UNIVERSITAT ROVIRA i VIRGILI

Escola Tècnica Superior d'Enginyeria Química

etsEQ

FINAL MASTER PROJECT

MASTER IN ENVIRONMENTAL ENGINEERING AND SUSTAINABLE ENERGIES

Determination of weather datasets for building energy modelling and their impact on energy analysis

By*: Mohammad Sajjadi*

Supervisors:

Dr. Joan Manel Vallès Rasquera

Dr. Dieter Thomas Boer

Tarragona, February 2024

Acknowledgements

I would like to express my sincere gratitude to my esteemed thesis advisors, Dr. Manel Valles and Dr. Dieter Boer, for their unwavering support and profound insights throughout the research process. Their expertise and encouragement played a pivotal role in shaping the trajectory of this thesis. I would also like to acknowledge the supports of SUSCAPE research group. The camaraderie and intellectual exchange within the group fostered an enriching academic environment. Special thanks to my fellow researchers and colleagues Dr. Adedamola Shobo and Mr. Raul Saez for their support, stimulating discussions, and shared experiences. In addition, I would like to express my appreciation to school of chemical engineering at the University of Rovira i Virgili and Dr. Sandra Contreras for providing and coordinating the master program in environmental engineering and sustainable energies. This thesis is a testament to the collective efforts of a remarkable community, and I am grateful for the sense of belonging and inspiration that this academic center has provided throughout my master's journey. At the end, I extend heartfelt appreciation to my parents, whose boundless love, encouragement, and sacrifices have been the cornerstone of my educational journey. I am profoundly grateful for their belief in my capabilities and their continuous encouragement to pursue my academic aspirations.

Index

List of Tables

List of Figures

Summary

Increasing energy efficiency of building industry is one of the essential measures for reducing the repercussions of climate change. Besides the building structural parameters and HVAC system design, accurate weather input data has an important role in energy performance estimations. Meanwhile, meteorological data from a local weather station that is either nearby or inside the building is not always available which leads to using weather datasets with public availability such as those at airports and capital cities. In current paper, authors tried to utilize Energy Plus model to estimate effects of these deviations in weather input data on building energy performance in Tarragona Province in Spain. It concluded that using local weather datasets instead of available climate datasets not only led to differences in total energy consumption but also made variations in heating and cooling demands. The difference between Amposta local station dataset and Tarragona capital municipality was about 2.2% since both of them are located in same way coastal lines. Meanwhile, this value for El Perello, Falset and Vinebre as interior rural regions was 5.6 %, 12.7%, and 17.6% respectively. Likewise, deviation reached its peak at 44.1% for Prades due to its inherent severe weather conditions in higher elevations. Also, simulation results showed that using third party for meteorological data such as NASA and Meteonorm weather datasets promised better estimations. In addition, a building parametric study proved that deviations in weather datasets could have larger effects on the energy consumption of well-designed buildings than that of non-optimized arrangements. Moreover, the results signified the importance of considering global warming in building energy performance.

Keywords: Rural Energy Communities, Building Energy, Weather datasets, HVAC Systems

1. Introduction

It is a fact that because of climate change, environmental problems have become major topics of discussion in both established and rising economies in our modern era. This also begs the question of whether or not greenhouse gas emissions, which are the main cause of global warming and climate change, are also occasionally connected to natural phenomena such as volcanic eruptions and ocean currents, as well as direct and indirect human activities that alter the composition of the atmosphere globally and the variability of the environment. However, researchers contend that the main causes of climate change are the intensification of human activities brought on by urbanization, industrialization, and the expansion of the world population. In other words, various aspects like enormous fossil fuel consumption for meeting increased energy demand, commercial and agricultural deforestation, and changes in land use brought on by population expansion all greatly boost greenhouse gas emissions [1]. It is also said that the building industry is one of the major energy consumers, contributing 28% of the world's total carbon emissions [2].

Accordingly, to fulfill the increasing demand for energy in cities, appropriate measures must be taken. The environment and energy are heavily burdened by this fast urbanization. Researchers and politicians agree that cutting building energy use and enhancing the use of renewable energy is one of the best ways to address current energy issues. In this regard, a great deal of studies have been conducted to determine the variables influencing building energy usage via different aspects such as building exterior thermal performance, occupant behavior, and indoor equipment and system efficiency [3]. Huang et. al. developed a thermal performance optimization model of the building envelope and it was proposed that the ultimate and optimum energy saving ratio achieved are inversely proportional to the U-value of windows while improving the performance of windows cannot necessarily achieve the best economic benefit [4]. Happle and his colleagues showed that diversity in building occupancy profiles significantly impacts simulation results [5]. In 2022, Building energy efficiency and load flexibility optimization by using phase change materials under a futuristic grid scenario has been studied in another research [6]. The results showed that up to 33.6% and 10.8% can be achieved for annual load flexibility and energy savings respectively via PCM-integrated buildings. In a comparative study of the effects of static and dynamic shading systems on building energy consumption and cooling load assessment, De Luca et. al. suggested that dynamic blind systems can have more uniform performance and usually outperform static shading [7]. In addition to constructional and geometrical aspects, some research begins with social and economic variables, such as household income, age, and other parameters that can affect the amount of energy used in buildings [8]. In another study, the Role of Extensive Green Roofs on Decreasing Building Energy Consumption [9]. The findings demonstrate that green roofs have a beneficial effect on moderating roof surface temperature, which is more noticeable in the summer than in the winter. As a consequence, improved comfort conditions are shown by the narrowing of the gap between the inside and outside conditions.

On the other hand, there are many studies on the effects of weather conditions on building energy performance [10]. Also, current researches attempts are being made using a variety of statistical or physical algorithms to predict the evolution of the building load or heat generation to optimize the building energy management [11]. Papakostas et. al. provided an evaluation of the impact of the ambient temperature rise on the energy consumption for heating and cooling in residential buildings in Greek [12]. These findings indicate that there is a decrease in the energy used for heating by 11.5% in Athens and 4.9% in Thessaloniki, and a comparable rise in cooling by 26.1% in Athens and 10.2% in Thessaloniki which was the effect of global warming in that region. In another article by Jafarour and Berardi, provided an evaluation of the effects of climate changes on building energy demand and thermal comfort in Canadian office buildings adopting different temperature set points [13]. According to simulation results, buildings' cooling loads significantly increase while their heating loads decrease as a result of climate change. This study determined that through modifying temperature set points, an average decrease up to 8.7%, for Quebec City, and 9.9% for Vancouver is possible. In 2023, the influence of temperature and humidity on the thermal conductivity of building insulation materials has been conducted by Wang et. al in an experimental study [14]. The outlines proposed that the thermal conductivity of building insulation materials went up linearly with increasing temperature from 3.9 to 22.7% in the examined temperature range. Besides, Palyvos developed a model to estimate wind convection coefficient correlations for building envelope energy systems [15]. Sepulvedo and his colleagues proposed a Solar radiation-based method for early design stages to balance daylight and thermal comfort in office buildings.

Furthermore, the evaluation of weather datasets on building energy simulation has been carried out by Bhandari et. al to compare provided different climate characteristics with data collected from a weather station inaccessible to the service providers. Depending on the meteorological data at the given location, monthly building loads can vary by ±40% and annual building energy consumption by ±7% [16]. In another research, the typical-year and multi-year building energy simulation approaches have been compared critically by Evola et. al [17]. Different Typical Weather Years' (TWY) are taken into consideration; they can be TWYs that are already on the public databases or ones that the writers designed in accordance with international standards and local measurements. Based on the outcomes of this study, the use of a TWY is beneficial in determining the average long-term energy demand. Nonetheless, TWYs would underestimate the residential building's peak cooling load by about 18% and peak heating load by 12.5%. Segarra e.al provided a methodology to analyze the impact on the simulation results when using an on-site weather station and the weather data calculated by a third-party provider to study if the data provided by the third-party can be used instead of the measured weather data. Based on the results the wind speed and outdoor temperature were the most influential weather parameters [18]. In 2023, Saez and his colleagues indicated the climate parameter's difference between local stations and the available capital dataset from software or online databases via a case study of the Tarragona province in Spain through 43 weather stations homogeneously distributed across the intended region [19]. Findings reveal a higher correlation in temperature and solar irradiation between local data and the province's capital data than with third-party sources, despite climatic differences.

2. Scope of work and novelty

Rural areas are strategic assets to ensure sustainable energy transition due to their potential to implement renewable energy production. In this context, the EU seeks to promote synergies between renewable energy deployment and rural development, through several funding programs and supporting policies that benefit both parties. Consequently, the number of rural Energy Communities is increasing, and researchers are focusing on optimizing their designs. In this regard, one critical aspect when simulating the energy demand of Energy Communities is the use of weather data which are mostly not available for specific locations. In these cases, data from nearby urban centers are typically used, if available. But these data may not be representative of the typical weather conditions of the specific rural area under study which will negatively affect such design.

In other words, when it comes to meteorological data, it is ideal to use information from a weather station that is either inside the building or close by, but this isn't always feasible because of the upfront costs and ongoing upkeep. Therefore, building energy models are mostly calibrated using weather stations whose data is accessible to the public, including those at airports or capital cities. This point makes the necessity of energy demand simulation of buildings to determine how these variations affect the designs of rural energy communities. In this regard, the current paper elaborated on the impacts of using different weather datasets on building energy consumption in 6 towns in suburban areas of Tarragona. The authors utilized Design Builder Software for simulation which is integrated with the Energy Plus model. Also, the novel comparative approach of this study could be mentioned as follows which has been conducted to indicate intended climate data effects among various aspects:

- Comparison between local station and common available dataset from the Energy Plus database for interior towns and the capital.
- Evaluation for impacts of these differences while using weather datasets generated by third parties and satellite data
- Determine the effects of intended deviation of climate data on the energy performance of well-designed and non-optimized buildings.
- Indication of effects of global warming on climate data and its ripple effects on energy performance of buildings.

3. Methodology

For determining the energy consumption of a building for evaluation of available weather datasets, the authors utilized Design Builder Software version 7 for simulation which is integrated with the Energy Plus model. Also since it was said that ANSI AHSRE Standard 140-2001 is the proper approach for the analysis and validation of energy performance of buildings [20]. Accordingly, the introduced building dimension and specification based on this method have been selected for evaluation in this work to provide simulation results and extrapolation for various scenarios.

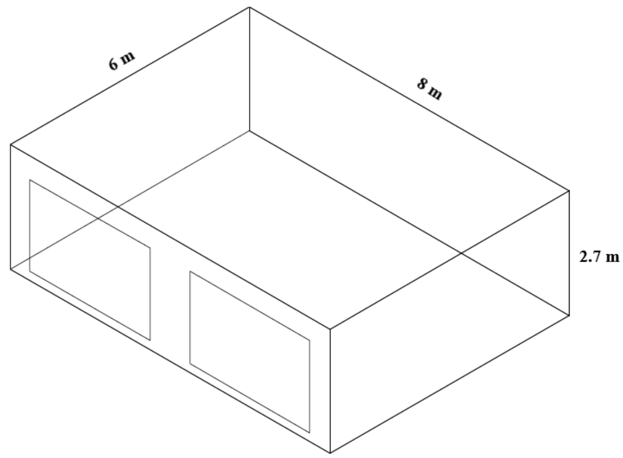

Fig.1 - The basic test building geometry based on ANSI AHSRE Standard 140-2001 [21]

The basic test building (Fig. 1) is a rectangular single zone (8 m wide x 6 m long x 2.7 m high) with no interior partitions and 12 m^2 of windows on the south exposure. The building is of lightweight construction material (thermal mass) and low insulation accompanied by clear glass type and without a glass glazing layer.

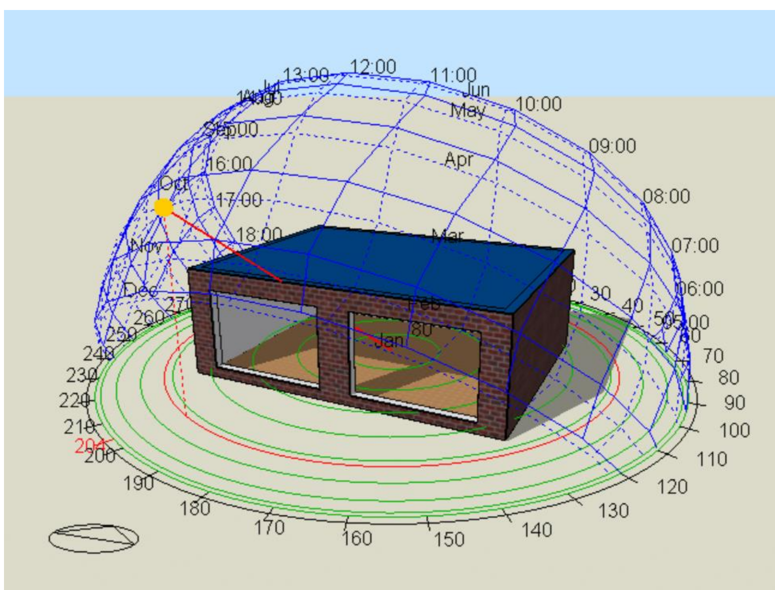

Fig.2 – Generated schematic of testing building in Design Builder software for energy simulation

Based on the above assumptions, the visualized schematic of the building accompanied with an indication of solar radiation and its accordance shading effects has been generated via Design Builder which is indicated in Fig.2. Also, for the HVAC system for this simulation, the packaged terminal air conditioner (PTAC) module in intended software with gross rated COP value of 3 has been used to conduct study in various conditions. Accordingly, to conduct evaluations for the mentioned four comparative categories, following assumptions and methods have been considered for each of them:

a) Comparison between local station datasets and Energy Plus available dataset

Obviously, it is desirable to use meteorological data from a weather station that is in the same location as the building, however, due to installation and maintenance expenditures of measurement devices and lack of local weather stations, this point isn't always possible. As a result, weather stations that provide data to the public, such as those located at airports or major cities such as climate information for Tarragona capital in the Energy Plus data bank, are typically used to simulate building energy demands. In this regard, for evaluating these geographical aspects of weather data in building energy performance, a comparative simulation has been developed for 6 various locations that have been selected in Tarragona Province, Spain comprising different geographical specifications like locating in coastal lines in the Mediterranean Sea or mountains. It should be mentioned that for local climate conditions, the multi-year weather data supporting this work have been recorded by the weather stations owned by METEOCAT (Meteorological Service of Catalonia) from 2010 to 2019 at the intended locations around the province of Tarragona. Also, the typical meteorological year weather data generated in the authors' previous statistical study in the same location has been utilized for simulation as a synthesized single year of weather data that represents multiple years of historical weather data [19].

The detail information for selected locations are indicated in Fig 3. It is tried to consider enough variety for each elevation category. In other words, it can be seen that Tarragona and Ampostaare located in the coastal line of the Mediterranean Sea while El Perello and Falset are placed in interior regions compared to those. Meanwhile Prades station is placed in higher elevations.

b) Evaluation for impacts of using weather datasets generated by third parties and satellite data

Regarding the effects of different weather datasets on the total energy consumption of buildings generated by third parties and satellite data, authors tried to investigate those effects on the performance of intended design by comparing results from NASA satellite data, Meteonorm dataset, local station weather data and Energy Plus available climate data sets for Tarragona capital.

Location	Dataset Source	Population	Altitude	Latitude	Longitude
Amposta	Local	21317	3 m	40.7078	0.6321
EI Perello	Local	2846	179 m	40.8729	0.7158
Falset	Local	2724	359 m	41.1537	0.8195
Prades	Local	602	926 m	41.3148	0.9816
Vinebre	Local	427	53 m	41.185	0.5938
Tarragona	Energy Plus	135436	5 m	41.1039	1.201

Fig.3 – The detail information for selected locations in Tarragona Province, Spain

c) Determining the effects of intended different climate data on energy performance of well-designed and non-optimized building

Understanding the differences in weather datasets and their effects on energy performance will become more important especially when the various building design parameters can show different behavior in accordance with those weather data deviations which can lead to changes in the total energy consumption of the building. In this regard, authors tried to conduct step-wise parametric optimization on intended reference building design for various criteria such as building orientation, thermal mass type, insulation level, glass type, and glass glazing layer to determine the optimum characteristics for the intended building. In fact, this comparative approach could be a kind of indication for old and new building designs in rural communities that have various structures and building construction dates and methods. Accordingly, 16 different cases have been evaluated for this comparison which their parameters are summarized in Table. 1 as follows:

Table. 1 – Parameters of 16 different cases for the optimizations step

Number	Orientation	Thermal Mass	Insulation	Glass Type	Glass Layer	Shading
Base Case	South	Low	Low	Clear	Single	No
Case 01	East	Low	Low	Clear	Single	No
Case 02	North	Low	Low	Clear	Single	No
Case 03	West	Low	Low	Clear	Single	No
Case 04	South	Medium	Low	Clear	Single	No
Case 05	South	High	Low	Clear	Single	No
Case 06	South	Low	Medium	Clear	Single	No
Case 07	South	Low	High	Clear	Single	No
Case 08	South	Low	Low	Absorb	Single	No
Case 09	South	Low	Low	Reflect	Single	No
Case 10	South	Low	Low	Abs & Refl	Single	No
Case 11	South	Low	Low	Low-E	Single	No
Case 12	South	Low	Low	Spectral	Single	No
Case 13	South	Low	Low	Clear	Double	No
Case 14	South	Low	Low	Clear	Triple	No
Case 15	South	Low	Low	Clear	Single	Overhang
Case 16	South	Low	Low	Clear	Single	Louvre

Then, after reaching the optimum design, the simulation result for the base case and optimum design could be compared in terms of the effect of deviation of weather data set in one of the local stations.

d) Effect of global warming on the weather datasets and its ripple effect on energy performance

The impact of global warming on weather data sets and energy consumption is a topic of significant concern and scientific inquiries. As global temperatures continue to rise due to human activities and greenhouse gas emissions, the intricate dynamics of weather patterns are being significantly altered. Weather data sets, which serve as crucial inputs for forecasting models and climate studies, are experiencing shifts in their long-term averages, increased frequency and intensity of extreme weather events, and altered precipitation patterns. These changes pose challenges to accurate weather predictions and the effective management of resources, particularly in sectors heavily reliant on weather data such as agriculture, transportation, and disaster preparedness. Furthermore, the increase in energy consumption, driven by the need for cooling in warmer climates and heating in colder conditions increased demand for energy-intensive cooling systems contributes to further greenhouse gas emissions.

In this regard, in a simplified approach authors weather data generated from Tarragona local station in 2021 has been compared with its past 10 years' average weather data to indicate the effects of climate change on the trend of for instance temperature.

4. Results and Discussion

Regarding the evaluation of the effects of using local stations' weather datasets and the available climate datasets from the Energy Plus data bank for Tarragona capital, Figure 4 and 5 provides detailed results of the simulation in this manner.

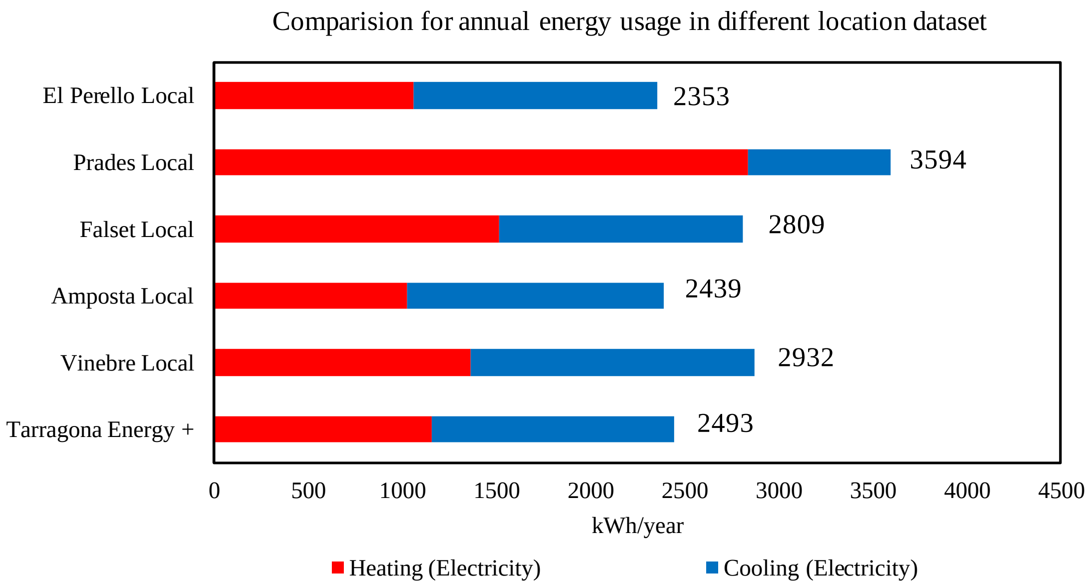

Fig. 4 – Annual energy consumption for the intended building based on different weather datasets

It can be observed that using local weather datasets instead of Energy plus data for rural regions not only led to differences in total energy consumption of buildings but also made variations in heating and cooling demands based on the inherent local site climate condition. Regarding Fig.3, the annual energy usage of the intended design was 2743 kWh via Energy plus data for Tarragona capital as the available dataset while that of Ampostawas 2565 kWh which was a town located in the costal line of the Mediterranean Sea same as Tarragona. Also, it can be seen that the annual energy consumption based on the Falest local dataset was more than the predicted consumption based on the reference dataset due to being located in interior regions. Furthermore, the annual energy usage of Vinebre represented almost a similar portion for heating and cooling demands compared to the results of the Energy plus weather dataset while the total energy utilization was 2809. On the other hand, Prades local station registered the highest annual energy consumption at

3594 kWh accompanied with larger heating requirements compared to Tarragona capital because being in mountainous regions and far distance from the sea.

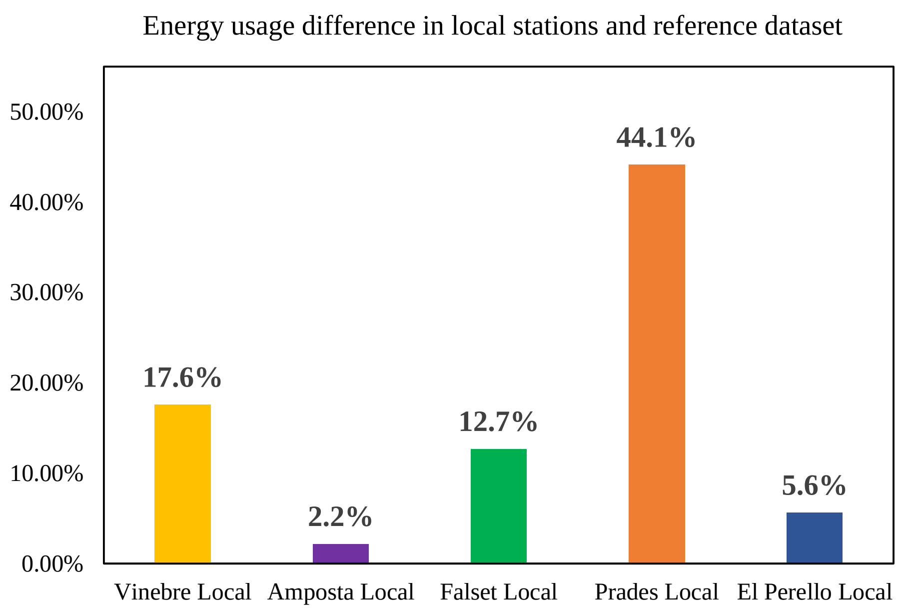

Fig. 5 – Energy usage differences between local stations and reference dataset

Fig. 5 indicated the differences in energy consumption of the intended building via comparing the results generated from reference climate datasets and those of local climate stations. It can be seen that the annual energy consumption difference between Tarragona and Amposta was about 2% since both of them kicked in the same way costal line. This value was 5.6 % and 12.7% for El Perello and Falset respectively due to placing in interior regions. In the meanwhile, since the Vinebre comprises more severe winter and summer, it showed an 17.6% difference in total energy demand. Furthermore, the highest difference belongs to Prades station with a 44% difference due to its high elevation compared to Tarragona.

In addition, previous researches suggested to use of third-party meteorological data in case of lack of local station climate measurement due to equipment and maintenance costs which can provide a better building energy model [22]. In this regard, simulation for Vinebre has been conducted by considering TMY input data from Meteonorm, NASA, local station, and the available Energy plus weather datasets. Based on Fig. 6, it is proved that utilizing third-party meteorological climate datasets can provide a closer estimation of the energy consumption of buildings to real situation. It can be seen that using NASA and Meteonorm weather datasets led to minor difference with the intended local station which is meaningfully better than that of available input data from Tarragona capital generated by the Energy Plus data bank.

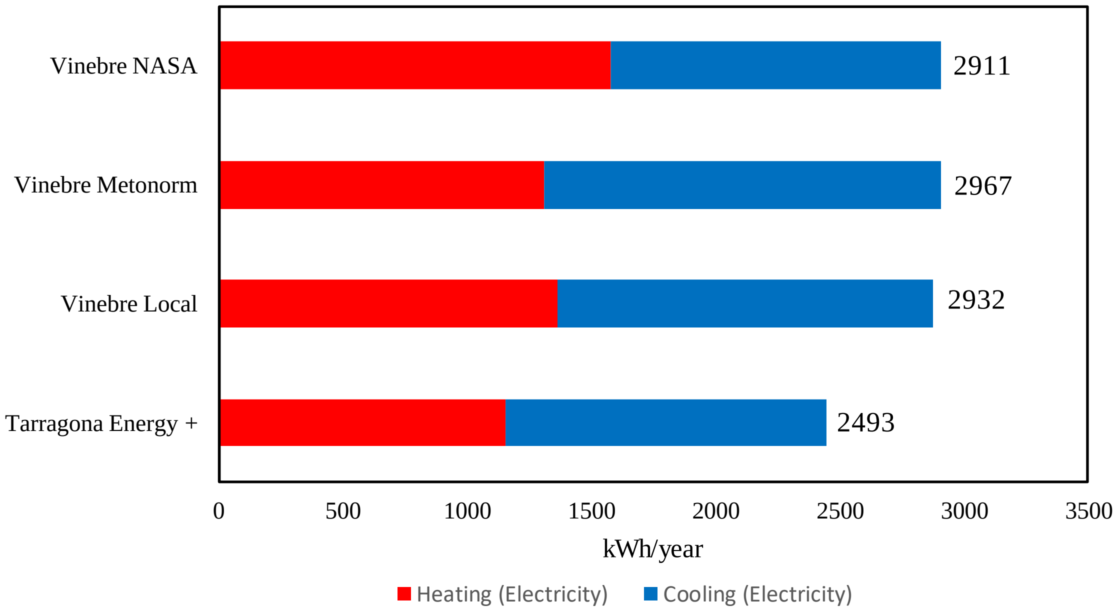

Fig. 6 – Comparison of annual energy usage in different dataset

Besides, for determining the effects of intended different climate data differences on the energy performance of well-designed and non-optimized buildings parametric evaluation has been developed. Fig. 7 revealed that the south orientation had the lowest overall energy consumption while the north and east orientation had the highest energy demands with the majority of heating requirements. From Fig. 8 and Fig. 9 it can be observed that having a higher insulation layer and thermal mass can provide a reduction in the total energy consumption of the intended building. Meanwhile, as shown in Fig. 10, window glass types can lead to different results. Although the clear, absorb, and reflect glass types had almost same overall energy consumption with slight deviations, reflect and absorb types comprise higher heating energy requirements for the intended building respectively. While hybrid absorb-reflect glass type registered the highest energy consumption, Low-E and Spectral types promised the lowest energy usage among others. Spectral had higher heating requirements than Low-E. In addition, Fig. 11 provided a comparison between glass layer types. It is shown that the triple layer and double layer provide 24% and 18% reduction in the overall energy consumption of buildings respectively. Furthermore, Fig. 12 illustrated the difference between using the windows shading device in which louvers design provides lower energy demands. Also, it is worth mentioning that the most effective categories were thermal mass, glazing and insulation for total energy usage reduction with 62%, 35%, and 33% respectively.

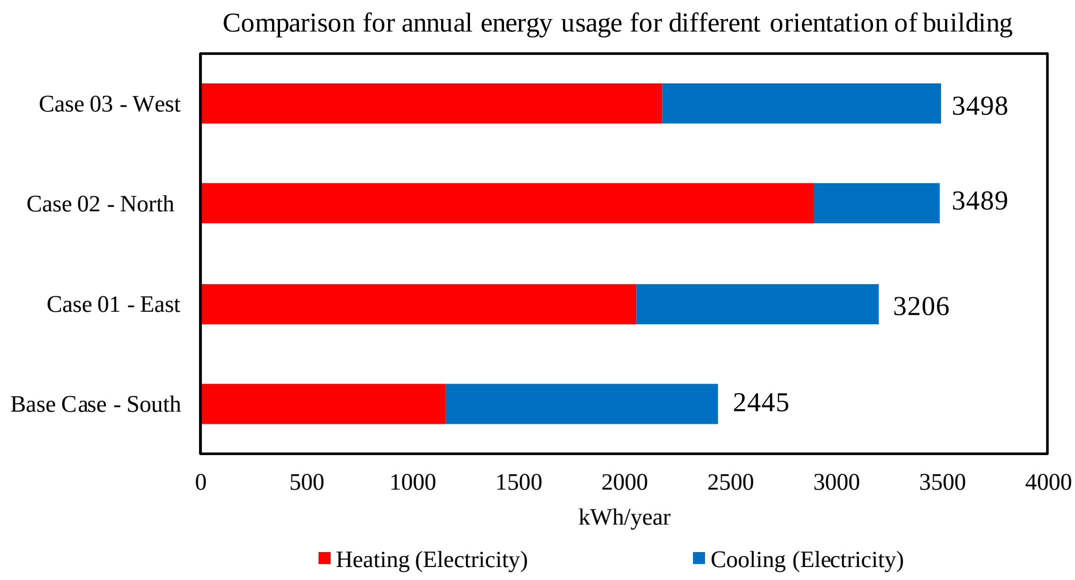

Fig. 7 - Simulation results for comparison of annual energy usage via different building orientations

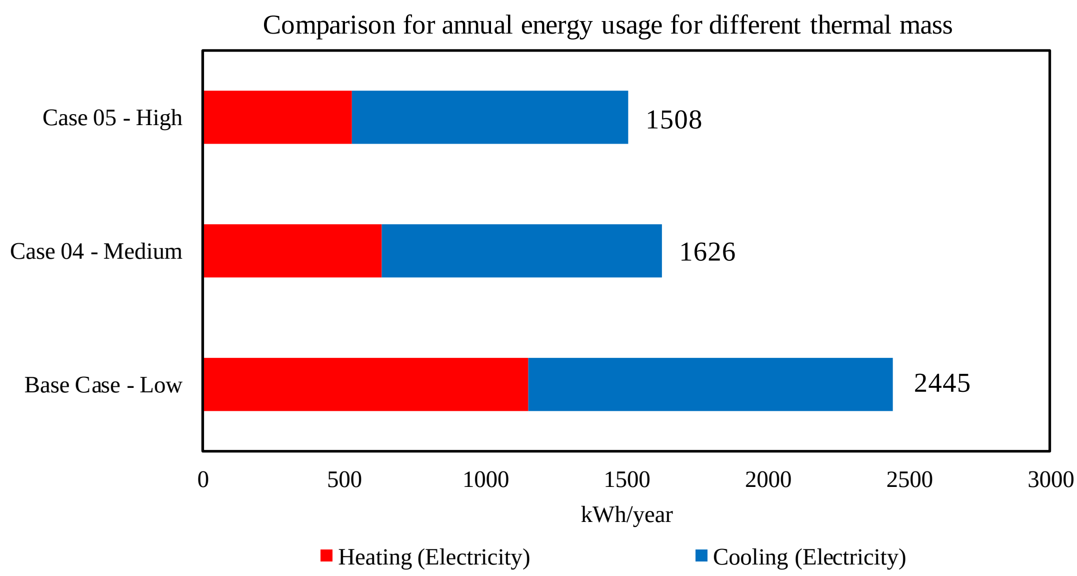

Fig. 8 - Simulation results for comparison of annual energy usage via different thermal mass

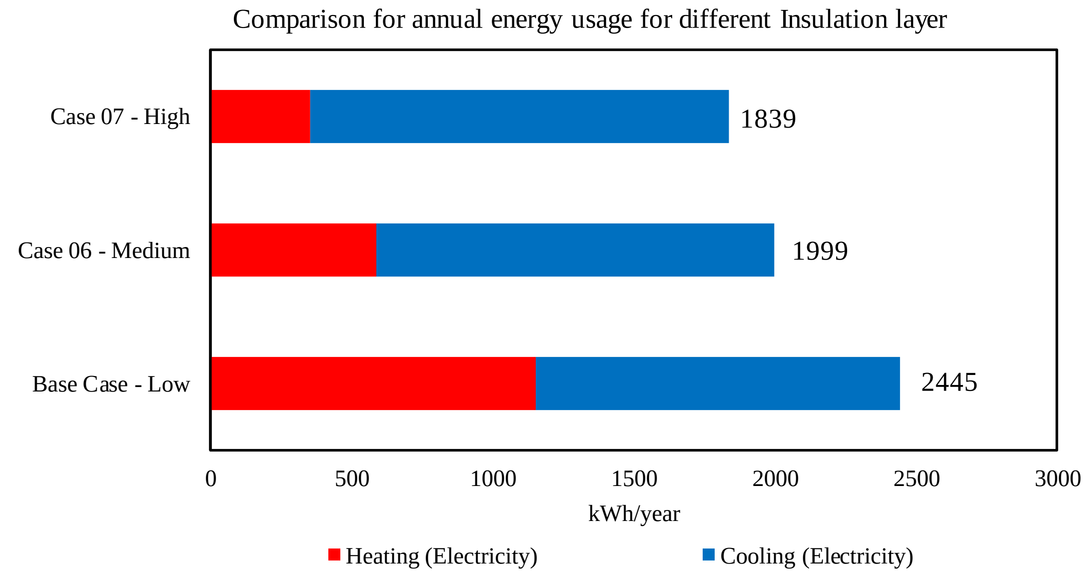

Fig. 9 - Simulation results for comparison of annual energy usage via different insulation layer

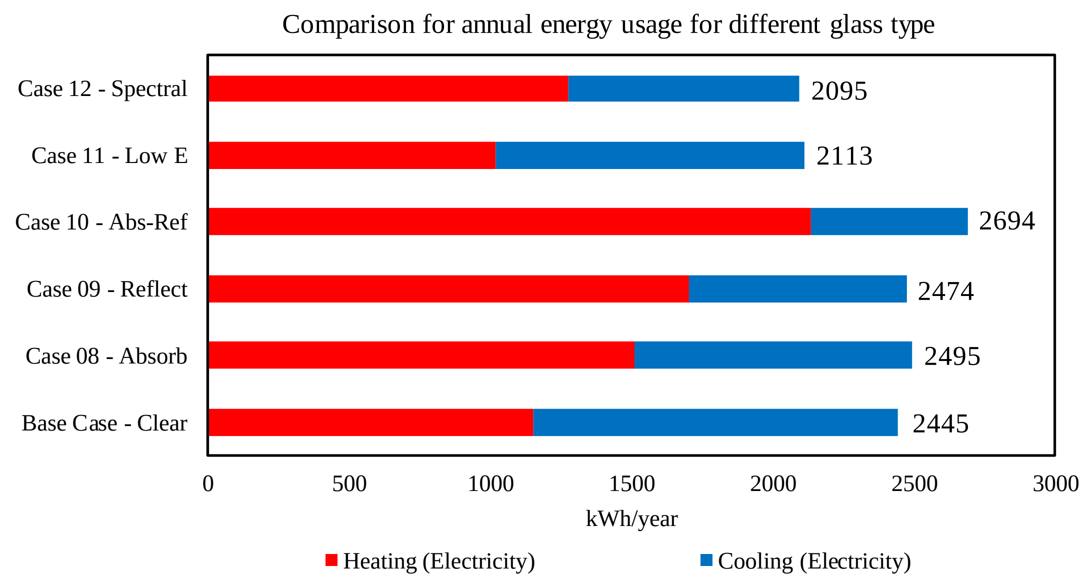

Fig. 10 - Simulation results for comparison of annual energy usage via different glass type

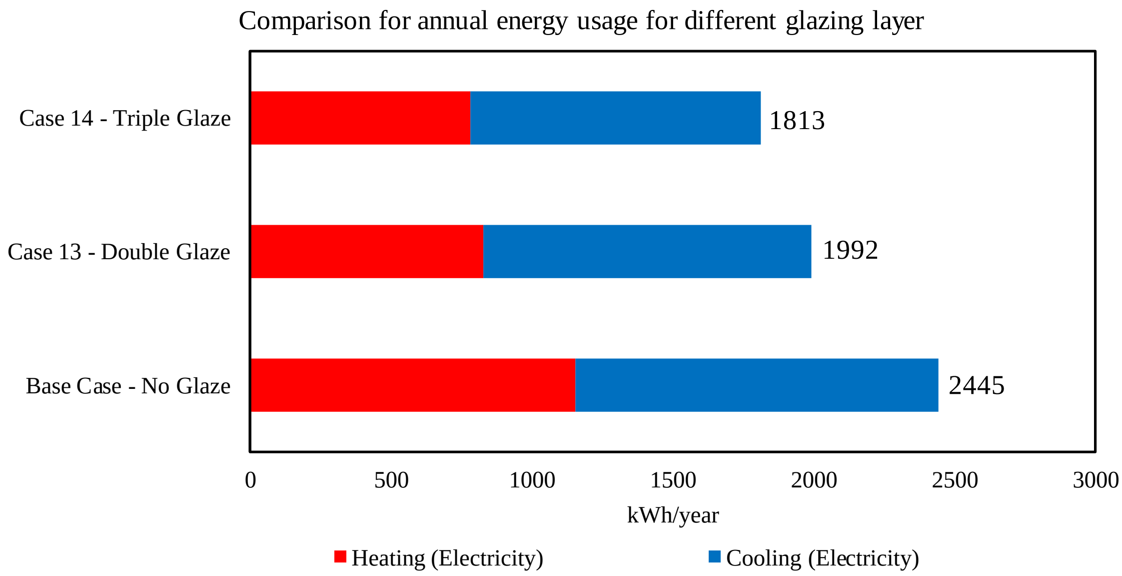

Fig. 11 - Simulation results for comparison of annual energy usage via different glass glazing layer

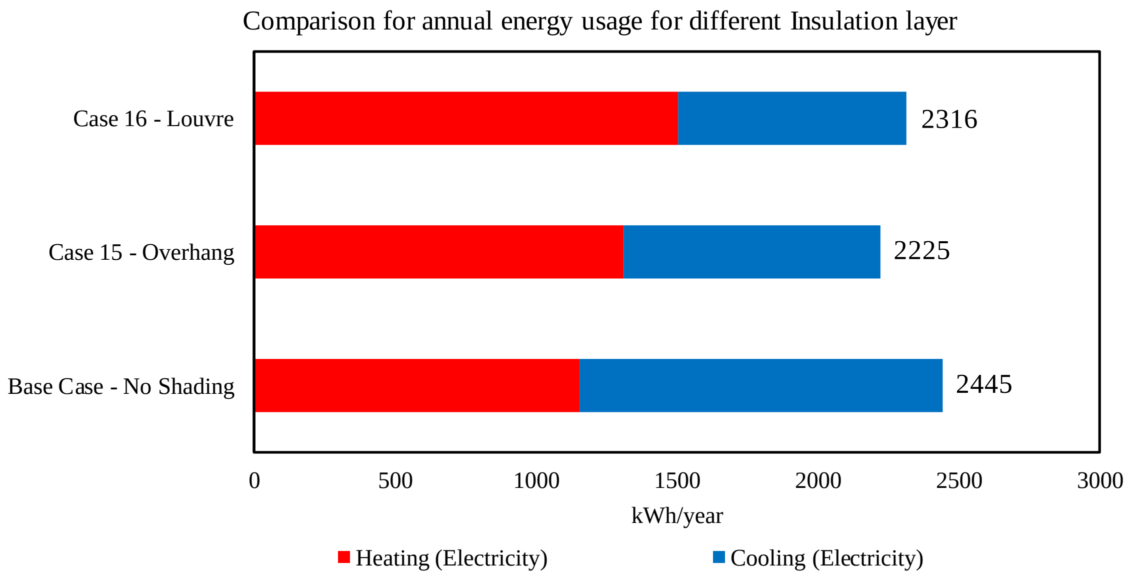

Fig. 12 - Simulation results for comparison of annual energy usage via different window shading devices

Therefore, based on the obtained results for the parametric study, optimum cases in each category have been selected to make the optimized design. In this regard, Fig. 13 illustrated the performance of the optimized-designed and non-optimum design for the intended building. It is shown that the annual energy consumption of a building could be reduced from 2445 kWh to 730 kWh via using the Energy Plus weather data set. Then another comparison was carried out for differences between Vinebre local weather dataset and reference climate data for the mentioned design arrangements. The simulation results indicated that the annual energy consumption in optimum design for the Vinebre local dataset was 962 kWh while that of for reference weather dataset in Tarragona province was 730 kWh. The results showed that using non-local weather datasets led to higher differences in energy consumption. In other words, using local station information led to 18% differences in energy usage for non-optimum building design compared to that when reference weather datasets were utilized. Meanwhile, this difference was 32% for well-designed buildings. Accordingly, it is proved that deviations in weather datasets could have larger effects on the energy performance of well-designed buildings than that of non-optimized arrangements. The reason for this higher deviation may come from the performance of insulations and heat saving throughout the building. In fact, a change in weather has a more pronounced effect on the energy performance of a well-insulated building compared to a non-insulated building because of how insulation impacts the building's ability to regulate its internal temperature.

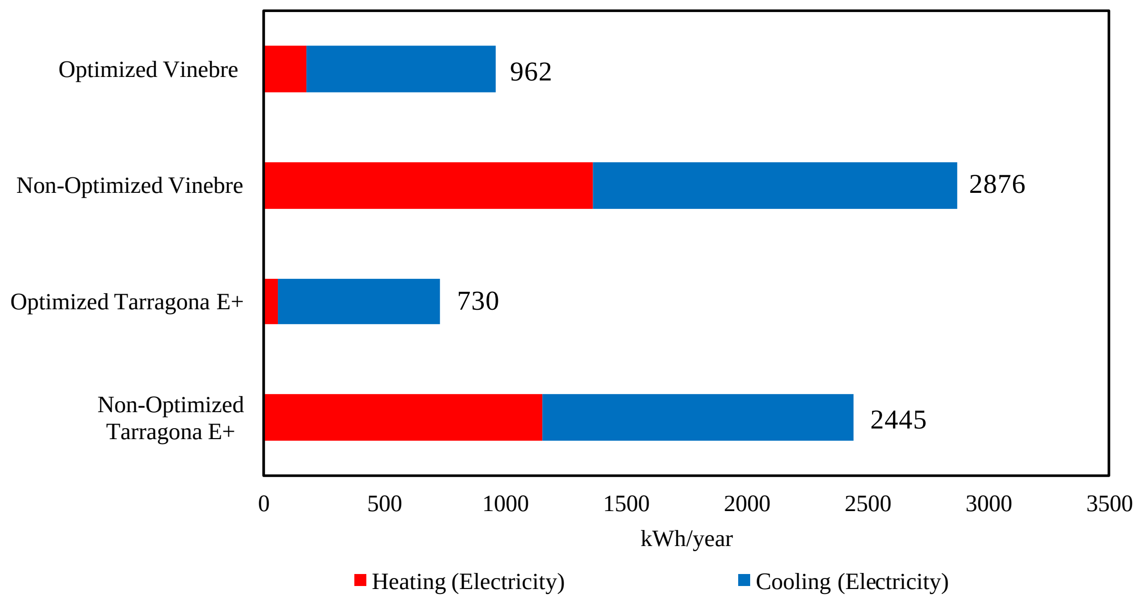

Fig. 13 – Results for effects of different weather datasets on well-designed and non-optimum building

This effect is primarily due to the concept of thermal mass and the response time of insulated vs. non-insulated buildings to external temperature changes. It is worth mentioning that well-insulated buildings typically have more thermal mass, which means they can store and retain heat or coolness for longer periods. Thermal mass refers to the ability of materials in a building (such as concrete, brick, or even the insulation itself) to absorb and store heat. Also, when the external temperature changes, well-insulated buildings respond more slowly to these changes because of their thermal mass. They can buffer the temperature fluctuations, resulting in a more stable and comfortable indoor environment. On the other hand, non-insulated buildings lack the thermal resistance that insulation provides. As a result, they are more influenced by the immediate external temperature conditions. When it's cold outside, heat quickly escapes the building, and when it's hot, heat enters rapidly. This leads to rapid temperature swings inside the building. However, well-insulated buildings can maintain a relatively stable indoor temperature. When it's cold outside, they retain heat effectively and require less heating to stay warm. When it's hot outside, they keep the indoor temperature cooler and require less cooling. This also means that the well-insulated building takes longer to reach an equilibrium with the external temperature, and weather changes are less immediately noticeable indoors. Accordingly, while well-insulated buildings offer better thermal comfort and energy efficiency over the long term, they may seem to be more affected by weather changes in the short term because their thermal mass allows for a slower response to external temperature fluctuations. This effect might make it seem like they are more impacted by changes in weather data compared to non-insulated buildings, which exhibit rapid temperature fluctuations in response to external conditions. Over a year, though, the well-insulated building will consume less energy due to its ability to maintain a consistent indoor temperature. In this regard, Fig. 14 showed the difference in annual energy consumption change due to using local weather dataset for Vinebre.

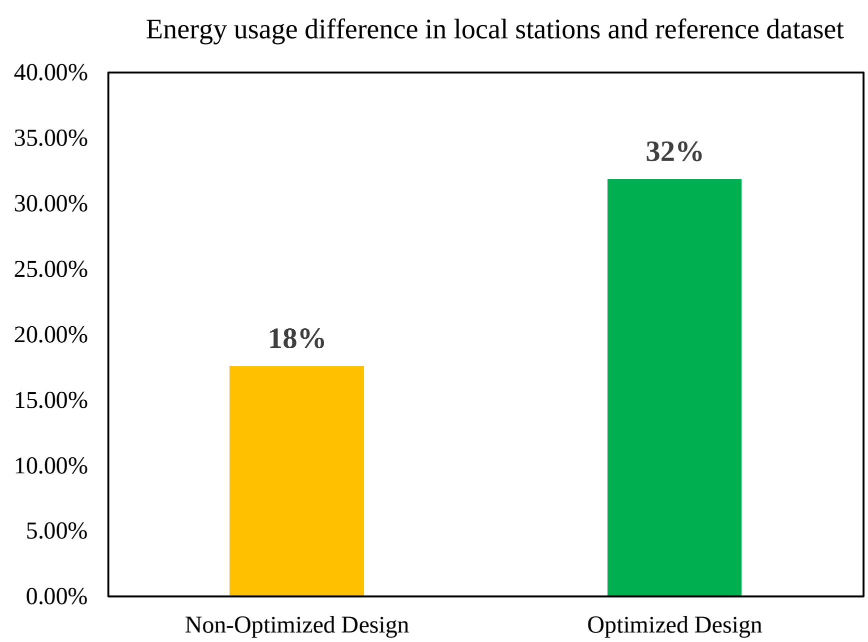

Fig. 14 – Energy Usage change due to using local weather data and reference dataset for optimized and non-optimized design

On the other hand, the implications of global warming on weather datasets profoundly affect building simulation and performance, demanding thoughtful adaptations in design and construction practices. In this regard, Table 3 provided a simplified indication of the effects of global warming on the energy performance of a building. Based on the simulation results, the total amount of annual energy consumption was 2497 kWh for the year 2021 meanwhile that of for its past 10 years was 2445 kWh per year. Likewise, the cooling energy requirement faced almost a 10% rise for 2021 when the heating demand decreased by 80 kWh.

Table. 2 – Effects of global warming on intended building energy performance

Energy Data Source	Heating (kWh)	Cooling (kWh)	Total (kWh)
Tarragona data for the past 10 years	1154	1291	2445
Tarragona data for the year 2021	1074	1424	2497

As temperatures rise globally, there is an increased demand for cooling systems to counteract more frequent and intense heat waves. Buildings in regions experiencing elevated temperatures may require prolonged use of air conditioning units, leading to higher energy consumption for cooling. Additionally, the changing climate can alter traditional heating and cooling patterns, requiring adjustments in HVAC systems to maintain indoor comfort. In the context of global warming, the intricate relationship between rising temperatures and building energy consumption is further compounded by shifts in solar radiation patterns. Changes in cloud cover and atmospheric conditions impact the efficiency of solar panels, potentially reducing their effectiveness. Moreover, alterations in seasonal patterns can disrupt the natural balance in heating and cooling needs, requiring buildings to adapt to new climate conditions. As global warming continues to drive environmental changes, the cumulative effect on building energy consumption becomes apparent, necessitating strategic approaches to design and retrofit buildings for improved energy efficiency and resilience in the face of a changing climate.

5. Conclusion

A principal factor in determining the efficiency and sustainability of our built environment is the energy design of buildings. As a proactive measure for minimizing the environmental impact of buildings, thoughtful and well-executed energy design goes beyond simply satisfying short-term comfort demands. A carefully planned energy design incorporates features such as effective insulation and building structure, optimized HVAC systems, and the integration of renewable energy sources, as well as accuracy in weather datasets as important input information for energy simulation. It is ideal to use meteorological data from a weather station that is either nearby or inside the building, however due to initial expenditures and ongoing maintenance, this isn't always possible especially for rural regions. As a result, weather stations with publicly available data such as those at airports and capital cities are typically used to evaluate building energy models. In this regard, this paper showed the impacts of using different weather datasets on building energy consumption in Tarragona Province. Accordingly, authors tried to utilize Design Builder Software to estimate the effects of these devotions in weather input data on the energy performance of a reference building introduced by ANSI AHSRE Standard 140-2001 which main results were as follows:

- It was concluded that using local weather datasets instead of available Energy plus climate data for rural regions not only led to differences in total energy consumption of buildings but also made variations in heating and cooling demands based on the inherent local site climate condition. It was shown that the annual energy consumption difference between the Amposta local station dataset and Tarragona capital municipality was about 2% since both of them located in the same way coastal line of the Mediterranean Sea. Meanwhile, this value for El Perello and Falset as interior rural regions was 5.6 % and 12.7% respectively. On the other hand, for towns with severe climate conditions like Vinebre, 18% deviation in energy consumption was registered. And this difference reached its peak at 44.1% for Prades local measuring stations in mountainous regions. Accordingly, the significance of using local or nearby weather datasets has been highlighted.

- The simulation results for the Vinebre region showed that considering typical meteorological year (TMY) input data from NASA and Meteonorm weather datasets as third party for meteorological data led to about 1% differences compared to the intended local station in annual energy consumption which were meaningfully better than that of for available input data from Tarragona capital generated by Energy Plus data bank.
- The building parametric study revealed that deviation in weather input data could make larger differences in the energy performance of well-designed buildings than that of for non-optimized arrangements which could be considered as the performance of old and new buildings in rural communities.
- The results proved that considering effects of global warming should be considered in building energy design which led to total energy consumption rise and change in cooling and heating demand distribution in the intended studied case.

Finally, this paper provided a detailed analysis of the impact of available weather dataset deviations on building energy performance. Meanwhile, an evaluation of the mentioned differences for various HVAC systems and also roof-top solar energy production systems could be suggested for future outlines.

6. References

1. Li, J., M. Irfan, S. Samad, B. Ali, Y. Zhang, D. Badulescu, and A. Badulescu, *The Relationship between Energy Consumption, CO2 Emissions, Economic Growth, and Health Indicators.* International Journal of Environmental Research and Public Health, 2023. **20**(3): p. 2325.
2. Petroleum, B., *Energy Outlook 2020 edition explores the forces shaping the global energy transition out to 2050 and the surrounding that.* BP Energy Outlook 2030, Stat. Rev. London Br. Pet, 2020. **81**.
3. Liu, K., X. Xu, R. Zhang, L. Kong, W. Wang, and W. Deng, *Impact of urban form on building energy consumption and solar energy potential: A case study of residential blocks in Jianhu, China.* Energy and Buildings, 2023. **280**: p. 112727.
4. Huang, J., S. Wang, F. Teng, and W. Feng, *Thermal performance optimization of envelope in the energy-saving renovation of existing residential buildings.* Energy and Buildings, 2021. **247**: p. 111103.

5. Happle, G., J.A. Fonseca, and A. Schlueter, *Impacts of diversity in commercial building occupancy profiles on district energy demand and supply.* Applied Energy, 2020. **277**: p. 115594.
6. Wijesuriya, S., C. Booten, M.V.A. Bianchi, and R.A. Kishore, *Building energy efficiency and load flexibility optimization using phase change materials under futuristic grid scenario.* Journal of Cleaner Production, 2022. **339**: p. 130561.
7. De Luca, F., H. Voll, and M. Thalfeldt, *Comparison of static and dynamic shading systems for office building energy consumption and cooling load assessment.* Management of Environmental Quality: An International Journal, 2018. **29**(5): p. 978-998.
8. Mashhoodi, B., *Who is more dependent on gas consumption? Income, gender, age, and urbanity impacts.* Applied Geography, 2021. **137**: p. 102602.
9. Maiolo, M., B. Pirouz, R. Bruno, S.A. Palermo, N. Arcuri, and P. Piro, *The Role of the Extensive Green Roofs on Decreasing Building Energy Consumption in the Mediterranean Climate.* Sustainability, 2020. **12**(1): p. 359.
10. Fumo, N., *A review on the basics of building energy estimation.* Renewable and Sustainable Energy Reviews, 2014. **31**: p. 53-60.
11. Lazos, D., A.B. Sproul, and M. Kay, *Optimisation of energy management in commercial buildings with weather forecasting inputs: A review.* Renewable and Sustainable Energy Reviews, 2014. **39**: p. 587-603.
12. Papakostas, K., T. Mavromatis, and N. Kyriakis, *Impact of the ambient temperature rise on the energy consumption for heating and cooling in residential buildings of Greece.* Renewable Energy, 2010. **35**(7): p. 1376-1379.
13. Jafarpur, P. and U. Berardi, *Effects of climate changes on building energy demand and thermal comfort in Canadian office buildings adopting different temperature setpoints.* Journal of Building Engineering, 2021. **42**: p. 102725.
14. Wang, Y., S. Zhang, D. Wang, and Y. Liu, *Experimental study on the influence of temperature and humidity on the thermal conductivity of building insulation materials.* Energy and Built Environment, 2023. **4**(4): p. 386-398.
15. Palyvos, J.A., *A survey of wind convection coefficient correlations for building envelope energy systems' modeling.* Applied Thermal Engineering, 2008. **28**(8): p. 801-808.
16. Bhandari, M., S. Shrestha, and J. New, *Evaluation of weather datasets for building energy simulation.* Energy and Buildings, 2012. **49**: p. 109-118.
17. Evola, G., V. Costanzo, M. Infantone, and L. Marletta, *Typical-year and multi-year building energy simulation approaches: A critical comparison.* Energy, 2021. **219**: p. 119591.
18. Segarra, E.L., G.R. Ruiz, V.G. González, A. Peppas, and C.F. Bandera, *Impact Assessment for Building Energy Models Using Observed vs. Third-Party Weather Data Sets.* Sustainability, 2020. **12**(17): p. 6788.
19. Saeza, R., R. Kazemib, M. Vallèsc, D. Boerd, and A. Shoboe, *Evaluation of weather datasets for rural energy communities simulation.* 36th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems (ECOS 2023), 2023.
20. Martínez, S., P. Eguía, E. Granada, A. Moazami, and M. Hamdy, *A performance comparison of multi-objective optimization-based approaches for calibrating white-box building energy models.* Energy and Buildings, 2020. **216**: p. 109942.

21. Analytics, G., *EnergyPlus Testing with ANSI/ASHRAE Standard 140-2001 (BESTEST)*. 2004, EnergyPlus Version.
22. Gutiérrez González, V., G. Ramos Ruiz, H. Du, A. Sánchez-Ostiz, and C. Fernández Bandera, *Weather Files for the Calibration of Building Energy Models*. Applied Sciences, 2022. **12**(15): p. 7361.