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Executive Summary

This document is an updated (version 2) of the Deliverable D1.4 on Performance Measurement and Verification Methodology. Detail analysis used for the construction of the baseline that is necessary for the methodology is presented in the first part, while the last part focuses on the previously developed KPIs, providing some further comments, modifications and additional KPIs to be taken into account.

The Performance Measurement and Verification Methodology was described in detail in Deliverable D1.4, while in this one the baseline for the energy consumption for the two pilot sites is constructed, using real historical data. In specific, we analysed smart metering data from the previous year for both sites and with different degrees of granularity and asset disaggregation. We present the results of the exploratory data analysis (EDA) through a multitude of graphs, figures, and tables, and we provide meaningful insights on the patterns and correlations of energy demand with the environment or the occupancy conditions. For the modelling of baseline energy demand of the assets, or sometimes-complete buildings, we have used multivariate linear regression models, also presented here.

The KPIs that are used to evaluate the project are briefly mentioned once more in this document. Thereafter, the discussion is focused on specific elements of some of the quantitative KPIs in relation to the two pilot sites, and the data that we need to collect from the sites for calculating each KPI. Some of the KPIs will be evaluated in the same way in both pilot sites, whereas others fit best only to one of the two pilot sites, either due to site specific characteristics or to lack of data. Following comments from the respective partners involved in the pilot sites on some KPIs, either some of their initial target values have been re-evaluated or the KPIs themselves have been calculated in a different way. Finally, some additional KPIs for the project evaluation are proposed for building a better picture of the project. In general, due to the ongoing development of the pilot sites (in some cases delayed due to COVID-19) and the dynamic nature of its evaluation, it has been decided that for a few of the KPIs further modifications should be necessary. These might undertake at a later stage and will be documented in the respective report of WP7 on the pilot sites evaluation.

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List of Acronyms and Abbreviations

Term	Description
EDA	Exploratory Data Analysis
ML	Machine Learning
ABT	Analytical Base Table
HDH	Heating Degree Hours
CDH	Cooling Degree Hours
HDD	Heating Degree Days
CDD	Cooling Degree Days
HDM	Heating Degree Minutes
CDM	Cooling Degree Minutes
RH	Relative Humidity (%)
Tamb	Ambient Temperature (ºC)
KPIs	Key Performance Indicators
GHI	Global Horizontal Irradiance
Gpoa	Global plane of array irradiance
QL	Qualitative
QT	Quantitative
DD	Other Delta Deliverable
DR	Demand Response
RES	Renewable Energy Sources
VPP	Virtual Power Plant
DSO	Distribution System Operator
FEID	Fog-enabled intelligent device
KPI	Key Performance Indicator
LVDD	Low Voltage Demand Disconnection
LFDD	Low Frequency Demand Disconnection

1. Introduction

This deliverable is the second version of deliverable D1.4 on Performance Measurement and Verification Methodology report. Smart metering data for the two pilot sites were made available from pilot partners' side and were analysed accordingly. Meaningful insights on the patterns and correlations of demand with environment or occupancy conditions were acquired. In the modelling part, multivariate linear regression models have been used for modelling energy demand in pilot site buildings and assets. All the relevant results are presented accordingly.

1.1 Scope and objectives of the deliverable

In this second version of the deliverable 1.4, smart metering data from the two pilot sites of the DELTA project have been used in order to perform exploratory data analysis (EDA) and energy baseline modelling. For modelling purposes the multivariate linear regression approach was used, as suggested by European and international standards. All the variables used as potential predictors of energy demand and results obtained are described in respective sections.

1.2 Structure of the deliverable

Section 1 introduces the deliverable scope and objectives, determines its relation to other tasks and deliverables, summarizes the previous version of the report and justifies the use of exploratory data analysis and energy baseline modelling for the two pilot sites. Section 2 presents the results of the EDA that was performed on the historical data. Section 3 presents the results on energy baseline modelling on historical data using a multivariate linear regression model. Section 4 presents Key Performance Indicators and adjustments that were performed for the needs of this work. Section 5 concludes the report.

1.3 Relation to Other Tasks and Deliverables

The relation of this Deliverable to other tasks and deliverables is described as follows:

- This deliverable is the second version of the deliverable D1.4 on Performance Measurement & Verification Methodology report
- The work developed in this deliverable will support the validation activities during the deployment of DELTA DR programs
- EDA and energy baseline modelling for the two pilot sites are provided accordingly
- Key Performance Indicators to be evaluated with their final adjustments for the needs of the deployment of DR programs are provided

1.4 Summary of the previous Report

The present report complements the deliverable D1.4 – Performance Measurement & Verification methodology report. In that report we described the methodology to be followed in the DELTA project, as far as Performance Measurement and Verification (PMV) is concerned. Using this methodology, the various outcomes of the project will be evaluated. The outcomes refer to many aspects, from technologies and services to business models and stakeholders' satisfaction.

The proposed PMV methodology was chosen after carefully reviewing available standards on measurement and verification of energy savings in other European and international projects, as well as the International Performance Measurement and Verification Protocol (IPMVP), which was selected as a reference work.

Since the PMV methodology will be applied to the outcomes of the project mainly coming from the pilot sites, these were also presented in the previous report, in order to clarify how the PMV methodology can be applied on the actual sites. In specific, we described in detail both pilot sites, the available facilities and their specific technical characteristics, and the energy schematic diagrams that depict the types of energy carriers available per site. Moreover, some critical issues for the success of the project were highlighted.

To evaluate all the different aspects in a proper way, we proposed the use of three groups of Key Performance Indicators (KPIs):

a) **quantitative** KPIs calculated using mathematical expressions, which usually evaluate technical outcomes,
b) **qualitative** KPIs assessed through feedback from the relevant stakeholders, which evaluate aspects such as user satisfaction, effectiveness of business models, etc., and
KPIs with a target value to be met through the successful implementation of the pilot sites or through other tasks and deliverables.

Moreover, these KPIs were selected in a way to address the expected impact of DELTA in the Work Programme, therefore they were also categorised according to their objectives as follows:

1. **Four** KPIs relevant and compatible with the broad EU energy policy context (Energy Union, Climate related packages, etc).
2. **Two** KPIs addressing ongoing policy developments in the field of the design of the internal electricity market, of the retail market and discussions on self-consumption
3. **Three** KPIs addressing interconnections between Member States and/or between energy networks
4. **Three** KPIs assessing the capability of the EU power network to integrate large share of renewables in a stable and secure way
5. **Three** KPIs assessing the ability of EU based companies to deliver adequate competitive products and services in the market, 5-10 years after the end of the project
6. **Ten** KPIs enabling and/or enhancing DR schemes to bring proven and quantified benefits for the grid, the aggregators/retailers, and the consumers/prosumers; validation of business models
7. **One** KPI showing quantified benefits for the Ad-hoc DELTA indicators

This cross-categorization of KPIs in three groups and seven categories is presented in the table below.

Table 1 List of initial KPIs (D1.4)

KPI	Title / **Target**	Group
1.1	Emission savings / **At least 20% lower carbon emissions in the Customers of the pilot activities**	QT
1.2	Increase in trust and security / **At least 75% of the Customers in the sites will acknowledge DELTA integrity**	QL
1.3	Peak load reduction / **At least 44% peak load reduction is expected during the demonstration activities**	QT
1.4	Energy efficiency / **At least 20% energy savings expected for the pilots' participants**	QT
2.1	Guidelines regarding current policies for including the DELTA solution / **Consolidating relevant outputs of workshops in at least 2 white papers**	DD
2.2	Recommendations for policy makers for developing appropriate regulations to accelerate market adoption of the project solutions / **A number of recommendations would be included from the various Stakeholders and organizations**	DD
3.1	Workshops organization and participation / **4 workshops will be organized throughout the project lifetime**	DD
3.2	Number of people participating in workshops / **At least 100 people/workshop are expected to participate**	DD
3.3	Utilities willingness to validate the solution / **At least 4 Utilities will be interested in validating the solution, during the project**	DD

4.1	Inclusion of distribution grid-connected RES and energy storage in VPP / **A 10 MW of installed capacity PV park and 1MWh Storage will be included and participate in the VPP-based DELTA solution, along with residential prosumers, during the demonstration activities**	DD
4.2	Reduced imbalance penalties-related costs due to RES supply volatility / **Aggregators and Retailers will validate a minimum reduction of imbalance-related costs of 15-20%**	QT
4.3	Increase of distribution grid capacity to support RES / **At least 30% more grid capacity will be evaluated by the Cyprus pilot DSO**	QT
5.1	Validation of DELTA solution from key Energy Stakeholders / **At least 1 Aggregator, 1 DSO and 1 Retailer will validate the solution during pilot activities**	DD
5.2	Number of software products delivered / **At least 5 (collaboration, award, visualization, segmentation and forecasting)**	DD
5.3	Customers, Retailers, SMEs acceptance for future use / **At least 70% of participants would express their interest for future use of the DELTA solution**	QL
6.1.1	Number of successfully delivered and validated business models / **At least three complete business models will be conceived and two will be validated during the pilot activities**	DD
6.1.2	Delivery of DR-enabling tools and devices for utilization from Retailers/Aggregators **Delivery Decision Support System for Aggregators, Virtual-Node-Platform, Fog-Enabled Devices and deployment in the pilots' phase**	DD
6.1.3	Increase of revenues / **Revenues for Aggregators are expected to exceed 20%, compared with current best DR practices in single buildings**	QT
6.1.4	Customers' Responsiveness / **Customers' responsiveness that use a FEID combined with BMS will go beyond 95% (fully-automated solution)**	DD
6.2.1	Discount in Customers' costs / **At least 25% discount in Customers' costs during the demonstration activities**	QT
6.2.2	Number of Customers successfully engaged / **At least 100 end-users will participate in the two real-life demonstrators of DELTA technologies (residential and non-residential blocks of buildings)**	DD
6.2.3	Customers' satisfaction and user friendliness of the UIs / **More than 70% of the involved customers in the demonstration sites express positive opinion on the ease of use solution**	QL
6.3.1	Full-scale provision of grid balancing and ancillary services / **At least 70% of the services delivered/tested during the demonstration activities**	QT
6.3.2	Smart load shedding, instead of Low Voltage/Frequency Demand Disconnection (LVDD&LFDD) / **100% achieved/tested during the demonstration activities**	QT
6.3.3	Distribution Grid congestion losses reduced / **At least 15% losses reduction during the demonstration activities**	QT
7.1	Timely and full (at the designated percentage) provision of defined indicators at the end of each year / **Respective KPIs should have reached their target at the end of each year**	DD

For evaluating KPIs that deal with the successful implementation of demand response, it is necessary to calculate a baseline, which is the energy consumption profile in the current conditions, i.e. without any demand response. The baseline serves as a reference tool and is fundamental to evaluate the project results. Therefore, another contribution of the previous report was the provision of guidelines to determine the baseline for energy/power demand in DELTA pilot sites. Based on the literature review, three baselining approaches (regression models, meter before/meter after, and day match baselining) were presented. A regression model is the proper option when metering data are available at the building level. Thus, for the DELTA pilot sites, where historical data are also available, we selected to develop a regression model to associate the dependent variables (energy/power demand) with independent ones, such as outdoor humidity, outdoor temperature, type of day (weekday, weekend, holiday), etc. For more details on the regression model the reader can refer to sub-chapter 2.3.1 of the previous report.

In the present report, after discussions with the pilot sites' owners and respective technical partners of the consortium, the above list of KPIs has been slightly modified. First of all, some of their target values were considered unrealistic, thus changed appropriately to reflect to a more achievable target. Moreover, in the process of pilot sites' implementation, some of the KPIs have been found to be relevant or appropriate for only one of the two sites (in UK or Cyprus). Finally, a few new KPIs were included. In the next chapters, the updated KPIs will be described. Moreover, building on the above mentioned work with respect to baselining, in the present report we perform a statistical analysis of historical data coming from the two pilot sites to determine which of the initially considered independent variables have a significant impact on energy/power demand. In this way, we build a final regression model that calculates the baseline for the energy profiles of various types of consumption. This process is explained in more detail in the following sub-chapters.

1.5 Exploratory Data Analysis

The large-scale deployment of smart metering solutions makes it easier to monitor, with high granularity, energy consumption in buildings. Energy consumption takes place for the fulfilment of different types of needs e.g. heating, cooling, lighting, etc. during different period of time within a day and in different ways between seasons. Ambient conditions in the geographic area where energy consumption takes place may be an important determinant of demand. Similarly, the occupancy profiles within buildings may act as a major determinant as well, since the presence of people in buildings drives the demand patterns for the fulfilment of specific needs and tasks e.g. heating/cooling of administration buildings and industrial processes, lighting needs of universities, and households, etc. In order for the analyst to perform meaningful exploratory data analysis, the data on energy consumption and the potential determinants of demand should be available with a timestamp. This condition simplified the investigation of potentials correlations of the dependent variable, i.e. energy demand with the independent variables, i.e. the chosen predictors.

For the needs of this work, energy consumption data from the pilot sites where made available for analysis. A granularity of 15 minutes was considered as adequate enough for the needs of the analysis and modelling work performed. The potential energy demand determinants included heating and cooling degree days (HDD, CDD) of the considered site, relative humidity (%), ambient temperature (^oC) and global horizontal irradiance (W/m^2) as well as the occupancy profiles (%) of the considered buildings. A number of features was extracted from the energy demand timestamp. These are day of the month, hour of the day, minute of the day, day of the year, week of the year, day of the week, indicator variables for the weekdays and weekend days, indicator variables for holidays and emergency conditions (e.g. Corona virus), and indicator variables for month and season of the year.

The exploratory data analysis was performed for both pilots for data points between 01/01/2019 and 31/07/2020, aiming at capturing adequately the variation of the environment (temperature, relative humidity, etc.) and human driven (e.g. occupancy profile) conditions in the given sites. The results of the work, including plethora of graphs, were generated and are presented in respective sub-sections for the two pilot sites. The big picture of demand and the effect of the chosen variables on energy demand were analysed and are presented in the two sections dedicated to the pilot sites, below.

1.6 Energy Baseline

The capacity of an organization to adequately forecast its energy demand could potentially add value to the coordination of its activities e.g. participation in DR programs managed by electricity DSOs and aggregators, for the financial and organizational benefit of the organization. In the previous version of this report [1], the construction of a multivariable linear regression model was qualified for doing so. A number of independent variables, which were introduced in the previous section, could be used for this purpose. Several European Standards, [2][3][4][5], suggest the use of such models for the calculation of baseline energy demand in buildings. This is the approach followed in this work. A multivariate linear regression model, on the whole dataset, was constructed aiming to investigate the coefficient of determination (adjusted R-squared) for all the buildings and assets that are available in the two pilot sites of the Delta project. Due to the fact that energy demand in buildings is subject to seasonality effects, an alternative approach would be to split the initial dataset into seasons. An analytical base table (ABT), i.e. a table consisting of numerical and indicator variables, has been used as input for energy baseline modelling. Results are obtained and presented. The use of control group buildings for energy baseline purposes is strongly advised.

As both pilot sites have been described in the previous version of this report in detail, only a brief overview is presented in the following sections.

2. UCY Pilot Site

UCY pilot site is one of the two pilot sites where the DELTA solution will be deployed. Figure 1 depicts the overview of the electricity flows, on the treatment group buildings, at the UCY pilot site.

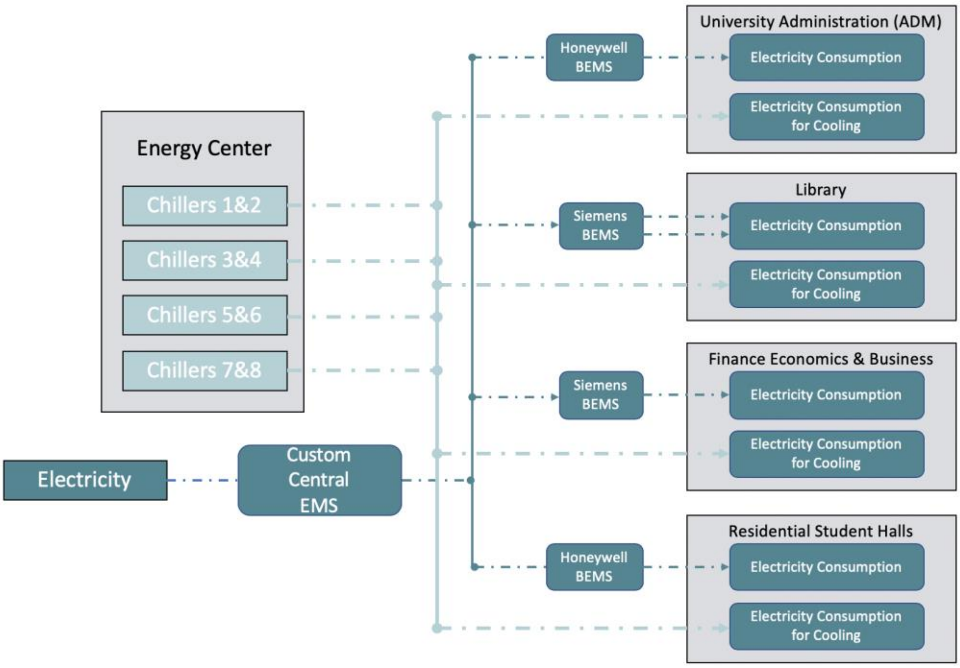


Figure 1. Overview of electricity flows at UCY pilot site

Table 2 presents the aggregated energy consumption, CO_2 emissions and costs for the period of analysis considered in this report. The CO_2 emissions conversion factor at UCY facilities is 0.677 kg of CO_2 per kWh consumed. For the calculation of aggregated energy costs, the equation
(1) has been used:

$$N*(Meter\_Reading\_Charge + Supply\_Charge) + \sum E_c * (Energy_{charge} + Network_{charge} + Ancillary_{Services_{Charge}}) \quad (1)$$

where N: number of months falling into period of analysis. All the charges use the same timestamp as the timestamp of the analysis considered in this report.

Table 2. Aggregated energy consumption and costs at UCY pilot site

Building/Load	Aggregated energy consumption (kWh)	Aggregated CO2 emissions (tons)	Aggregated energy costs (€)
Administration Building	1,138,248.2	770.60	3,652,584.05€
Chillers 1 & 2	1,493,220.8	1,010.92	234,597.84€
Chillers 3 & 4	1,970,380.8	1,333.95	309,455.70€
Chillers 5 & 6	1,553,762.1	1,051.90	243,955.62€
Chillers 7 & 8	569,117.0	385.92	89,406.46€
Finance Economics & Business	2,009,548.1	1,360.46	315,553.87€
Library 1	13,221,631.2	8,951.04	662,864.36€
Library 2	16,803,741.8	11,376.13	1,225,412.36€
Students' Residence Building A	835,862.2	565.88	131,285.09€

In buildings where PV installations are present, for the calculation of CO_2 emissions the net electricity demand was taken into account. When the net demand is negative the corresponding amount can be used for offsetting the emissions of other buildings connected to the same feeder. E.g. in the case of Students' Residence Building A the emissions associated with the net demand were 416.37 tons of CO_2; an amount of 104.60 tons of CO_2 corresponds to negative net demand, i.e. all the time intervals where PV production exceeds load demand. This amount can offset emissions from other buildings connected to the same feeder. During pilot deployment phase, such conditions need to be taken into account. Table 3 depicts the situation.

Table 3. Net Demand and CO_2 emissions calculation

Condition	Amount of CO_2 emissions (tons)
NetDemand * 0.677 > 0	'NetDemand * 0.677' for the consumption of the relevant building
NetDemand * 0.677 < 0	'NetDemand * 0.677' transferred to offset the emissions of other buildings connected to the same feeder

Table 4 presents the two-rate tariff structure for medium voltage consumers at UCY pilot site.

Table 4. Monthly Medium Voltage Seasonal Two-Rate Commercial and Industrial Use Tariff (Code 40)

		Charge per Unit (cent/kWh)				Monthly Charge (€)
Tariff charges	**Periods**	**October – May**		**June – September**		
		Weekdays	**Weekends /Holidays**	**Weekdays**	**Weekends /Holidays**	
Energy Charge	**Peak**	8,72	8,40	13,56	8,42	-
	Off-peak	7,50	7,17	8,34	8,13	-
Network Charge	**Peak**	1,80	1,80	1,80	1,80	-
	Off-peak	1,80	1,80	1,80	1,80	-
Ancillary Service Charge	**Peak**	0,64	0,64	0,64	0,64	-
	Off-peak	0,64	0,64	0,64	0,64	-
Meter Reading Charge	**Peak**	-				0,49€
Supply Charge	**Off-peak**	-				2,39€

Figure 2 presents the correlation heat map of energy demand in the UCY pilot loads participating in DR programs for the needs of the DELTA project. In some cases, strong correlations are observed. This condition may act as an indication of load grouping for the needs of DR program deployment.

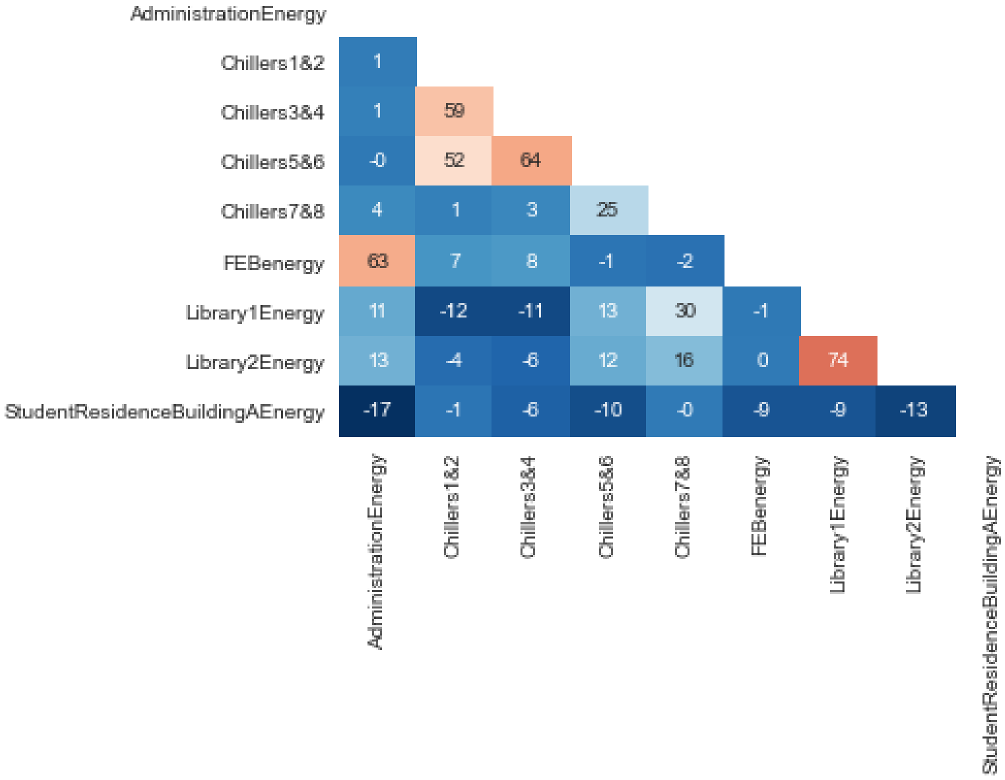


Figure 2. Correlation heat map of energy demand in UCY pilot loads

2.1 Environment conditions

In this section, the environment conditions profiles at UCY pilot site are presented along with the heating and cooling degrees profiles. For the calculation of HDH and CDH formulas adjusted from work performed at Eurostat [6] were used. The base temperature for heating, i.e. the lowest hourly mean air temperature not leading to indoor heating was set at 15 °C. Similarly, the base temperature for cooling, i.e. the highest hourly mean temperature not leading to indoor cooling was considered to be 23 °C. Equation (2) and Equation (3) were used for the calculations that were performed for determining the profiles of HDH and CDH for each hour of the day.

$$\text{If } Tm \leq 15^{o}C \text{ Then } HDM = 18^{o}C - Tm \text{ Else } HDM = 0 \quad (2)$$

$$\text{If } Tm \geq 23^{o}C \text{ Then } CDM = Tm - 21^{o}C \text{ Else } CDM = 0 \quad (3)$$

where *Tm* is the average temperature with 15-min granularity observed at UCY pilot site. Figure 3 presents the ambient temperature and relative humidity profiles. Figure 4 presents the global horizontal and plane of array irradiance profiles. Figure 5 present the heating and cooling degree minutes profiles. Figure 6 and Figure 7 present the distribution and box plots of environment conditions at UCY pilot site. A limited number of outliers is observed for the variables of GHI, Gpoa, and CDM. For the HDM variable, all the values appear as outliers due to the fact that the temperature conditions come from a non-shaded sensor. This situation will be corrected during pilot deployment phase, where for the calculation of HDM temperature readings from shaded sensor will be used.

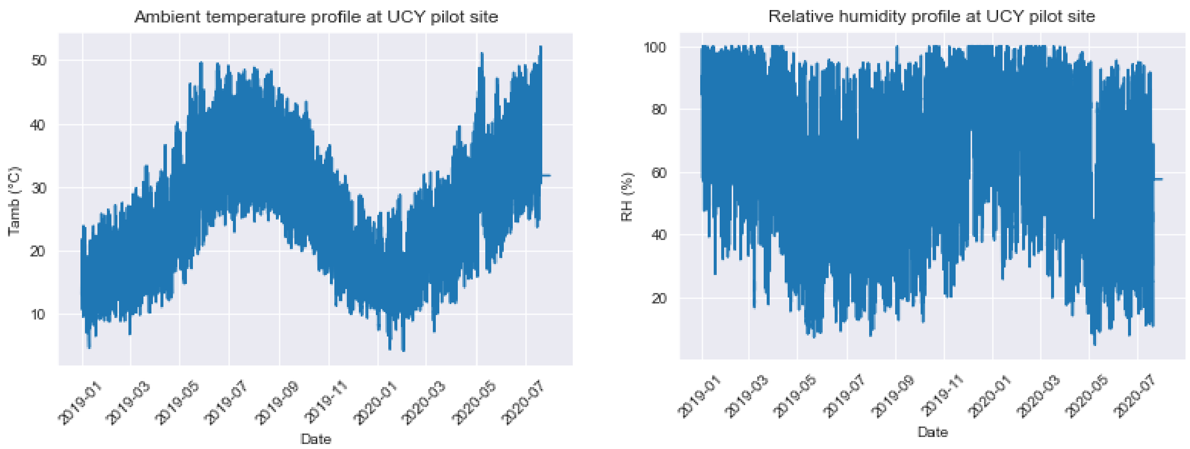


Figure 3. Ambient temperature (ºC) and relative humidity (%) profiles at UCY pilot site

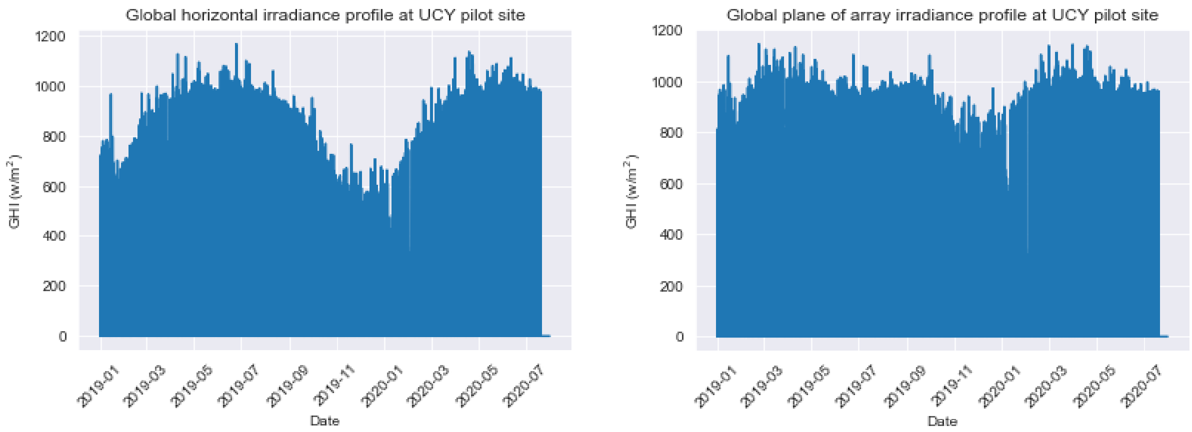


Figure 4. Global horizontal and plane of array irradiance (W/m^2) profiles at UCY pilot site

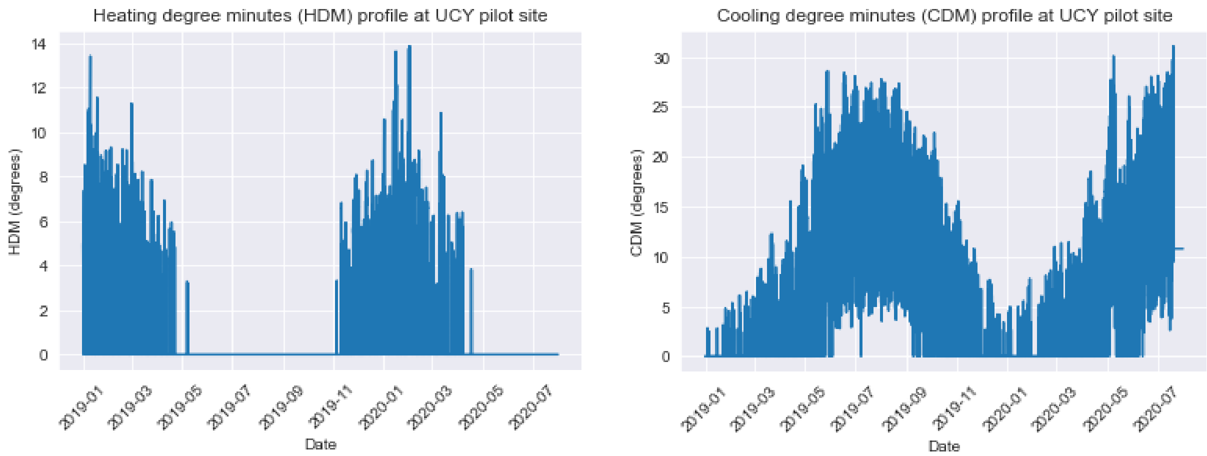


Figure 5. Heating (HDM) and cooling (CDM) degree minutes profiles at UCY pilot site

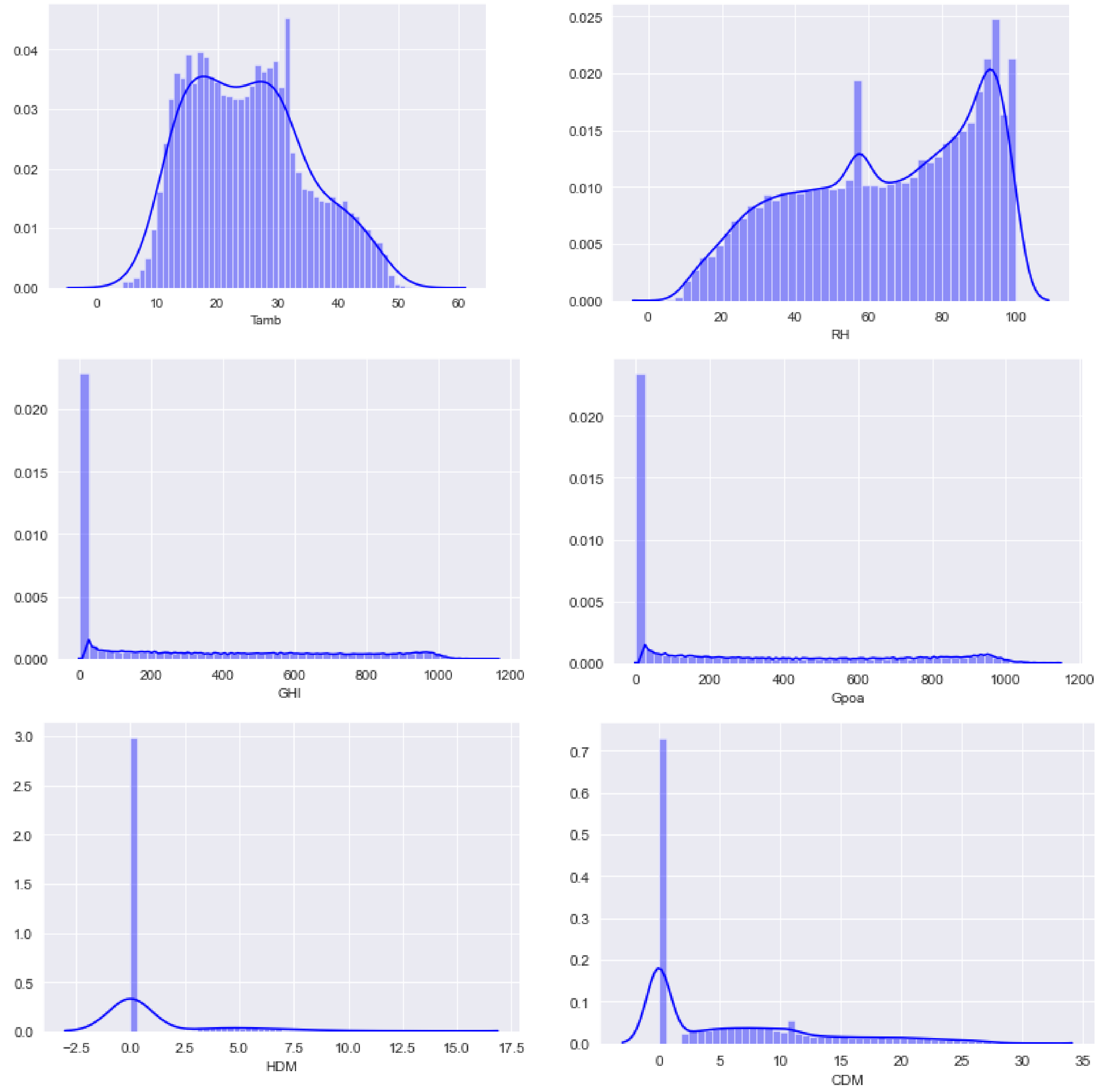


Figure 6. Distribution plots of environment conditions at UCY pilot site

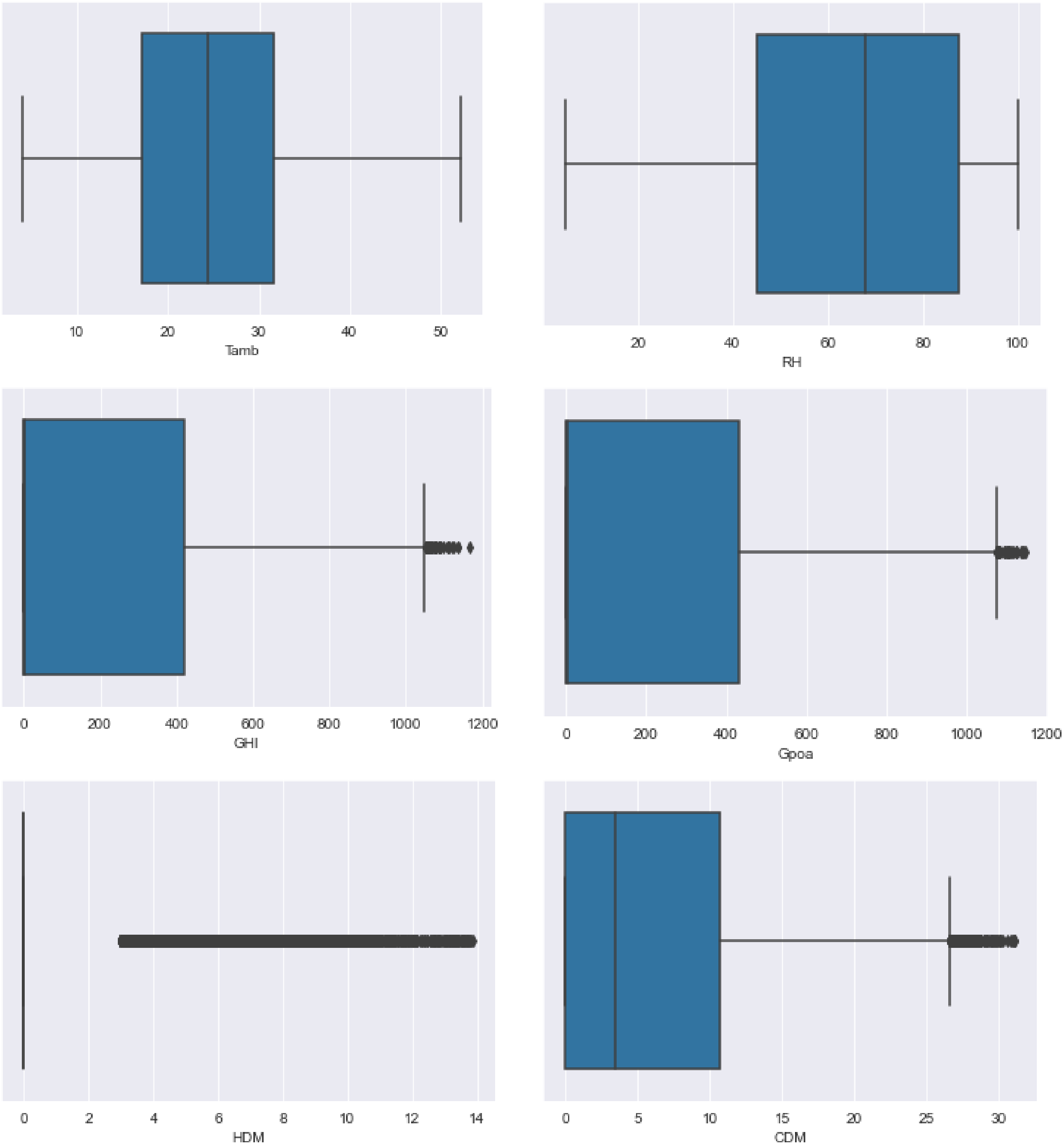


Figure 7. Boxplots of environment conditions are UCY pilot site

2.2 Exploratory Data Analysis

Table 5 presents the public holidays in Cyprus, falling within the analysis period, for the years 2019 and 2020. The dates are encoded into an indicator variables, i.e. 1: holiday, 0: non-holiday. In this way, the analyst may get meaningful insights regarding the effect that the holidays have on energy demand compared to non-holidays.

Table 5. Public Holidays in Cyprus for 2019 and 2020

Public Holidays 2019	
1st of January	New Year's Day
6th of January	Epiphany
11th of March	Green Monday
25th of March	Hellenic National Day
1st of April	National Day
26th of April	Good Friday
29th of April	Easter Monday
1st of May	May Day
17th of June	Whit Monday
15th of August	Assumption Day
1st of October	Independence Day
28th of October	Hellenic National Day
24th of December	Christmas Eve
25th of December	Christmas Day
26th of December	Boxing Day
Public Holidays 2020	
1st of January	New Year's Day
6th of January	Epiphany
2nd of March	Green Monday
25th of March	Hellenic National Day
1st of April	National Day
17th of April	Good Friday
20th of April	Easter Monday
1st of May	May Day
8th of June	Whit Monday

Table 6 presents the features that were engineered for EDA and energy modelling purposes at the UCY pilot site.

Table 6. Features engineered for the EDA and the modelling of energy demand at UCY pilot site

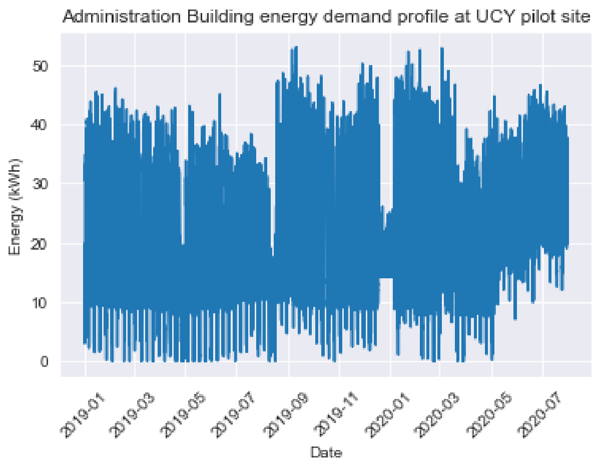
Feature	Range of Values	Description
Holiday	0 or 1	Indicator variable for holidays
Corona emergency (full lockdown)	0 or 1	Indicator variable for Corona emergency period
Corona emergency (restriction measures)	0 or 1	Indicator variable for special measures due to Corona virus
Day Of Month	{1…31}	Discrete value for the day of each month
Day of Week	{Mon, Tues, Wed, Thurs, Frid, Sat, Sun}	Categorical variable for each day of week
Day of Year	{1…365}	Discrete value for each day of year
Month of Year	{Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec}	Categorical variable for month of the year
{Mon, Tues, Wed, Thurs, Frid}	0 or 1	Indicator variables for weekdays
{Sat, Sun}	0 or 1	Indicator variables for weekend days
Season	{Summer, Autumn, Winter, Spring}	Categorical variables for season of year

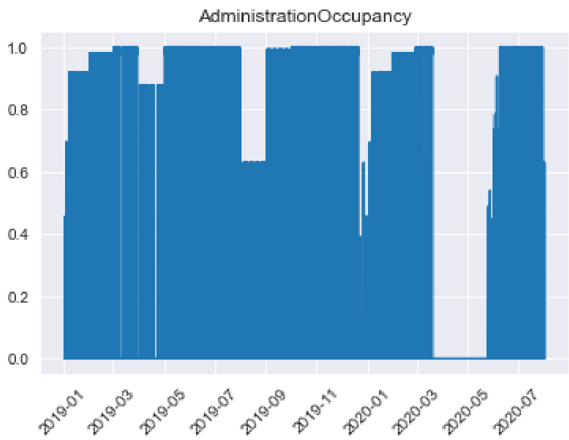
Hour of day	{1…24}	Discrete value for each hour of the day
Minute of day	{0, 15, 30, 45}	Discrete values in line with the granularity of the dataset
Week of year	{1…52}	Discrete variable for the week of year
Normalized occupancy profile[1]	{0…1)	Continuous variable depicting the occupancy status

The Corona emergency period at UCY pilot site spans, for the needs of the analysis performed, between 19/03/2020 and 24/05/2020. Restriction measures, e.g. 50% telework, are still in place and are encoded accordingly. For the needs of the analysis, restriction measures period spans between 25/05/2020 and 31/07/2020.

2.2.1 Administration Building

Figure 8 presents the demand profile, the occupancy profile, and distribution and box plots for energy demand at the administration building at the UCY pilot site. A limited amount of outliers is observed for the energy demand at the administration building. Figure 9 presents the bar plots of energy demand in the administration building with respect to days of the week and months accounting for the season of the year. As expected, during weekends the energy demand is lower than during weekdays. Figure 10 the violin plots of energy demand in the administration building of UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. During weekends and holidays, the range of demand is limited compared to normal operating conditions. Figure 11 presents the violin plot of energy demand in the administration building of UCY pilot site accounting for the day of the week. As observed, during the weekends the range of demand is limited. The density distribution of demand is observed as well. Figure 12 presents the violin plot of energy demand in the administration building of UCY pilot site accounting for the season of the year. The range of demand is of the same order of magnitude. The density distribution of demand during each season is observed as well. Figure 13 presents the correlation heat map of the continuous variables accounting for the energy demand in the administration building. Strong correlation with the occupancy profile is observed. The rest of the variables do not seem to be correlated with energy demand at the administration building. A week correlation with the period where Corona restrictions are in place is observed as well. This situation could attributed to environment conditions during the restrictions periods, i.e. hotter climate conditions as can be observed in the correlation heat map.





[1] Occupancy profile is used as predictor when relevant data are available. Applies to Administration, Finance Economics & Business, Student Residence A and Libraries buildings.

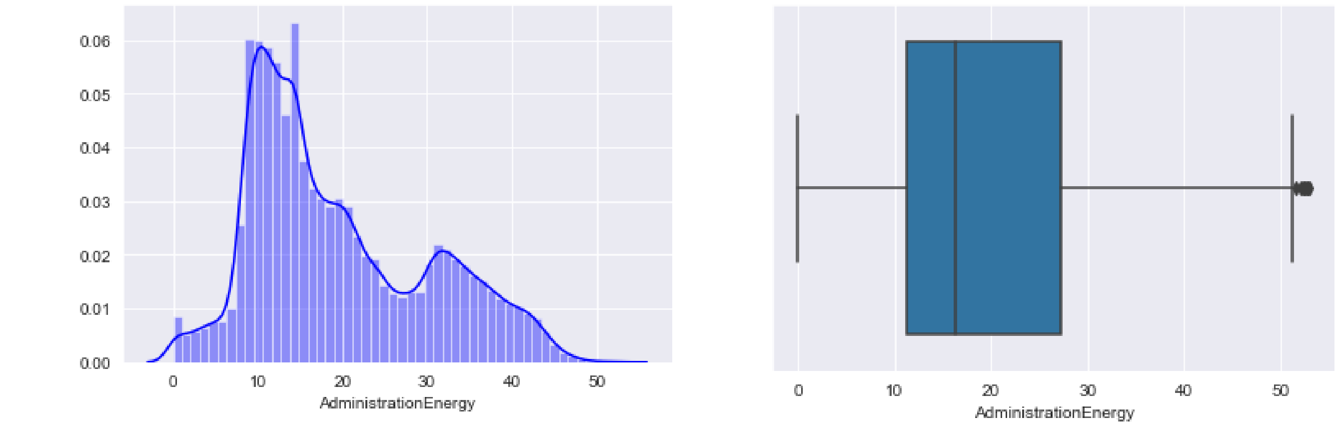


Figure 8. Demand, occupancy profile, distribution and box plots for energy demand in the administration building at UCY pilot site

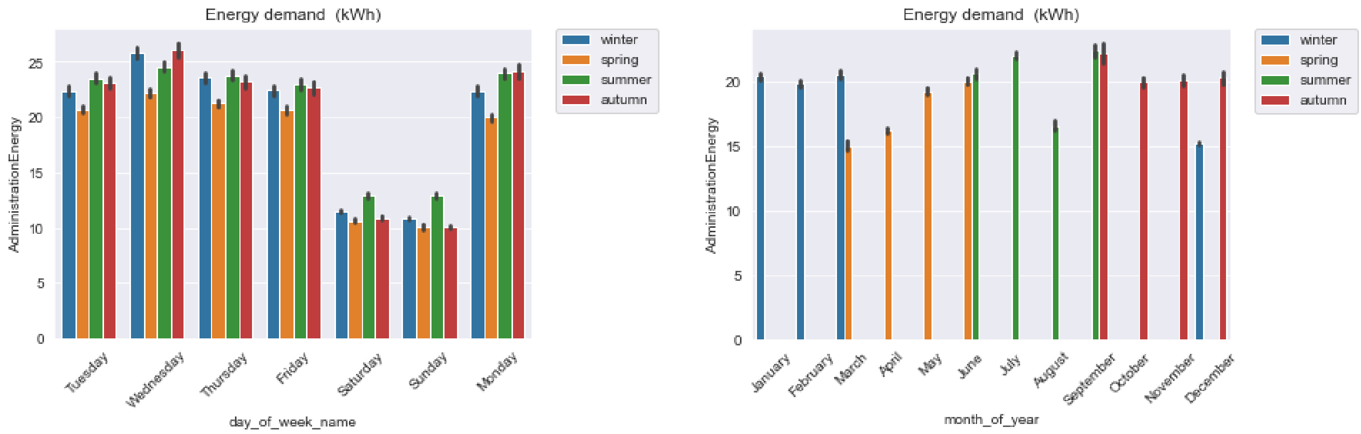


Figure 9. Bar plots of energy demand in the administration building at UCY pilot site with respect to weekdays and months accounting for the season of the year

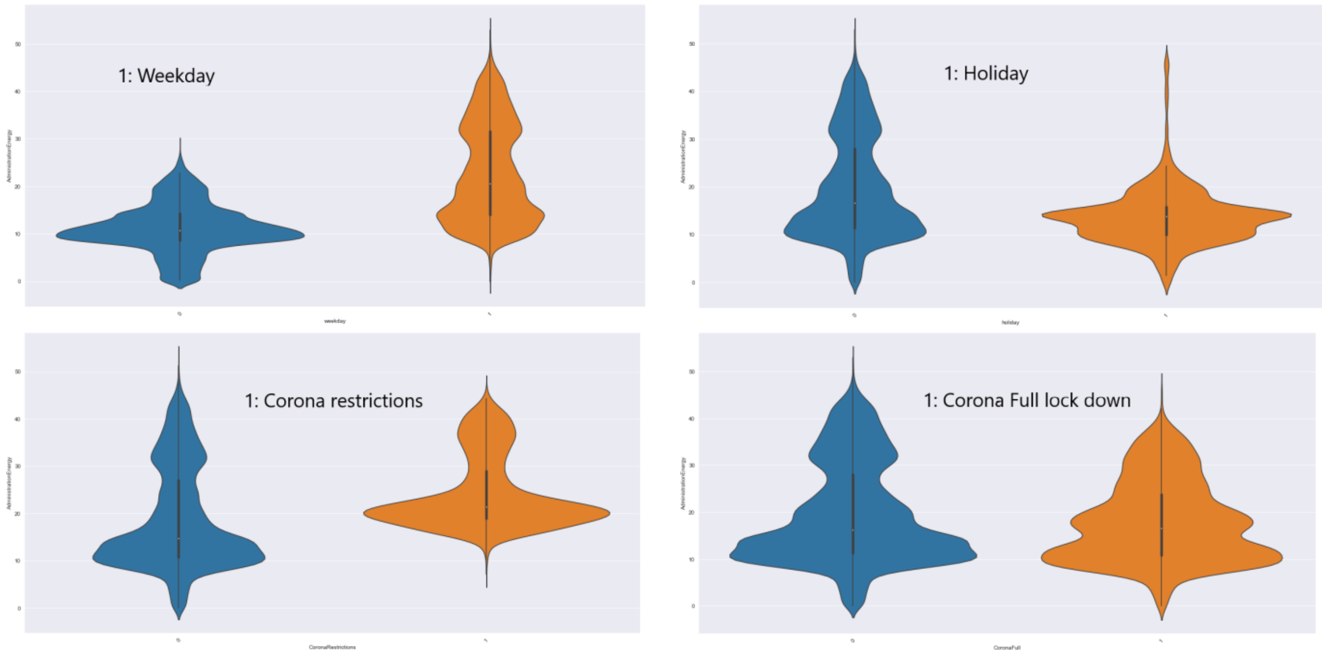


Figure 10. Violin plots of energy demand in the administration building at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

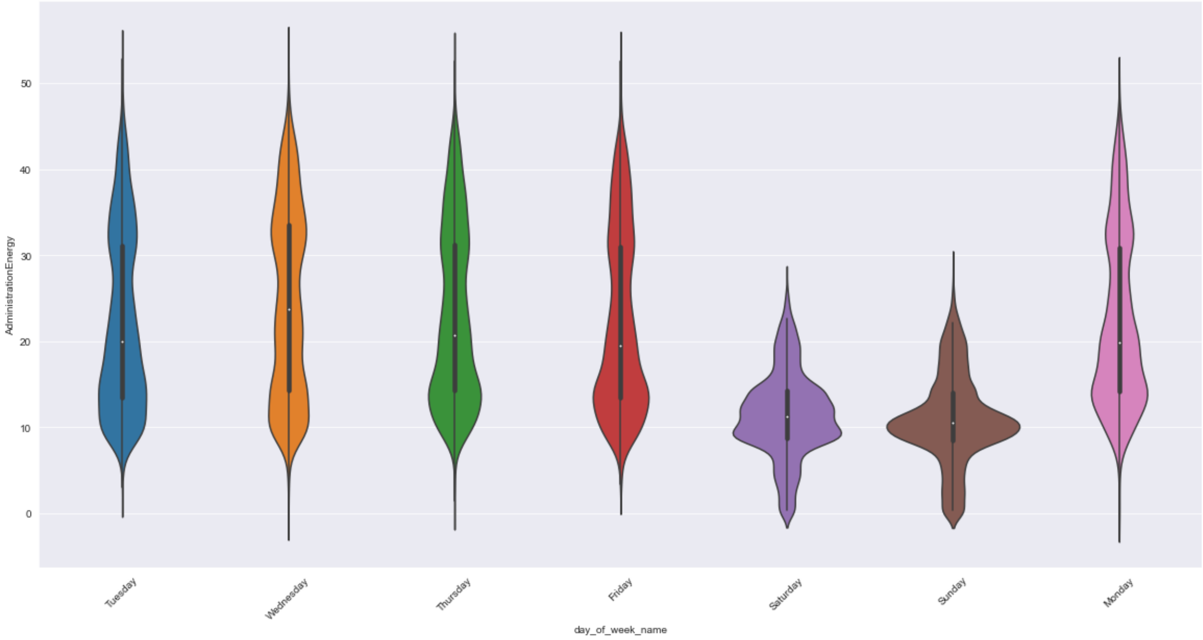


Figure 11. Violin plot of energy demand in the administration building at UCY pilot site accounting for the day of the week

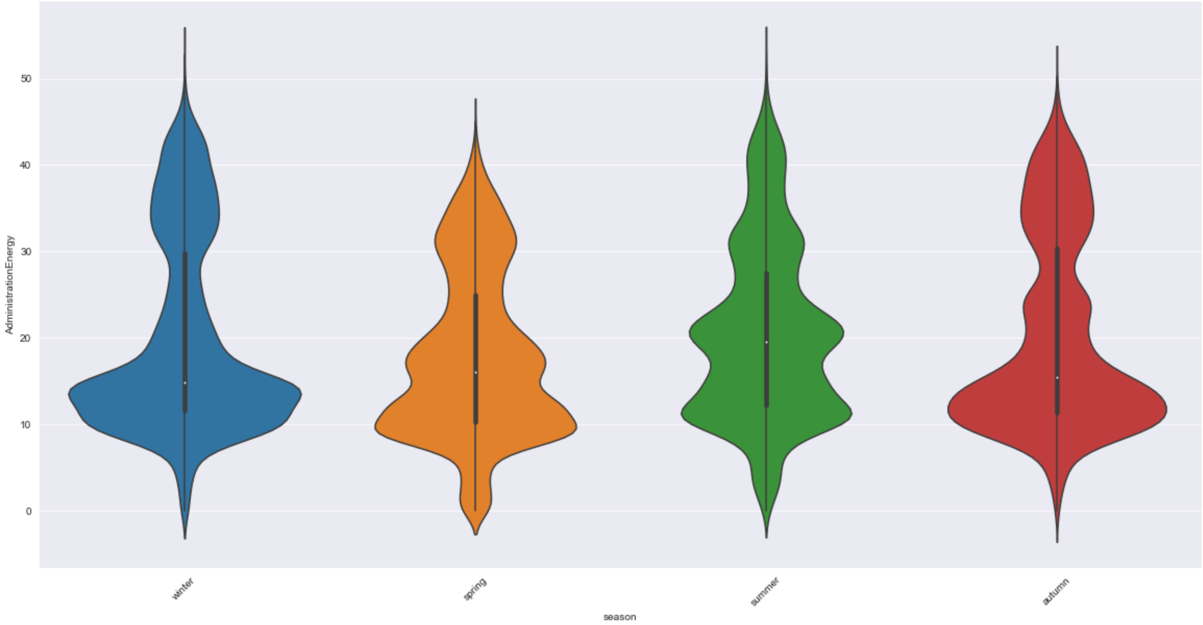


Figure 12. Violin plot of energy demand in the administration building at UCY pilot site accounting for the season of the year

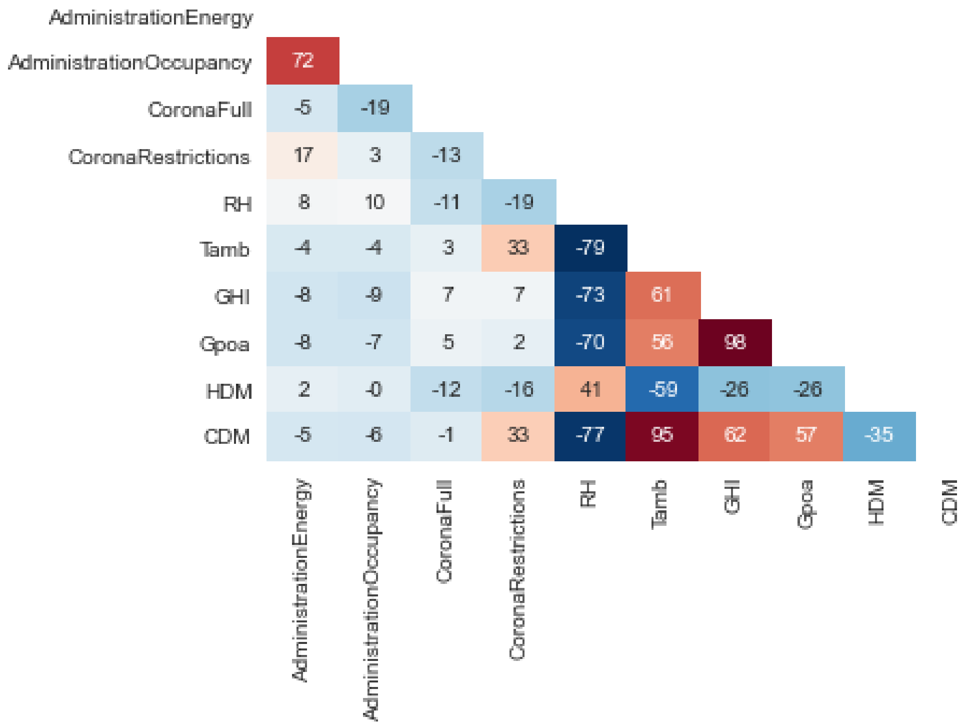


Figure 13. Correlation heat map of the continuous variables accounting for the energy demand at the Administration building at UCY pilot site

2.2.2 Chillers 1 & 2

Figure 14 presents the energy demand profile in Chillers 1&2 at UCY pilot site. Figure 15 presents the distribution and box plots of energy demand in Chiller 1&2 at UCY pilot site. A number of outlier values is observed. Figure 16 presents the bar plots of energy demand in Chillers 1&2 at UCY pilot site with respect to the days of the week and months accounting for the season of the year. Higher amounts of demand are observed during summer months, followed by autumn months. Seasonal patterns for energy demand in Chillers 1&2 during different days of the week are observed. Figure 17 presents the violin plots of energy demand in the Chillers 1&2 of UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. During holidays an impact on energy demand range is observed. The full lock down during the Corona emergency affected extensively energy demand in Chillers 1&2. Figure 18 presents the violin plot of energy demand in Chillers 1&2 at UCY pilot site accounting for the day of the week. During most days the energy demand range and patterns are similar, except for Sunday where slightly lower range in demand is observed Figure 19 present the violin plot of energy demand in Chillers 1&2 at UCY pilot site accounting for the season of the year. Higher range in the values of energy demand are observed during summer. Figure 20 presents the correlation heat map of the continuous variables accounting for the energy demand in Chillers 1&2 at UCY pilot site. Positive correlations are observed between the energy demand in Chillers 1&2 and ambient temperature (Tamb), cooling degrees (CDM), and corona virus restrictions period variables. Negative correlations are observed between the energy demand in Chillers 1&2 and relative humidity (RH), corona virus full lock down period and heating degrees (HDM) variables.

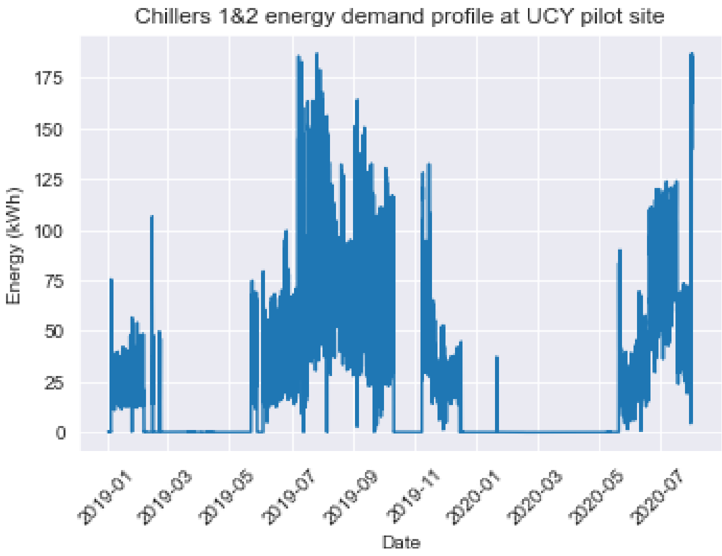


Figure 14. Energy demand profile in Chillers 1&2 at UCY pilot site

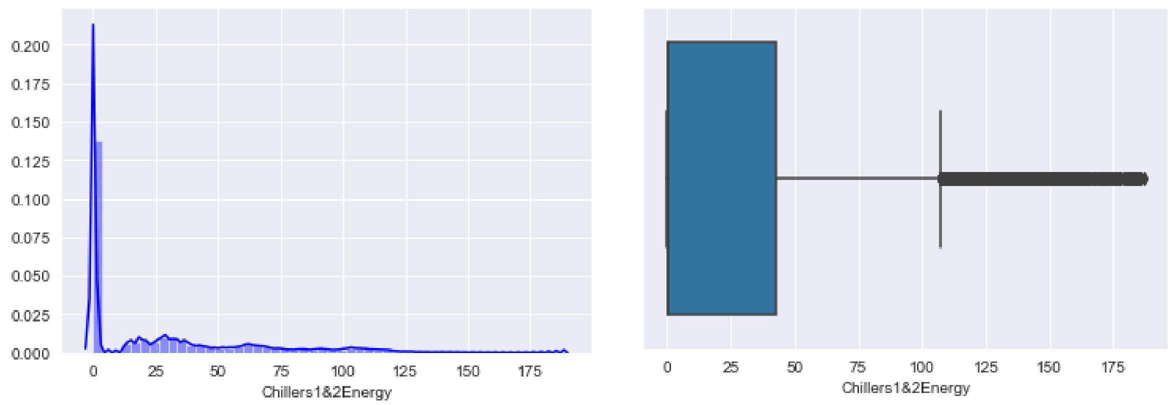


Figure 15. Distribution and box plots of energy demand in Chillers 1&2 at UCY pilot site

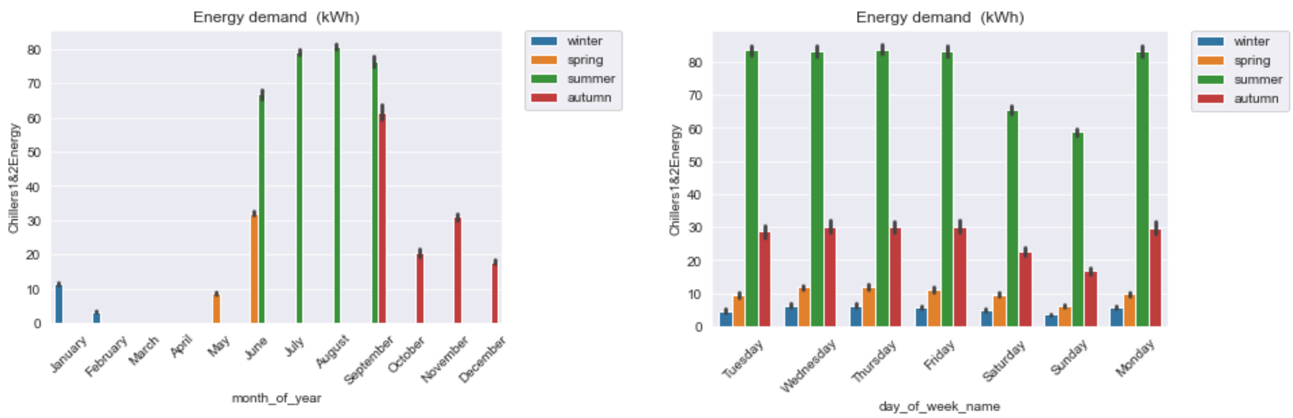


Figure 16. Bar plots of energy demand in Chillers 1&2 at UCY pilot site with respect to weekdays and months accounting for the season of the year

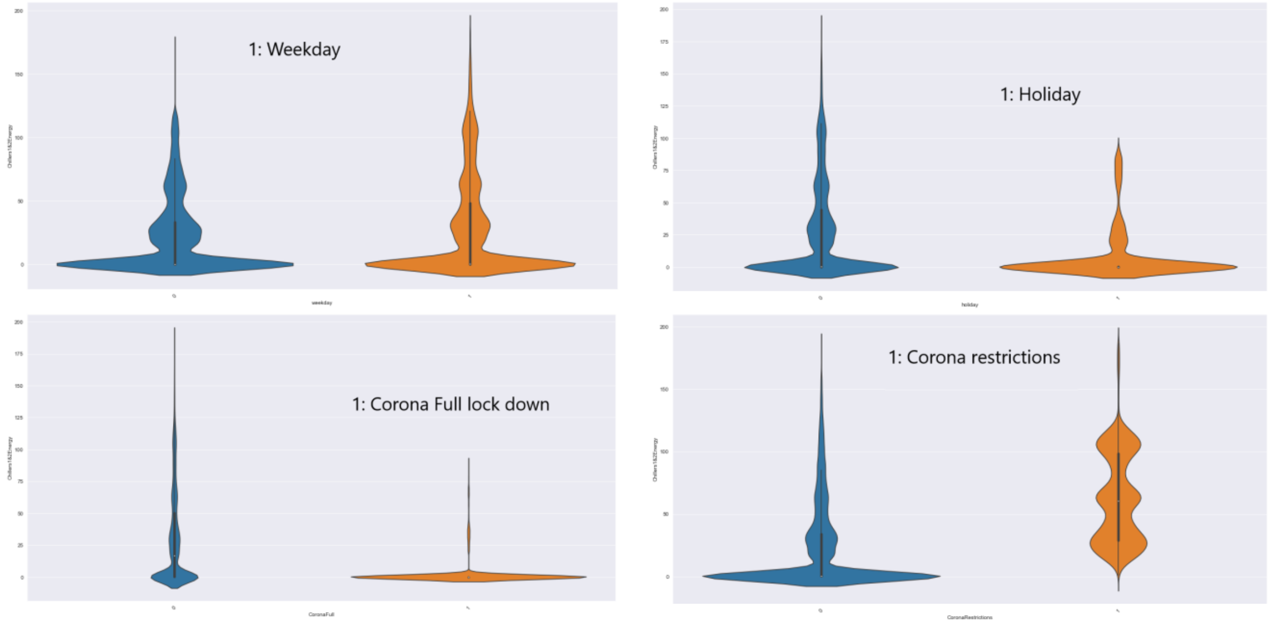


Figure 17. Violin plots of energy demand in the Chillers 1&2 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

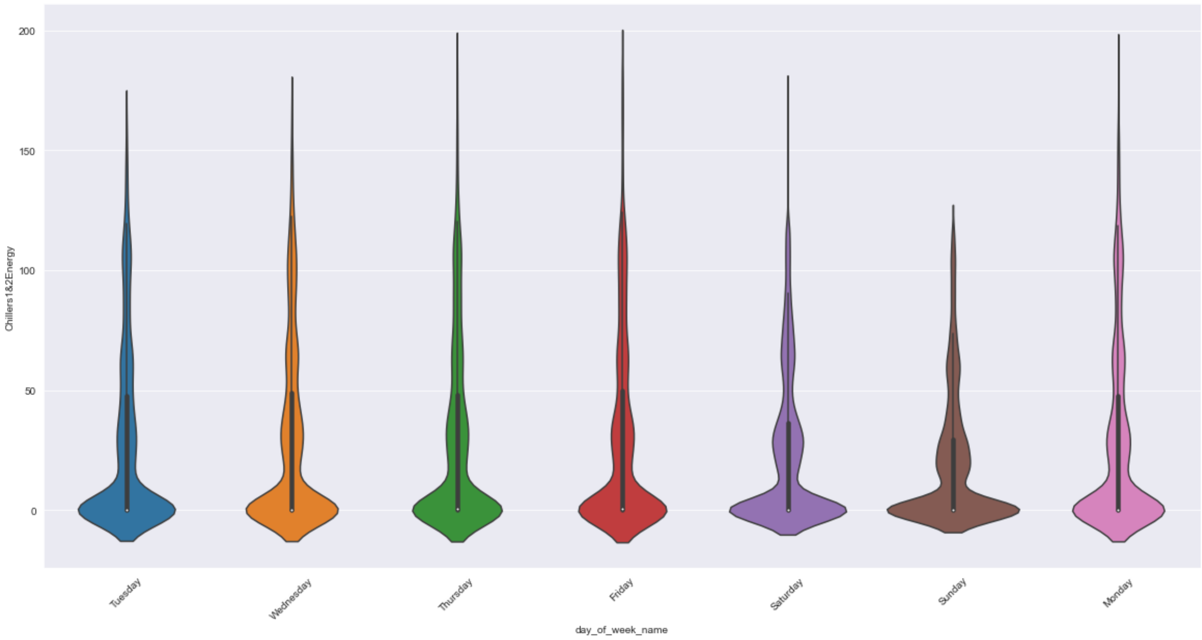


Figure 18. Violin plot of energy demand in Chillers 1&2 at UCY pilot site accounting for the day of the week

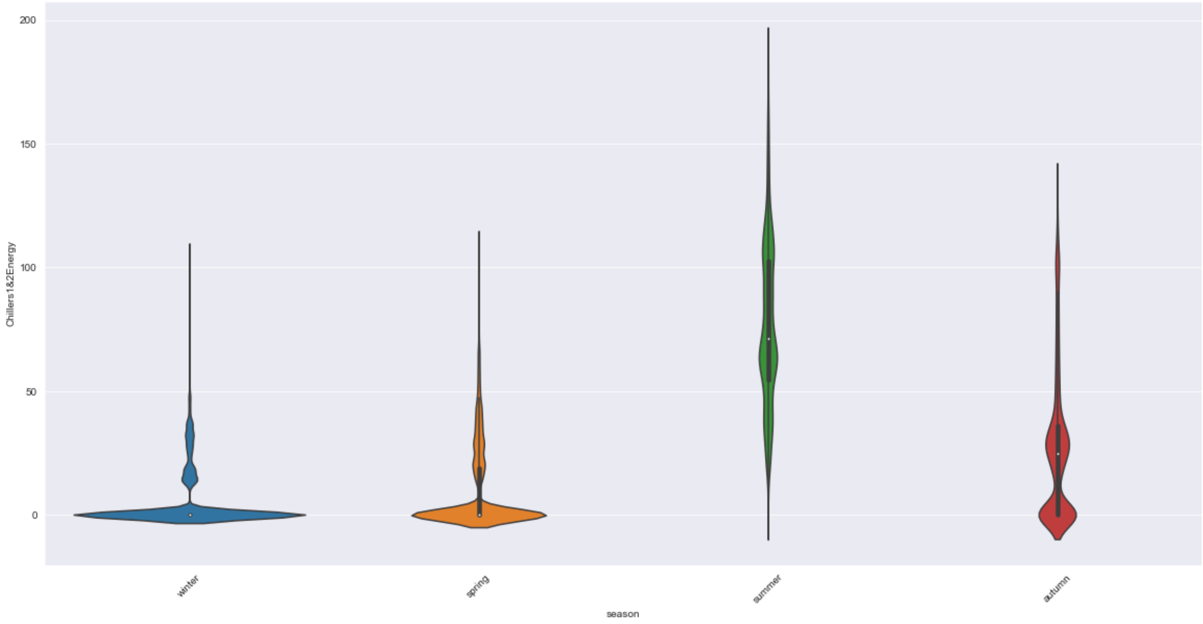


Figure 19. Violin plot of energy demand in Chillers 1&2 at UCY pilot site accounting for the season of the year

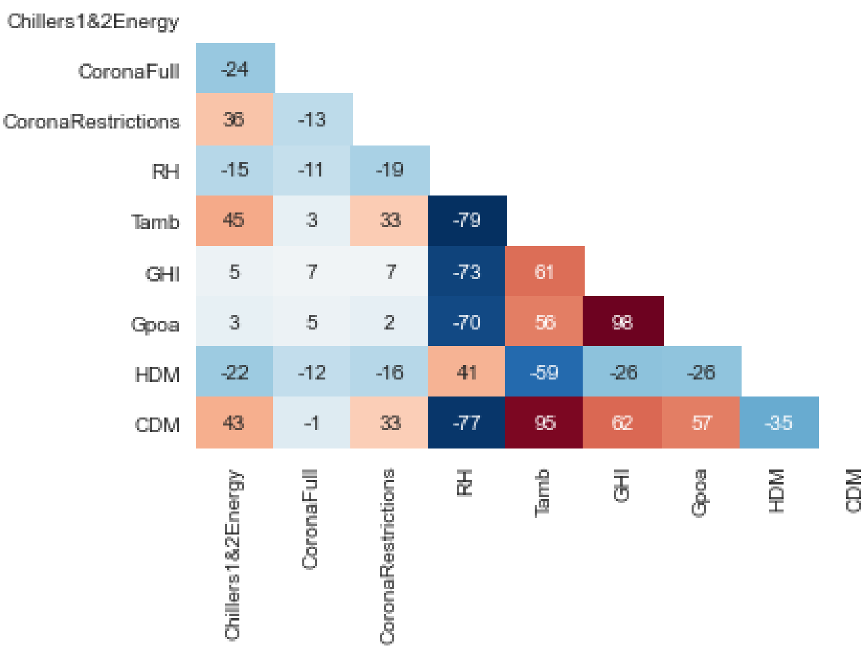


Figure 20. Correlation heat map of the continuous variables accounting for the energy demand in Chillers 1&2 at UCY pilot site

2.2.3 Chillers 3 & 4

Figure 21 presents the energy demand profiles in Chillers 3&4. Figure 22 presents the distribution and box plots of energy demand in Chillers 3&4. A limited amount of outliers is observed. Figure 23 presents the bar plots of energy demand in Chillers 3&4 at UCY pilot site with respect to weekdays and months accounting for the season of the year. Summer months contribute most to energy consumption in Chillers 3&4, followed by spring and autumn. Figure 24 presents the violin plots of energy demand in the Chillers 3&4 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. As observed, during holidays the range of demand is lower than the rest of the days. Full lock down due to coronavirus emergency had an impact on the energy demand as well. Finally, during weekdays the range of demand is slightly higher than the weekends. Figure 25 presents the violin plot of energy demand in Chillers 3&4 at UCY pilot site accounting for the day of the week. Overall, the patterns are similar. Slightly lower amounts in energy demand range are observed during Sundays. Figure 26 presents the violin plot of energy demand in Chillers 3&4 at UCY pilot site accounting for the season of the year. Spring, summer and autumn contribute most to energy demand with relevant distributions. Figure 27 presents the correlation heat map of the continuous variables accounting for the energy demand in Chillers 3&4 at UCY pilot site. Positive correlations are observed between the energy demand in Chillers 3&4 and ambient temperature (Tamb), cooling degrees (CDM), and corona virus restrictions period variables. Negative correlations are observed between the energy demand in Chillers 3&4 and relative humidity (RH), corona virus full lock down period and heating degrees (HDM) variables.

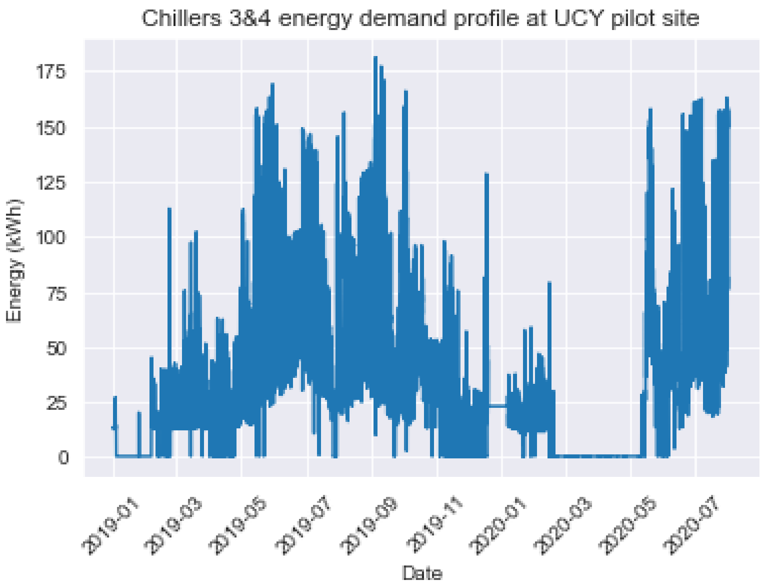


Figure 21. Energy demand profile in Chillers 3&4 at UCY pilot site

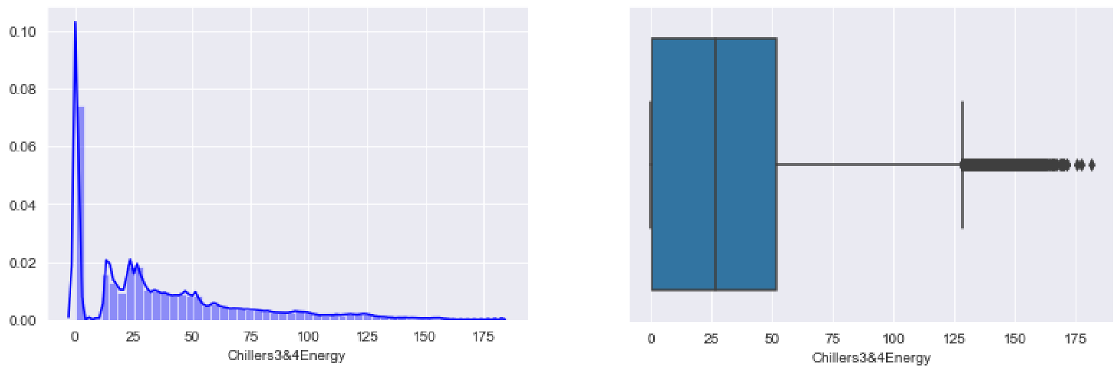


Figure 22. Distribution and box plots of energy demand in Chillers 3&4 at UCY pilot site

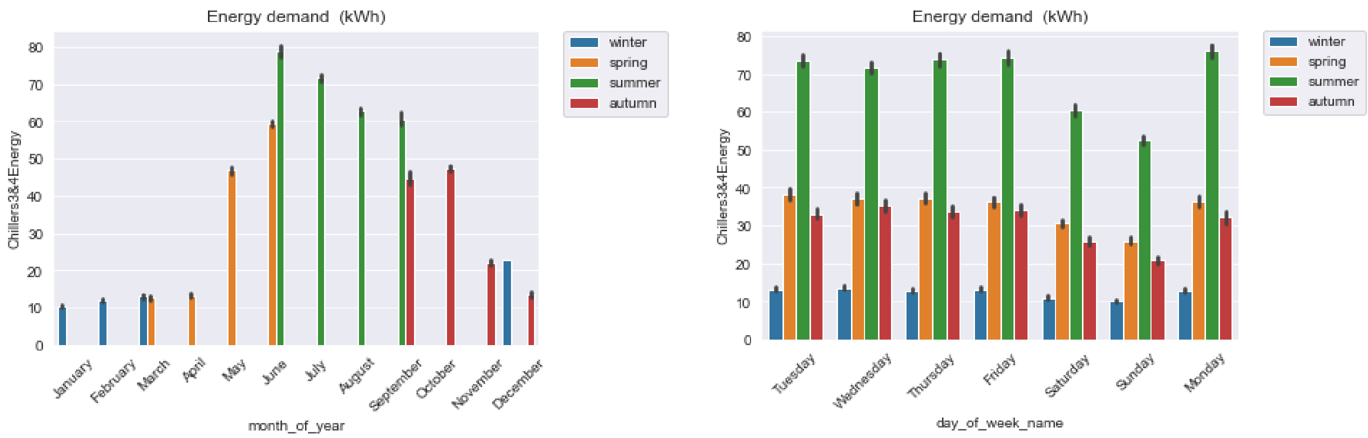


Figure 23. Bar plots of energy demand in Chillers 3&4 at UCY pilot site with respect to weekdays and months accounting for the season of the year

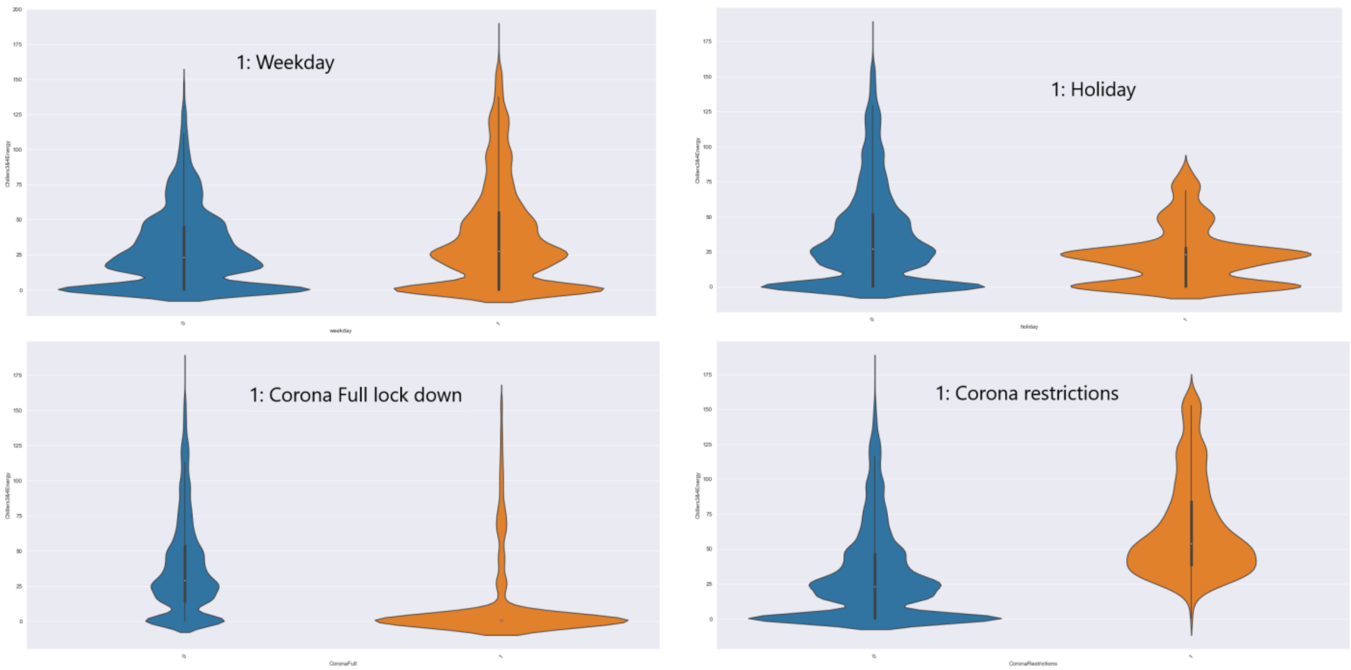


Figure 24. Violin plots of energy demand in the Chillers 3&4 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

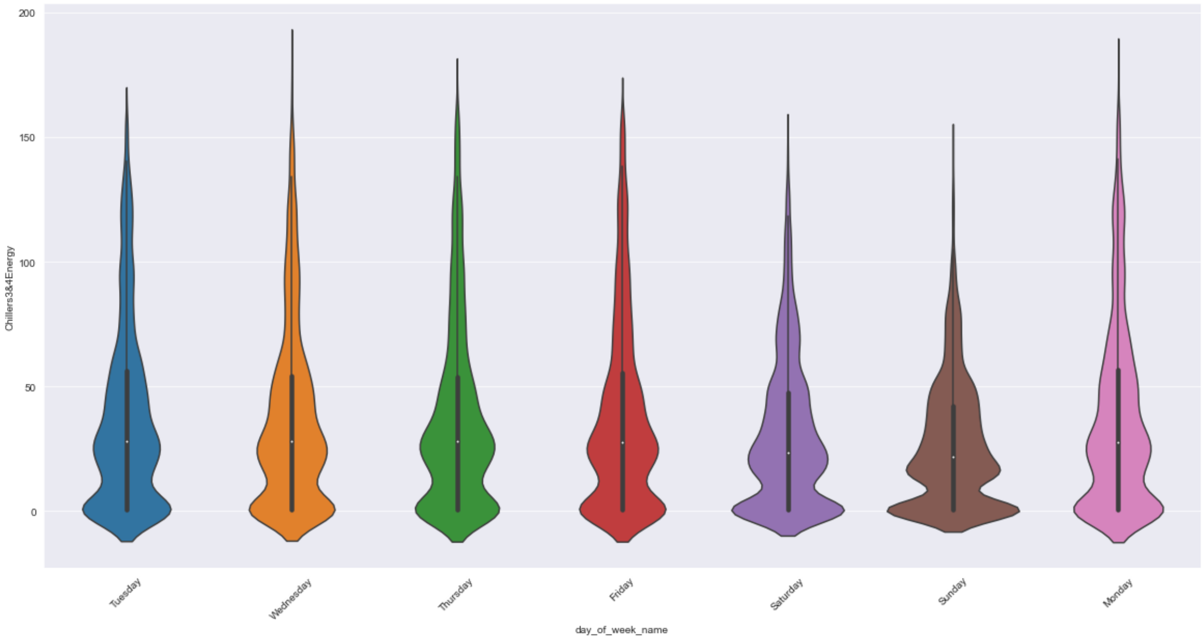


Figure 25. Violin plot of energy demand in Chillers 3&4 at UCY pilot site accounting for the day of the week

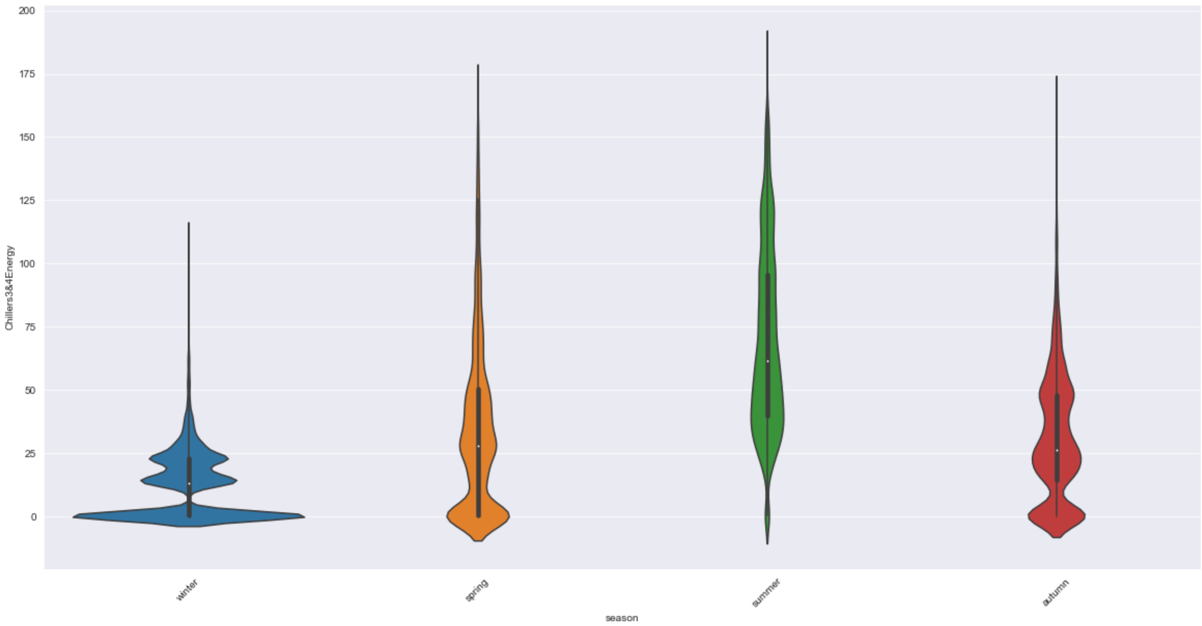


Figure 26. Violin plot of energy demand in Chillers 3&4 at UCY pilot site accounting for the season of the year

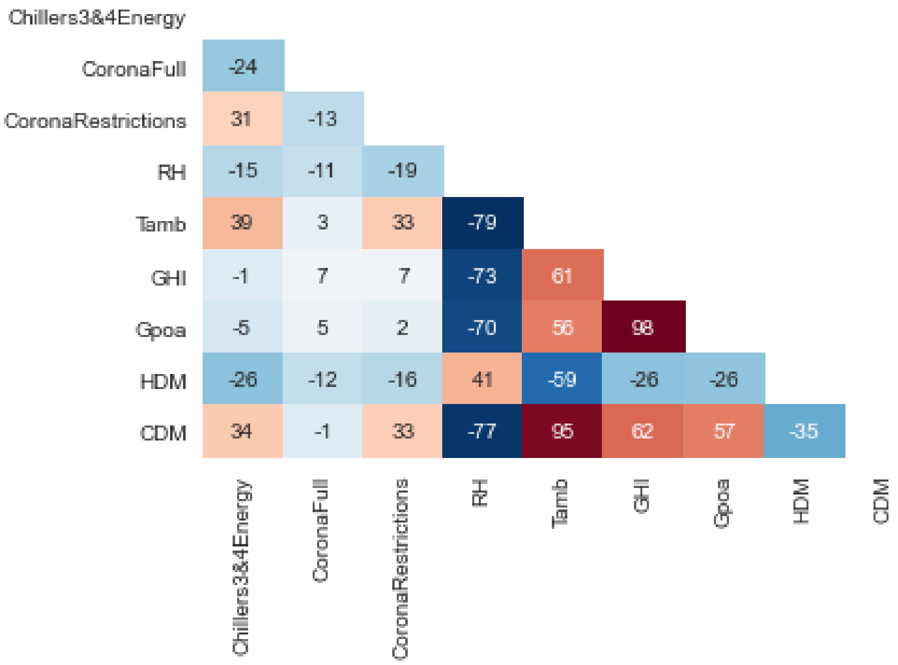


Figure 27. Correlation heat map of the continuous variables accounting for the energy demand in Chillers 3&4 at UCY pilot site

2.2.4 Chillers 5 & 6

Figure 28 presents the energy demand profiles in Chillers 5&6. Figure 29 presents the distribution and box plots of energy demand in Chillers 5&6. A limited amount of outliers is observed. Figure 30 presents the bar plots of energy demand in Chillers 5&6 at UCY pilot site with respect to weekdays and months accounting for the season of the year. Summer months contribute most to energy consumption in Chillers 5&6, followed by spring and autumn. Figure 31 presents the violin plots of energy demand in the Chillers 5&6 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. As observed, during holidays the range of demand is lower than the rest of the days. As observed, during weekdays the range of demand is slightly higher than the weekends. Figure 32 presents the violin plot of energy demand in Chillers 5&6 at UCY pilot site accounting for the day of the week. Overall, the patterns are similar. Slightly lower amounts in energy demand range are observed during weekends. Figure 33 presents the violin plot of energy demand in Chillers 5&6 at UCY pilot site accounting for the season of the year. Spring, summer and autumn contribute most to energy demand with relevant distributions. Figure 34 presents the correlation heat map of the continuous variables accounting for the energy demand in Chillers 5&6 at UCY pilot site. Positive correlations are observed between the energy demand in Chillers 5&6 and ambient temperature (Tamb), cooling degrees (CDM), and corona virus restrictions period variables. Negative correlations are observed between the energy demand in Chillers 5&6 and heating degrees (HDM), relative humidity (RH), GHI, Gpoa variables.

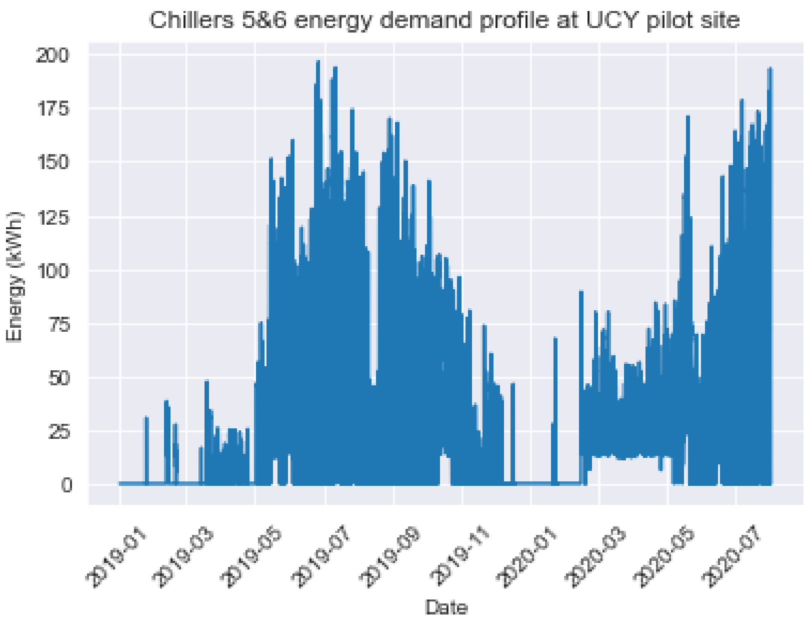
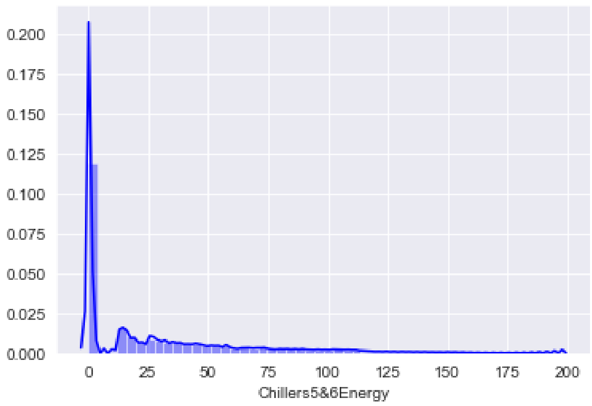


Figure 28. Energy demand profile in Chillers 5&6 at UCY pilot site



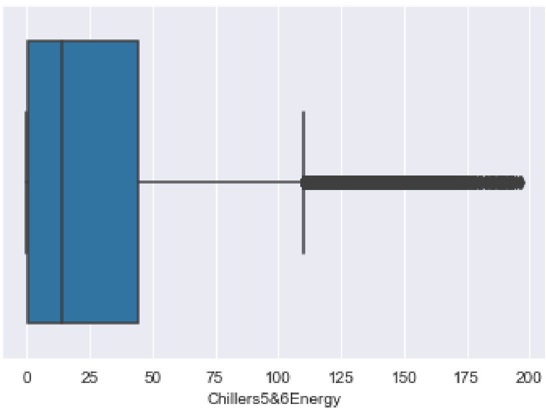


Figure 29. Distribution and box plots of energy demand in Chillers 5&6 at UCY pilot site

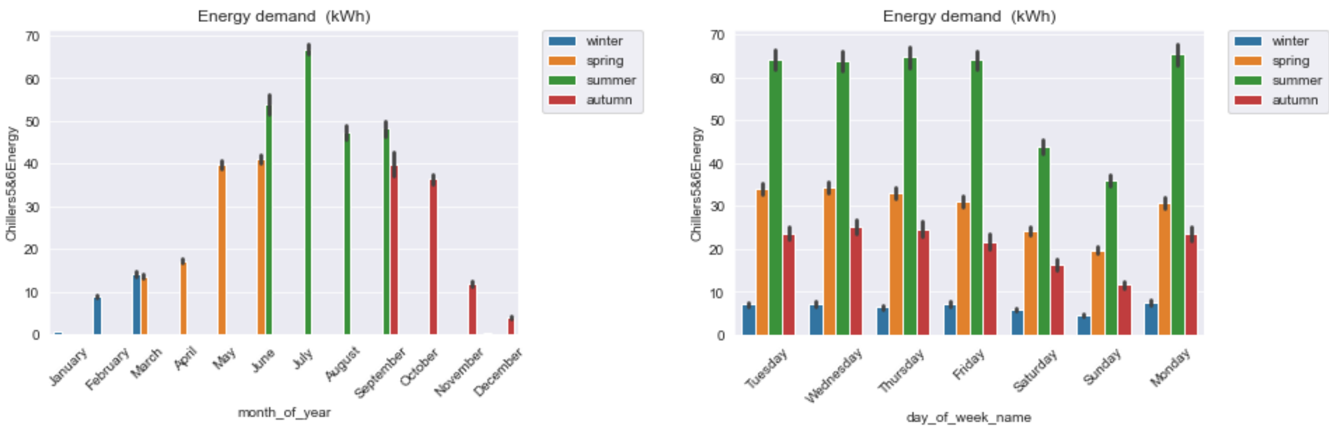


Figure 30. Bar plots of energy demand in Chillers 5&6 at UCY pilot site with respect to weekdays and months accounting for the season of the year

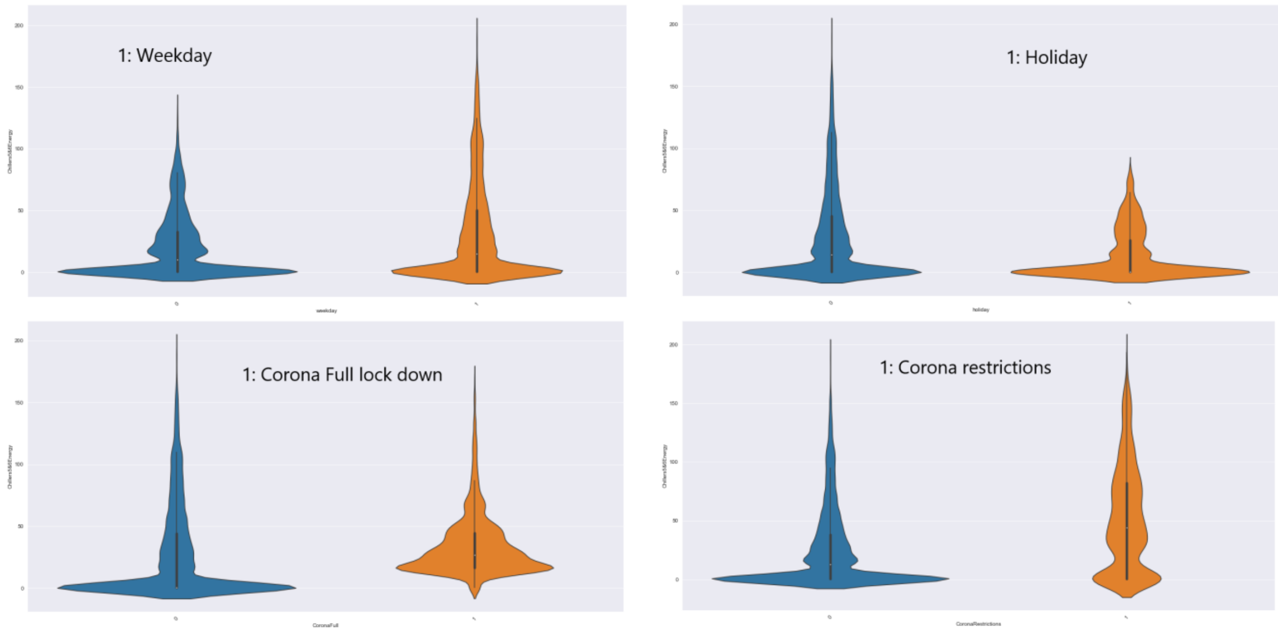


Figure 31. Violin plots of energy demand in the Chillers 5&6 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

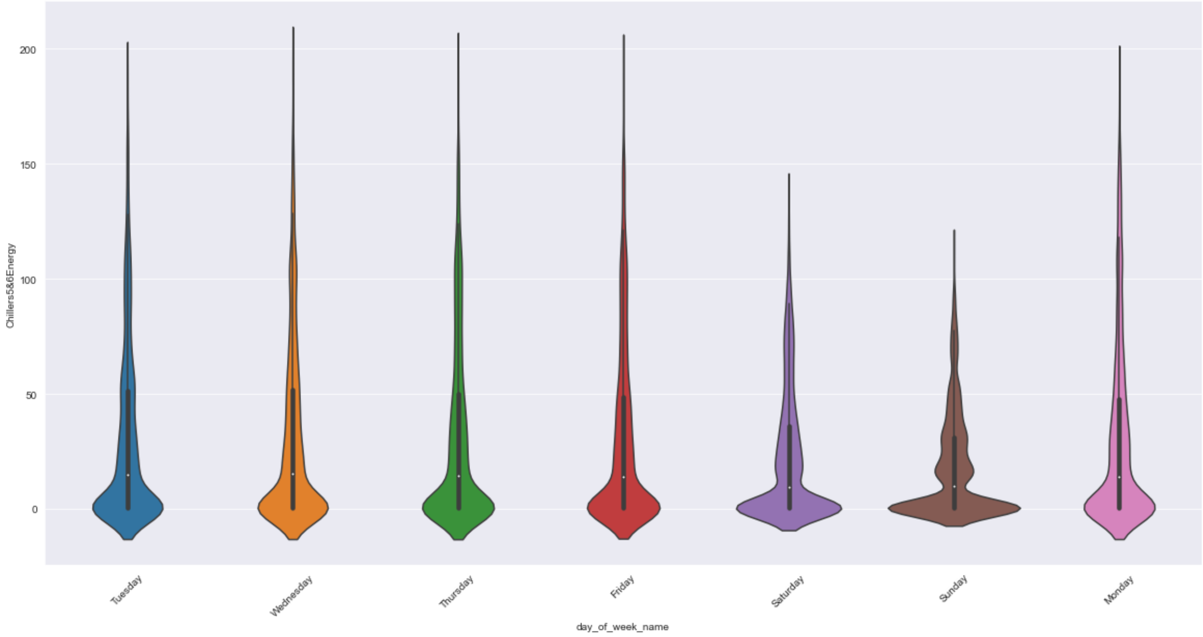


Figure 32. Violin plot of energy demand in Chillers 3&4 at UCY pilot site accounting for the day of the week

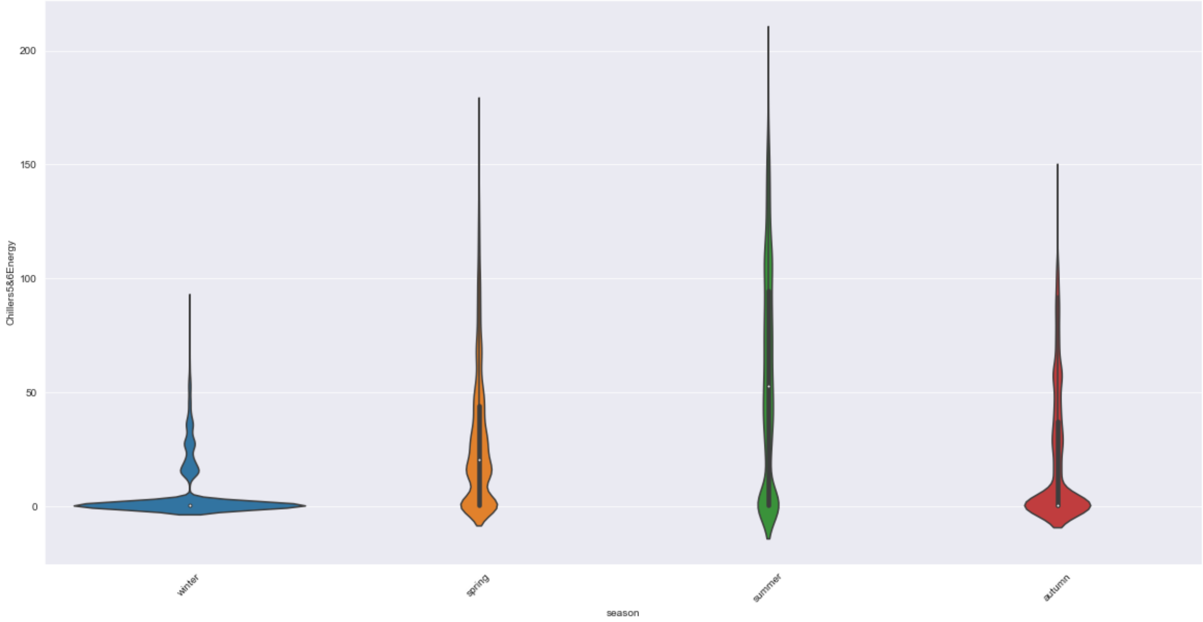


Figure 33. Violin plot of energy demand in Chillers 5&6 at UCY pilot site accounting for the season of the year

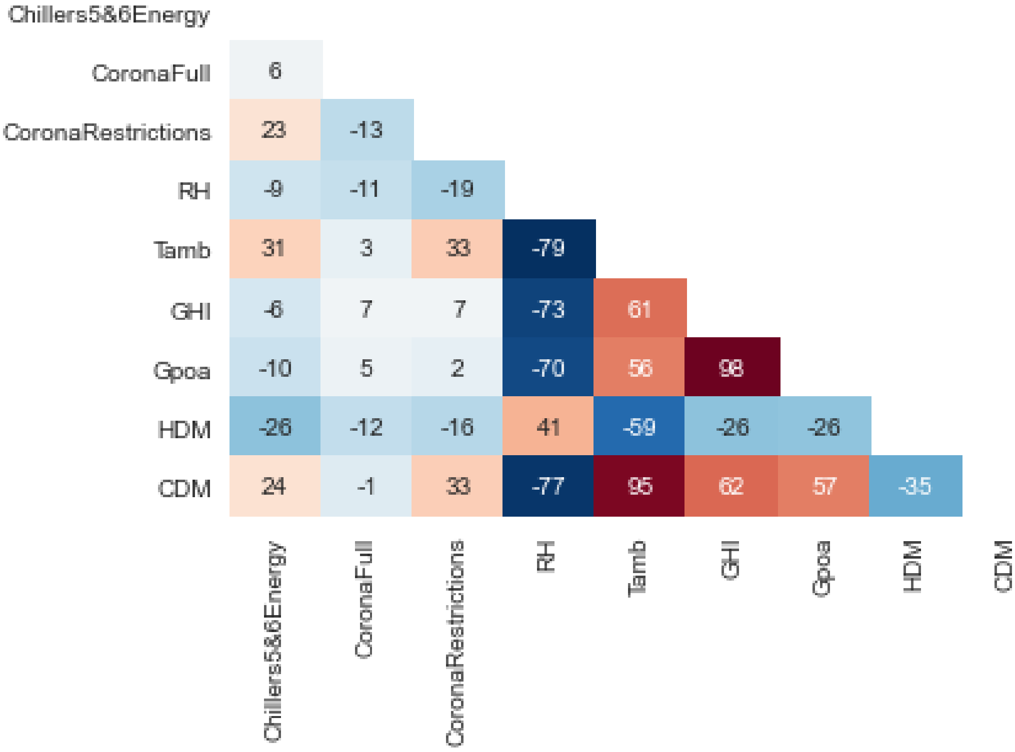


Figure 34. Correlation heat map of the continuous variables accounting for the energy demand in Chillers 5&6 at UCY pilot site

2.2.5 Chillers 7 & 8

Figure 35 presents the energy demand profiles in Chillers 7&8. Figure 36 presents the distribution and box plots of energy demand in Chillers 7&8. The values appear as outliers in the box plot due to the fact that most of the time energy demand is zero. A limited amount of outliers is observed. Figure 37 presents the bar plots of energy demand in Chillers 7&8 at UCY pilot site with respect to weekdays and months accounting for the season of the year. Summer months contribute most to energy consumption in Chillers 5&6, followed by spring and autumn. Figure 38 presents the violin plots of energy demand in the Chillers 7&8 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. As observed, during holidays the range of demand is lower than the rest of the days. As observed, during weekdays the range of demand is slightly higher than the weekends. Figure 39 presents the violin plot of energy demand in Chillers 7&8 at UCY pilot site accounting for the day of the week. Overall, the patterns are similar. Slightly lower amounts in energy demand range are observed during weekends. Figure 40 presents the violin plot of energy demand in Chillers 7&8 at UCY pilot site accounting for the season of the year. Spring, summer and autumn contribute most to energy demand with relevant distributions. Figure 41 presents the correlation heat map of the continuous variables accounting for the energy demand in Chillers 7&8 at UCY pilot site. Positive correlations are observed between the energy demand in Chillers 5&6 and ambient temperature (Tamb), cooling degrees (CDM), and corona virus restrictions period variables. Negative correlations are observed between the energy demand in Chillers 5&6 and heating degrees (HDM), relative humidity (RH), GHI, Gpoa variables.

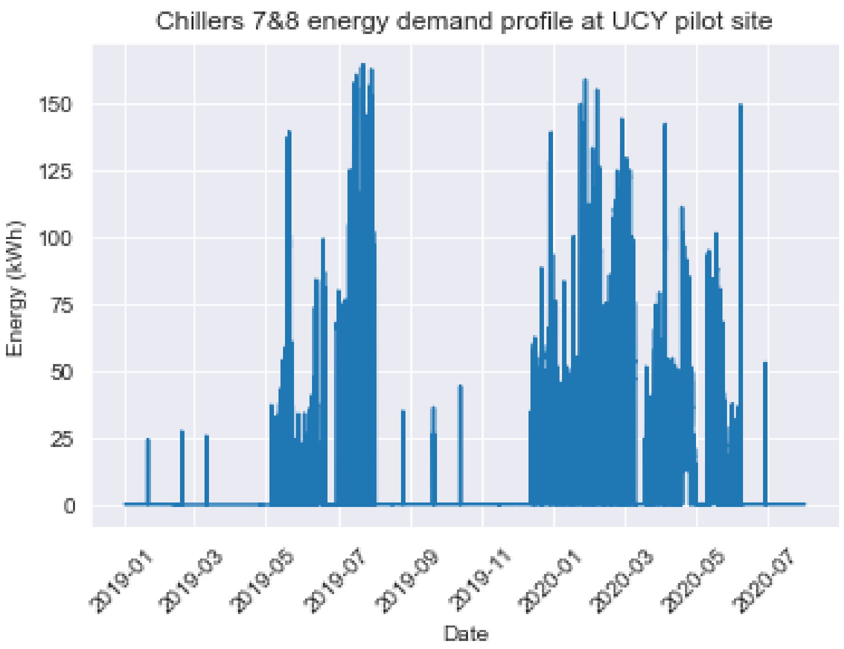


Figure 35. Energy demand profile in Chillers 7&8 at UCY pilot site

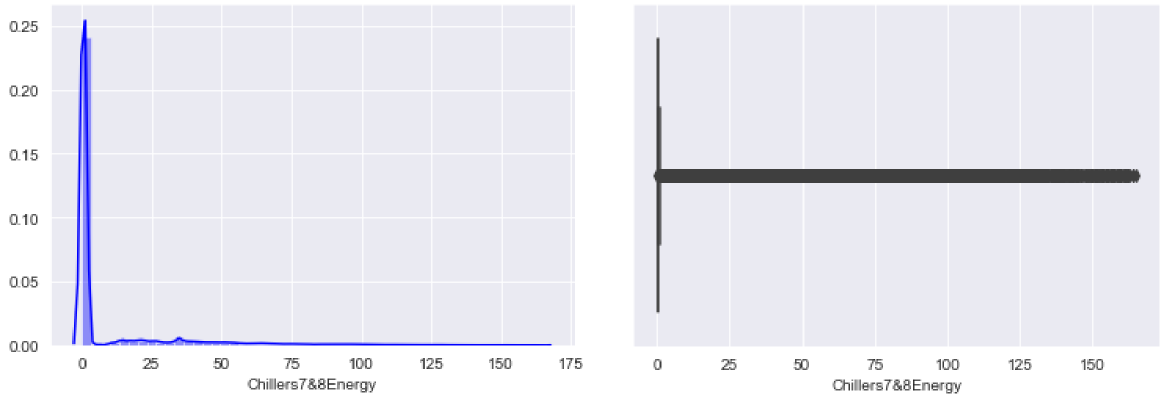


Figure 36. Distribution and box plots of energy demand in Chillers 7&8 at UCY pilot site

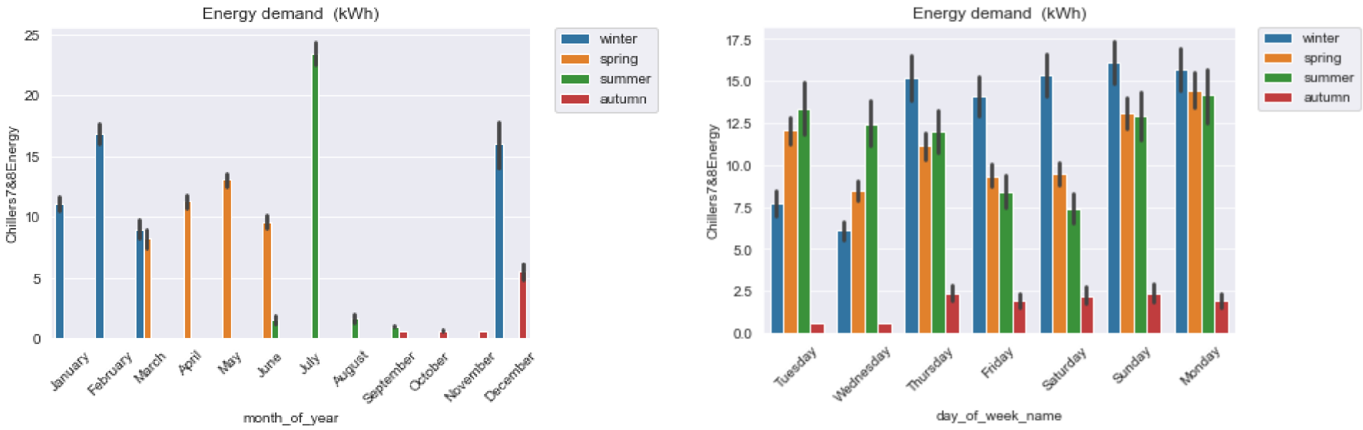


Figure 37. Bar plots of energy demand in Chillers 7&8 at UCY pilot site with respect to weekdays and months accounting for the season of the year

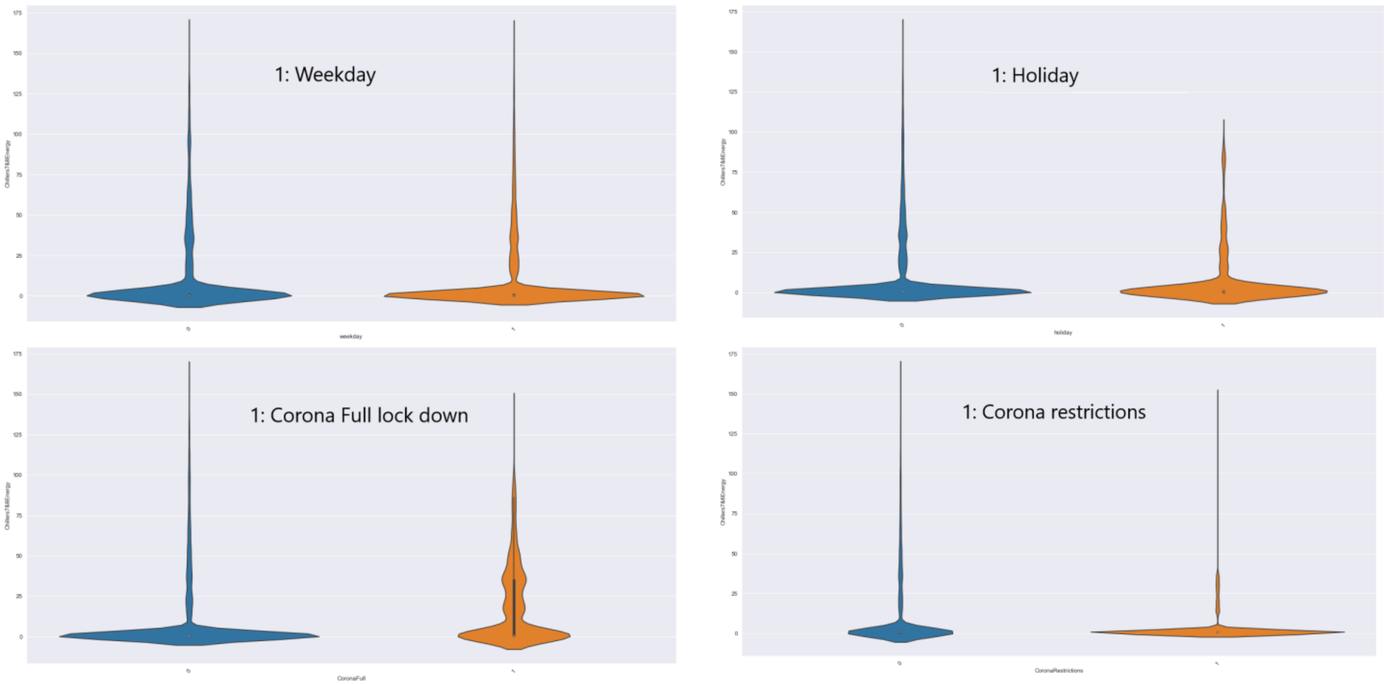


Figure 38. Violin plots of energy demand in the Chillers 7&8 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

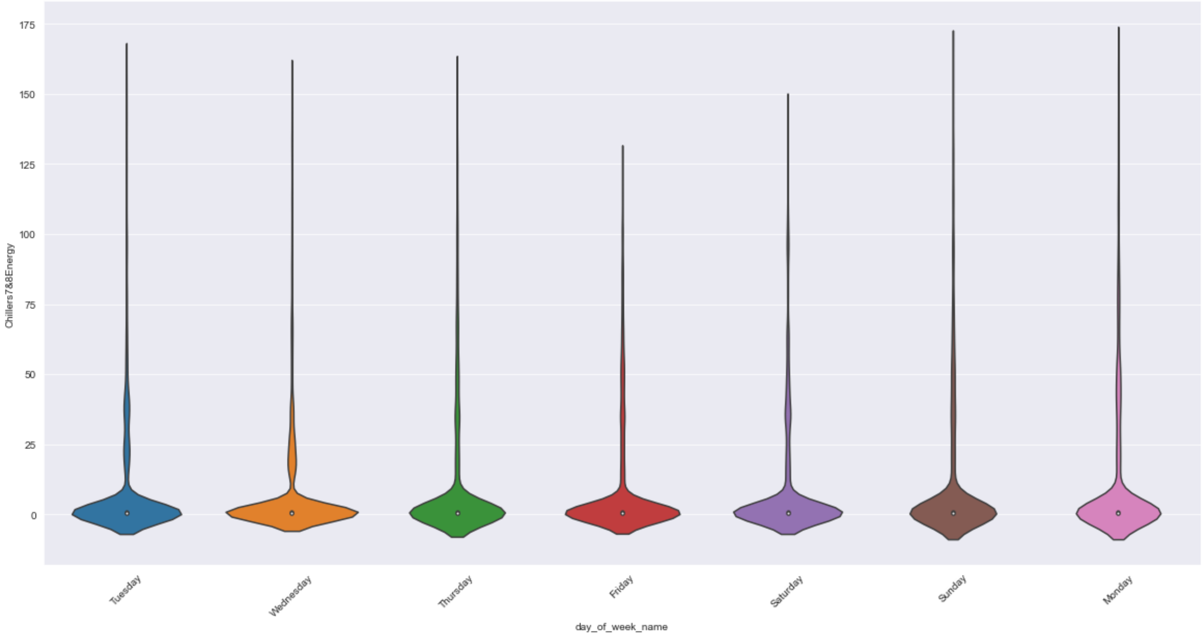


Figure 39. Violin plot of energy demand in Chillers 7&8 at UCY pilot site accounting for the day of the week

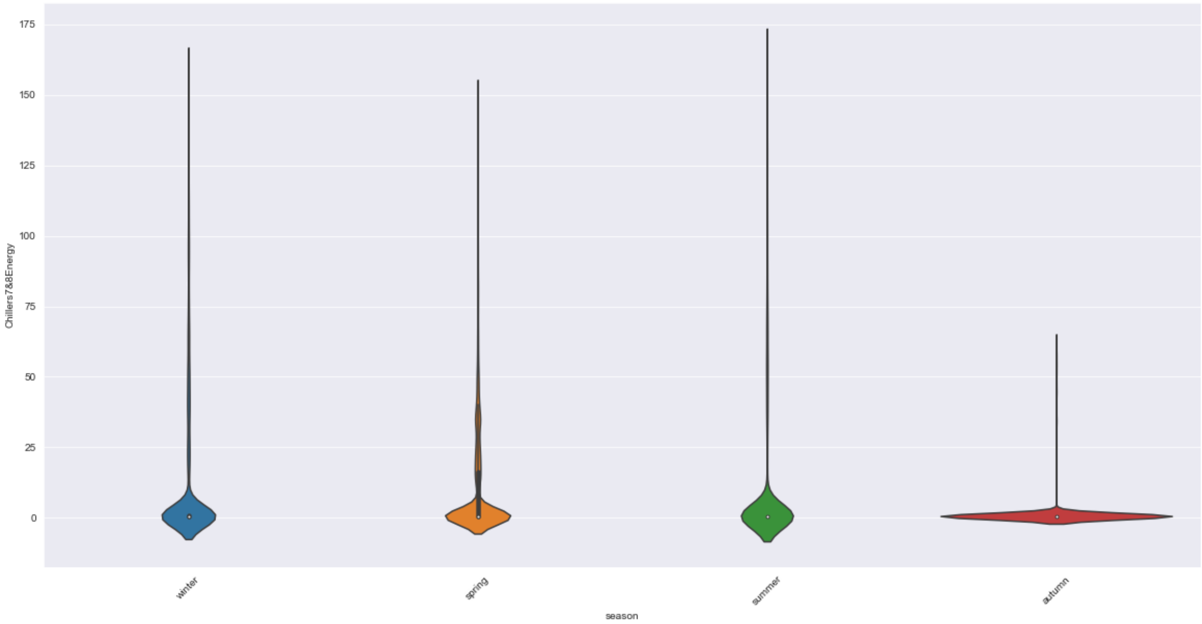


Figure 40. Violin plot of energy demand in Chillers 7&8 at UCY pilot site accounting for the season of the year

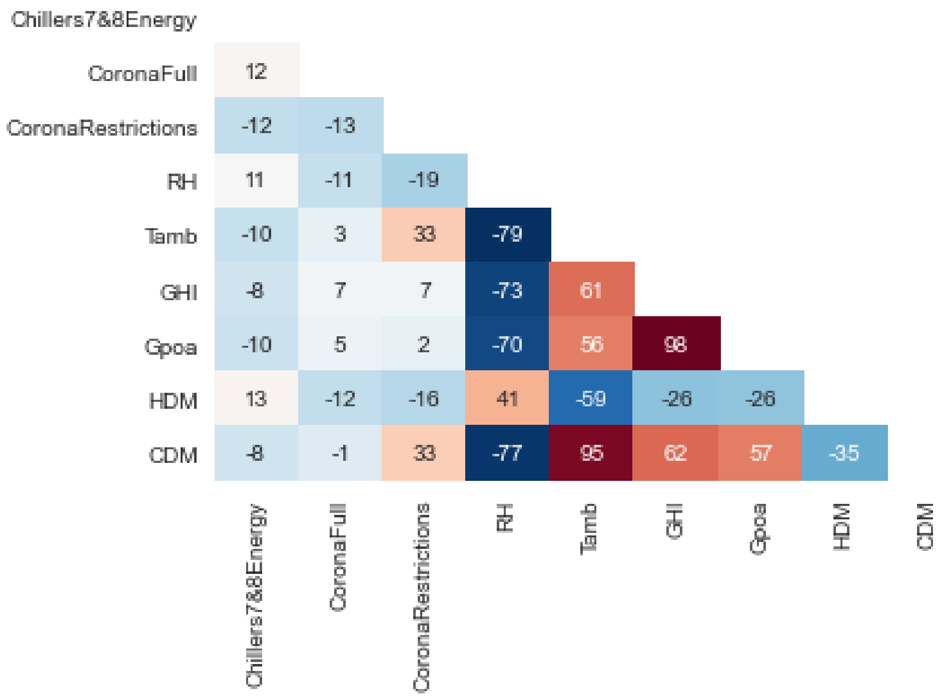


Figure 41. Correlation heat map of the continuous variables accounting for the energy demand in Chillers 7&8 at UCY pilot site

2.2.6 Finance Economics & Business

Figure 42 presents the energy demand profile, the occupancy profile, and the distribution and box plots of energy demand in the Finance Economics & Business building at UCY pilot site. A limited amount of outliers is observed. Figure 43 present the bar plots of energy demand in Finance Economics & Business building at UCY pilot site with respect to weekdays and months accounting for the season of the year. Higher amounts of demand are observed during autumn and winter periods. Figure 44 presents the violin plots of energy demand in the Finance Economics & Business at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. Full lock down period due to the coronavirus emergency had a significant impact on the energy demand. The pattern was restored after partial lifting of full lock down. Figure 45 presents the violin plot of energy demand in the Finance Economics & Business at UCY pilot site accounting for the day of the week. Similar patterns are observed for all days of the week. Figure 46 presents the violin plot of energy demand in the Finance Economics & Business building at UCY pilot site accounting for the season of the year. Lower range in demand are observed during spring period. Figure 47 present the correlation heat map of the continuous variables accounting for the energy demand in the Finance Economics & Business building at UCY pilot site. Week positive correlation between the occupancy profile and energy demand is observed. Moderate negative correlation between full lock down period and energy demand is observed.

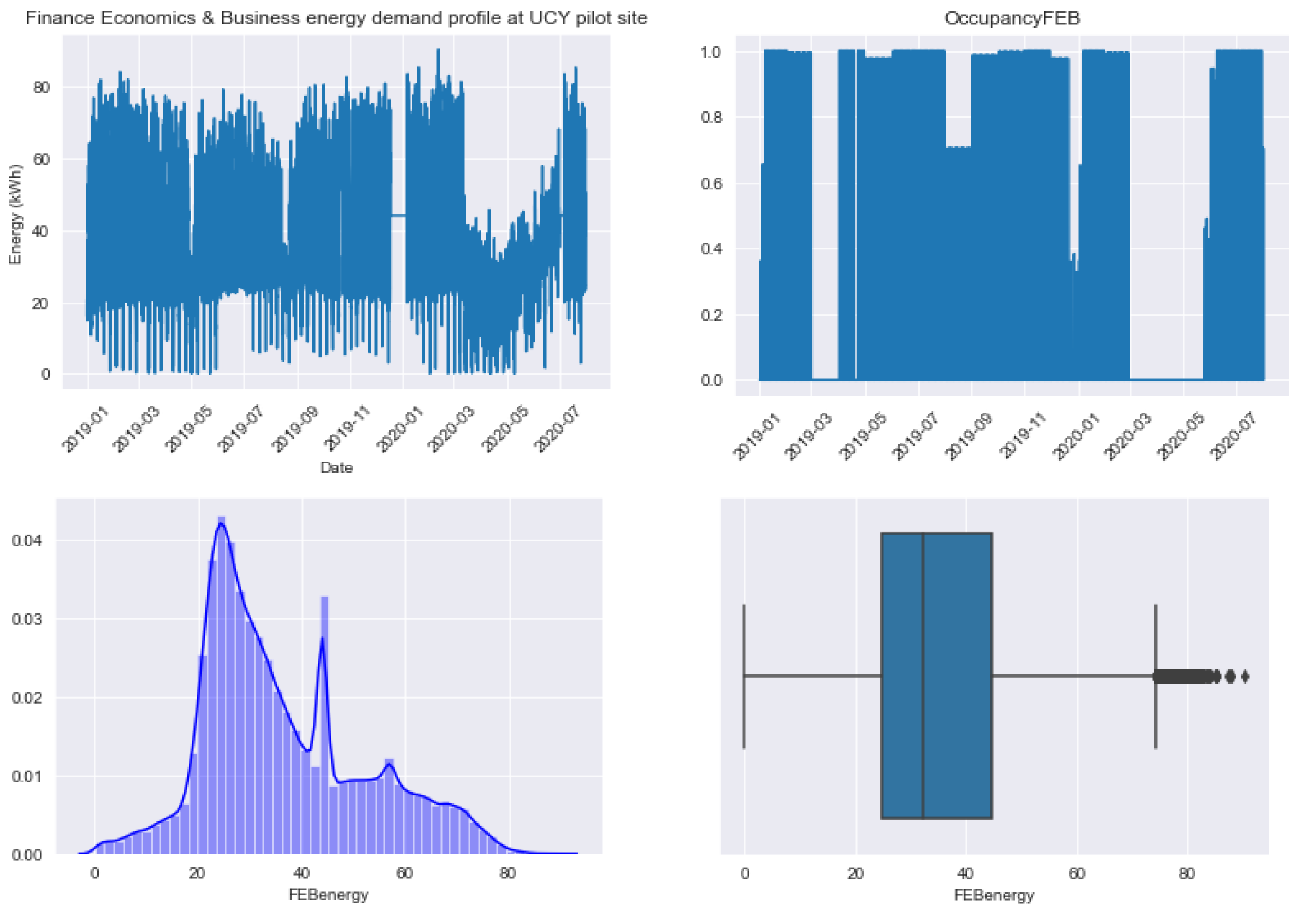


Figure 42. Energy demand profile, occupancy profile, distribution and box plots of energy demand in the Finance Economics & Business at UCY pilot site

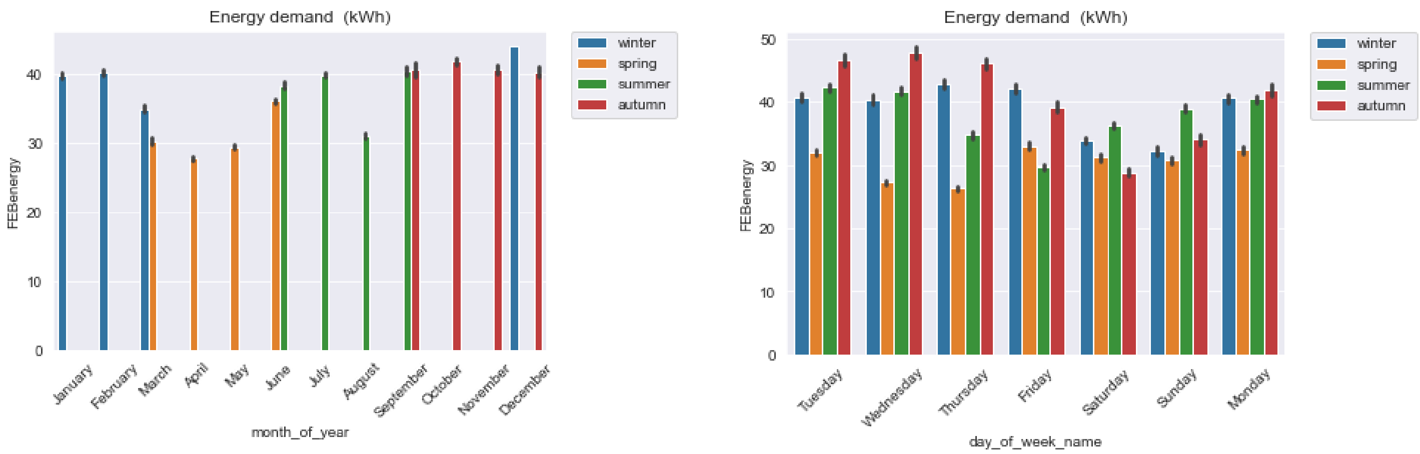


Figure 43. Bar plots of energy demand in the Finance Economics & Business at UCY pilot site with respect to weekdays and months accounting for the season of the year

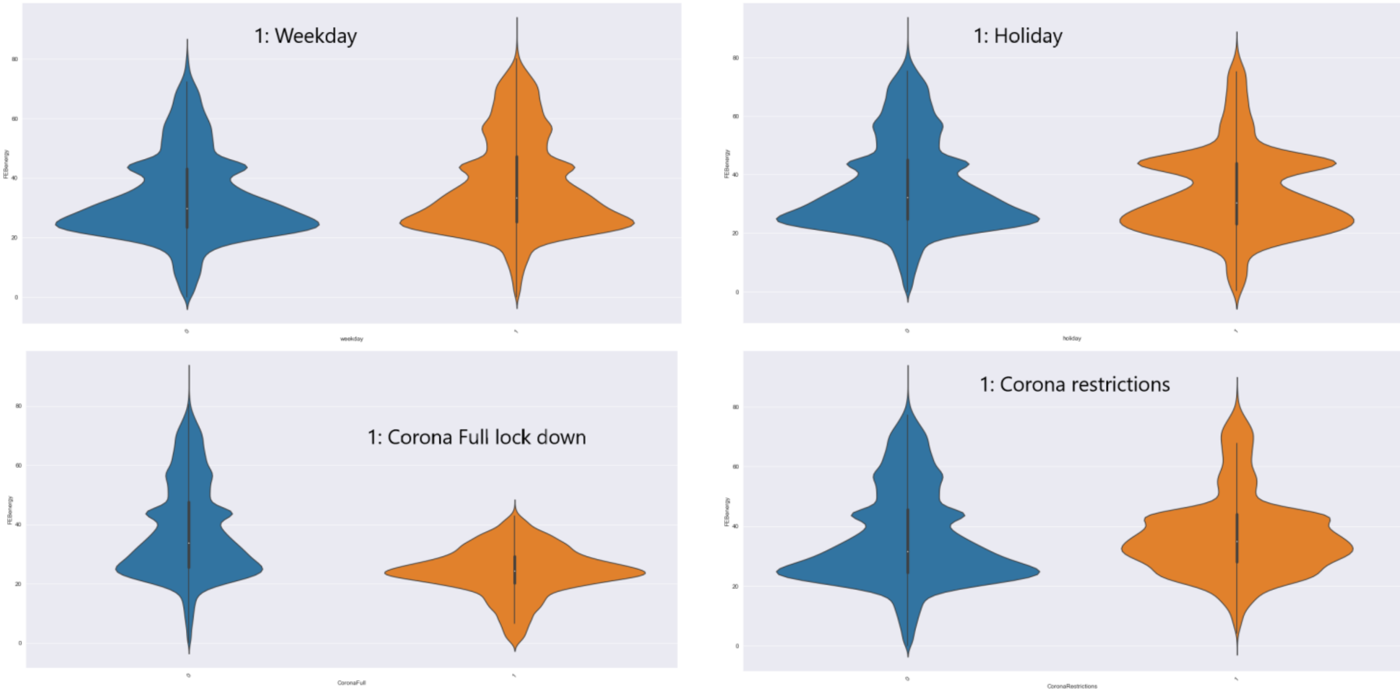


Figure 44. Violin plots of energy demand in the Finance Economics & Business at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

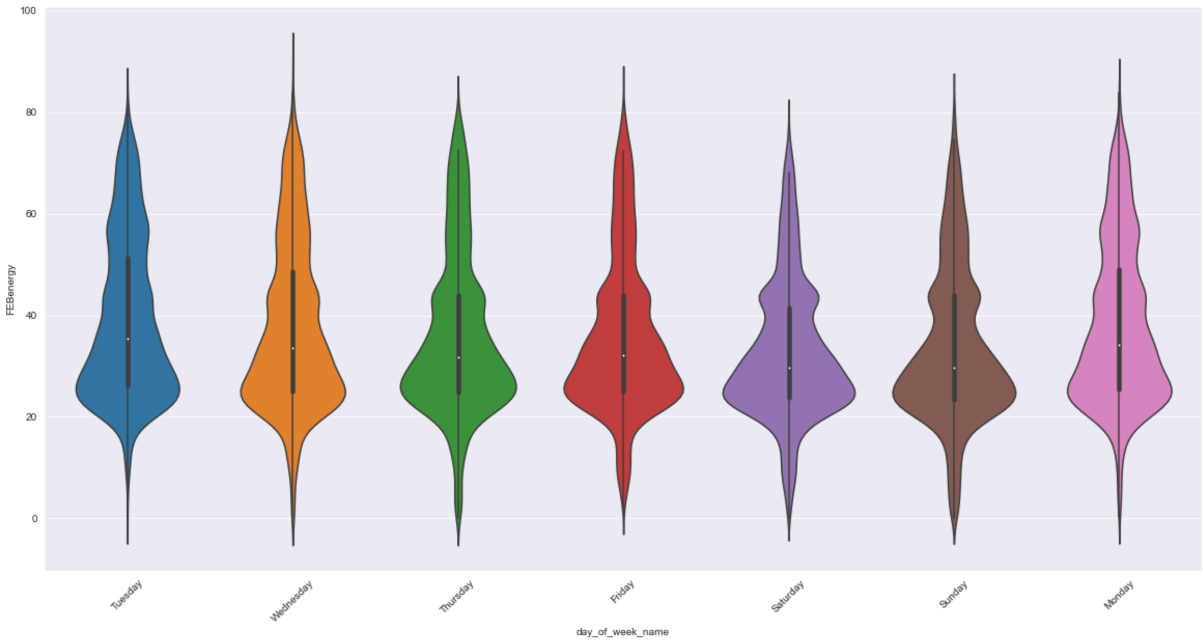


Figure 45. Violin plot of energy demand in the Finance Economics & Business at UCY pilot site accounting for the day of the week

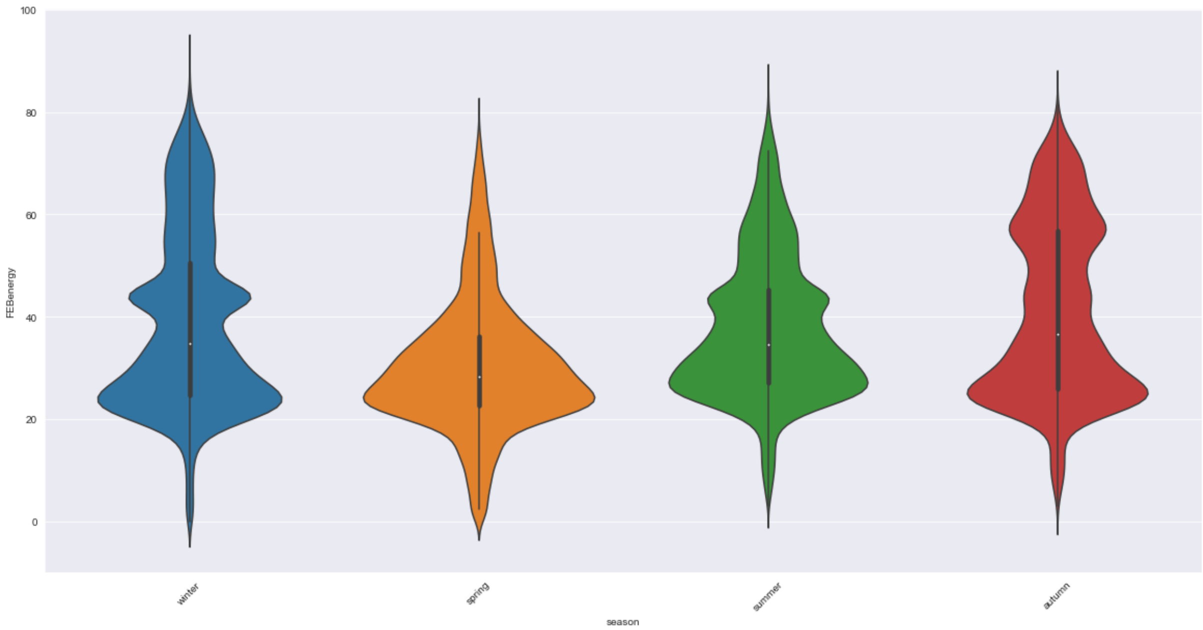


Figure 46. Violin plot of energy demand in the Finance Economics & Business building at UCY pilot site accounting for the season of the year

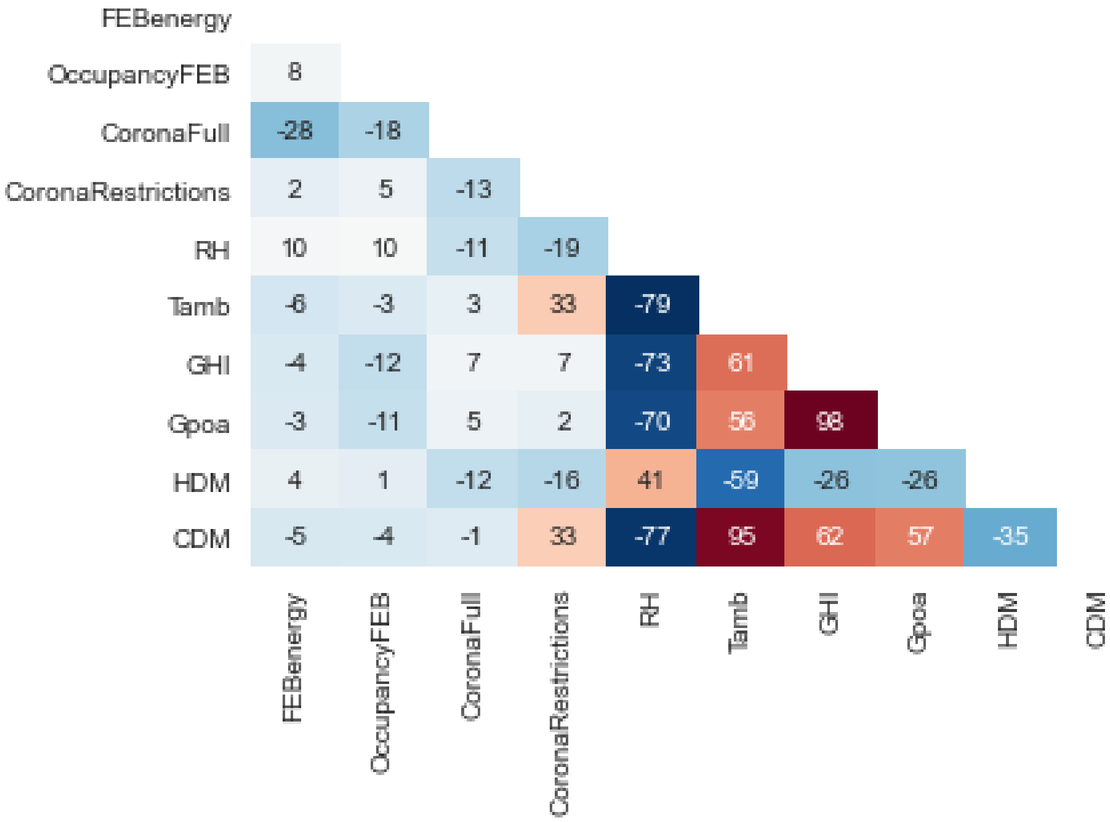


Figure 47. Correlation heat map of the continuous variables accounting for the energy demand in the Finance Economics & Business building at UCY pilot site

2.2.7 Library 1

Figure 48 presents the energy demand profile, the occupancy profile, and the distribution and box plots in the Library 1 at UCY pilot site. A number of outlier values is observed. Figure 49 presents the bar plots of energy demand in the Library 1 at UCY pilot site with respect to weekdays and months accounting for the season of the year. Higher amounts in demand are observed during spring and winter. Figure 50 presents the violin plots of energy demand in the Library 1 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. During holidays as well as during full lock down and restrictions periods due to the coronavirus emergency lower amounts of demand are observed. Figure 51 presents the violin plot of energy demand in the Library 1 at UCY pilot site accounting for the day of the week. Lower amounts of demand are observed during weekends. Figure 52 presents the violin plot of energy demand in the Library 1 at UCY pilot site accounting for the season of the year. Higher amount of demand are observed during winter. During autumn, the library was not fully operational and this explains why the observed demand was is extremely low this season. Figure 53 presents the correlation heat map of the continuous variables accounting for the energy demand in the Library 1 at UCY pilot site. Positive correlations are observed between energy demand and coronal full lock down and restrictions periods. This is explained due to the fact that the library became fully operational close to the end of 2019.

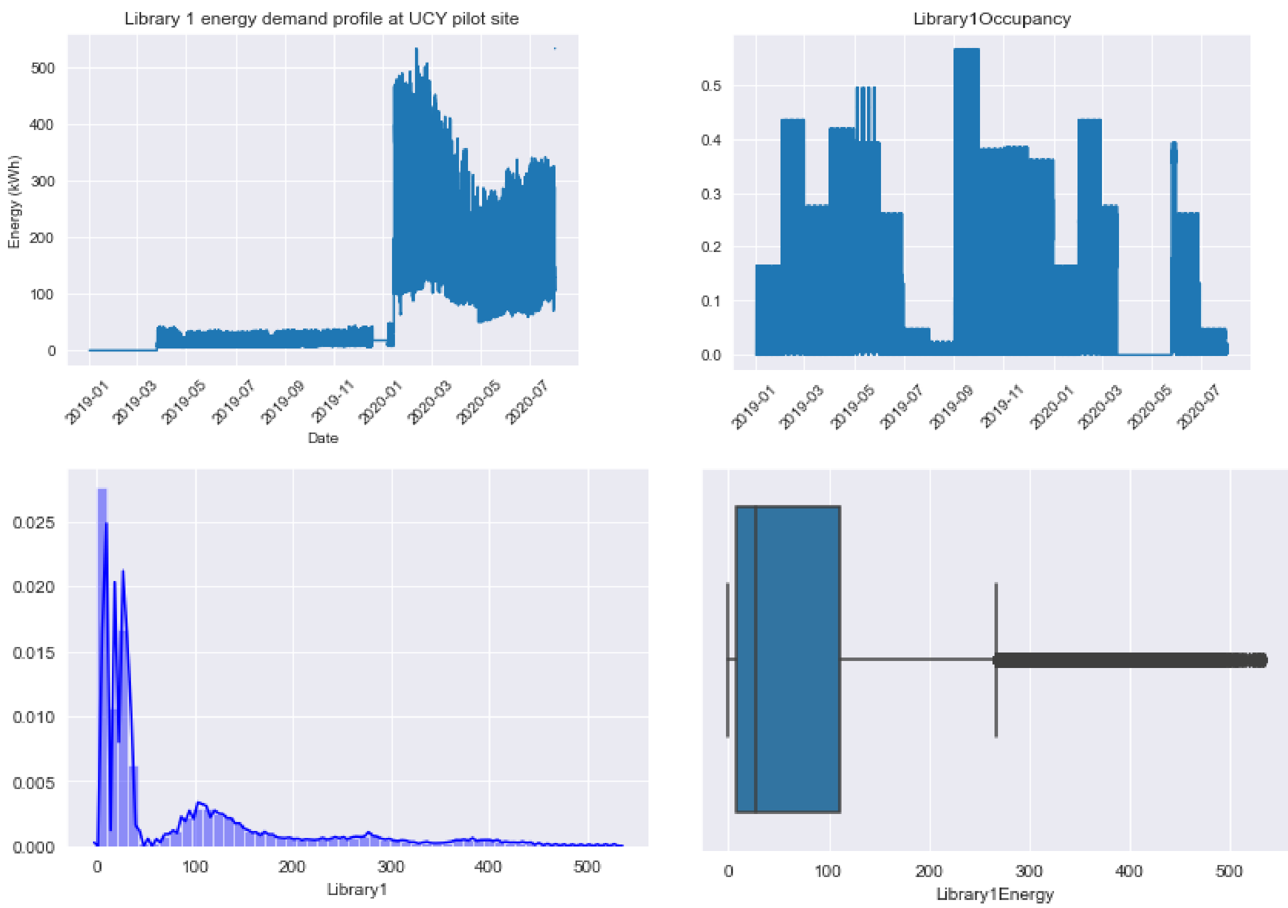


Figure 48. Energy demand profile, occupancy profile, distribution and box plots of energy demand in the Library 1 at UCY pilot site

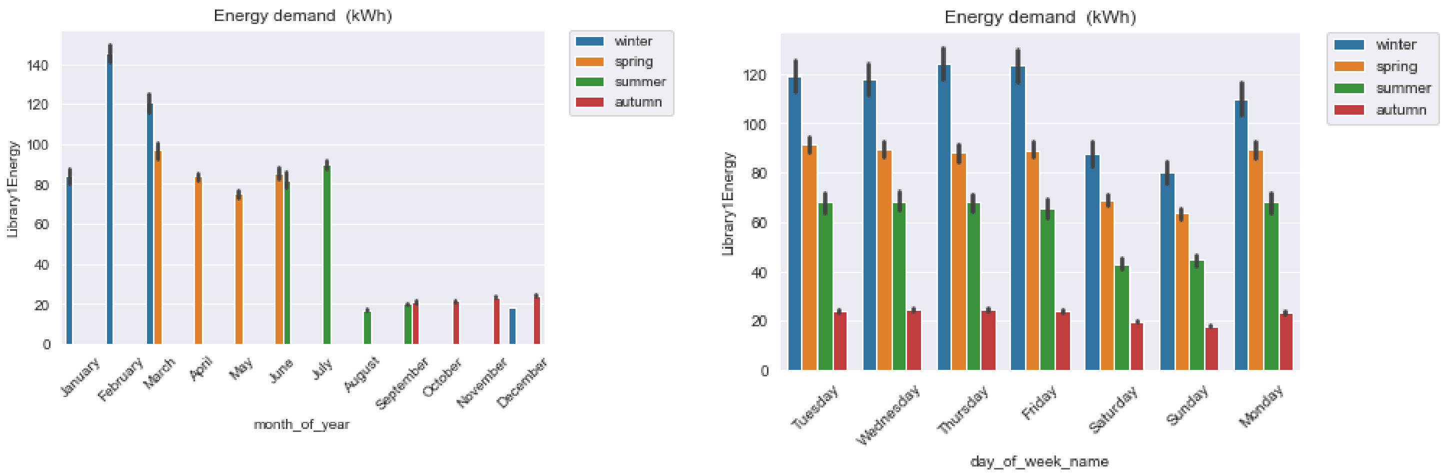


Figure 49. Bar plots of energy demand in the Library 1 at UCY pilot site with respect to weekdays and months accounting for the season of the year

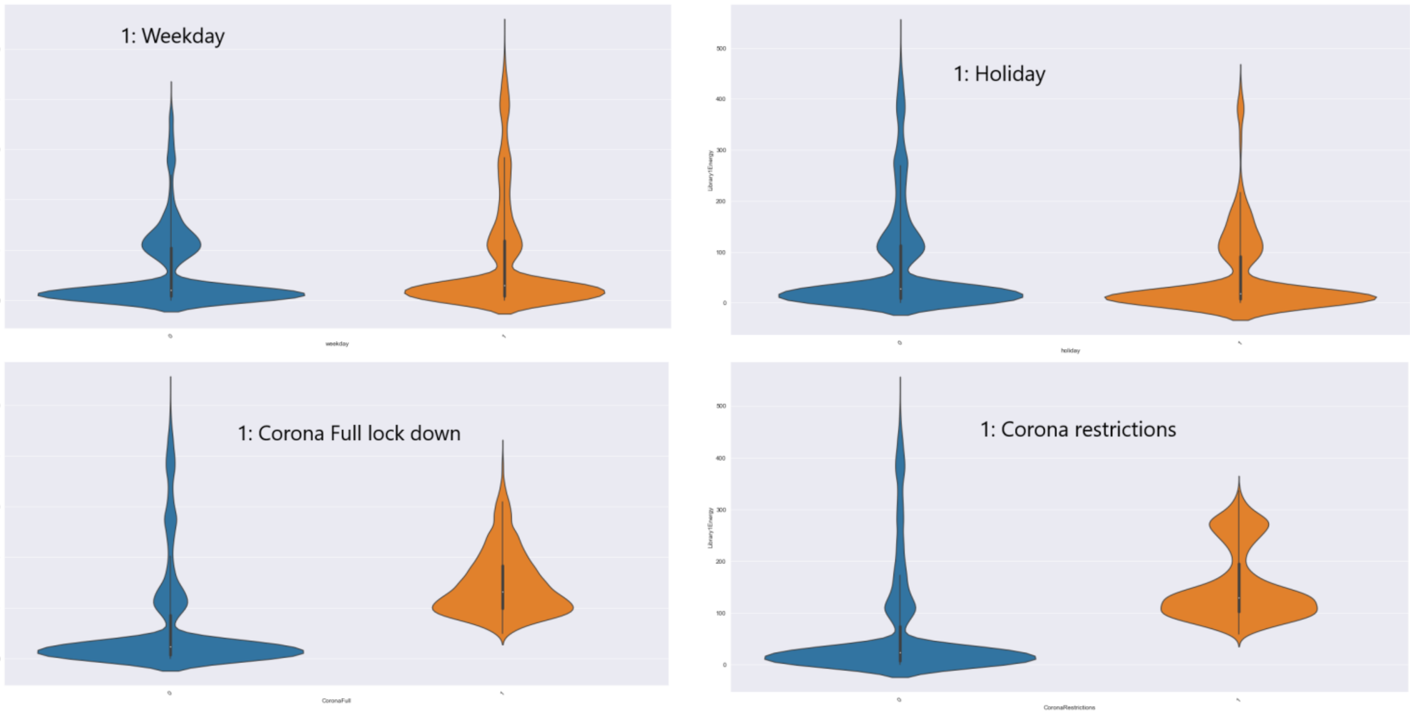


Figure 50. Violin plots of energy demand in the Library 1 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

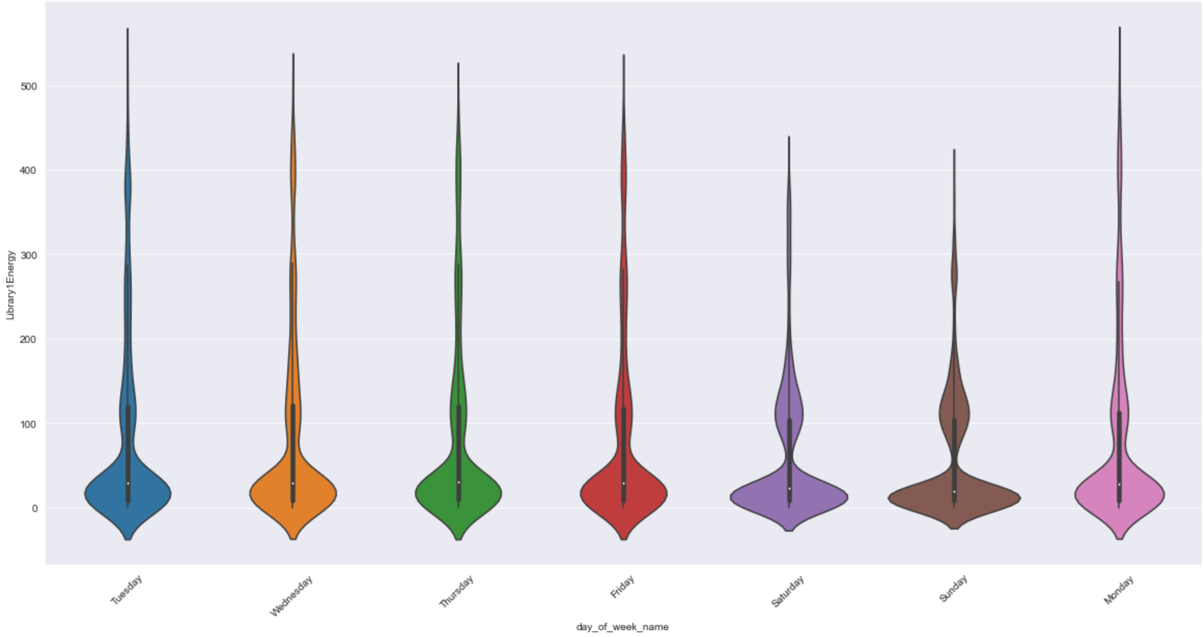


Figure 51. Violin plot of energy demand in the Library 1 at UCY pilot site accounting for the day of the week

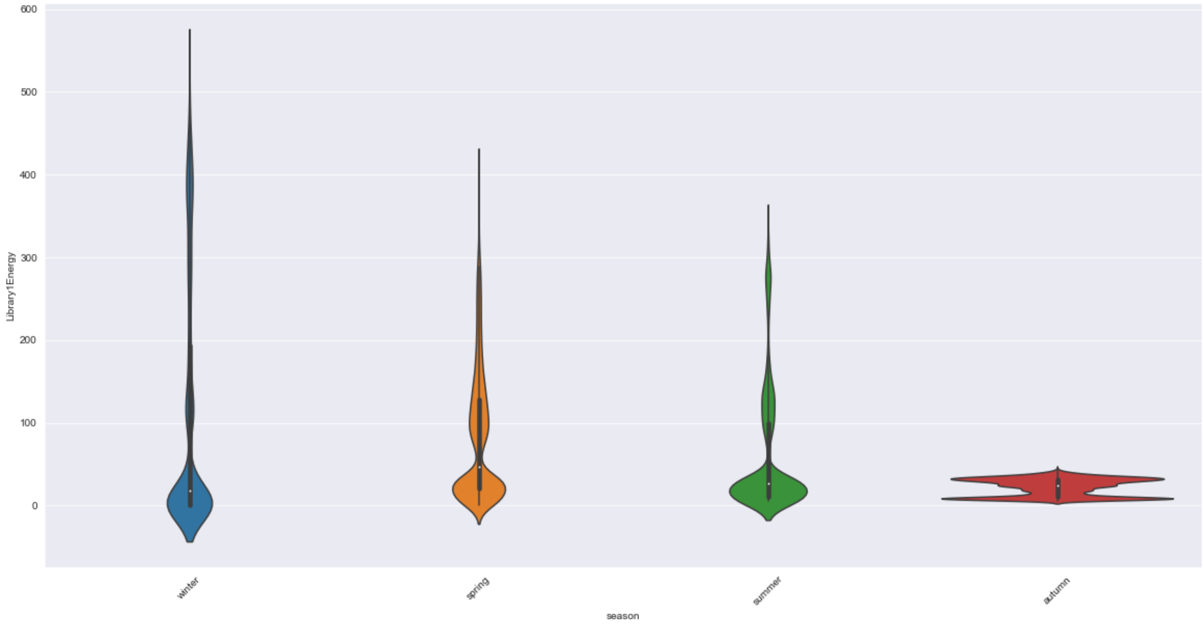


Figure 52. Violin plot of energy demand in the Library 1 at UCY pilot site accounting for the season of the year

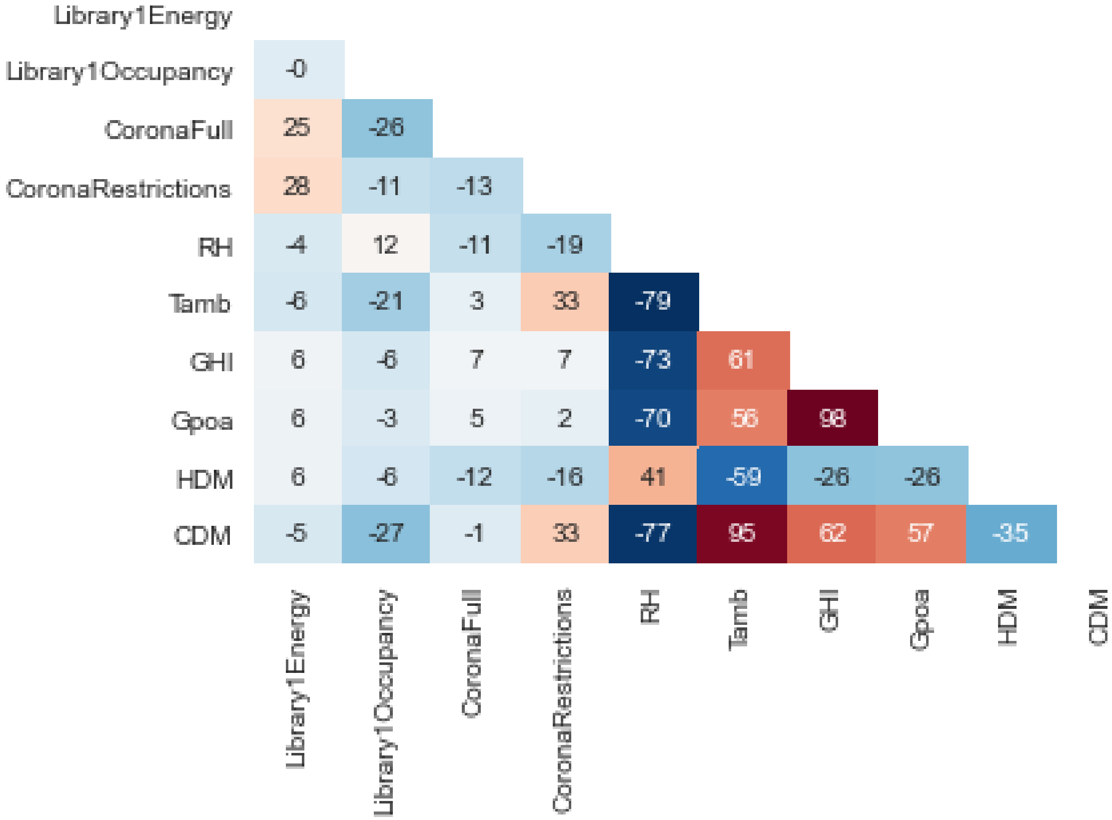


Figure 53. Correlation heat map of the continuous variables accounting for the energy demand in the Library 1 at UCY pilot site

2.2.8 Library 2

Figure 54 presents the energy demand profile, the occupancy profile, and the distribution and box plots of energy demand in Library 2 at UCY pilot site. Figure 55 presents the bar plots of energy demand in the Library 2 at UCY pilot site with respect to weekdays and months accounting for the season of the year. Higher amount of demand are observed during winter. During weekends the amount of demand is lower compared to the rest of the days. Figure 56 presents the violin plots of energy demand in the Library 2 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. Figure 57 presents the violin plot of energy demand in the Library 2 at UCY pilot site accounting for the day of the week. Figure 58 presents the violin plot of energy demand in the Library 2 at UCY pilot site accounting for the season of the year. Figure 59 presents the Correlation heat map of the continuous variables accounting for the energy demand in the Library 2 at UCY pilot site. Positive correlations are observed between energy demand and full lock down and restriction periods due to the coronavirus emergency. This is explained by the fact that the library became fully operational during close to the end of 2019 and loads running 24 hours are incorporated in it.

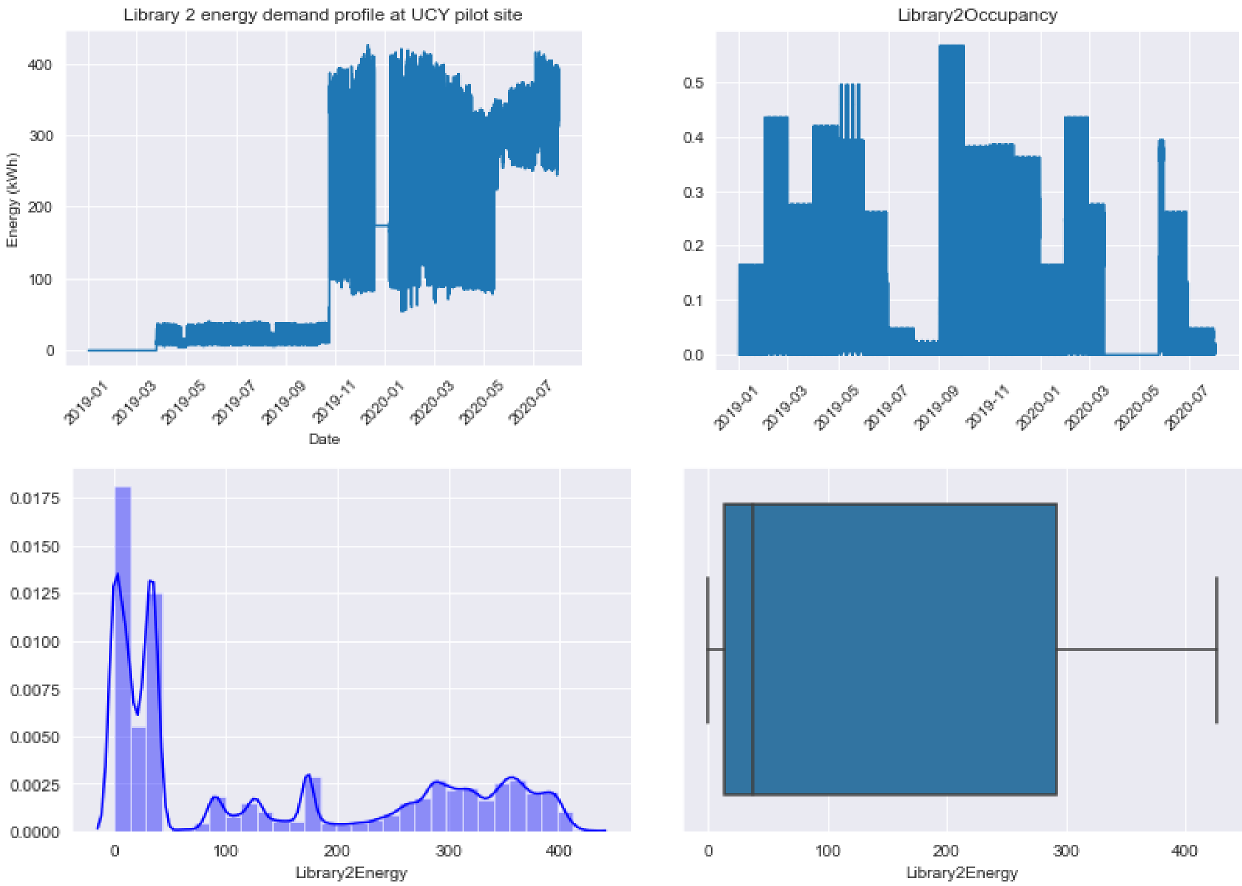


Figure 54. Energy demand profile, occupancy profile, distribution and box plots of energy demand in the Library 2 at UCY pilot site

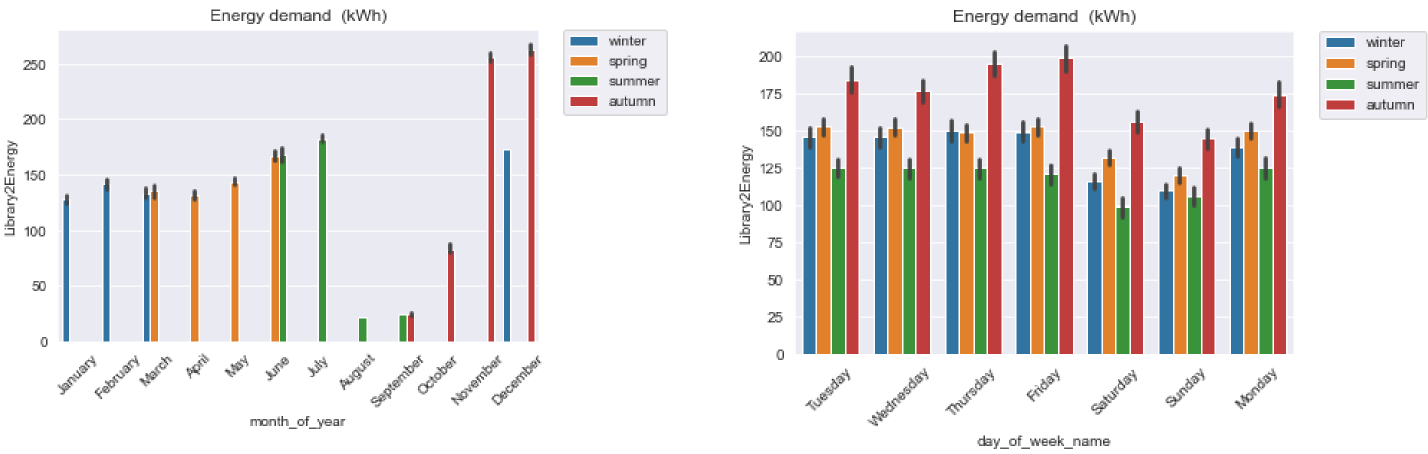


Figure 55. Bar plots of energy demand in the Library 2 at UCY pilot site with respect to weekdays and months accounting for the season of the year

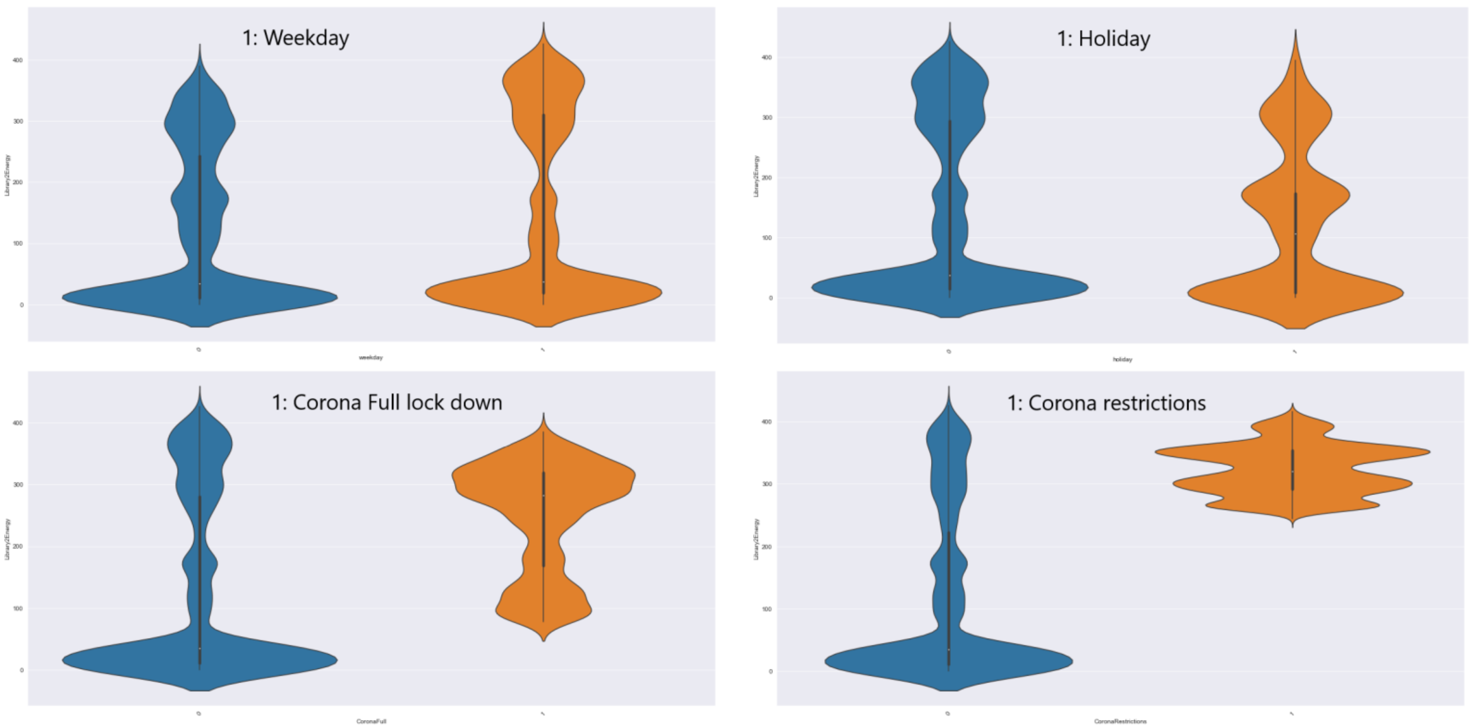


Figure 56. Violin plots of energy demand in the Library 2 at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

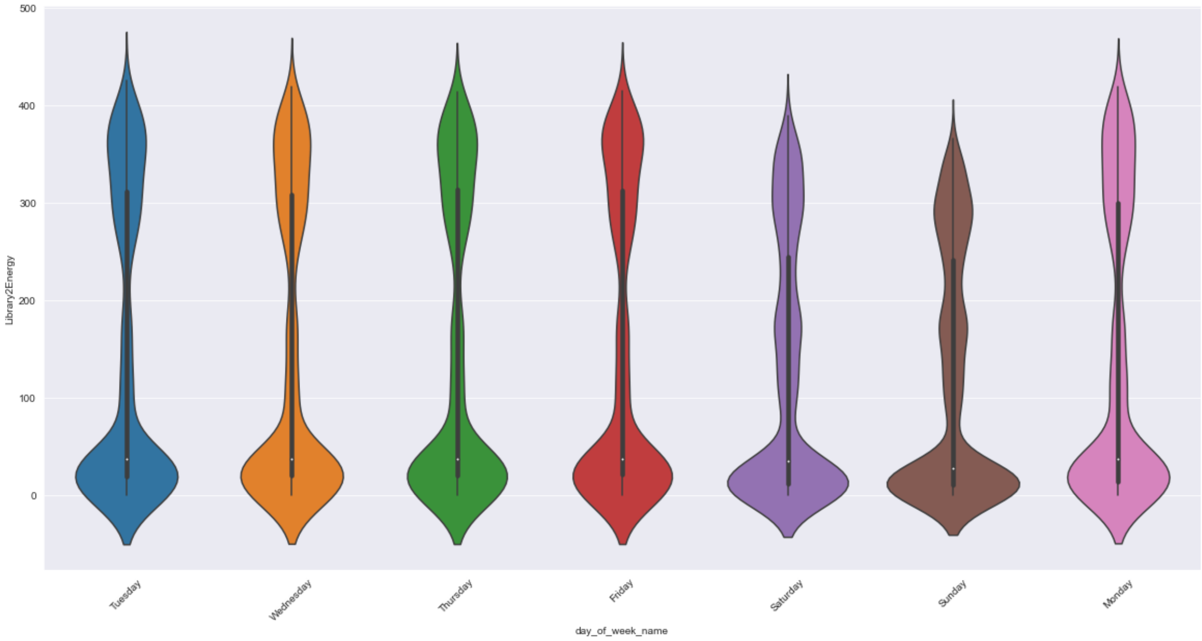


Figure 57. Violin plot of energy demand in the Library 2 at UCY pilot site accounting for the day of the week

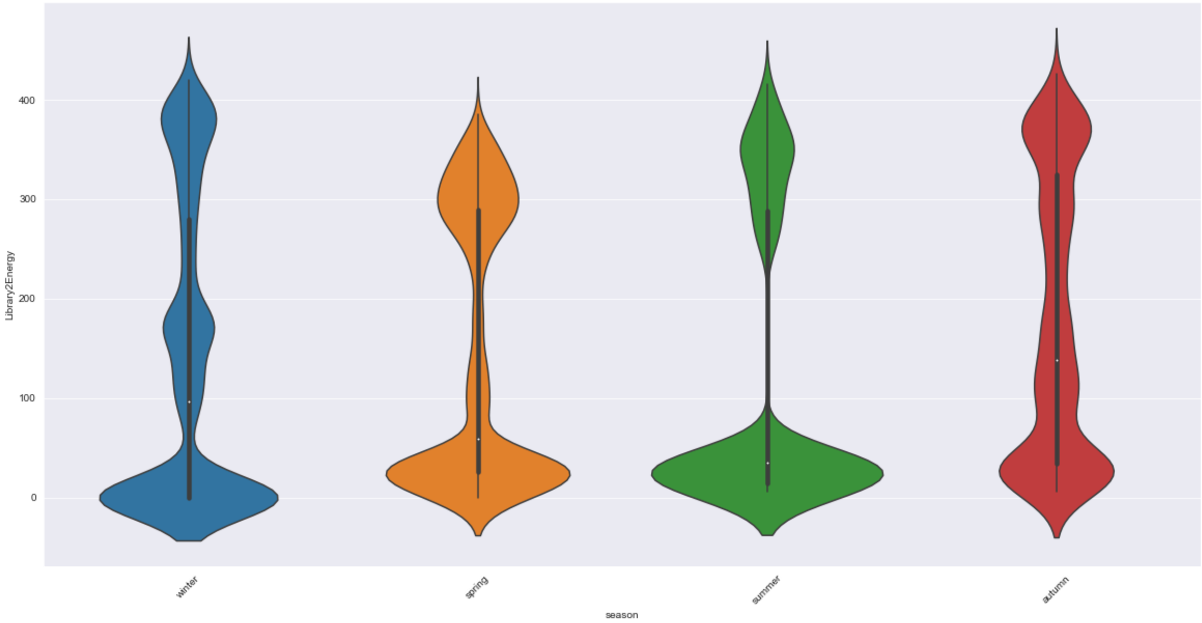


Figure 58. Violin plot of energy demand in the Library 2 at UCY pilot site accounting for the season of the year

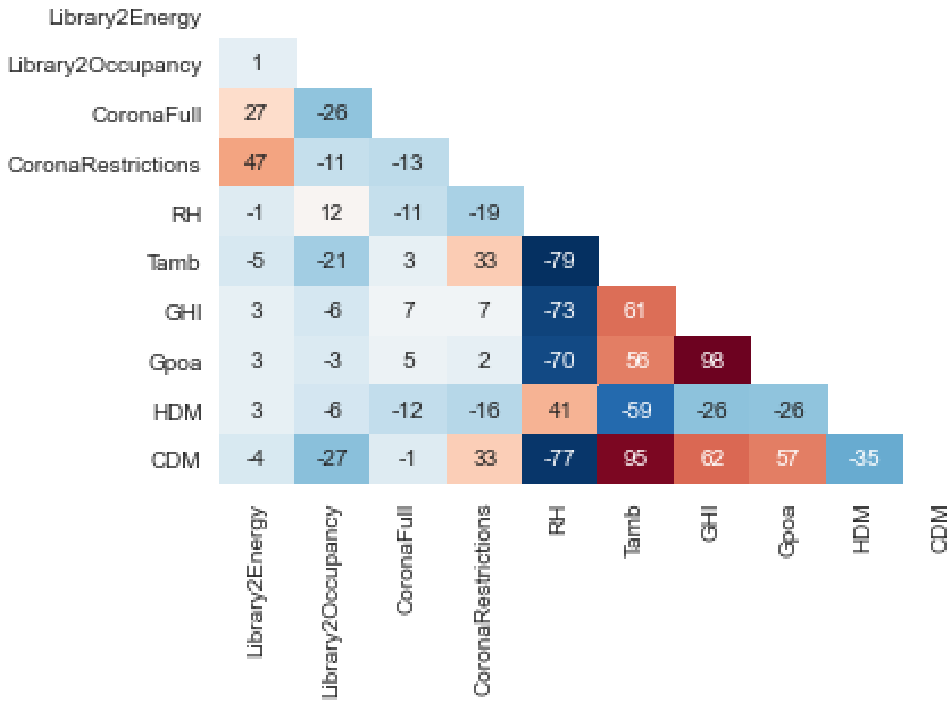


Figure 59. Correlation heat map of the continuous variables accounting for the energy demand in the Library 2 at UCY pilot site

2.2.9 Students Residence Building A

Figure 60 presents the energy demand profile, the occupancy profile, and the distribution and box plots of energy demand in the Students Residence Building A at UCY pilot site. A limited amount of outliers are observed. Figure 61 presents the bar plots of energy demand in the Student Residence Building A at UCY pilot site with respect to weekdays and months accounting for the season of the year. Higher amounts are observed during autumn and winter periods. Similar demand profiles are observed during all of the weekdays. Figure 62 presents the violin plots of energy demand in the Student Residence Building A at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables. Lower amounts of energy demand are observe during holidays, full lock down and restrictions periods due to the coronavirus emergency. Figure 63 presents the violin plot of energy demand in the Students Residence Building A at UCY pilot site accounting for the day of the week. Similar patterns are observed during all the days of the week. Figure 64 presents the violin plot of energy demand in the Students Residence Building A at UCY pilot site accounting for the season of the year. Similar patterns are observed during all the seasons of the year. Figure 65 presents the correlation heat map of the continuous variables accounting for the energy demand in the Students Residence Building A at UCY pilot site. Weak positive correlations between the energy demand and occupancy profile, GHI, Gpoa variables is observed. Weak negative correlations between energy demand and full lock down and restrictions periods are observed as well.

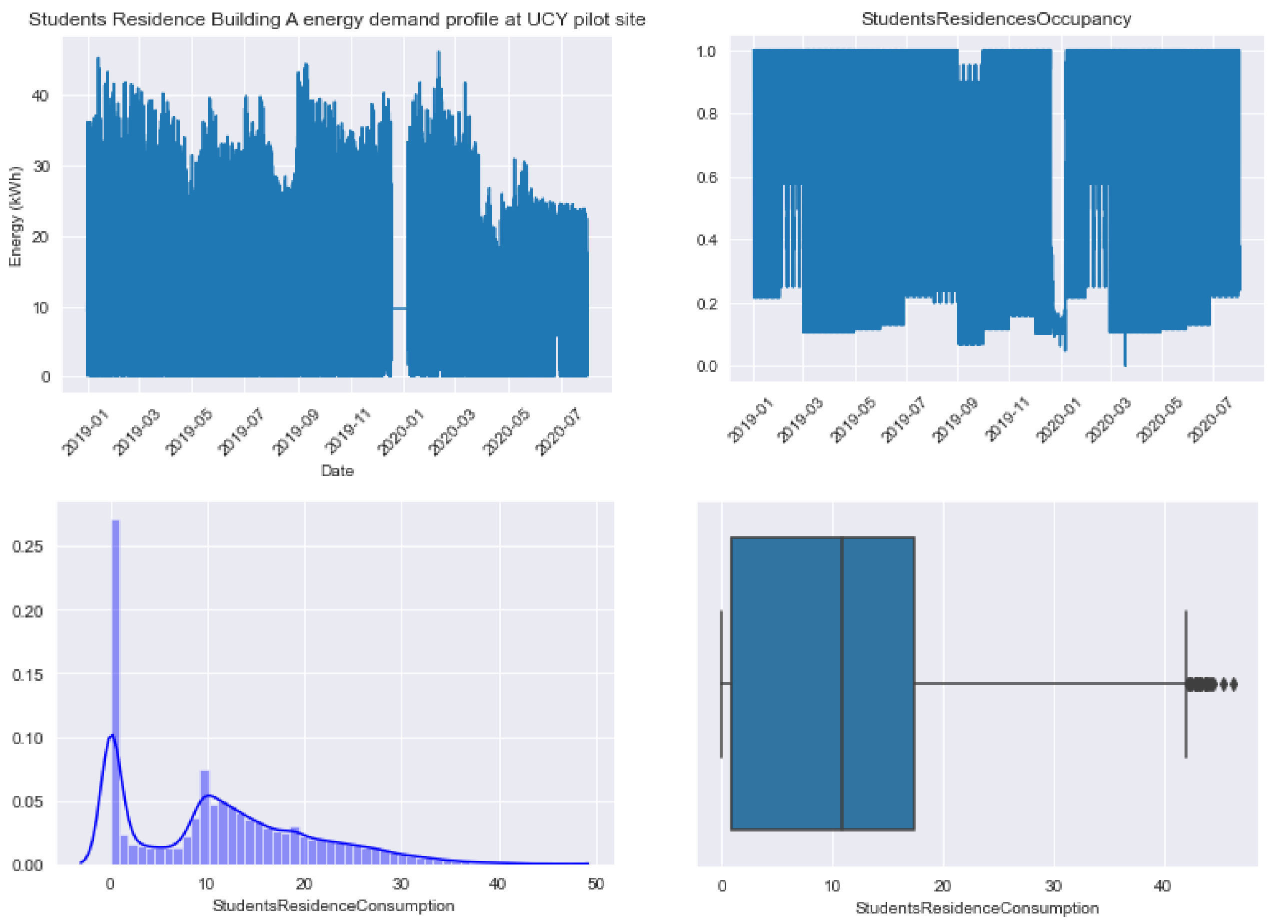


Figure 60. Energy demand profile, occupancy profile and distribution and box plots in the Students Residence Building A at UCY pilot site

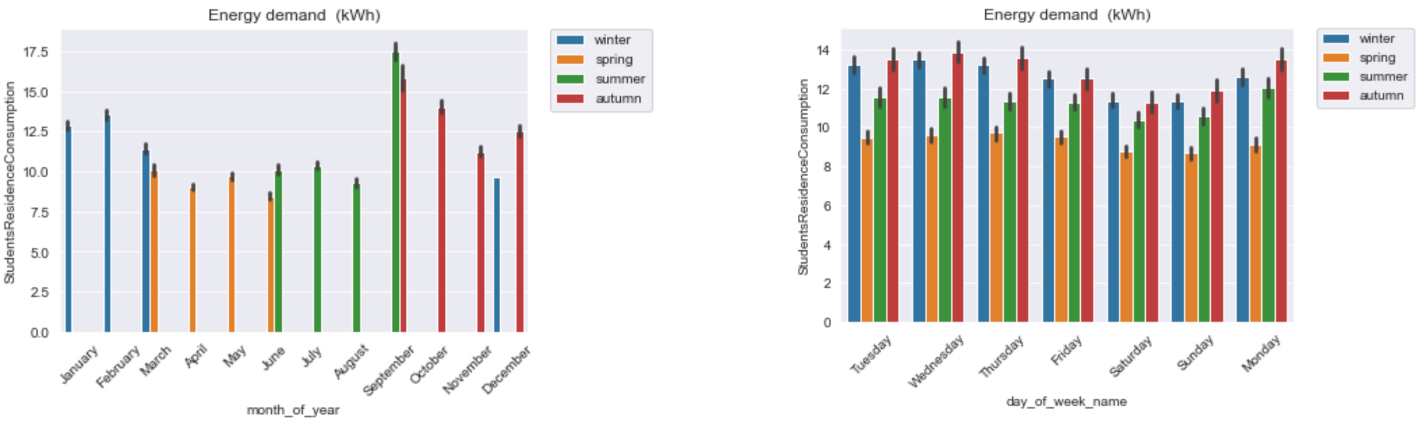


Figure 61. Bar plots of energy demand in the Student Residence Building A at UCY pilot site with respect to weekdays and months accounting for the season of the year

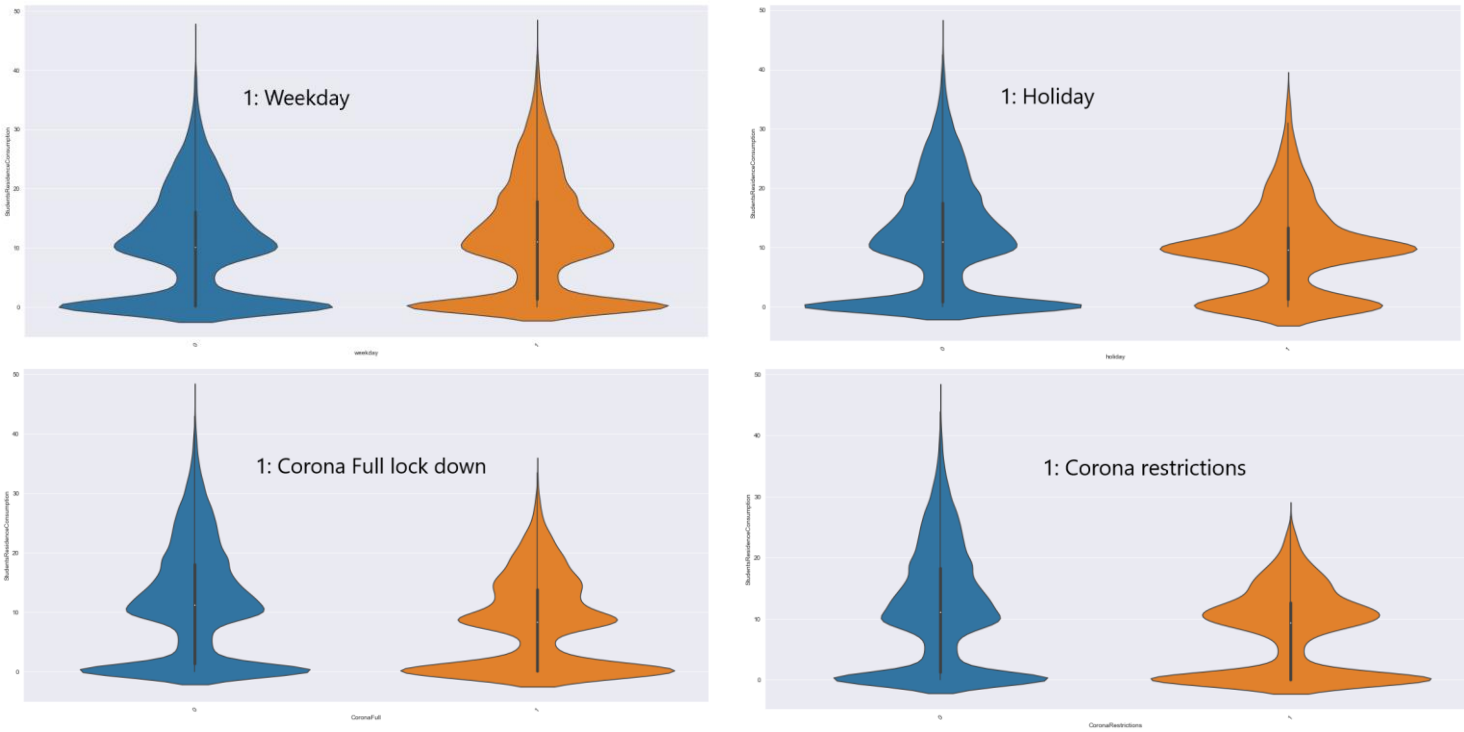


Figure 62. Violin plots of energy demand in the Student Residence Building A at UCY pilot site accounting for Weekday, Holiday, Corona restrictions and full lock down indicator variables

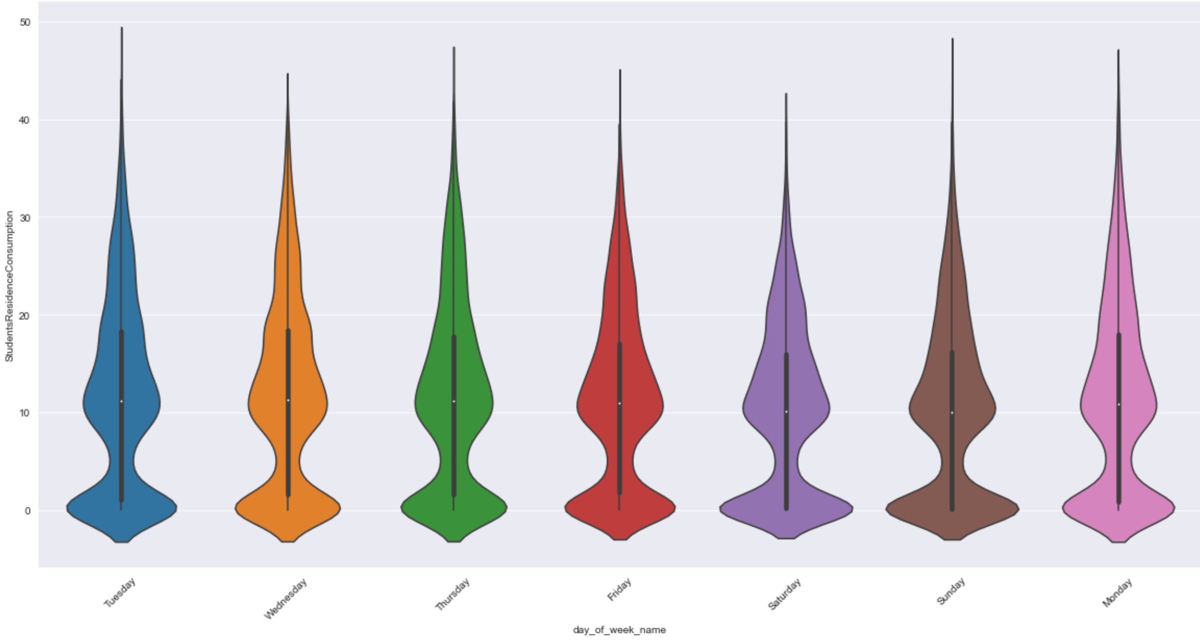


Figure 63. Violin plot of energy demand in the Students Residence Building A at UCY pilot site accounting for the day of the week

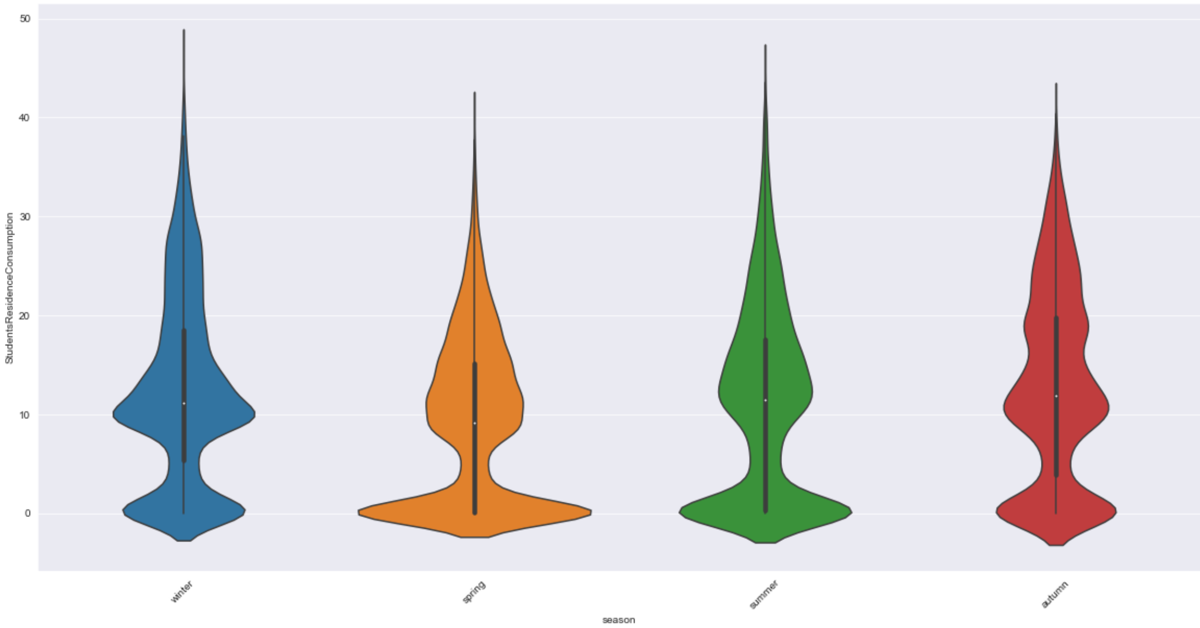


Figure 64. Violin plot of energy demand in the Students Residence Building A at UCY pilot site accounting for the season of the year

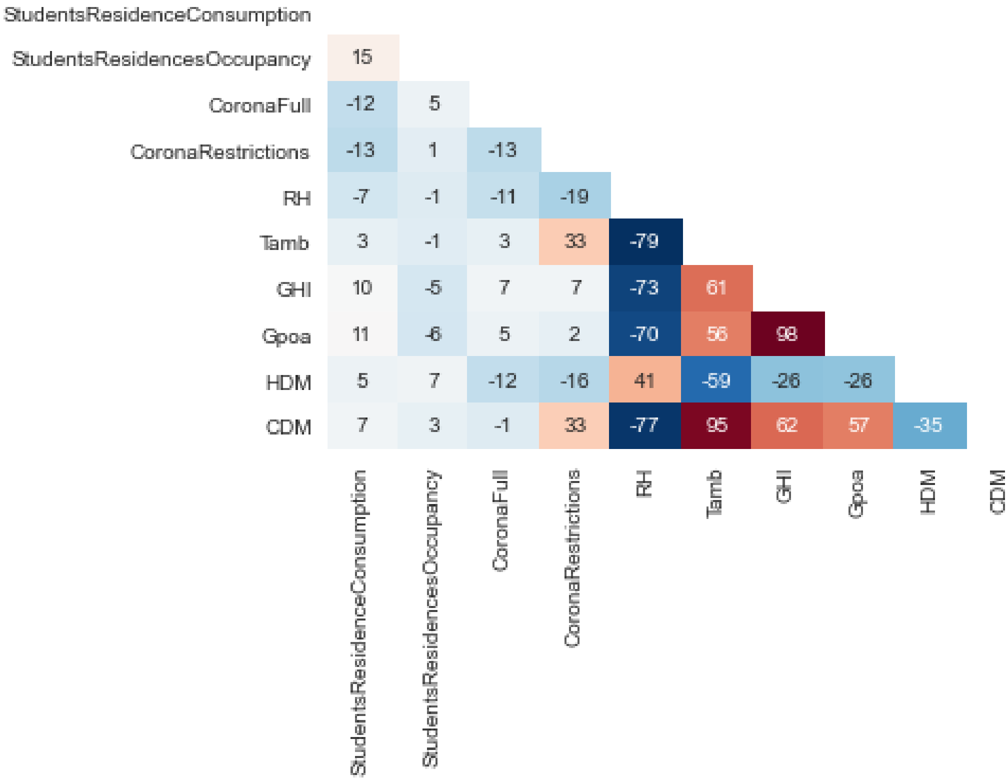


Figure 65. Correlation heat map of the continuous variables accounting for the energy demand in the Students Residence Building A at UCY pilot site

2.3 Energy Baseline

In this section, the approach followed for the determination of energy baselines on the historical data available at UCY pilot site is presented.

Additionally, a 'control/treatment' group approach was foreseen to be used for comparisons between energy demand during the deployment of pilot DR programs and energy demand when no DR program is deployed. Buildings falling under the category of **treatment group** are:

- Administration Building
- Faculty Economics & Business
- Library
- Student Residences
- PV Technology Lab (PVTL)[2]. It is labelled as STP Lab in the dataset files.

Buildings falling under the category of **control group** are:

- Sport Centre and Fields
- Faculty of Science 1
- Faculty of Science 2
- Social Facility Centre

An alternative approach for the determination of the baseline would be to forecast the values of the predictors/features that have been chosen to act as determinants and accordingly forecast the energy consumption with an adequate enough granularity, i.e. 1 or 15 minutes.

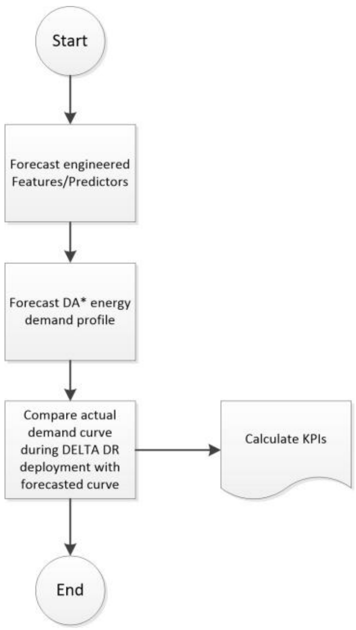


Figure 66. Alternative approach for determining the energy baseline for calculating DELTA KPIs during pilot deployment

The ABT for each building is used as input for modelling purposes. When present, outliers for energy demand have been replace with the value of the 95th percentile of the energy demand vector. The results of the application of the multivariate linear regression model on the dataset are presented below. The performance of the model was tested on the whole dataset. An alternative approach would be to split the dataset into seasons, run the model on each season and obtain performance results. For the needs of the

[2] Labelled as STP lab

modelling performed, all outlier values have been replaced with the 95th quintile of the respective time series of energy demand.

2.3.1 Administration Building

Table 7 presents the linear model coefficients for the multivariate linear regression models for the energy demand in the Administration building of UCY pilot site.

Table 7. Linear Model coefficients for energy consumption in the Administration Building

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	119.3	20	weekday_Friday_indicator	0.12
1	AdministrationOccupancy	3.03	21	weekday_Saturday_indicator	-0.86
2	CoronaFull	1.81	22	weekday_Sunday_indicator	0.75
3	CoronaRestrictions	4.40	23	holiday_indicator	-0.79
4	RH	0.00	24	month_of_year_January	-304.68
5	Tamb	-0.31	25	month_of_year_February	-250.92
6	GHI	0.00	26	month_of_year_March	-199.97
7	Gpoa	0.00	27	month_of_year_April	-142.66
8	HDM	-0.38	28	month_of_year_May	-86.83
9	CDM	0.21	29	month_of_year_June	-29.04
10	day_of_moth	1.86	30	month_of_year_July	27.02
11	hour_of_day	0.05	31	month_of_year_August	79.74
12	minute_of_day	0.00	32	month_of_year_September	141.10
13	day_of_year	-1.82	33	month_of_year_October	199.97
14	week_of_year	0.02	34	month_of_year_November	254.61
15	weekday_indicator	0.11	35	month_of_year_December	311.16
16	weekday_Monday_indicator	0.18	36	season_winter_indicator	4.40
17	weekday_Tuesday_indicator	0.26	37	season_spring_indicator	0.61
18	weekday_Wednesday_indicator	0.24	38	season_summer_indicator	0.05
19	weekday_Thursday_indicator	-0.69	39	season_autumn_indicator	-5.05

Figure 67 graphically illustrates the information presented in Table 7. The value of 0.119 for the adjusted R^2 metric indicates that the multivariate linear regression model cannot adequately explain the variance of energy demand in the Administration building of UCY pilot site. For the needs of validation of results during pilot deployment activities, the control group buildings shall be used.

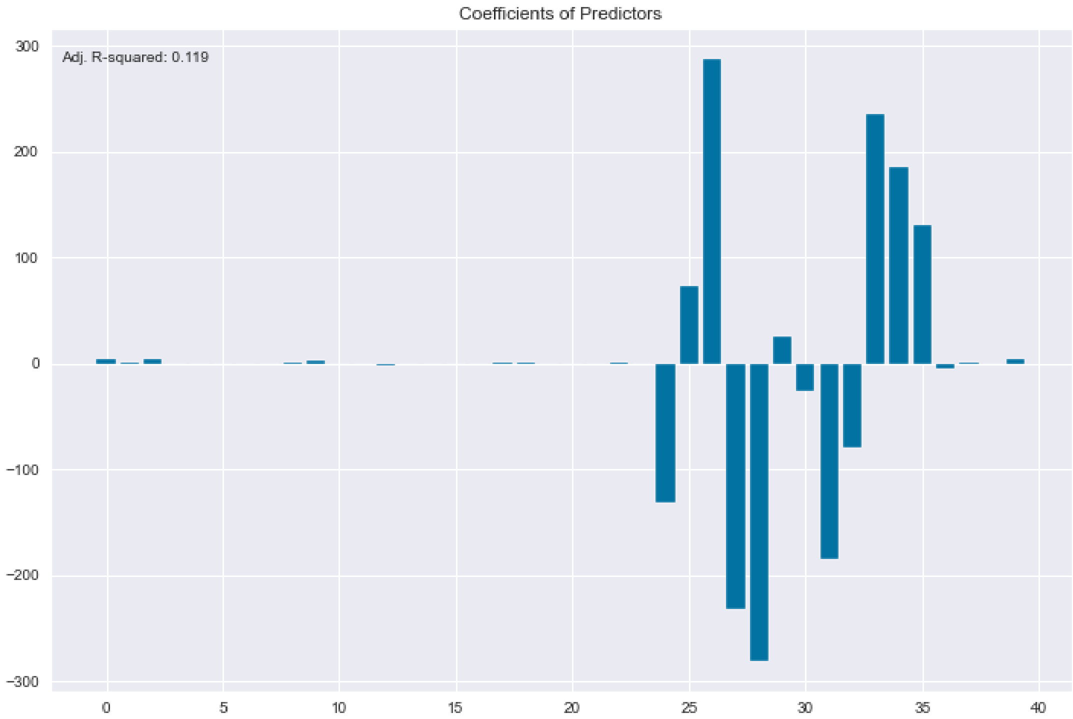


Figure 67. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.2 Chillers 1&2

Table 8 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chillers 1&2 of UCY pilot site.

Table 8. Linear Model coefficients for energy consumption in the Chillers 1&2

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	30.09	20	weekday_Saturday_indicator	-0.15
1	CoronaFull	0.76	21	weekday_Sunday_indicator	-2.56
2	CoronaRestrictions	14.19	22	holiday_indicator	-3.89
3	RH	0.15	23	month_of_year_January	-90.90
4	Tamb	0.92	24	month_of_year_February	-83.54
5	GHI	0.01	25	month_of_year_March	-71.86
6	Gpoa	0.00	26	month_of_year_April	-55.84
7	HDM	0.81	27	month_of_year_May	-30.44
8	CDM	-1.29	28	month_of_year_June	3.30
9	day_of_moth	0.47	29	month_of_year_July	30.47
10	hour_of_day	0.52	30	month_of_year_August	54.74
11	minute_of_day	0.00	31	month_of_year_September	65.78
12	day_of_year	-0.52	32	month_of_year_October	41.37
13	week_of_year	0.04	33	month_of_year_November	68.09
14	weekday_indicator	2.72	34	month_of_year_December	68.83
15	weekday_Monday_indicator	-1.34	35	season_winter_indicator	-13.63
16	weekday_Tuesday_indicator	-0.91	36	season_spring_indicator	-13.20
17	weekday_Wednesday_indicator	0.98	37	season_summer_indicator	23.20
18	weekday_Thursday_indicator	1.68	38	season_autumn_indicator	3.64
19	weekday_Friday_indicator	2.30			

Figure 68 graphically illustrates the information presented in Table 8. The value of 0.705 for the adjusted R^2 metric indicates that the multivariate linear regression model can adequately explain the variance of energy demand in the Chillers 1&2 of the UCY pilot site. The use of control buildings for validation purposes may accompany the validation of results during pilot deployment activities.

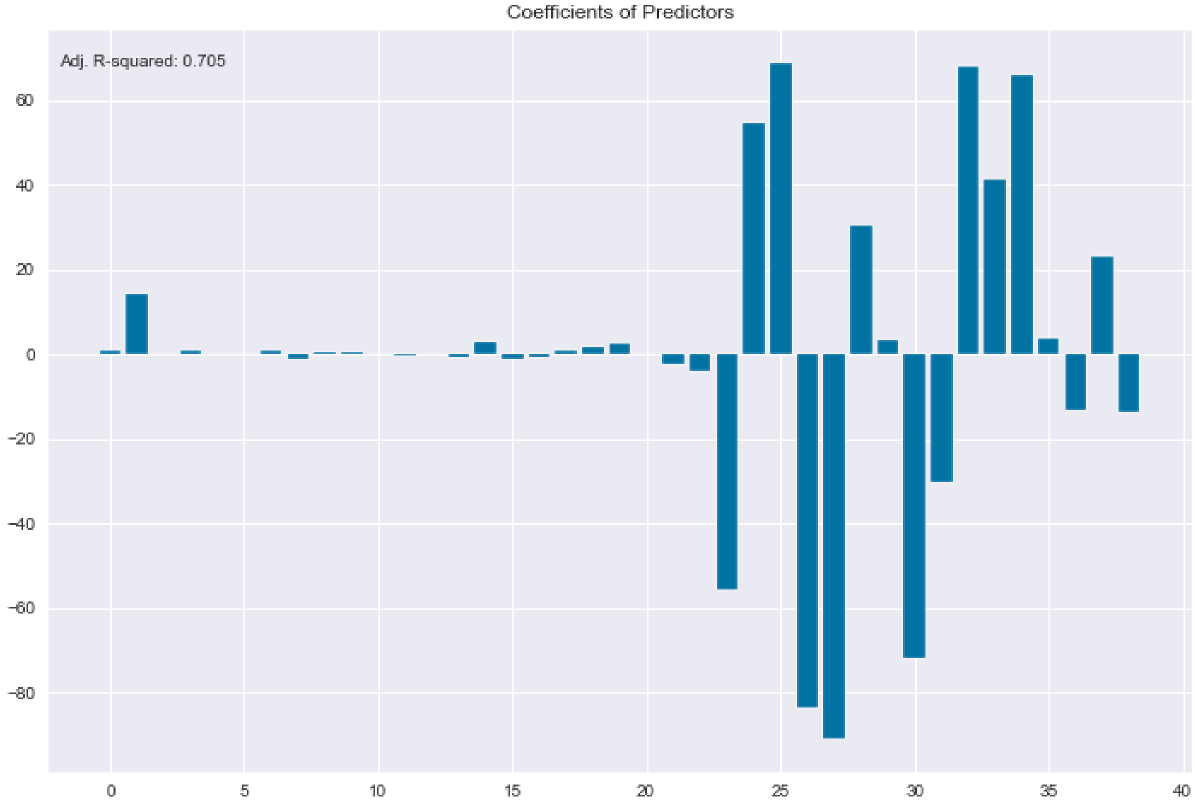


Figure 68. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.3 Chillers 3&4

Table 9 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chillers 3&4 of UCY pilot site.

Table 9. Linear Model coefficients for energy consumption in the Chillers 3&4

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	1591.96	20	weekday_Saturday_indicator	0.07
1	CoronaFull	4.23	21	weekday_Sunday_indicator	-3.12
2	CoronaRestrictions	21.62	22	holiday_indicator	-4.99
3	RH	0.00	23	month_of_year_January	-4393.58
4	Tamb	0.79	24	month_of_year_February	-3579.50
5	GHI	0.00	25	month_of_year_March	-2830.85
6	Gpoa	0.01	26	month_of_year_April	-2015.92
7	HDM	0.92	27	month_of_year_May	-1193.53
8	CDM	-2.08	28	month_of_year_June	-371.78
9	day_of_moth	26.23	29	month_of_year_July	406.70
10	hour_of_day	0.72	30	month_of_year_August	1207.67
11	minute_of_day	0.00	31	month_of_year_September	2015.03
12	day_of_year	-26.19	32	month_of_year_October	2804.05
13	week_of_year	0.08	33	month_of_year_November	3587.77
14	weekday_indicator	3.05	34	month_of_year_December	4363.94
15	weekday_Monday_indicator	-1.54	35	season_winter_indicator	-1.61
16	weekday_Tuesday_indicator	-0.44	36	season_spring_indicator	-5.04

17	weekday_Wednesday_indicator	-0.40	37	season_summer_indicator	15.82
18	weekday_Thursday_indicator	1.71	38	season_autumn_indicator	-9.17
19	weekday_Friday_indicator	2.93			

Figure 69 graphically illustrates the information presented in Table 9. Linear Model coefficients for energy consumption in the Chillers 3&4. The value of 0.583 for the adjusted R^2 metric indicates that the multivariate linear regression model can moderately explain the variance of energy demand in the Chillers 3&4 of the UCY pilot site. The use of control buildings for validation purposes must accompany the validation of results during pilot deployment activities.

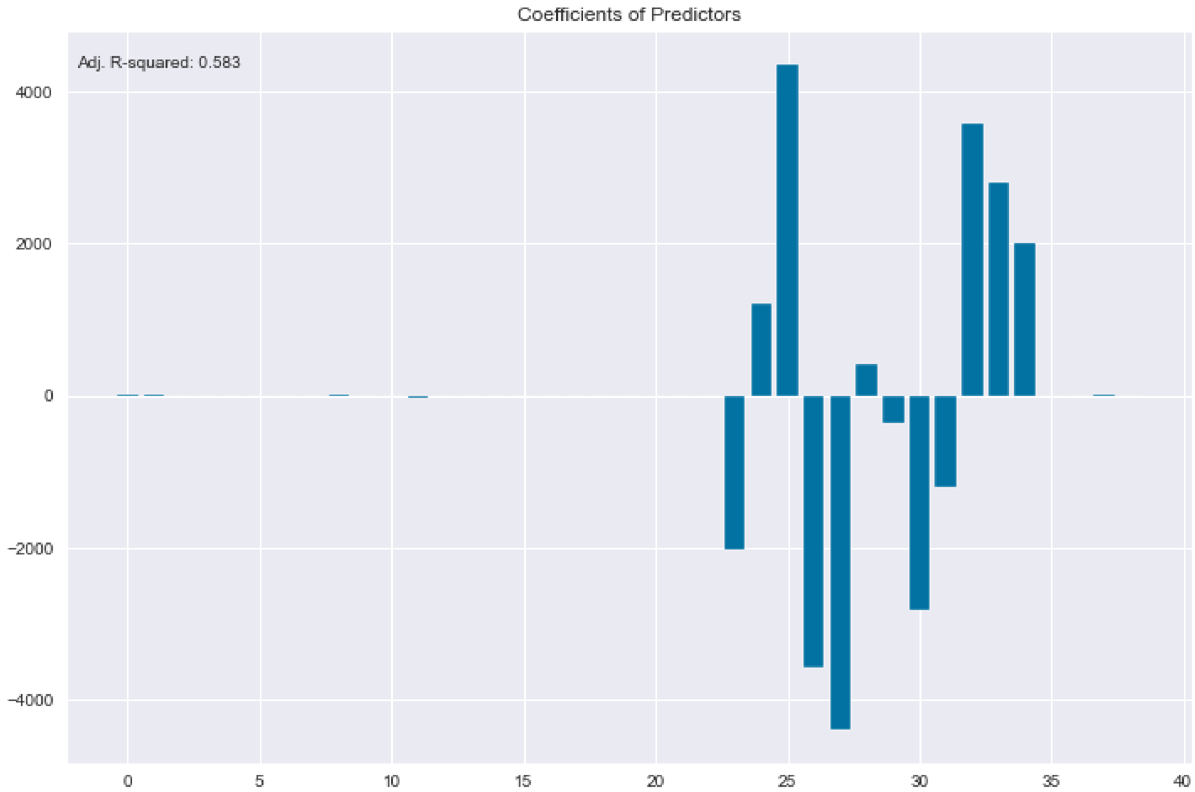


Figure 69. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.4 Chillers 5&6

Table 10 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chillers 5&6 of UCY pilot site.

Table 10. Linear Model coefficients for energy consumption in the Chillers 5&6

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-1721.08	20	weekday_Saturday_indicator	-0.50
1	CoronaFull	-8.52	21	weekday_Sunday_indicator	-3.00
2	CoronaRestrictions	-33.34	22	holiday_indicator	-7.94
3	RH	0.11	23	month_of_year_January	4699.30
4	Tamb	1.93	24	month_of_year_February	3827.78
5	GHI	0.01	25	month_of_year_March	3025.80
6	Gpoa	-0.02	26	month_of_year_April	2152.37
7	HDM	1.48	27	month_of_year_May	1333.17
8	CDM	-3.20	28	month_of_year_June	466.53

9	day_of_moth	-28.12	29	month_of_year_July	-371.98
10	hour_of_day	0.34	30	month_of_year_August	-1273.03
11	minute_of_day	0.00	31	month_of_year_September	-2155.25
12	day_of_year	28.35	32	month_of_year_October	-3011.09
13	week_of_year	0.21	33	month_of_year_November	-3916.14
14	weekday_indicator	3.50	34	month_of_year_December	-4777.46
15	weekday_Monday_indicator	-1.84	35	season_winter_indicator	-4.73
16	weekday_Tuesday_indicator	-0.46	36	season_spring_indicator	-3.05
17	weekday_Wednesday_indicator	0.86	37	season_summer_indicator	11.47
18	weekday_Thursday_indicator	1.97	38	season_autumn_indicator	-3.70
19	weekday_Friday_indicator	2.97			

Figure 70 graphically illustrates the information presented in Table 10. Linear Model coefficients for energy consumption in the Chillers 5&6Table 8. The value of 0.443 for the adjusted R^2 metric indicates that the multivariate linear regression model can moderately explain the variance of energy demand in the Chillers 5&6 of the UCY pilot site. The use of control buildings for validation purposes must accompany the validation of results during pilot deployment activities.

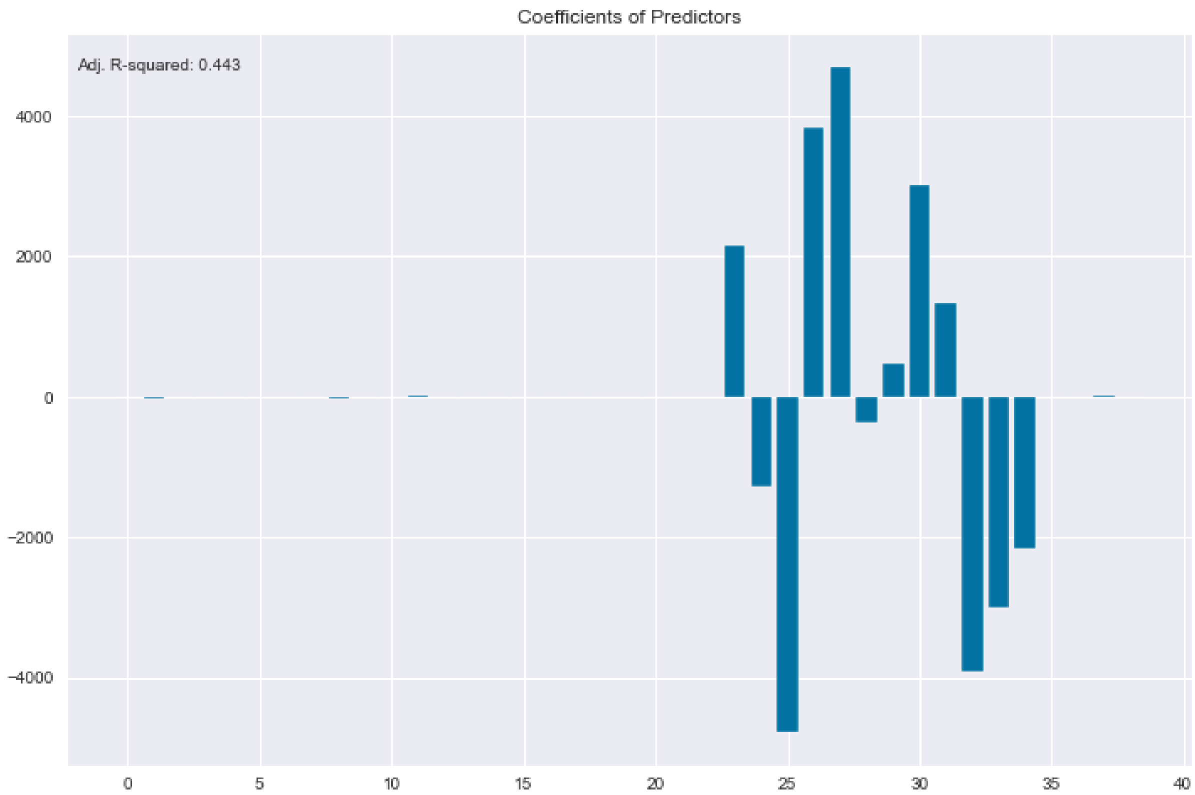


Figure 70. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.5 Chillers 7&8

Table 11 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chillers 7&8 of UCY pilot site.

Table 11. Linear Model coefficients for energy consumption in the Chillers 7&8

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-1242.52	20	weekday_Saturday_indicator	-1.27

1	CoronaFull	-7.90	21	weekday_Sunday_indicator	2.22
2	CoronaRestrictions	-43.06	22	holiday_indicator	-3.86
3	RH	0.07	23	month_of_year_January	3412.83
4	Tamb	0.19	24	month_of_year_February	2783.08
5	GHI	0.00	25	month_of_year_March	2192.13
6	Gpoa	0.00	26	month_of_year_April	1562.04
7	HDM	1.66	27	month_of_year_May	956.21
8	CDM	-0.84	28	month_of_year_June	330.67
9	day_of_moth	-20.26	29	month_of_year_July	-262.47
10	hour_of_day	0.11	30	month_of_year_August	-933.10
11	minute_of_day	0.00	31	month_of_year_September	-1573.35
12	day_of_year	20.53	32	month_of_year_October	-2190.58
13	week_of_year	0.23	33	month_of_year_November	-2831.35
14	weekday_indicator	-0.95	34	month_of_year_December	-3446.10
15	weekday_Monday_indicator	2.68	35	season_winter_indicator	4.09
16	weekday_Tuesday_indicator	-0.87	36	season_spring_indicator	5.86
17	weekday_Wednesday_indicator	-2.77	37	season_summer_indicator	-3.31
18	weekday_Thursday_indicator	0.72	38	season_autumn_indicator	-6.64
19	weekday_Friday_indicator	-0.70			

Figure 71 graphically illustrates the information presented in Table 11. Linear Model coefficients for energy consumption in the Chillers 7&8. The value of 0.223 for the adjusted R^2 metric indicates that the multivariate linear regression model can poorly explain the variance of energy demand in the Chillers 7&8 of the UCY pilot site. The use of control buildings for validation purposes must accompany the validation of results during pilot deployment activities.

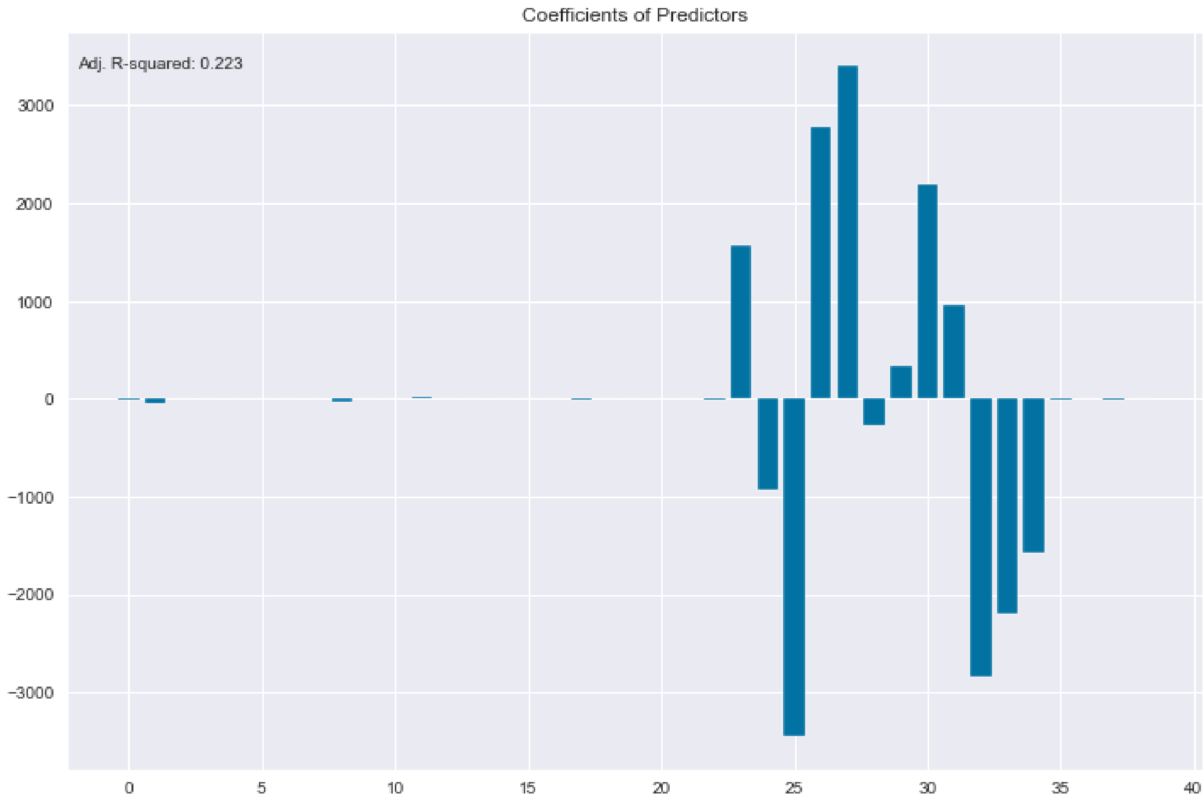


Figure 71. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.6 Finance Economics & Business

Table 12 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Finance Economics & Business building of UCY pilot site.

Table 12. Linear Model coefficients for energy consumption in the Finance Economics & Business building

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	252.56	20	weekday_Friday_indicator	0.52
1	FEBOccupancy	-0.961	21	weekday_Saturday_indicator	-1.26
2	CoronaFull	-4.72	22	weekday_Sunday_indicator	0.40
3	CoronaRestrictions	2.55	23	holiday_indicator	-2.60
4	RH	0.02	24	month_of_year_January	-640.42
5	Tamb	-0.88	25	month_of_year_February	-521.39
6	GHI	0.01	26	month_of_year_March	-416.80
7	Gpoa	0.00	27	month_of_year_April	-299.37
8	HDM	-1.35	28	month_of_year_May	-182.40
9	CDM	0.82	29	month_of_year_June	-58.86
10	day_of_moth	3.87	30	month_of_year_July	58.52
11	hour_of_day	0.06	31	month_of_year_August	168.64
12	minute_of_day	0.00	32	month_of_year_September	297.58
13	day_of_year	-3.85	33	month_of_year_October	415.09
14	week_of_year	0.06	34	month_of_year_November	532.47
15	weekday_indicator	0.86	35	month_of_year_December	646.93
16	weekday_Monday_indicator	-0.69	36	season_winter_indicator	2.07
17	weekday_Tuesday_indicator	0.95	37	season_spring_indicator	-1.21
18	weekday_Wednesday_indicator	0.25	38	season_summer_indicator	0.44
19	weekday_Thursday_indicator	-0.16	39	season_autumn_indicator	-1.30

Figure 72 graphically illustrates the information presented in Table 12. The value of 0.153 for the adjusted R^2 metric indicates that the multivariate linear regression model can adequately explain the variance of energy demand in the Finance Economics & Business building of the UCY pilot site. The use of control buildings for validation purposes must accompany the validation of results during pilot deployment activities.

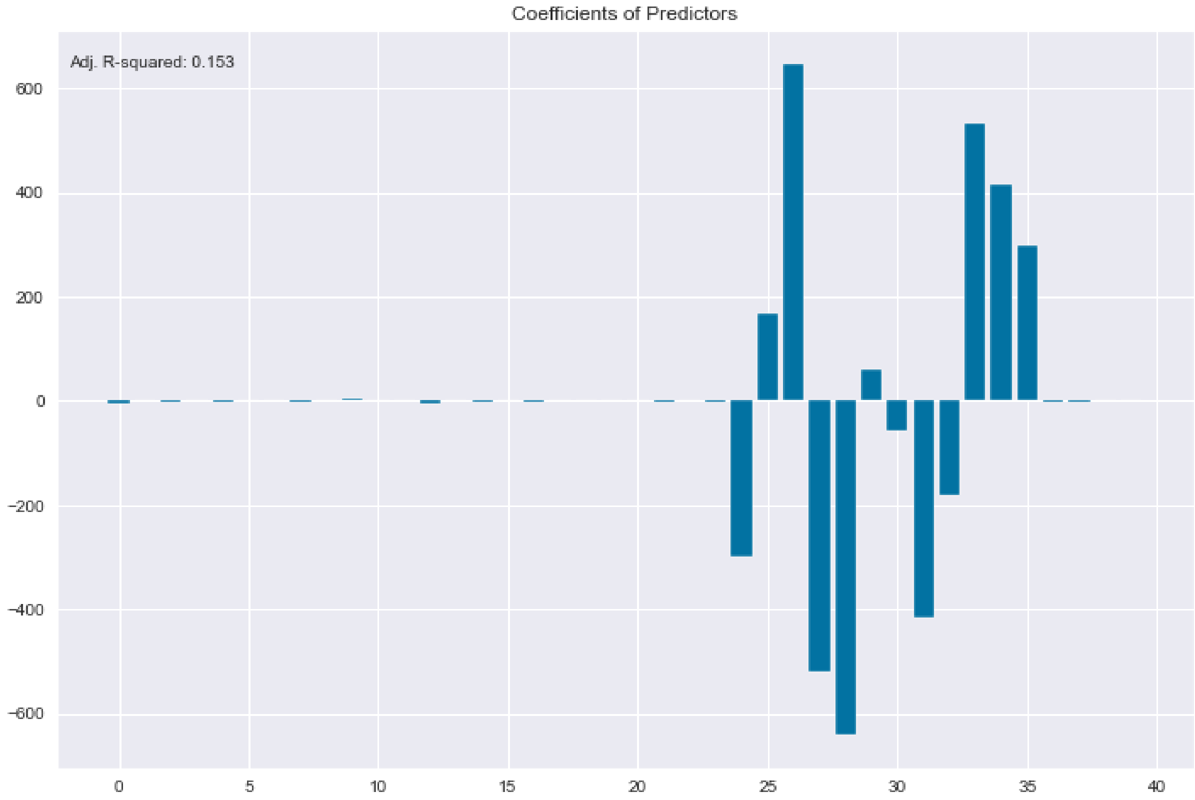


Figure 72. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.7 Library 1

Table 13presents the linear model coefficients for the multivariate linear regression models for the energy demand in the Library 1 of UCY pilot site.

Table 13. Linear Model coefficients for energy consumption in Library 1

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-14410.00	20	weekday_Friday_indicator	6.66
1	Library1Occupancy	108.61	21	weekday_Saturday_indicator	-1.95
2	CoronaFull	-88.94	22	weekday_Sunday_indicator	-5.31
3	CoronaRestrictions	-102.47	23	holiday_indicator	-24.42
4	RH	-0.30	24	month_of_year_January	39763.43
5	Tamb	0.71	25	month_of_year_February	32424.95
6	GHI	0.03	26	month_of_year_March	25616.53
7	Gpoa	0.00	27	month_of_year_April	18209.83
8	HDM	3.47	28	month_of_year_May	11042.53
9	CDM	-2.26	29	month_of_year_June	3680.65
10	day_of_moth	-237.71	30	month_of_year_July	-3456.72
11	hour_of_day	-0.23	31	month_of_year_August	-10854.11
12	minute_of_day	0.02	32	month_of_year_September	-18252.52
13	day_of_year	238.41	33	month_of_year_October	-25408.30
14	week_of_year	0.78	34	month_of_year_November	-32805.85
15	weekday_indicator	7.26	35	month_of_year_December	-39960.51
16	weekday_Monday_indicator	-4.39	36	season_winter_indicator	-4.61
17	weekday_Tuesday_indicator	0.13	37	season_spring_indicator	10.82

18	weekday_Wednesday_indicator	1.74	38	season_summer_indicator	0.96
19	weekday_Thursday_indicator	3.12	39	season_autumn_indicator	-4.61

Figure 73 graphically illustrates the information presented in Table 13. The value of 0.446 for the adjusted R^2 metric indicates that the multivariate linear regression model can moderately explain the variance of energy demand in the Library 1 of the UCY pilot site. The use of control buildings for validation purposes must accompany the validation of results during pilot deployment activities.

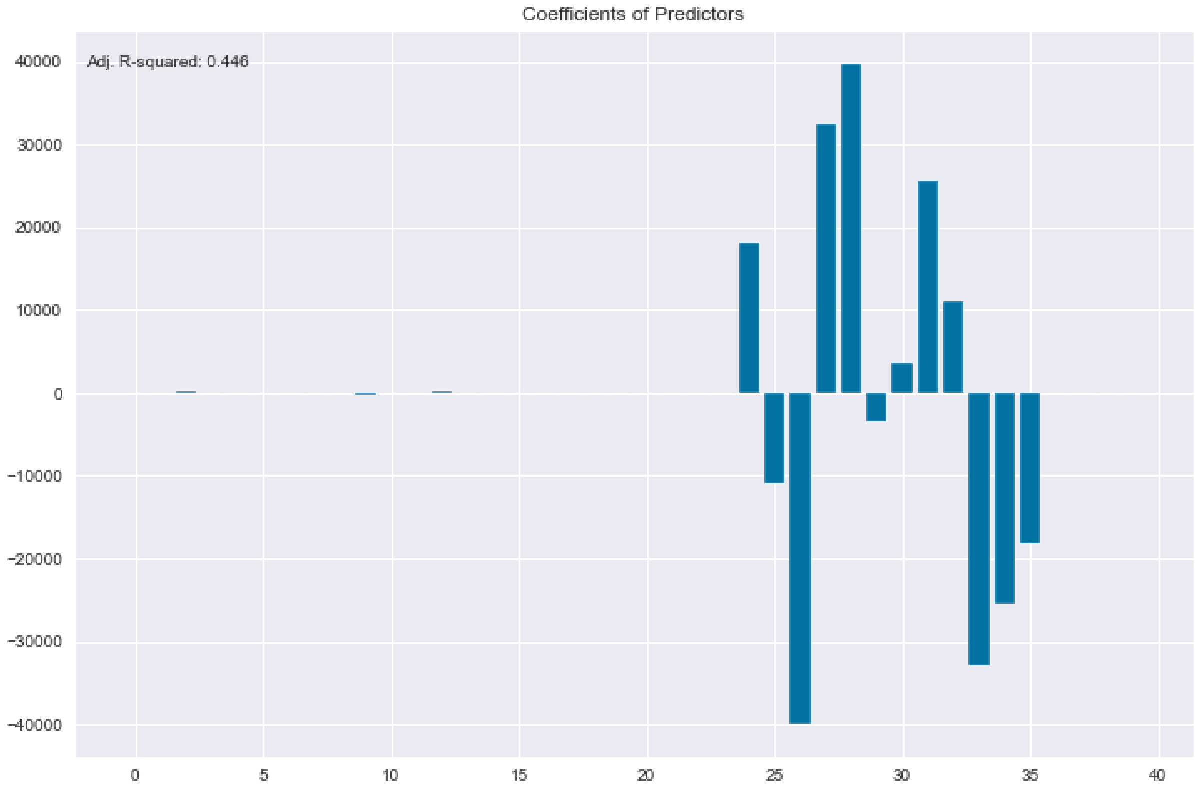


Figure 73. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.8 Library 2

Table 14 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Library 2 of UCY pilot site.

Table 14. Linear Model coefficients for energy consumption in Library 2

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-16540.00	20	weekday_Friday_indicator	7.37
1	Library2Occupancy	147.46	21	weekday_Saturday_indicator	-1.40
2	CoronaFull	-21.56	22	weekday_Sunday_indicator	-7.16
3	CoronaRestrictions	23.36	23	holiday_indicator	-18.5
4	RH	-0.18	24	month_of_year_January	45744.04
5	Tamb	-2.77	25	month_of_year_February	37245.74
6	GHI	0.05	26	month_of_year_March	29429.61
7	Gpoa	0.00	27	month_of_year_April	20914.44
8	HDM	1.80	28	month_of_year_May	12692.54
9	CDM	0.56	29	month_of_year_June	4209.06
10	day_of_moth	-273.81	30	month_of_year_July	-4005.18
11	hour_of_day	0.95	31	month_of_year_August	-12522.07
12	minute_of_day	-0.01	32	month_of_year_September	-21044.18

13	day_of_year	274.22	33	month_of_year_October	-29243.80
14	week_of_year	1.12	34	month_of_year_November	-37589.99
15	weekday_indicator	8.55	35	month_of_year_December	-45830.20
16	weekday_Monday_indicator	-5.71	36	season_winter_indicator	-31.27
17	weekday_Tuesday_indicator	0.16	37	season_spring_indicator	-3.02
18	weekday_Wednesday_indicator	1.96	38	season_summer_indicator	8.40
19	weekday_Thursday_indicator	4.76	39	season_autumn_indicator	25.89

Figure 74 graphically illustrates the information presented in Table 14. The value of 0.637 for the adjusted R^2 metric indicates that the multivariate linear regression model can moderately explain the variance of energy demand in the Library 2 of the UCY pilot site. The use of control buildings for validation purposes must accompany the validation of results during pilot deployment activities.

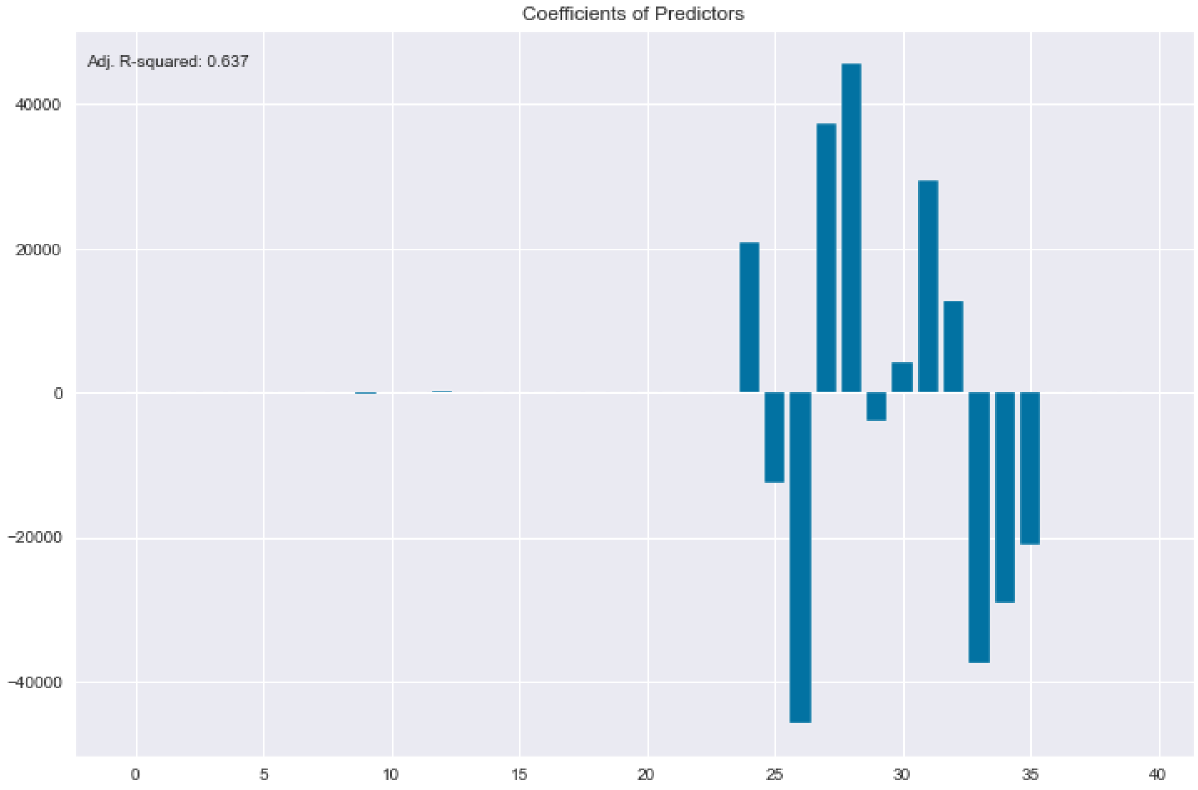


Figure 74. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

2.3.9 Students Residence Building A

Table 15 presents the linear model coefficients for the multivariate linear regression models for the energy demand in the Students Residence A building of UCY pilot site.

Table 15. Linear Model coefficients for energy consumption in Students Residence Building A

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	133.59	20	weekday_Friday_indicator	-0.18
1	StudentsResidenceOccupancy	2.86	21	weekday_Saturday_indicator	-0.11
2	CoronaFull	-0.49	22	weekday_Sunday_indicator	0.08
3	CoronaRestrictions	-0.71	23	holiday_indicator	0.11
4	RH	-0.01	24	month_of_year_January	-446.50
5	Tamb	0.17	25	month_of_year_February	-362.96

6	GHI	0.00	26	month_of_year_March	-287.82
7	Gpoa	0.00	27	month_of_year_April	-206.03
8	HDM	0.30	28	month_of_year_May	-125.96
9	CDM	-0.10	29	month_of_year_June	-43.62
10	day_of_moth	2.68	30	month_of_year_July	37.80
11	hour_of_day	0.07	31	month_of_year_August	118.65
12	minute_of_day	0.00	32	month_of_year_September	208.92
13	day_of_year	-2.68	33	month_of_year_October	287.44
14	week_of_year	0.00	34	month_of_year_November	369.33
15	weekday_indicator	0.03	35	month_of_year_December	450.74
16	weekday_Monday_indicator	-0.06	36	season_winter_indicator	1.16
17	weekday_Tuesday_indicator	-0.08	37	season_spring_indicator	0.42
18	weekday_Wednesday_indicator	0.23	38	season_summer_indicator	0.23
19	weekday_Thursday_indicator	0.12	39	season_autumn_indicator	-1.82

Figure 68 graphically illustrates the information presented in Table 8. The value of 0.074 for the adjusted R^2 metric indicates that the multivariate linear regression model can poorly explain the variance of energy demand in the Students Residence building A of the UCY pilot site. The use of control buildings for validation purposes must accompany the validation of results during pilot deployment activities.

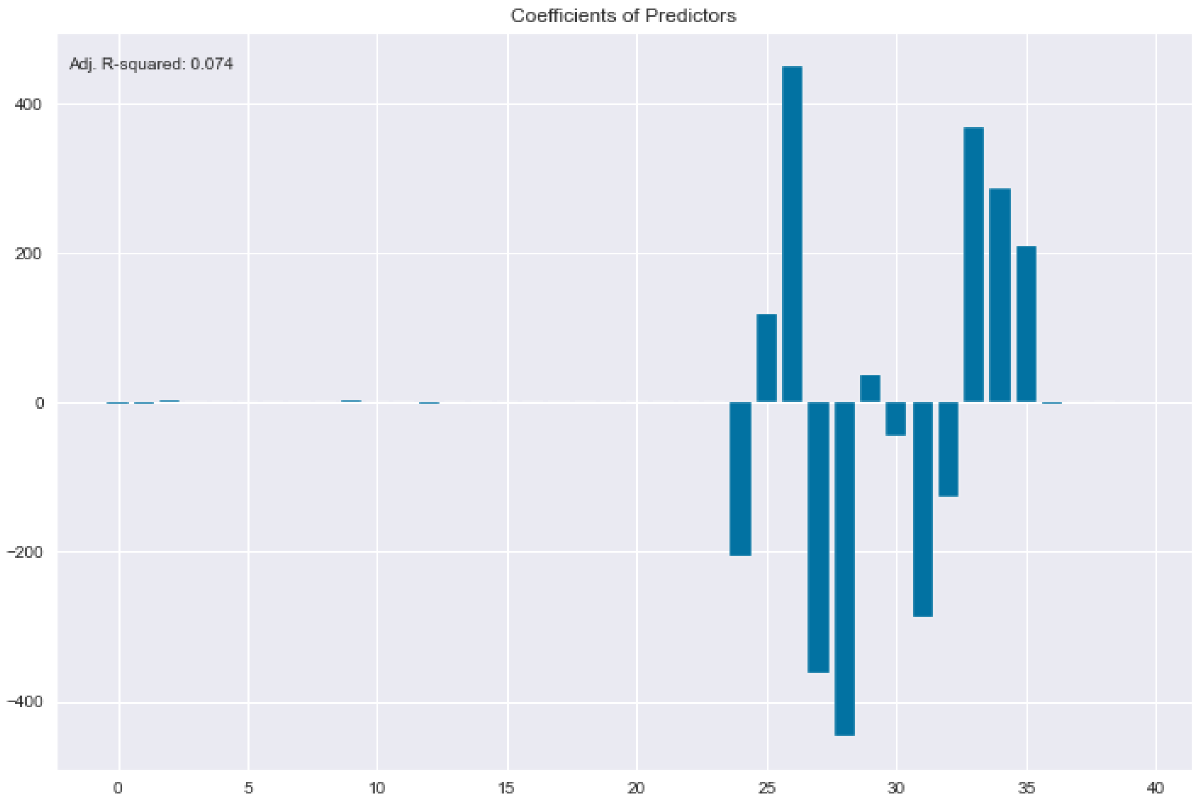


Figure 75. Graphical illustration of linear model coefficients for energy demand in the Administration building at UCY pilot site

3. Kiwi Pilot Site

In this section, an analysis of the environmental conditions along with EDA and energy baseline determination on the dataset provided by Kiwi was performed. The goal was to investigate the effect of the variation of the chosen environmental variables to energy demand at the Kiwi pilot site. All the data were provided by the pilot site operator, i.e. Kiwi personnel.

A number of features were engineering for the needs of the EDA in order to investigate how temporal variables, special days during the year, i.e. holidays and special conditions e.g. Corona emergency period affect the energy demand at the Kiwi pilot site. Analysis performed, results and graphs obtained are presented below.

An ABT, i.e. a table containing only numeric and indicator variables was constructed in order to be used as input for the needs of the modelling work performed for determining energy baselines for the facilities involved in the DELTA pilot deployment.

Historical data spanning between 01/01/2019 and 31/07/2020, with a granularity of 30 minutes, were used as input for the work performed. Figure 76 presents an overview of the assets present at the London Moor House at Kiwi pilot site.

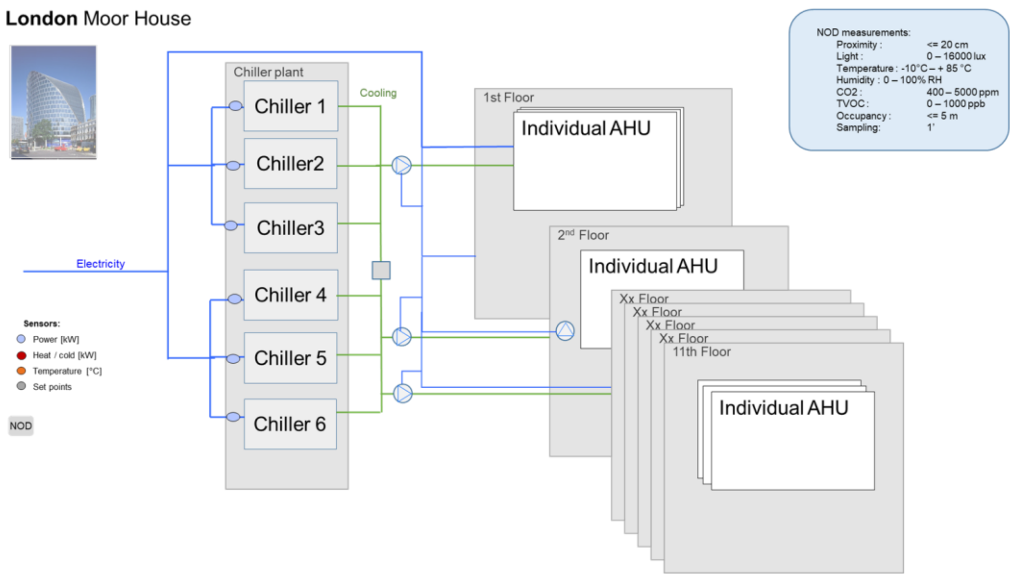


Figure 76. London Moor House assets at Kiwi pilot site

3.1 Environmental Conditions

Table 16 presents the environmental conditions variables that were taken into account in the analysis performed for the Kiwi pilot site for the period under consideration.

Table 16. Environmental conditions variables at Kiwi pilot site

Variable	Unit
Ambient temperature	ºC
Relative humidity	%
Atmospheric pressure	hPa
Wind speed	m/s
Wind speed direction	Degrees
Cloud coverage	%
HDH	-

CDH	-

Equation

(1) and (2) were used for the calculations that were performed for determining the profiles of HDH and CDH for each hour of the day. Where Tm is the mean hourly temperature observed at Kiwi pilot site. Figure 77 presents the HDH and CDH, Figure 78 presents the ambient temperature and RH profiles, Figure 3 presents the ambient wind speed and wind speed direction, and Figure 4 presents the atmospheric pressure and cloud coverage profiles at Kiwi pilot site. Figure 81 presents the weather type distribution at Kiwi pilot site. For almost half of the time period considered in this analysis the environment was cloudy. Around 40% of time the environment was clear and around 10% was rainy. Less frequent weather conditions along with their distribution, observed for around 2% of the considered time, are presented in Figure 82. Figure 83 presents the distribution plots and Figure 85 the box plots of the environmental conditions at Kiwi pilot site. In Figure 84 CDH appear to all as outliers due to the fact that most of time this variable is equal to zero.

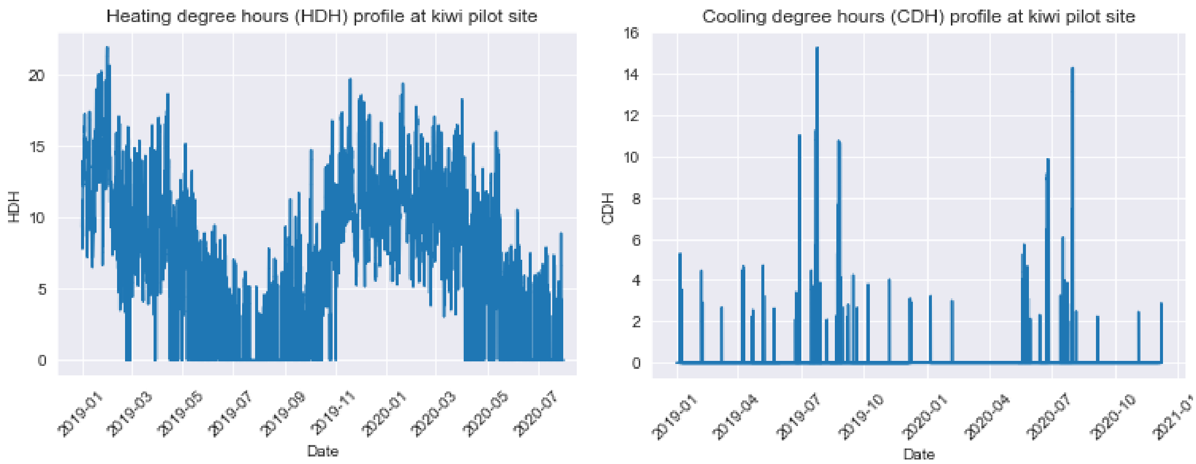


Figure 77. HDH and CDH profiles at Kiwi pilot site

Figure 78. Ambient temperature and RH profiles at Kiwi pilot site

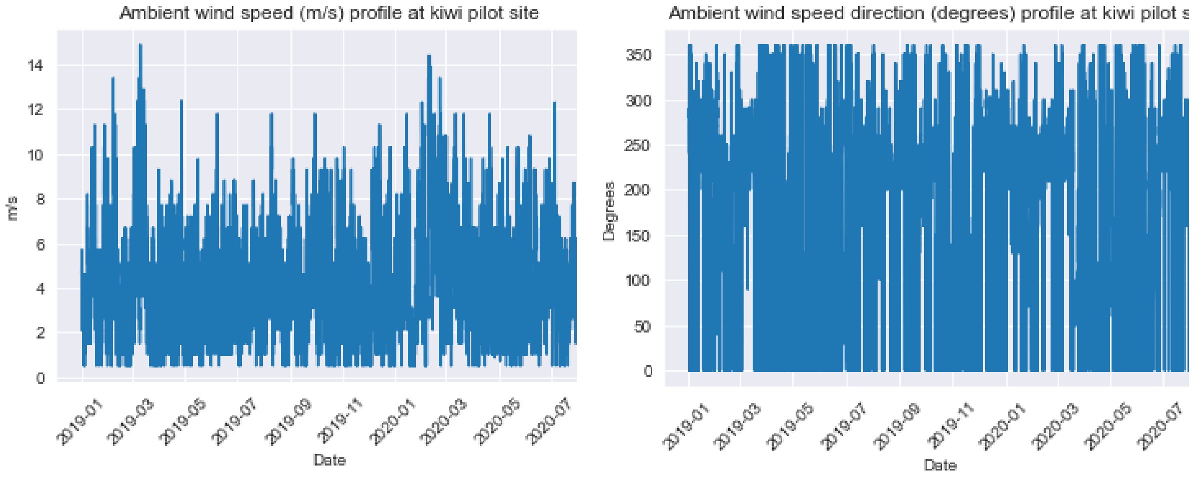


Figure 79. Ambient wind speed (m/s) and wind speed direction (degrees) profiles at Kiwi pilot site

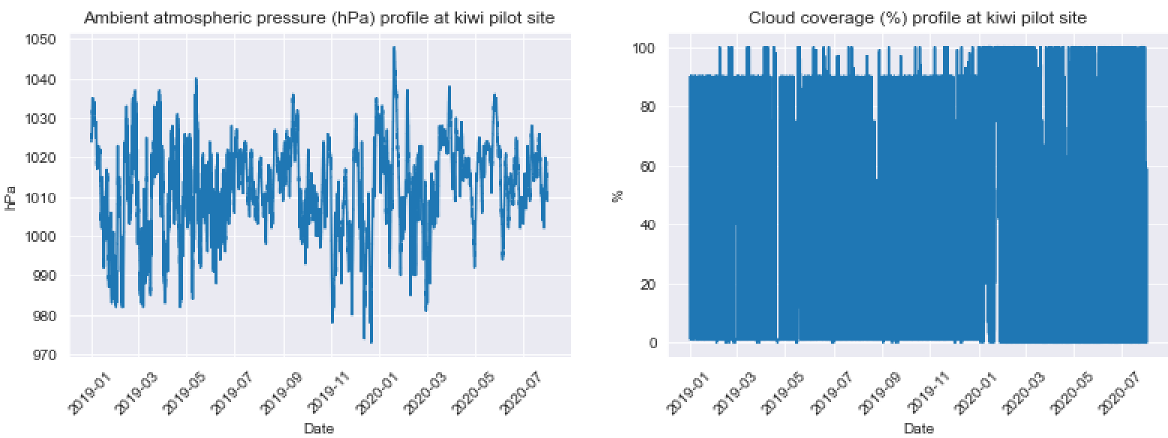


Figure 80. Ambient atmospheric pressure (hPa) and cloud coverage (%) profiles at Kiwi pilot site

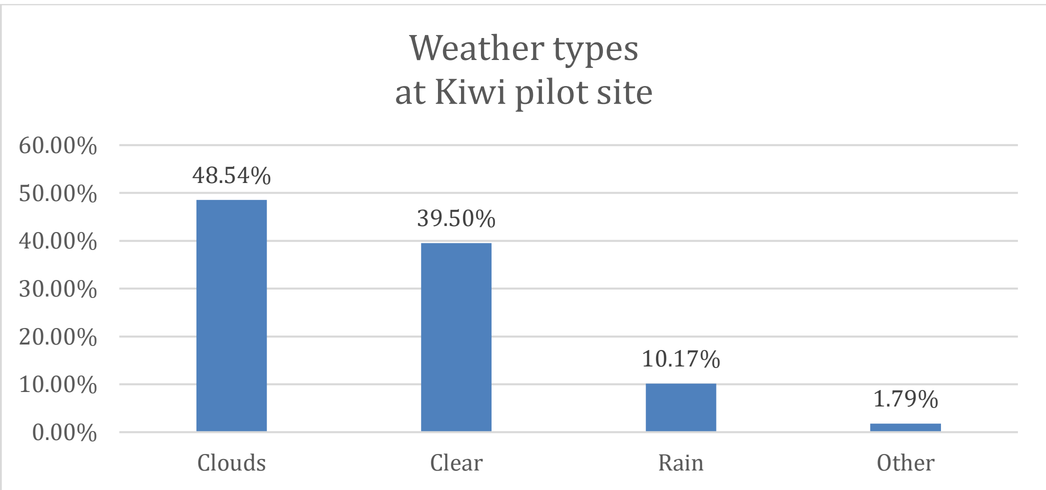


Figure 81. Weather types distribution at Kiwi pilot site for the considered period

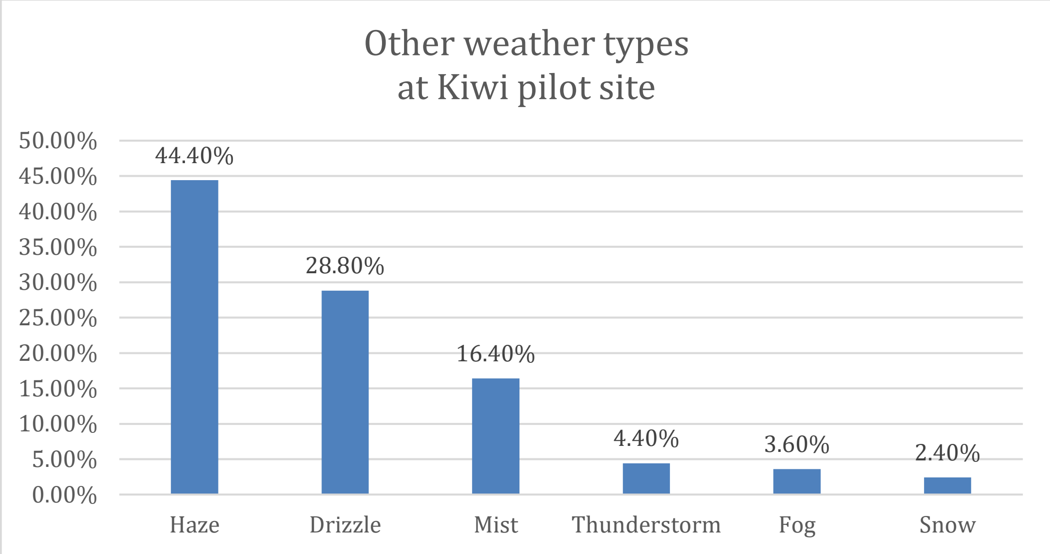
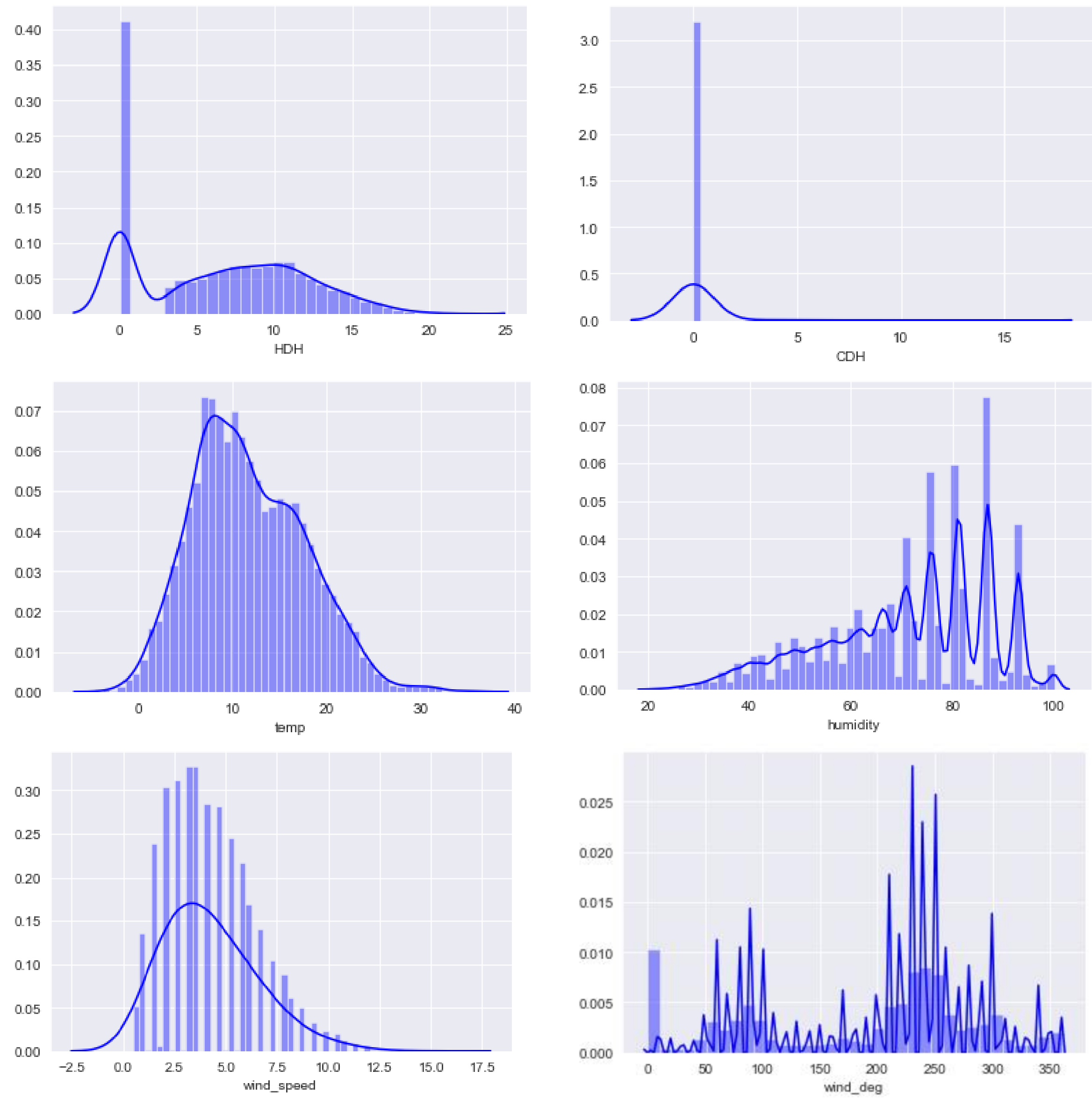


Figure 82. Other weather types distribution at Kiwi pilot site.



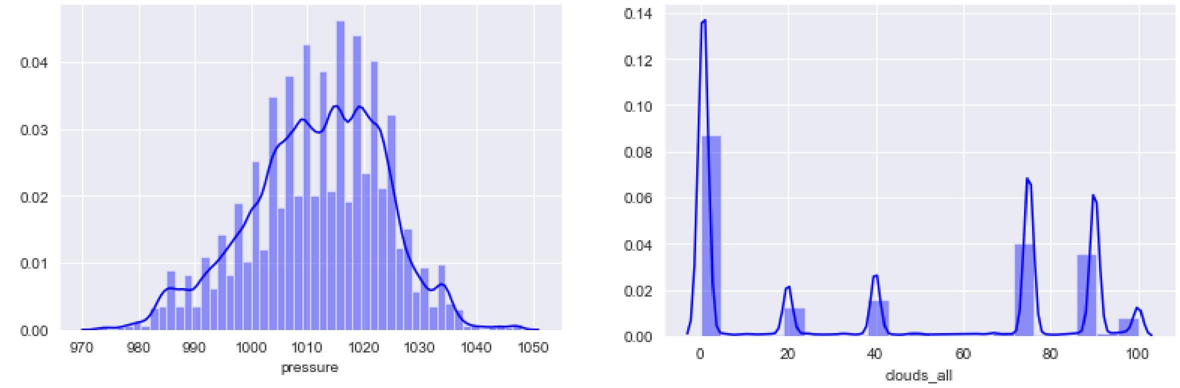
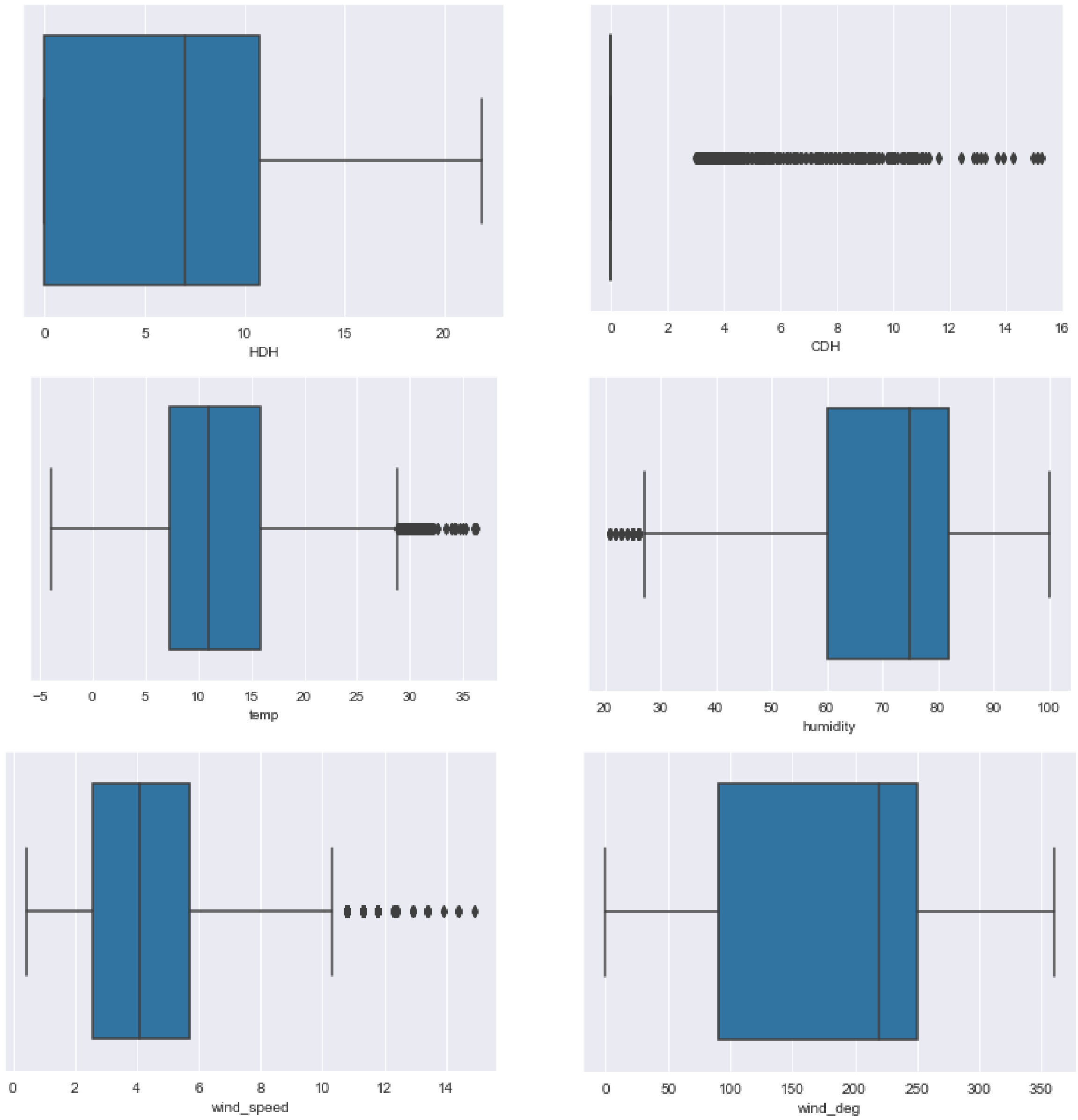


Figure 83. Distribution plots of environment conditions at Kiwi pilot site



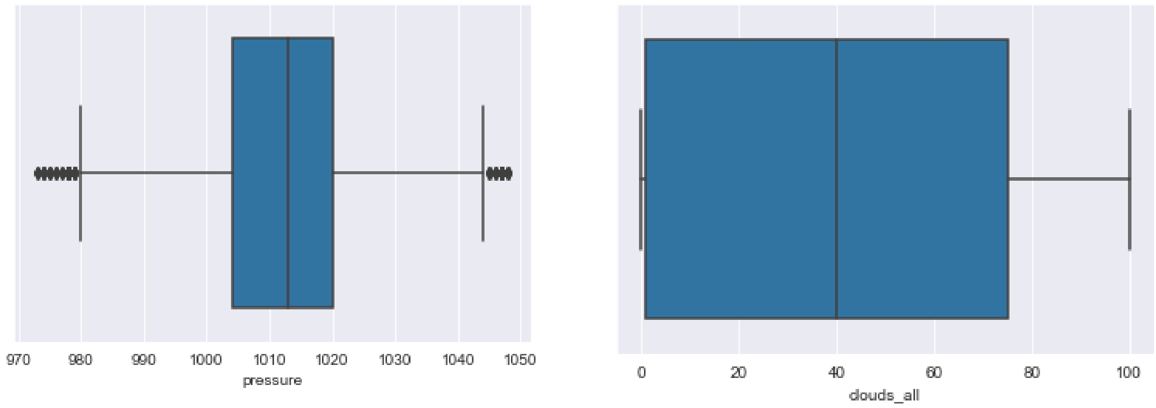
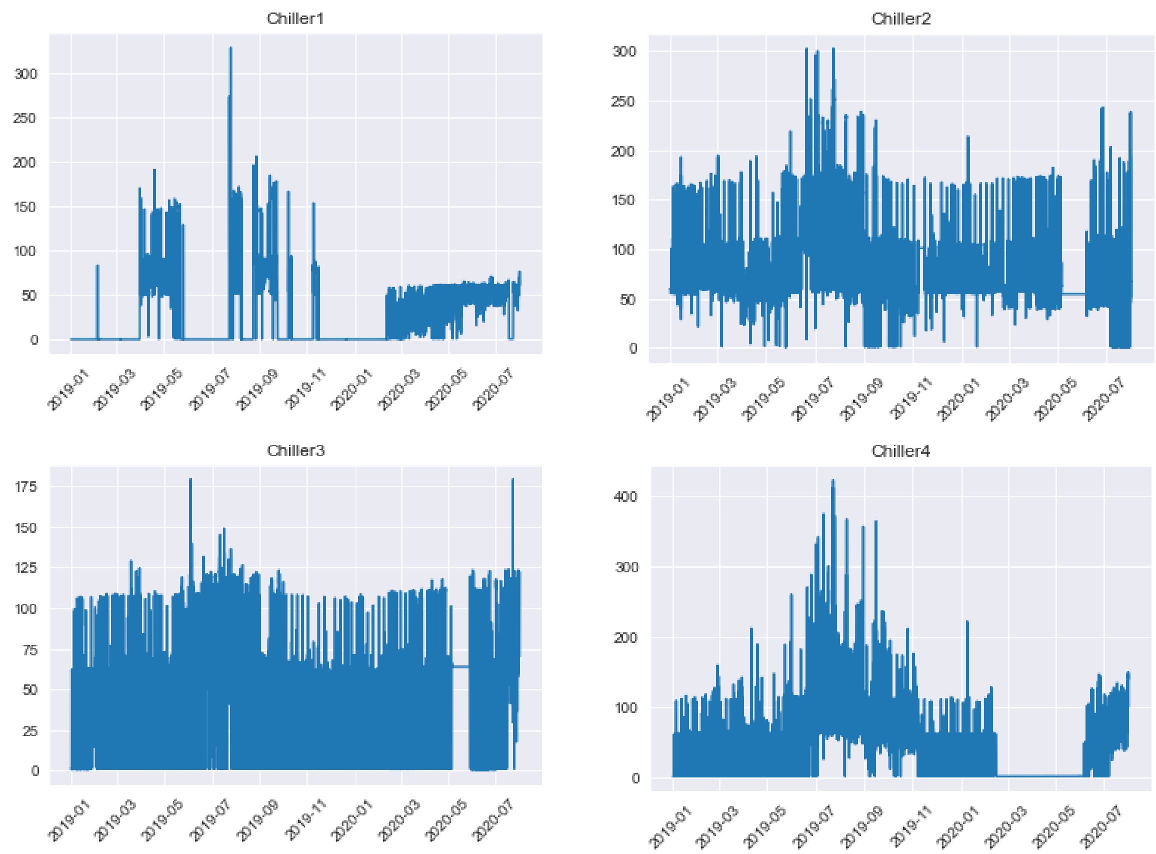


Figure 84. Box plots of the environment conditions at Kiwi pilot site

3.2 Exploratory Data Analysis

For the needs of the EDA on the dataset, first, historical energy demand patterns, for the considered period and for the considered loads, were extracted. In this way, the analyst can instantly inspect the energy demand patterns of the considered loads, i.e. Chillers and Apartments at Kiwi pilot site. Next, a number of plots including box plots, violin plots, line plots, plots of categorical variables were generated in order to investigate how the features that were chosen to act as predictors of energy demand affect the historical energy demand. Finally, a correlation heat map was generated in order to provide an overview of how strong (positively or negatively) the chosen predictors affect energy demand in the Kiwi pilot site. Figure 85 illustrates historical energy demand profiles of Chillers at the London Moore House in the Kiwi pilot site. A quick overview of different energy demand patterns can be obtained.



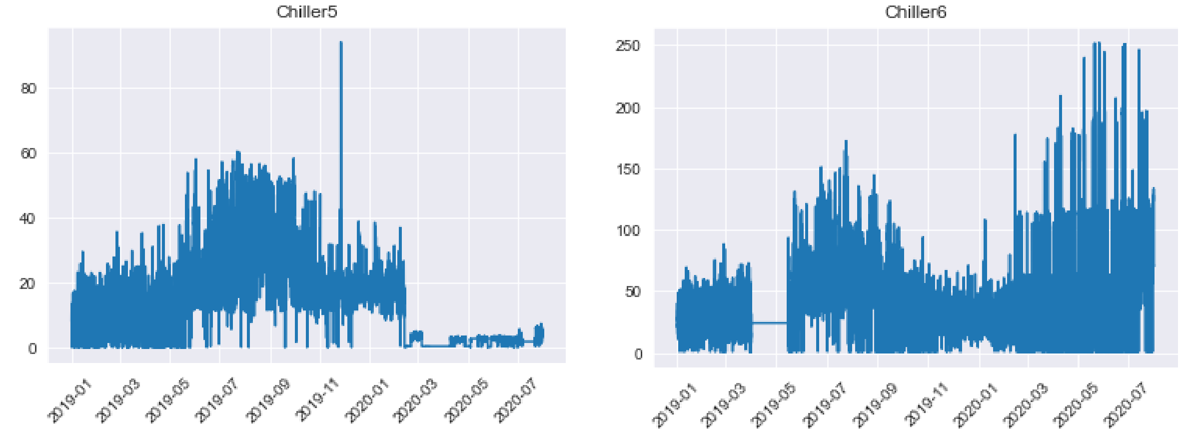


Figure 85. Historical energy demand profiles of Chillers at Kiwi pilot site

Table 17 presents the aggregated energy consumption and costs for the London Moor house for the considered period. For the calculation of energy costs an average value of 0.21 euros per kWh was considered [7].

Table 17. Aggregated energy consumption & costs at Kiwi pilot sites, for the period of analysis

Load/Building	Aggregated energy consumption (kWh)	Aggregated CO2 emissions (tonnes)	Aggregated energy costs (€)
Chiller 1	806,677	228.35	169,402.17€
Chiller 2	2,135,775	604.58	448,512.75€
Chiller 3	1,190,464	336.98	249,997.44€
Chiller 4	1,202,091	340.28	252,439.11€
Chiller 5	389,498	110.26	81,794.58€
Chiller 6	1,206,665	341.57	253,399.65€
Apartment	8,931	2.53	1,875.51€

Table 18 presents the public holidays in England, falling within the analysis period, for the years 2019 and 2020. The dates are encoded into indicator variables, i.e. 1: holiday, 0: non-holiday. In this way, the analyst may get meaningful insights regarding the effect that the holidays have on energy demand compared to non-holidays.

Table 18. Public Holidays in England for 2019 and 2020

Public Holidays 2019	
1st of January	New Year's Day
19th of April	Good Friday
22nd of April	Easter Monday
6th of May	Early May bank holiday
27th of May	Spring bank holiday
26th of August	Summer bank holiday
25th of December	Christmas Day
26th of December	Boxing Day
Public Holidays 2020	
1st of January	New Year's Day
10th of April	Good Friday
13th of April	Easter Monday
8th of May	Early May bank holiday (VE day)
25th of May	Spring bank holiday

Except for the environmental conditions variables that may act as determinants of energy demand, a number of temporal features and other indicator variables was engineering from the Timestamp variable. Table 19 presents the features along with the respective range of values and their description.

Table 19. Features engineered for the EDA and the modelling of energy demand at Kiwi pilot site

Feature	Range of Values	Description
Holiday	0 or 1	Indicator variable for holidays
Corona Emergency	0 or 1	Indicator variable for Corona emergency period
Day Of Month	{1…31}	Discrete value for the day of each month
Day of Week	{Mon, Tues, Wed, Thurs, Frid, Sat, Sun}	Categorical variable for each day of week
Day of Year	{1…365}	Discrete value for each day of year
Month of Year	{Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec}	Categorical variable for month of the year
{Mon, Tues, Wed, Thurs, Frid}	0 or 1	Indicator variables for weekdays
{Sat, Sun}	0 or 1	Indicator variables for weekend days
Season	{Summer, Autumn, Winter, Spring}	Categorical variables for season of year
Hour of day	{1…24}	Discrete value for each hour of the day
Minute of day	0 or 30	Discrete values in line with the granularity of the dataset
Week of year	{1…52}	Discrete variable for the week of year

The Corona emergency period at Kiwi pilot site spans, for the needs of the analysis performed, between 01/02/2020 and 31/07/2020. Figure 86 presents the correlation heat map of energy demand in Chillers at London Moor house at Kiwi pilot site. The fact that strong correlations are observed between energy demands in the Chillers may act as an indication for load grouping for the needs of DR program deployment.

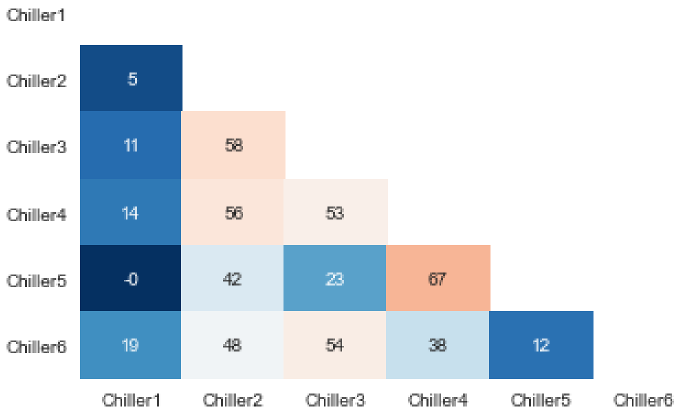


Figure 86. Correlation heat map of energy demand in Chillers at London Moor house at Kiwi pilot site

3.2.1 London Moor House

In this sub-section, an EDA is performed for all of the assets, i.e. Chillers, present at the London Moor House. A number of plots clarifying the energy demand patterns during different days of the week and under different conditions e.g. corona emergency are all provided. A correlation heat map of the continuous variables of the dataset is provided, as well, as a means of investigating possible causal relationships. The added value of such a work lies on the fact a quick overview of different dimensions of energy demand can be obtained. Not all the range of graphs used are presents for all of the Chillers. Only insightful and visually appealing graphs were chosen to be included in the EDA that was performed.

3.2.1.1 Chiller 1

Figure 87 presents the distribution and box plots of energy demand at Chiller 1. A number of outlier values are observed in the box plot. Figure 88 presents the bar plots of energy demand at Chiller 1 during different days and months of the year and under different weather conditions accounting for the season. During spring and summer higher energy demand patters are observed. Similarly, during weekdays, the average energy demand is higher than in weekends. Figure 89 presents the violin plots of energy demand with respect to holiday and weekday indicator variables. Interestingly, the holiday indicator variable seems not to affect the energy demand at Chiller 1. Different patterns of energy demand are observed when accounting for the weekday indicator variable, as well. Figure 90 presents the violin plot of the effect of corona emergency indicator variable to the energy demand at Chiller 1. Interestingly, the impact of the corona emergency on the energy demand at Chiller 1 is significant since the demand during this period is practically zero. Finally, Figure 94 presents the correlation heat map of the continuous variables used in this EDA, along with the energy demand at Chiller 1. Energy demand at Chiller 1 is, moderately, positively correlated with temperature and CDH variables and negatively with HDH.

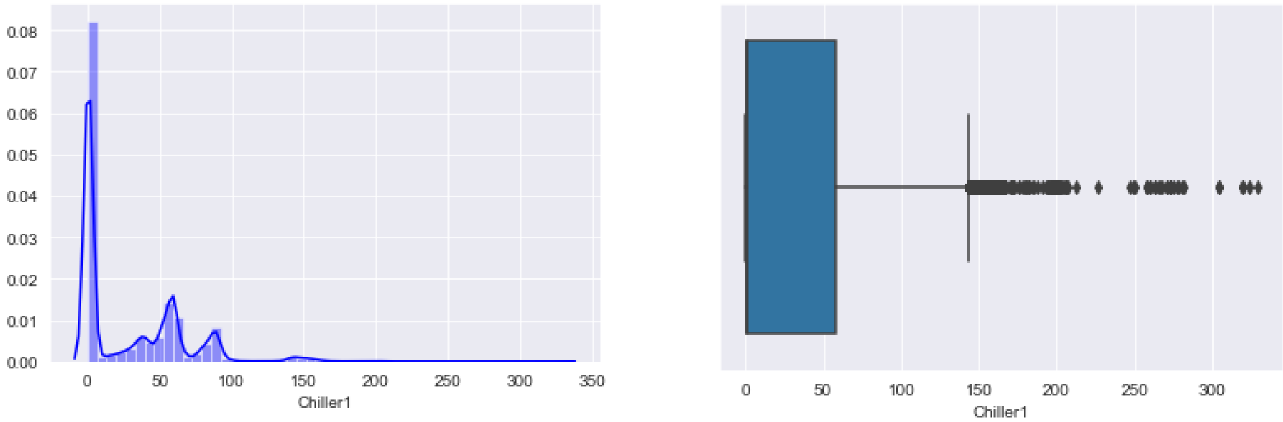


Figure 87. Distribution and box plots of Energy demand of Chiller 1

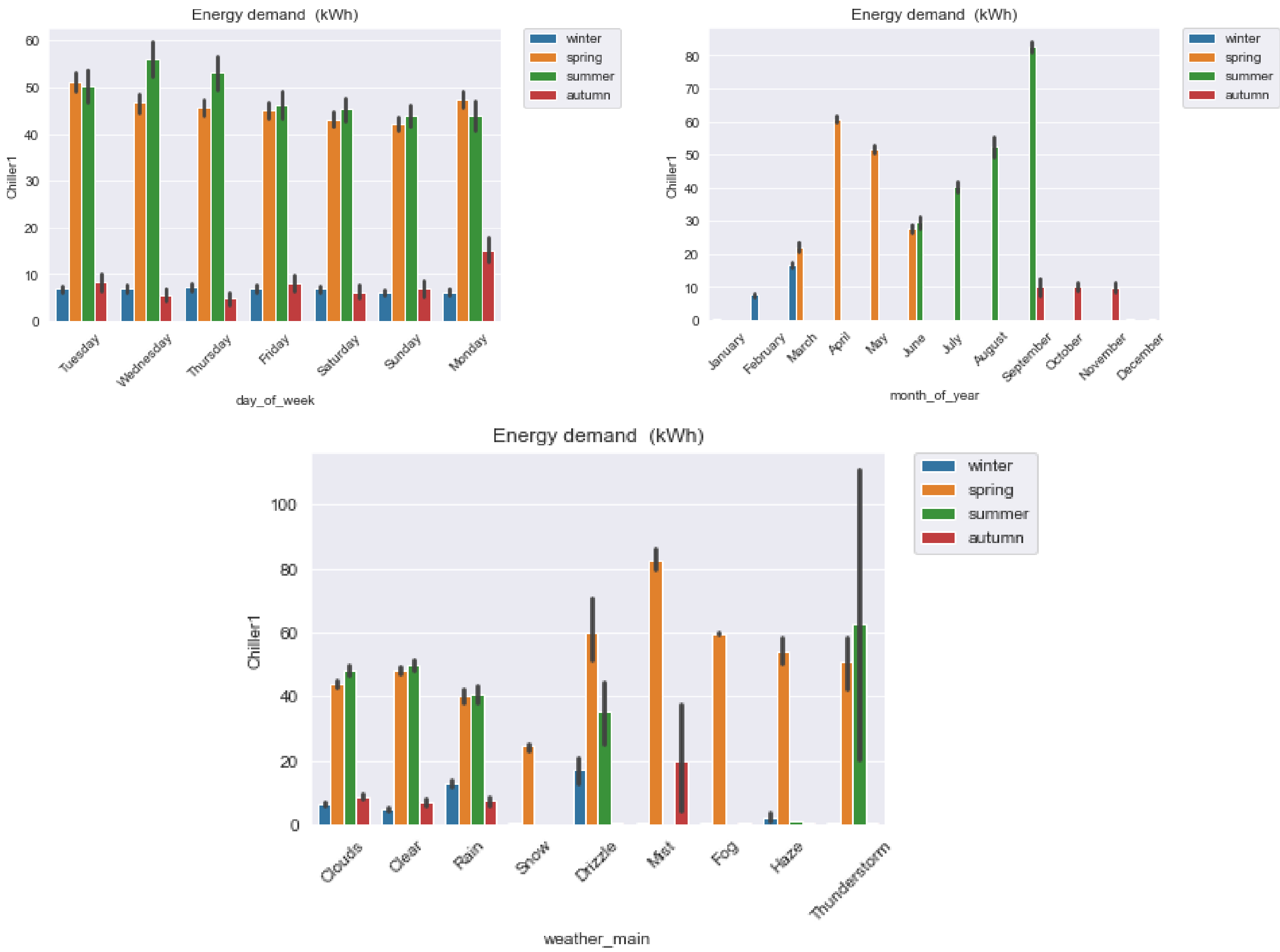


Figure 88. Bar plots of energy demand at Chiller 1 during different days and months with respect to the season of the year

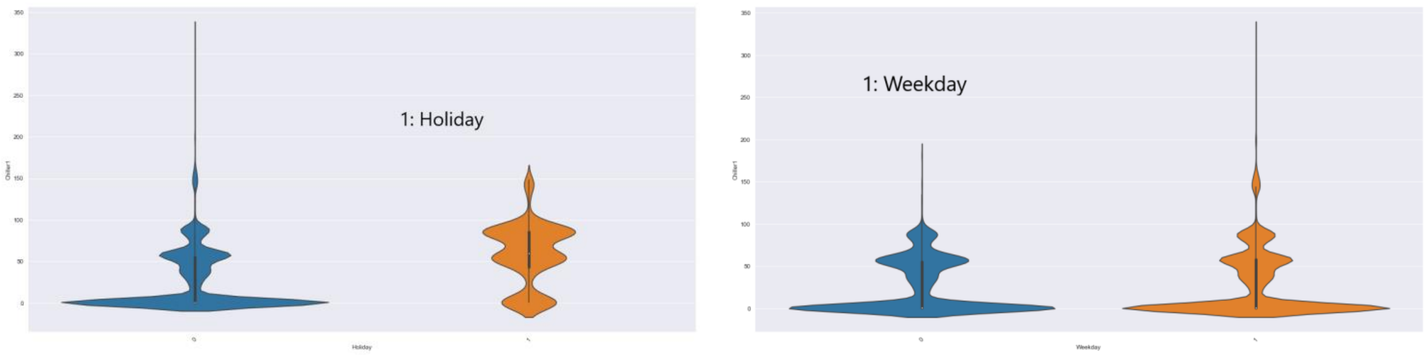


Figure 89. Violin plots of energy demand at Chiller 1 accounting for Holiday and Weekday indicator variables

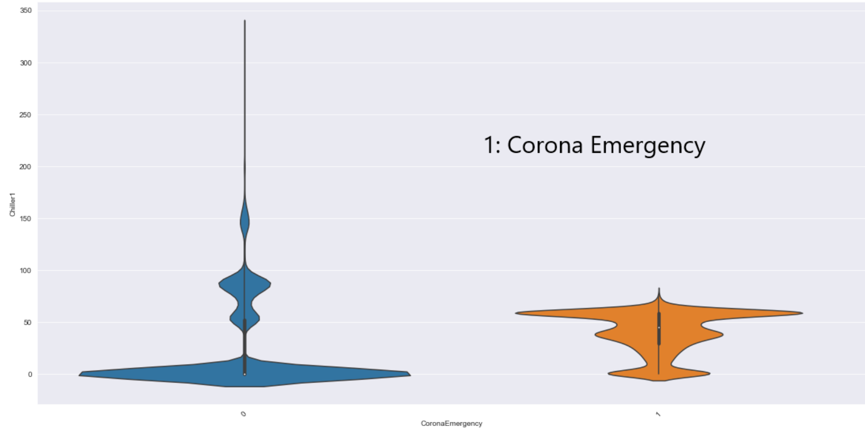


Figure 90. Violin plot of the effect of the Corona emergency period on the energy demand at Chiller 1

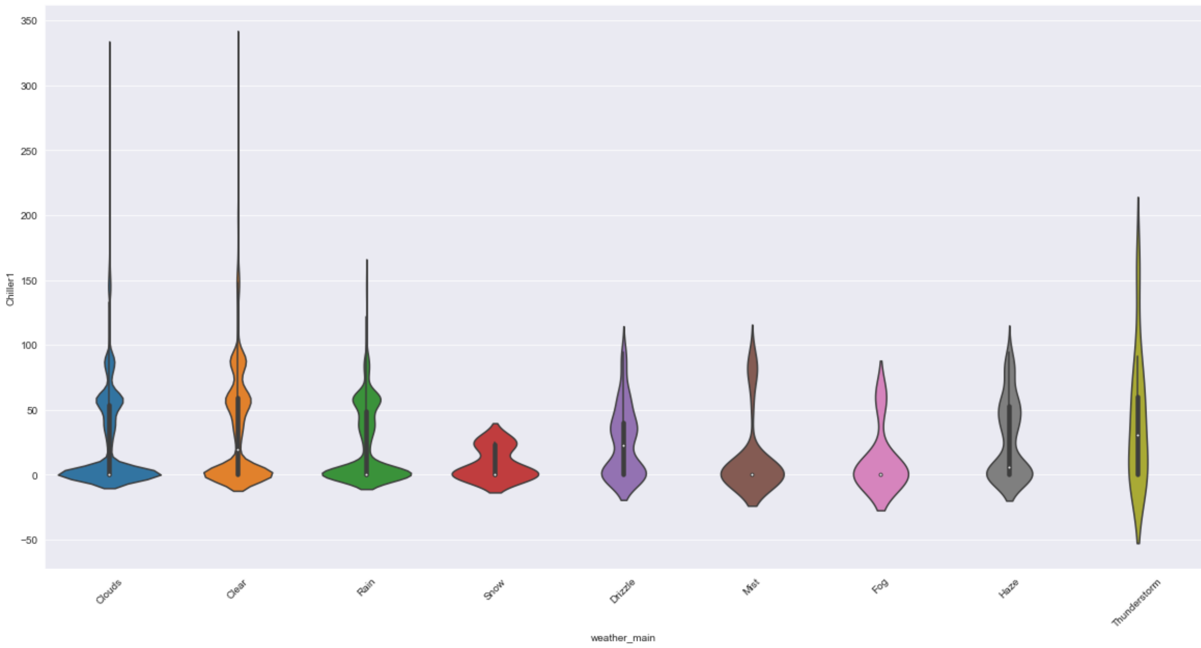


Figure 91. Violin plot of energy demand at Chiller 1 with respect to the type of weather present

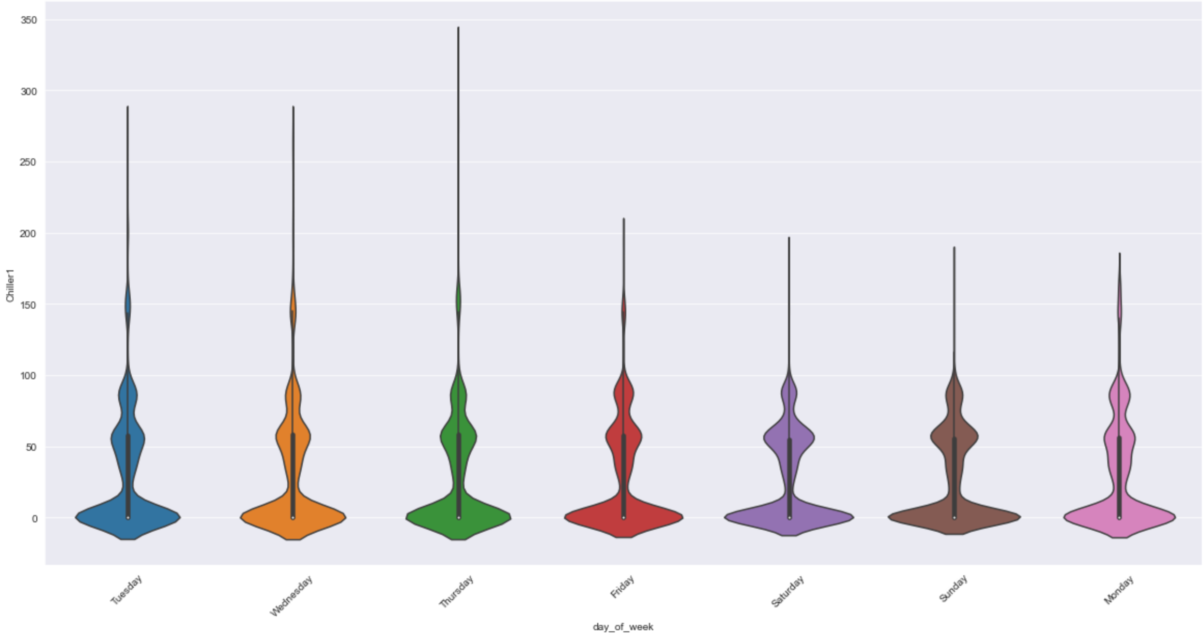


Figure 92. Violin plot of energy demand at Chiller 1 with respect to the day of the week

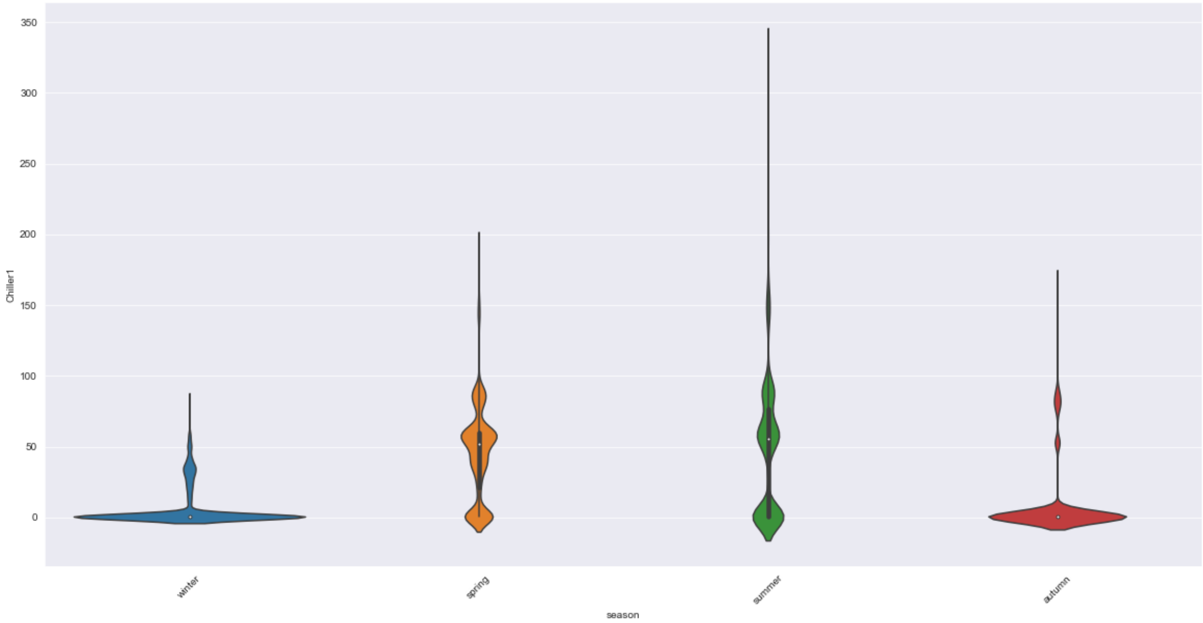


Figure 93. Violin plot of the energy demand at Chiller 1 with respect to the season of the year

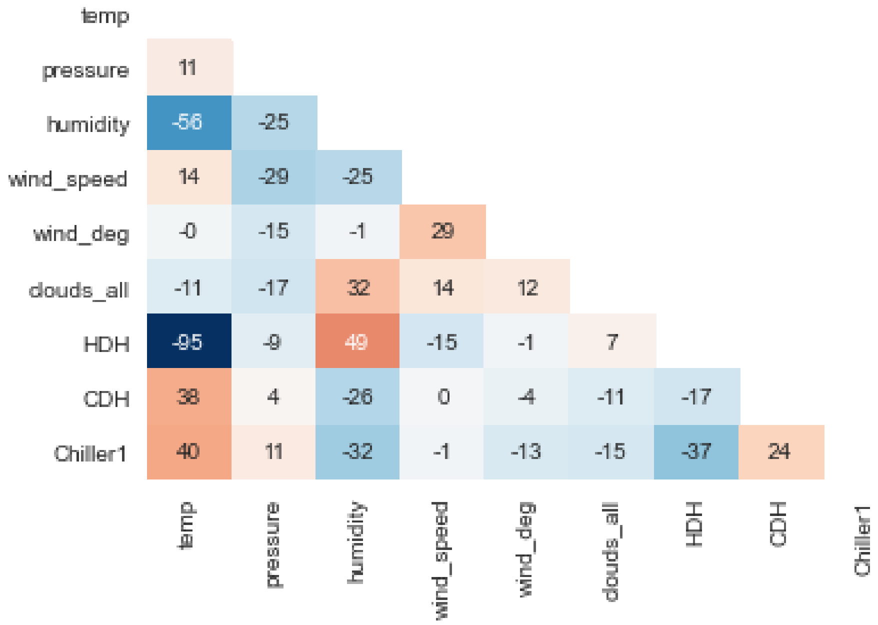


Figure 94. Correlation heat map of the continues variables accounting for the energy demand at the Chiller 1

3.2.1.2 Chiller 2

Figure 95 presents the distribution and box plots of energy demand at Chiller 2. A number of outliers are observed. Figure 96 presents the bar plots of energy demand during different days, months and under different weather conditions with respect to the season of year. Most of the weather types occur in all seasons, except for snow, mist and fog, which occur only in specific seasons. Figure 97 presents the violin plots of energy demand at Chiller 2 accounting for holiday, weekday and coronavirus emergency indicator variables. Figure 98 presents the violin plot of energy demand at Chiller 2 with respect to the type of weather present when the demand was taking place. During the most common weather conditions, i.e. clouds, clear and rain the range of demand is much higher than in the rest of the cases. Figure 99 presents the violin plot of energy demand in Chiller 2 with respect to the day of the week in which the demand was taking place. As the time comes closer to the end of the week the range of demand decreases. Figure 100 presents the violin plot of energy demand in Chiller 2 with respect to the season of the year. During autumn, the range of demand is the least. The highest amount of range in demand is observed during summer, followed closely by spring. Figure 101 presents the correlation heat map of the continuous variables used in this EDA, along with the energy demand at Chiller 2. Moderately, positive correlations are observed between temperature and CDH variables and negative correlations between HDH and humidity levels and energy demand at Chiller 2.

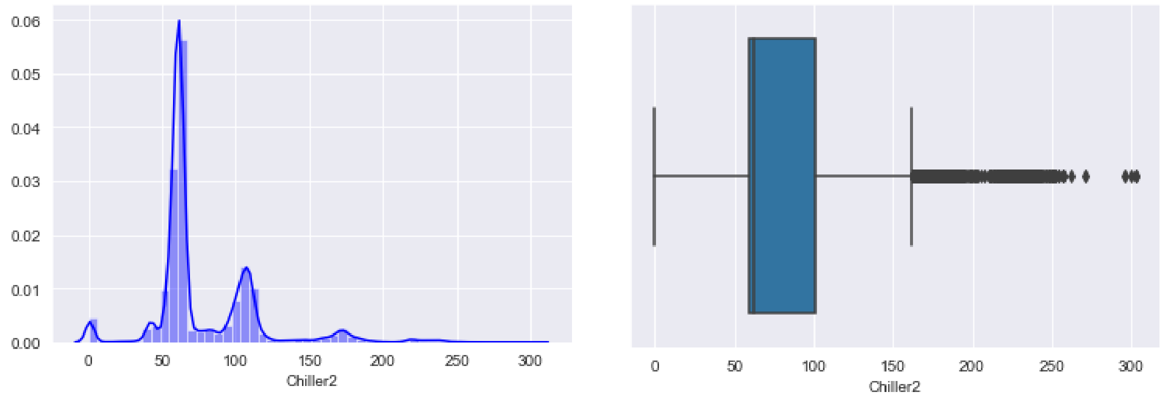


Figure 95. Distribution and box plots of the energy demand at Chiller 2

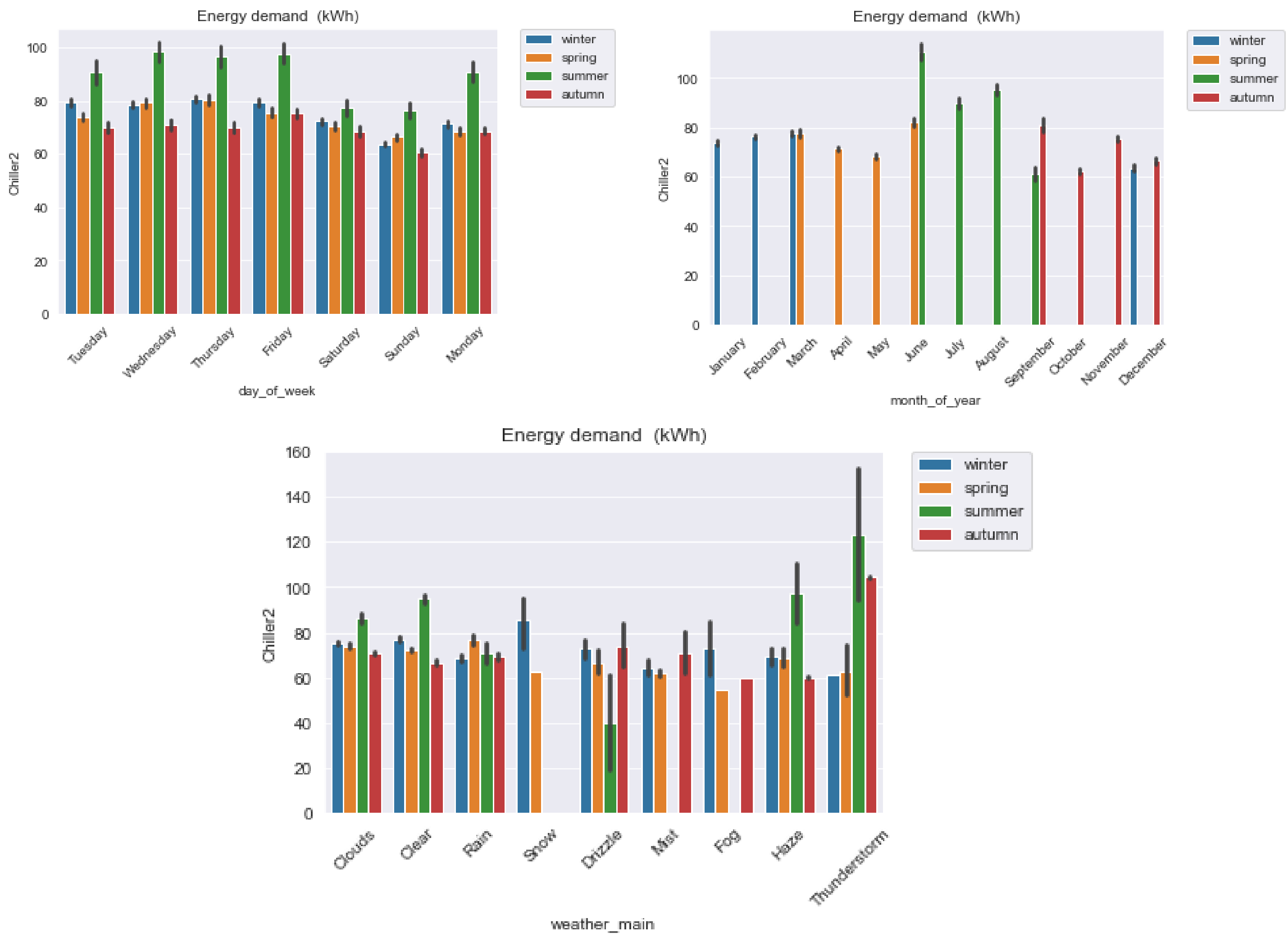


Figure 96. Bar plots of energy demand at Chiller 2 during different days, months and under different weather conditions with respect to the season of the year

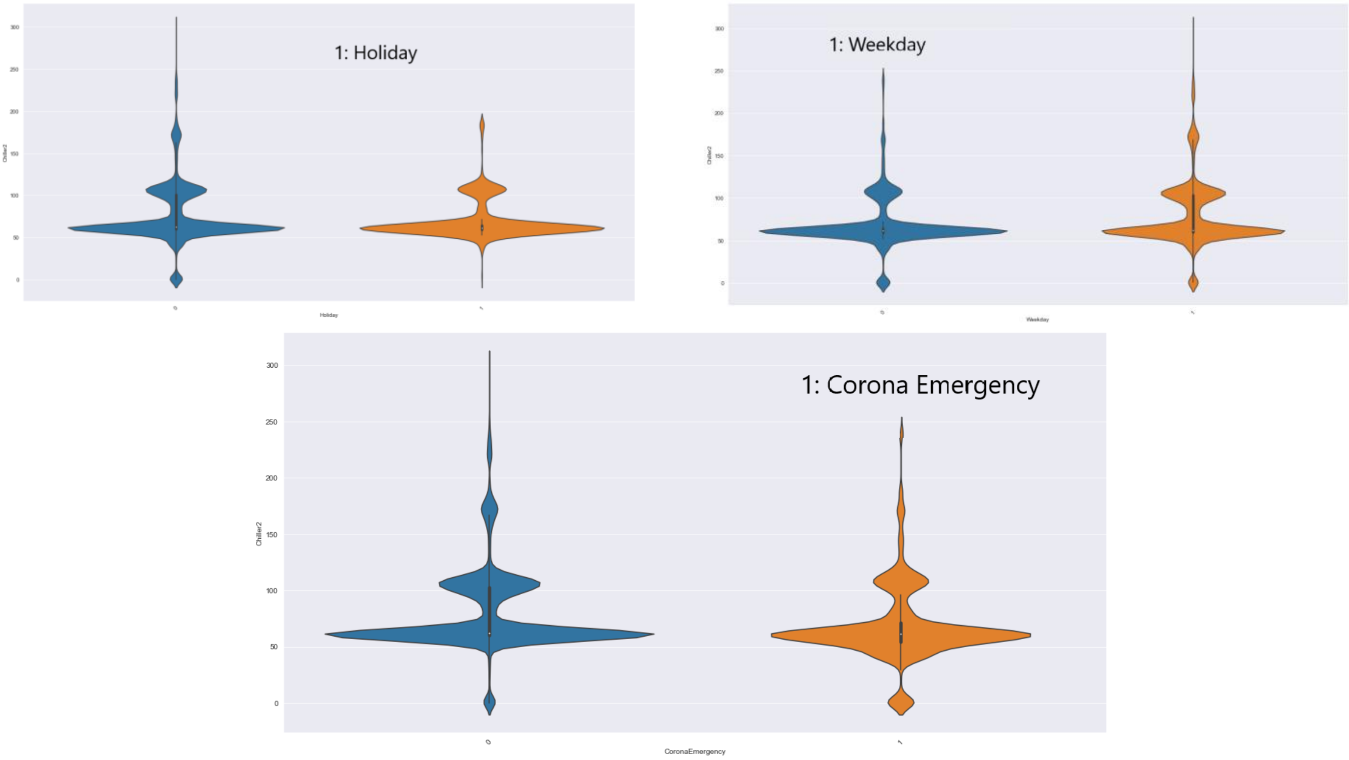


Figure 97. Violin plots of energy demand at Chiller 2 accounting for Holiday, Weekday and Coronavirus emergency indicator variables

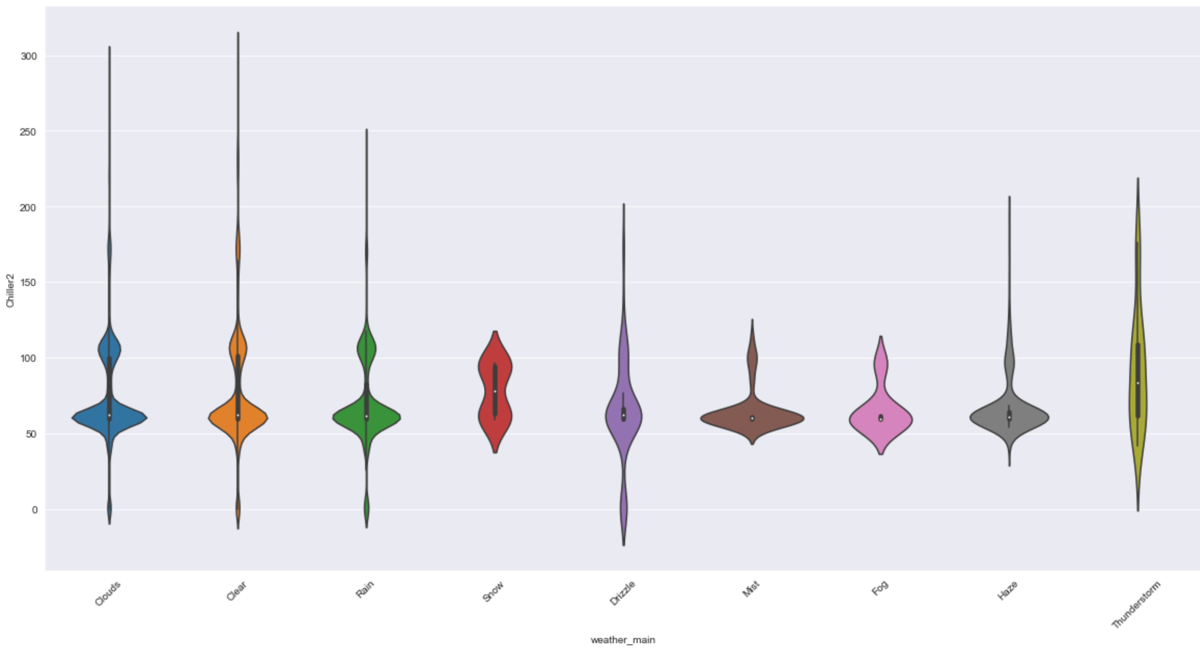


Figure 98. Violin plot of energy demand at Chiller 2 with respect to the type of weather present

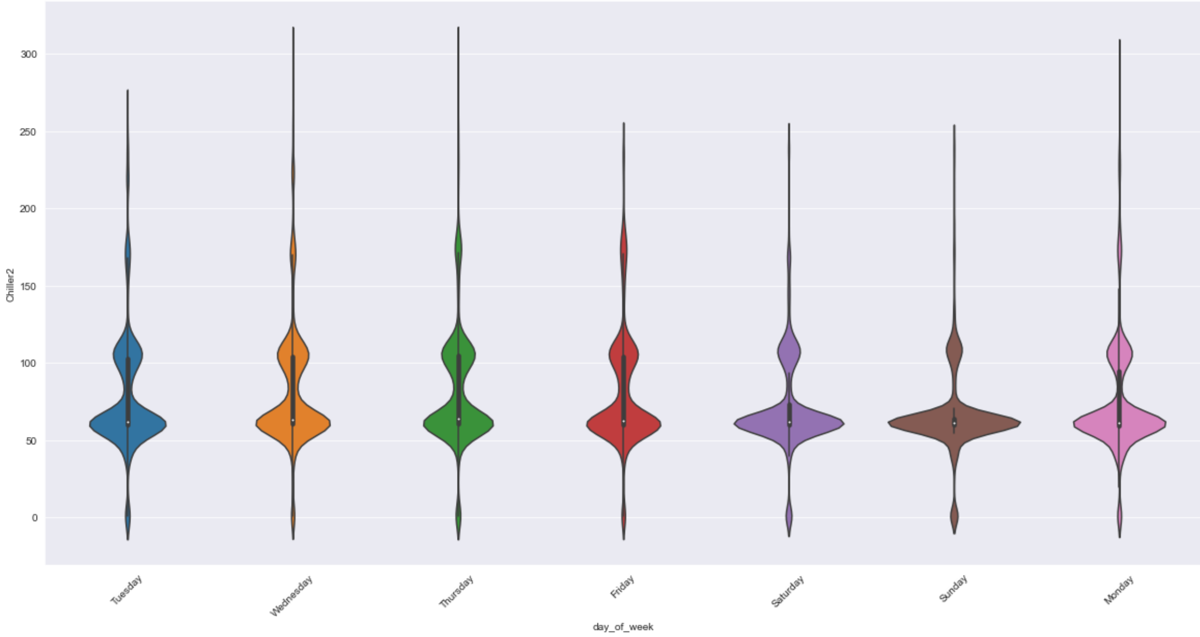


Figure 99. Violin plot of energy demand at Chiller 2 with respect to the day of the week

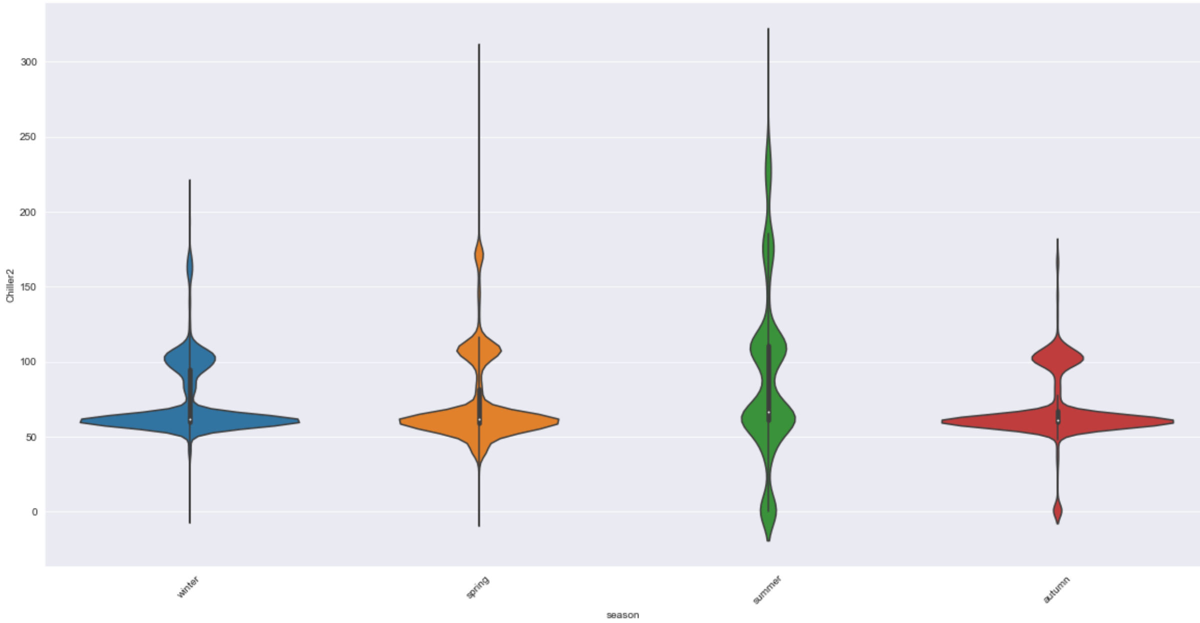


Figure 100. Violin plot of the energy demand at Chiller 2 with respect to the season of the year

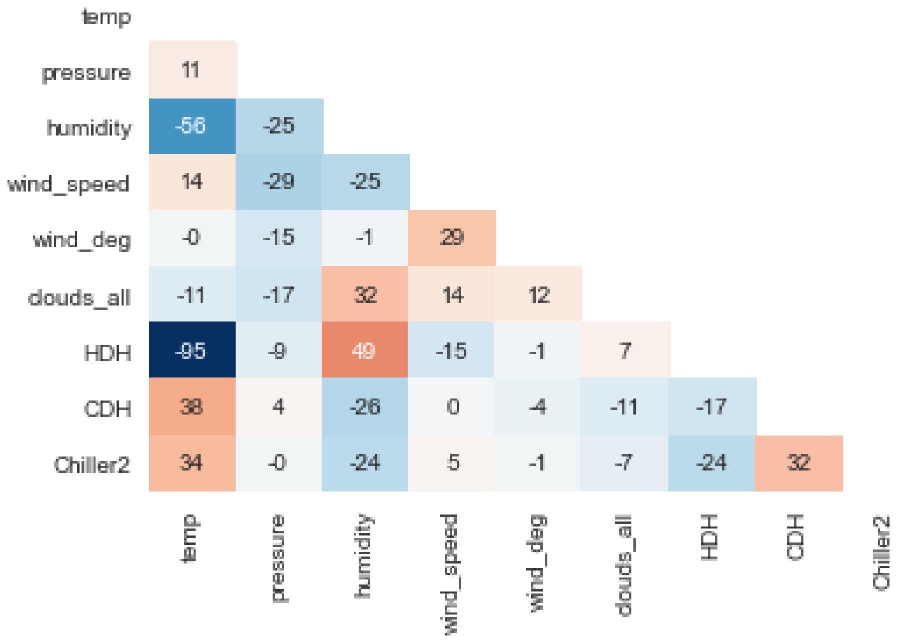


Figure 101. Correlation heat map of the continues variables accounting for the energy demand at Chiller 2

3.2.1.3 Chiller 3

Figure 102 presents the distribution and box plots of energy demand at Chiller 3. A limited amount of outliers is observed. Figure 103 presents the bar plots of energy demand at Chiller 3 with respect to the day of the week and the season. Overall, reduced demand is observed during weekends and the season of autumn. Figure 104 presents the effect of holiday, weekday and corona emergency to the energy demand at Chiller 3. Overall, during holidays, weekends and the corona emergency period the range of energy demand is reduced compared to normal operation. Figure 106 the violin plot of energy demand at Chiller 3 with respect to the day of the week. Similar patterns with, slightly, different ranges of demand are observed. Figure 107 presents the violin plot of energy demand at Chiller 3 with respect to the season of the year. In autumn, the energy demand is lower than the rest of the seasons. Figure 108 presents the correlation heat map of the continuous variables used in this EDA, along with the energy demand at Chiller 3. Moderate, positive correlations are observed between temperature and CDH variables and negative correlations between HDH and humidity levels and energy demand at Chiller 3.

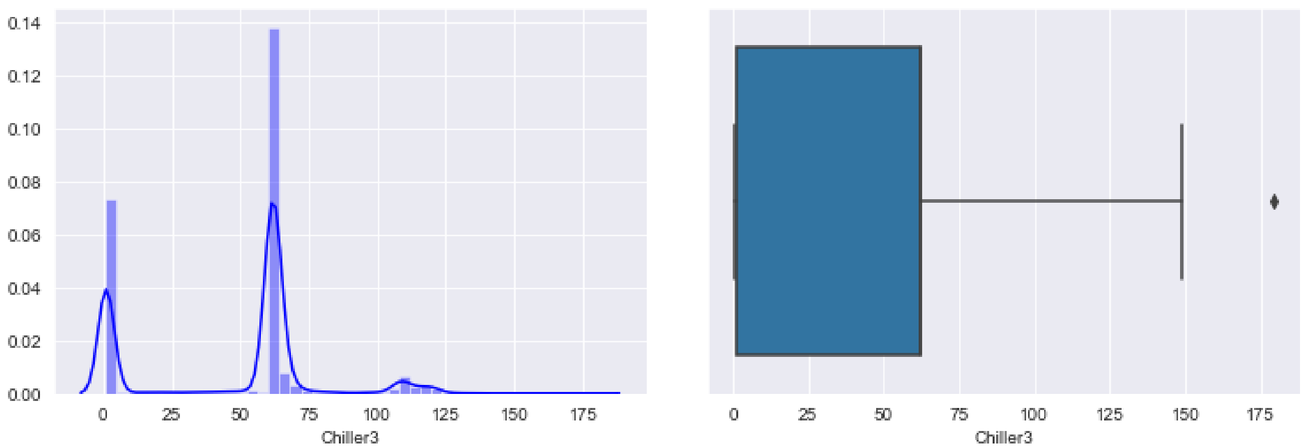


Figure 102. Distribution and box plots of the energy demand at Chiller 3

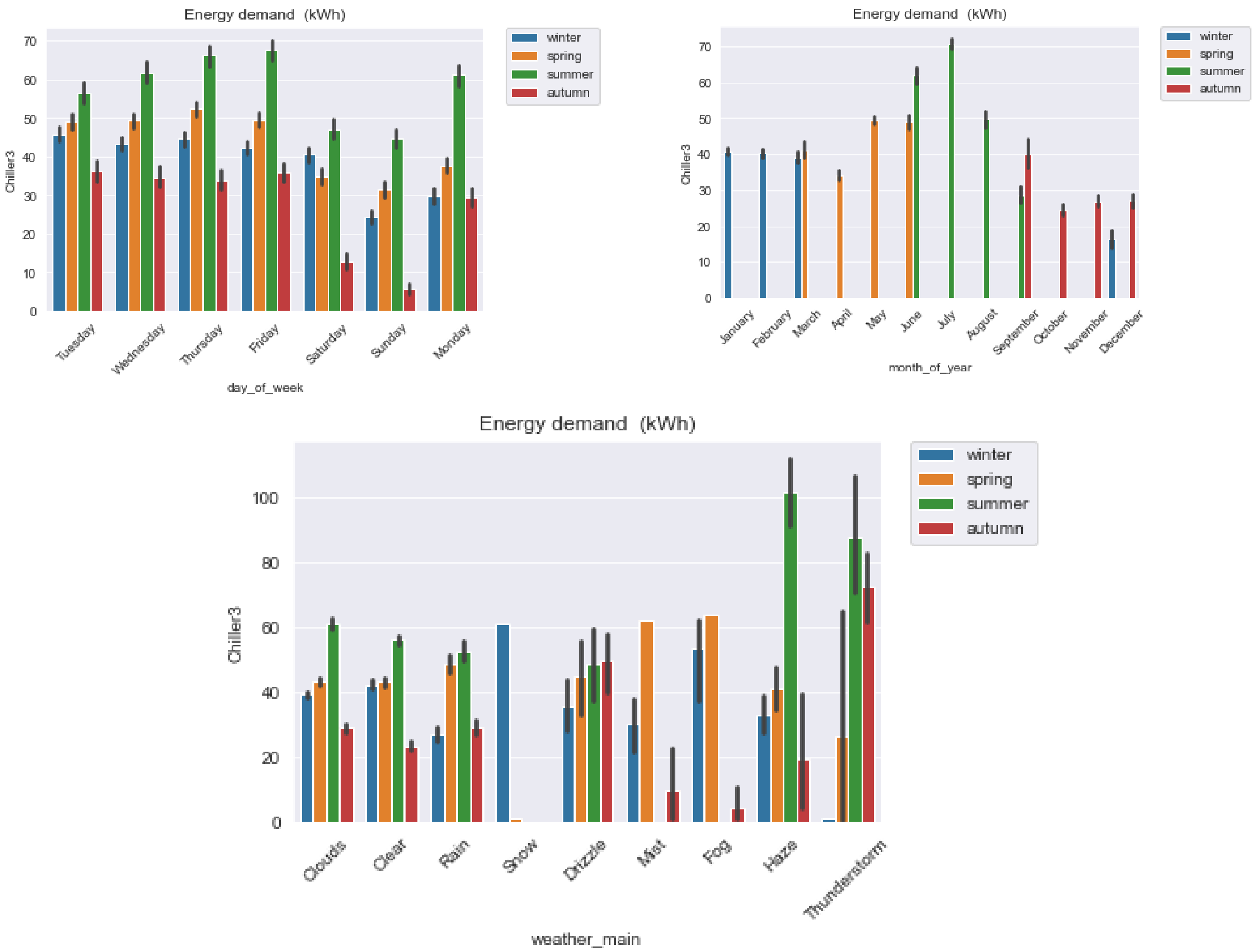
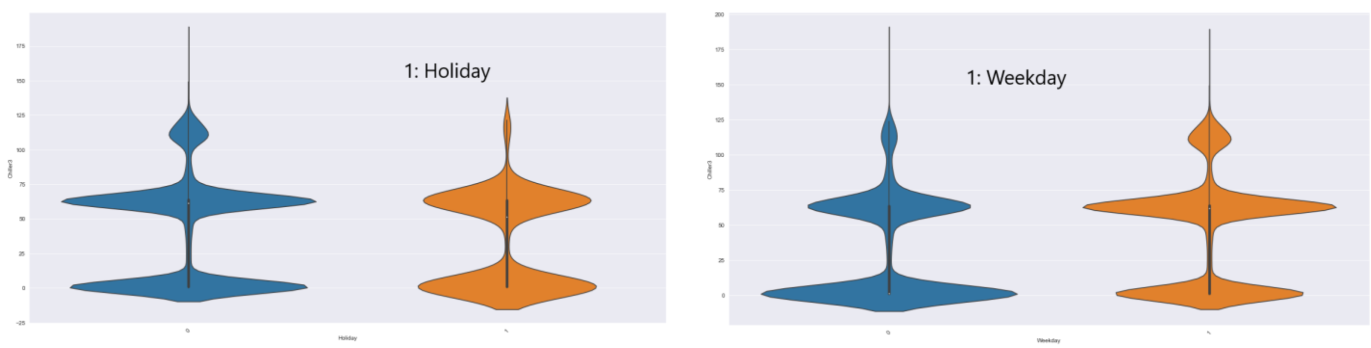


Figure 103. Bar plots of energy demand at Chiller 3 during different days and months under different weather conditions with respect to the season of the year



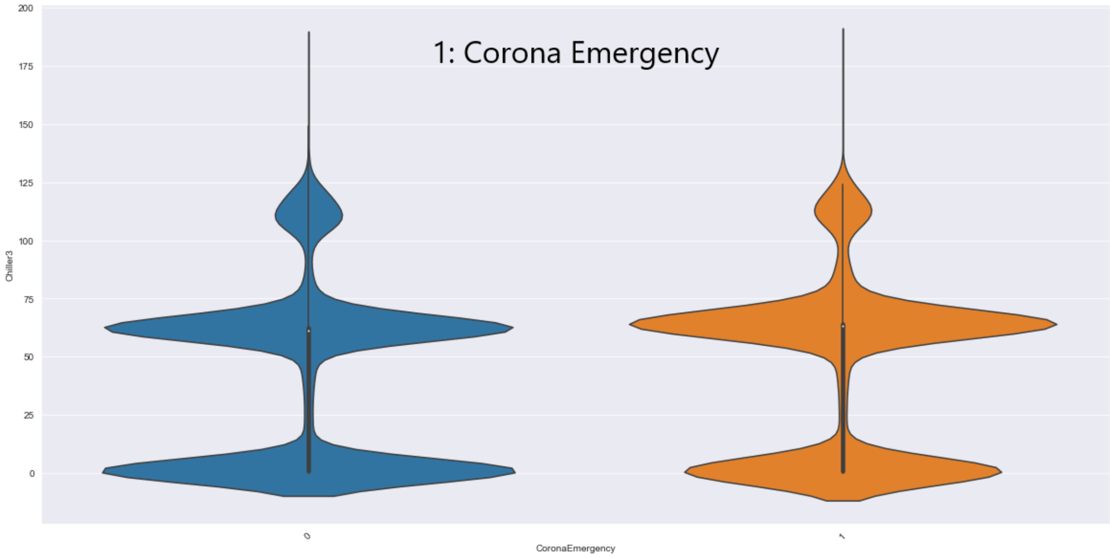


Figure 104. Violin plots of energy demand at Chiller 3 accounting for Holiday, Weekday and Coronavirus emergency indicator variables

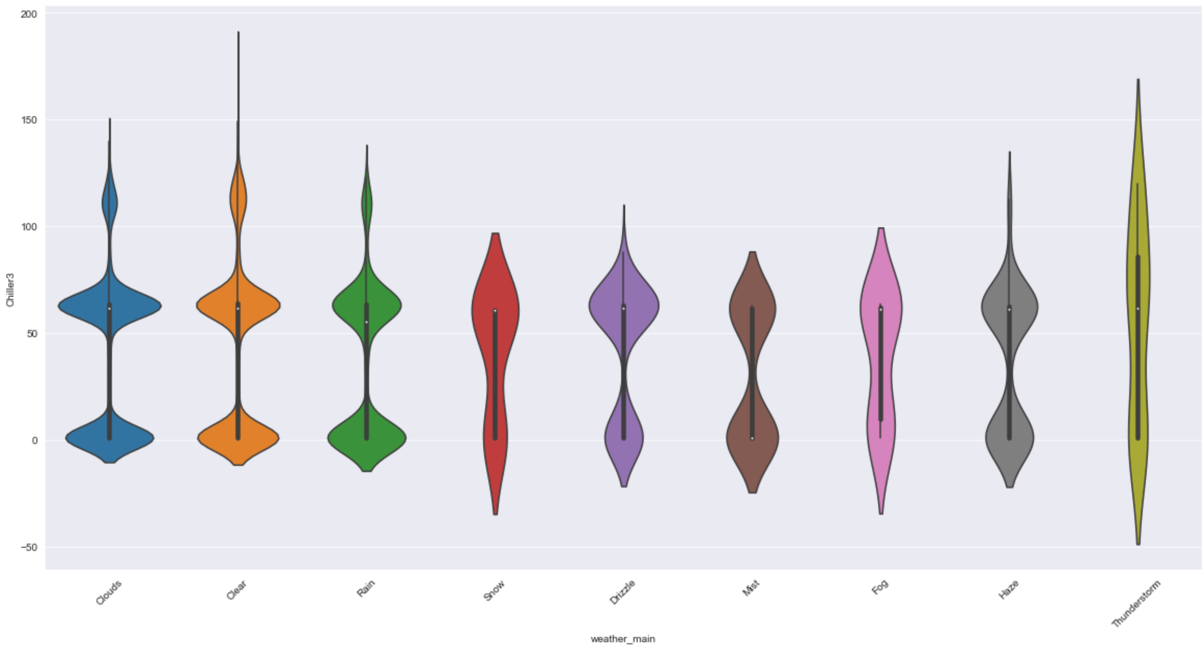


Figure 105. Violin plot of energy demand at Chiller 3 with respect to the type of weather present

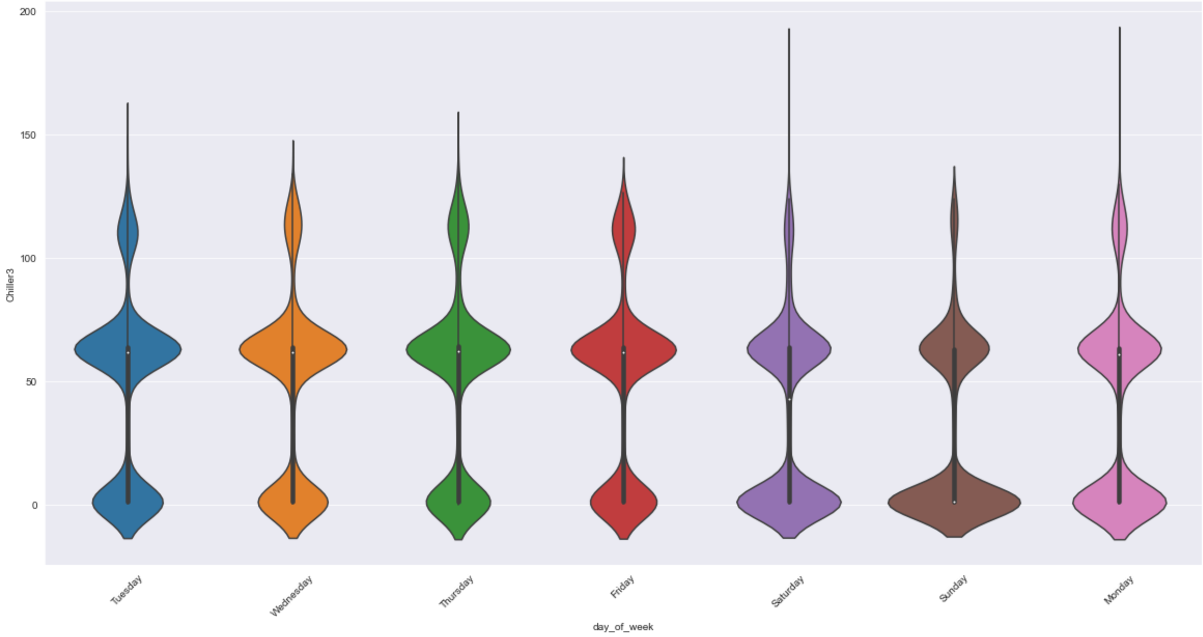


Figure 106. Violin plot of energy demand at Chiller 3 with respect to the day of the week

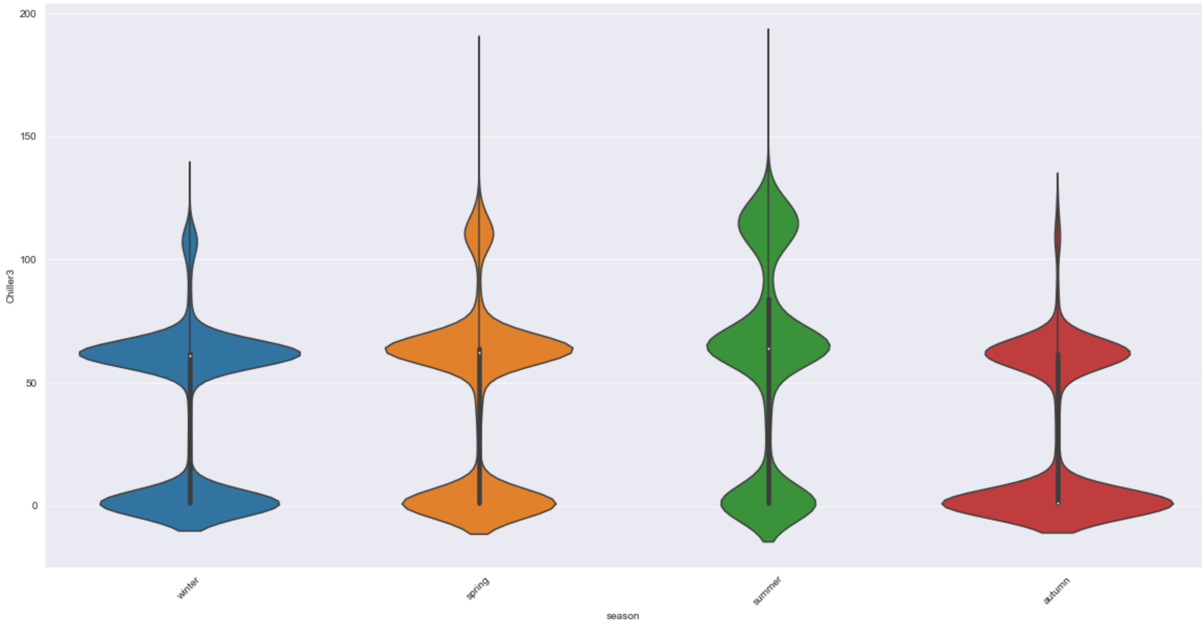


Figure 107. Violin plot of the energy demand at Chiller 3 with respect to the season of the year

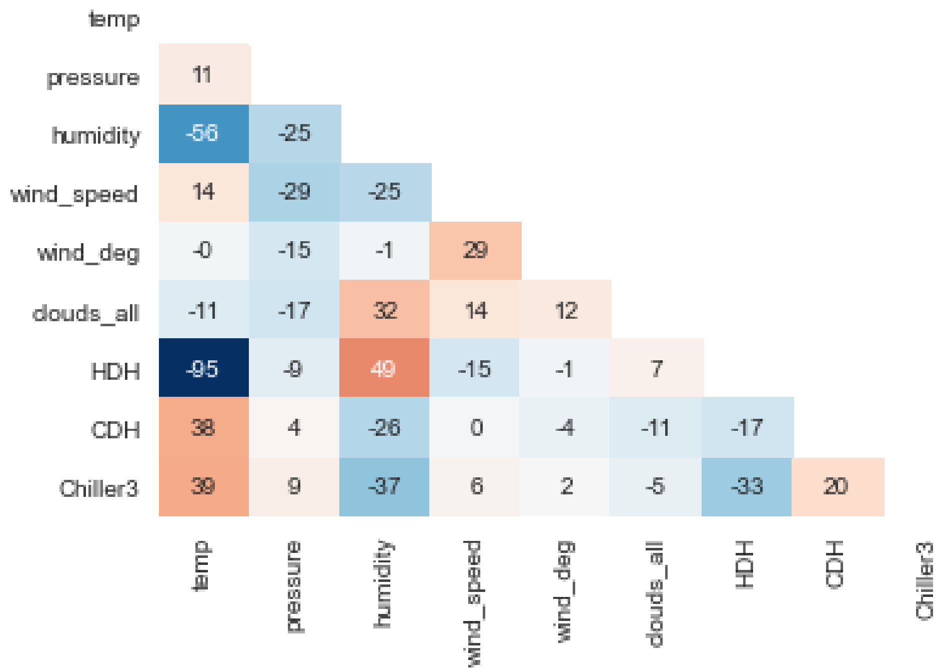


Figure 108. Correlation heat map of the continues variables accounting for the energy demand at Chiller 3

3.2.1.4 Chiller 4

Figure 109 presents the distribution and box plots of energy demand at Chiller 4. A number of outliers in energy demand is observed. Figure 110 present the effect of day of week, month of the year and weather type on the energy demand at Chiller 4. Overall, a reduced energy demand during the weekends is observed. Interestingly, during thunderstorms energy demand is higher compared to the rest of the weather types. Figure 111 presents the effect of holiday, weekday and Corona emergency period on the energy demand at Chiller 4. During holidays, the energy demand is less compared to normal days. The day of the week does not seem to affect the pattern of demand since energy demand during weekdays and weekends is following a similar pattern. Corona emergency has a huge impact on the energy demand range which is limited compared to the normal operating conditions. Figure 112 presents violin plot of the energy demand at Chiller 4 with respect to the weather type. Different patterns and ranges of demand are observed. Figure 113 presents the violin plot of energy demand at Chiller 4 with respect to the day of the week. During Saturdays the range of demand is limited compared to the rest of the days. Figure 114 present the violin plot of energy demand at Chiller 4 with respect to the season of the year. Limited range of demand is observed during autumn and winter compared to spring and summer. Figure 115 presents the correlation heat map of the continuous variables used in this EDA, along with the energy demand at Chiller 4. Strong, positive correlation is observed between temperature and energy demand at Chiller 4. Moderate, positive correlation is observed between CDH and energy demand at Chiller 4. Strong negative correlation is observed between HDH and moderate negative between humidity and energy demand at Chiller 4.

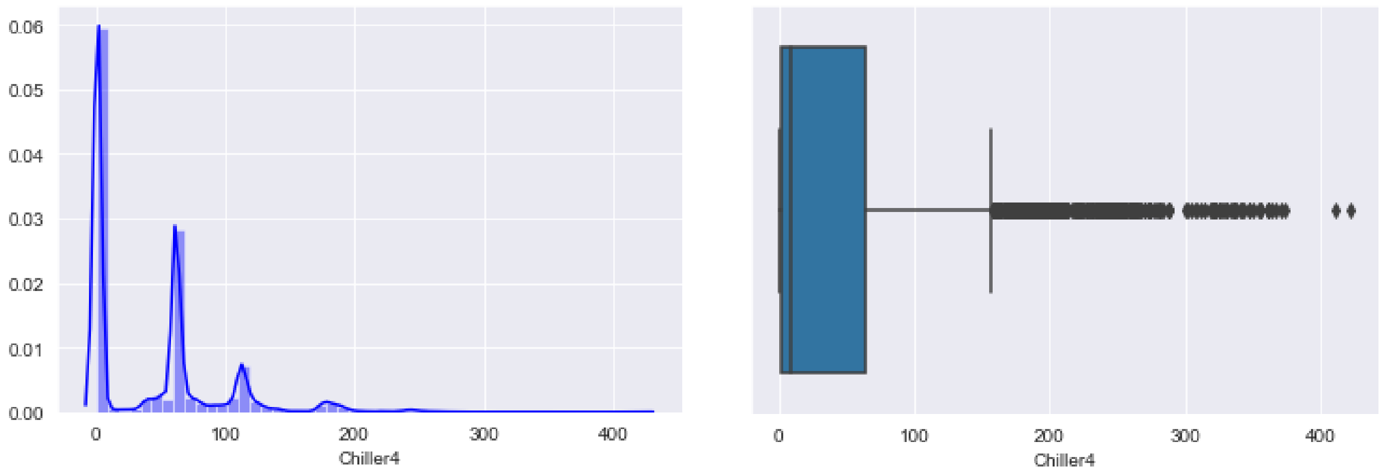


Figure 109. Distribution and box plots of energy demand at Chiller 4

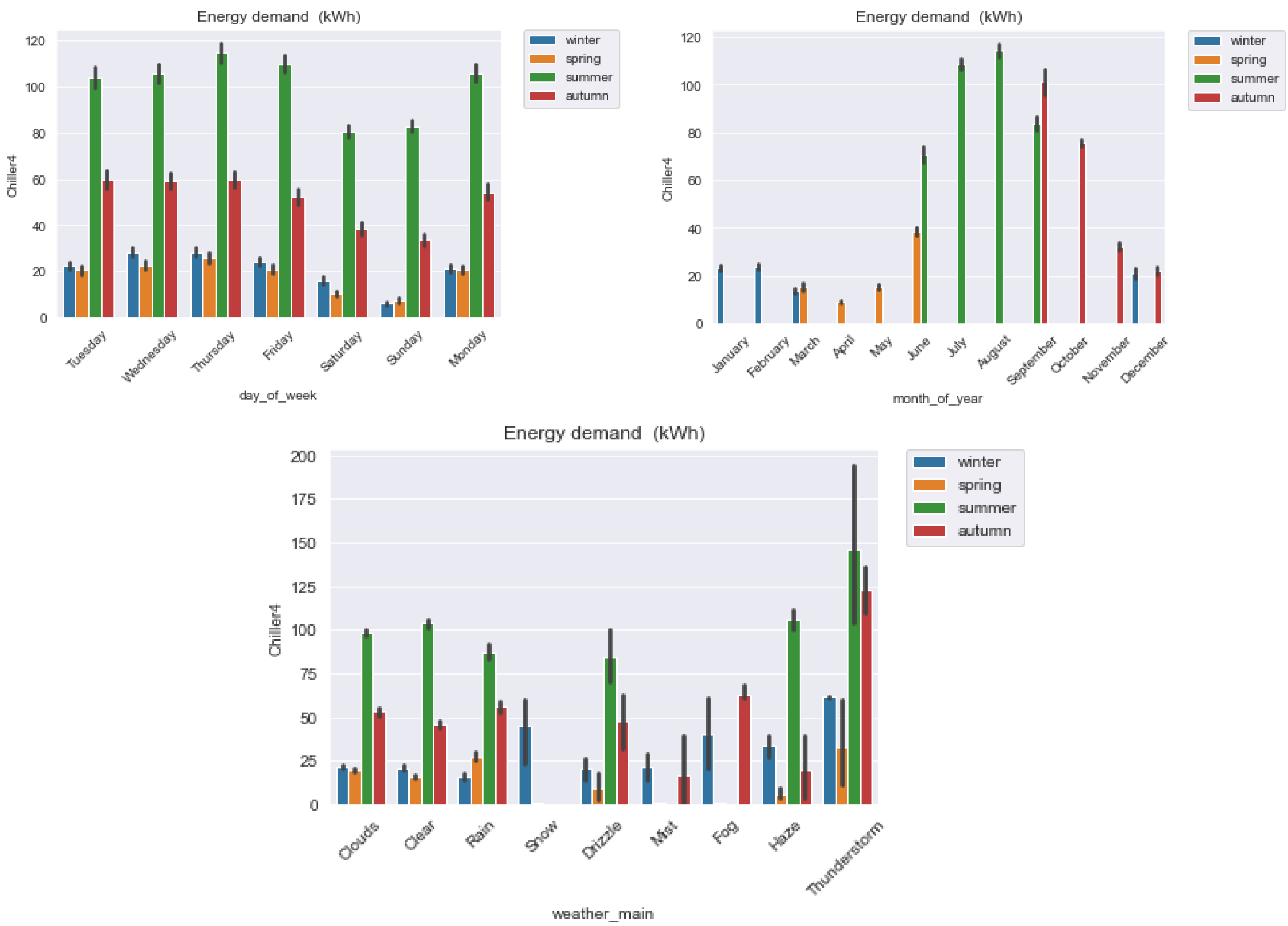


Figure 110. Bar plots of energy demand at Chiller 4 during different days, months and under different weather conditions with respect to the season of the year

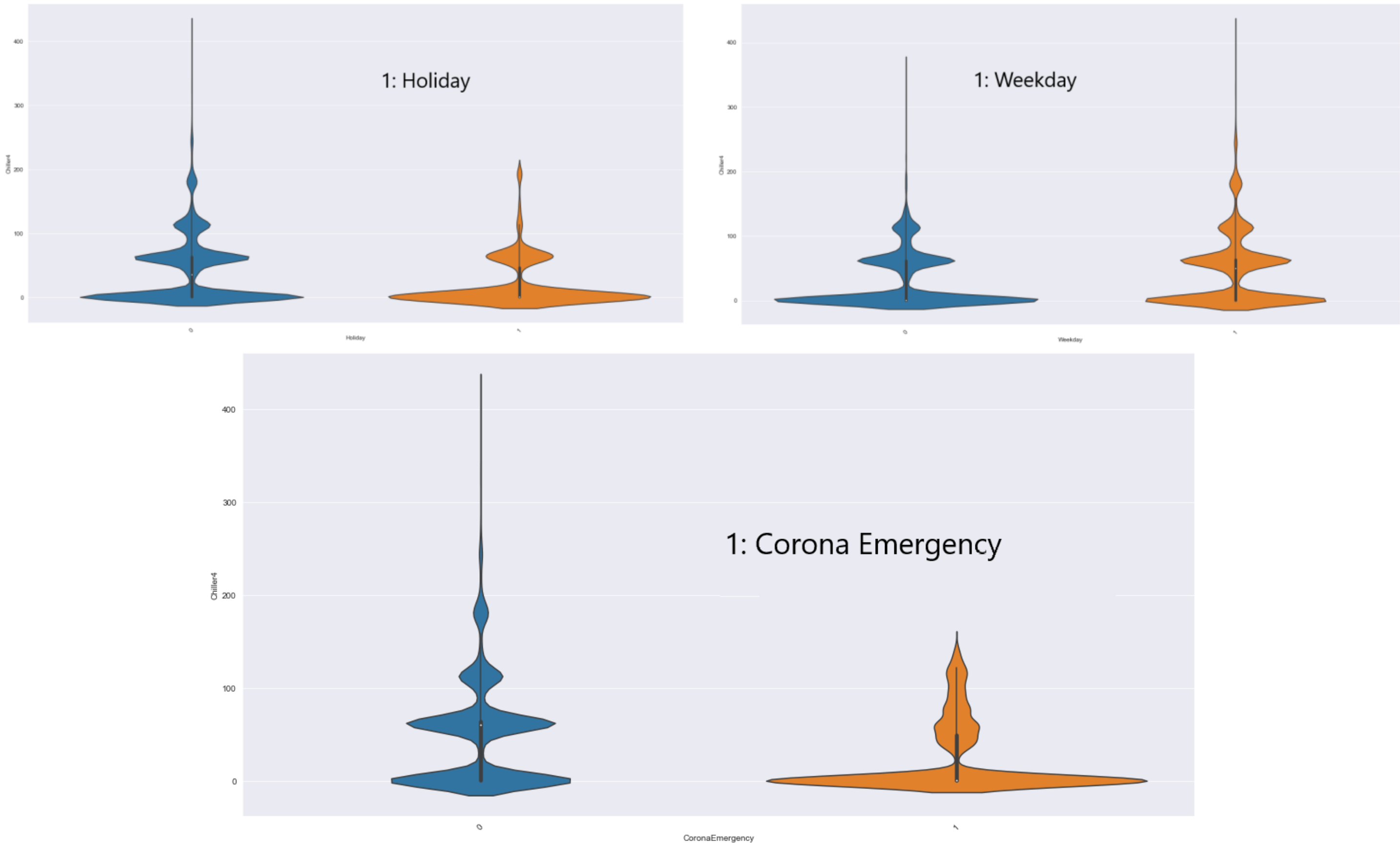


Figure 111. Violin plots of energy demand at Chiller 4 accounting for Holiday, Weekday and Coronavirus emergency indicator variables

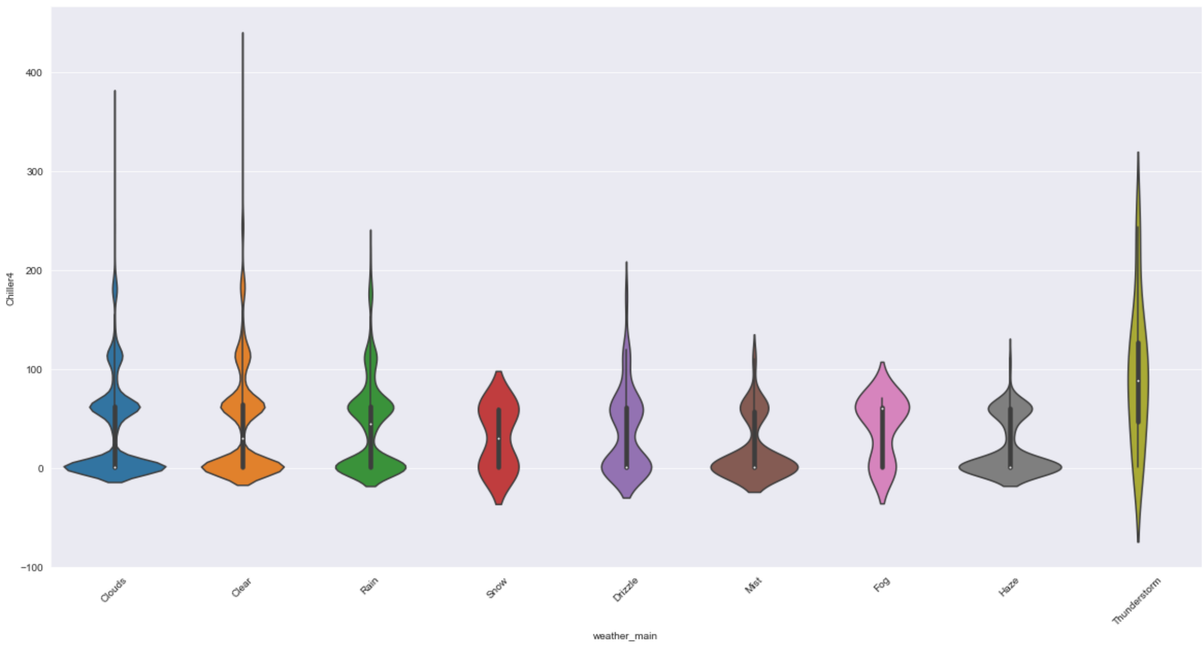


Figure 112. Violin plot of energy demand at Chiller 4 with respect to the type of weather present

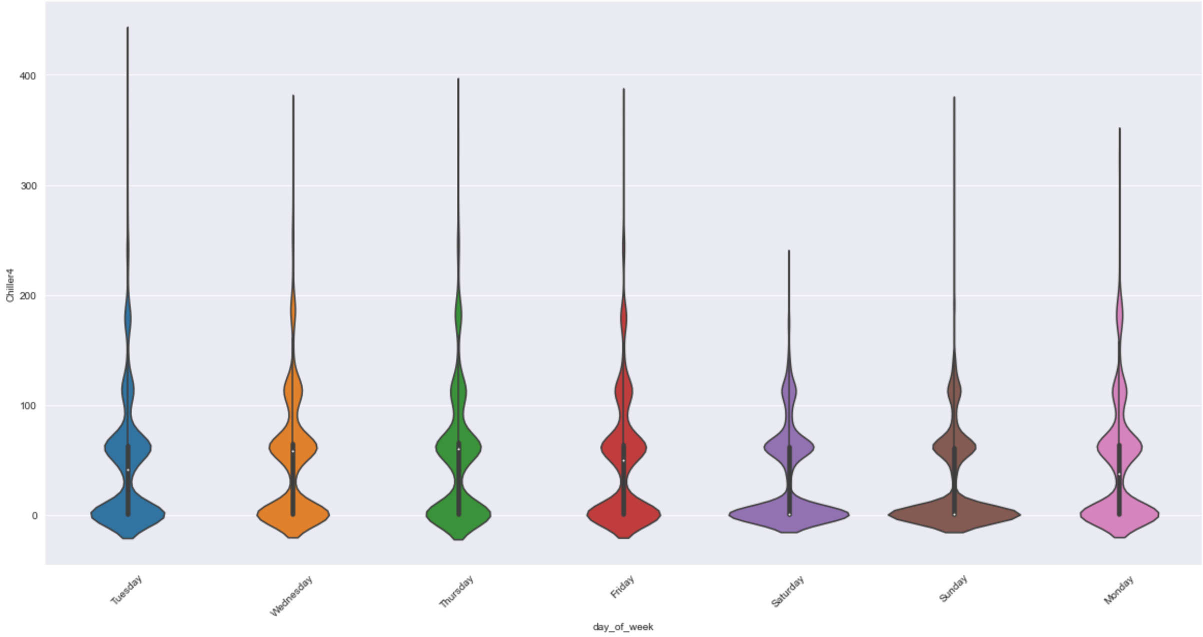


Figure 113. Violin plot of energy demand at Chiller 4 with respect to the day of the week

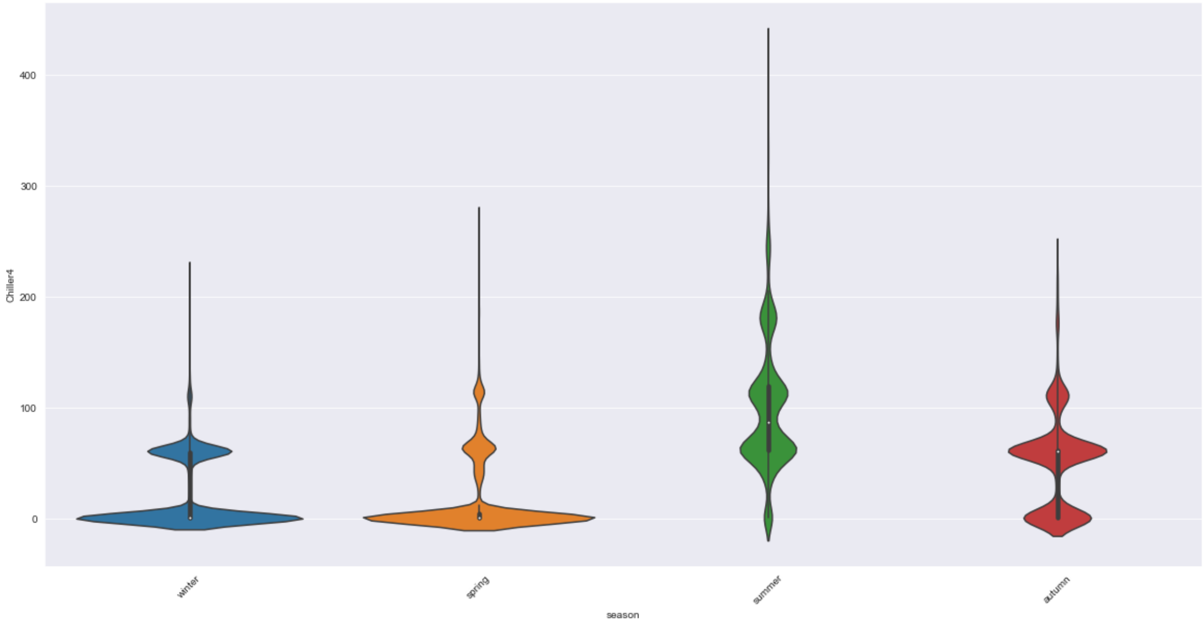


Figure 114. Violin plot of the energy demand at Chiller 4 with respect to the season of the year

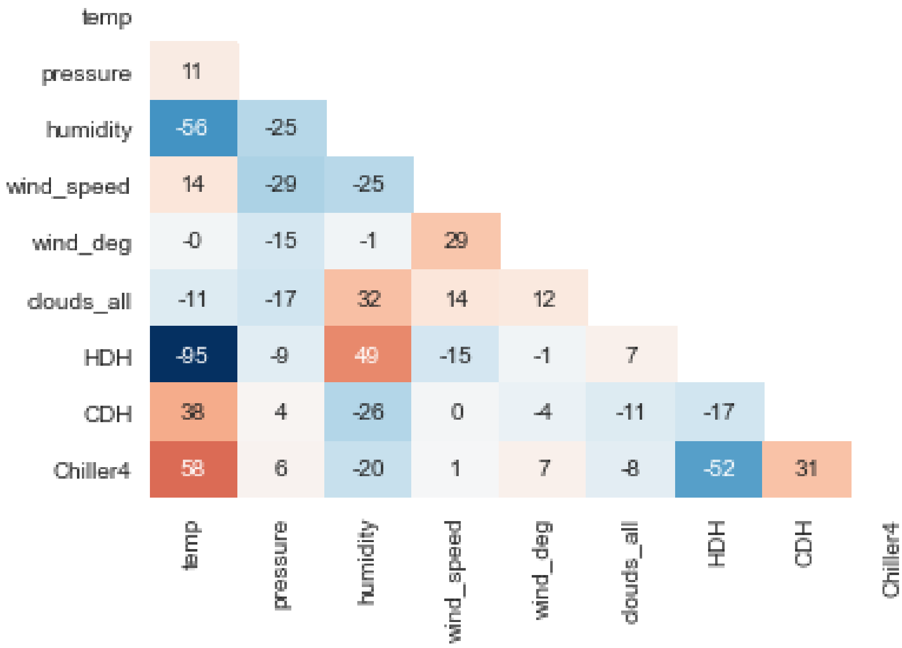


Figure 115. Correlation heat map of the continues variables accounting for the energy demand at Chiller 4

3.2.1.5 Chiller 5

Figure 116 presents the distribution and box plots of energy demand at Chiller 5. A limited amount of outliers is observed. Figure 117 the bar plots of day of the week, month of the year and weather type of energy demand at Chiller 5. Slightly reduced amount of energy is consumed during the weekends. Overall, the energy demand at Chiller 5 is higher during summer and autumn. This is true for the case of thunderstorms as well. Figure 118 presents the effect of holiday, weekday and corona emergency period on the energy demand at Chiller 5. During holidays and weekends the range of demand is less than the rest of the days. The corona emergency periods has a huge impact on the demand, which is practically nullified. Figure 119 presents the effect of different weather types on energy demand at Chiller 5. Different patterns are observed. Figure 120 present the violin plot of the energy demand at Chiller 5 with respect to the day of the week. Patterns are similar except for Wednesdays where the range is of energy demand is higher. Figure 121 presents the violin plot of energy demand at Chiller 5 with respect to the season of the year. Different patterns are observed. The range of energy demand is the highest during autumn and the lowest during winter. Figure 122 presents the correlation heat map of the continuous variables used in this EDA, along with the energy demand at Chiller 5. Moderate, positive correlations are observed between temperature and CDH variables and negative correlations between HDH and energy demand at Chiller 5.

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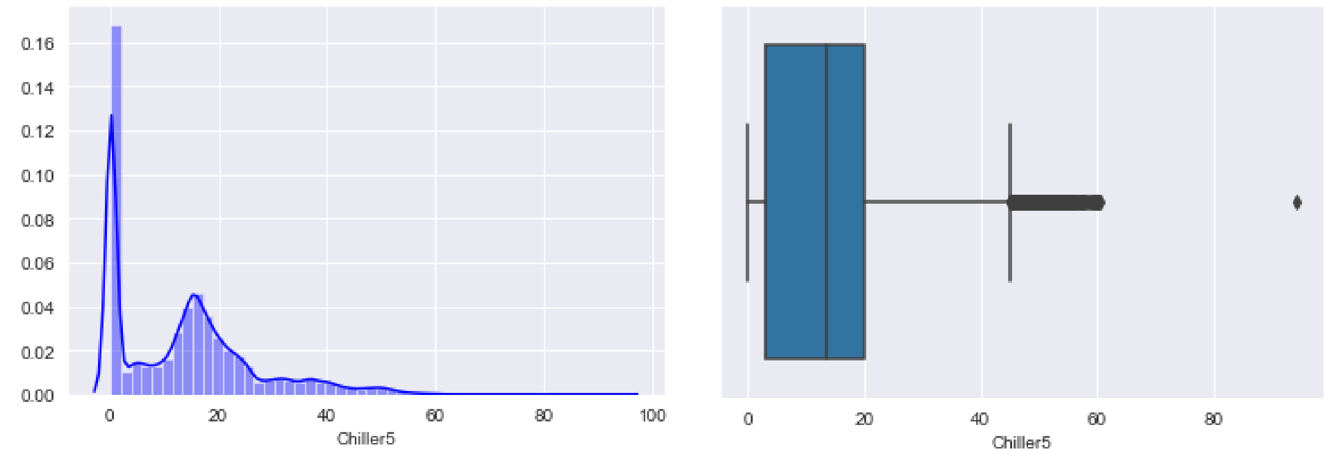
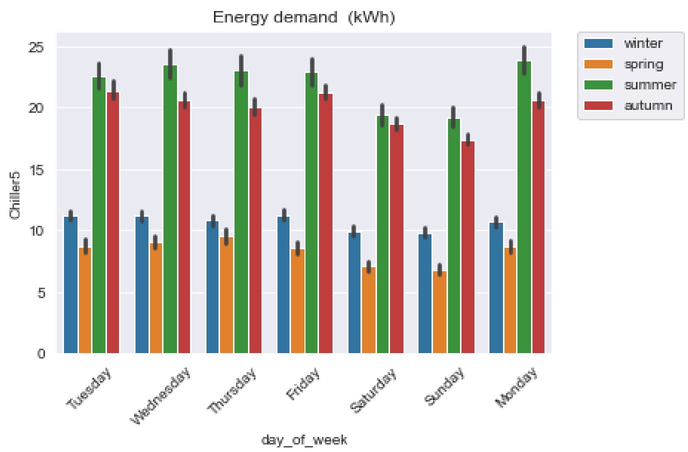
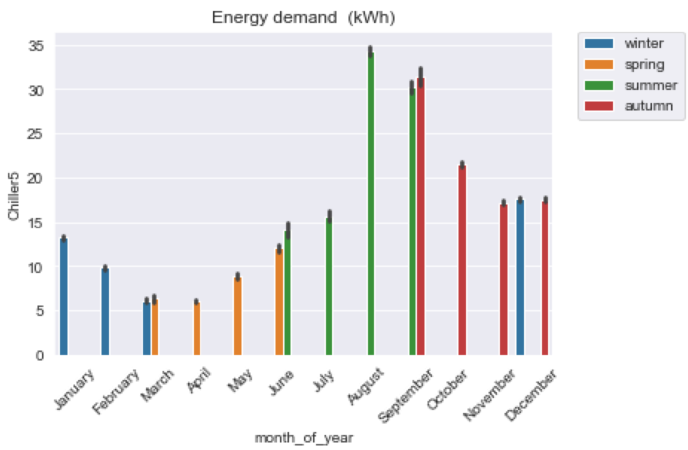


Figure 116. Distribution and box plots of energy demand at Chiller 5





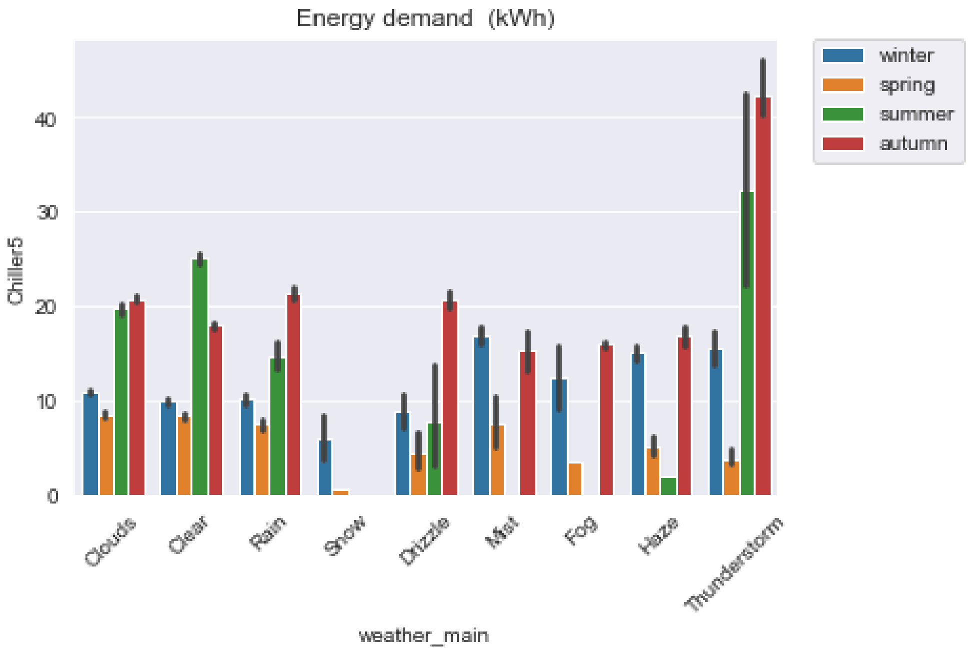


Figure 117. Bar plots of energy demand at Chiller 5 during different days, months and under different weather conditions with respect to the season of the year

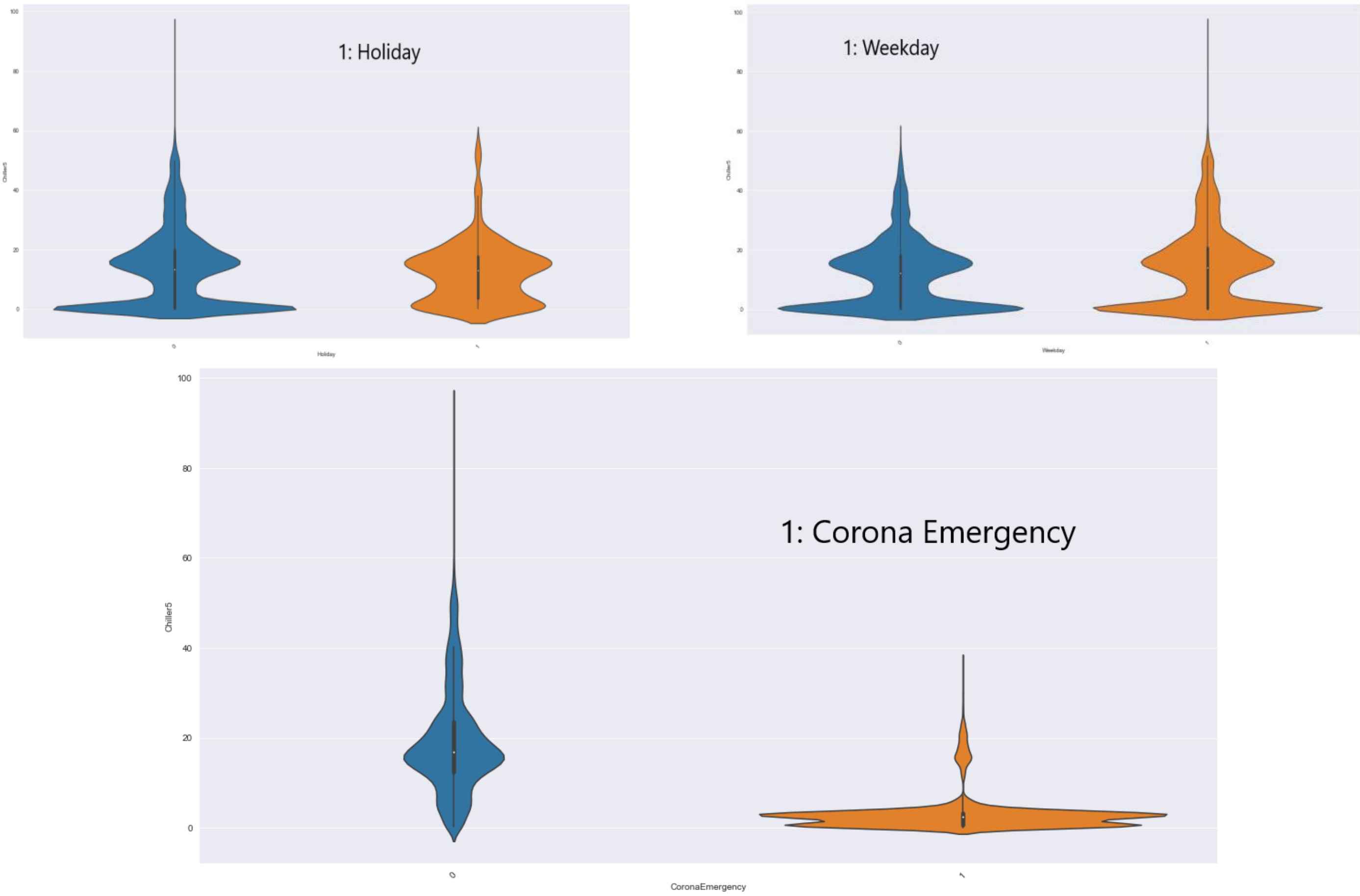


Figure 118. Violin plots of energy demand at Chiller 5 accounting for Holiday, Weekday and Coronavirus emergency indicator variables

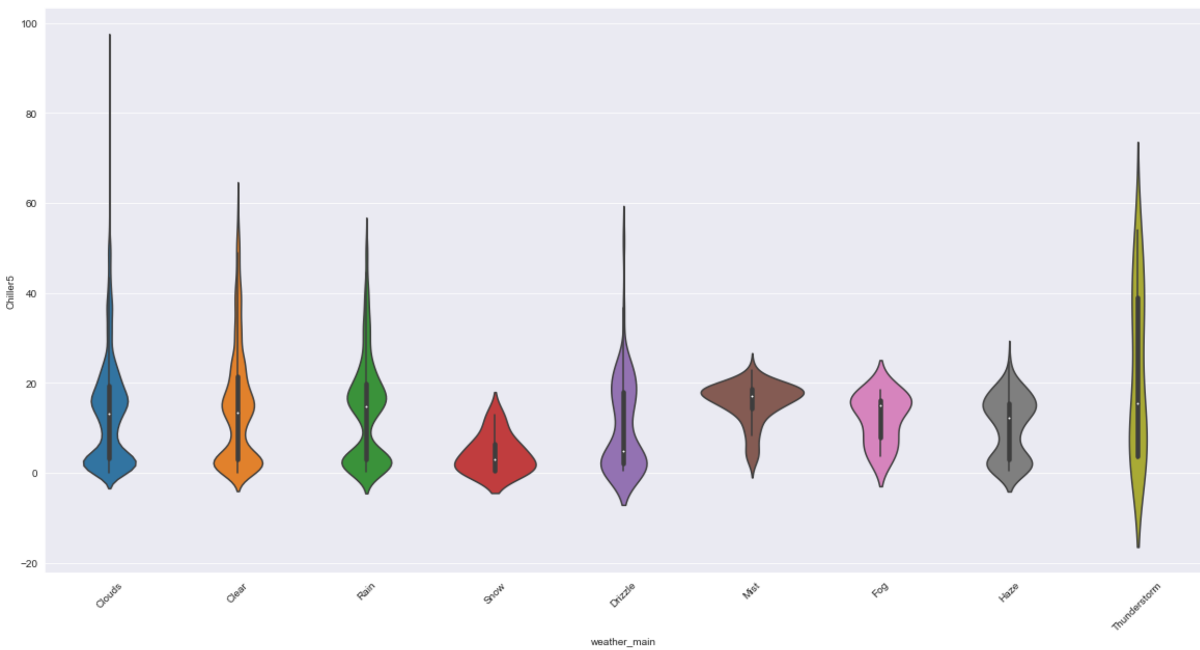


Figure 119. Violin plot of energy demand at Chiller 5 with respect to the type of weather present

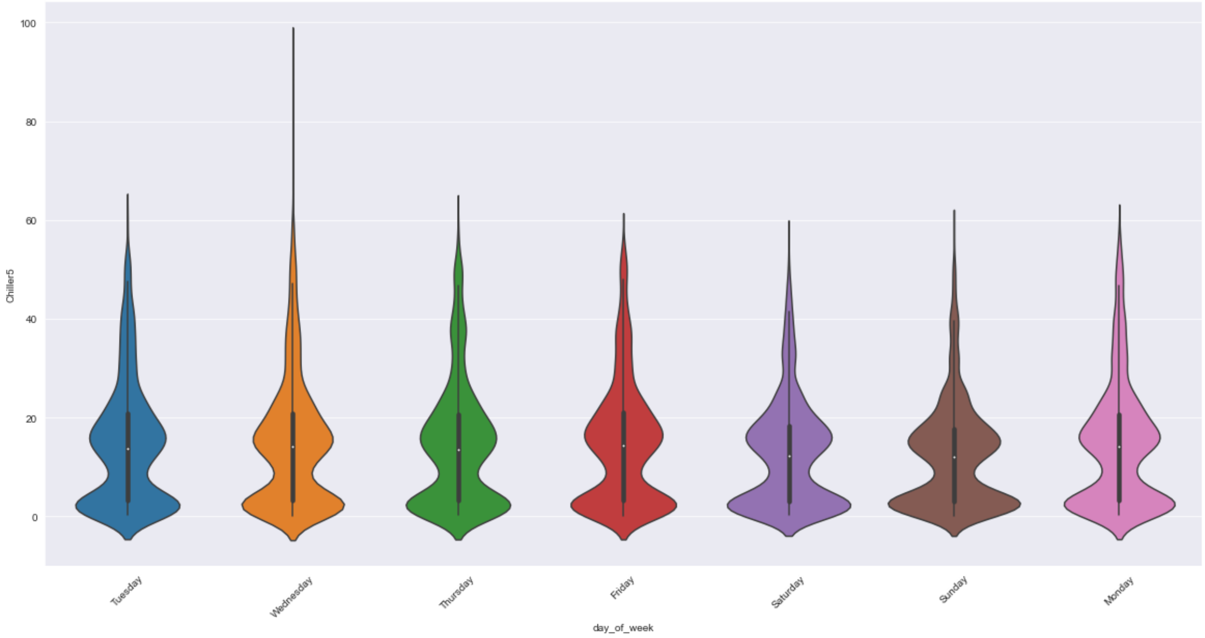


Figure 120. Violin plot of energy demand at Chiller 5 with respect to the day of the week

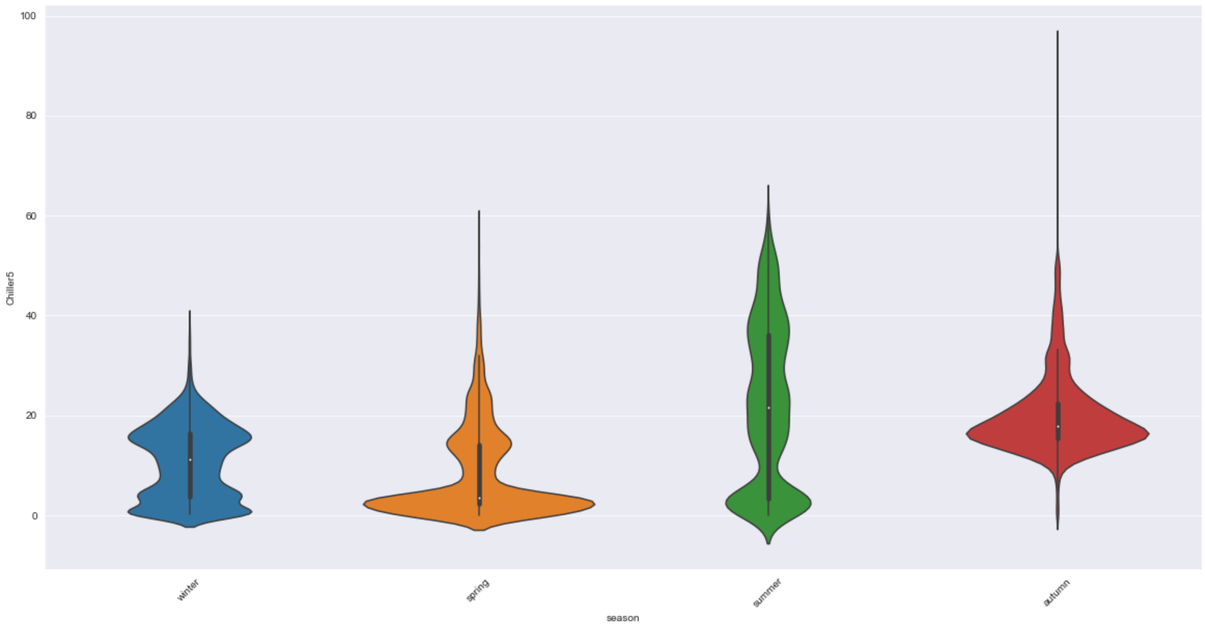


Figure 121. Violin plot of the energy demand at Chiller 5 with respect to the season of the year

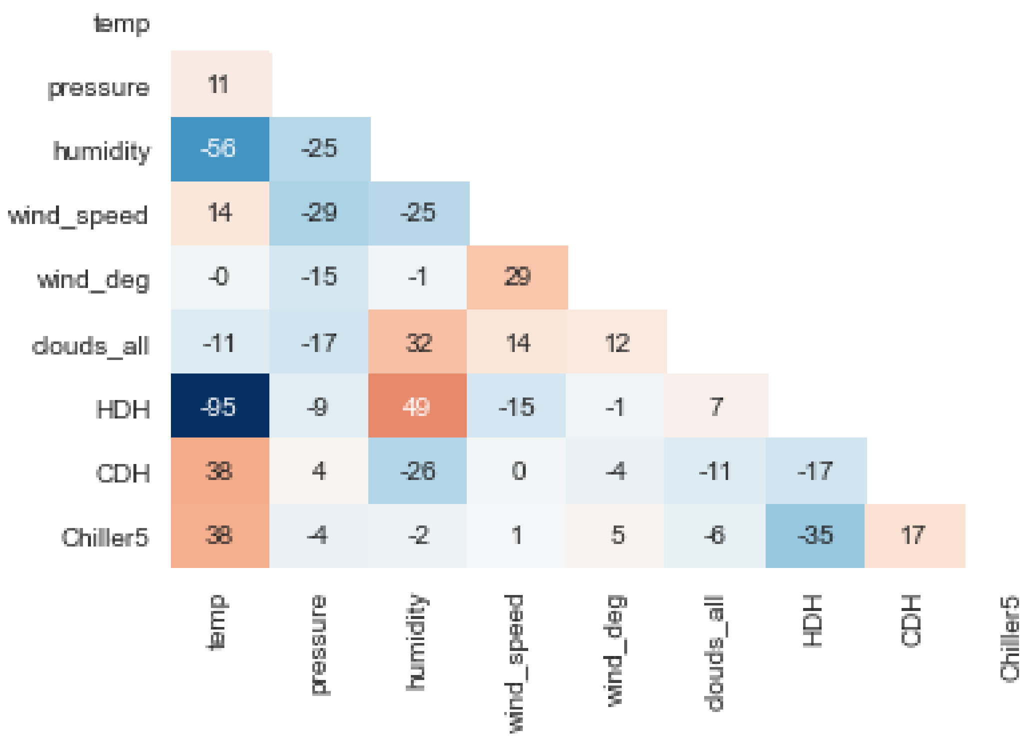


Figure 122. Correlation heat map of the continues variables accounting for the energy demand at Chiller 5

3.2.1.6 Chiller 6

Figure 123 presents the distribution and box plots of energy demand at Chiller 6. A number of outliers is observed. Figure 124 presents the bar plots of energy demand at Chiller 6 with respect to the days of the week, the months of the year and the weather type. Energy demand is higher during the summer. Thunderstorms during summer and autumn lead to higher energy demand at Chiller 6 as well. Figure 125 presents the effect of holiday, weekday and corona emergency period on the energy demand at Chiller 6. During holidays, slightly, less energy demand is observed. During the weekends, although the pattern of demand is similar, the range of energy demand is lower. During the corona emergency period the energy demand at Chiller 6 seems to be fixed to a value of around 40kWh. Figure 126 presents the effect of different weather type on energy demand at Chiller 6. Different patterns are observed. Figure 127 presents the effect of the day of the week on energy demand at Chiller 6. Lower range of demand is observed during weekends. Figure 128 presents the effect of the season on the energy demand at Chiller 6. The highest range is observed during summer and the lowest during autumn. Figure 129 presents the correlation heat map of the continuous variables used in this EDA, along with the energy demand at Chiller 6. Strong, positive, correlation is observed between the energy demand at Chiller 6 and the variable of temperature. Moderate, positive, correlation is observed between CDH and energy demand at Chiller 6. Moderate, negative correlation is observed between HDH and humidity and energy demand at Chiller 6.

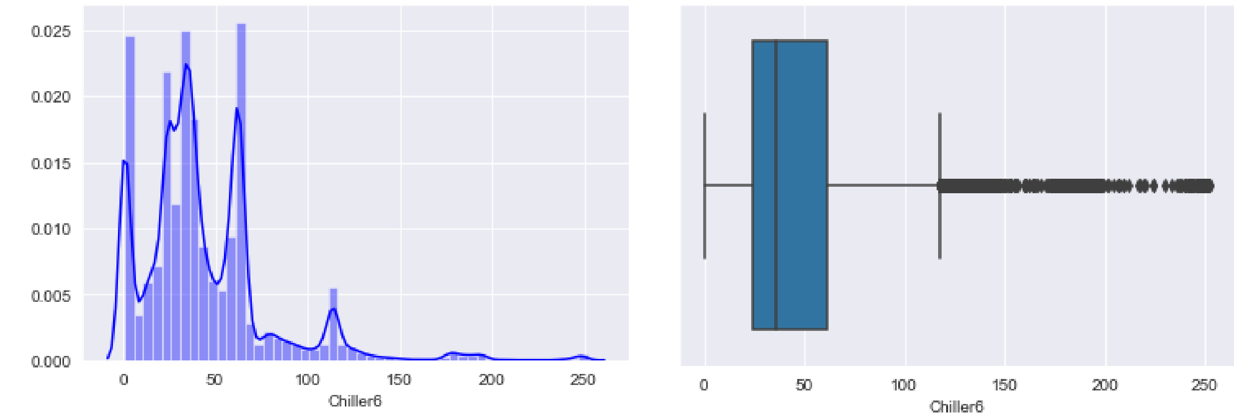


Figure 123. Distribution and box plots of energy demand at Chiller 6

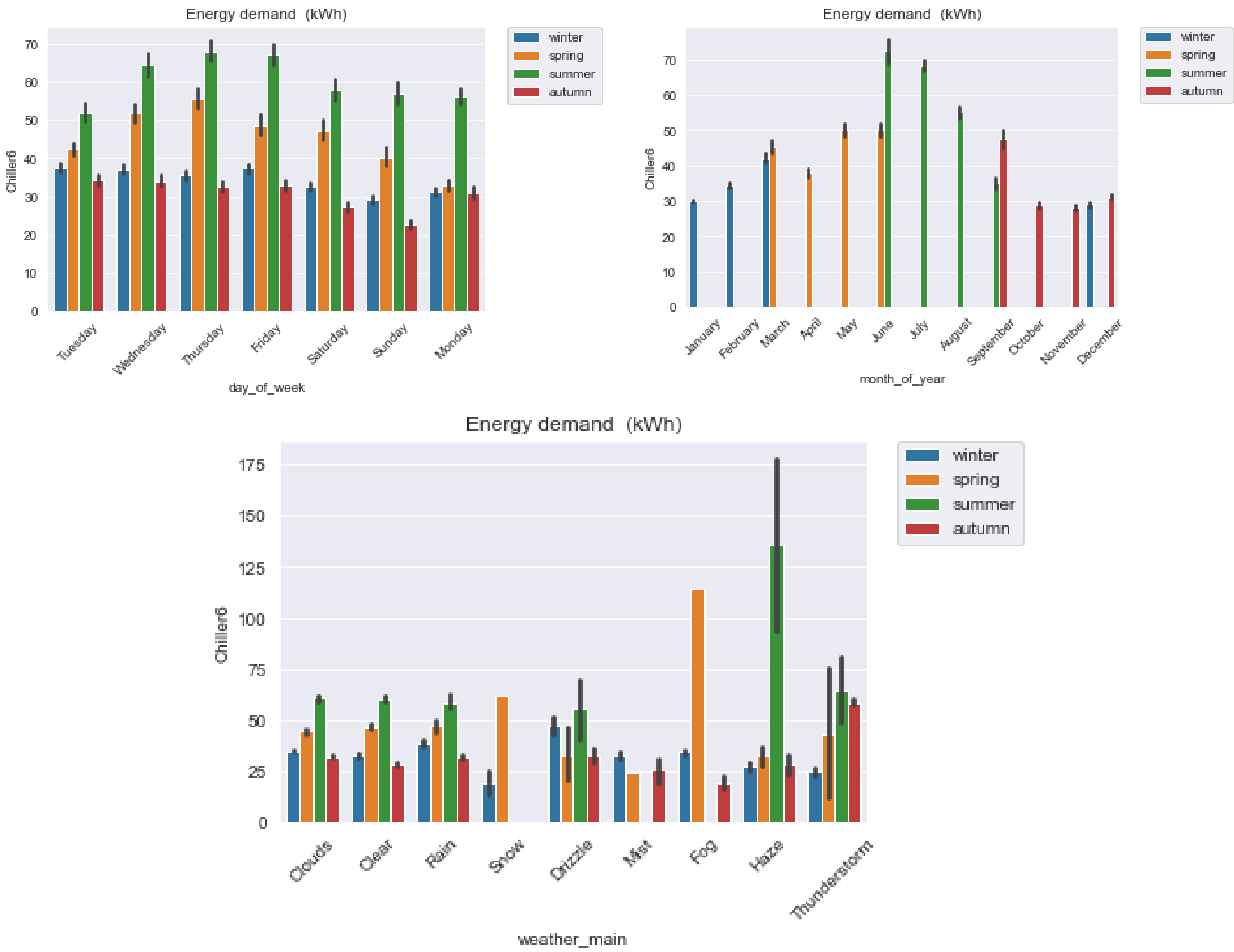


Figure 124. Bar plots of energy demand at Chiller 6 during different days, months and under different weather conditions with respect to the season of the year

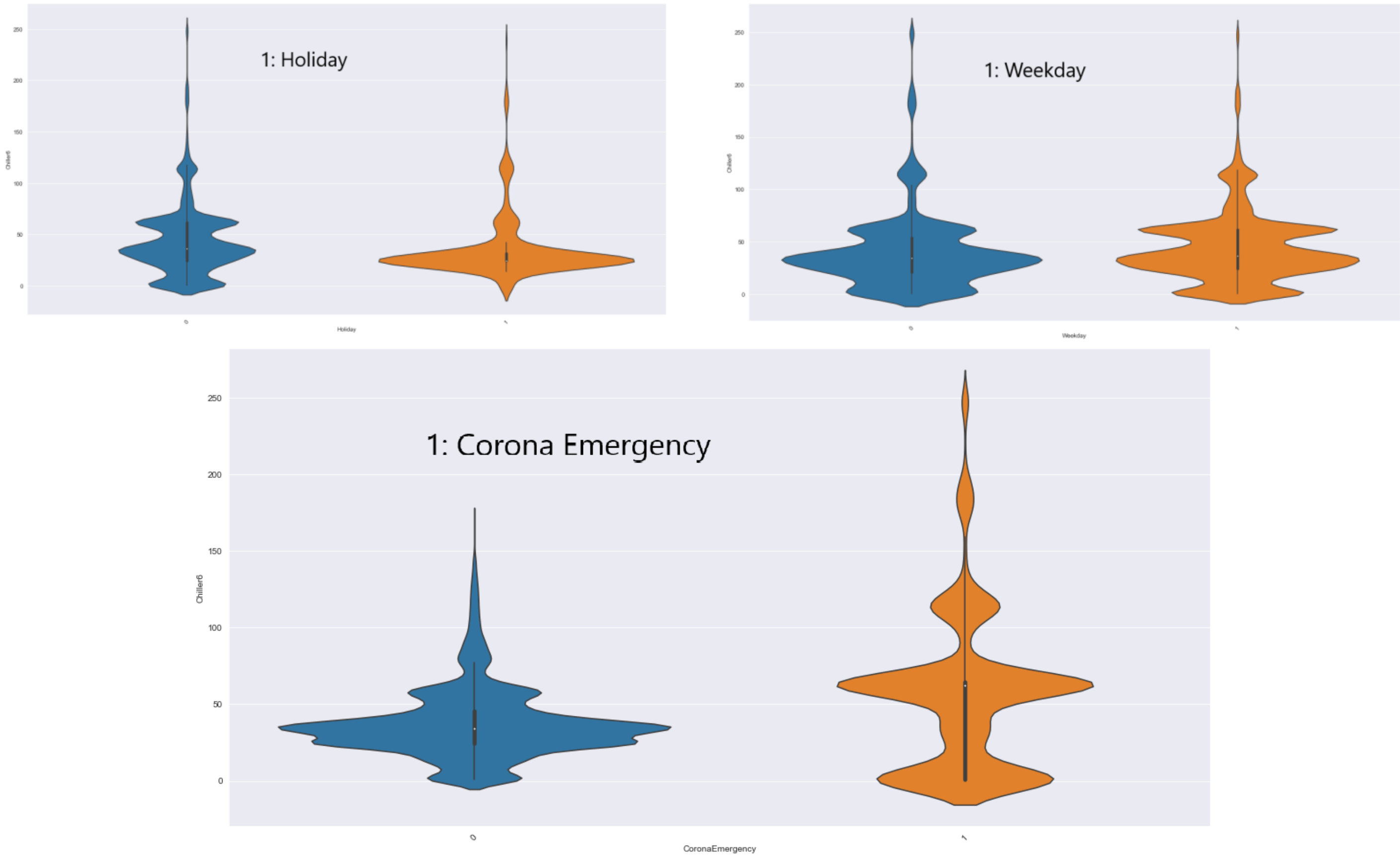


Figure 125. Violin plots of energy demand at Chiller 6 accounting for Holiday, Weekday and Coronavirus emergency indicator variables

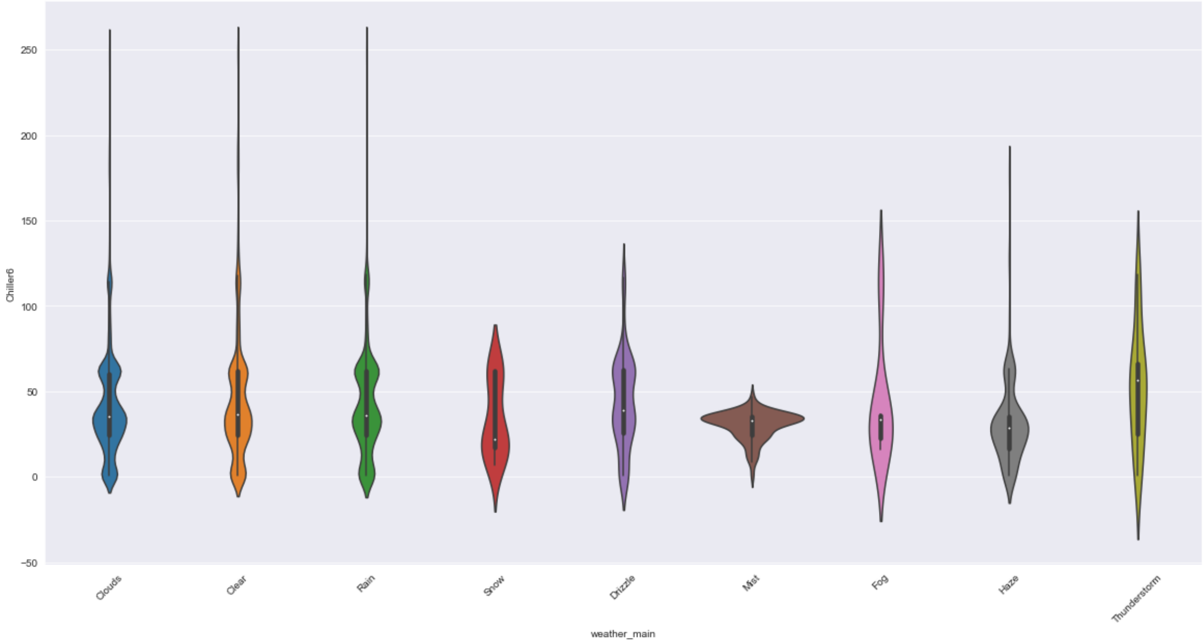


Figure 126. Violin plot of energy demand at Chiller 6 with respect to the type of weather present

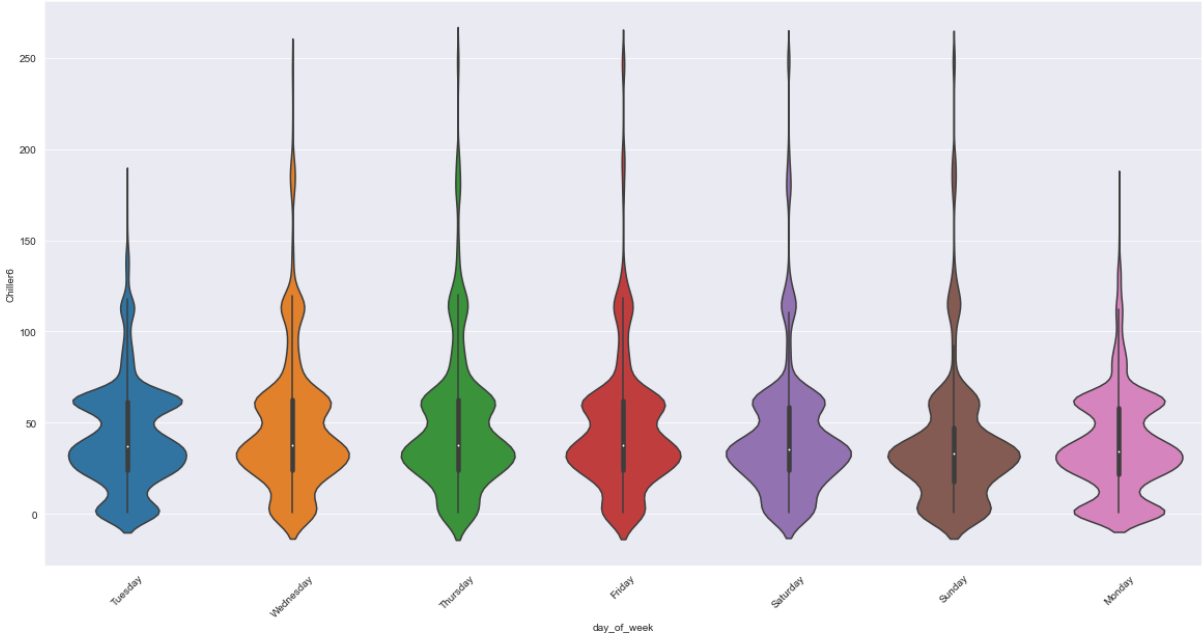


Figure 127. Violin plot of energy demand at Chiller 6 with respect to the day of the week

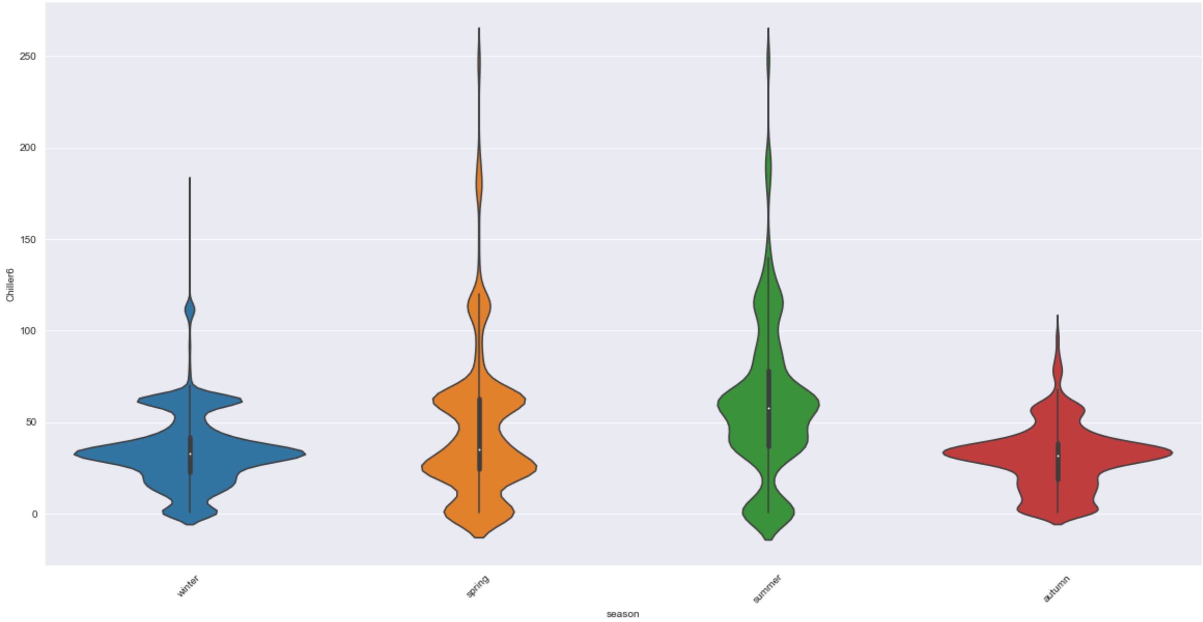


Figure 128. Violin plot of the energy demand at Chiller 6 with respect to the season of the year

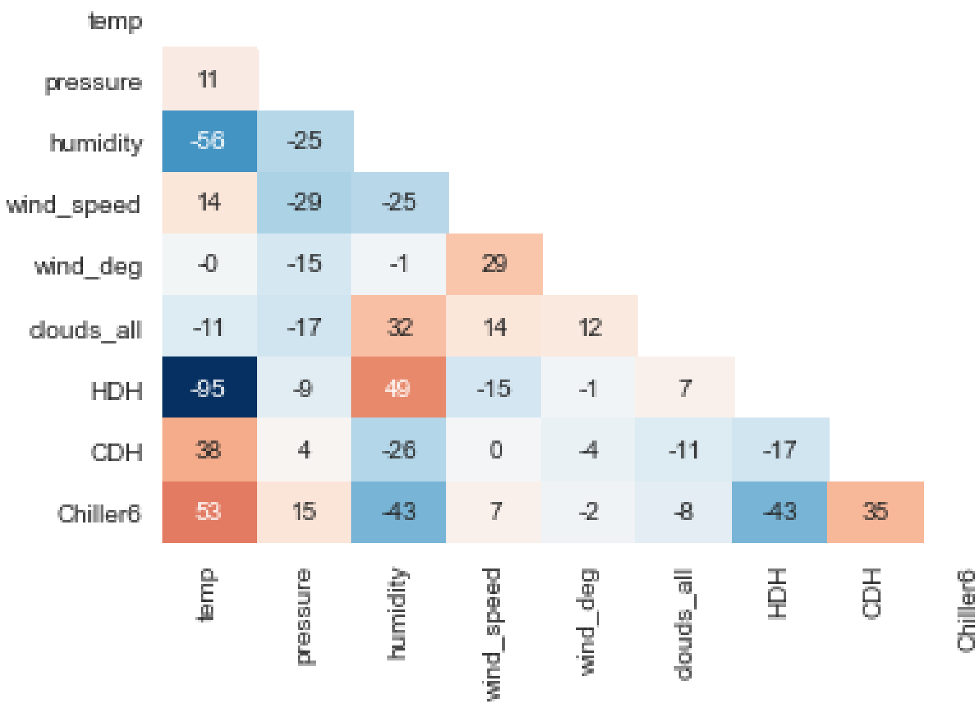


Figure 129. Correlation heat map of the continues variables accounting for the energy demand at Chiller 6

3.2.2 Apartment

The energy demand profile of a typical apartment at Kiwi pilot site was used for EDA and energy baseline purposes. The dataset with energy consumption readings was available with hourly granularity for a period of time spanning between 01/05/2019 and 31/07/2020. The aggregated historical electricity consumption was 8,923 kWh and the aggregate electricity procurement costs were [value of costs] €.

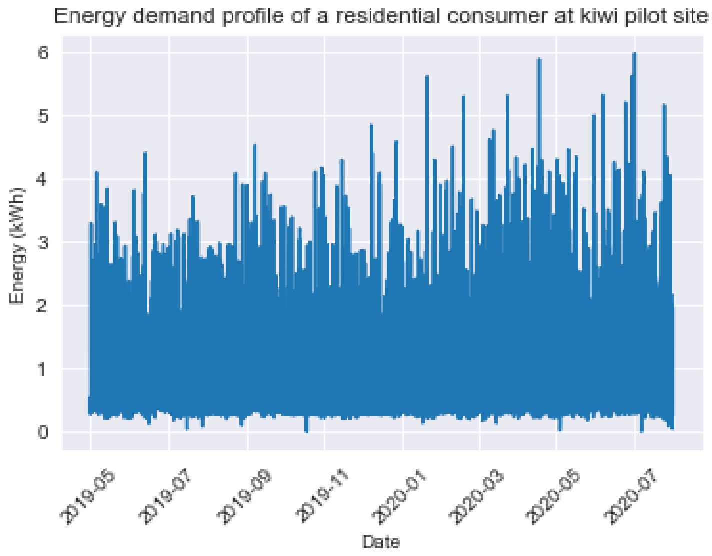


Figure 130. Load demand profile, for the period of analysis, for a residential consumer at Kiwi pilot site

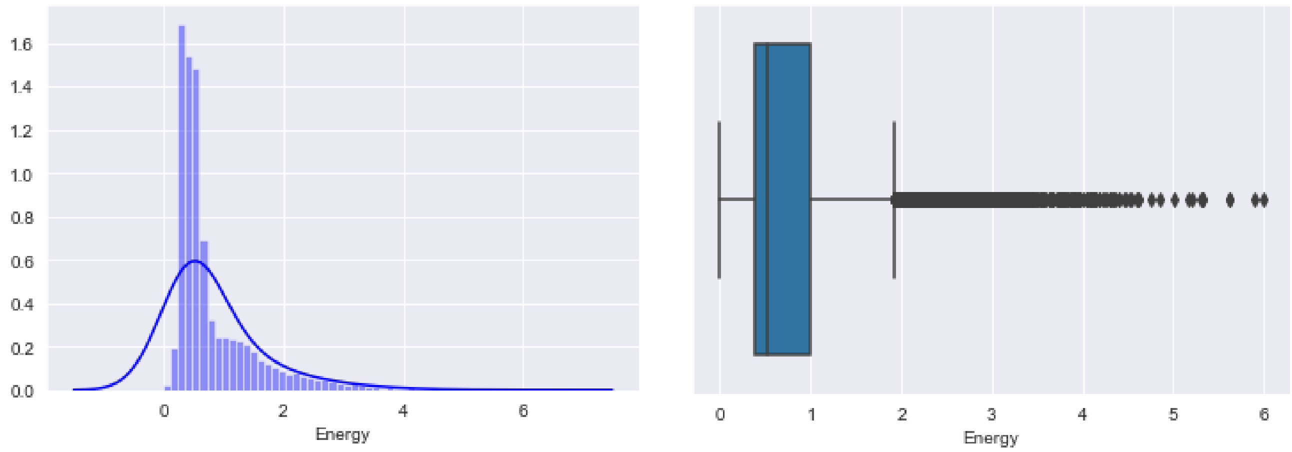


Figure 131. Distribution and box plots of energy demand for a residential consumer at Kiwi pilot site

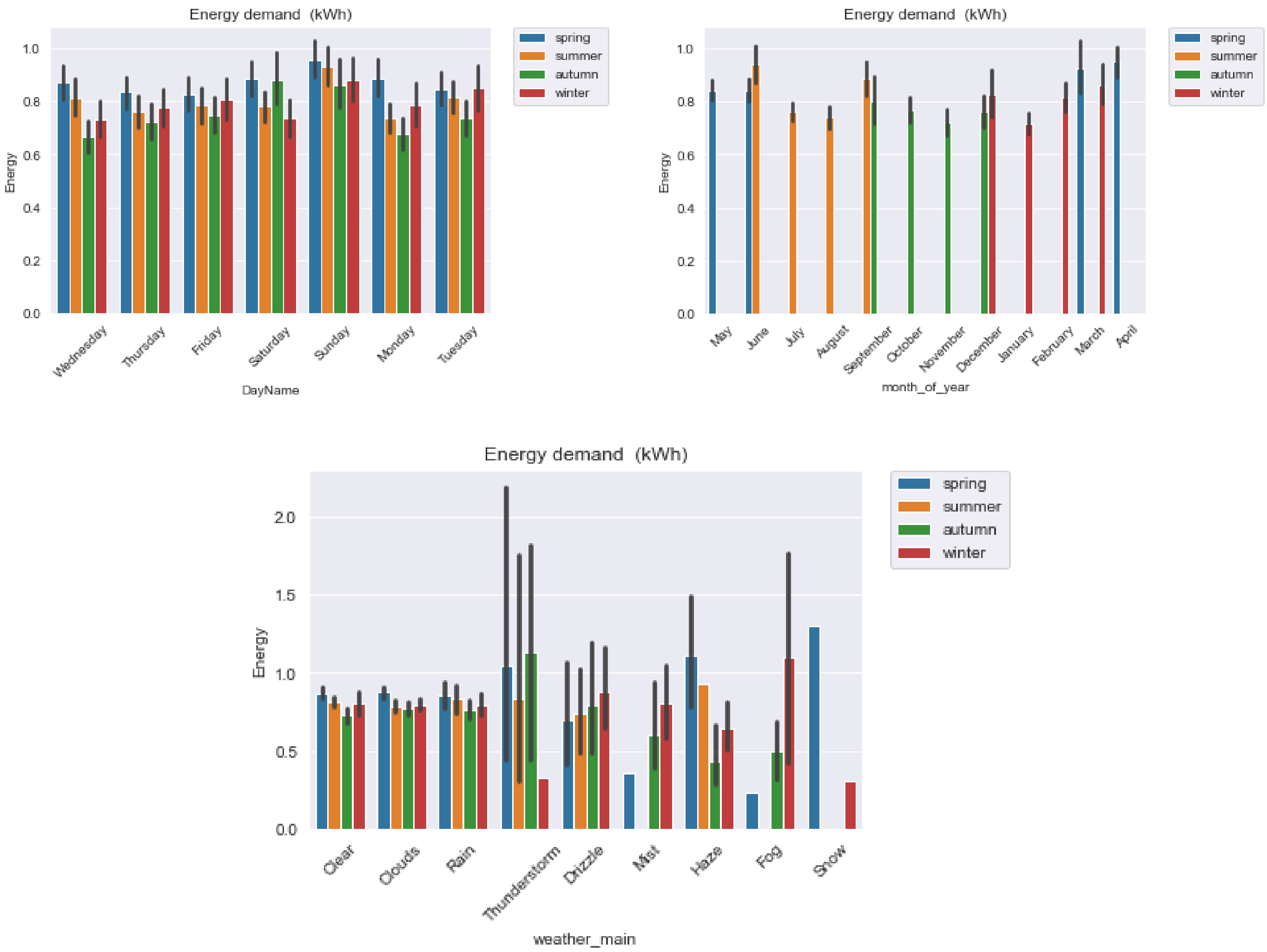
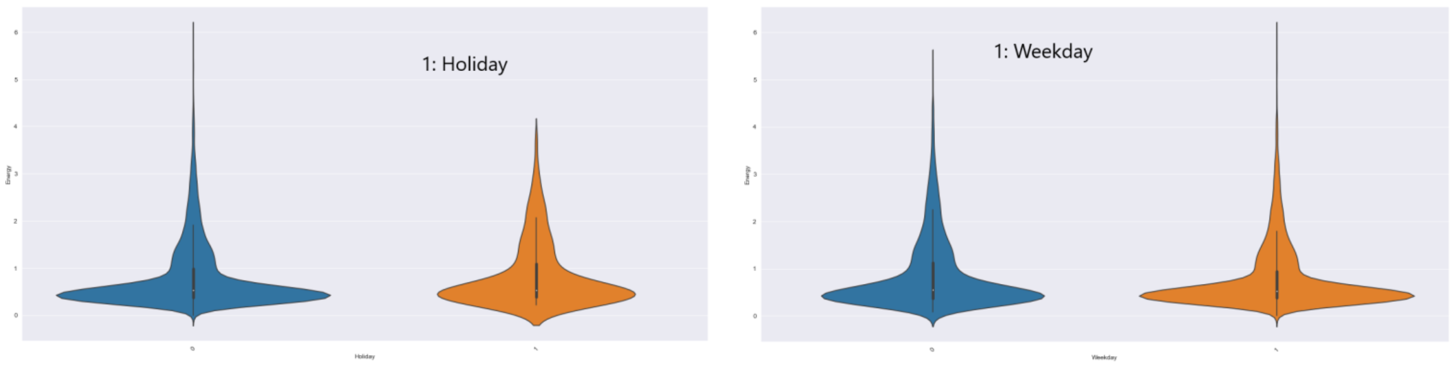


Figure 132. Bar plots of energy demand at the Apartment during different days, months and under different weather conditions with respect to the season of the year



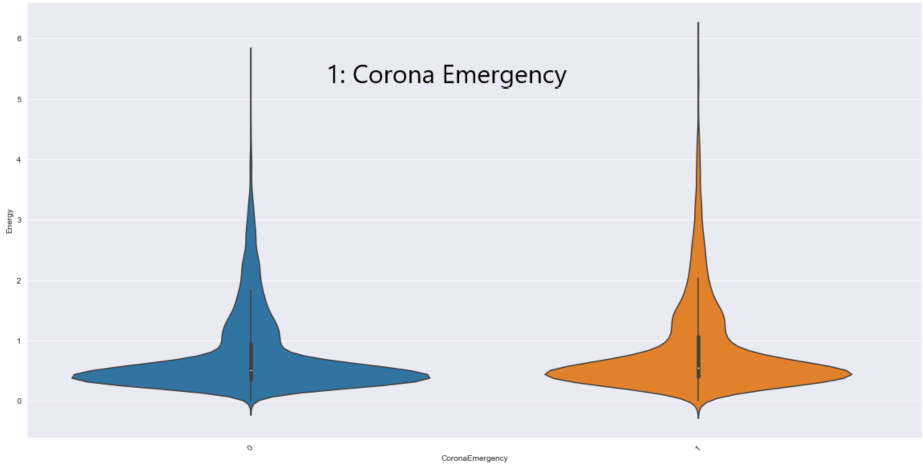


Figure 133. Violin plots of energy demand at the Apartment accounting for Holiday, Weekday and Coronavirus emergency indicator variables

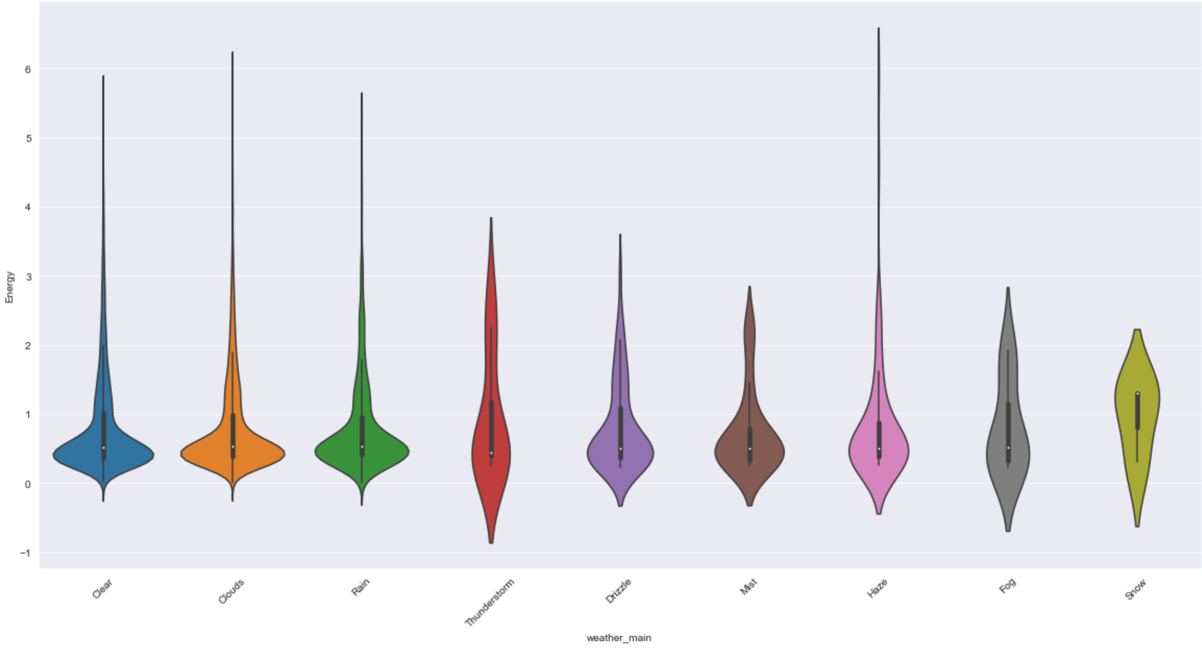


Figure 134. Violin plot of energy demand at the Apartment with respect to the type of weather present

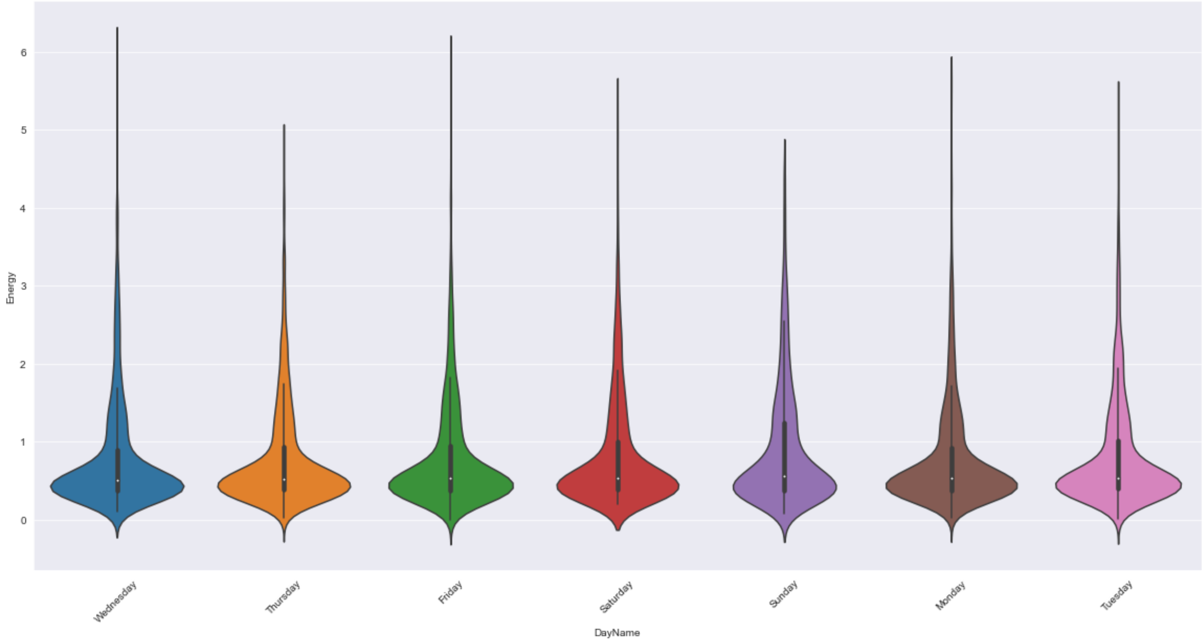


Figure 135. Violin plot of energy demand at the Apartment with respect to the day of the week

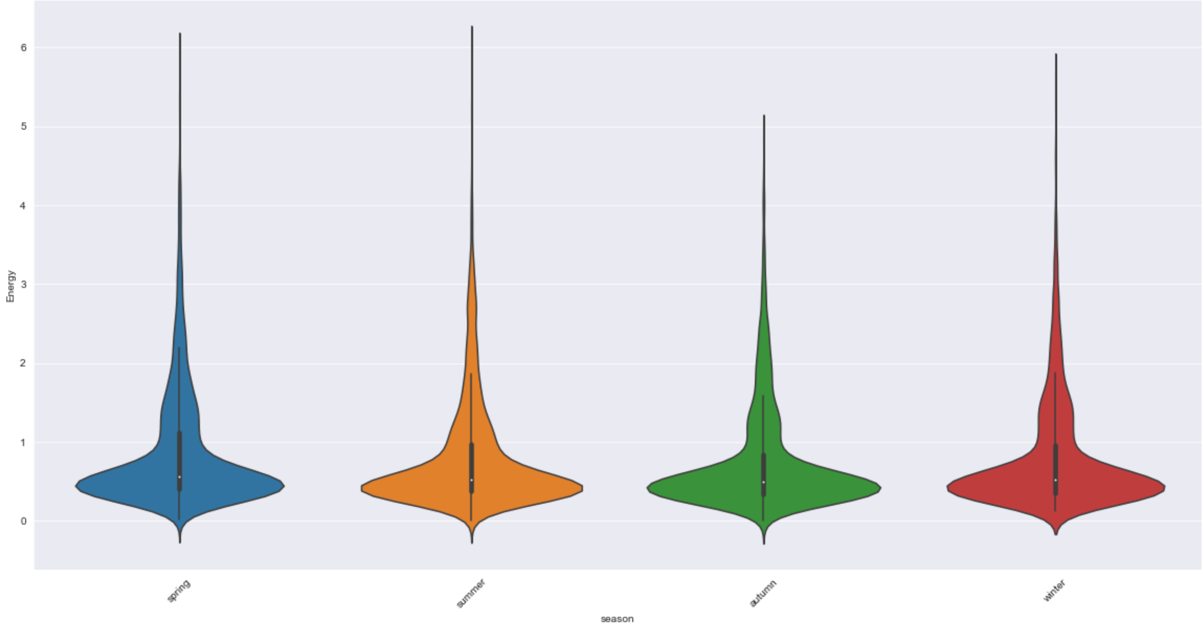


Figure 136. Violin plot of the energy demand at the Apartment with respect to the season of the year

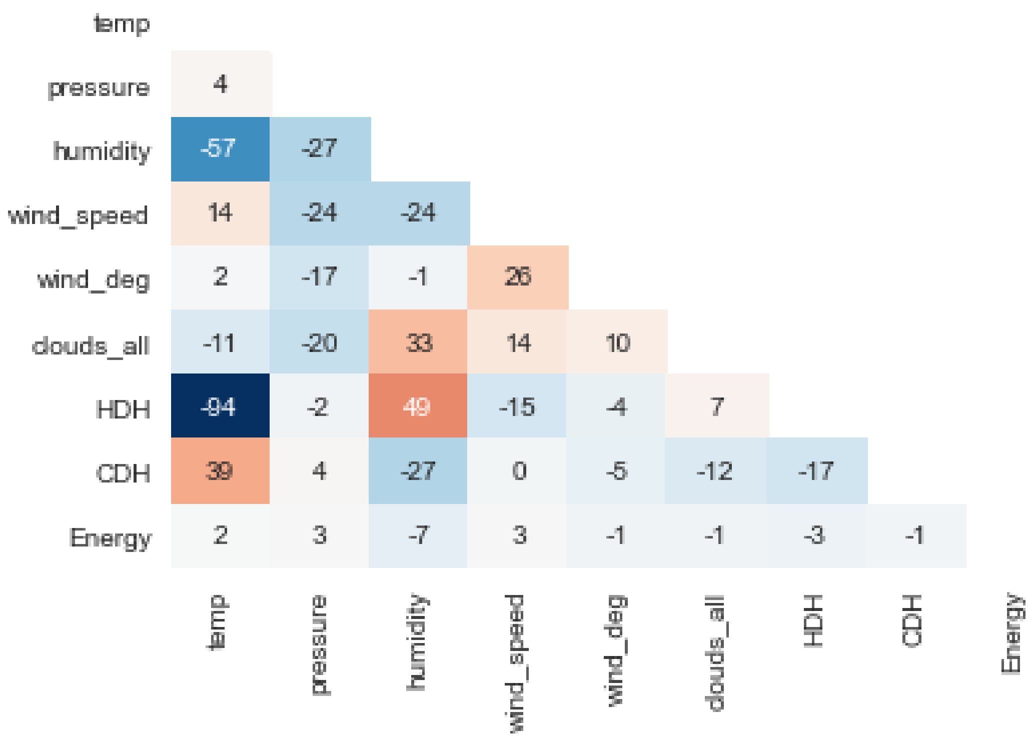


Figure 137. Correlation heat map of the continues variables accounting for the energy demand at the Apartment

3.3 Energy Baseline

In this chapter, the results of the application of multivariate linear regression models on the dataset for the assets in London Moor house and an apartment at Kiwi pilot site are presented. For the needs of the modelling work performed, all outlier values have been replace with the 85th quintile of the respective timeseries of energy demand.

3.3.1 Moor House

In this section, the results obtained from the application of multivariate linear regression technique on the dataset that was constructed for London Moor House assets for the needs of the report are presented.

3.3.1.1 Chiller 1

Table 20 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chiller 1 of London Moor House at Kiwi Pilot site.

Table 20. Linear Model coefficients for energy consumption in Chiller 1

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	89.039	19	month_of_year_January	-30.44
0	Temperature	1.11	20	month_of_year_February	-29.61
1	RH	0.05	21	month_of_year_March	-21.72
2	CoronaEmergency	17.70	22	month_of_year_April	5.18
3	HDH	0.66	23	month_of_year_May	-0.29
4	CDH	2.36	24	month_of_year_June	-22.14
5	day_of_month	-0.11	25	month_of_year_July	-19.30
6	hour_of_day	0.00	26	month_of_year_August	0.64
7	minute_of_day	0.00	27	month_of_year_September	37.49

8	day_of_year	-0.14	28	month_of_year_October	28.08
9	week_of_year	0.15	29	month_of_year_November	31.62
10	weekday_indicator	0.54	30	month_of_year_December	20.50
11	weekday_Monday_indicator	-0.11	31	season_winter_indicator	-7.85
12	weekday_Tuesday_indicator	1.06	32	season_spring_indicator	12.21
13	weekday_Wednesday_indicator	0.68	33	season_summer_indicator	21.74
14	weekday_Thursday_indicator	-0.12	34	season_autumn_indicator	-7.85
15	weekday_Friday_indicator	-0.97			
16	weekday_Saturday_indicator	0.02			
17	weekday_Sunday_indicator	-0.57			
18	holiday_indicator	15.54			

Figure 138 graphically illustrates the information presented in Table 20. The value of 0.500 for the adjusted R^2 metric indicates that the multivariate linear regression model can moderately explain the variance of energy demand in the Chiller 1 of London Moor House at Kiwi pilot site. The use of control buildings for energy baseline validation purposes must accompany the validation of results during pilot deployment activities.

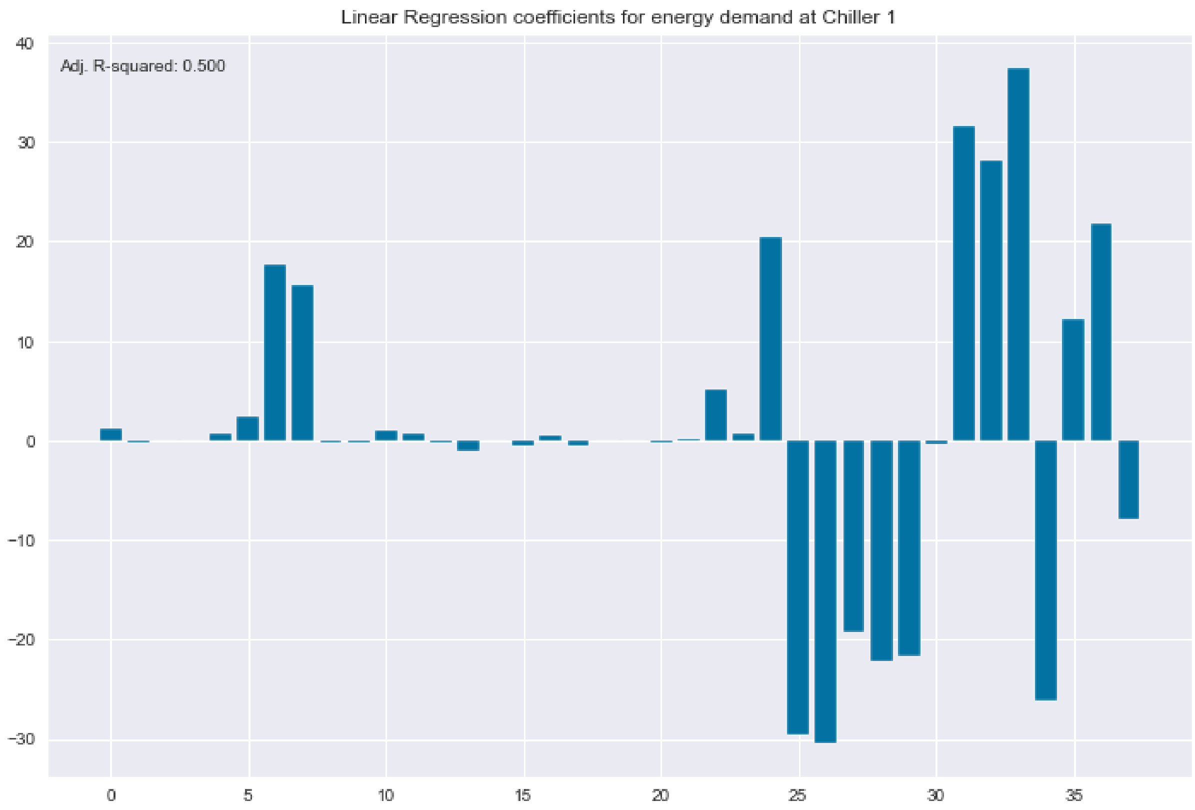


Figure 138. Relative importance of the linear regression coefficients for energy consumption at Chiller 1

3.3.1.2 Chiller 2

Table 21 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chiller 2 of London Moor House at Kiwi Pilot site.

Table 21. Linear Model coefficients for energy consumption in Chiller 2

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-21.87	19	month_of_year_January	34.56
0	Temperature	2.29	20	month_of_year_February	38.76
1	RH	-0.20	21	month_of_year_March	33.79
2	CoronaEmergency	-18.17	22	month_of_year_April	24.57
3	HDH	1.01	23	month_of_year_May	9.02
4	CDH	-0.48	24	month_of_year_June	16.76
5	day_of_moth	-0.09	25	month_of_year_July	-3.42
6	hour_of_day	-0.27	26	month_of_year_August	-7.07
7	minute_of_day	0.00	27	month_of_year_September	-30.72
8	day_of_year	0.18	28	month_of_year_October	-44.00
9	week_of_year	0.06	29	month_of_year_November	-29.18
10	weekday_indicator	2.90	30	month_of_year_December	-43.08
11	weekday_Monday_indicator	-3.64	31	season_winter_indicator	2.03
12	weekday_Tuesday_indicator	-0.29	32	season_spring_indicator	-6.51
13	weekday_Wednesday_indicator	2.35	33	season_summer_indicator	-5.90
14	weekday_Thursday_indicator	2.68	34	season_autumn_indicator	10.40
15	weekday_Friday_indicator	1.80			
16	weekday_Saturday_indicator	0.34			
17	weekday_Sunday_indicator	-3.24			
18	holiday_indicator	-4.84			

Figure 139 graphically illustrates the information presented in Table 21. The value of 0.248 for the adjusted R^2 metric indicates that the multivariate linear regression model can poorly explain the variance of energy demand in the Chiller 2 of London Moor House at Kiwi pilot site. The use of control buildings for energy baseline validation purposes must accompany the validation of results during pilot deployment activities.

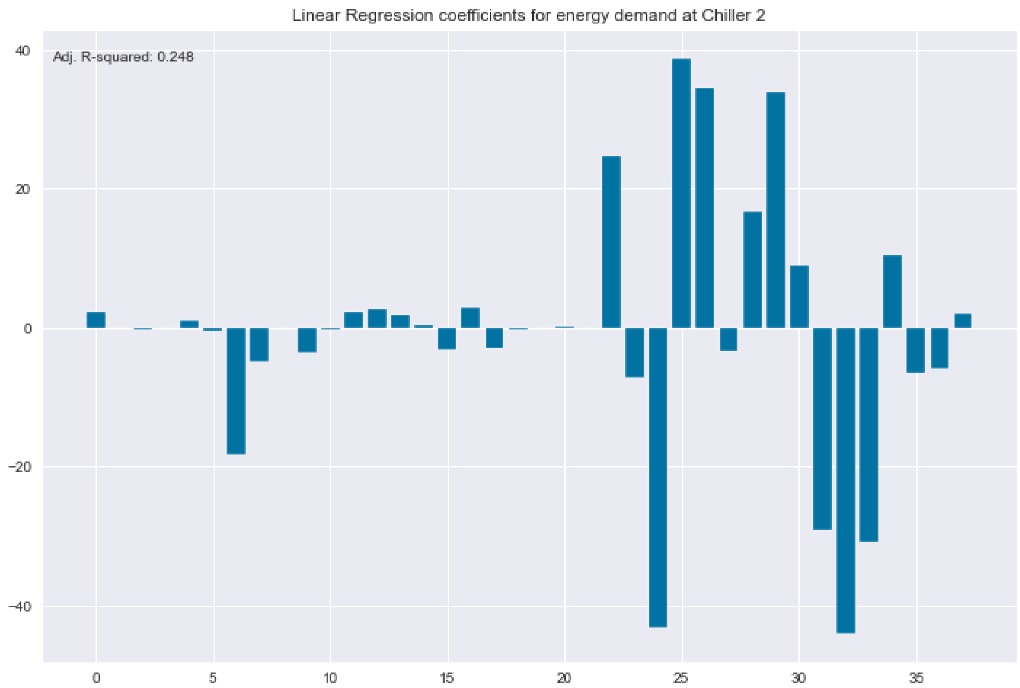


Figure 139. Relative importance of the linear regression coefficients for energy consumption at Chiller 2

3.3.1.3 Chiller 3

Table 22 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chiller 3 of London Moor House at Kiwi Pilot site.

Table 22. Linear Model coefficients for energy consumption in Chiller 3

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	16.19	19	month_of_year_January	7.64
0	Temperature	3.04	20	month_of_year_February	7.63
1	RH	-0.43	21	month_of_year_March	5.28
2	CoronaEmergency	-6.06	22	month_of_year_April	-1.45
3	HDH	1.26	23	month_of_year_May	6.94
4	CDH	-2.04	24	month_of_year_June	5.32
5	day_of_moth	0.16	25	month_of_year_July	12.96
6	hour_of_day	-0.14	26	month_of_year_August	-5.30
7	minute_of_day	0.00	27	month_of_year_September	-13.43
8	day_of_year	-0.03	28	month_of_year_October	-18.09
9	week_of_year	-0.11	29	month_of_year_November	-4.39
10	weekday_indicator	7.94	30	month_of_year_December	-3.12
11	weekday_Monday_indicator	-5.73	31	season_winter_indicator	-0.67
12	weekday_Tuesday_indicator	2.57	32	season_spring_indicator	-5.83
13	weekday_Wednesday_indicator	2.65	33	season_summer_indicator	-3.96
14	weekday_Thursday_indicator	4.30	34	season_autumn_indicator	10.46
15	weekday_Friday_indicator	4.20			
16	weekday_Saturday_indicator	-0.67			
17	weekday_Sunday_indicator	-7.27			
18	holiday_indicator	-7.26			

Figure 140 graphically illustrates the information presented in Table 22. The value of 0.268 for the adjusted R^2 metric indicates that the multivariate linear regression model can poorly explain the variance of energy demand in the Chiller 3 of London Moor House at Kiwi pilot site. The use of control buildings for energy baseline validation purposes must accompany the validation of results during pilot deployment activities.

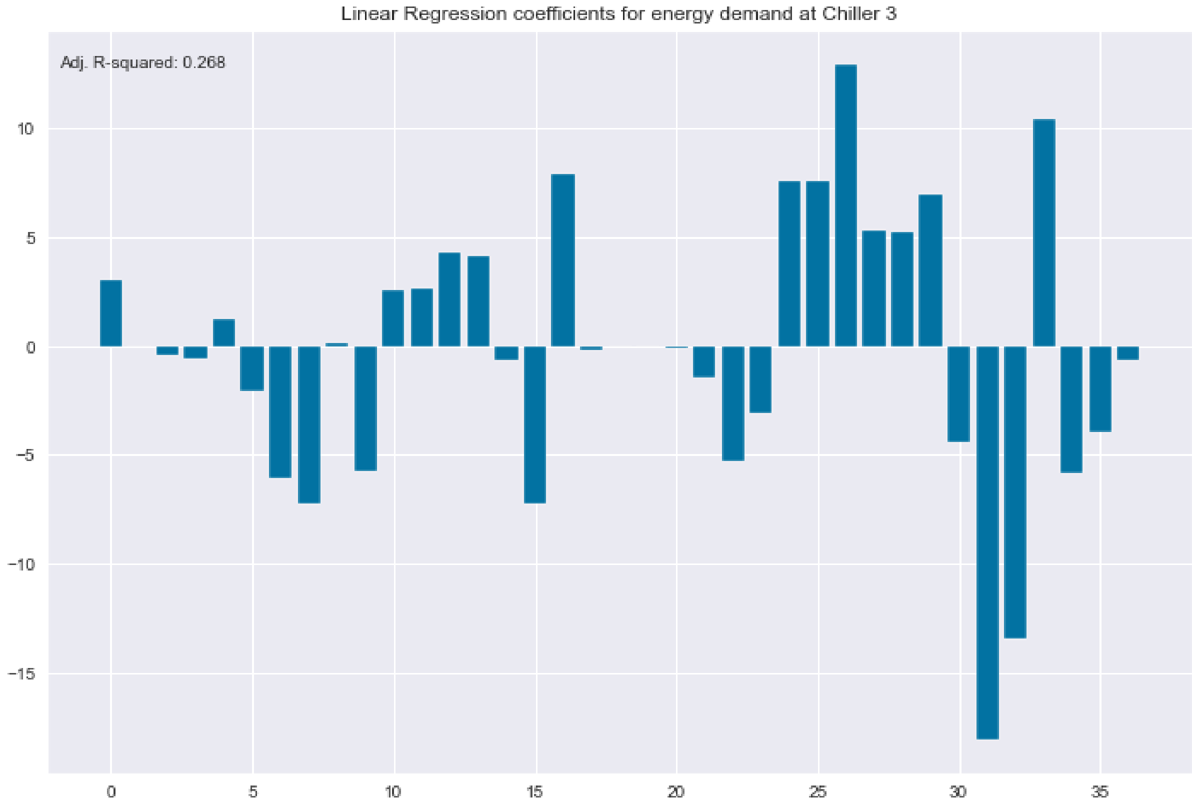


Figure 140. Relative importance of the linear regression coefficients for energy consumption at Chiller 3

3.3.1.4 Chiller 4

Table 23 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chiller 4 of London Moor House at Kiwi Pilot site.

Table 23. Linear Model coefficients for energy consumption in Chiller 4

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	0.25	19	month_of_year_January	8.68
0	Temperature	3.27	20	month_of_year_February	12.27
1	RH	-0.19	21	month_of_year_March	-1.79
2	CoronaEmergency	-19.20	22	month_of_year_April	-14.43
3	HDH	0.61	23	month_of_year_May	-20.31
4	CDH	-1.49	24	month_of_year_June	-0.62
5	day_of_moth	0.03	25	month_of_year_July	25.25
6	hour_of_day	-0.29	26	month_of_year_August	16.61
7	minute_of_day	0.00	27	month_of_year_September	9.86
8	day_of_year	0.10	28	month_of_year_October	13.20
9	week_of_year	-0.10	29	month_of_year_November	-19.31
10	weekday_indicator	8.01	30	month_of_year_December	-29.42
11	weekday_Monday_indicator	-0.68	31	season_winter_indicator	-2.32
12	weekday_Tuesday_indicator	-0.34	32	season_spring_indicator	-6.99
13	weekday_Wednesday_indicator	3.30	33	season_summer_indicator	3.54
14	weekday_Thursday_indicator	4.27	34	season_autumn_indicator	5.77
15	weekday_Friday_indicator	1.46			
16	weekday_Saturday_indicator	-2.26			
17	weekday_Sunday_indicator	-5.75			
18	holiday_indicator	-3.18			

Figure 141 graphically illustrates the information presented in Table 23. The value of 0.613 for the adjusted R^2 metric indicates that the multivariate linear regression model can moderately explain the variance of energy demand in the Chiller 2 of London Moor House at Kiwi pilot site. The use of control buildings for energy baseline validation purposes must accompany the validation of results during pilot deployment activities.

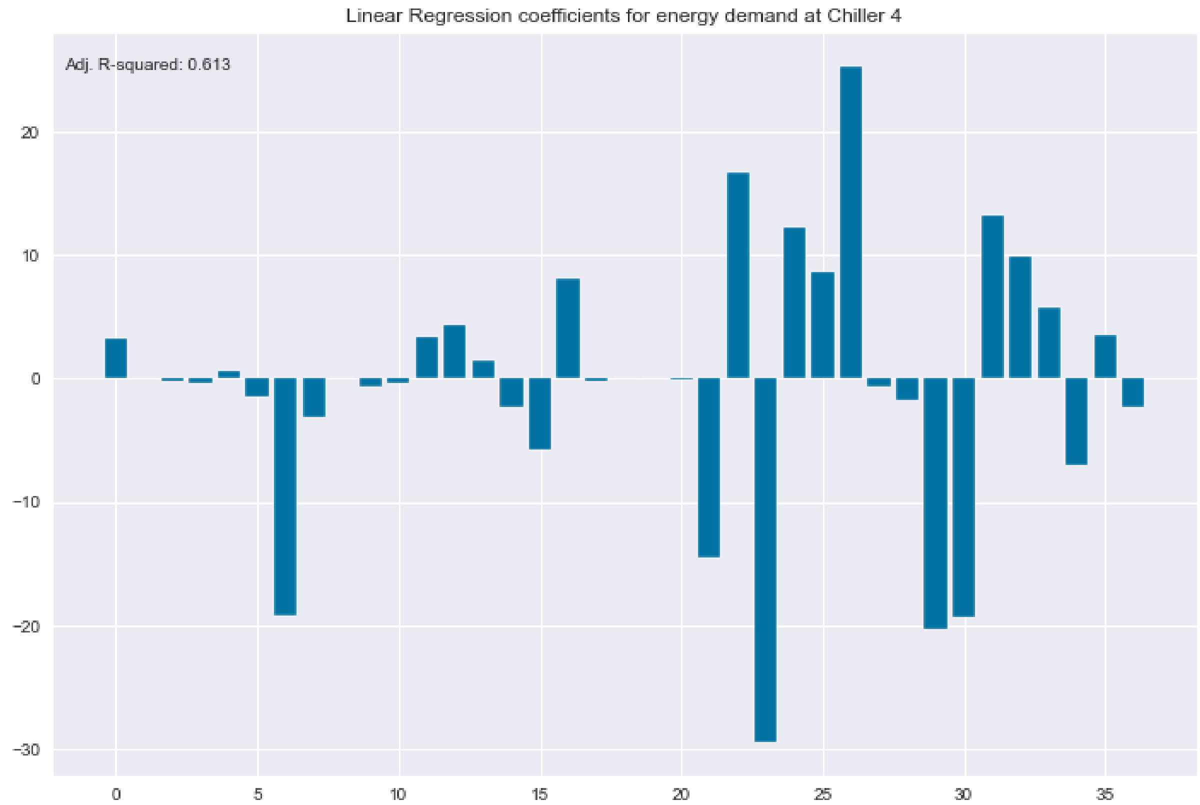


Figure 141. Relative importance of the linear regression coefficients for energy consumption at Chiller 4

3.3.1.5 Chiller 5

Table 24 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chiller 5 of London Moor House at Kiwi Pilot site.

Table 24. Linear Model coefficients for energy consumption in Chiller 5

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-12.91	19	month_of_year_January	-9.02
0	Temperature	0.99	20	month_of_year_February	-5.47
1	RH	0.00	21	month_of_year_March	-8.70
2	CoronaEmergency	-13.49	22	month_of_year_April	-9.53
3	HDH	0.12	23	month_of_year_May	-7.91
4	CDH	-0.23	24	month_of_year_June	-4.59
5	day_of_moth	0.02	25	month_of_year_July	-2.13
6	hour_of_day	-0.08	26	month_of_year_August	10.00
7	minute_of_day	0.00	27	month_of_year_September	10.66
8	day_of_year	-0.05	28	month_of_year_October	7.28
9	week_of_year	0.04	29	month_of_year_November	8.76

10	weekday_indicator	1.34	30	month_of_year_December	10.64
11	weekday_Monday_indicator	0.03	31	season_winter_indicator	0.09
12	weekday_Tuesday_indicator	0.42	32	season_spring_indicator	0.51
13	weekday_Wednesday_indicator	0.54	33	season_summer_indicator	-0.94
14	weekday_Thursday_indicator	0.25	34	season_autumn_indicator	0.34
15	weekday_Friday_indicator	0.12			
16	weekday_Saturday_indicator	-0.56			
17	weekday_Sunday_indicator	-0.79			
18	holiday_indicator	-0.80			

Figure 142 graphically illustrates the information presented in Table 24. The value of 0.703 for the adjusted R^2 metric indicates that the multivariate linear regression model can adequately explain the variance of energy demand in the Chiller 2 of London Moor House at Kiwi pilot site. The use of control buildings for energy baseline validation purposes shall accompany the validation of results during pilot deployment activities.

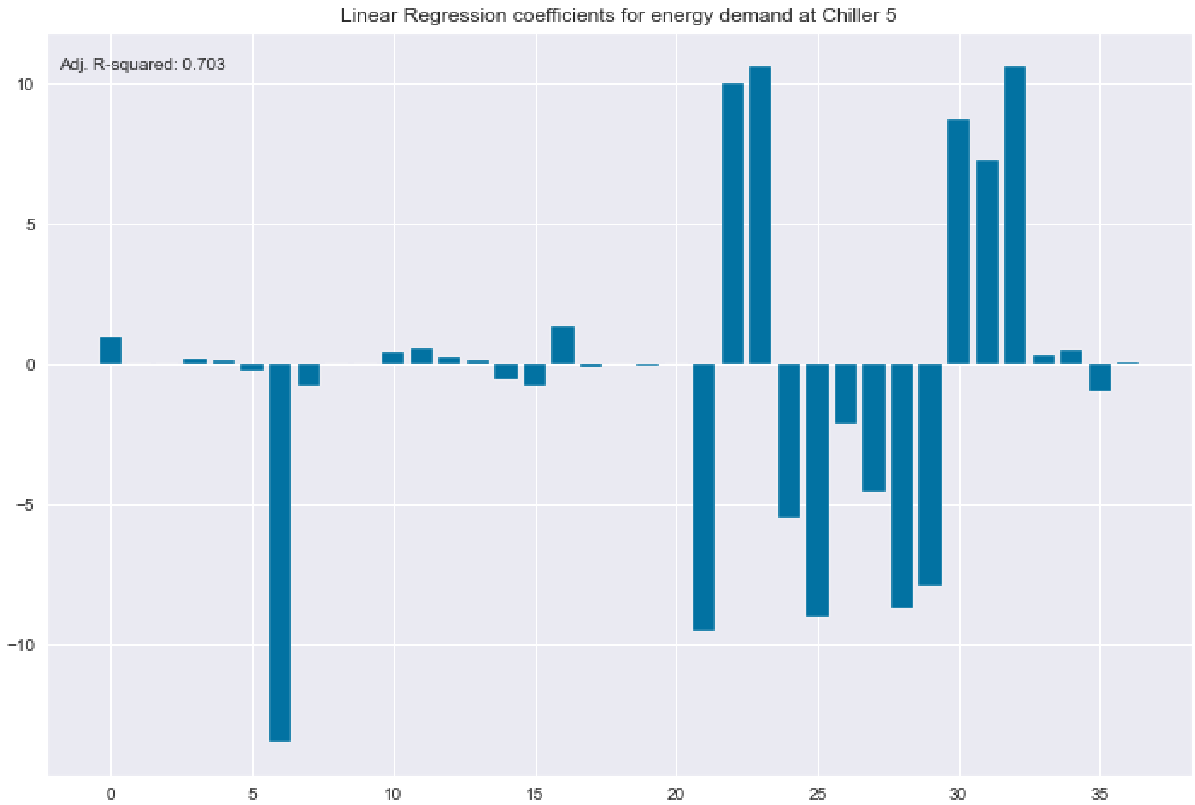


Figure 142. Relative importance of the linear regression coefficients for energy consumption at Chiller 5

3.3.1.6 Chiller 6

Table 25 presents the linear model coefficients for the multivariate linear regression models for the energy demand in Chiller 6 of London Moor House at Kiwi Pilot site.

Table 25. Linear Model coefficients for energy consumption in Chiller 6

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-74.52	19	month_of_year_January	13.07
0	Temperature	5.32	20	month_of_year_February	8.32
1	RH	-0.24	21	month_of_year_March	14.00
2	CoronaEmergency	8.68	22	month_of_year_April	1.53

3	HDH	2.68	23	month_of_year_May	-1.42
4	CDH	-1.94	24	month_of_year_June	1.44
5	day_of_moth	0.06	25	month_of_year_July	3.56
6	hour_of_day	-0.51	26	month_of_year_August	-1.21
7	minute_of_day	0.00	27	month_of_year_September	-10.41
8	day_of_year	0.02	28	month_of_year_October	-18.40
9	week_of_year	0.10	29	month_of_year_November	-7.32
10	weekday_indicator	3.46	30	month_of_year_December	-3.16
11	weekday_Monday_indicator	-5.53	31	season_winter_indicator	1.46
12	weekday_Tuesday_indicator	-0.74	32	season_spring_indicator	-3.83
13	weekday_Wednesday_indicator	3.45	33	season_summer_indicator	-6.04
14	weekday_Thursday_indicator	3.82	34	season_autumn_indicator	8.41
15	weekday_Friday_indicator	2.48			
16	weekday_Saturday_indicator	0.04			
17	weekday_Sunday_indicator	-3.51			
18	holiday_indicator	-3.92			

Figure 143 graphically illustrates the information presented in Table 25. The value of 0.404 for the adjusted R^2 metric indicates that the multivariate linear regression model can moderately explain the variance of energy demand in the Chiller 2 of London Moor House at Kiwi pilot site. The use of control buildings for energy baseline validation purposes must accompany the validation of results during pilot deployment activities.

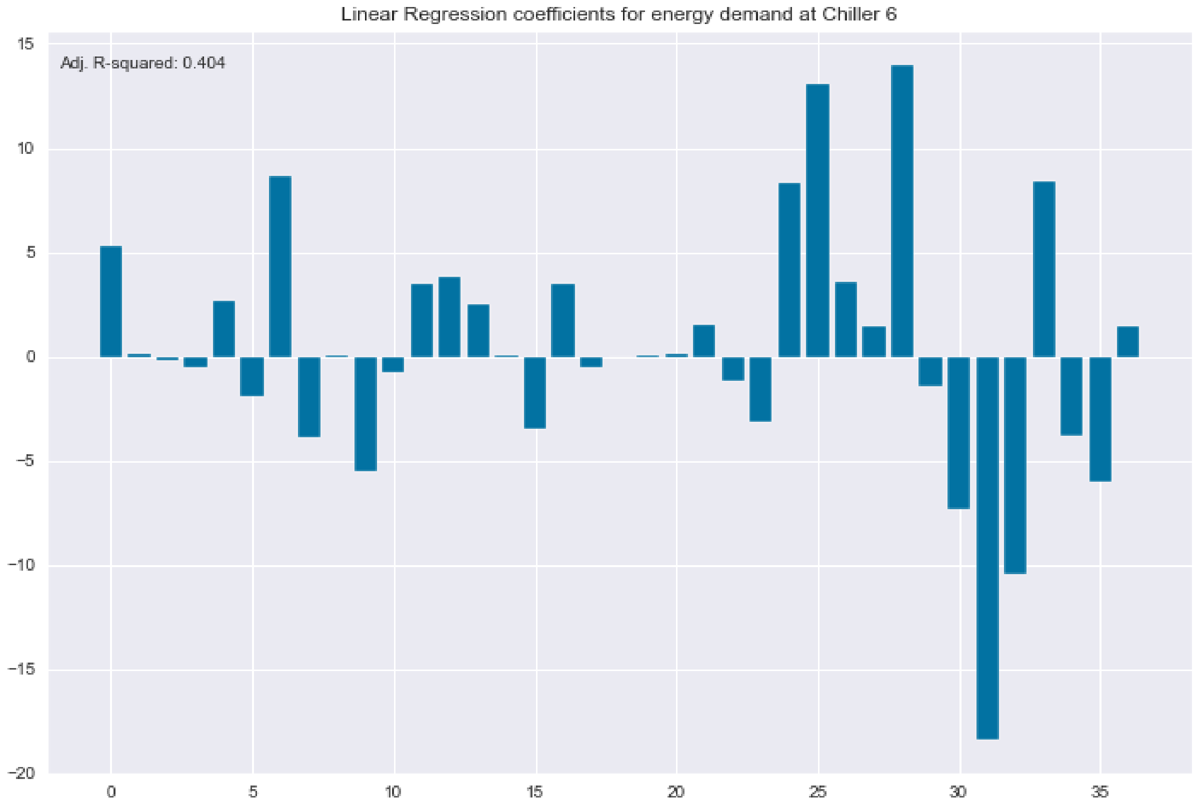


Figure 143. Relative importance of the linear regression coefficients for energy consumption at Chiller 6

3.3.2 Apartment

In this section, the results obtained from the application of multivariate linear regression technique on the dataset that was constructed for an apartment for the needs of the report are presented.

Table 26 presents the linear model coefficients for the multivariate linear regression models for the energy demand in a typical apartment at Kiwi Pilot site.

Table 26. Linear Model coefficients for energy consumption in an apartment

Index	Coefficient	Value	Index	Coefficient	Value
	Constant	-16.59	19	month_of_year_January	27.88
0	Temperature	-0.03	20	month_of_year_February	22.90
1	RH	0.00	21	month_of_year_March	18.08
2	CoronaEmergency	-0.14	22	month_of_year_April	12.94
3	HDH	0.00	23	month_of_year_May	7.84
4	CDH	0.00	24	month_of_year_June	2.65
5	day_of_moth	-0.17	25	month_of_year_July	-2.55
6	hour_of_day	0.04	26	month_of_year_August	-7.74
7	minute_of_day	0.00	27	month_of_year_September	-12.84
8	day_of_year	0.17	28	month_of_year_October	-17.90
9	week_of_year	0.00	29	month_of_year_November	-23.13
10	weekday_indicator	-0.04	30	month_of_year_December	-28.14
11	weekday_Monday_indicator	-0.02	31	season_winter_indicator	-0.02
12	weekday_Tuesday_indicator	0.02	32	season_spring_indicator	-0.02
13	weekday_Wednesday_indicator	-0.02	33	season_summer_indicator	0.06
14	weekday_Thursday_indicator	-0.01	34	season_autumn_indicator	0.00
15	weekday_Friday_indicator	0.00			
16	weekday_Saturday_indicator	-0.02			
17	weekday_Sunday_indicator	0.05			
18	holiday_indicator	0.04			

Figure 144 graphically illustrates the information presented in Table 24. The value of 0.259 for the adjusted R^2 metric indicates that the multivariate linear regression model can poorly explain the variance of energy demand in a typical apartment at Kiwi pilot site. The use of control buildings for energy baseline validation purposes must accompany the validation of results during pilot deployment activities.

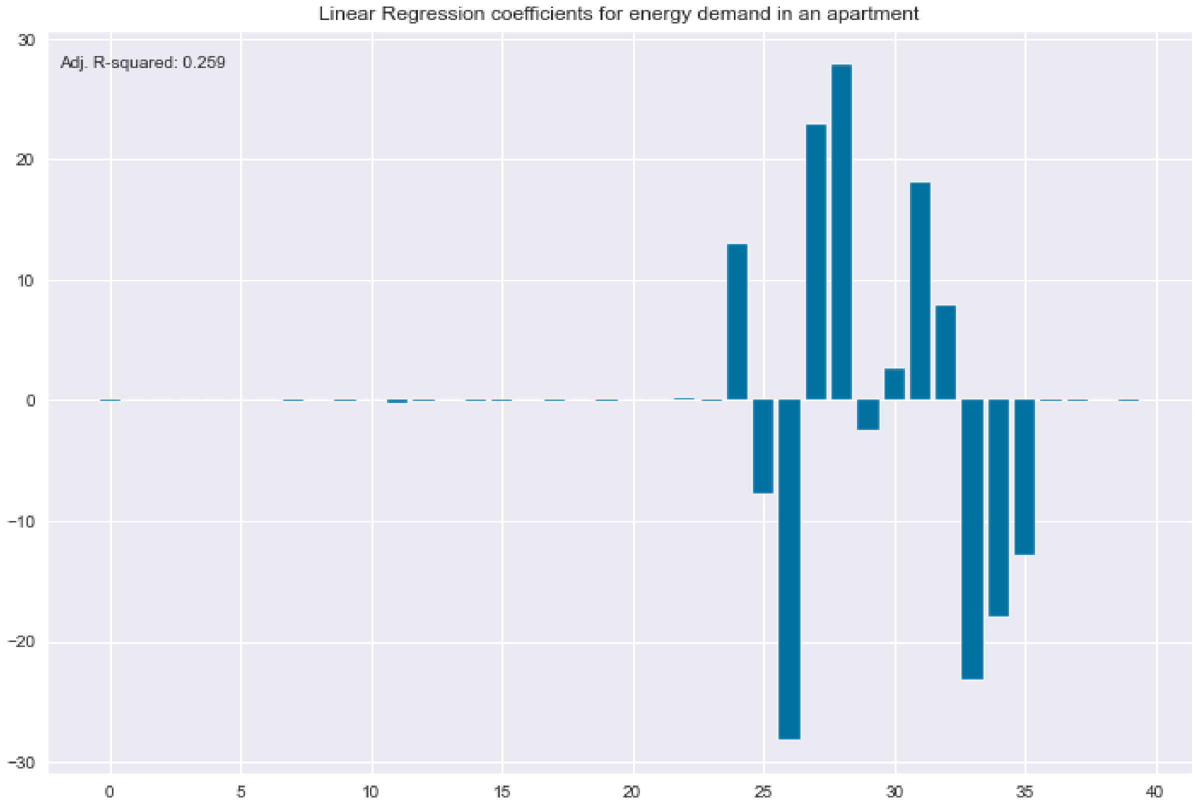


Figure 144. Relative importance of the linear regression coefficients for energy consumption in an apartment

4. Key Performance Indicators

In this chapter, we first give a short description of the KPIs to be used in order to evaluate the project and we further discuss specific elements valid on the pilot sites, which will affect the KPIs calculation. It is worth noticing that some of the KPIs will be evaluated in the same way in both pilot sites, whereas others fit best only one of the two pilot sites. In this report, we briefly give the formulas, where necessary for the calculation of the KPIs. For a more detailed description, the reader is directed to the first version of the report.

In addition, the targets set for these KPIs are re-evaluated and concerns for their achievement are discussed. Finally, we present some extra KPIs to be included for the project evaluation, which have not been described in the previous version of the report. Since the project is being developed and there is a dynamic nature of its evaluation, it has been judged necessary to include a few extra KPIs contributing in a better overall picture of the project.

4.1 KPIs to be evaluated for both pilot sites

4.1.1 Emission Savings

The indicator is calculated in $kgCO_2$ by the formula below:

$$I_{CO_2,reduction}(\Delta t) = \sum_{t\in\Delta t} \Delta I_{CO_2}(t) \tag{4}$$

where:

$$\Delta I_{CO_2} = \sum_{source\in\{sources\}} \left(D_{DR,elec}(t) - D_{baseline,elec}(t)\right) \cdot MIX_{source}(t)EF_{source} + \sum_{fuel\epsilon\{sources\}} \left(C_{DR,fuel}(t) - C_{baseline,fuel}(t)\right) EF_{fuel} + \left(D_{DR,distrheating}(t) - D_{baseline,distrheating}(t)\right) EF_{distrheating} \tag{5}$$

Since electricity is the only energy source and there is no district heating at the pilot sites that participate in the DR programs, the two last terms of the equation regarding other fuels and district heating are omitted and the formula is simplified to:

$$\Delta I_{CO_2} = \sum\nolimits_{source\in\{sources\}} \left(D_{DR,elec}(t) - D_{baseline,elec}(t)\right) \cdot MIX_{source}(t)EF_{source} \tag{6}$$

The data needed for this KPI calculation is:

- D_{DR}(t): energy demand during DR event in kW – this can be obtained once the pilot sites run and consumption data is available
- $D_{baseline}$(t): energy demand without DR event in kW – this can be obtained by the baseline calculations.

On the other hand, the parameters extracted from databases are: MIX_{source}(t), Ef_{source} , EF_{fuel}, where:

MIX_{source}(t): national electricity mix; production sources of electricity that can be extracted from ENTSO-E database

EF_{source}: emission factors of national production sources and district heating supplier in $kgCO_2/kWh$
EF_{fuel}: emission factors of fuel consumed in $kgCO_2/kg$

4.1.2 Peak Load Reduction

This KPI is the difference between the two peaks: the electricity peak_with respect to the baseline and the electricity peak with respect to the Demand Response event:

$$D_{elec,peak\_reduction}(\Delta t) = max_{t\in\Delta t}\left(D_{elec,baseline}\right) - max_{t\in\Delta t}\left(D_{elec,DR}\right) \quad (7)$$

$$D_{elec,peak\_reduction}[\%] = \frac{D_{elec,peak\_reduction}[kW]}{max_{t\in\Delta t}\left(D_{elec,baseline}[kW]\right)} \quad (8)$$

The peaks can be derived from the consumption profiles in both pilot sites, once the consumption data from pilot sites are available, whereas Δt can be set as low as 1 day.

4.1.3 Energy Efficiency

This KPI refers to savings for electricity:

$$\boldsymbol{E_{savings,\,elec}(\Delta t) = \int_{t\in\Delta t}\left(P_{baseline,\,elec}(t) - P_{DR,elec}(t)\right)\cdot \delta_{DRactive}(t).dt} \quad (9)$$

For the calculations in both pilot sites, discrete values are used instead of continuous, and the following formula is used:

$$E_{savings,elec}(\Delta t) \approx \sum_{t\epsilon\Delta t}\left(\overline{P}_{baseline,elec}(t) - \overline{P}_{DR,elec}(t)\right)\cdot \delta_{DRactive}(t) \quad (10)$$

The savings for energy efficiency will be calculated throughout the operation of the pilot sites. The DR event trigger refers to when a demand response event occurs or not (δ = 1 when a demand response occurs, δ = 0 if no demand response occurs). Apart from the time moment when a DR event occurs, and the time and duration of this DR event, the following data is needed for the calculation of this KPI:

- $P_{DR}(t)$: real energy consumption during a DR event (kW), which can be obtained once the pilot sites run.
- $P_{baseline}(t)$: baseline energy consumptions when no DR event occurs, which is obtained after baseline calculations.

4.1.4 Discount in customers' costs

This KPI has to do with economic gains for customers and is calculated by the formula:

$$EG(\Delta t) = \Delta FR(\Delta t) + \sum_{t\epsilon\Delta t}\Delta Ex(t) \quad (11)$$

where *Δex:* energy expenses variations and *ΔFR:* financial rewards.

$$\Delta Ex(t) = \left(D_{baseline,distr\_heating}(t) - D_{DR,distr\_heating}(t)\right) Pr_{distr\_heating} + \left(D_{baseline,elec}(t) - D_{DR,elec}(t)\right) Pr_{elec}(t) + \sum_{fuel \in \{fuels\}} \left(C_{baseline,fuel}(t) - C_{DR,fuel}(t)\right) Pr_{fuel} \quad (12)$$

Since there is no other source of energy used in demand response activities apart from electricity and no district heating either, Eq. (12) becomes:

$$\Delta Ex(t) = \left(D_{baseline,elec}(t) - D_{DR,elec}(t)\right) Pr_{elec}(t) \quad (13)$$

As it can be observed, for the calculation of this KPI, demand values and tariffs will be used as data input here.

The variables are:

- **D_{DR}(t):** real energy demand during DR event (kW)
- **$D_{baseline}$(t):** energy demand without DR event (kW)
- **$S_{DR,elec}$(t):** Electricity selling during DR event (kW)
- **$S_{baseline, elec}$(t):** Electricity selling without DR (kW)
- **$C_{DR,fuel}$(t):** real fuel consumption during DR event in m^3/h.
- **$C_{baseline,fuel}$(t):** baseline fuel consumption (without DR event, in m^3/h)
- **Pr_{elec}(t):** electricity sales tariff in national currency per kWh
- **$Pr_{elec,feedin}$(t):** electricity feed-in tariff (sold to the grid)
- **Pr_{fuel}:** fuel tariff in national currency per m^3
- **$Pr_{distr\_heating}$:** district heating tariff, in national currency per kWh
- **$FR_{DR,util}$:** Utilization payment of related DR program in national currency or national currency per kW per hour
- **$FR_{DR,avail}$:** Availability payment of related DR program

4.1.5 Smart load shedding, instead of Low Voltage/ Frequency Demand Disconnection

This KPI can be calculated via simulations. The DIgSILENT model available for the Cypriot grid model will run twice for this purpose: once with the actual load profiles including the DR offered by the DELTA solution, and once using the baseline load profile. This approach can be used for the KPI calculation both in Cyprus and in the UK. It is worth noticing that the model can be applied for the pilot site in the UK, provided that the network topology is known and modelled in DIgSILENT.

In case the simulation results are deemed unsatisfactory, due to the nature of this small distribution network, an alternative way will be used for the calculation of this KPI, given by:

$$LSER = 100\% \cdot \sum_{i=1}^{B} [\sum_{t=1}^{t=N} Ev_S]/Ev_T \quad (14)$$

where:

- *B*: total number of houses/apartments/buildings where assets are needed to be disconnected for DR purposes
- Ev_T: the total number of events when a smart load is disconnected
- Ev_{LS}: the number of events when smart load shedding occurs

The data to be used for the calculation of this KPI is: **the events** of smart load shedding/ disconnection; **the number of assets** disconnected each time.

4.2 KPIs to be evaluated for the pilot site in the UK

Two KPIs are evaluated only for the UK pilot site, as described below.

4.2.1 Reduced imbalance penalties-related costs due to RES supply volatility

This KPI is not calculated for the Cypriot pilot site, since there is no available data for imbalance costs, due to a non-existent market at the moment. For the pilot site in the UK, the initial idea (see Deliverable 1.4) was to calculate this KPI through the initial bid and the final contribution of each DR asset. However, as it was later discussed among the partners and confirmed by Kiwi (the aggregator involved), this was unrealistic, since Kiwi being a commercial business does not do anything that would incur penalties. Therefore, it was decided to focus instead on the reduction of the overall costs of the aggregator, due to RES supply volatility. In order to do this, we will use a new price forecasting model for the balancing energy market based on machine-learning regression, which was developed by JRC, in close cooperation with Kiwi (Task 4.3). Thus, for the evaluation of this KPI, Kiwi will be comparing the accuracy results of this tool and the current one in use. A comparison of the costs to the aggregator (Kiwi) will also be performed to address the benefits of model in monetary terms.

4.2.2 Increase of Revenues

This KPI is calculated only for the pilot site in the UK, since there is no market for demand response in Cyprus and there are no DR activities taking place so as to result in a revenue. The target value for the KPI will refer to the whole portfolio, not a single asset after DELTA DR solutions are applied. It will be calculated by the aggregator (Kiwi), ex post due to the confidentiality nature of revenues.

4.3 KPIs to be evaluated for the pilot site in Cyprus

4.3.1 Increase of distribution grid capacity to support RES

This KPI typically refers to the maximum capacity of the grid to integrate RES without violating the voltage limits (over/under-voltage). Its calculation involves the modelling of the distribution grid; for this purpose the DIgSILENT grid model will be used for this KPI. Real data of the medium voltage distribution grid will be used.

4.3.2 Distribution grid congestion losses

For this KPI calculation, the grid model DIgSILENT will be used again. As a first step, the congestion losses without any DR event will be calculated and afterwards, the equivalent losses after the application of the DR event will be evaluated. A comparison of these two calculations will provide the KPI.

4.4 Qualitative KPIs and KPIs to be evaluated through other deliverables – evaluated in both pilot sites

Apart from the KPIs described above, which are mainly calculated through formulas or simulations, there are other KPIs that are evaluated through qualitative criteria or KPIs that refer to milestones of the project. We briefly refer to them at this point to complete the picture of the KPIs. For more information, the reader is directed to the first version of this deliverable.

Qualitative KPIs:

- Increase in security and trust – target: **at least 75%** of the customers participating in the demonstration sites will acknowledge DELTA integrity
- Customers, retailers, SMEs acceptance for future use – target: **at least 70% expressing their interest** for future use of the DELTA solution

- Customers' satisfaction and user friendliness of the UIs – target: **more than 70%** of the involved customers expressing **a positive opinion** with respect to the **ease-of-use**

As for the KPIs referring to the completion of other deliverables and milestones of the project, these are listed in the table below; their detailed explanation takes place in the first version of the deliverable.

Table 27: List of KPIs depending on other deliverables

KPI	Title / Target
2.1	Guidelines regarding current policies for including the DELTA solution / **Consolidating relevant outputs of workshops in at least 2 white papers**
2.2	Recommendations for policy makers for developing appropriate regulations to accelerate market adoption of the project solutions / **A number of recommendations would be included from the various Stakeholders and organizations**
3.1	Workshops organization and participation / **4 workshops will be organized throughout the project lifetime**
3.2	Number of people participating in workshops / **At least 100 people/workshop are expected to participate**
3.3	Utilities willingness to validate the solution / **At least 4 Utilities will be interested in validating the solution, during the project**
4.1	Inclusion of distribution grid-connected RES and energy storage in VPP / **A 10 MW of installed capacity PV park and 1MWh Storage will be included and participate in the VPP-based DELTA solution, along with residential prosumers, during the demonstration activities**
5.1	Validation of DELTA solution from key Energy Stakeholders / **At least 1 Aggregator, 1 DSO and 1 Retailer will validate the solution during pilot activities**
5.2	Number of software products delivered / **At least 5 (collaboration, award, visualization, segmentation and forecasting)**
6.1.1	Number of successfully delivered and validated business models / **At least three complete business models will be conceived and two will be validated during the pilot activities**
6.1.2	Delivery of DR-enabling tools and devices for utilization from Retailers/Aggregators **Delivery Decision Support System for Aggregators, Virtual-Node-Platform, Fog-Enabled Devices and deployment in the pilots' phase**
6.1.4	Customers' Responsiveness / **Customers' responsiveness that use a FEID combined with BMS will go beyond 95% (fully-automated solution)**
6.2.2	Number of Customers successfully engaged / **At least 100 end-users will participate in the two real-life demonstrators of DELTA technologies (residential and non-residential blocks of buildings)**
7.1	Timely and full (at the designated percentage) provision of defined indicators at the end of each year / **Respective KPIs should have reached their target at the end of each year**

4.5 Targets for the KPIs

The targets of the KPIs have been defined back when the technical annex was built. However, since the pilot site needs change dynamically, as the project evolves, there is the need to have an evaluation of the KPIs in a dynamic way and adjust some initial targets set. The table below shows comments and concerns for the KPIs evaluation from the pilot site partners.

Table 28: Comments for the KPI target

KPI ID	Initial KPI Target Value	UCY Comments – Pilot site in Cyprus	Kiwi Comments – Pilot site in the UK
Energy Policy Context			
KPI-1.1: Emissions savings	At least 20% lower carbon emissions are expected in the Customers that participate in the pilot activities	At least 15% lower carbon emissions are expected in the Customers that participate in the pilot activities	5-15% energy reduction would equate to 15% reduction in CO2? Scale to be considered, it could be that it has less impact on CO2.
KPI-1.2: Increase in security and trust	At least 75% of the Customers participating in the demonstration sites will acknowledge DELTA integrity	Achievable	60%
KPI-1.3: Peak load reduction	At least 44% peak load reduction is expected during the demonstration activities	Reducing the peak demand of the campus by almost half is impossible due to the nature of the facilities. 14% is more feasible.	Moor House: we can turn down 15% of the chillers, but these are just a part of the consumption. So overall it would have to be <15%. 10%?
KPI-1.4: Energy efficiency	At least 20% energy savings expected for the pilots' participants	Achievable	Moor House: <20% (chillers) 10-15% (Comparison with the baseline only, no access to overall consumption)
Integrating large share of renewables			
KPI-4.1: Inclusion of distribution grid-connected RES and energy storage in VPP	A 10 MW of installed capacity PV park and 1MWh Storage will be included and participate in the VPP-based DELTA solution, along with residential prosumers, during the demonstration activities	Target value to be discussed. Not certain for the actual MW/MWh figures.	N/A

KPI-4.2: Reduced imbalance penalties-related costs due to RES supply volatility	Aggregators and Retailers will validate a minimum reduction of imbalance-related costs of 15- 20%	No available data for imbalance costs. Alternatively, the impact of the RES forecasting accuracy can be assessed.	Change to “Reduced overall costs”. JRC, in close cooperation with Kiwi, has developed a new price forecasting model for the balancing energy market using machine-learning regression. For the evaluation of this KPI, Kiwi will be comparing the accuracy results of this tool and the current one in use. A comparison of the costs to the aggregator (Kiwi) will also be performed to address the benefits of model in monetary terms. Target value to be defined.
KPI-4.3: Increase of distribution grid capacity to support RES	At least 30% more grid capacity will be evaluated by the Cyprus pilot DSO.	EAC has a network model of the pilot site (University of Cyprus) with real data of the Medium Voltage distribution grid and the line and transformer equipment, prepared in DIgSILENT PowerFactory. Various capacity levels and flexibilities will be evaluated.	N/A to UK site
Adequate competitive product and services on the market			
KPI-5.1: Validation of DELTA solution from key Energy Stakeholders	At least 1 Aggregator, 1 DSO and 1 Retailer will validate the solution during pilot activities	1 Aggregator (UCY) 1 DSO (EAC)	1 Aggregator (Kiwi)
KPI-5.2: Number of software products delivered	At least 5 (collaboration, award, visualization, segmentation and forecasting)	Achievable	
KPI-5.3: Customers, Retailers, SMEs acceptance for future use	At least 70% of participants would express their interest for future use of the DELTA solution	Achievable	
Quantified Benefits for Aggregators/Retailers			

KPI-6.1.1: Number of successfully delivered and validated business models	At least three complete business models will be conceived and two will be validated during the pilot activities	Implicit DR Explicit DR Microgrid Management	
KPI-6.1.2: Delivery of DR-enabling tools and devices for utilization from Retailers/Aggregators	Delivery Decision Support System for Aggregators, Virtual-Node-Platform, Fog-Enabled Devices and deployment in the pilots' phase	Achievable	
KPI-6.1.3: Increase of revenues	Revenues for Aggregators are expected to exceed 20%, compared with current best DR practices in single buildings	No DR market available. All DR practices will lead to revenues for the aggregator.	This is unrealistic. The reality for Kiwi is that DELTA would probably only increase their profits in a marginal way, since they already optimize. Kiwi suggests therefore to change the target value to 0.5-1% revenues increase for the aggregator. The target for 20% might be kept, if somehow we can calculate the revenues for the residential customers.
KPI-6.1.4: Customers' Responsiveness	Customers' responsiveness that use a FEID combined with BMS will go beyond 95% (fully- automated solution)	Achievable	
Quantified Benefits for Prosumers			
KPI-6.2.1: Discount in Customers' costs	At least 25% discount in Customers' costs during the demonstration activities	At least 15% discount in Customers' costs during the demonstration activities	

KPI-6.2.2: Number of Customers successfully engaged	At least 100 end-users will participate in the two real-life demonstrators of DELTA technologies (residential and non-residential blocks of buildings)	Achievable	
KPI-6.2.3: Customers' satisfaction and user friendliness of the UIs	More than 70% of the involved customers in the demonstration sites express positive opinion on the ease of use solution.	Achievable	
Quantified benefits for the Grid			
KPI-6.3.1: Full-scale provision of grid balancing and ancillary services	At least 70% of the services delivered/tested during the demonstration activities	Achievable	
KPI-6.3.2: Smart load shedding, instead of Low Voltage/Frequency Demand Disconnection (LVDD&LFDD)	100% achieved/tested during the demonstration activities	Achievable	
KPI-6.3.3: Distribution Grid congestion losses reduced	at least 15% losses reduction during the demonstration activities	The available grid model will be run twice, once with the actual load profiles including the DR offered by the DELTA solution, and once using the baseline load profile (made from historical data).	N/A to UK site.

As it can be observed from the table above, some of the KPIs targets are considered achievable by the respective pilot partners, whereas others are not. This happens because the initial evaluation may have been optimistic with respect to actual pilot site conditions, which could not have been known back when the technical annex was conducted. Two of such KPIs are the emission savings and the discount on customers' costs; however, it is noticed that for example for the pilot site in Cyprus, the new estimated targets are 5 and 10 percentage points different from the original target. For this pilot site, the only KPI that declines significantly from the initial estimation is the peak load reduction KPI. This is because the initial estimation of the pilot site, which is the campus in this case, was found to be over-optimistic; the deviation for the peak load reduction without DR activities and the one with the actually planned DR activities has been re-calculated and found that the target for this should be set at a lower level.

4.6 KPIs to be added to the evaluation

As the project evolves, the pilot sites are ready to function and more deliverables are published, it has been judged necessary to include a few more KPIs. Two of them refer to demand response reliability and they are calculated quantitatively. The next two KPIs refer to fairness, meaning that these are metrics evaluating if the requestor of flexibility turns equally to all customers or not for obtaining this flexibility. Another KPI is added and refers to the successful delivery of other deliverables, specifically to D5.3. For these KPIs, and especially for the ones requiring quantitative evaluation, there is no specific target set, but the outcome will define the reliability of the customers and the ability of the system to cope up with demand response events, as well as how fair the system is, meaning its ability to request flexibility equally from different customers.

4.6.1 DR request Reliability

This KPI does not depend on what is requested and from whom. The concept behind this KPI is to depict the system's capability in order to cope up efficiently with demand response requests. It can be calculated either in terms of energy or in terms of power.

With respect to energy, a time period of t_{DR} is defined, during which a demand response request is sent with an energy setpoint of E_S. This demand response request can derive either from a third party (i.e. DSO) or internally for self-optimization. At the end of this predefined period, the actual overall energy delivered by the system is calculated (E_D). The absolute reliability of the request is:

$$R_{Ae} = (E_D / E_S) \cdot 100\% \quad (15)$$

Otherwise, this KPI can be calculated in terms of power. The demand response request can again come either from a third party or internally for self-optimization. The absolute reliability is given as:

$$R_{Ap} = 100\% \cdot \frac{1}{T} \sum_{t=1}^{T} \frac{P_{Dt}}{P_{St}} \quad (16)$$

where:

T: the overall time in minutes during which the demand response request is made
$t \in [1, \dots T]$: for each minute that the request is made
P_{Dt} : The actual power offered at each time slot (1 minute)
P_{St} : The power set points for each time slot

It should be noted at this point, that the above equations are valid for one demand response event. As an extra metric, it could be useful to take into account the total number of DR events in which a client participates successfully. So, Eq. (16) becomes:

$$TR_{Ap} = (1/N) \cdot \sum_{n=1}^{N} \left[\sum_{t=1}^{T} \frac{P_{Dt}}{P_{St}} \right] \cdot \frac{100\%}{T} \tag{17}$$

where:

N: the total number of DR events

n ϵ [1, … N]: for each DR event

Besides the above KPI that provides the absolute DR request reliability, there is also the possibility to calculate a relative KPI for cross-customer comparison. Such a relative DR request reliability KPI is optional and might be developed later in WP7, when the pilots will start producing real-life data.

4.6.2 Fairness per Customer

This KPI refers mostly to the DR events themselves, meaning that it evaluates the amount of DR events at which the clients are requested to participate. It is given by:

$$F_{Aclient} = \frac{N_{DRc}}{TN_{DR}} \cdot 100\% \tag{18}$$

where:

N_{DRc} : number of DR requests in which the customer is requested to participate

TN_{DR} : total number of DR requests

Besides the above KPI that provides the absolute fairness per customer, there is also the possibility to calculate a relative KPI for cross-customer comparison. Such a KPI, called capacity fairness per customer, is optional and might be developed later in WP7, when the pilots will start producing real-life data.

4.6.3 DELTA security within D5.3

This KPI is considered successful with the successful completion of D5.3. It refers to security aspects and ensures that a list of security-related objectives are met successfully. The complete list of KPIs referring to such security aspects will be published in the deliverable D5.3.

5. Conclusions

In this report, historical data from the two pilot sites under the DELTA project have been used for the purposes of EDA and baseline definition. A number of features were engineered in order to study the effects that these features have on energy demand. All the results that were obtained are presented in respective figures. With the EDA the big picture of energy demand, weather conditions and all the relevant correlations have been clarified. For the needs of energy modelling, the results of the application of multivariate linear regression model, as suggested by European and International standards, are presented. In some cases, linear regression models are not adequate in explaining the variance of energy demand, at least, with the features/predictors that have been selected for this purpose. During pilot deployment phase, control group buildings are needed for the establishment of energy baselines. In this way, the validation of KPIs will be more accurate. Finally, all the adjustments that have been done to the KPIs for the two pilot sites are presented along with comments from pilot site operators on whether they are achievable or not.

6. References

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