when technologies began to improve and reduce costs (Basile, 2016). The first commercial air conditioner was developed in 1902 in the United States. However, these devices were very expensive and could only be used by the rich. In the 1920s, new technologies began to be developed, which made it possible to produce cheaper and more efficient air conditioners. This led to an increase in demand for air conditioners, which began to be used even in commercial premises. In the 1950s, air conditioners began to be massively used in households. This was due to several factors, including:

- Growing population: A greater number of people lived in urban areas where summers can be very hot and humid.
- Rising standard of living: People began to appreciate comfort more and were willing to pay more for air conditioners.

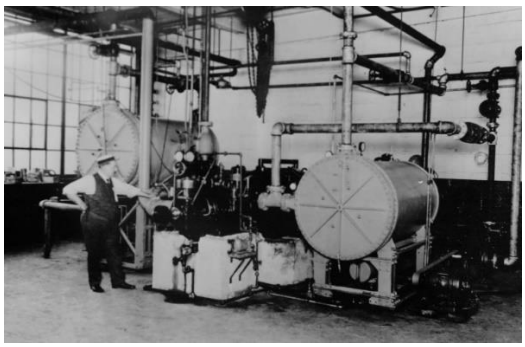
In recent decades, the use of air conditioners has continued to increase. This is due to several factors, including:

- Upcoming climate crises (Lynas, 2008) (Polya, 2020): Climate change is making summers warmer and more humid in many parts of the world. This increases the demand for air conditioners that provide a comfortable indoor temperature.
- Reducing the cost of air conditioners: Air conditioners have become cheaper in recent years. This made them more accessible and contributed to an increase in demand.

- Development of new technologies: The development of new technologies (Silberstein et al., 2024), such as inverter air conditioners, has increased the energy efficiency of air conditioners. This contributed to reducing their negative impact on the environment.

Today, air conditioners are used in all parts of the world. In some parts of the world, such as the United States, household air conditioners are almost indispensable.

Figure 1. *Centrifugal cooling machine from 1922*



Source: (Magazine, 2019)

2. Methodology

This study analyzed data from 17 countries that account for more than 70% of the world's air conditioner electricity consumption. The analysis included data from organizations such as the International Energy Agency (IEA, 2022), the World Meteorological Organization (WMO, 2023), and the World Bank (2023). The study evaluated variables such as national electricity consumption, GDP per capita, and the average summer temperature at 12 PM in the capitals of each country. Macroeconomic variables such as GDP are frequently used in empirical energy studies to explain cross-country differences in consumption patterns (Boduri & Pjetri, 2024). The statistical correlation was analyzed using the Pearson correlation coefficient.

2.1 Research questions

1. What is the global electricity consumption of air conditioners?
2. How does electricity consumption of air conditioners relate to GDP in each country?
3. How does electricity consumption of air conditioners relate to the average summer temperature in each country?

2.2 Research Objectives

The aim of this research is to determine how electricity consumption of air conditioners, GDP, and average summer temperature relate to each other. The results of the research may be useful for designing policies that will help reduce electricity consumption and greenhouse gas emissions from air conditioners.

3. Electricity consumption and greenhouse gas production

All electricity consumers are responsible for greenhouse gas production, specifically CO_2 (MacKay, 2013). The amount of CO_2 produced depends on how the electricity is produced. The average CO_2 emission per 1 kWh per country depends on the structure of electricity production in that country.

Countries that produce most of their electricity from renewable sources have lower CO_2 emissions than countries that produce most of their electricity from fossil fuels. The average global CO_2 emission per 1 kWh is 0.55 kg/kWh. This emission varies depending on the energy source used to produce electricity (Eldesouki et al., 2023). Renewable energy sources such as solar, wind and hydropower have the lowest emissions (Lave & Hendricks, 2013). These energy sources do not produce any CO_2 emissions, but it should be borne in mind that a lot of energy is needed to produce the technology that captures renewable sources and that these sources are very volatile. High emissions are produced by fossil fuels such as coal, oil and natural gas (IPCC, 2013). The production of electricity from these sources releases large amounts of CO_2.

Air conditioners accounted for 1.6% of global greenhouse gas emissions in 2020 (IEA, 2022), equivalent to 4.8 billion tonnes of CO2. Emissions from air conditioners have been increasing in recent years as demand for them has increased. Demand is driven by global warming, which is causing rising temperatures during the summer months. By comparison, lighting accounted for about 2.4% of global greenhouse gas emissions. That's about 7.2 billion tons of CO_2. Emissions from lighting are decreasing as more and more efficient lighting such as LED bulbs are used. So far, only refrigeration appliances contribute more greenhouse gases to households. They accounted for 2.2% of global greenhouse gas emissions in 2020. That's 6.6 billion tonnes of CO_2. In line with the expected thermal heating and the consequent increasing use of air conditioners, in a few years air conditioners can be expected to become the largest consumer of electricity and consequently, the main cause of greenhouse gases in households. If the trend of electricity consumption continues, this could cause significant problems for global electric energy. Air conditioners are important consumers of electricity and their consumption contributes to an increase in greenhouse gas emissions.

3.1 Measurement of electricity consumption for air conditioning operation

To conduct research on the use of air conditioners, a lot of data was obtained. For accurate data, measurements should be carried out on each air conditioner. Since such measurements are not carried out, certain values are given approximately, which were obtained with the help of previously conducted public research.

The amount of electricity consumed by a particular air conditioner is determined by (Wang, 2001):

- Outdoor temperature
- Set temperature in the room
- Insulation of air-conditioned space
- Proper use of air conditioning
- Installation location of an external device
- Air conditioning device maintenance
- Energy class
- The method of using the air conditioner, etc.

The consumption of electricity at the national level is determined by the number of installed devices. Here also, the values are given from various surveys, since the exact number of working devices is unknown. Air conditioners are mainly used for cooling living quarters.

Therefore, the key to use of air conditioners is outdoor temperature. The study used data on the average temperature during the 2 warmest months of the year at 12 p.m. in the country's capital (WMO, 2023). The reason for choosing the capital, and not the average temperature to countries, lies in the reliability of the data. The reason for using the average temperature data at 12 o'clock is because there can be large differences between day and night temperatures, but air conditioners should only be used for outdoor temperatures higher than 26°C.

4. The use of air conditioners in the world

The number of built-in air conditioners is rapidly increasing. In 2022, around 3.6 billion air conditioners were operating worldwide, 50% more than in 2010 (IEA, 2022). The number of air conditioners is expected to increase to 9.2 billion by 2050. According to the world's population – 8 billion, 0.45 air conditioners are installed per capita.

Figure 2 shows the increasing electricity consumption for air conditioners globally. In 2022, it amounted to 2,700 TWh, representing 8% of global electricity consumption. In Europe, this figure is 7%, in the United States it is 15%. Electricity consumption of air conditioners increases as average temperatures on Earth rise, as does air conditioning availability. According to projections (IEA, 2022), this share will increase to 18% and 3,000 TWh respectively by 2050.

Figure 2. *Trend of rising CO_2 and electricity consumption due to air conditioners*

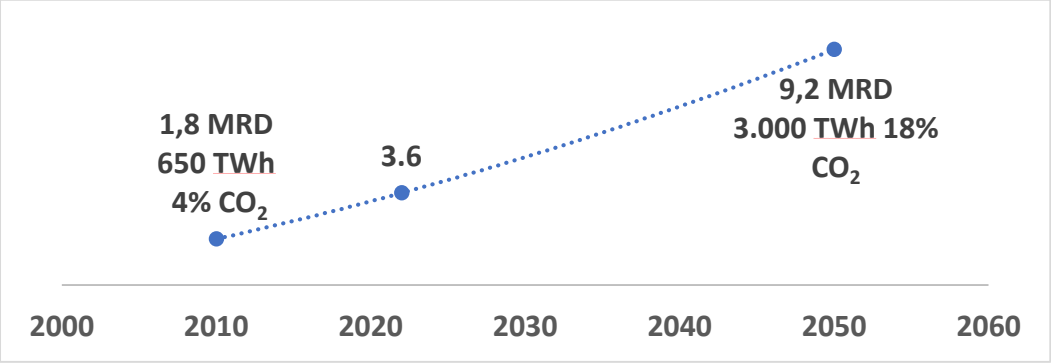
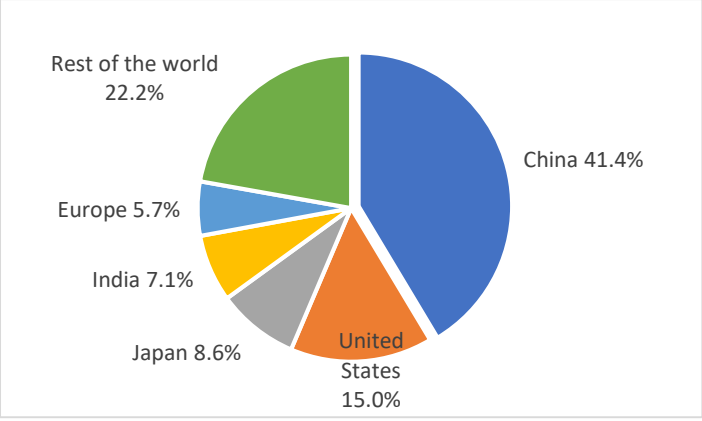


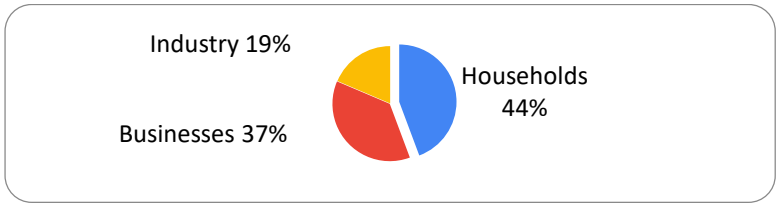
Figure 3 shows that more than 40% of all air conditioners are used in China, which is somewhat expected as China is the largest in terms of number of people and has also the largest production capacity.

Figure 3. *Distribution of electricity consumption due to the use of air conditioners*



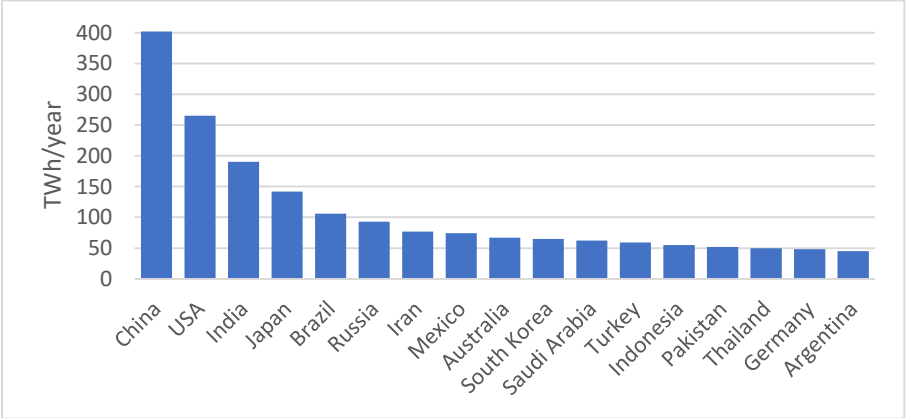
Most air conditioners are installed in households. With the current share of installed air conditioners, it can be expected that the number of installed appliances will increase most significantly precisely in household use, since a significant part of the developing world does not yet use mass air conditioners compared to the developed world. Furthermore, more and more people, in general, work from home.

Figure 4. *Distribution of installed air conditioners by sector*



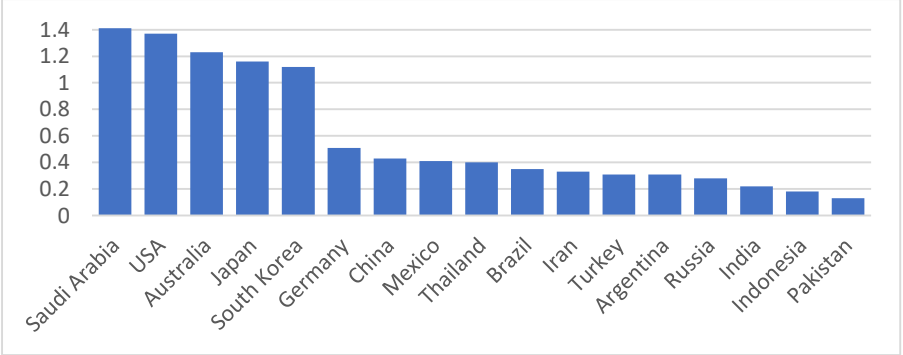
For further detailed analysis, 17 countries that consume more than 70% of the world's electricity - consumed by air conditioners - have been selected. Figure 5 shows that the largest consumer is China. As we will see in later analyses, high consumption is due to the population of a particular country and not due to the excessive use of air conditioners.

Figure 5: *Countries with the highest electricity consumption for air conditioners*



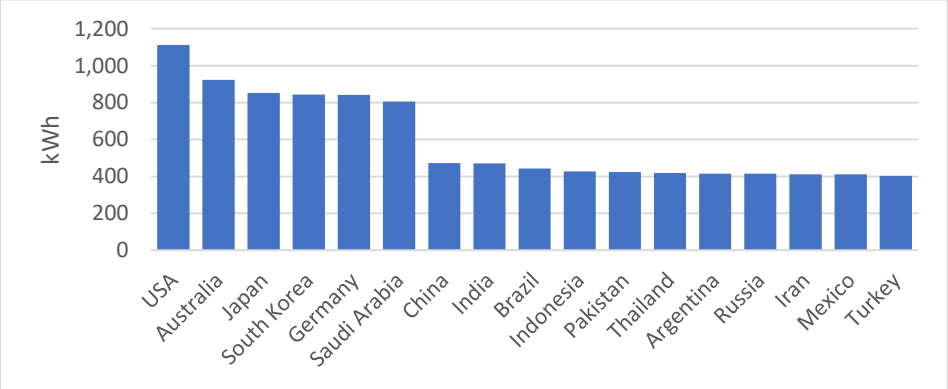
A better indicator of the overall use of air conditioners in each country is the number of installed appliances per capita. Figure 6 shows that Saudi Arabia uses the most devices per capita - 1.4 devices per capita, followed by the USA, Australia and Japan. The global average is 0.45 climates per capita.

Figure 6: *Number of installed air conditioners per capita*



In addition to the average number of air conditioners per individual, it is also important how much the appliance is used. The following Figure 7 shows how much kWh of electricity is accounted for by the average air conditioning user. It is clear that the use of air conditioners is the highest in the United States, followed by Australia and Japan.

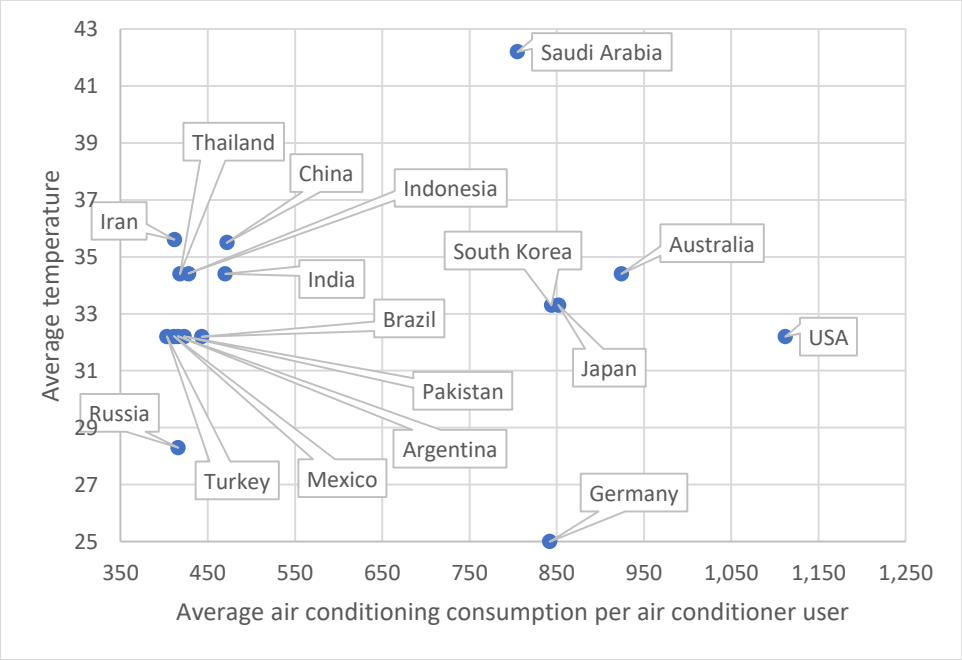
Figure 7: *Average air conditioning consumption per air conditioner user*



Logically, we would expect that consumption would depend on external temperatures - the warmer the location of a particular country, the greater the use of air conditioners (Nguyen et al., 2017). However, Figure 8 shows a large consumption gap between countries with comparable outdoor temperatures. In terms of consumption, the United States stand out strongly, while Germany stands out for its low average temperature.

When establishing the statistical correlation between outdoor temperature and electricity consumption per air conditioner the Peason correlation coefficient was applied (Blalock, 1972). Since the coefficient is only 0.019, we can conclude that the use of air conditioners is not related to outdoor temperature.

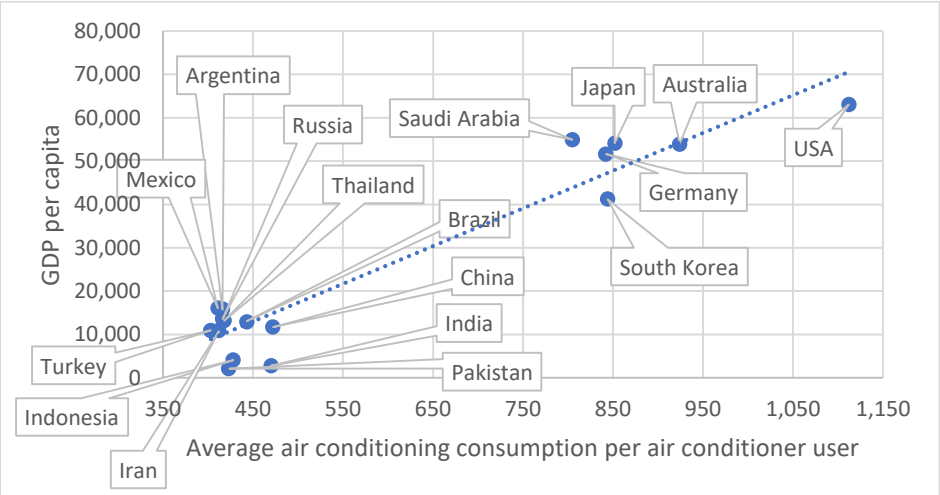
Figure 8. *Consumption depending on outdoor temperature*



The survey then examined whether the use of air conditioners is related to the GDP of each country (World Bank, 2023). Figure 9 shows that countries are divided into two groups. The first group contains countries that have low GDP and also have low electricity consumption for air conditioners. The second group consists of rich countries – the United States, Australia, Japan, Saudi Arabia, Germany and South Korea, which also consume the most energy.

The link between consumption and GDP is also statistically provable, with the Pearson correlation coefficient of 0.956, which translates into a very high correlation. The trend line shown in the graph also proves the correlation. From the data obtained, we can conclude that the use of air conditioners does not depend on temperature conditions, but primarily on the level of the standard of living. We can conclude that, especially in more affluent countries, air conditioners are being over-utilized.

Figure 9. *Spending as a function of government GDP*



4.1 Rational use of air conditioners

The purpose of air conditioners is to create a temperature zone of comfort. In order for a person to feel well, however, several factors need to be taken into account. Air conditioning can only affect temperature and humidity.

The comfort zone depends on (Nicol et al., 2022):

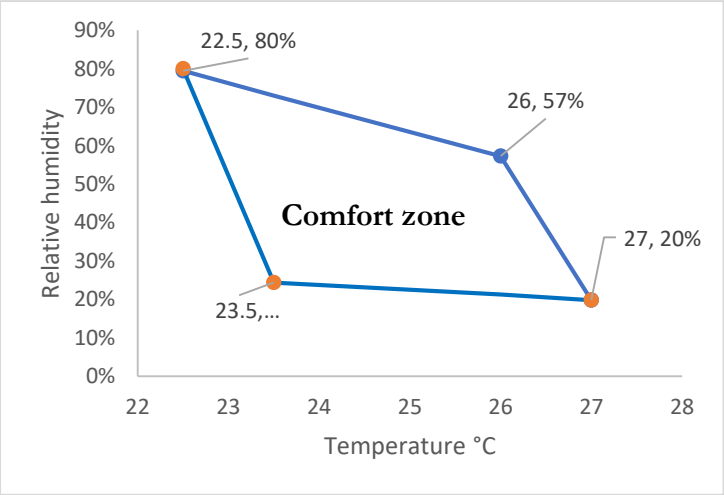
- Human activities. The activities of a person are usually conditioned by his work which is impossible to control.
- Wall temperatures. The temperature of the walls is highly dependent on the insulation used. With proper insulation, we can significantly influence energy consumption both in winter and summer (Zhang et al., 2022). With good insulation and built-in ventilation system, a favourable temperature can be maintained in most cases without the use of air conditioners.
- Relative humidity. The humidity in the room is mostly influenced by the climate in which we are located or the air in the vicinity of the building. The humidity of the air can be largely regulated by the ventilation of the premises.
- Air temperatures. The air temperature depends on the outdoor temperature, the number of devices that heat the air and the number of people in the room. We can greatly

influence the temperature in the room by properly shading and preventing direct sunlight during the summer months.

- The speed of air movement. The speed of air movement depends on the mode of ventilation and air conditioners, which, with unprofessional installation, can greatly affect the comfort zone.
- Clothing. The right temperature can be greatly influenced by choosing suitable clothing. We use light and airy clothing during the hot months.

All of the above influences whether we will feel comfortable at a lower or higher temperature.

Figure 10. *Comfort zone where temperature and relative humidity are taken into account*



Most people set the temperature of the air conditioner to their feel. Such adjustment leads to an incorrectly defined temperature. Setting the thermostat too low not only wastes energy but also increases the risk of respiratory illnesses. International standards ANSI ASHRAE55 (ASHRAE, 2021) (Fig. 10) and ISO7730 can help to set up air conditioners correctly (Loveday et al., 2002). The standards define the comfort zone, where the temperature and relative humidity in the room for work in the office and in the locals in general are taken into account. A favourable temperature is determined between 22.5°C and 27°C. By lowering the desired temperature, we influence a higher consumption of electricity (Pita, 2008) (Kato et al., 2018). With each degree, electricity consumption increases by 6-8% (Wang et al., 2013). The difference between the set maximum (27°C) and the minimum temperature (22.5°C) can be more than 30% in electricity consumption (El Berry, 2019). Many air conditioners are set below the recommended minimum temperature and electricity consumption is even higher. The optimal use of air conditioners would be automatic adjustment of their operation according to the relative humidity and temperature in the room.

5. Discussions and Conclusions

This study has presented important insights into the rising global use of air conditioners and its relationship with economic development and climate. One of the key findings is that electricity consumption for air conditioning is much more closely related to a country's GDP than to its average outdoor temperature. This suggests that comfort and lifestyle, driven by economic capability, are stronger motivators than actual climatic needs.

The strength of this study lies in its use of cross-national data and its statistical approach, including Pearson correlation, which offers strong evidence for the conclusions drawn. However, one limitation is the reliance on average national data, which may overlook regional variations within countries. Additionally, some of the data, such as the number of functioning air conditioning units, had to be estimated due to lack of direct measurements.

The results are generally consistent with previous research (Nguyen et al., 2017; AIJES, 2024), reinforcing the concern that increased access to cooling, if unmanaged, can escalate energy demand and CO2 emissions significantly. While smart and energy-efficient technologies can mitigate this trend, behavioral adaptations and policy regulation remain critical.

Although this study does not employ primary data collection, its analytical approach allows for generalisation across many countries, especially those in similar stages of economic development. Future research could include deeper case studies or household-level surveys to validate the observed macro trends.

In practical terms, the study underlines the need for:

- Policy incentives for energy-efficient cooling;
- Greater enforcement of international temperature standards;
- Improved insulation regulations in building codes;
- Public campaigns that promote sustainable cooling habits.

These findings provide valuable input for decision-makers and urban planners aiming to reduce the environmental burden of rising cooling demand. More interdisciplinary research will be necessary to further integrate engineering, behavioral science, and public policy approaches in this field.

Findings indicate that air conditioner electricity consumption is strongly correlated with GDP rather than outdoor temperature. Countries with higher GDPs exhibit higher electricity consumption from air conditioners, suggesting overuse rather than necessity. This aligns with previous studies, such as Nguyen et al. (2017), which found that energy consumption patterns depend more on economic prosperity than climatic conditions.

A comparative analysis with prior literature, including studies published in AIJES (2024), supports the idea that improvements in insulation, energy efficiency, and smart cooling technologies can significantly reduce electricity consumption and mitigate environmental impacts. AIJES research highlights the importance of integrating adaptive cooling systems and enforcing energy policies that address the increasing demand for cooling in both developed and developing regions.

Policy recommendations include:

- Implementing international temperature-setting standards (ASHRAE, 2021) to prevent unnecessary overcooling.
- Promoting energy-efficient air conditioners (El Berry, 2019) to optimize energy use.
- Enhancing building insulation (Zhang et al., 2022) to reduce dependency on artificial cooling.
- Public awareness campaigns to encourage responsible air conditioner use and sustainable practices.

If the current global trend in air conditioner consumption continues, it could pose severe challenges for electricity infrastructure and climate policies. Addressing this issue requires a collaborative effort involving policymakers, manufacturers, and consumers to implement energy-efficient solutions effectively.

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