sustainability

MDPI

Article

Characterization of the Thermal Behavior of Semi-Exterior Laundry Spaces in an Overheating Passivhaus Residential Building in Bilbao, Spain

Jorge Otaegi *, Rufino J. Hernández-Minguillón and Iñigo Rodríguez-Vidal

CAVIAR Research Group, Department of Architecture, University of the Basque Country UPV/EHU, Plaza Oñati, 2, 20018 Donostia-San Sebastián, Spain
* Correspondence: jorge.otaegui@ehu.eus

Abstract: Overheating in buildings is a growing challenge in temperate climates, even in those where the traditional design focus was on protecting from cold and winter energy savings. This paper addresses a collateral problem that arose during the study of overheating in a residential Passivhaus building in Bilbao, northern Spain. Specifically, the local climate of three laundry spaces was investigated, where high daytime and nighttime temperatures were recorded. An extensive monitoring campaign was carried out with different durations up to more than 21,000 h over four years, and the collected data were compared with outdoor climatic conditions. The results allowed for characterizing the thermal behavior of these semi-outdoor spaces and show the magnitude of the problem, quantifying it. Laundry spaces were confirmed to be hotter and dryer than the outdoor climate almost always. The mean average difference between the monitored rooms and the exterior was quantified to be around positive 5 °C during both daytime and nighttime. Extreme heat events were documented, with maximum temperatures above 50 °C and temperature differentials of up to 15.85 °C. In addition, this article comments on the impact of overheating these laundry spaces on the interior of the dwellings, pointing out the differences between the assumptions made during the design phase of the project and the observed or measured reality. Questions were raised about the possible implications of the peculiar performance of these semi-outdoor spaces on the mechanical heat recovery ventilation system (MHRV). The data presented in this article revealed and quantified a design flaw that went unnoticed by all agents involved in the planning, design, and construction of the 361-apartment project. The inability to predict the behavior of the studied spaces has had a negative impact on building performance during the summer months and has prevented the implementation of strategies that could have been beneficial in other periods. A thorough analysis of the thermal behavior of similar spaces becomes essential to prevent performance gaps in future projects and to inform adequate building modeling in the design stages.

Keywords: overheating; thermal comfort; energy performance; nZEB; energy efficiency; sunspaces; solar energy; ventilation; Passivhaus; climate; indoor environment quality (IEQ); housing

check for updates

Citation: Otaegi, J.; Hernández-Minguillón, R.J.; Rodríguez-Vidal, I. Characterization of the Thermal Behavior of Semi-Exterior Laundry Spaces in an Overheating Passivhaus Residential Building in Bilbao, Spain. *Sustainability* **2024**, *16*, 470. https://doi.org/10.3390/su16020470

Academic Editor: Antonio Caggiano

Received: 30 November 2023
Revised: 29 December 2023
Accepted: 3 January 2024
Published: 5 January 2024

1. Introduction

Excessive indoor temperature, commonly referred to as overheating in buildings, can lead to discomfort and potential health problems [1]. It is, in fact, one of the main comorbidities [2,3], with implications on all aspects of human health [4–9]. Climate change is expected to affect heating and cooling dynamics in regions traditionally focused on winter design [10,11], which will also affect energy infrastructure [12]. In other words, building designers should start thinking about resilience to overheating, even in climates where summer has never been a design challenge. To ensure a sustainable and healthy future, it is crucial to ensure occupant comfort and well-being by preventing overheating in dwellings. Several strategies, such as effective shading, proper ventilation practices, and well-sized heating and cooling systems, play a key role in addressing this problem [13,14].

Near-zero energy buildings (nZEBs) [15] are designed to have minimal heating, cooling, and ventilation requirements, while having a high level of insulation and airtightness. It is evident that the need to construct near-zero-energy buildings has pushed building science, construction practice, and the training of building professionals considerably in recent decades; so has the technology in buildings and in the process of envisioning, simulating, optimizing, and ultimately designing them before they are built. However, overheating can still occur due to factors such as excessive solar gain and occupancy levels, which are not always sufficiently well controlled.

In this regard, a recent collective article focusing on overheating in cold and temperate European climates emphasized the need for dwellings traditionally designed to keep warm during the winter to be adapted to reduce indoor temperatures during the summer [16]. In fact, the increase in energy efficiency requirements has made residential buildings more complex systems, especially in climates with marked seasonal variability. It is not possible to establish a univocal relationship between superinsulation, airtightness, and other efficiency measures typical of nZEBs with overheating. However, we can say that as we pursue ever more finely tuned “living machines”, we are more likely to make design flaws, or for an unforeseen or supervening situation to throw the balance out of whack.

Climate change models only call into question the efforts made in recent decades, and the housing stock, old, new, or refurbished, will be put to the test in this regard, especially since we are still designing for past (historical) climates, with notable exceptions.

Ventilation systems have been essential for indoor temperature and humidity regulation throughout the year in energy-efficient buildings, especially in cold climates. Certainly, to ensure air quality as well, certain standards, such as Passivhaus [17], give ventilation systems with heat recovery a central importance in building design, sometimes giving them the role of providing heating and cooling; although there are opposite approaches that have shown good results [18].

As the use of air conditioning systems increases, the need to ensure that future cooling demands are reduced as much as possible becomes more pressing and limited in the yet unregulated interventions in buildings. The challenge is to carry this out without harming people’s comfort and health, and here, European Directives and national standards play a crucial role in shaping our approach to the growing heat dilemma. This includes determining what constitutes overheating and mechanisms for anticipating overheating in new construction and assessing the resilience of existing buildings. Despite some of the literature [19], there is no overheating standard in Spain nor any other mandatory verification or compliance procedure aimed at preventing this problem. The opening of simplified ways of justifying compliance with the energy efficiency of new building projects, disregarding dynamic simulation and allowing for the application of simplified methods, which are more popular because of their relative ease of use, is a step backwards in our ability to design a resilient built environment.

This paper presents the results of the long-term monitoring carried out in the laundry drying rooms, semi-outdoor spaces dedicated to drying clothes, of several dwellings in a building in which a persistent situation of overheating has been observed [20,21]. During the surveys that were carried out in the first post-occupancy evaluation campaign [20], as well as during some interviews with inhabitants of the building, the problem of overheating in these semi-outdoor spaces arose, which motivated the extension of the monitoring period and, later, the analysis presented here. To this end, Section 2 presents the case study, explains the means used in the monitoring procedure, and the way in which the data used in the analysis were obtained. Section 3 presents the results of an initial exploratory analysis and then a quantitative analysis of all the available data, which are discussed in Section 4. Finally, Section 5 presents the conclusions drawn from the analyses carried out and sets out the future lines of research opened up by this work.

2. Materials and Methods

2.1. Description of the Case Study

The urban regeneration project of Bolueta, in Bilbao, aimed to recover unused industrial land for its transformation into housing and to improve the urban quality of the area, which was in a situation similar to that of other run-down industrial zones in metropolitan Bilbao. To this end, an urban plan was designed that included 1100 dwellings, of which 608 were subjected to some type of protection (e.g., social housing, limited, or subsidized price housing). The partial territorial plan for the functional area of metropolitan Bilbao, in its initial approval on April 2023, continues to classify Bolueta as an "area in need of very high intervention" in its regeneration, renovation, and rehabilitation annex [22].

The case study building, 27 stories high, is part of a two-tower social housing development located in said urban regeneration area of Bolueta, with a total of 361 dwellings. The first, built in 2018 [23], houses 171 dwellings, of which 9 are one-bedroom apartments, 40 two-bedroom apartments, of which 7 are adapted for people with reduced mobility, and 122 three-bedroom apartments. The second tower is a little lower, 20 floors, and was delivered in 2020 [24] according to the same project and the same construction techniques as the first tower. It houses 190 apartments, of which 78 are two-bedroom apartments and 112 are three-bedroom apartments. It has 8 adapted dwellings, all of which are two-bedroom units. Overall, between the two blocks, 64.8% of the dwellings are three-room dwellings, 32.7% are two-room dwellings, and the remaining 2.5% are one-bedroom dwellings. Figure 1 shows the location of Bolueta tower 1.

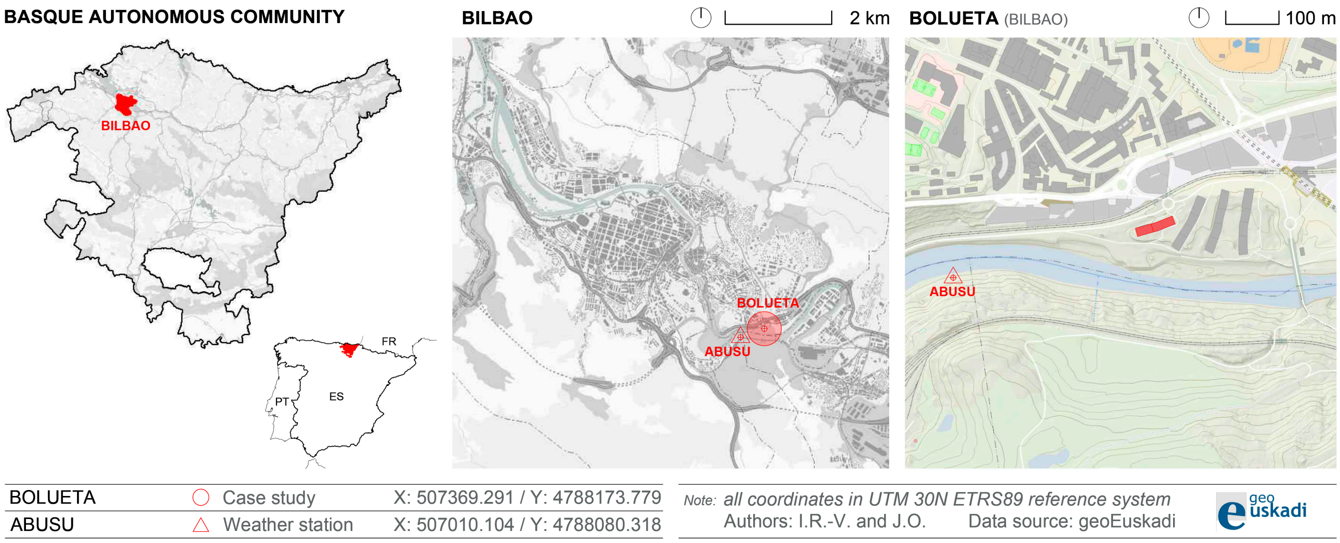
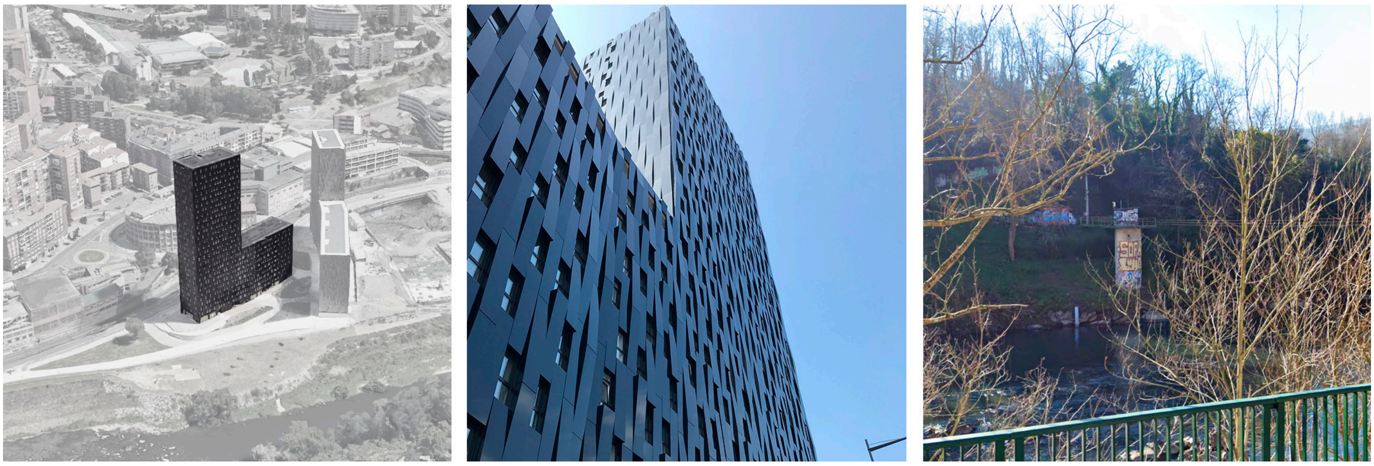


Figure 1. Location of the case study building and Abusu meteorological station. Source: Authors.

In the Bolueta development, one-bedroom apartments have a useful interior area of about 42 m^2; two-bedroom dwellings range from 55 to 69 m^2 of useful interior area, and three-bedroom dwellings range from 72 to 87 m^2. The weighted average surface area, excluding dwellings for the disabled, is 41.89 m^2 for one-bedroom dwellings, 64.27 m^2 for two-bedroom dwellings, and 82.22 m^2 for three-bedroom dwellings. It can be said, therefore, that these are modestly sized dwellings.

A notable difference between the two buildings is that the first tower (the black one) is certified under the Passivhaus standard [25], while the second (gray) has not been certified as such. The blocks of the urban planning are slightly rotated, so that while the block known as tower 1 is roughly aligned east–west in its length, block 2 is almost north–south or, rather, northeast–southwest.

The website of Visesa, the public company responsible for these projects, advertised the projects, alluding to four fundamental aspects in their view of their own development: energy saving or efficiency, high thermal and acoustic comfort, good indoor air quality, and construction with natural and healthy materials [26], for which they relied, precisely, on the Passivhaus standard. Figure 2 shows Bolueta tower 1 (highlighted) and tower 2 to its right:



(**a**) (**b**) (**c**)

Figure 2. Exterior images of the case study. Aerial view of Bolueta tower 1 (**a**); picture of Bolueta Tower 1 from the street level (**b**); and view of Abusu meteorological station (**c**).

The first tower has a black facade made of aluminum composite panels, while the second has a facade of the same type, but in a lighter gray color. The color of the facade was, at least in tower 1, the result of public consultation. The facades and roofs have a high degree of thermal insulation, corresponding to the envelope of a Passivhaus building. The windows are equipped with triple-glazed panels and only have internal solar shading, namely a light-colored interior screen. The structure is made entirely of concrete, columns, and beams, using walls in the communication cores for greater rigidity in the towers. For the floor slabs, semi-precast precast elements were used. The interior partitions were made of a lightweight gypsum plaster fiberboard system. The partitions between different units and with common areas were made with brick walls, which were then lined with insulation and laminated gypsum boards. A construction detail of the typical facade solution can be found in [21]. Table 1 summarizes the characteristic values of the building envelope Bolueta of Tower 1, whose values have been obtained from [25,27], as well as from the building's construction project. The average pondered U-value for windows (U_w) was calculated to be 0.83 W/m^{2}K.

Table 1. Summary of constructive elements' properties of Bolueta tower 1.

No. of Floors	YoC [1]	Walls		Windows			Airtightness n_{50}	Partitions
		U_{facade}	U_{roof}	U_{frame}	U_{glass}	g		
27	2018	0.22 W/m^{2}K	0.21 W/m^{2}K	1.10 W/m^{2}K	0.55 W/m^{2}K	0.57	0.3 h^{-1}	Lightweight

[1] Year of construction. Data were gathered from [25,27].

In addition to what has already been mentioned, it should be added that in the design of the building, special care was taken to avoid the appearance of thermal bridges and that, despite the fact that many of the construction systems are heavy (floor slabs, primary partition walls, heavy facade bricks, etc.), all this inertia is always covered with thermal insulation, both in the floors and vertical elements.

Each and every one of the 361 units has a space dedicated to the natural air drying of clothes, most of the times connected to the kitchen, although sometimes this space is accessed through a bedroom or the living room. These laundry spaces do not contain the washing machine nor any drying machine; they are only devoted to hanging clothes. In the case of the towers of Bolueta, these laundry rooms are more closed than usual, since they are closed on at least 3 sides. They are rectangular or square spaces of between 1.64 and

5.18 m^2 and 2.50 m high, with an opening of 82–85 cm wide by 203–205 cm high, following the modulation of the windows, on the facade. About 60% of the time, that opening is simply open, but the other 40% (approximately) is covered by a perforated sheet of a black metallic panel that forms the rest of the facade. Table 2 shows the number of dwellings by type of laundry in both buildings.

Table 2. Description of laundry spaces in towers 1 and 2 of Bolueta.

	***Laundry* sp. Type**	**No. of Units**		**No. of Dwellings**	**Total**
Tower 1	Open	99	(57.9%)	171 dwellings	361 dwellings
	Closed	72	(42.1%)		
Tower 2	Open	112	(58.9%)	190 dwellings	
	Closed	78	(41.1%)		

The laundry spaces are oriented to the east, southeast, south, and southwest in tower 1, according to the normalized orientations of the Spanish standard [28]. In tower 2, there are laundries oriented to the east, southeast, south, southwest, and, occasionally, also to the northwest, following the same orientation criteria. The "closed" type laundries are concentrated on the east and west facades in tower 1 and on the north and southwest facades in tower 2. In principle, there is no explanation for this closure other than the architectural composition of the facade. Figure 3 shows the appearance of the laundry space from the interior and exterior. The perforated panel can be appreciated in Figure 3a,c.

(**a**) (**b**) (**c**) (**d**)

Figure 3. Descriptive images of the laundry spaces. Example of laundry with perforated metal cladding enclosure (**a**); interior image of one of the laundries (**b**); and images showing the ventilation equipment installed in said spaces (**c**,**d**).

Regarding the number of laundry spaces monitored, it must be said that data have been obtained from three different spaces, each one from a dwelling. All belong to tower 1 of Bolueta, which was the first to be built and the one with the Passivhaus certificate.

Laundry 1 belongs to an apartment located on the 27th floor, has an area of 1.86 m^2, and is one of those closed by a perforated panel. It is oriented to the west. Laundry 2 belongs to a dwelling on the 8th floor and is oriented south-east. It has an area of 2.86 m^2. Laundry 3 is located in a two-bedroom apartment on the 4th floor and has an area of 3.24 m^2, oriented to the south. Laundries 2 and 3 are of the open type, with an opening of the mentioned size. The approximate volumes of these laundry spaces are 4.70, 7.22, and 8.18 m^3, respectively.

2.2. Data Sourcing and Monitoring

The outdoor climate data were obtained by direct download from the open data system of the Basque regional government, Euskadi Open Data [29], for the Abusu weather station, located in the vicinity of Bolueta. It is a meteorological station for gauging control of the Ibaizabal river, whose data have already been used in other research [20,21]. A picture of Abusu can be seen in Figure 2. This station, despite its proximity, has the disadvantage of not collecting solar radiation data, so it has had to be completed with data from the Arrigorriaga weather station, which is located a few kilometers away in an urban environment to the northeast. Data for the years 2019, 2020, 2021, and 2022 have been used.

To monitor the conditions of the laundry spaces, specialized logging devices from T&D were utilized, factory calibrated. In case of laundry 1 and laundry 3, a TR72 device was used to monitor temperature and relative humidity. TR72's temperature measurement capability ranges from 0 to 55 degrees Celsius (with an accuracy margin of $\pm$0.5 degrees and a resolution of 0.1 °C), and it can gauge humidity levels from 10% to 95% RH (with a 5% accuracy at standard conditions of 25 degrees Celsius and 50% RH). To monitor the conditions of laundry 2, the RTR-574 datalogger was used, with the same accuracy as the TR72 device. A more exhaustive explanation of the instruments that were employed can be found in [20,30].

In total, laundry 1 has been monitored for about 21,000 h over three years; laundry 2 for three discontinuous periods totaling 7859 h, which unfortunately do not include summers due to data loss; and finally, laundry 3 for a period of about 14 months, with 10,238 h monitored, including the entire summer of 2021. Figure 4 shows the timeline of the data analyzed in this article for each of these spaces.

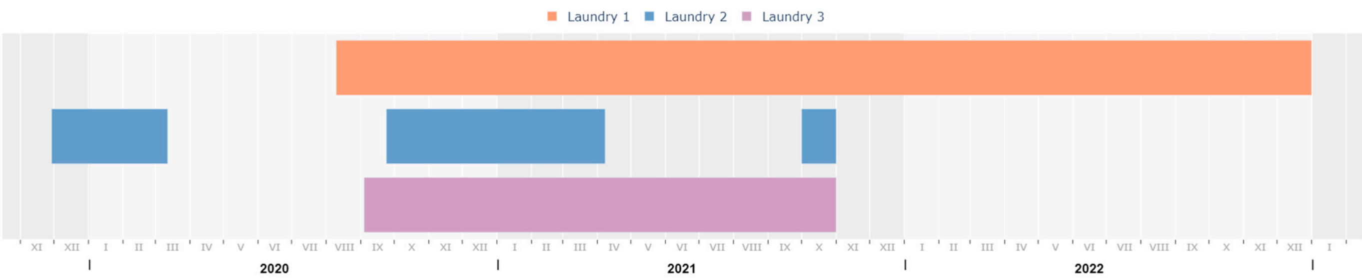


Figure 4. Timeline of the monitoring campaign.

2.3. Data Analysis

To describe the outdoor climate during the study period, the seasonal reports prepared by the Spanish Meteorological Agency (AEMET) for the years 2019, 2020, 2021, and 2022 were consulted to obtain a contextualization of how the weather was in Spain in those years. Then, monthly averages of temperature, relative humidity, and horizontal global radiation were obtained from the weather stations of Abusu, located a few meters from the case study and Venta Alta, in Arrigorriaga, because Abusu does not collect solar radiation data. Mean daily maximum and minimum temperatures were calculated, as well as absolute maximum and minimum temperatures. The same was carried out with relative humidity.

Exploratory analyses denote the process of discovering patterns, relationships, and insights within a dataset without a predefined hypothesis or model. Their primary goal is to understand the data and pinpoint areas of potential interest for further analysis. This usually involves tasks such as visualizing data, summarizing key statistics, and identifying outliers or missing values, leading to a deeper understanding of the data and critical areas of interest.

For this exploratory analysis, the goal was to identify key weeks that represented various scenarios of performance of the studied housing under both typical and extreme conditions during the summer and winter. The selection of these five weeks took into account three criteria based on outdoor weather data from the Abusu weather station:

1. Proximity of the weekly maximum/minimum temperature to the maximum/minimum temperature range of the period (summer/winter).
2. Proximity to the average temperature of the respective summer or winter period or to the highest/lowest weekly averages, as the case may be.
3. Proximity to the average or maximum heating or cooling degree hours, as appropriate.

Heating degree hours (HDHs) were calculated using a base temperature of 15.5 °C, while cooling degree hours (CDHs) used a base of 22 °C, in line with European standards. To select W5, we looked for the week with the highest number of tropical nights (nights where the outside temperature does not drop below 25 °C), controlling that it was not already selected as W3 or W4.

To numerically assess the difference between the temperature of the laundry and the outside temperature, the mean absolute difference (hereinafter, MAD) was calculated, as shown in Equation (1). This measurement has been calculated for different periods of time (for daytime, nighttime, monthly, and for the entire study period:

$$\text{Mean Absolute Difference} = \frac{\sum_{t=1}^{n} |T_{a,l} - T_{a,e}|}{n} \quad (1)$$

where $T_{a,l}$ is the air temperature recorded in the laundry, for a time t, in degrees °C; $T_{a,e}$ is the air temperature taken at Abusu meteorological station for the same time t; and n is the number of timesteps in the period considered, in this case, the number of hours considered.

In addition to the MAD, for completeness in the analysis, medians, means, average daily maximums, and average daily minimums were calculated, as well as the typical statistical measures, and numerical comparisons were carried out to narrow down the difference in performance between the semi-outdoor laundries and the outdoor climate, as presented in Section 3.3. Finally, a correlation analysis between laundry temperature and outdoor temperature and another one between daily radiation and laundry temperature was performed. It should be taken into account that global horizontal radiation and outdoor temperature are not independent variables.

3. Results

This section presents the results of the analyzed data, as well as their interpretation.

3.1. Exterior Climate Contextualisation

In 2019, the year began with a winter characterized by mild temperatures, a trend that continued into the spring. The summer of 2019 was hot in Spain, according to the report corresponding to the season from the AEMET agency [31], marked by significant heat waves, especially in June and July. In autumn, above-average temperatures continued, concluding a warm year overall.

In 2020, the trend of high temperatures continued. The winter of 2020–2021 was a mix of cold snaps and mild periods, but overall warmer than historical averages, again according to the AEMET report [32]. The following seasons, especially the summer, were marked by extreme heat. The winter of 2021–2022 again showed a mix of cold and milder periods, but with a trend towards warmer conditions. This trend was accentuated in the spring and summer of 2021, with extreme heat waves in the latter [33]. The summer of 2022 was particularly notable for its high temperatures [34]. In the winter of 2022–2023, despite some cold snaps, the overall weather was milder compared to historical averages [35].

The coastal climate of the Basque Country, influenced by its proximity to the coast and its varied orography, experiences more diverse and less predictable weather, which contrasts with general climate trends in Spain. This highlights the distinct microclimates and geographic influences of the Basque Country, underscoring the complexity of its climate relative to Spain as a whole. The article published by the authors of [21] contains an explanation of some relevant microclimatic aspects in this region.

In that sense, meteorological data from the Abusu station in Bilbao, Spain, during the years from 2019 to 2022, seem to show, however, some deviation from the analysis performed by the AEMET for the whole country. During the summer months, the years 2020 and 2022 stand out for the highest maximum temperatures recorded, indicative of particularly warm conditions. Consequently, these years also witnessed the warmest nights, as evidenced by the high minimum temperatures, suggesting a significant impact on the nocturnal thermal environment.

In contrast, the winter seasons of 2021 and 2022 were characterized by noticeably cooler temperatures both day and night, which was a marked contrast to the preceding summer's warmth. Temperature fluctuations within these colder months were relatively limited, indicating a trend towards more stable, albeit colder, conditions. Figure 5 shows the evolution of temperatures over the four years noted at the Abusu station.

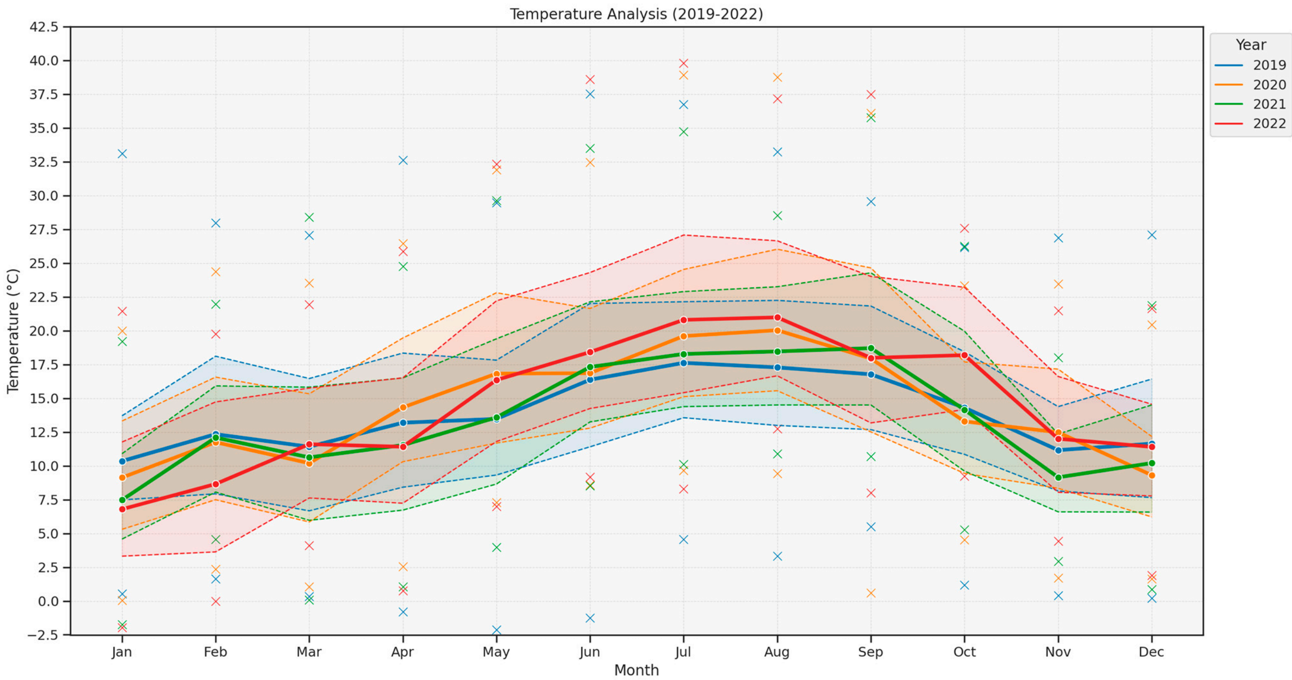


Figure 5. Evolution of average monthly temperatures (centerlines), average daily maximum and minimum temperatures (dashed), and absolute maximum and minimum temperatures (marks) recorded in Abusu in the years 2019, 2020, 2021, and 2022. (Source: Authors based on data from Euskalmet).

An analysis of mean daily maximum and minimum temperatures reveals a progressive increase in maximum temperatures during the summer, with a particularly pronounced increase in the year 2022. This ascending pattern underlines a trend towards hotter summer days during the observed period. In contrast, the winter months show a downward trajectory in daily minimum temperatures, with the years 2021 and 2022 experiencing some decline. The year 2022 is particularly notable for the increase in summer temperatures, while 2021 is distinguished by colder winter temperatures. These variations highlight the dynamic nature of the local climate and underline the importance of continuous monitoring and analysis to understand the evolution of temperatures and their environmental and building performance implications, and in our analysis.

Regarding solar radiation, taking the global horizontal radiation collected by the Venta Alta weather station in Arrigorriaga (Abusu does not have radiation data), 2019 was the sunniest year, followed by 2022. In third place, 2021, and in last place, 2020. The sunniest months were, during the four years, May, June, and April, in that order and as recorded at the aforementioned weather station.

The climate data analyzed can be found summarized in Tables A1 and A2 in Appendix A, which provides additional graphs and data summaries.

3.2. Results of the Exploratory Analysis

The methodology described in Section 2.3, based on exterior temperatures, resulted in the selection of the following weeks for exploratory analysis, as summarized in Table 3.

Table 3. Summary of the weeks that were selected for exploratory analysis.

Week	Start–End	Description
W1	4 January 2021–10 January 2022	Week with the third lowest minimum temperature in the considered winter periods (−1.6 °C), the coldest average temperature of the considered winters, and the highest sum of HDH.
W2	16 November 2020–22 November 2020	Week with an average temperature close to the average of the weekly mean temperatures of the winter period (±0.5 °C), although with a minimum temperature slightly lower than the mean of the weekly minimums (±1.1 °C). Similar to the weekly average HDH (±10%).
W3	11 July 2022–17 July 2022	Week with the hottest maximum temperature of the studied summers, at 39.8 °C, and hottest week of the analyzed period by average temperature (24.91 °C). It was also the week with the highest accumulated CDH. It was also the week with the highest recorded radiation.
W4	28 June 2021–4 July 2021	Fourth week closest to the average of the mean weekly temperatures (±0.2 °C), and very close to the mean CDH (±5%). Although it presented a higher max temperature than the weekly average max (+5 °C), it was chosen because there were data available for two laundry spaces.
W5	12 September 2022–18 September 2022	Week with the highest number of tropical nights (2) in the studied summers.

The following paragraphs explain the results that were obtained through exploration of the selected weeks and observation of the graphs.

3.2.1. Week 1: A Cold Winter Week

The mean outdoor temperature for this week was 3.0 °C, and the third lowest temperature of the studied period was recorded in this week (−1.6 °C). It was also the week with the second-largest HDH15.5 = 2094 °C·h. The maximum outdoor temperature recorded this week was below the 10 °C mark. There were a couple of nights where the exterior temperature bordered or fell below 0 °C, but the temperatures usually remained within the 0–10 °C range. Exterior relative humidity stayed in the 60 to 100% range. There were three clear days where radiation maxed out at 300–400 W/m^2 and four cloudy days where it topped at 100 or 150 W/m^2. The sum of global horizontal graduation of W1 was 7.74 kWh/m^2. Figure 6 shows the monitored data for this cold week of winter.

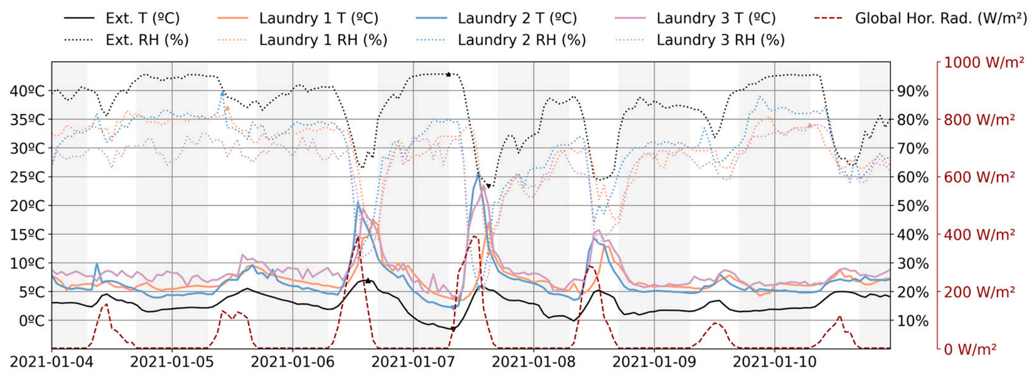


Figure 6. W1, a cold winter week. Exterior and laundry spaces' temperature and relative humidity graph during week 1 of the exploratory analysis.

The average temperatures of laundry 1, laundry 2, and laundry 3 were 7.3 °C, 7.0 °C, and 8.5 °C, respectively, which are 4 to 5.5 °C higher than the exterior average. The minimum temperatures recorded in the laundry spaces (marked in the figure with colored triangular indicators) showed a similar offset from the exterior temperature curve. During most of the week, the laundry temperatures did not go below 5 °C. In the coldest days, it can be seen that the minimum temperature of the laundries was higher than the maximum outdoors. During the sunny days, Wednesday–Friday, it can be observed that the effect of solar radiation decoupled the exterior and the laundries' temperature curves, with peaks of 20 and 25 °C reached in these spaces, respectively, even if the outdoor temperature barely reached 5 °C.

The range of relative humidity recorded in the laundries mostly went from 40 to 85%, with exceptional dryness observed when the sun heats the space and RH reaches minimums of around 20%. The average RH in the three studied spaces was 66.7%, 68.3%, and 63.1%, which was around 20% lower than the mean exterior relative humidity during this week (82.2%).

3.2.2. Week 2: A Typical Winter Week

The selected week had an outdoor average temperature (9.41 °C) very close to that of the considered winter weeks (9.86 °C) and a weekly minimum temperature of 1.9 °C. The number of degree hours calculated on the base of 15.5 °C (60 °F) was 1081.3 (average of the period: 964; median: 999; and max: 2094). The maximum temperature reached outdoors was slightly over 21 °C (Wednesday) but remained below that for the rest of the week. Outdoor temperatures typically lied between 5 and 15 °C, with a couple of hotter days, and relative humidity stayed in the range of 50–100%. The recorded data for this week can be seen in Figure 7, in which the downward trend in outdoor temperature can be seen through the end of the week. Radiation-wise, there were mostly clear days, with a cloudier day in the middle of the week, Thursday 19. The total weekly horizontal radiation was 14.22 kWh/m^2.

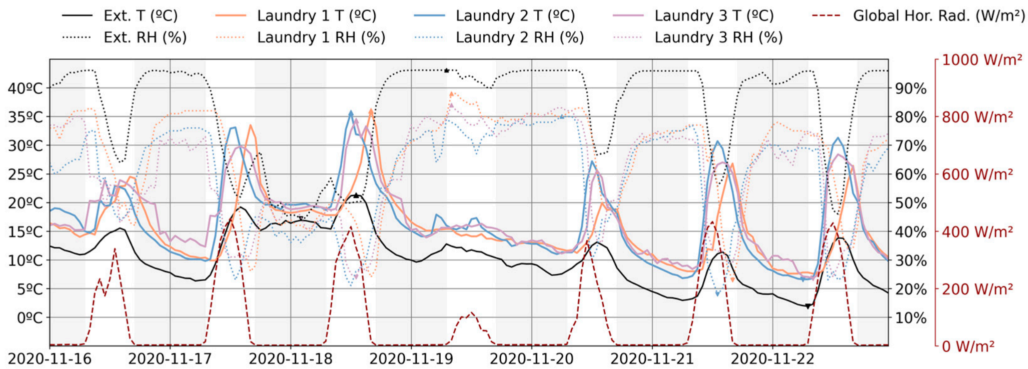


Figure 7. W2, a typical winter week. Temperature, RH, and radiation plot.

This week allowed us to compare days with different outdoor temperatures but similar radiation profiles, as Tuesday, Wednesday, Friday, Saturday, and Sunday had relatively comparable sums of global radiation. The average laundry temperatures were 15.1, 16.2, and 16.6 °C for laundry 1, laundry 2, and laundry 3, respectively, which are 5.5 to 7.5 °C higher than the exterior average. In days with little radiation, the offset between the temperature and relative humidity curves of the laundry and the exterior are consistent during the day and night. When the sun shined, however, the laundries heated up to 30 or 35 °C. It can be observed that in days with similar radiation but lower temperatures, the maximum temperature reached in the laundries was lower, but it was still 10–15 °C higher than the exterior.

Relative humidity acted similarly to what was observed in W1, with average values of 64.0%, 57.6%, and 59.8%, which was 20–25% lower than the outdoor average RH (82.6%). During the peaks in temperature, relative humidities as low as 20–25% were recorded in all three laundry rooms.

3.2.3. Week 3: A Hot Summer Week

The average outdoor temperature in the selected hot week was 24.91 °C, with a maximum exterior temperature of 39.4 °C. During this week, there were three days with extremely high maximum temperatures (>35 °C). The lowest recorded outdoor temperature was 14.9 °C. Relative humidity stayed in the range of 50–100% during the milder days of the week but was lower in the warmer days. The cooling degree hours of the selected week were the highest of the period at 475 Celsius degree hours (weekly average: 45; median: 18). This was the week with the highest amount of solar radiation (52.97 kWh/m^2), with all days exceeding 800 W/m^2 at midday. Figure 8 displays the monitored data for week 3.

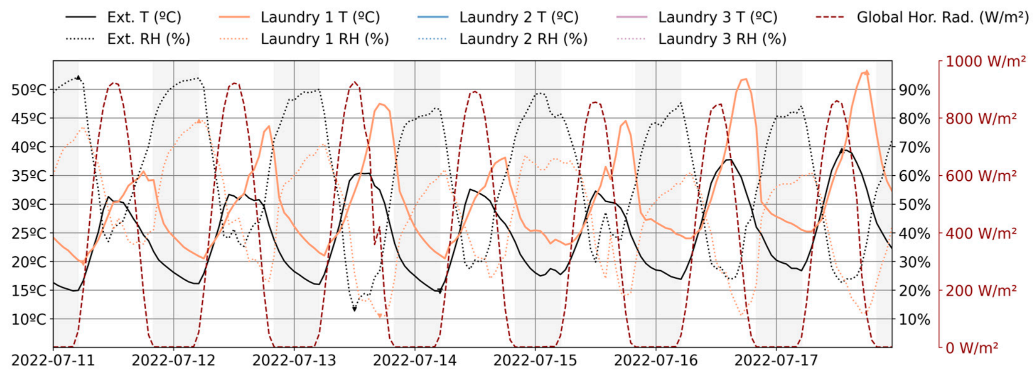


Figure 8. W3, a hot week during the summer. Temperature, RH, and radiation graph.

For this week, there were only data for laundry 1. It had an average temperature of 30.9 °C and a mean RH of 45.4%, which is 6 °C higher and 14% lower than the outdoor averages, respectively. The maximum temperature of laundry 1 was recorded during this week, at 53.0 °C, on Sunday, when the maximum outdoor temperature was 39.4 °C. On Saturday, temperatures over 50 °C were also recorded in laundry 1. A time offset between laundry temperature and exterior temperature can be observed in the graph above (Figure 8). The difference between outdoor max and laundry maximum ranged from 5 to 15 °C. During the whole week, the temperature at laundry 1 barely went lower than 20 °C, with some nights not going below 25 °C.

3.2.4. Week 4: A Typical Week in the Summer

The search for a typical summer week led to the selection of this last week of June 2021, with an average temperature of 19.1 °C, which is very close to the average of weekly mean temperatures (18.8 °C). The average of weekly max temperatures of the summer periods was 29.4 °C, and W4 had a maximum of 34.1 °C, which is higher. Exterior RH ranged from 50 to 90%. There was a mix of more and less sunny days, with some days being clear throughout and others only during the morning or afternoon. The sum of the weekly global horizontal radiation was 38.75 kWh/m^2. The weekly sum of CDH was 43, just close to the average of 45. Figure 9 shows the recorded data available for this week (laundries 1 and 3).

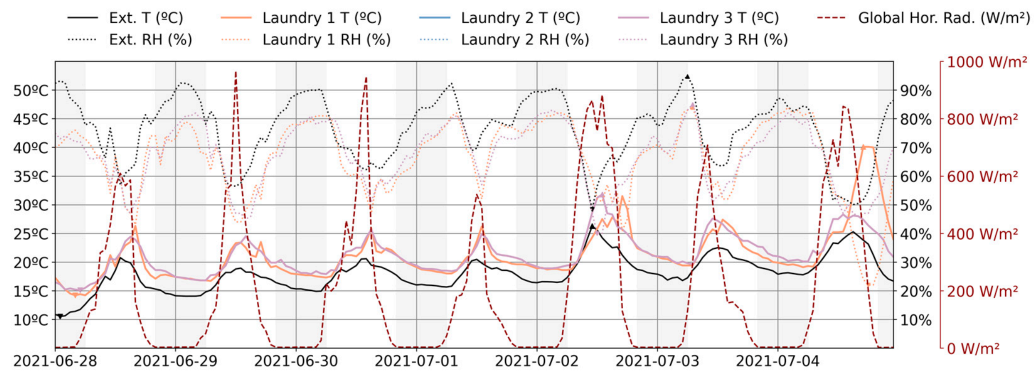


Figure 9. W4, a typical week of summer. Temperature, RH, and radiation graph.

The average recorded temperature was 22.4 °C and 22.3 °C for laundries 1 and 3, respectively. The temperature curves for both laundries was parallel until Sunday afternoon, when the temperature recorded at laundry 1 rose to 40 °C. The maximum temperatures recorded in the laundries were milder, in the 25 to 32 °C range. Relative humidity mostly stayed within the 40–80% range.

3.2.5. Week 5: A Summer Week with Limited Night Cooling

The criteria to look for a week with possible summer discomfort resulted in the selection of a week at the end of summer, just before the beginning of autumn. Monday and Tuesday were two relatively hot days, with the particularity that the nights were warmer than usual and the temperature did not drop as much as it normally does, as can be seen in comparison with W4. Both nights can be considered 'tropical nights' since the temperature did not go below 20 °C. The maximum recorded temperature of this week was 34.0 °C, with an average of 20.87 °C. Temperatures can be seen to take a downward trend towards the end of the week. Exterior relative humidity had a quite a big range, from 30% to 100%. Figure 10 shows the evolution of temperature and RH during W5.

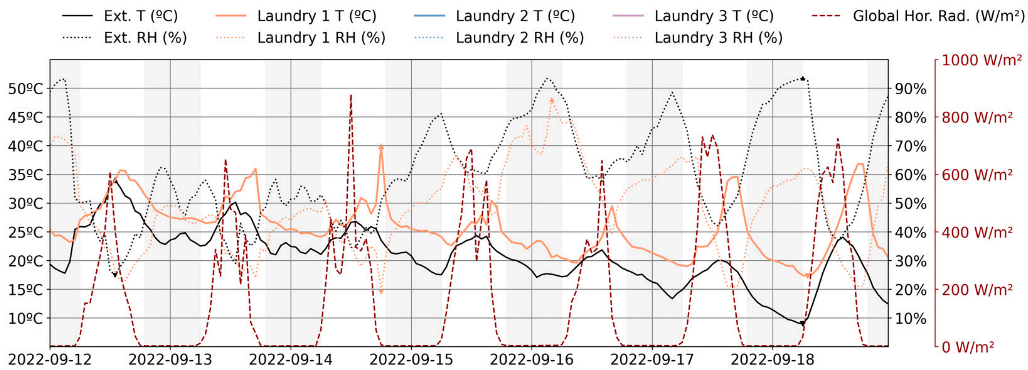


Figure 10. Temperature, RH, and radiation graph for W5.

During this week, the temperature of the laundry room reached a maximum of 39.9 °C, and the minimum temperature was 8 °C higher than the minimum temperature recorded in Abusu. For several days, the maximum temperature recorded in laundry 1 exceeded 35 °C. The temperature of the laundry can be seen to accompany the downward trend of the exterior temperature, although the difference becomes wider. Relative humidity, especially at the beginning of the week, was particularly low. During the tropical nights, the temperature of laundry 1 barely managed to drop below 25° C, maintaining the usual distance from the outside temperature.

3.3. Results of the Quantitative Analysis

Table 4 summarizes the analysis carried out on the temperature data taken in laundry spaces 1, 2, and 3.

It can be seen that the average temperatures obtained are similar in the three spaces, although slightly lower in laundry 1. However, higher maximum temperatures were recorded. Tables A3, A5 and A7 complete the data. On the one hand, the mild average temperatures recorded in the spaces studied are striking, as well as the very high maximum temperatures (equal to or greater than 30 °C) recorded during the winter. Figure 11 shows the air temperature distributions for the available data, year by year. The horizontal axis displays the air temperature scale, while the vertical axis represents the relative frequency, in unitary terms. It can be seen that the analyzed phenomenon materializes in a shift to the right (higher temperature) of the distributions corresponding to the laundries, with respect to that outside. To interpret these graphs, the composition of the data must be taken into account (laundry 2 does not have data from March or May to October, for example).

Table 4. Summary of the average, minimum, and maximum air temperatures (°C) recorded in the monitored spaces.

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Overall
Laundry 1														
2020	Avg. T (°C)								23.59	22.37	16.45	16.83	11.85	17.88 [1]
	Min. T (°C)								15.0	11.9	7.8	7.5	5.3	5.3 [1]
	Max. T (°C)								46.5	48.0	35.4	36.0	26.1	48.0 [1]
2021	Avg. T (°C)	10.74	14.78	14.64	16.07	17.18	20.98	21.78	22.06	22.98	18.88	12.24	13.48	17.16
	Min. T (°C)	3.5	8.3	5.5	6.0	8.9	12.0	14.5	14.8	14.9	9.8	5.8	4.9	3.5
	Max. T (°C)	27.8	33.8	42.4	38.8	40.1	46.8	42.3	42.4	41.3	40.1	32.4	34	46.8
2022	Avg. T (°C)	11.47	12.89	14.91	15.08	19.89	21.81	25.03	24.60	22.70	22.15	15.78	14.37	18.43
	Min. T (°C)	2.3	4.4	7.7	4.9	11.7	13.3	12.5	15.9	12.8	12.8	7.8	5.8	2.3
	Max. T (°C)	31.0	35.6	34.8	40.8	45.4	48.8	53.0	45.5	48.0	40.7	36.6	30.1	53.0
Laundry 2														
		Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Total**
2019	Avg. T (°C)												14.12	14.12 [1]
	Min. T (°C)												4.1	4.1 [1]
	Max. T (°C)												34.6	34.6 [1]
2020	Avg. T (°C)	13.19	16.56								17.55	17.86	12.62	16.60 [1]
	Min. T (°C)	3.8	5.7								7.5	6.6	5.8	3.8 [1]
	Max. T (°C)	31.2	33.1								34.5	35.7	30.7	35.7 [1]
2021	Avg. T (°C)	11.07	15.52	15.06	21.99						19.83			15.45 [1]
	Min. T (°C)	2.1	8.2	4.2	6.8						9.7			2.1 [1]
	Max. T (°C)	32.3	32.3	34.3	27.9						36.9			36.9 [1]
Laundry 3														
		Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Total**
2020	Avg. T (°C)									23.08	17.65	18.43	13.74	19.95 [1]
	Min. T (°C)									13.1	9.8	6.8	7.2	6.8 [1]
	Max. T (°C)									31.3	33.7	34.3	31	34.3 [1]
2021	Avg. T (°C)	12.20	16.06	15.56	16.24	17.43	20.89	21.84	22.54	23.62	19.82			18.62 [1]
	Min. T (°C)	3.9	9.0	6.2	5.3	8.9	12.5	15.1	15.5	15.2	10.5			3.9 [1]
	Max. T (°C)	29.6	32.4	35.0	30.4	33.4	36.9	35.2	35.1	42.7	37.6			42.7 [1]

[1] Incomplete period.

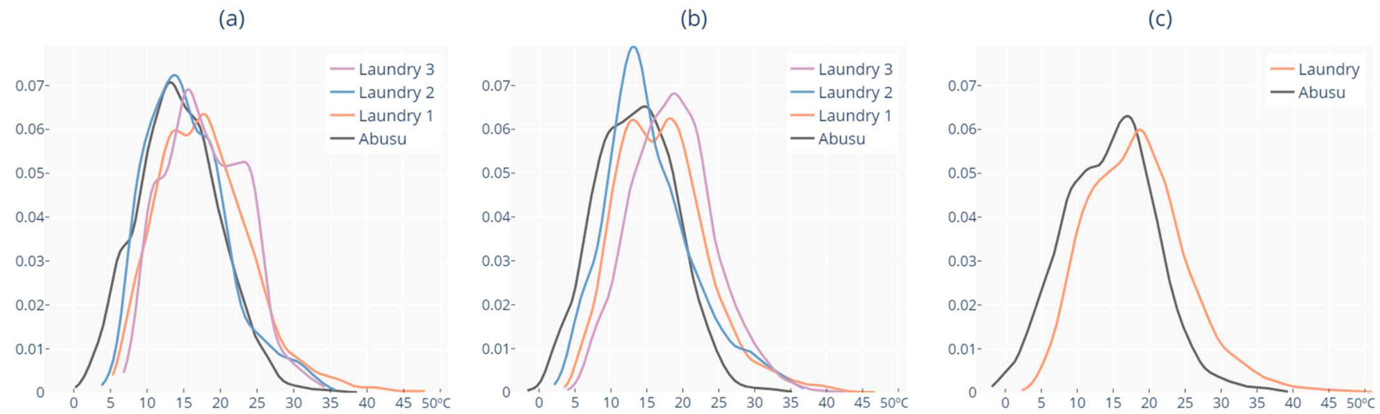


Figure 11. Exterior laundry spaces and outdoor temperature distribution comparison plot for the monitored periods: 2020 (**a**); 2021; (**b**) and 2022 (**c**). All available data are plotted. Source: authors.

Table 5 summarizes, in an equivalent manner, the relative humidity data recorded on laundry 1, laundry 2, and laundry 3:

Table 5. Summary of the average, minimum, and maximum relative humidity RH (%) recorded in the monitored spaces.

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Overall
Laundry 1														
2020	Avg. RH (%)								65.07	61.41	69.74	60.73	68.28	65.1 [1]
	Min. RH (%)								6	13	24	23	27	6 [1]
	Max. RH (%)								90	96	97	89	100	100 [1]
2021	Avg. RH (%)	69.20	61.03	58.38	55.07	62.50	67.25	67.72	68.04	65.56	62.66	75.32	65.98	64.91
	Min. RH (%)	27	17	7	11	19	18	21	17	23	16	19	19	7
	Max. RH (%)	95	94	96	91	91	93	92	92	91	91	100	98	100
2022	Avg. RH (%)	64.67	58.10	62.75	62.60	67.40	59.40	66.01	58.19	57.63	64.23	63.94	64.67	62.36
	Min. RH (%)	3	12	14	12	19	11	19	10	15	18	15	3	3
	Max. RH (%)	92	90	91	89	93	90	94	94	90	92	93	92	94
Laundry 2														
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
2019	Avg. RH (%)												61.16	61.16 [1]
	Min. RH (%)												15	15 [1]
	Max. RH (%)												91	91 [1]
2020	Avg. RH (%)	59.01	56.54								63.17	54.68	62.51	59.53 [1]
	Min. RH (%)	16	20								22	18	20	16 [1]
	Max. RH (%)	91	84								89	82	88	82 [1]
2021	Avg. RH (%)	66.09	56	54.47	22.41						57.14			57.95 [1]
	Min. RH (%)	17	16	10	15						17			10 [1]
	Max. RH (%)	94	84	84	76						83			76 [1]
Laundry 3														
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
2020	Avg. RH (%)									62.06	66.49	56.68	62.13	62.31 [1]
	Min. RH (%)									30	23	22	20	20 [1]
	Max. RH (%)									86	89	84	84	89 [1]
2021	Avg. RH (%)	64.27	57.55	55.53	54.07	62.50	68.34	68.47	67.08	64.33	60.79			59.65 [1]
	Min. RH (%)	17	20	12	15	25	31	29	26	22	19			12 [1]
	Max. RH (%)	91	87	85	85	87	88	89	91	85	87			91 [1]

[1] Incomplete period.

These data are completed in Tables A4, A6 and A8 in Appendix A. If the relative humidity data are plotted as a distribution (Figure 12), the crunching effect that occurs when heating the outside air in the laundry rooms can be observed. This results in a relatively drier microclimate compared to the high relative humidity of the Abusu meteorological station. This is to be expected as a consequence of the increase in temperature, as the amount of absolute humidity in the air remains similar.

The data presented in Table 6 offer a comprehensive overview of the monthly temperature differences between monitored laundry 1 and the Abusu station over a span of three years, from August 2020 to December 2022. Each of the columns presents the difference between the enunciated measurement in laundry 1 and the same measure in the exterior. The column "average daily minimum", for instance, contains the difference between the average daily minimum temperature recorded each month in laundry 1 minus the average daily minimum temperature measured at Abusu.

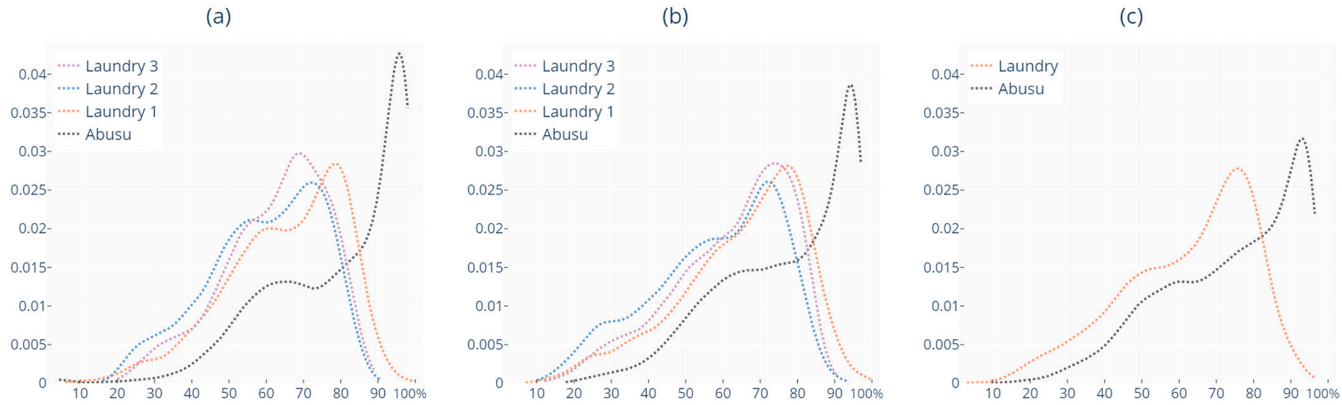


Figure 12. Exterior laundry spaces and outdoor relative humidity distribution comparison plot for the monitored periods: 2020 (**a**); 2021; (**b**) and 2022 (**c**). All available data are plotted. Source: authors.

This calculation allows us to calculate the variation in average temperature between +2.69 °C and +4.75 °C in the case of laundry 1. The monthly absolute minimum temperature varies similarly but slightly higher, with some outliers such as September 2021, a month in which the minimum temperature recorded was 11.3 °C higher than the outdoors.

The absolute maximum temperature was also always higher in laundry 1 than outdoors, specifically between +5.65 and +15.12 °C. It is notable that all the differences were positive; that is, there was no month in the monitoring period in which the outside was warmer than laundry 1 for any of the measurements presented, neither in the average temperature nor in the absolute monthly maximums, etc.

As expected from the evolution of temperatures, the difference between relative humidities was mostly negative, as shown in Table 7. With some exceptions, the measured relative humidity was lower, with a difference between the means of between −8% and −14%.

Repeating the same analysis for laundry 2 (Table 8), differences are obtained between the monthly average temperatures of the order of +3.60 to +5.68 °C and differences between the maximums of between +5.90 and +13.08 °C, consistent with what was measured in laundry 1. The difference between the minimum temperatures is also positive and similar to what was previously mentioned. The difference between RH also remains consistent (Table 9). The fact that the difference between the monthly maximum temperatures is greater than the difference between the monthly minimum temperatures is similar to that observed in the exploratory analysis in Section 3.2.

Table 10 contains the same analysis for the period from September 2020 to October 2021 for laundry 3. The difference between the means was between +3.57 °C and +5.67 °C. The difference between the maximum temperatures shows in the case of laundry 3 a different behavior between the winter and summer, with differences of +10 °C during the coldest months, but a much smaller difference between May and September. This pattern is shown more clearly in this case than in laundry 1; it is not noticeable in laundry 2 because there were no data available for the summer period. Table 11 shows the difference in relative humidity between laundry 3 and Abusu.

Table 12 presents a time-based analysis. Firstly, it compares the temperatures measured in each laundry with those outside to quantify during which part of the monitored time the laundries were colder, the same, or warmer than the outside. Then, it segments the temperature differences into 2 °C steps.

Table 6. Monthly temperature difference (ΔT) between the monitored laundry 1 and the Abusu station, August 2020–December 2022.

	2020					2021					2022				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						+3.26 °C	+5.23 °C	+8.58 °C	+3.78 °C	+4.71 °C	+4.56 °C	+4.27 °C	+9.55 °C	+4.40 °C	+9.32 °C
Feb.						+2.69 °C	+3.73 °C	+11.82 °C	+3.53 °C	+4.83 °C	+4.24 °C	+4.42 °C	+15.85 °C	+5.03 °C	+7.53 °C
Mar.						+4.02 °C	+5.43 °C	+14.00 °C	+4.67 °C	+7.99 °C	+3.31 °C	+3.60 °C	+12.85 °C	+3.54 °C	+6.30 °C
Apr.						+4.54 °C	+4.94 °C	+14.03 °C	+4.70 °C	+9.01 °C	+3.67 °C	+4.13 °C	+14.92 °C	+3.54 °C	+7.23 °C
May						+3.60 °C	+4.93 °C	+10.48 °C	+4.19 °C	+6.23 °C	+3.54 °C	+4.70 °C	+13.08 °C	+3.63 °C	+6.38 °C
Jun.						+3.66 °C	+3.48 °C	+13.30 °C	+3.83 °C	+5.76 °C	+3.39 °C	+4.13 °C	+10.20 °C	+3.29 °C	+5.31 °C
Jul.						+3.51 °C	+4.38 °C	+7.56 °C	+3.51 °C	+6.36 °C	+4.23 °C	+4.20 °C	+13.20 °C	+4.06 °C	+7.30 °C
Aug.	+3.56 °C	+5.57 °C	+7.73 °C	+3.92 °C	+5.03 °C	+3.59 °C	+3.90 °C	+13.87 °C	+3.43 °C	+6.61 °C	+3.61 °C	+3.20 °C	+8.30 °C	+4.12 °C	+5.58 °C
Sep.	+4.43 °C	+11.30 °C	+11.90 °C	+4.67 °C	+7.64 °C	+4.27 °C	+4.20 °C	+5.53 °C	+4.60 °C	+6.24 °C	+4.72 °C	+4.80 °C	+10.50 °C	+5.16 °C	+7.19 °C
Oct.	+3.17 °C	+3.28 °C	+12.06 °C	+3.73 °C	+5.07 °C	+4.74 °C	+4.51 °C	+13.86 °C	+4.23 °C	+9.88 °C	+3.96 °C	+3.55 °C	+13.12 °C	+4.07 °C	+7.64 °C
Nov.	+4.35 °C	+5.78 °C	+12.53 °C	+4.52 °C	+8.64 °C	+3.09 °C	+2.87 °C	+14.40 °C	+3.25 °C	+5.43 °C	+3.78 °C	+3.37 °C	+15.12 °C	+4.09 °C	+5.82 °C
Dec.	+2.54 °C	+3.67 °C	+5.65 °C	+3.39 °C	+3.68 °C	+3.28 °C	+4.03 °C	+12.14 °C	+3.69 °C	+7.02 °C	+2.97 °C	+3.89 °C	+8.47 °C	+3.87 °C	+5.08 °C

Table 7. Monthly relative humidity difference between the monitored laundry 1 and the Abusu station, August 2020–December 2022.

	2020					2021					2022				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						−11.1%	−4.2%	−1.3%	−7.7%	−12.2%	−14.3%	−13.6%	0.9%	−16.7%	−14.2%
Feb.						−7.1%	−4.1%	−2.1%	−8.2%	−12.1%	−13.5%	−2.3%	−4.3%	−11.6%	−14.5%
Mar.						−11.2%	−9.6%	−0.1%	−10.3%	−15.5%	−9.5%	−13.8%	−5.9%	−9.9%	−12.8%
Apr.						−13.1%	−9.9%	−5.3%	−13.0%	−17.9%	−12.0%	−10.6%	−5.2%	−12.2%	−13.6%
May						−12.0%	−8.3%	−5.2%	−11.3%	−14.6%	−10.9%	−12.5%	−7.2%	−10.9%	−13.5%
Jun.						−11.8%	−14.1%	−3.9%	−12.1%	−12.1%	−10.1%	−0.4%	−3.3%	−10.8%	−9.0%
Jul.						−11.0%	−7.6%	−4.3%	−13.1%	−11.4%	−10.8%	−1.0%	−6.0%	−10.4%	−13.4%
Aug.	−11.6%	−6.2%	−6.3%	−7.6%	−12.4%	−11.1%	−21.0%	−5.3%	−12.3%	−12.0%	−9.1%	−3.0%	−3.0%	−9.3%	−11.1%
Sep.	−11.5%	7.2%	−0.3%	−7.0%	−12.5%	−14.3%	−4.6%	−6.4%	−11.9%	−14.1%	−13.4%	−6.0%	−3.0%	−10.3%	−16.0%
Oct.	−11.6%	−10.2%	0.7%	−9.6%	−10.6%	−16.0%	−19.2%	−5.9%	−17.8%	−14.5%	−13.0%	−6.0%	−6.4%	−14.4%	−14.8%
Nov.	−13.9%	−17.1%	−7.2%	−16.6%	−15.4%	−11.6%	−23.0%	2.9%	−12.1%	−8.6%	−14.0%	−12.3%	−4.2%	−10.7%	−13.7%
Dec.	−8.0%	−10.2%	3.8%	−5.6%	−10.0%	−9.8%	−9.8%	1.7%	−12.8%	−13.0%	−9.9%	1.9%	−3.1%	−10.8%	−12.7%

Table 8. Monthly ΔT between laundry 2 and the exterior, 2020–2021.

	2020					2021				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						+3.60 °C	+3.83 °C	+13.08 °C	+3.39 °C	+6.76 °C
Feb.						+3.43 °C	+3.63 °C	+10.32 °C	+3.57 °C	+5.79 °C
Mar.						+4.44 °C	+4.13 °C	+5.90 °C	+4.21 °C	+6.86 °C
Apr.										
May										
Jun.										
Jul.										
Aug.										
Sep.										
Oct.	+4.26 °C	+2.98 °C	+11.16 °C	+3.84 °C	+6.48 °C					
Nov.	+5.38 °C	+4.88 °C	+12.23 °C	+4.32 °C	+10.54 °C					
Dec.	+3.31 °C	+4.17 °C	+10.25 °C	+3.37 °C	+6.55 °C					

Table 9. Monthly RH difference between the monitored laundry 2 and the exterior, 2020–2021.

	2020					2021				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						−14.2%	−14.2%	−2.3%	−13.5%	−13.1%
Feb.						−12.2%	−5.1%	−12.1%	−11.7%	−17.0%
Mar.						−15.1%	−6.6%	−12.1%	−10.8%	−19.5%
Apr.										
May										
Jun.										
Jul.										
Aug.										
Sep.										
Oct.	−18.2%	−12.2%	−7.3%	−15.1%	−17.2%					
Nov.	−19.9%	−22.1%	−14.2%	−21.8%	−20.2%					
Dec.	−13.8%	−17.2%	−8.2%	−12.1%	−16.0%					

The temperature of laundry 1 was higher than that outside for 91.2% of the time. The temperature of laundry 2 exceeded that of the outside during 99.7% of the monitored time, while in laundry 3, this happened 97.5% of the time, if we consider the entirety of each dataset.

To analyze whether the measured difference remains the same during the day as well as at night, Figure 13 shows the distributions of temperature and relative humidity during the daytime and nighttime for all the data available in each laundry.

As can be seen, the difference (horizontal displacement in the graph) is maintained between the day and the night, although in the case of laundry 2, which does not have data for the summer months, a smaller difference is observed. It is noticeable, however, that the tail of the distribution on the lower temperature side shifts to the right, indicating a tempering of the cooler parts of the outdoor climate.

In terms of relative humidity, there is a noticeable difference between the day and the night, which is more humid. While the nights in the Abusu data are concentrated between 80% and 100% relative humidity, the laundries generally range between 60% and 90%. In the case of the daytime, the relative humidity curve shifts to the left (reduction) and the 80–100% part of the distribution practically disappears.

Table 10. Monthly ΔT between laundry 3 and the exterior, 2020–2021.

	2020					**2021**				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						+4.73 °C	+5.63 °C	+10.38 °C	+4.66 °C	+7.20 °C
Feb.						+3.97 °C	+4.43 °C	+10.42 °C	+4.57 °C	+6.35 °C
Mar.						+4.94 °C	+6.13 °C	+6.60 °C	+5.14 °C	+6.86 °C
Apr.						+4.71 °C	+4.24 °C	+5.63 °C	+4.88 °C	+6.11 °C
May						+3.85 °C	+4.93 °C	+3.78 °C	+4.42 °C	+4.54 °C
Jun.						+3.57 °C	+3.98 °C	+3.40 °C	+3.86 °C	+4.14 °C
Jul.						+3.56 °C	+4.98 °C	+0.46 °C	+3.70 °C	+4.23 °C
Aug.						+4.08 °C	+4.60 °C	+6.57 °C	+3.86 °C	+5.54 °C
Sep.	+5.14 °C	+12.50 °C	−4.80 °C	+8.69 °C	+0.80 °C	+4.91 °C	+4.50 °C	+6.93 °C	+4.79 °C	+6.59 °C
Oct.	+4.36 °C	+5.28 °C	+10.36 °C	+4.35 °C	+6.11 °C	+5.67 °C	+5.21 °C	+11.36 °C	+4.67 °C	+9.10 °C
Nov.	+5.95 °C	+5.08 °C	+10.83 °C	+5.20 °C	+10.00 °C					
Dec.	+4.43 °C	+5.57 °C	+10.55 °C	+4.56 °C	+7.32 °C					

Table 11. Monthly RH difference between laundry 3 and the exterior, 2020–2021.

	2020					**2021**				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						−16.0%	−14.2%	−5.3%	−14.1%	−15.7%
Feb.						−10.6%	−1.1%	−9.1%	−10.8%	−16.0%
Mar.						−14.0%	−4.6%	−11.1%	−10.7%	−18.0%
Apr.						−14.1%	−5.9%	−11.3%	−10.4%	−18.8%
May						−12.0%	−2.3%	−9.2%	−7.5%	−14.9%
Jun.						−10.7%	−1.1%	−8.9%	−7.7%	−12.2%
Jul.						−10.3%	0.4%	−7.3%	−7.3%	−11.7%
Aug.						−12.0%	−12.0%	−6.3%	−11.0%	−12.6%
Sep.	−10.8%	+24.2%	−10.3%	10.7%	−21.3%	−15.6%	−5.6%	−12.4%	−11.1%	−15.8%
Oct.	−14.8%	−11.2%	−7.3%	−12.8%	−14.1%	−17.8%	−16.2%	−9.9%	−16.2%	−15.9%
Nov.	−17.9%	−18.1%	−12.2%	−18.8%	−18.6%					
Dec.	−14.2%	−17.2%	−12.2%	−13.0%	−17.5%					

Figure 14 presents a month-by-month comparison of daytime temperatures over the year 2021 using a box-and-whisker plot. It can be seen that the three laundries function more or less equivalently, although laundries 2 and 3 tend to be slightly warmer than laundry 1, overall.

Table 13 presents the median values calculated on a month-by-month basis for the three laundries and the outdoor data, which corresponds to what is depicted in Figure 14. It also presents the MAD calculations for the daytime and nighttime time periods on a month-by-month basis.

Figure 15 presents a month-by-month comparison of nighttime temperatures over the year 2021 using the same box-and-whisker plot as before. In 2021, there was no relative warming observed between the monitored laundry spaces and the outdoors. However, the effect begins to be felt in February and March and becomes more pronounced during the summer, when the lower boundary of the third quartile of the laundries tends to coincide with the upper boundary of the second quartile.

Table 14 presents the results of the temperature and time analysis applied to the daytime hours.

Table 12. Laundry and Abusu station temperature comparison in terms of percentage of time.

Laundry 1									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	3.3%	5.4%	91.2%	69.9%	35.4%	16.5%	8.8%	5.1%	3.1%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	3.3%	6.4%	90.3%	68.3%	35.6%	15.4%	8.4%	4.8%	2.9%
2021	3.0%	5.2%	91.8%	69.9%	33.6%	15.8%	8.5%	5.0%	2.9%
2022	3.6%	5.3%	91.1%	70.5%	37.3%	17.6%	9.1%	5.3%	3.3%
Laundry 2									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	0.0%	0.3%	99.7%	84.8%	38.7%	18.4%	10.4%	6.3%	4.1%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	0.0%	0.3%	99.7%	83.7%	39.0%	19.0%	10.5%	6.4%	4.3%
2021 [1]	0.0%	0.2%	99.8%	87.7%	40.0%	18.5%	10.1%	5.8%	3.5%
Laundry 3									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	1.0%	1.4%	97.5%	89.4%	55.3%	19.7%	8.2%	4.0%	1.5%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	2.4%	1.3%	96.3%	87.4%	58.6%	26.4%	13.8%	7.2%	2.9%
2021 [1]	0.5%	1.5%	98.0%	90.2%	54.1%	17.1%	6.1%	2.7%	0.9%

[1] Incomplete year (not a full natural year).

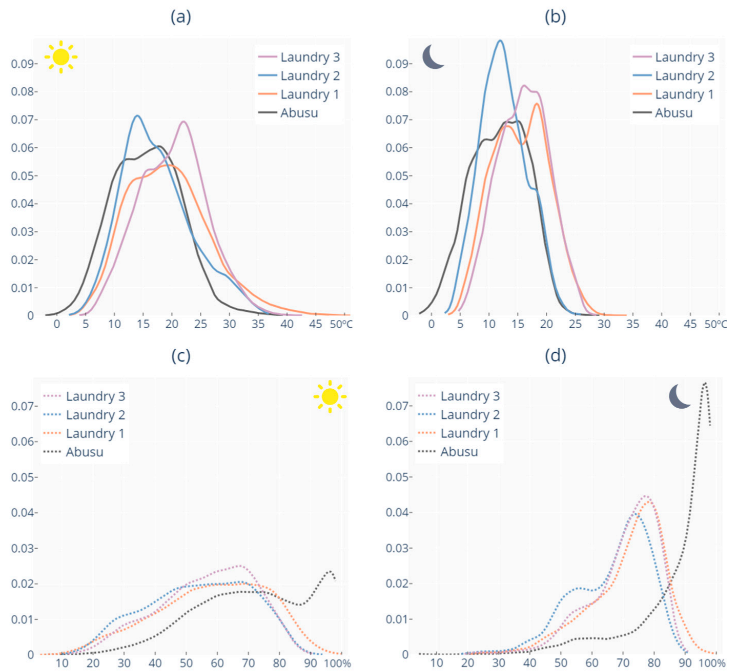


Figure 13. Temperature distributions of all the studied laundries during the daytime (**a**) and the nighttime (**b**), and relative humidity distributions of the daytime (**c**) and the nighttime (**d**). All available data are plotted.

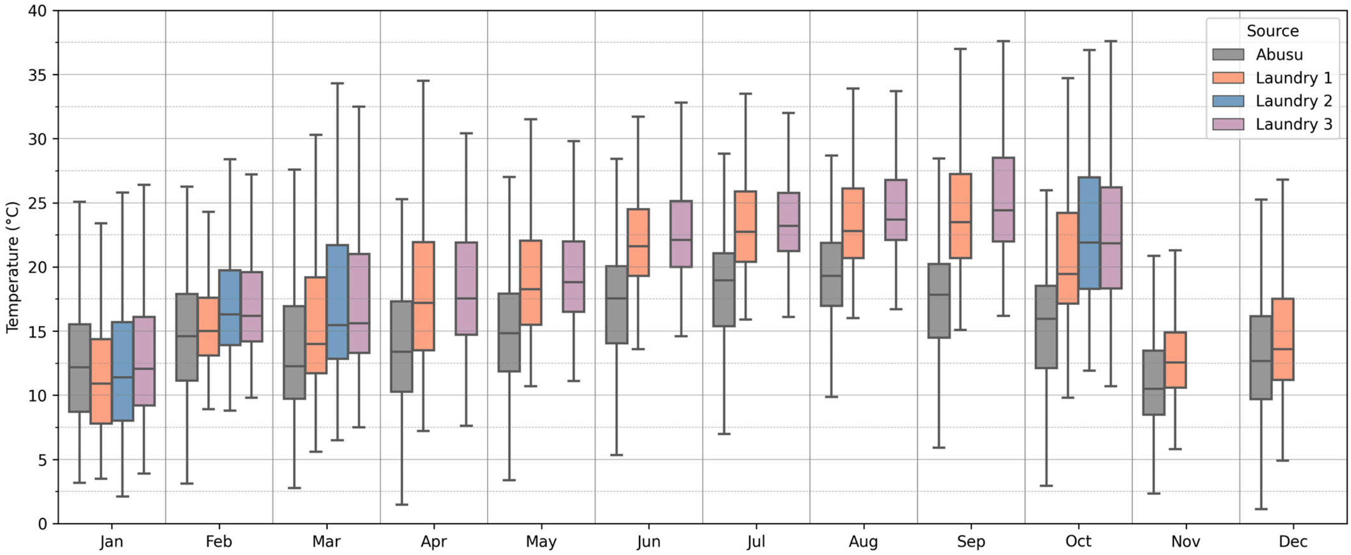


Figure 14. Monthly temperature comparison—daytime.

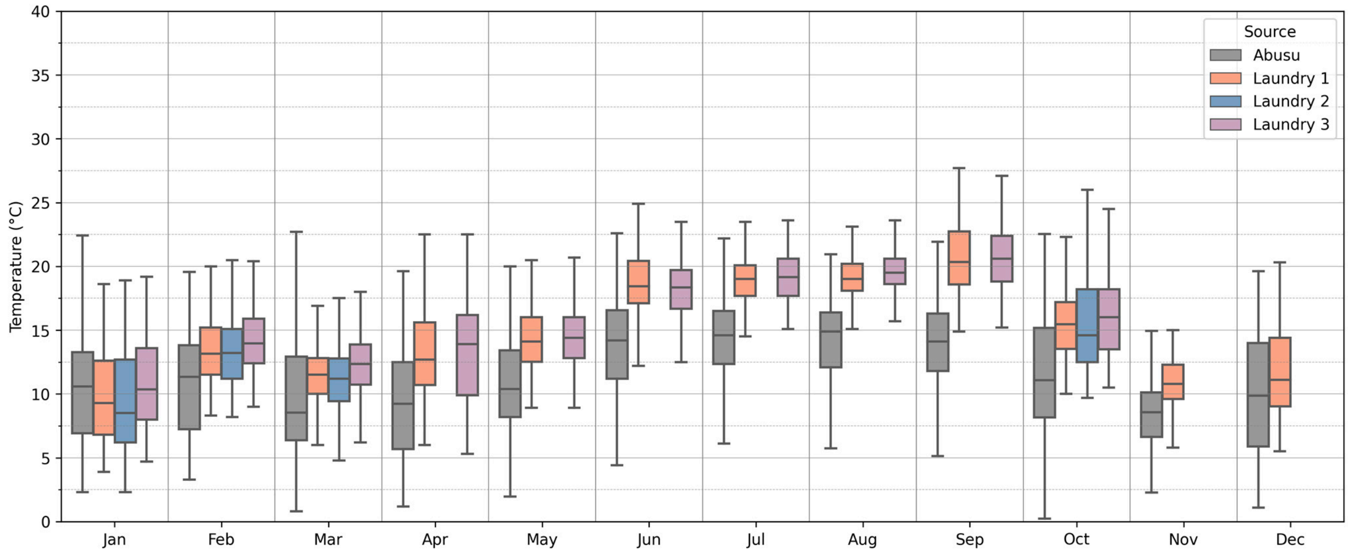


Figure 15. Monthly temperature comparison—nighttime.

Table 15 presents the same for nighttime hours.

As explained in Section 2.3, a correlation analysis was carried out between the outdoor temperature and the temperature in the laundries and between the sum of the daily radiation and the maximum temperature reached in the laundries on each day. Figure 16 presents this correlation analysis graphically, as well as the calculated coefficients.

The graph on the left shows the correlation between the outdoor temperature and the air temperature recorded in our monitoring campaign. If the project's assumption that these studied spaces were a perfect exterior were true, the Pearson's coefficient would be unity (r = 1). The calculated PCCs were, however, 0.58 and 0.57 for laundries 1 and 3, respectively. For laundry 2, with more biased data, without summer, an r = 0.47 value was obtained. The correlation is, however, positive and moderate.

Positive Pearson coefficients were also obtained for the comparison between the daily sum of radiation and the maximum daily temperature reached, although with more moderate values.

Table 13. Monthly day/night median comparison and MAD comparison between the three monitored laundry spaces and the Abusu meteorological station.

Year	Month	Median								Mean Absolute Difference					
		Abusu		Laundry 1		Laundry 2		Laundry 3		Laundry 1		Laundry 2		Laundry 3	
		Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
2019	Dec.	13.43	9.56			15.25	11.20					+5.26	+3.31		
2020	Jan.	13.47	10.87			14.15	9.60					+4.23	+3.79		
	Feb.	12.41	9.79			17.80	12.90					+6.33	+4.47		
	Mar.	12.65	9.05			14.60	10.90					+7.36	+4.41		
	Apr.	15.45	12.48												
	May	17.88	12.67												
	Jun.	18.26	14.03												
	Jul.	20.98	16.04												
	Aug.	20.09	15.10	24.60	21.00					+5.01	+5.10				
	Sep.	18.34	13.99	23.95	19.40	20.50	17.40	23.50	23.30	+6.43	+5.19	+5.78	+5.38	+4.93	+7.10
	Oct.	14.55	11.29	17.35	14.30	18.85	14.75	18.70	15.20	+3.80	+3.45	+5.00	+3.60	+4.88	+4.03
	Nov.	13.04	11.13	17.90	14.60	19.30	14.70	20.20	15.80	+5.72	+4.47	+6.97	+4.48	+7.44	+5.08
	Dec.	12.05	10.06	11.60	10.85	12.95	10.40	13.80	11.80	+3.88	+3.25	+4.77	+3.24	+5.15	+3.85
2021	Jan.	12.16	10.59	10.90	9.30	11.40	8.50	12.05	10.35	+4.98	+4.35	+5.64	+4.39	+5.58	+4.55
	Feb.	14.60	11.35	15.00	13.15	16.30	13.20	16.20	13.95	+4.34	+3.60	+4.99	+3.55	+5.15	+4.18
	Mar.	12.25	8.54	14.00	11.50	15.45	11.20	15.60	12.35	+5.36	+4.62	+6.04	+4.33	+5.91	+5.06
	Apr.	13.39	9.24	17.20	12.70			17.55	13.90	+5.43	+4.87			+5.12	+4.86
	May	14.83	10.38	18.25	14.10			18.80	14.40	+4.89	+3.91			+4.90	+3.91
	Jun.	17.54	14.19	21.60	18.45			22.10	18.35	+6.03	+5.16			+6.09	+4.88
	Jul.	18.96	14.59	22.75	19.00			23.20	19.15	+6.52	+5.87			+6.34	+6.01
	Aug.	19.31	14.89	22.80	19.00			23.70	19.50	+5.99	+5.53			+6.38	+5.94
	Sep.	17.82	14.11	23.50	20.35			24.40	20.60	+7.62	+7.11			+8.62	+7.25
	Oct.	15.96	11.08	19.45	15.45	21.90	14.60	21.85	16.00	+6.17	+4.86	+7.57	+4.75	+7.18	+5.17
	Nov.	10.51	8.57	12.55	10.80					+3.65	+3.26				
	Dec.	12.66	9.86	13.60	11.10					+4.98	+4.20				
2022	Jan.	8.38	4.58	11.50	8.60					+6.07	+5.18				
	Feb.	12.08	7.75	13.20	10.40					+4.78	+4.19				
	Mar.	14.28	10.94	14.95	12.60					+4.61	+4.04				
	Apr.	13.93	10.88	16.10	12.90					+4.89	+4.06				
	May	18.07	13.74	20.80	16.75					+5.23	+4.17				
	Jun.	18.33	15.29	22.50	18.50					+6.07	+5.36				
	Jul.	21.24	16.58	26.00	20.90					+6.80	+6.08				
	Aug.	20.48	16.49	25.55	22.00					+6.74	+6.16				
	Sep.	17.20	12.70	23.70	20.45					+7.14	+6.90				
	Oct.	20.02	15.94	23.05	19.35					+5.46	+4.63				
	Nov.	12.26	9.92	15.90	13.50					+5.29	+3.74				
	Dec.	15.73	13.43	15.30	13.30					+4.24	+3.59				

Table 14. Laundry and Abusu station temperature comparison. Daytime hours (08:00–21:00 h).

Laundry 1—Daytime									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	5.3%	7.8%	86.8%	62.2%	33.3%	20.3%	13.3%	8.5%	5.3%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	5.2%	9.1%	85.7%	60.9%	33.0%	19.8%	12.4%	7.9%	5.0%
2021	4.9%	7.6%	87.6%	62.0%	31.7%	19.4%	13.0%	8.3%	5.0%
2022	5.9%	7.5%	86.5%	63.0%	35.1%	21.4%	13.9%	8.9%	5.7%
Laundry 2—Daytime									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	0.0%	0.1%	99.9%	88.0%	50.1%	28.4%	17.3%	10.7%	7.0%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	0.0%	0.2%	99.8%	87.0%	51.0%	28.3%	17.4%	10.9%	7.4%
2021 [1]	0.0%	0.0%	100.0%	91.2%	50.7%	29.3%	16.5%	9.8%	5.9%
Laundry 3—Daytime									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	1.7%	2.0%	96.2%	86.8%	56.7%	25.7%	12.2%	6.2%	2.5%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	4.1%	2.0%	94.0%	83.7%	56.7%	31.2%	17.8%	10.5%	4.8%
2021 [1]	0.8%	2.1%	97.1%	88.0%	56.7%	23.6%	9.9%	4.5%	1.6%

[1] Incomplete year (not a full natural year).

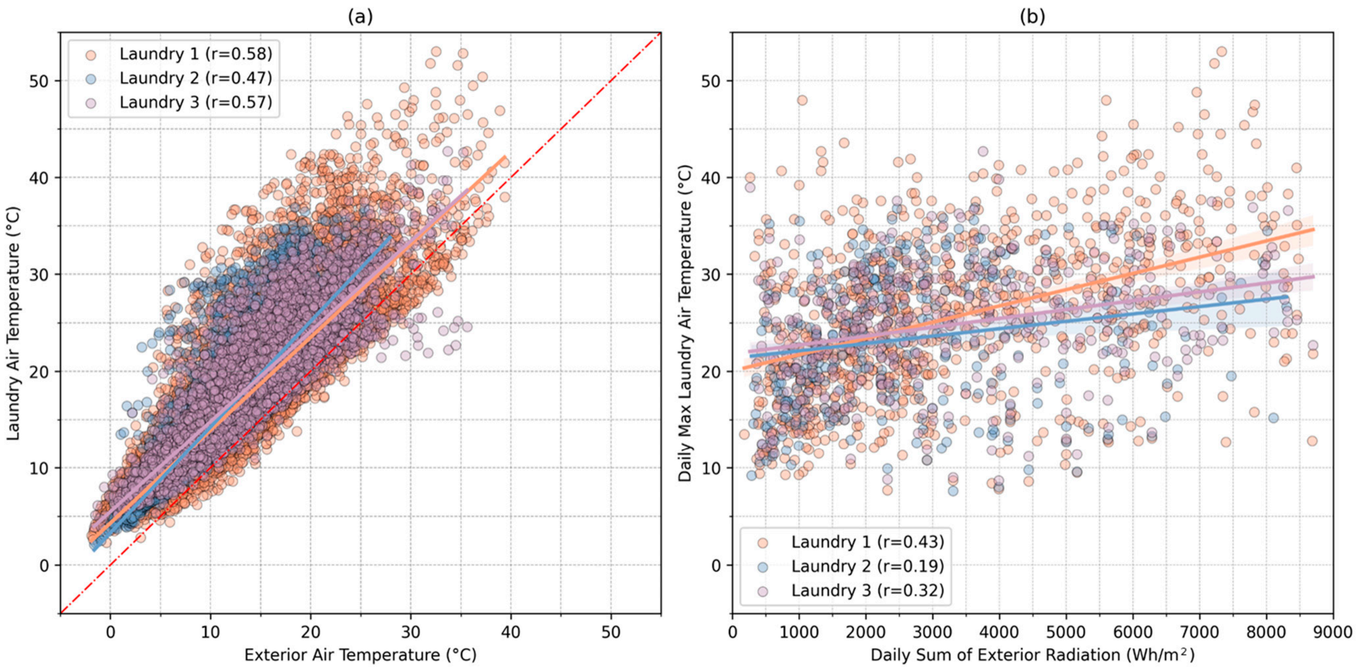


Figure 16. Correlation between outdoor air temperature and laundry air temperature (**a**) and correlation between the daily sum of global horizontal radiation and daily maximum temperature recorded in the laundries (**b**), for the whole dataset (source: authors).

Table 15. Laundry and Abusu station temperature comparison. Nighttime hours (22:00–07:00 h).

Laundry 1—Nighttime									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	0.4%	2.2%	97.4%	80.6%	38.4%	11.2%	2.4%	0.4%	0.0%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	0.6%	2.8%	96.7%	78.8%	39.3%	9.2%	2.8%	0.5%	0.0%
2021	0.4%	1.9%	97.6%	81.0%	36.2%	10.8%	2.2%	0.4%	0.0%
2022	0.4%	2.2%	97.5%	81.0%	40.3%	12.4%	2.5%	0.4%	0.0%
Laundry 2—Nighttime									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	0.0%	0.7%	99.3%	80.5%	22.6%	4.4%	0.9%	0.2%	0.1%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	0.0%	0.4%	99.6%	78.9%	22.3%	5.9%	0.8%	0.2%	0.0%
2021 [1]	0.0%	0.5%	99.5%	82.8%	24.9%	3.4%	1.2%	0.2%	0.2%
Laundry 3—Nighttime									
	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole available period	0.0%	0.6%	99.3%	93.1%	53.4%	11.3%	2.7%	0.8%	0.1%
Yearly analysis									
Year	$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]	0.0%	0.3%	99.7%	92.6%	61.2%	19.7%	8.1%	2.7%	0.3%
2021 [1]	0.1%	0.7%	99.2%	93.3%	50.4%	8.1%	0.7%	0.0%	0.0%

[1] Incomplete year (not a full natural year).

4. Discussion

The following insights can be gathered from the performed quantitative and exploratory analysis:

- Temperature and humidity variation with solar radiation: The temperature and relative humidity in the laundry spaces significantly deviate from the outdoor conditions in response to solar radiation. On sunny days, temperatures in the laundries rise notably above the exterior temperatures, while the relative humidity in these spaces drops below the outdoor levels. The highest laundry temperatures, thus, the lowest RH, occur under hot weather with high solar radiation.
- Consistent temperature difference across seasons: The laundry spaces consistently maintain higher temperatures than the outdoor environment, irrespective of whether it is the winter or summer seasons. This trend is also observed in terms of relative humidity but in reverse, with the laundry spaces generally having lower humidity levels than the outdoors.
- Minimum vs. maximum temperature disparity: The disparity between the indoor and outdoor temperatures is more pronounced at the maximum temperatures than at the minimum.
- High laundry temperatures during the winter: On clear winter days, despite the outdoor maximum temperatures not exceeding 15 °C, the laundry spaces can reach temperatures around 30 °C. This demonstrates a substantial amplification of heat within these enclosed spaces during sunny winter days.
- Extreme conditions under hot weather: During the hottest weather conditions of the year, like the hottest week of the summer, the laundry rooms exhibit significantly higher temperatures compared to the outdoor environment.

- Nighttime temperature patterns: During the nighttime, the temperature drops but does not reach equilibrium with the outdoor conditions.
- Relative humidity trend and dryness: The relative humidity in the laundry spaces showed lower levels compared to the outdoors, with notable drops during periods of high indoor temperatures.
- The temperature recorded in the laundries exceeded the outside temperature for 87–100% of the time during the daytime, and for 97–100% during the nighttime.
- This difference was at least 2 °C for 62–88% of the time during the day and 80–93% during the night.
- During the day, the temperature difference between the laundries and the outside exceeded 12 °C for 5% of the time (daytime) for laundry 1, 7% in the case of laundry 2, and 2.5% in the case of laundry 3.
- During the night, the magnitude of the temperature difference was smaller, and heat differentials of 6 °C or more were measured for 11.2%, 4.4%, and 11.3% of the time for laundry 1, 2, and 3, respectively.
- The average temperature difference, MAD, was calculated to be ranging in monthly values from +3.80 °C to +8.62 °C. The average monthly MAD was +5.66 °C during the daytime and +4.70 °C during the nighttime.

5. Conclusions

The collected data and its analysis have allowed for us to determine that the temperatures reached in the studied spaces are significantly higher that the outdoor climate, in line with the already documented phenomenon of indoor overheating in previous publications [21,30]. The three semi-exterior laundries reach high temperatures, especially during the summer, in a process that appears to be partially driven by direct solar radiation, albeit with some lag relative to the outside temperature, in an operation comparable to that of a car parked in the sun. On hot summer days, these spaces can reach extreme temperatures, exceeding 50 °C at times.

In addition, this article has revealed a critical design flaw in the building's production process that remained undetected by all the agents involved: the failure to predict and accurately model the semi-exterior space of the laundries. This highlights the complex nature of architectural planning and its adaptability to unforeseen challenges. This oversight has resulted in negative impacts on the building's performance during the summer, with the extent of these effects yet to be fully determined and quantified. It can be anticipated, at least, that this may have adverse effects on efficiency, people, machinery, and equipment.

Furthermore, the inability to anticipate has led to a missed opportunity in harnessing excess heat in the laundry rooms during certain times of the year. The unpredictability of this phenomenon made the potential implementation of beneficial strategies impossible. This study provides valuable insights into the behavior of similar spaces, emphasizing the importance of detailed consideration of the thermal dynamics of unconventional spaces to prevent future imbalances.

Author Contributions: Conceptualization, J.O. and I.R.-V.; methodology, J.O. and I.R.-V.; software, J.O.; validation, J.O., R.J.H.-M. and I.R.-V.; formal analysis, J.O. and I.R.-V.; investigation, J.O. and I.R.-V.; resources, J.O., R.J.H.-M. and I.R.-V.; data curation, J.O.; writing—original draft preparation, J.O.; writing—review and editing, J.O. and I.R.-V.; visualization, J.O.; supervision, R.J.H.-M. and I.R.-V.; project administration, I.R.-V.; funding acquisition, I.R.-V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Department of Territorial Planning and Housing of the Basque Government. The same funder covered both the acquisition of the equipment and the APC.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this publication are not publicly available due to privacy agreements. Formal requests for data could be studied upon petition to the corresponding author.

Acknowledgments: This research work is part of the corresponding author's doctoral dissertation, funded by the University of the Basque Country UPV/EHU under grant number PIF21/235. The authors would like to thank the residents of Bolueta who participated in this study, as well as the administration personnel of the School of Architecture of the UPV/EHU. The authors would also like to thank N. Aguier-Frango for her technical feedback during the preparation of this manuscript.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results, neither did they have access to the manuscript before submission or the article before publication.

Abbreviations

°C	Degree Celsius
AEMET	Agencia Estatal de Meteorología (English: State Meteorological Agency)
CDHs	Cooling degree hours
CIBSE	Chartered Institution of Building Services Engineers (UK)
CO_2	Carbon dioxide
DHW	Domestic hot water
g	Solar energy transmittance coefficient
h	Hour
HDHs	Heating degree hours
IAQ	Indoor air quality
IEQ	Indoor environment quality
MAD	Mean absolute difference
MHRV	Mechanical heat recovery ventilation
n_{50}	Leakage rate at a reference pressure of 50 Pascals
nZEB	Net zero energy building
PCC	Pearson correlation coefficient
PH	Passivhaus
PHI	Passivhaus Institut
POE	Post-occupancy evaluation
RH	Relative humidity
RITE	Reglamento de Instalaciones Térmicas en los Edificios (English: Regulation of Thermal Installations in Buildings)
T	Temperature
T&D	T&D Corporation, company devoted to the fabrication of precision dataloggers
TM	Technical memorandum
U	Thermal transmittance, rate of transfer of heat through a building component or system
UTM	Universal transverse Mercator coordinate system
W	Watt
YoC	Year of construction

Appendix A

This appendix includes tables and graphs complementary to those cited in the body of this article, which have been separated to allow for a smoother reading of this article. Representations of data taken over the entire period available are included, such as the following figures:

- Figure A1: Monthly temperature distributions for Abusu meteorological station and the three studied laundry spaces in December 2019 and available data for 2020.
- Figure A2: Monthly temperature distributions for Abusu meteorological station and the three studied laundry spaces for 2021.
- Figure A3: Monthly temperature distributions for Abusu meteorological station and Laundry 3 for 2022.
- And tables:
- Table A1: Abusu meteorological station. Summary of monthly temperature recordings, January 2020–December 2022.
- Table A2: Abusu meteorological station. Summary of monthly relative humidity recordings, January 2020–December 2022.
- Table A3: Laundry 1. Summary of monthly temperature recordings, January 2020–December 2022.
- Table A4: Laundry 1. Summary of monthly relative humidity recordings, January 2020–December 2022.
- Table A5: Laundry 2. Summary of monthly temperature recordings, all available data.
- Table A6: Laundry 2. Summary of monthly relative humidity recordings, all available data.
- Table A7: Laundry 3. Summary of monthly temperature recordings, all available data.
- Table A8: Laundry 3. Summary of monthly relative humidity recordings, all available data.
- Table A9: Laundry 1 and Abusu station monthly temperature comparison.
- Table A10: Laundry 1 and Abusu temperature comparison, daytime hours (08:00–21:00 h).
- Table A11: Laundry 1 and Abusu temperature comparison, nighttime hours (22:00–07:00 h).
- Table A12: Laundry 2 and Abusu station monthly temperature comparison.
- Table A13: Laundry 2 and Abusu temperature comparison, daytime hours (08:00–21:00 h).
- Table A14: Laundry 2 and Abusu temperature comparison, nighttime hours (22:00–07:00 h).
- Table A15: Laundry 3 and Abusu station monthly temperature comparison.
- Table A16: Laundry 3 and Abusu temperature comparison, daytime hours (08:00–21:00 h).
- Table A17: Laundry 3 and Abusu temperature comparison, nighttime hours (22:00–07:00 h).

Figure A1. Monthly temperature distributions for Abusu meteorological station and the three studied laundry spaces in December 2019 and available data for 2020.

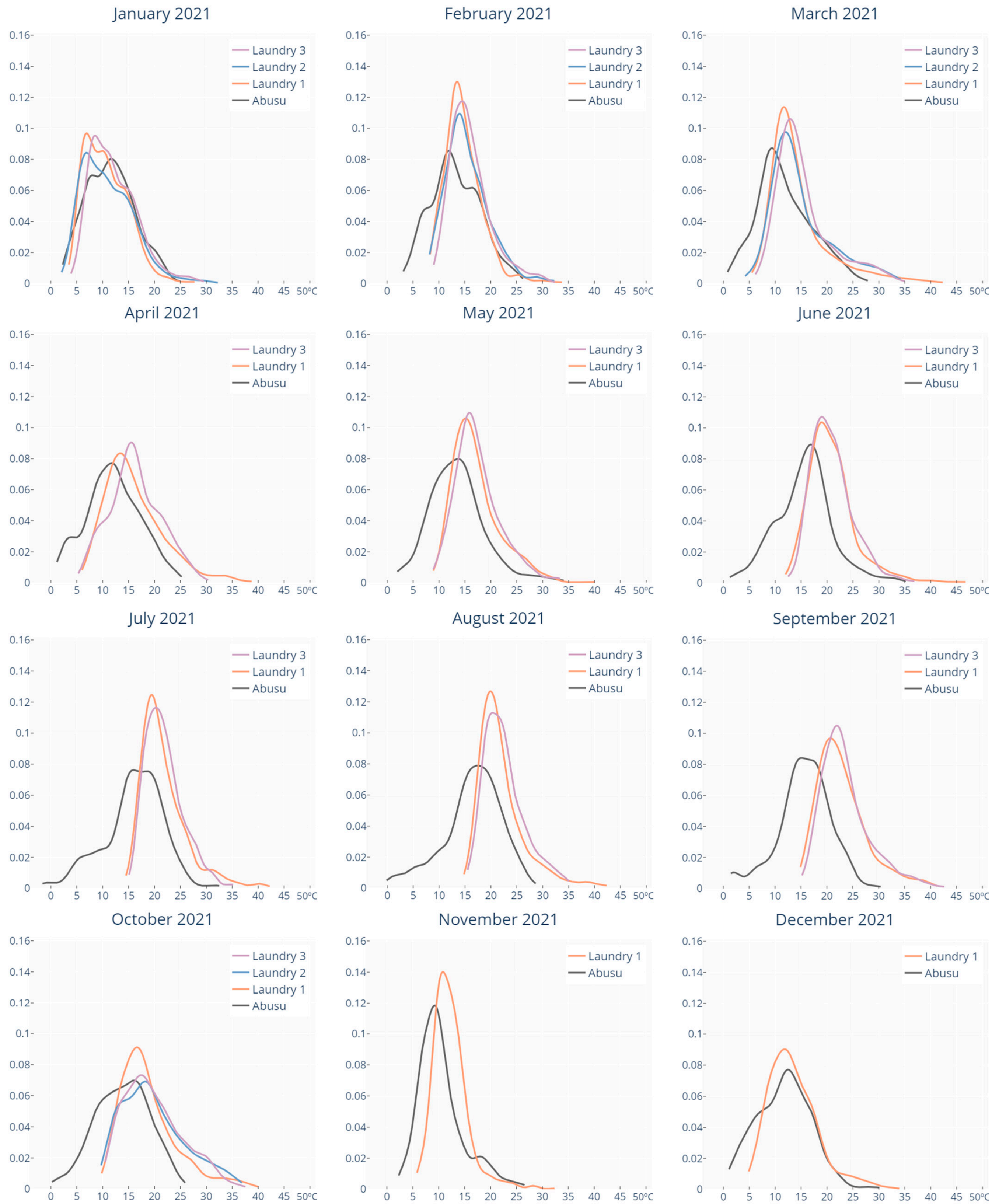


Figure A2. Monthly temperature distributions for Abusu meteorological station and the three studied laundry spaces for 2021.

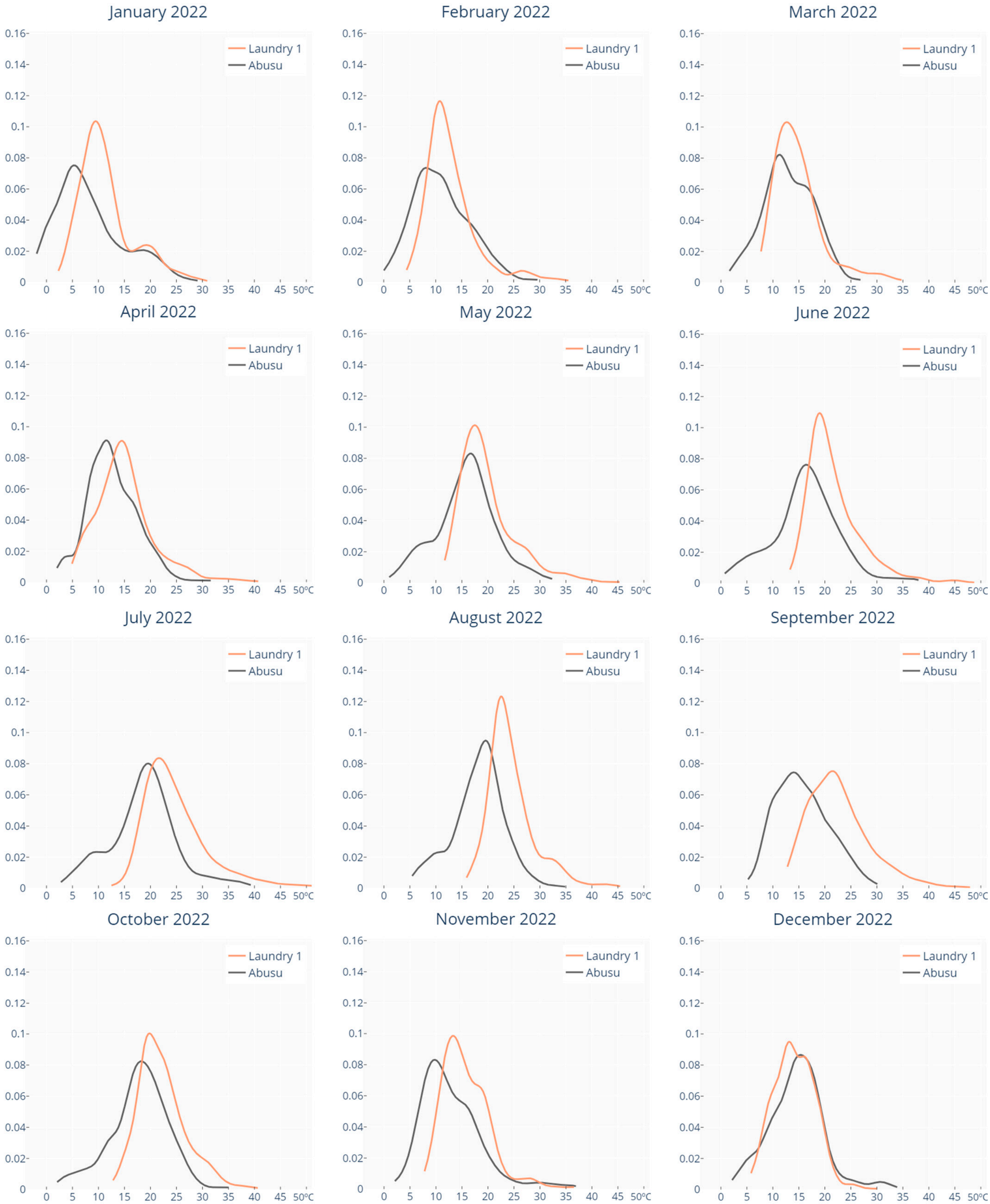


Figure A3. Monthly temperature distributions for Abusu meteorological station and Laundry 3 for 2022.

Table A1. Abusu meteorological station. Summary of monthly temperature recordings, January 2020–December 2022.

	2020					2021					2022				
	Average	Absolute Min.	Absolute Max.	Avg. Daily Min.	Avg. Daily Max.	Average	Absolute Min.	Absolute Max.	Avg. Daily Min.	Avg. Daily Max.	Average	Absolute Min.	Absolute Max.	Avg. Daily Min.	Avg. Daily Max.
Jan.	9.13 °C	0.04 °C	19.99 °C	5.30 °C	13.32 °C	7.47 °C	−1.73 °C	19.22 °C	4.58 °C	10.90 °C	6.91 °C	−1.97 °C	21.45 °C	3.24 °C	11.82 °C
Feb.	11.74 °C	2.37 °C	24.38 °C	7.49 °C	16.56 °C	12.09 °C	4.57 °C	21.98 °C	8.06 °C	15.91 °C	8.65 °C	−0.02 °C	19.75 °C	3.63 °C	14.73 °C
Mar.	10.19 °C	1.07 °C	23.54 °C	5.85 °C	15.33 °C	10.62 °C	0.07 °C	28.40 °C	5.97 °C	15.82 °C	11.60 °C	4.10 °C	21.95 °C	7.62 °C	15.75 °C
Apr.	14.32 °C	2.55 °C	26.44 °C	10.31 °C	19.46 °C	11.53 °C	1.06 °C	24.77 °C	6.72 °C	16.50 °C	11.41 °C	0.77 °C	25.88 °C	7.23 °C	16.51 °C
May	16.81 °C	7.30 °C	31.90 °C	10.14 °C	22.80 °C	13.58 °C	3.97 °C	29.62 °C	8.65 °C	19.40 °C	16.35 °C	7.00 °C	32.32 °C	11.80 °C	22.21 °C
Jun.	16.86 °C	8.58 °C	32.47 °C	12.79 °C	21.64 °C	17.31 °C	8.52 °C	33.50 °C	13.25 °C	22.13 °C	18.42 °C	9.17 °C	38.60 °C	14.24 °C	24.30 °C
Jul.	19.60 °C	9.67 °C	38.91 °C	15.12 °C	24.53 °C	18.27 °C	10.12 °C	34.74 °C	14.38 °C	22.89 °C	20.80 °C	8.30 °C	39.80 °C	15.41 °C	27.08 °C
Aug.	20.03 °C	9.43 °C	38.77 °C	15.56 °C	26.03 °C	18.46 °C	10.90 °C	28.53 °C	14.50 °C	23.25 °C	20.99 °C	12.70 °C	37.20 °C	16.67 °C	26.65 °C
Sep.	17.94 °C	0.60 °C	36.10 °C	12.51 °C	24.64 °C	18.71 °C	10.70 °C	35.77 °C	14.50 °C	24.28 °C	17.98 °C	8.00 °C	37.50 °C	13.18 °C	24.02 °C
Oct.	13.29 °C	4.52 °C	23.34 °C	9.44 °C	17.69 °C	14.15 °C	5.29 °C	26.24 °C	9.61 °C	19.96 °C	18.19 °C	9.25 °C	27.58 °C	14.16 °C	23.21 °C
Nov.	12.48 °C	1.72 °C	23.47 °C	8.34 °C	17.16 °C	9.15 °C	2.93 °C	18.00 °C	6.60 °C	12.35 °C	12.00 °C	4.43 °C	21.48 °C	8.04 °C	16.61 °C
Dec.	9.31 °C	1.63 °C	20.45 °C	6.22 °C	12.17 °C	10.20 °C	0.87 °C	21.86 °C	6.58 °C	14.50 °C	11.40 °C	1.91 °C	21.63 °C	7.77 °C	14.56 °C

Table A2. Abusu meteorological station. Summary of monthly relative humidity recordings, January 2020–December 2022.

	2020					2021					2022				
	Average	Absolute Min.	Absolute Max.	Avg. Daily Min.	Avg. Daily Max.	Average	Absolute Min.	Absolute Max.	Avg. Daily Min.	Avg. Daily Max.	Average	Absolute Min.	Absolute Max.	Avg. Daily Min.	Avg. Daily Max.
Jan.	97.3%	83.4%	98.2%	94.9%	98.0%	80.3%	31.2%	96.3%	60.2%	92.5%	78.0%	27.6%	96.1%	54.0%	92.2%
Feb.	92.9%	25.2%	98.2%	85.4%	97.3%	68.2%	21.1%	96.1%	49.5%	88.9%	78.1%	5.3%	96.3%	49.6%	94.6%
Mar.	76.6%	27.7%	96.3%	52.5%	93.9%	69.6%	16.6%	96.1%	44.7%	89.6%	67.6%	25.8%	95.9%	46.8%	86.4%
Apr.	76.0%	23.3%	96.3%	52.0%	94.5%	68.2%	20.9%	96.3%	44.9%	90.2%	74.7%	24.6%	96.2%	49.7%	93.0%
May	75.4%	10.9%	96.3%	47.9%	95.2%	74.5%	27.3%	96.2%	47.3%	94.9%	73.5%	24.5%	96.2%	49.4%	92.6%
Jun.	77.8%	35.5%	96.2%	54.6%	95.1%	79.0%	32.1%	96.9%	57.2%	95.0%	77.5%	19.4%	96.3%	53.2%	94.0%
Jul.	75.3%	21.4%	96.3%	53.2%	94.5%	78.8%	28.6%	96.3%	57.3%	94.4%	70.2%	12.0%	96.0%	45.5%	90.9%
Aug.	76.7%	12.2%	96.3%	49.6%	94.6%	79.1%	38.0%	97.3%	56.5%	95.1%	75.1%	22.0%	97.0%	50.7%	93.0%
Sep.	72.9%	5.8%	96.3%	41.1%	92.3%	79.9%	27.6%	97.4%	52.6%	95.3%	71.5%	16.0%	97.0%	45.2%	90.8%
Oct.	81.3%	34.2%	96.3%	57.8%	95.3%	78.6%	35.2%	96.9%	51.1%	94.7%	70.7%	21.0%	96.4%	48.3%	87.2%
Nov.	74.6%	40.1%	96.2%	53.9%	90.4%	86.9%	42.0%	97.1%	66.6%	96.0%	78.2%	30.3%	96.2%	51.3%	93.7%
Dec.	76.3%	37.2%	96.2%	56.1%	93.4%	75.7%	28.8%	96.3%	56.4%	90.9%	73.9%	13.2%	96.1%	56.5%	90.0%

Table A3. Laundry 1. Summary of monthly temperature recordings, January 2020–December 2022.

	2020					2021					2022				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						10.74 °C	3.5 °C	27.8 °C	8.35 °C	15.61 °C	11.47 °C	2.3 °C	31.0 °C	7.64 °C	21.14 °C
Feb.						14.78 °C	8.3 °C	33.8 °C	11.59 °C	20.74 °C	12.89 °C	4.4 °C	35.6 °C	8.66 °C	22.26 °C
Mar.						14.64 °C	5.5 °C	42.4 °C	10.64 °C	23.82 °C	14.91 °C	7.7 °C	34.8 °C	11.16 °C	22.05 °C
Apr.						16.07 °C	6.0 °C	38.8 °C	11.43 °C	25.51 °C	15.08 °C	4.9 °C	40.8 °C	10.78 °C	23.73 °C
May						17.18 °C	8.9 °C	40.1 °C	12.85 °C	25.63 °C	19.89 °C	11.7 °C	45.4 °C	15.43 °C	28.58 °C
Jun.						20.98 °C	12.0 °C	46.8 °C	17.08 °C	27.89 °C	21.81 °C	13.3 °C	48.8 °C	17.53 °C	29.61 °C
Jul.						21.78 °C	14.5 °C	42.3 °C	17.89 °C	29.25 °C	25.03 °C	12.5 °C	53.0 °C	19.47 °C	34.38 °C
Aug.	23.59 °C	15.0 °C	46.5 °C	19.48 °C	31.06 °C	22.06 °C	14.8 °C	42.4 °C	17.94 °C	29.86 °C	24.60 °C	15.9 °C	45.5 °C	20.79 °C	32.23 °C
Sep.	22.37 °C	11.9 °C	48.0 °C	17.18 °C	32.28 °C	22.98 °C	14.9 °C	41.3 °C	19.10 °C	30.52 °C	22.70 °C	12.8 °C	48.0 °C	18.34 °C	31.21 °C
Oct.	16.45 °C	7.8 °C	35.4 °C	13.17 °C	22.76 °C	18.88 °C	9.8 °C	40.1 °C	13.85 °C	29.84 °C	22.15 °C	12.80 °C	40.70 °C	18.23 °C	30.85 °C
Nov.	16.83 °C	7.5 °C	36.0 °C	12.86 °C	25.80 °C	12.24 °C	5.8 °C	32.4 °C	9.85 °C	17.78 °C	15.78 °C	7.80 °C	36.60 °C	12.13 °C	22.43 °C
Dec.	11.85 °C	5.3 °C	26.1 °C	9.61 °C	15.85 °C	13.48 °C	4.9 °C	34.0 °C	10.26 °C	21.53 °C	14.37 °C	5.80 °C	30.10 °C	11.65 °C	19.64 °C

Table A4. Laundry 1. Summary of monthly relative humidity recordings, January 2020–December 2022.

	2020					2021					2022				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						69.2%	27%	95%	52.5%	80.3%	63.7%	14%	97%	37.3%	78.0%
Feb.						61.0%	17%	94%	41.3%	76.8%	64.7%	3%	92%	38.0%	80.2%
Mar.						58.4%	7%	96%	34.4%	74.2%	58.1%	12%	90%	36.9%	73.6%
Apr.						55.1%	11%	91%	31.9%	72.3%	62.7%	14%	91%	37.5%	79.4%
May						62.5%	19%	91%	36.0%	80.3%	62.6%	12%	89%	38.5%	79.1%
Jun.						67.3%	18%	93%	45.1%	82.9%	67.4%	19%	93%	42.4%	85.0%
Jul.						67.7%	21%	92%	44.2%	83.0%	59.4%	11%	90%	35.1%	77.5%
Aug.	65.1%	6%	90%	42.0%	82.3%	68.0%	17%	92%	44.2%	83.2%	66.0%	19%	94%	41.5%	81.9%
Sep.	61.4%	13%	96%	34.1%	79.8%	65.6%	23%	91%	40.7%	81.2%	58.2%	10%	94%	34.9%	74.8%
Oct.	69.7%	24%	97%	48.1%	84.8%	62.7%	16%	91%	33.3%	80.1%	57.6%	15%	90%	33.9%	72.4%
Nov.	60.7%	23%	89%	37.3%	75.0%	75.3%	19%	100%	54.5%	87.4%	64.2%	18%	92%	40.6%	80.0%
Dec.	68.3%	27%	100%	50.5%	83.4%	66.0%	19%	98%	43.6%	77.9%	63.9%	15%	93%	45.7%	77.4%

The following table summarizes the recorded data for Laundry 2.

Table A5. Laundry 2. Summary of monthly temperature recordings, all available data.

	2020					2021				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						11.07 °C	2.1 °C	32.3 °C	7.97 °C	17.66 °C
Feb.						15.52 °C	8.2 °C	32.3 °C	11.63 °C	21.70 °C
Mar.						15.06 °C	4.2 °C	34.3 °C	10.18 °C	22.68 °C
Apr.						21.99 °C	6.8 °C	27.9 °C	20.84 °C	23.35 °C
May										
Jun.										
Jul.										
Aug.										
Sep.										
Oct.	17.55 °C	7.5 °C	34.5 °C	13.28 °C	24.17 °C					
Nov.	17.86 °C	6.6 °C	35.7 °C	12.66 °C	27.70 °C					
Dec.	12.62 °C	5.8 °C	30.7 °C	9.59 °C	18.72 °C					

Table A6. Laundry 2. Summary of monthly relative humidity recordings, all available data.

	2020					2021				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						66.1%	17%	94%	46.7%	79.4%
Feb.						56.0%	16%	84%	37.8%	71.9%
Mar.						54.5%	10%	84%	33.9%	70.2%
Apr.						22.4%	15%	76%	18.9%	26.5%
May										
Jun.										
Jul.										
Aug.										
Sep.										
Oct.	63.2%	22%	89%	42.7%	78.2%					
Nov.	54.7%	18%	82%	32.1%	70.2%					
Dec.	62.5%	20%	88%	44.0%	77.4%					

The following table summarizes the recorded data for Laundry 3.

Table A7. Laundry 3. Summary of monthly temperature recordings, all available data.

	2020					2021				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						12.20 °C	3.9 °C	29.6 °C	9.24 °C	18.10 °C
Feb.						16.06 °C	9.0 °C	32.4 °C	12.63 °C	22.26 °C
Mar.						15.56 °C	6.2 °C	35.0 °C	11.11 °C	22.69 °C
Apr.						16.24 °C	5.3 °C	30.4 °C	11.60 °C	22.61 °C
May						17.43 °C	8.9 °C	33.4 °C	13.07 °C	23.94 °C
Jun.						20.89 °C	12.5 °C	36.9 °C	17.11 °C	26.28 °C
Jul.						21.84 °C	15.1 °C	35.2 °C	18.08 °C	27.12 °C
Aug.						22.54 °C	15.5 °C	35.1 °C	18.36 °C	28.79 °C
Sep.	23.08 °C	13.1 °C	31.3 °C	21.20 °C	25.44 °C	23.62 °C	15.2 °C	42.7 °C	19.29 °C	30.87 °C
Oct.	17.65 °C	9.8 °C	33.7 °C	13.79 °C	23.80 °C	19.82 °C	10.5 °C	37.6 °C	14.28 °C	29.05 °C
Nov.	18.43 °C	6.8 °C	34.3 °C	13.54 °C	27.15 °C					
Dec.	13.74 °C	7.2 °C	31.0 °C	10.78 °C	19.49 °C					

Table A8. Laundry 3. Summary of monthly relative humidity recordings, all available data.

	2020					2021				
	Average	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**	**Average**	**Absolute Min.**	**Absolute Max.**	**Avg. Daily Min.**	**Avg. Daily Max.**
Jan.						64.3%	17%	91%	46.1%	76.8%
Feb.						57.5%	20%	87%	38.7%	72.9%
Mar.						55.5%	12%	85%	34.0%	71.6%
Apr.						54.1%	15%	85%	34.5%	71.4%
May						62.5%	25%	87%	39.8%	80.0%
Jun.						68.3%	31%	88%	49.5%	82.8%
Jul.						68.5%	29%	89%	50.0%	82.7%
Aug.						67.1%	26%	91%	45.5%	82.6%
Sep.	62.1%	30%	86%	51.8%	71.0%	64.3%	22%	85%	41.5%	79.5%
Oct.	66.5%	23%	89%	45.0%	81.2%	60.8%	19%	87%	34.8%	78.7%
Nov.	56.7%	22%	84%	35.1%	71.8%					
Dec.	62.1%	20%	84%	43.2%	75.9%					

Table A9. Laundry 1 and Abusu station monthly temperature comparison.

		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2$ °C	$\Delta T > 4$ °C	$\Delta T > 6$ °C	$\Delta T > 8$ °C	$\Delta T > 10$ °C	$\Delta T > 12$ °C
Whole Period Analysis										
August 2020–December 2022		5.9%	7.7%	86.3%	61.8%	33.3%	20.6%	13.6%	8.8%	5.4%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2$ °C	$\Delta T > 4$ °C	$\Delta T > 6$ °C	$\Delta T > 8$ °C	$\Delta T > 10$ °C	$\Delta T > 12$ °C
2020		5.2%	9.1%	85.7%	60.9%	33.0%	19.8%	12.4%	7.9%	5.0%
2021		4.9%	7.6%	87.6%	62.0%	31.7%	19.4%	13.0%	8.3%	5.0%
2022		7.5%	7.3%	85.1%	62.2%	35.7%	22.6%	15.1%	9.8%	6.1%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2$ °C	$\Delta T > 4$ °C	$\Delta T > 6$ °C	$\Delta T > 8$ °C	$\Delta T > 10$ °C	$\Delta T > 12$ °C
2020	Aug. [1]	3.9%	5.8%	90.1%	71.8%	37.2%	15.0%	10.3%	4.9%	3.0%
	Sep.	5.7%	6.9%	87.4%	74.9%	47.6%	24.7%	14.2%	8.3%	5.4%
	Oct.	3.8%	5.4%	90.9%	66.1%	29.0%	10.8%	5.4%	3.0%	1.3%
	Nov.	1.9%	5.8%	92.2%	74.9%	45.0%	23.3%	11.8%	7.6%	5.0%
	Dec.	1.2%	8.1%	90.7%	55.4%	20.3%	3.6%	1.2%	0.5%	0.1%
2021	Jan.	1.1%	4.4%	94.5%	75.0%	26.7%	6.7%	2.4%	1.6%	0.5%
	Feb.	3.7%	9.8%	86.5%	58.8%	21.1%	6.0%	3.9%	1.5%	1.0%
	Mar.	4.8%	4.4%	90.7%	69.9%	38.8%	20.3%	10.9%	6.3%	4.7%
	Apr.	3.8%	4.2%	92.1%	74.6%	43.1%	23.8%	14.2%	8.3%	5.8%
	May	5.6%	6.0%	88.3%	70.2%	37.6%	16.7%	8.1%	4.2%	2.0%
	Jun.	2.5%	3.8%	93.8%	71.1%	32.9%	16.8%	10.6%	5.0%	1.7%
	Jul.	3.0%	5.0%	92.1%	69.0%	30.0%	12.8%	7.8%	5.2%	3.2%
	Aug.	2.3%	5.4%	92.3%	69.0%	30.4%	13.4%	8.5%	5.1%	3.5%
	Sep.	2.1%	2.2%	95.7%	83.1%	42.5%	24.0%	9.9%	4.9%	1.9%
	Oct.	2.6%	4.8%	92.5%	74.5%	48.5%	23.1%	14.5%	10.2%	6.0%
	Nov.	1.0%	3.9%	95.1%	66.7%	20.3%	9.0%	4.3%	2.5%	1.5%
	Dec.	3.9%	8.7%	87.4%	56.7%	29.6%	16.5%	7.1%	5.1%	3.0%
2022	Jan.	2.7%	3.1%	94.2%	74.6%	46.5%	24.1%	12.0%	7.5%	4.4%
	Feb.	5.7%	3.7%	90.6%	76.5%	45.4%	24.6%	10.6%	6.3%	3.7%
	Mar.	3.4%	7.1%	89.5%	61.7%	31.5%	12.2%	6.2%	4.0%	2.7%
	Apr.	4.6%	6.7%	88.8%	67.9%	34.4%	15.0%	8.8%	5.6%	4.0%
	May	6.5%	5.4%	88.0%	62.2%	32.4%	16.4%	9.7%	6.5%	3.2%
	Jun.	5.0%	4.9%	90.1%	69.3%	29.2%	12.8%	7.6%	4.3%	1.8%
	Jul.	6.6%	5.8%	87.5%	70.8%	41.4%	23.8%	12.6%	8.1%	5.6%
	Aug.	3.4%	5.0%	91.4%	70.4%	35.5%	16.1%	7.0%	3.6%	1.6%
	Sep.	3.3%	4.0%	92.6%	78.6%	51.1%	31.0%	17.6%	7.6%	5.0%
	Oct.	0.8%	5.2%	94.0%	76.9%	38.0%	17.1%	8.3%	5.1%	3.8%
	Nov.	0.7%	5.1%	94.2%	75.3%	37.4%	14.0%	6.7%	3.8%	2.5%
	Dec.	0.7%	7.3%	92.1%	62.8%	25.4%	5.5%	2.8%	1.6%	1.2%

[1] Incomplete month. Comparison begins 9 August 2020.

Table A10. Laundry 1 and Abusu temperature comparison, daytime hours (08:00–21:00 h).

		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^\circ C$	$\Delta T > 4\ ^\circ C$	$\Delta T > 6\ ^\circ C$	$\Delta T > 8\ ^\circ C$	$\Delta T > 10\ ^\circ C$	$\Delta T > 12\ ^\circ C$
Whole Period Analysis										
August 2020–December 2022		5.3%	7.8%	86.8%	62.2%	33.3%	20.3%	13.3%	8.5%	5.3%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^\circ C$	$\Delta T > 4\ ^\circ C$	$\Delta T > 6\ ^\circ C$	$\Delta T > 8\ ^\circ C$	$\Delta T > 10\ ^\circ C$	$\Delta T > 12\ ^\circ C$
2020		5.2%	9.1%	85.7%	60.9%	33.0%	19.8%	12.4%	7.9%	5.0%
2021		4.9%	7.6%	87.6%	62.0%	31.7%	19.4%	13.0%	8.3%	5.0%
2022		5.9%	7.5%	86.5%	63.0%	35.1%	21.4%	13.9%	8.9%	5.7%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^\circ C$	$\Delta T > 4\ ^\circ C$	$\Delta T > 6\ ^\circ C$	$\Delta T > 8\ ^\circ C$	$\Delta T > 10\ ^\circ C$	$\Delta T > 12\ ^\circ C$
2020	Aug. [1]	6.7%	9.6%	83.4%	61.3%	30.0%	17.9%	12.5%	8.0%	5.1%
	Sep.	9.0%	10.5%	80.5%	61.4%	41.7%	27.9%	19.3%	12.9%	9.3%
	Oct.	6.0%	7.6%	86.4%	57.6%	29.5%	16.4%	9.2%	5.1%	2.3%
	Nov.	3.1%	7.9%	89.0%	71.0%	44.5%	32.1%	19.5%	13.1%	8.6%
	Dec.	1.6%	9.9%	88.5%	53.5%	18.9%	4.8%	1.8%	0.9%	0.2%
2021	Jan.	1.6%	5.5%	92.9%	71.0%	25.6%	9.0%	3.9%	2.8%	0.9%
	Feb.	6.1%	11.0%	82.9%	54.8%	21.9%	9.2%	6.6%	2.6%	1.8%
	Mar.	8.3%	7.6%	84.1%	57.6%	32.9%	22.1%	17.1%	10.8%	8.1%
	Apr.	6.2%	6.7%	87.1%	67.1%	40.0%	24.5%	19.5%	14.0%	10.0%
	May	9.0%	8.3%	82.7%	60.4%	34.3%	22.6%	13.4%	7.1%	3.5%
	Jun.	4.3%	5.5%	90.2%	61.4%	29.8%	18.3%	11.4%	7.4%	2.9%
	Jul.	5.1%	7.8%	87.1%	63.1%	30.6%	16.8%	12.7%	9.0%	5.5%
	Aug.	3.9%	9.2%	86.9%	56.7%	29.0%	19.1%	14.1%	8.8%	6.0%
	Sep.	3.6%	3.8%	92.6%	73.8%	38.1%	23.8%	15.5%	8.3%	3.3%
	Oct.	3.5%	6.7%	89.6%	67.7%	44.0%	30.4%	22.1%	15.2%	10.4%
	Nov.	1.7%	6.0%	92.4%	56.2%	22.4%	14.5%	7.4%	4.3%	2.6%
	Dec.	5.3%	12.7%	82.0%	53.5%	30.6%	21.7%	12.0%	8.8%	5.1%
2022	Jan.	4.6%	3.9%	91.5%	67.3%	42.9%	28.8%	19.8%	12.9%	7.6%
	Feb.	9.4%	6.1%	84.4%	64.3%	38.3%	26.3%	16.8%	10.7%	6.4%
	Mar.	5.1%	9.2%	85.7%	56.2%	31.3%	16.4%	10.1%	6.7%	4.6%
	Apr.	7.6%	9.8%	82.6%	59.8%	34.5%	21.9%	14.8%	9.5%	6.9%
	May	10.4%	7.8%	81.6%	55.1%	31.1%	21.9%	16.1%	11.1%	5.5%
	Jun.	8.3%	6.4%	85.2%	64.3%	32.6%	17.9%	12.6%	7.4%	3.1%
	Jul.	11.3%	8.5%	80.0%	61.1%	38.5%	25.3%	17.5%	12.9%	9.7%
	Aug.	5.8%	8.1%	85.7%	61.3%	30.0%	19.8%	12.0%	6.2%	2.8%
	Sep.	5.5%	5.7%	88.8%	70.7%	42.1%	25.2%	16.7%	11.2%	8.6%
	Oct.	0.9%	8.5%	90.6%	66.8%	39.4%	24.4%	14.3%	8.8%	6.5%
	Nov.	1.0%	6.7%	92.4%	71.0%	36.2%	20.0%	11.4%	6.4%	4.3%
	Dec.	0.9%	9.2%	89.9%	59.2%	24.9%	9.0%	4.8%	2.8%	2.1%

[1] Incomplete month. Comparison begins 9 August 2020.

Table A11. Laundry 1 and Abusu temperature comparison, nighttime hours (22:00–07:00 h).

Whole Period Analysis										
		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^{\circ}C$	$\Delta T > 4\ ^{\circ}C$	$\Delta T > 6\ ^{\circ}C$	$\Delta T > 8\ ^{\circ}C$	$\Delta T > 10\ ^{\circ}C$	$\Delta T > 12\ ^{\circ}C$
August 2020–December 2022		0.4%	2.2%	97.4%	80.6%	38.4%	11.2%	2.4%	0.4%	0.0%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^{\circ}C$	$\Delta T > 4\ ^{\circ}C$	$\Delta T > 6\ ^{\circ}C$	$\Delta T > 8\ ^{\circ}C$	$\Delta T > 10\ ^{\circ}C$	$\Delta T > 12\ ^{\circ}C$
2020		0.6%	2.8%	96.7%	78.8%	39.3%	9.2%	2.8%	0.5%	0.0%
2021		0.4%	1.9%	97.6%	81.0%	36.2%	10.8%	2.2%	0.4%	0.0%
2022		0.4%	2.2%	97.5%	81.0%	40.3%	12.4%	2.5%	0.4%	0.0%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^{\circ}C$	$\Delta T > 4\ ^{\circ}C$	$\Delta T > 6\ ^{\circ}C$	$\Delta T > 8\ ^{\circ}C$	$\Delta T > 10\ ^{\circ}C$	$\Delta T > 12\ ^{\circ}C$
2020	Aug. [1]	0.0%	0.5%	99.5%	86.5%	47.3%	10.8%	7.2%	0.5%	0.0%
	Sep.	1.0%	2.0%	97.0%	93.7%	56.0%	20.3%	7.0%	2.0%	0.0%
	Oct.	0.6%	2.3%	97.1%	78.1%	28.4%	2.9%	0.0%	0.0%	0.0%
	Nov.	0.3%	3.0%	96.7%	80.3%	45.7%	11.0%	1.0%	0.0%	0.0%
	Dec.	0.6%	5.5%	93.9%	58.1%	22.3%	1.9%	0.3%	0.0%	0.0%
2021	Jan.	0.3%	2.9%	96.8%	80.6%	28.4%	3.5%	0.3%	0.0%	0.0%
	Feb.	0.4%	8.2%	91.4%	64.3%	20.0%	1.4%	0.0%	0.0%	0.0%
	Mar.	0.0%	0.0%	100.0%	87.1%	47.1%	17.7%	2.3%	0.0%	0.0%
	Apr.	0.3%	0.7%	99.0%	85.0%	47.3%	22.7%	6.7%	0.3%	0.0%
	May	1.0%	2.9%	96.1%	83.9%	42.3%	8.4%	0.6%	0.0%	0.0%
	Jun.	0.0%	1.3%	98.7%	84.7%	37.3%	14.7%	9.3%	1.7%	0.0%
	Jul.	0.0%	1.0%	99.0%	77.1%	29.0%	7.1%	1.0%	0.0%	0.0%
	Aug.	0.0%	0.0%	100.%	86.1%	32.3%	5.5%	0.6%	0.0%	0.0%
	Sep.	0.0%	0.0%	100%	96.0%	48.7%	24.3%	2.0%	0.0%	0.0%
	Oct.	1.3%	2.3%	96.5%	83.9%	54.8%	12.9%	3.9%	3.2%	0.0%
	Nov.	0.0%	1.0%	99.0%	81.3%	17.3%	1.3%	0.0%	0.0%	0.0%
	Dec.	1.9%	3.2%	94.8%	61.3%	28.1%	9.4%	0.3%	0.0%	0.0%
2022	Jan.	0.0%	1.9%	98.1%	84.8%	51.6%	17.4%	1.0%	0.0%	0.0%
	Feb.	0.4%	0.4%	99.3%	93.6%	55.4%	22.1%	1.8%	0.0%	0.0%
	Mar.	1.0%	4.2%	94.8%	69.4%	31.6%	6.5%	0.6%	0.3%	0.0%
	Apr.	0.3%	2.3%	97.3%	79.3%	34.3%	5.3%	0.3%	0.0%	0.0%
	May	1.0%	1.9%	97.1%	72.3%	34.2%	8.7%	0.6%	0.0%	0.0%
	Jun.	0.3%	2.7%	97.0%	76.3%	24.3%	5.7%	0.7%	0.0%	0.0%
	Jul.	0.0%	1.9%	98.1%	84.5%	45.5%	21.6%	5.8%	1.3%	0.0%
	Aug.	0.0%	0.6%	99.4%	83.2%	43.2%	11.0%	0.0%	0.0%	0.0%
	Sep.	0.3%	1.7%	98.0%	89.7%	63.7%	39.0%	19.0%	2.7%	0.0%
	Oct.	0.6%	0.6%	98.7%	91.0%	36.1%	6.8%	0.0%	0.0%	0.0%
	Nov.	0.3%	3.0%	96.7%	81.3%	39.0%	5.7%	0.0%	0.0%	0.0%
	Dec.	0.3%	4.5%	95.2%	67.7%	26.1%	0.6%	0.0%	0.0%	0.0%

[1] Incomplete month. Comparison begins 9 August 2020.

Table A12. Laundry 2 and Abusu station monthly temperature comparison.

		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole Period Analysis										
Whole available period		0.0%	0.3%	99.7%	84.8%	38.7%	18.4%	10.4%	6.3%	4.1%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2019 [1]		0.0%	1.2%	98.8%	79.6%	31.6%	15.3%	11.6%	7.7%	5.5%
2020 [1]		0.0%	0.3%	99.7%	83.7%	39.0%	19.0%	10.5%	6.4%	4.3%
2021 [1]		0.0%	0.2%	99.8%	87.7%	40.0%	18.5%	10.1%	5.8%	3.5%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2019	Dec.	0.0%	1.2%	98.8%	79.6%	31.6%	15.3%	4.8%	7.7%	5.5%
2020	Jan.	0.0%	0.7%	99.3%	77.3%	30.2%	13.8%	10.2%	7.7%	6.2%
	Feb.	0.0%	0.1%	99.9%	86.5%	45.1%	26.1%	14.7%	8.9%	5.3%
	Mar. [1]	0.0%	0.0%	100.0%	78.1%	22.3%	9.6%	5.8%	3.1%	1.9%
	Apr.									
	May									
	Jun.									
	Jul.									
	Aug.									
	Sep. [1]	0.0%	0.0%	100.0%	99.4%	83.0%	34.7%	7.4%	4.0%	2.3%
	Oct.	0.0%	0.0%	100.0%	89.7%	39.7%	17.9%	7.8%	3.6%	2.3%
	Nov.	0.0%	0.0%	100.0%	89.6%	54.7%	29.2%	17.8%	11.5%	7.8%
	Dec.	0.0%	0.8%	99.2%	73.9%	21.8%	8.1%	4.8%	2.6%	1.6%
2021	Jan.	0.0%	0.1%	99.9%	83.3%	23.4%	9.1%	5.8%	2.8%	1.9%
	Feb.	0.0%	0.7%	99.3%	76.2%	25.7%	10.6%	3.1%	1.6%	0.9%
	Mar.	0.0%	0.0%	100.0%	93.7%	44.5%	19.1%	8.5%	3.8%	1.7%
	Apr.	0.0%	0.0%	100.0%	98.8%	50.6%	26.8%	16.1%	11.9%	7.7%
	May									
	Jun.									
	Jul.									
	Aug.									
	Sep. [1]	0.0%	0.0%	100.0%	100.0%	100.0%	92.9%	50.0%	35.7%	7.1%
	Oct.	0.0%	0.0%	100.0%	93.7%	61.3%	31.3%	20.4%	12.8%	8.2%

[1] Incomplete month or year.

Table A13. Laundry 2 and Abusu temperature comparison, daytime hours (08:00–21:00 h).

		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^\circ C$	$\Delta T > 4\ ^\circ C$	$\Delta T > 6\ ^\circ C$	$\Delta T > 8\ ^\circ C$	$\Delta T > 10\ ^\circ C$	$\Delta T > 12\ ^\circ C$
Whole Period Analysis										
Whole available period		0.0%	0.1%	99.9%	88.0%	50.1%	28.4%	17.3%	10.7%	7.0%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^\circ C$	$\Delta T > 4\ ^\circ C$	$\Delta T > 6\ ^\circ C$	$\Delta T > 8\ ^\circ C$	$\Delta T > 10\ ^\circ C$	$\Delta T > 12\ ^\circ C$
2019 [1]		0.0%	0.0%	100.0%	79.7%	43.3%	25.6%	19.8%	13.1%	9.4%
2020 [1]		0.0%	0.2%	99.8%	87.0%	51.0%	28.3%	17.4%	10.9%	7.4%
2021 [1]		0.0%	0.0%	100.0%	91.2%	50.7%	29.3%	16.5%	9.8%	5.9%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ ^\circ C$	$\Delta T > 4\ ^\circ C$	$\Delta T > 6\ ^\circ C$	$\Delta T > 8\ ^\circ C$	$\Delta T > 10\ ^\circ C$	$\Delta T > 12\ ^\circ C$
2019	Dec.	0.0%	0.0%	100.0%	23.7%	43.3%	25.6%	19.8%	13.1%	9.4%
2020	Jan.	0.0%	0.7%	99.3%	80.9%	44.0%	23.0%	17.5%	13.1%	10.6%
	Feb.	0.0%	0.0%	100.0%	92.4%	59.6%	37.2%	23.2%	15.0%	9.1%
	Mar. [1]	0.0%	0.0%	100.0%	86.2%	36.8%	16.4%	9.9%	5.3%	3.3%
	Apr.									
	May									
	Jun.									
	Jul.									
	Aug.									
	Sep. [1]	0.0%	0.0%	100.0%	99.0%	82.7%	33.7%	12.5%	6.7%	3.8%
	Oct.	0.0%	0.0%	100.0%	89.9%	53.5%	27.0%	13.1%	6.2%	3.9%
	Nov.	0.0%	0.0%	100.0%	91.4%	66.0%	44.3%	29.5%	19.3%	13.3%
	Dec.	0.0%	0.5%	99.5%	78.6%	30.2%	13.8%	8.3%	4.4%	2.8%
2021	Jan.	0.0%	0.0%	100.0%	84.6%	34.1%	15.4%	9.7%	4.6%	3.2%
	Feb.	0.0%	0.0%	100.0%	85.7%	37.8%	17.6%	5.4%	2.8%	1.5%
	Mar.	0.0%	0.0%	100.0%	94.5%	51.6%	30.2%	13.1%	6.5%	3.0%
	Apr.	0.0%	0.0%	100.0%	100.0%	58.2%	38.8%	24.5%	18.4%	11.2%
	May									
	Jun.									
	Jul.									
	Aug.									
	Sep. [1]	0.0%	0.0%	100.0%	100.0%	100.0%	91.7%	41.7%	41.7%	8.3%
	Oct.	0.0%	0.0%	100.0%	97.2%	74.9%	49.1%	34.1%	21.9%	14.1%

[1] Incomplete month or year.

Table A14. Laundry 2 and Abusu temperature comparison, nighttime hours (22:00–07:00 h).

		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	ΔT > 2 °C	ΔT > 4 °C	ΔT > 6 °C	ΔT > 8 °C	ΔT > 10 °C	ΔT > 12 °C
Whole Period Analysis										
Whole available period		0.0%	0.7%	99.3%	80.5%	22.6%	4.4%	0.9%	0.2%	0.1%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	ΔT > 2 °C	ΔT > 4 °C	ΔT > 6 °C	ΔT > 8 °C	ΔT > 10 °C	ΔT > 12 °C
2019 [1]		0.0%	2.9%	97.1%	79.4%	15.2%	1.0%	0.0%	0.0%	0.0%
2020 [1]		0.0%	0.4%	99.6%	78.9%	22.3%	5.9%	0.8%	0.2%	0.0%
2021 [1]		0.0%	0.5%	99.5%	82.8%	24.9%	3.4%	1.2%	0.2%	0.2%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	ΔT > 2 °C	ΔT > 4 °C	ΔT > 6 °C	ΔT > 8 °C	ΔT > 10 °C	ΔT > 12 °C
2019	Dec.	0.0%	2.9%	97.1%	79.4%	15.2%	1.0%	0.0%	0.0%	0.0%
2020	Jan.	0.0%	0.6%	99.4%	72.3%	11.0%	1.0%	0.0%	0.0%	0.0%
	Feb.	0.0%	0.3%	99.7%	78.3%	24.8%	10.7%	2.8%	0.3%	0.0%
	Mar. [1]	0.0%	0.0%	100.0%	66.7%	1.9%	0.0%	0.0%	0.0%	0.0%
	Apr.									
	May									
	Jun.									
	Jul.									
	Aug.									
	Sep. [1]	0.0%	0.0%	100.0%	100.0%	83.3%	36.1%	0.0%	0.0%	0.0%
	Oct.	0.0%	0.0%	100.0%	89.4%	20.3%	5.2%	0.3%	0.0%	0.0%
	Nov.	0.0%	0.0%	100.0%	87.0%	39.0%	8.0%	1.3%	0.7%	0.0%
	Dec.	0.0%	1.3%	98.7%	67.4%	10.0%	0.0%	0.0%	0.0%	0.0%
2021	Jan.	0.0%	0.3%	99.7%	81.6%	8.4%	0.3%	0.3%	0.3%	0.0%
	Feb.	0.0%	1.8%	98.2%	62.9%	8.9%	0.7%	0.0%	0.0%	0.0%
	Mar.	0.0%	0.0%	100.0%	92.6%	34.5%	3.5%	1.9%	0.0%	0.0%
	Apr.	0.0%	0.0%	100.0%	97.1%	40.0%	10.0%	4.3%	2.9%	2.9%
	May									
	Jun.									
	Jul.									
	Aug.									
	Sep. [1]	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%
	Oct.	0.0%	0.0%	100.0%	88.7%	42.3%	6.5%	1.3%	0.0%	0.0%

[1] Incomplete month or year.

Table A15. Laundry 3 and Abusu station monthly temperature comparison.

		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole Period Analysis										
Whole available period		1.0%	1.4%	97.5%	89.4%	55.3%	19.7%	8.2%	4.0%	1.5%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]		2.4%	1.3%	96.3%	87.4%	58.6%	26.4%	13.8%	7.2%	2.9%
2021 [1]		0.5%	1.5%	98.0%	90.2%	54.1%	17.1%	6.1%	2.7%	0.9%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020	Sep. [1]	10.1%	3.0%	86.8%	80.0%	60.8%	36.6%	18.0%	5.4%	0.6%
	Oct.	0.1%	1.6%	98.3%	87.5%	50.1%	18.4%	8.9%	4.8%	0.3%
	Nov.	0.0%	0.4%	99.6%	92.4%	71.3%	37.1%	21.5%	14.4%	8.6%
	Dec.	0.0%	0.3%	99.7%	89.0%	52.7%	15.1%	7.4%	4.3%	2.2%
2021	Jan.	0.1%	0.3%	99.6%	91.9%	59.7%	18.4%	7.4%	4.6%	2.3%
	Feb.	0.4%	2.5%	97.0%	83.2%	43.0%	13.2%	6.4%	2.4%	0.9%
	Mar.	0.7%	0.8%	98.5%	93.5%	63.6%	28.6%	8.7%	3.1%	0.4%
	Apr.	0.0%	1.3%	98.8%	92.6%	66.0%	21.0%	4.7%	0.7%	0.0%
	May	1.7%	2.3%	96.0%	87.5%	47.0%	8.6%	1.2%	0.3%	0.1%
	Jun.	0.4%	2.2%	97.4%	86.8%	35.3%	4.6%	1.1%	0.0%	0.0%
	Jul.	0.4%	1.5%	98.1%	90.1%	35.6%	3.6%	0.1%	0.0%	0.0%
	Aug.	0.3%	1.7%	98.0%	91.4%	50.0%	11.6%	1.1%	0.0%	0.0%
	Sep.	0.8%	1.0%	98.2%	95.1%	69.2%	23.9%	6.7%	1.3%	0.4%
	Oct.	0.3%	1.7%	98.0%	89.2%	69.4%	36.3%	21.6%	12.9%	4.6%

[1] Incomplete month or year.

Table A16. Laundry 3 and Abusu temperature comparison, daytime hours (08:00–21:00 h).

		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
Whole Period Analysis										
Whole available period		1.7%	2.0%	96.2%	86.8%	56.7%	25.7%	12.2%	6.2%	2.5%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020 [1]		4.1%	2.0%	94.0%	83.7%	56.7%	31.2%	17.8%	10.5%	4.8%
2021 [1]		0.8%	2.1%	97.1%	88.0%	56.7%	23.6%	9.9%	4.5%	1.6%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	$\Delta T > 2\ °C$	$\Delta T > 4\ °C$	$\Delta T > 6\ °C$	$\Delta T > 8\ °C$	$\Delta T > 10\ °C$	$\Delta T > 12\ °C$
2020	Sep. [1]	17.2%	4.9%	77.9%	67.6%	43.7%	22.1%	6.4%	1.5%	0.0%
	Oct.	0.2%	2.3%	97.5%	84.3%	53.2%	28.3%	15.0%	8.1%	0.5%
	Nov.	0.0%	0.7%	99.3%	93.1%	75.0%	51.9%	36.7%	24.5%	14.8%
	Dec.	0.0%	0.2%	99.8%	88.2%	54.1%	22.1%	12.7%	7.4%	3.7%
2021	Jan.	0.0%	0.5%	99.5%	91.5%	59.2%	23.3%	12.2%	7.8%	3.9%
	Feb.	0.8%	3.3%	95.9%	83.2%	45.9%	21.2%	11.0%	4.1%	1.5%
	Mar.	1.2%	1.4%	97.5%	88.9%	59.7%	33.9%	13.6%	5.1%	0.7%
	Apr.	0.0%	2.1%	97.9%	90.0%	67.9%	28.1%	7.9%	1.2%	0.0%
	May	2.8%	2.5%	94.7%	86.2%	49.5%	11.3%	1.6%	0.5%	0.2%
	Jun.	0.7%	3.1%	96.2%	85.0%	42.1%	6.7%	1.2%	0.0%	0.0%
	Jul.	0.7%	2.1%	97.2%	87.1%	41.9%	4.8%	0.2%	0.0%	0.0%
	Aug.	0.5%	3.0%	96.5%	88.0%	54.4%	18.2%	1.8%	0.0%	0.0%
	Sep.	1.4%	1.2%	97.4%	92.6%	72.1%	33.8%	11.4%	2.1%	0.7%
	Oct.	0.5%	1.8%	97.7%	87.8%	71.7%	52.1%	35.5%	22.1%	7.8%

[1] Incomplete month or year.

Table A17. Laundry 3 and Abusu temperature comparison, nighttime hours (22:00–07:00 h).

Whole Period Analysis										
		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	ΔT > 2 °C	ΔT > 4 °C	ΔT > 6 °C	ΔT > 8 °C	ΔT > 10 °C	ΔT > 12 °C
Whole available period		0.0%	0.6%	99.3%	93.1%	53.4%	11.3%	2.7%	0.8%	0.1%
Yearly Analysis										
Year		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	ΔT > 2 °C	ΔT > 4 °C	ΔT > 6 °C	ΔT > 8 °C	ΔT > 10 °C	ΔT > 12 °C
2020 [1]		0.0%	0.3%	99.7%	92.6%	61.2%	19.7%	8.1%	2.7%	0.3%
2021 [1]		0.1%	0.7%	99.2%	93.3%	50.4%	8.1%	0.7%	0.0%	0.0%
Monthly Analysis										
Month		$T_{laundry} < T_{ext}$	$T_{laundry} \approx T_{ext}$	$T_{laundry} > T_{ext}$	ΔT > 2 °C	ΔT > 4 °C	ΔT > 6 °C	ΔT > 8 °C	ΔT > 10 °C	ΔT > 12 °C
2020	Sep. [1]	0.0%	0.4%	99.6%	97.8%	85.3%	57.4%	34.6%	11.0%	1.5%
	Oct.	0.0%	0.6%	99.4%	91.9%	45.8%	4.5%	0.3%	0.3%	0.0%
	Nov.	0.0%	0.0%	100.0%	91.3%	66.0%	16.3%	0.3%	0.3%	0.0%
	Dec.	0.0%	0.3%	99.7%	90.0%	50.6%	5.2%	0.0%	0.0%	0.0%
2021	Jan.	0.3%	0.0%	99.7%	92.6%	60.3%	11.6%	0.6%	0.0%	0.0%
	Feb.	0.0%	1.4%	98.6%	83.2%	38.9%	2.1%	0.0%	0.0%	0.0%
	Mar.	0.0%	0.0%	100.0%	100.0%	69.0%	21.3%	1.9%	0.3%	0.0%
	Apr.	0.0%	0.0%	100.0%	96.3%	63.3%	11.0%	0.3%	0.0%	0.0%
	May	0.3%	1.9%	97.7%	89.4%	43.5%	4.8%	0.6%	0.0%	0.0%
	Jun.	0.0%	1.0%	99.0%	89.3%	25.7%	1.7%	1.0%	0.0%	0.0%
	Jul.	0.0%	0.6%	99.4%	94.2%	26.8%	1.9%	0.0%	0.0%	0.0%
	Aug.	0.0%	0.0%	100.0%	96.1%	43.9%	2.3%	0.0%	0.0%	0.0%
	Sep.	0.0%	0.7%	99.3%	98.7%	65.0%	10.0%	0.0%	0.0%	0.0%
	Oct.	0.0%	1.6%	98.4%	91.3%	66.1%	14.2%	2.3%	0.0%	0.0%

[1] Incomplete month or year.

References

1. Kumar, S.; Fisk, W.J. IEQ and the Impact on Building Occupants. *ASHRAE J.* **2002**, *44*, 50–52. Available online: https://www.osti.gov/biblio/803790 (accessed on 20 November 2022).
2. Heat Stress Related Illness | NIOSH | CDC. Available online: https://www.cdc.gov/niosh/topics/heatstress/heatrelillness.html (accessed on 21 November 2022).
3. Excess Mortality during Heat-Periods-Office for National Statistics. Available online: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/excessmortalityduringheatperiods/englandandwales1juneto31august2022#excess-mortality-during-heat-periods-data (accessed on 21 November 2022).
4. Lawrance, E.; Thompson, R.; Fontana, G.; Jennings, N. The Impact of Climate Change on Mental Health and Emotional Wellbeing: Current Evidence and Implications for Policy and Practice, London. 2021. Available online: https://spiral.imperial.ac.uk/bitstream/10044/1/88568/9/3343%20Climate%20change%20and%20mental%20health%20BP36_v6.pdf (accessed on 21 November 2022).
5. Heat Mortality Monitoring Report: 2020-GOV.UK. Available online: https://www.gov.uk/government/publications/heat-mortality-monitoring-reports/heat-mortality-monitoring-report-2020#heatwave-and-covid-19 (accessed on 21 November 2023).
6. Lin, Z.; Deng, S. A questionnaire survey on sleeping thermal environment and bedroom air conditioning in high-rise residences in Hong Kong. *Energy Build.* **2006**, *38*, 1302–1307. [CrossRef]
7. Zheng, G.; Li, K.; Wang, Y. The Effects of High-Temperature Weather on Human Sleep Quality and Appetite. *Int. J. Environ. Res. Public Health* **2019**, *16*, 270. [CrossRef] [PubMed]
8. Mullington, J.M.; Haack, M.; Toth, M.; Serrador, J.M.; Meier-Ewert, H.K. Cardiovascular, Inflammatory, and Metabolic Consequences of Sleep Deprivation. *Prog. Cardiovasc. Dis.* **2009**, *51*, 294–302. [CrossRef] [PubMed]
9. Okamoto-Mizuno, K.; Mizuno, K. Effects of thermal environment on sleep and circadian rhythm. *J. Physiol. Anthropol.* **2012**, *31*, 14. [CrossRef] [PubMed]
10. Mayrhofer, L.; Müller, A.; Bügelmayer-Blaschek, M.; Malla, A.; Kranzl, L. Modelling the effect of passive cooling measures on future energy needs for the Austrian building stock. *Energy Build.* **2023**, *296*, 113333. [CrossRef]

11. Miranda, N.D.; Lizana, J.; Sparrow, S.N.; Zachau-Walker, M.; Watson, P.A.G.; Wallom, D.C.H.; Khosla, R.; McCulloch, M. Change in cooling degree days with global mean temperature rise increasing from 1.5 °C to 2.0 °C. *Nat. Sustain.* **2023**, *6*, 1326–1330. [CrossRef]
12. Kapeller, R.; Bügelmayer-Blaschek, M.; Herndler, B.; Kranzl, L.; Müller, A.; Moser, S.; Natiesta, T.; Reichl, J.; Schwalbe, R. The effects of climate change-induced cooling demand on power grids. *Energy Rep.* **2024**, *11*, 674–691. [CrossRef]
13. Hao, L.; Herrera-Avellanosa, D.; Del Pero, C.; Troi, A. Overheating Risks and Adaptation Strategies of Energy Retrofitted Historic Buildings under the Impact of Climate Change: Case Studies in Alpine Region. *Appl. Sci.* **2022**, *12*, 7162. [CrossRef]
14. Borghero, L.; Clèries, E.; Péan, T.; Ortiz, J.; Salom, J. Comparing cooling strategies to assess thermal comfort resilience of residential buildings in Barcelona for present and future heatwaves. *Build. Environ.* **2023**, *231*, 110043. [CrossRef]
15. Jaysawal, R.K.; Chakraborty, S.; Elangovan, D. Padmanaban, Concept of net zero energy buildings (NZEB)—A literature review. *Clean Eng. Technol.* **2022**, *11*, 100582. [CrossRef]
16. Taylor, J.; McLeod, R.; Petrou, G.; Hopfe, C.; Mavrogianni, A.; Castaño-Rosa, R.; Pelsmakers, S.; Lomas, K. Ten questions concerning residential overheating in Central and Northern Europe. *Build. Environ.* **2023**, *234*, 110154. [CrossRef]
17. Moreno-Rangel, A. Passivhaus. *Encyclopedia* **2021**, *1*, 20–29. [CrossRef]
18. Observatoire BCC. Etude sur les Solutions Techniques et les Coûts Associés aux Labels Effinergie. 2022. Available online: https://www.effinergie.org/web/images/attach/base_doc/3112/20220419_Rapport%20LC.pdf (accessed on 29 November 2023).
19. Attia, S.; Benzidane, C.; Rahif, R.; Amaripadath, D.; Hamdy, M.; Holzer, P.; Koch, A.; Maas, A.; Moosberger, S.; Petersen, S.; et al. Overheating calculation methods, criteria, and indicators in European regulation for residential buildings. *Energy Build.* **2023**, *292*, 113170. [CrossRef]
20. Rodríguez-Vidal, I.; Otaegi, J.; Oregi, X. Thermal Comfort in NZEB Collective Housing in Northern Spain. *Sustainability* **2020**, *12*, 9630. [CrossRef]
21. Otaegi, J.; Hernández, R.J.; Oregi, X.; Martín-Garín, A.; Rodríguez-Vidal, I. Comparative Analysis of the Effect of the Evolution of Energy Saving Regulations on the Indoor Summer Comfort of Five Homes on the Coast of the Basque Country. *Buildings* **2022**, *12*, 1047. [CrossRef]
22. Coop, K.S. Annex IV. Urban Renewal Areas. Documento de Aprobación Inicial del PTP del Área Funcional de Bilbao Metropolitano. 2023. Available online: https://www.bizkaia.eus/hirigintza/lurraldekozatiegitasmoa/ptp_bilbao_aprobacion_provisional/ESCRITA/CAST/Anexos_normas/ANEXO%20IV_Reg_Ren_Rehab.pdf (accessed on 29 November 2023).
23. VISESA. Bolueta Tower 1 in the VISESA Database. Available online: https://apps.visesa.eus/app/promociones-detalle.asp?id=7363&idioma=1 (accessed on 29 November 2023).
24. VISESA. Bolueta Tower 2 in the VISESA Database. Available online: https://apps.visesa.eus/app/promociones-detalle.asp?id=8099&idioma=1 (accessed on 29 November 2023).
25. Passive House Database, Passive House Database. 2018. Available online: https://passivehouse-database.org/index.php?lang=en#d_5233 (accessed on 26 November 2023).
26. VISESA. Bolueta Urban Renewal Project Feature Page at the VISESA Website. Available online: https://www.visesa.euskadi.eus/bolueta/ (accessed on 29 November 2023).
27. Celada Ortiz de Apodaka, L.A.; Tina Galdós, F.J.; La Peña Irigoyen, H. Passivhaus en altura en Bolueta-Bilbao. Proyecto de 361 VPO, Sociales y Tasadas en dos Bloques (28 y 21 Alturas Sobrer Rasante) Cumple estándares Passivhaus. In *CONTART 2018: VII Convención de La Edificación*; Martos Pérez, V., Colegio Oficial de Aparejadores y Arquitectos Técnicos de Zaragoza, Eds.; Escuela Universitaria Politécnica de La Almunia: Zaragoza, Spain, 2018; pp. 331–339. Available online: https://2018.contart.es/wp-content/uploads/CONTART_LIBRO_2018_1_Junio-opt.pdf (accessed on 27 November 2022).
28. Ministerio de Transporte Movilidad y Agenda Urbana, Documento de Apoyo al Documento Básico DB-HE Ahorro de Energía, Madrid. 2020. Available online: https://www.codigotecnico.org/pdf/Documentos/HE/DA_DB-HE-1_Calculo_de_parametros_caracteristicos_de_la_envolvente.pdf (accessed on 29 November 2023).
29. Euskalmet Agencia Vasca de Meteorología | Open Data. Available online: https://www.euskalmet.euskadi.eus/servicios/open-data/ (accessed on 29 November 2023).
30. Rodríguez-Vidal, I.; Martín-Garín, A.; González-Quintial, F.; Rico-Martínez, J.M.; Hernández-Minguillón, R.J.; Otaegi, J. Response to the COVID-19 Pandemic in Classrooms at the University of the Basque Country through a User-Informed Natural Ventilation Demonstrator. *Int. J. Environ. Res. Public Health* **2022**, *19*, 14560. [CrossRef] [PubMed]
31. AEMET. Resumen Estacional Climatológico-Verano 2019. 2019. Available online: https://www.aemet.es/documentos/es/serviciosclimaticos/vigilancia_clima/resumenes_climat/estacionales/2019/Est_verano_2019.pdf (accessed on 29 November 2023).
32. AEMET. Resumen Estacional Climatológico-Invierno 2020–2021. 2020. Available online: https://www.aemet.es/documentos/es/serviciosclimaticos/vigilancia_clima/resumenes_climat/estacionales/2021/Est_invierno_21_22.pdf (accessed on 29 November 2023).
33. AEMET. Resumen Estacional Climatológico-Verano 2021. 2021. Available online: https://www.aemet.es/documentos/es/serviciosclimaticos/vigilancia_clima/resumenes_climat/estacionales/2021/Est_verano_21.pdf (accessed on 29 November 2023).

34. AEMET. Resumen Estacional Climatológico-Verano 2022. 2022. Available online: https://www.aemet.es/documentos/es/serviciosclimaticos/vigilancia_clima/resumenes_climat/estacionales/2022/Est_verano_22.pdf (accessed on 29 November 2023).
35. AEMET. Resumen Estacional Climatológico-Invierno 2022–2023. 2023. Available online: https://www.aemet.es/documentos/es/serviciosclimaticos/vigilancia_clima/resumenes_climat/estacionales/2022/Est_invierno_22_23.pdf (accessed on 29 November 2023).