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Electricity Consumption Forecasting and Target Setting for the Special Economic Zones in a GCC Country

TESI DI LAUREA MAGISTRALE IN
ENERGY ENGINEERING
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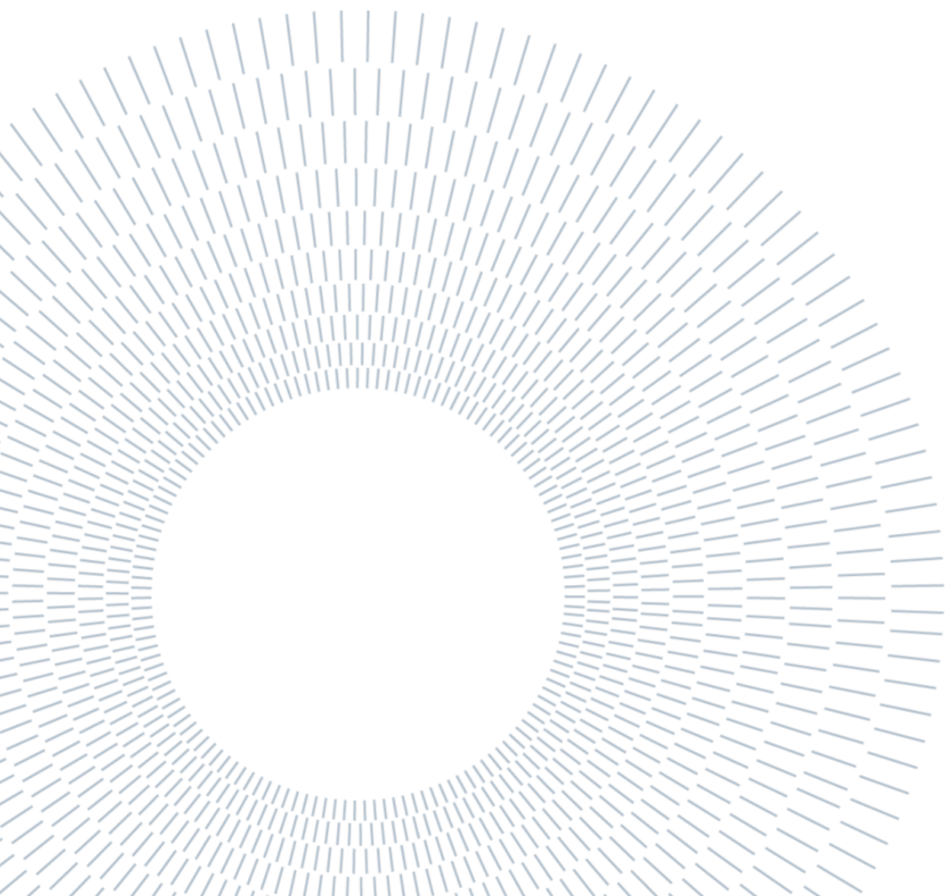


Abstract

This thesis explores the implementation of Demand Side Management (DSM) programs in Dubai's Special Economic Zones (Free Zones), with a focus on the current state of energy savings and presented energy savings target. The DSM programs are implemented across Dubai including the Free Zones. The study focuses on the energy consumption and savings part of the DSM programs. The Green Building Regulations, Building Retrofits, Outdoor Lighting, Efficient Cooling, Solar Power Generation (Shams Dubai). The current state assessment of the energy consumption and the savings due to the twelve free zones is done giving us the extent to which the DSM program implementation has penetrated in the free zones. After the current state assessment, In order to do the energy forecasting the relation of the energy consumption with the macroeconomic factors is established using the regression models. Utilizing the proposed model and inputting the projected features, the business-as-usual energy consumption is estimated. The ridge regression model is optimized by tuning the hyperparameters to achieve the optimal fit and minimize errors on the training dataset. The savings targets are set in line with the "The UAE Net Zero by 2050" of which the "Demand Side Management Strategy" is a subset. The study also suggest the upgradation and the initiation of the new DSM programs plus the implementation mechanisms to achieve the set targets. The research is relevant to policymakers, energy companies, investors, researchers, and the public interested in renewable energy.

Key-words: Demand Side Management, Current State Assessment, Regression Model, Target Setting.

Contents

Introduction

This thesis investigates the Demand Side Management Implementation in Dubai's Special Economic Zones. The research addresses two questions: the current state of the savings due to the demand side management programs in the special economic zones and the target setting for the free zones energy savings till the year 2030

 The findings will be useful to policymakers, energy companies, investors, researchers, and the public interested in renewable energy.

Outline of the thesis

The structure of the thesis is the following:

Chapter 1 discussed the Demand Side Management Strategy along with a discussion of the many energy and water conservation initiatives that have been established as part of the plan, which is being implemented in Dubai, United Arab Emirates.

Chapter 2 discusses the current state assessment of the free zones. It discussed the programs and the calculation that has been used to calculate the savings achieved by the free zones.

Chapter 3 discusses the methodology used to calculate the business as usual energy consumption of the free zones in the decade ahead and the based on the current amount of energy savings and setting targets in line with the national energy policies.

Chapter 4 proposes the improvements in the current energy savings programs and also the introduction of the new programs to the Demand Side Management Strategy. Apart from the program enhancement it drafts the implementation mechanism to help achieving the set targets of energy savings.

Chapter 5 concludes the work and discussed the challenges that the free zones face as of now in terms of energy efficiency and management.

1 The Context

The Dubai DSM Strategy was introduced in 2011 (updated in 2019) to create a roadmap for achieving a targeted savings of 30% on electricity and water usage in the emirate. The Demand Side Management (DSM) Strategy is part of the Dubai Integrated Energy Strategy (DIES) 2030, whose main goals are to secure Dubai's uninterrupted energy supply and moderate its growing electricity and water demand [1]

The DSM strategy is a key initiative in aligning Dubai and the UAE with the 2050 goals. The strategy supports government entities to develop programs, directives, laws, regulation with influence on the new building developments appliance and equipment.

The DSM Strategy comprises eight programmes, designed to address different aspects of electricity and water consumption sources in Dubai. Programmes are supported by implementation mechanisms, mainly policies and regulations, capability building, awareness improvement, measurement and verification, and financing [2].

Globally Demand Side Management Programs essentially have incentive mechanism to promote the time of use but in Dubai the Demand Side Management have no incentivization. The eleven programs that address different aspects of electricity and water consumption in Dubai are

1. Green Building Regulations
2. Building Retrofits
3. Outdoor Lighting
4. Efficient Cooling
5. Standards and Labels
6. Consumer Behaviour
7. Solar Power Generation (Shams Dubai)
8. Tariffs
9. Recycled & Ground Water Demand Management
10. Efficient Mobility and Smart Charging
11. Fuel & Engine Efficiency

Out of the eleven programs three programs have been recently introduced which are Consumer Behaviours, Efficient Mobility and Smart Charging and Fuel & Engine Efficiency.

The DSM targets both electricity and water but in this report, we are going to focus on the electricity savings and consumption.

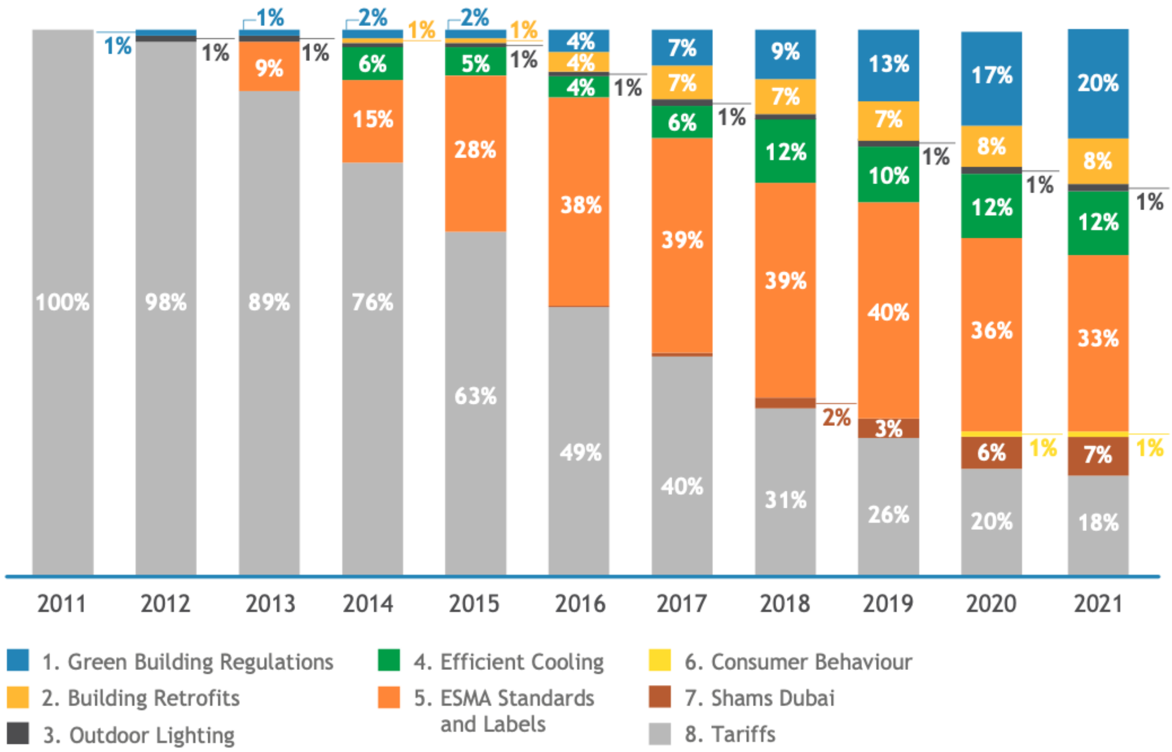


Figure 1: Percentage contribution of programmes to the total Dubai Demand Side Management Strategy savings, for years 2011 to 2021

As seen from the graph the equipment standards and labels have the highest percentage in savings which is followed by the green building program.
Now we briefly discuss each of the programs

1. **Building Regulations**

Dubai is implementing several green building regulation in order to encourage sustainable construction practices and reduce environmental impact of building. Some of the green building rating systems include Estidama Pearl Rating System, Dubai Green Building Code and Dubai Electricity and Water Authority apart from these the Leadership in Energy and Environmental Design (LEED) rating system developed by the US Green Building Council is a widely used rating system.
Green buildings make up 40% of all buildings commissioned in the market in 2018, and almost all buildings permitted by DM in that year are compliant to the latest regulations [3]

2. **Building Retrofits:**

In 2013, the government of a Dubai city launched a program called the Building Retrofits Programme to improve energy efficiency in buildings. A special company was created to encourage energy service companies to join the market. Accreditation schemes were also established for ESCOs and energy auditors. The government then issued a directive in 2015 requiring energy audits in all government buildings larger than 1000 m2, and retrofits were required if expected energy savings were greater than 20% and payback was less than 10 years. The goal was to reduce water and electricity usage by 20% in government buildings by 2021.

3. **District Cooling**

In Dubai, the need for cooling during hot seasons causes a significant increase in electricity consumption, with cooling accounting for half of the city's overall electricity usage and up to 70% during peak times. Various cooling technologies are available, but a study conducted by the RSB found that water-cooled solutions are more energy-efficient than air-cooled options, providing 35% to 45% better efficiency on average. In situations with high cooling load density and steady demand, water-cooled technology is generally the most appropriate choice. The District Cooling Programme aims to increase the use of district cooling (DC) to 40% of the city's cooling market by 2030, by integrating the technology in new construction projects and upgrading old ones. The program also assumes that DC companies will continue to enhance plant efficiency compared to a baseline. Additionally, since peak demand is less than 60% of the installed district cooling capacity, new connections can be made at a relatively low incremental cost.

4. **Standard and Labels for appliances and equipments**

According to the 2018 Annual Report of the Dubai Demand Side Management Strategy, the Energy Efficiency Standardisation and Labelling (EESL) Programme was established by the Emirates Authority for Standardization and Metrology (ESMA) in 2011 to promote the usage of more efficient products in the UAE market and prevent the influx of electricity and water inefficient appliances. The programme's key mechanisms, Minimum Energy Performance Standards (MEPS) and the Comparative Labelling Scheme, require regulated electricity and water appliances to meet minimum performance criteria and display a one to five star label indicating their efficiency level. These standards are raised every two to three years for each product category, with input from industry players and experts, leading to the removal of less efficient products from the market. As stated in the report, the EESL programme contributes to 22% and 17% of the overall DSM Strategy 2030 electricity and water targets, respectively. The success of the programme relies on both regulatory enforcement and public education to encourage the adoption of efficient appliances.

5. Water Reuse and Efficient Irrigation

According to the DSM Strategy outlined in the Dubai DSM Annual Report 2018, treated sewage effluent (TSE) is recognized as a valuable asset for the city of Dubai. The strategy seeks to optimize TSE consumption in the irrigation of public landscapes and divert excess volumes to other purposes that currently rely on desalinated water, such as private irrigation, district cooling (DC), and other industrial uses. In fact, Executive Council Resolution No. 27 of 2008 mandates the use of TSE in DC plants. Due to its significantly lower prices (more than 80% below desalinated water rates for most customer groups), there is significant market demand for this water source. Dubai Municipality (DM) has already implemented measures to reduce TSE consumption for public irrigation and free up volumes for other purposes. For instance, irrigation in some communities is reduced during summer following a one-day-per-week switch-off initiative. Additionally, the municipality has defined lower irrigation quantities for each plant type since 2015 and has been adopting the standards in new communities [3].

6. Outdoor Lighting

According to the Annual Dubai DSM Report of 2018, LED technology has been widely used and tested globally and its effectiveness has been proven. Dubai's Roads and Transport Authority (RTA) and Dubai Municipality (DM) have conducted pilot projects to evaluate the suitability of LED technology for the city's environmental conditions and road safety requirements. Consequently, the authorities have adopted LED technology for all new roads in Dubai and have initiated retrofit programs to replace old lighting assets with LEDs and other high efficiency technologies. The Outdoor Lighting Program has set a target of installing high efficiency lights in 75% of Dubai's street lights by 2030

7. Tariffs

the Tariff Rates Programme is a key component of the Dubai Demand Side Management (DSM) Strategy 2030. The programme aims to adjust electricity and water tariff rates in Dubai to be cost-reflective, ensure economic efficiency, and align ratepayers with DSM objectives. By using price signalling, the inclining slab structure of the current tariff system encourages energy-efficient behaviours from consumers. The latest Dubai Electricity and Water Authority (DEWA) tariff review was in 2011 and led to a 4% to 5% reduction in consumption of electricity and water, respectively, in the first two years of implementation. The Tariff Rates Programme has been a major contributor to the savings achieved in the initial years of the DSM Strategy 2030.

8. Shams Dubai

Shams Dubai was established to promote the use of solar photovoltaic (PV) systems on rooftops in Dubai, in line with the vision of His Highness Sheikh Mohammed Bin Rashid Al Maktoum. This framework is built on a net-metering scheme, which allows consumers to generate their own electricity and offset any excess generation from their bills. The program has been successful in some cases, as solar generation can address the majority of a building's electricity needs. However, there are regulatory conditions that must be followed, such as the installed solar capacity not exceeding the electrical load of a customer's land plot, and generated electricity only being consumed on the same land plot where it is generated. To ensure program quality, Dubai Electricity and Water Authority (DEWA) has established technical specifications for PV systems, an accreditation scheme for contractors and consultants, and a permitting and connection process. More than 100 contractors are currently enrolled in the Shams Dubai program, and in 2016, Etihad Energy Services launched Etihad Solar, a business unit aimed at further stimulating the Solar Rooftop market [3]

1.1 Problem description

There are twelve free zones in the Dubai which have variety of companies doing business in them all of which fall under a single authority. It is not clear for the authority the cumulative electricity consumption and the savings due to the various DSM program in all of the free zones. The savings across the free zones are not consolidated at a single point therefore not giving clear idea about the amount of savings that can be attributed to the free zones.

Through the consultations with the free zones following were the key challenges the free zones were facing.

- Lack of comprehensive savings validation for DSM programs
- Standards for data monitoring and equipment not applied across the free zones
- Regular energy audits of the buildings not taking place
- Lack of visibility of consumption and usage patterns in unowned assets within free zone authority jurisdiction
- Many free zones do not have a digital dashboard to receive and analyze live data
- Lack of submetering does not allow for data collection at a granular level

In order to achieve the UAE Net Zero Target by 2050, the free zones have to set a target for savings of at least 30% compared to the Business as Usual energy consumption. So therefore, in order to set a target for the savings till the year 2030, the business as usual electricity consumption trend needs to be forecasted taking into consideration the historic trends of the energy consumption and their relation with the certain econometric factors which are the GDP, Population, Urbanization and Temperature.

1.2 Aim of the research

The proposed research aims to develop a regression model to forecast the energy consumption of a free zone and the initiatives and implementation mechanisms to achieve the targeted savings. The model will consider the relationship between energy consumption and several key factors, including Gross Domestic Product (GDP), Urbanization, Weather, and Population growth.

To achieve this, the study will collect and analyse data from various sources to build a comprehensive dataset that includes historical energy consumption patterns, GDP, urbanization rates, weather patterns, and population growth trends. The data will be pre-processed and cleaned to ensure its accuracy and completeness.

Next, a suitable combination of the key factors will be selected and trained on the dataset to develop a model that can accurately predict future energy consumption based on the identified factors.

The findings of the study are expected to contribute to a better understanding of the complex relationship between energy consumption and the identified factors. Moreover, the developed regression model and initiatives and implementation mechanisms can serve as a valuable tool for policymakers and stakeholders in the free zone to plan and manage their energy resources efficiently and sustainably.

The findings of this research can inform the development of policies and strategies for promoting the savings from the DSM programs and help to identify the key barriers and opportunities for scaling up the implementation of these programs. Additionally, the research can contribute to the understanding of the regional energy transition and sustainability challenges and provide insights into the potential role of DSM in achieving national policy goals

The stakeholders that could benefit from the answers to this research question include Free zone authorities, free zones, policymakers, energy companies, investors, researchers, and other actors in the energy and sustainability fields, as well as the general public who are interested in investing in the business in the free zones

2 Current State Assessment

2.1 Request for Information

Each of the free zones was sent out an request for information (RFI) of in order to determine the electricity consumption from the year 2011 till date. The RFI include the information pertaining to the all the DSM program which have been beneficial in saving of electricity and water. Some of the zones were not able to provide all the data as the data reporting was not done and some of the zones had extensive reporting of the data.

Table 1: Annual data availability in each free zone

Free Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Zone 1	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✗
Zone 2	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Zone 3	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
Zone 4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zone 5	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zone 6	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zone 7	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗
Zone 8	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗
Zone 9	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zone 10	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zone 11	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Zone 12	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓

The current state assessment of all the zones was done once the data was accumulated. It included the Electricity and Water Consumption from 2011 till date for the zones that had the data available, regulative landscape they were following and the characteristics of the free zones.

Figure 2: Zone 1 Electricity and Water Consumption

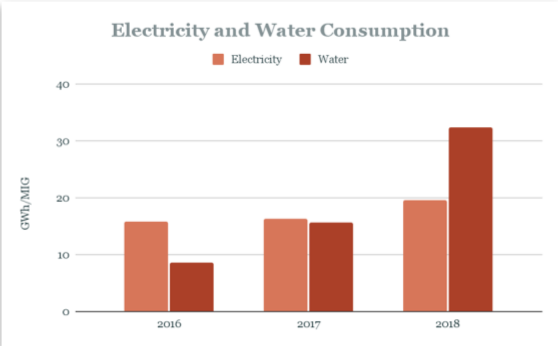


Figure 3: Zone 2 Electricity and Water Consumption

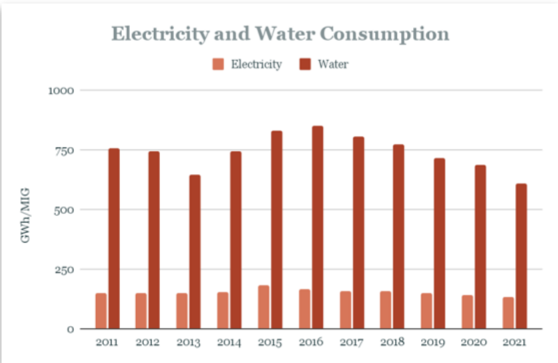


Figure 4: Zone 3 Electricity and Water Consumption

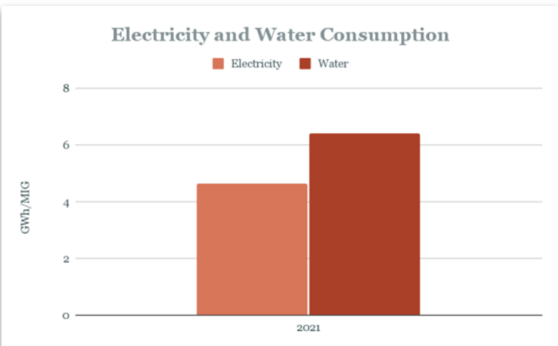


Figure 5 Zone 4 Electricity and Water Consumption

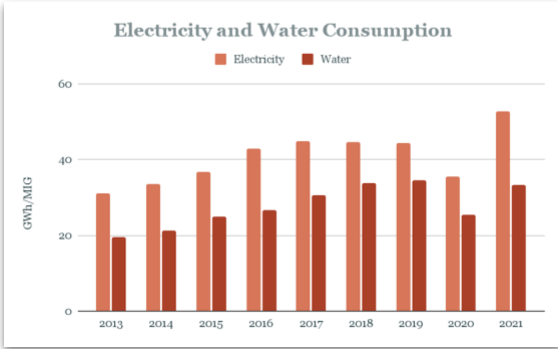


Figure 6 Zone 5 Electricity and Water Consumption

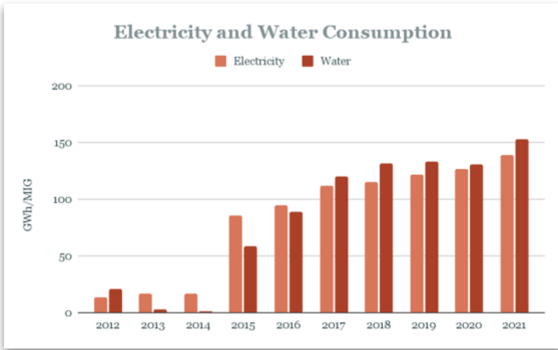


Figure 7 Zone 6 Electricity and Water Consumption

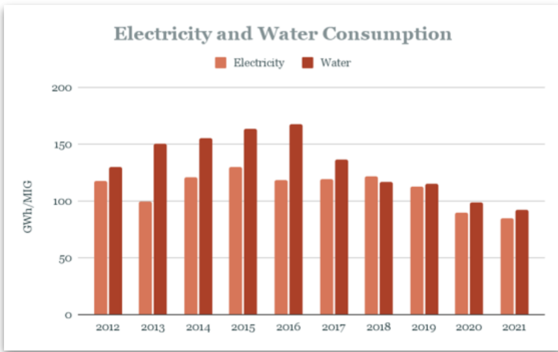


Figure 8 Zone 7 Electricity and Water Consumption

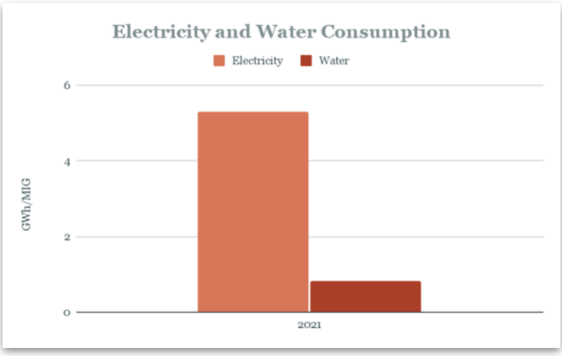


Figure 9: Zone 8 Electricity and Water Consumption

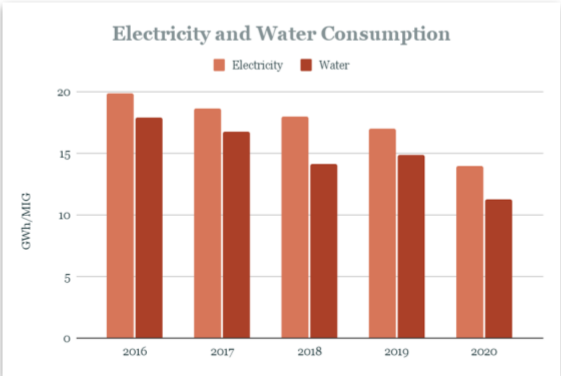


Figure 10 Zone 9 Electricity and Water Consumption

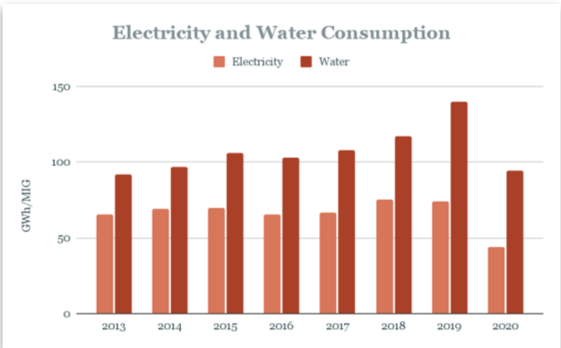


Figure 11 Zone 10 Electricity and Water Consumption

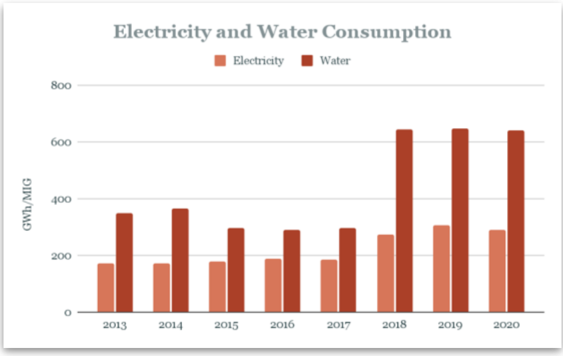
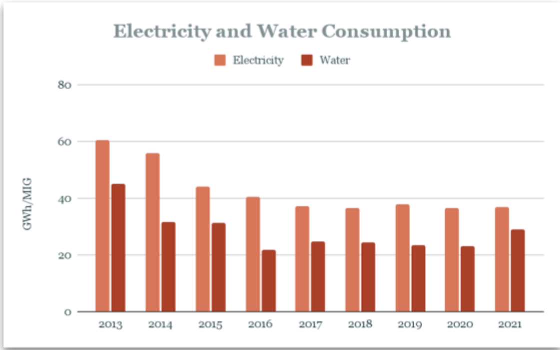


Figure 12 Zone 10 Electricity and Water Consumption



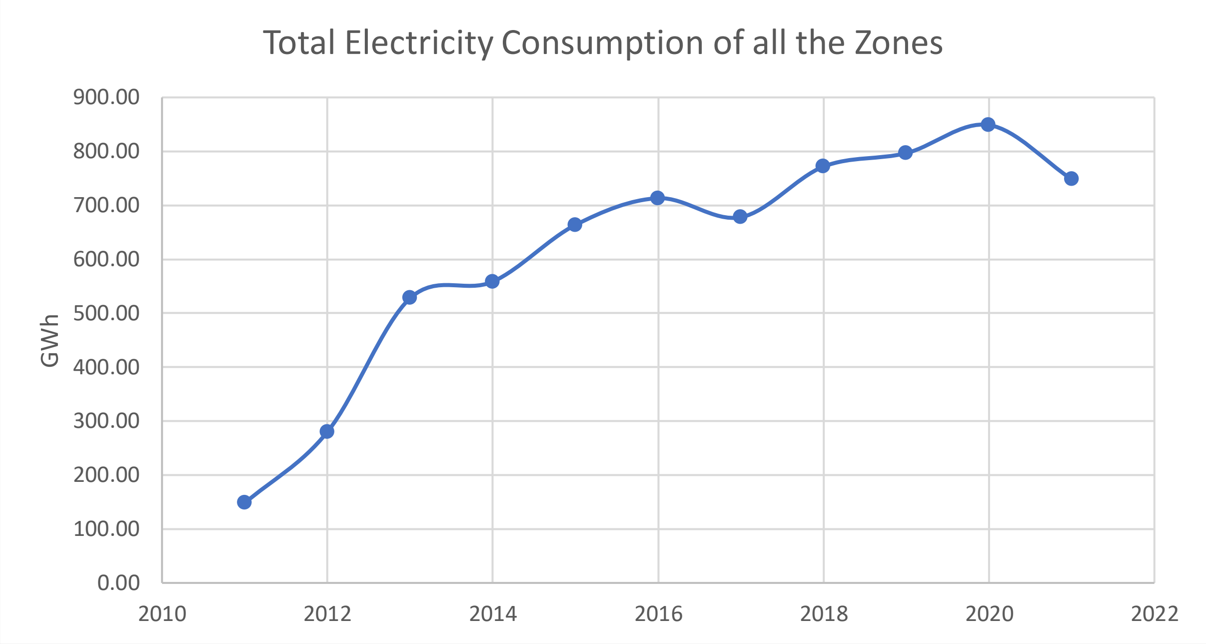


Figure 13: Total Electricity Consumption of all the Free Zones

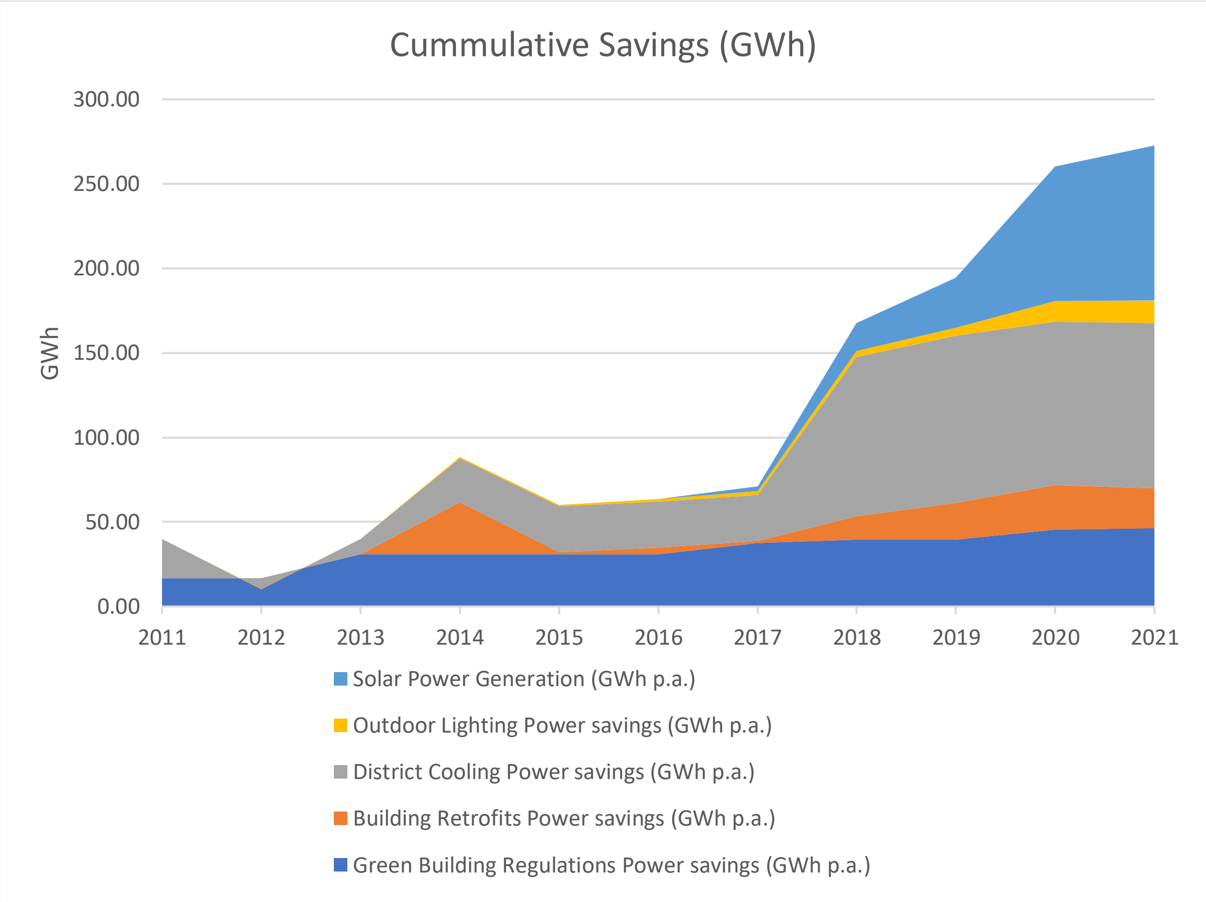


Figure 14 Program Wise Total Electricity Consumption

2.2 Savings Calculations

1. **Green Building Regulations (GBR)**

Based on the data provided, it is possible to calculate the energy savings achieved by different Free Zones through the implementation of Green Building Regulations. The savings can be estimated using the Energy Use Intensity (EUI) of the buildings, which is measured in kWh/m2 or IG/m2. The reduction in consumption resulting from the Green Building Regulations is assumed to be 33% for buildings certified with LEED Gold and Platinum, and 26% for those certified with LEED Silver. These assumptions are based on a study conducted by Liang and Ren in 2009, which evaluated the energy performance of 108 LEED-certified buildings in the United States. By applying these assumptions to the Gross Floor Area and Year of Commissioning of the Free Zone buildings, it is possible to estimate the energy savings achieved by each zone [4].

$$Savings\ (kWh) = Energy\ Use\ Intensity\ \left(\frac{kWh}{m^2}\right) \times Reduction\ in\ consumption\ from\ GBR\ (\%)$$

2. **Building Retrofits**

The building retrofits include a variety of energy-saving technologies aimed at reducing energy consumption and optimizing building performance. Some of the technologies used include interior lighting retrofits, building management system (BMS) fine-tuning, secondary side rebalancing, variable frequency drive (VFD) installation on air handling units, chiller plant optimization, and toilet retrofits. The interior lighting retrofits involve the replacement of outdated lighting fixtures with more energy-efficient ones. BMS fine-tuning involves the optimization of building automation systems to enhance energy performance. Secondary side rebalancing involves the adjustment of cooling systems to reduce energy consumption. VFD installation on air handling units allows for more efficient control of air flow, while chiller plant optimization involves the optimization of cooling systems to reduce energy usage. All of these technologies are aimed at reducing energy consumption and optimizing building performance, thereby contributing to a more sustainable and energy-efficient built environment. The savings are reported in the RFIs that were sent out to free zones

$$Savings\ (kWh\ or\ IG) = Savings\ Reported\ (kWh\ or\ IG)$$

3. **District Cooling**

District cooling is a system that provides cooling to buildings and facilities in a district or a group of buildings through a centralized cooling plant. It offers several benefits, such as energy efficiency, cost savings, and environmental sustainability, compared to traditional air conditioning systems. One of the key factors that determine the efficiency of a district cooling system is the efficiency of the cooling plant. The efficiency of an air-cooled chiller is typically lower than that of a water-cooled chiller due to the lower heat transfer rate and higher condenser temperatures.

$$Savings\ from\ Efficiency\ (kWh) = (Basline\ Non\ DC\ Efficiency\ - Actual\ Efficinecy)(\frac{kWh}{TRh}) \times\ DC\ Load\ (TRh)$$

4. **Outdoor Lighting**

The methodology used in this study involves collecting data from each Free Zone about their baseline and retrofitted wattage, number of lamps retrofitted, new lamps, and the year of installation. The energy savings are then calculated using the difference between the baseline consumption and the retrofitted consumption, multiplied by the number of lamps and operating hours. This method provides a simple yet effective way to estimate the energy savings due to outdoor lighting retrofits.

$$Savings\ (kWh) = \{Baseline\ Consumption\ (W) \times Number\ of\ Lamps\ \times Operating\ hours\ (h/y)\} - \ Retrofitted\ consumption\ (W)\ \times Number\ of\ lamps\ retrofitted\ \times Operating\ hours\}$$

5. **Solar Power Generation**

The methodology for calculating the savings due to solar power generation in free zones involves collecting data on the installed capacity of solar panels and the solar power generation yield. Based on this information, the savings are calculated using the following equation The solar yield was taken from the average of the Annual energy yield of different module technologies at different tilt [5]

angles

$$Savings\ (kWh)\ =\ Installed\ Solar\ PV\ Capacity\ (kW)\ x\ Solar\ Yield\ (kWh/kW)$$

3 Model:

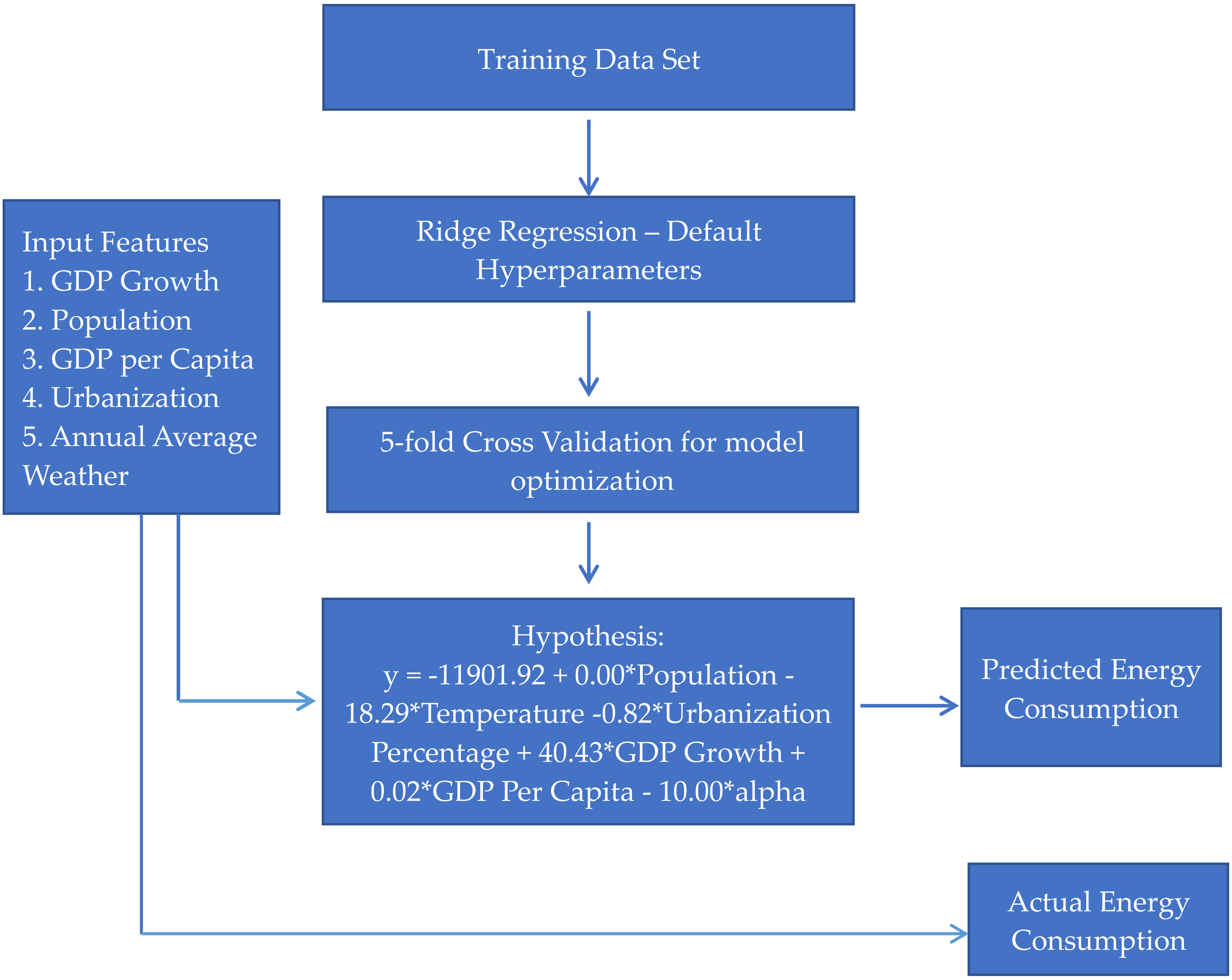


Figure 15 Model Flowchart

Electricity demand forecasting is an important research area that has attracted considerable attention from researchers in recent years. Among the various methods proposed for this task, linear regression and ridge regression models have emerged as popular choices due to their simplicity and effectiveness. Regression models have been used for both short term [6] electricity load forecasting and long term. [7]

3.1 Models with Econometric Parameters

Linear regression is a widely used method for predicting electricity demand, which involves estimating the relationship between a dependent variable, such as electricity demand, and one or more independent variables, such as population, GDP, and weather variables .Linear regression assumes that the relationship between the variables is linear and that the error terms are normally distributed and independent of each other. While linear regression is simple and easy to implement, it can suffer from the problem of multicollinearity, where the independent variables are highly correlated, leading to unstable and unreliable parameter estimates.

Economic, social, geographic, and demographic characteristics have been used to build a number of power forecasting models. Using multiple linear regression analysis, Egelioglu et al. investigated the impact of economic factors on Northern Cyprus' yearly power usage [8]. It was shown that the number of consumers, the price of electricity and the number of tourists correspond with annual electricity use. Price, according to Harris and Liu [9], is a significant factor in understanding electricity users' conservation behaviour.

The multiple linear regression models were proposed in a study effectively forecasting electricity consumption for Domestic, Non-Domestic, and Total in New Zealand, and their forecasts were comparable with national forecasts. The accuracy of these models depended on the accuracy of forecasts made for explaining variables, which were modelled using simple regression in this study [10].

3.2 Multi Collinearity

Multicollinearity is a phenomenon that occurs when two or more predictor variables in a regression model are highly correlated with each other. In other words, multicollinearity refers to a situation where there is a strong linear relationship between two or more predictor variables in a regression model.

Makridakis et al. [11] state that multicollinearity is first and foremost a computational problem. That is, if perfect multicollinearity exists in a regression problem then it is not simply possible to carry out a least squares solution. Variance Inflation Factor (VIF) is a measure that quantifies the degree of multicollinearity between predictor variables in a regression model. VIF is calculated for each predictor variable in the model and is based on the correlation between that predictor variable and all the other predictor variables in the model. A high VIF value for a predictor variable indicates that the variable is highly correlated with other predictor variables in the model, and therefore, may be causing multicollinearity.

To overcome the problem of multicollinearity, ridge regression was proposed as an alternative method for predicting electricity demand. Ridge regression is a variant of linear regression that involves adding a penalty term to the objective function, which shrinks the parameter estimates towards zero, reducing the variance of the estimates and improving the stability of the model [12]. Ridge regression has been shown to perform better than linear regression in scenarios where the independent variables are highly correlated and the sample size is small [13]. Overall, the literature suggests that both linear regression and ridge regression models can be effective for predicting electricity demand, with ridge regression performing better in scenarios where the independent variables are highly correlated. However, the choice of method ultimately depends on the specific requirements of the application and the available data.

3.3 Ridge Regression

The proposed research is a ridge regression model using GDP per capita, GDP percentage growth, population and Urbanization Percentage as selected variables deemed most relevant for Dubai electricity consumption.

The equation for Ridge regression can be written as:

$$y = b_o + b_1x_1 + b_2x_2 + \ldots + b_px_p + e$$

where y is the dependent variable, x1, x2, ..., xp are the independent variables, b0, b1, b2, ..., bp are the coefficients or weights of the independent variables, and e is the error term (residuals).

In Ridge regression, the coefficients are estimated by minimizing the following objective function:

$$J(b) = \{y - Xb\}^2 + alpha \times b^2$$

y is the target values and X is the predictor values where $||y - Xb||^2$ is the residual sum of squares, $||b||^2$ is the squared L2 norm of the coefficients, and alpha is the regularization parameter that controls the strength of the penalty term.

The value of alpha determines the degree of shrinkage of the coefficients: larger values of alpha result in greater shrinkage and a simpler model, while smaller values of alpha allow for more variance in the coefficients and a more complex model. The optimal value of alpha can be determined using cross-validation techniques.

So, Ridge regression models do use the equation of a line, but it is modified to include a regularization term that helps to prevent overfitting.

3.4 Low Data Cross Validation

Cross-validation is a technique used to evaluate the performance of a machine learning model and to tune its hyperparameters by using limited data more efficiently. In the case of ridge regression, cross-validation is used to overcome the problem of low data availability by allowing the model to be trained and tested on different subsets of the data.

When the amount of available data is limited, a traditional train/test split can result in poor model performance due to the high variance of the evaluation metric caused by the small size of the test set. In contrast, cross-validation involves dividing the data into k folds and training the model k times, each time using a different fold as the test set and the remaining folds as the training set.

For each fold, the model's hyperparameters can be tuned using the training data, and the performance can be evaluated on the held-out test data. The results from each fold are then averaged to obtain a more reliable estimate of the model's performance.

In the case of ridge regression, the hyperparameter alpha can be tuned using cross-validation to find the best value that minimizes the evaluation metric (RMSE) on the validation data. By tuning the hyperparameter alpha using cross-validation, the model can be regularized appropriately to prevent overfitting and improve its generalization performance on new, unseen data.

3.5 Cross Validation for Alpha

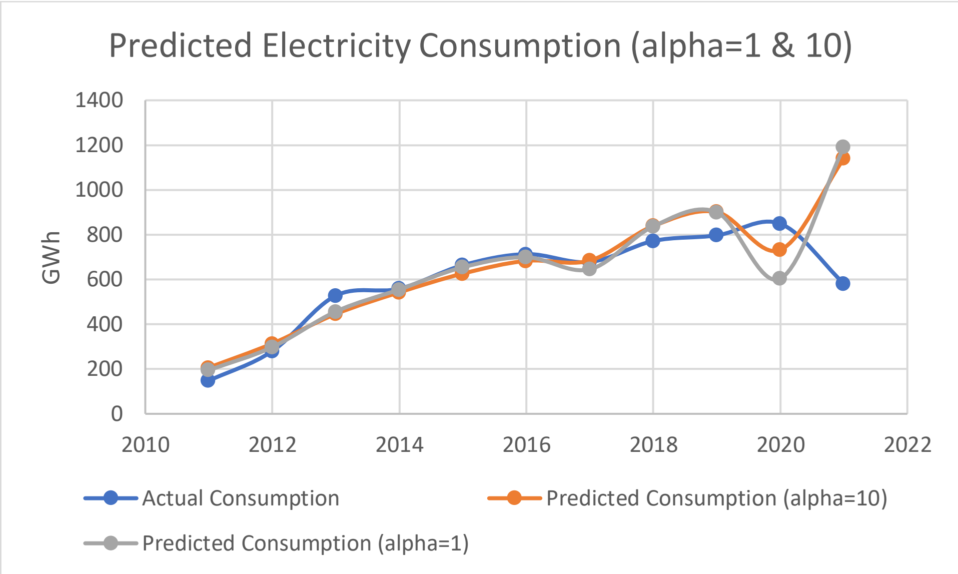


Figure 16 Two Cases of Predicted Electricity Consumption

Cross-validation to done to find the best value of the hyperparameter alpha for a Ridge regression model. The data used for training the model is from 2011 to 2018. The input features used for training are 'Population', 'Average Annual Temperature', 'Urbanisation Percentage', 'GDP Growth', and 'GDP Per Capita', and the target variable is 'Electricity Consumption'.

The Ridge regression model is set up with default parameters, and a parameter grid is defined to search over different values of alpha.

The 5-fold cross-validation is performed to evaluate the model's performance for each combination of hyperparameters in the parameter grid. The scoring metric used to evaluate the performance is the negative root mean squared error (RMSE), which is a common evaluation metric for regression problems.

Finally, the best value of alpha and the corresponding RMSE score are printed to the console. In this case, the best value of alpha is 10.0, and the corresponding RMSE score is 143.97.

Overall, cross-validation is used to tune the hyperparameter alpha for a Ridge regression model and find the best value of alpha that minimizes the RMSE score on the training data. The result is a more optimal Ridge regression model that can potentially improve the prediction performance on new, unseen data

3.6 The Correlation Matrix

	Population	Temperature	Urbanization	GDP Growth	GDP Per Capita	Consumption
Population	1.00	0.75	1.00	-0.67	-0.09	0.81
Temperature		1.00	0.74	-0.10	0.09	0.47
Urbanization			1.00	-0.67	-0.09	0.82
GDP Growth				1.00	0.26	-0.65
GDP Per Capita					1.00	-0.06
Consumption						1.00

Table 2 Correlation Matrix

The table above shows a correlation matrix between the variables of population, temperature, urbanization percentage, GDP growth, GDP Per-capita, and electricity consumption in the context of electricity demand forecasting. The correlation coefficient ranges from -1 to 1, with -1 indicating a perfect negative correlation and 1 indicating a perfect positive correlation.

Based on the matrix, it can be seen that population, urbanization percentage, and temperature are positively correlated with electricity consumption, with coefficients of 0.810, 0.815, and 0.468, respectively. On the other hand, GDP growth and GDP per capita are negatively correlated with electricity consumption, with coefficients of -0.646 and -0.064, respectively.
The high correlation between population and urbanisation percentage (0.999) suggests that they are highly related and may provide similar information. Thus, it may be beneficial to drop one of these variables to avoid multicollinearity in a regression analysis.
Furthermore, temperature and population are highly correlated with each other (0.748), indicating that these variables may be related to one another in predicting electricity consumption. It may be beneficial to consider the interaction between these two variables in a regression analysis.
Overall, this correlation matrix suggests that a multiple linear regression model using population, temperature, and percentage as independent variables may provide an appropriate forecasting model for electricity consumption.

3.7 Data

The data in the model was taken from the sum of all the electricity consumption of the free zones individually. As we are setting the target for the Dubai Free Zone council as a whole. The source of the data for the GDP Growth, GDP per capita, urbanisation and population was taken from the World Development Indicators Data Bank from the World Bank. [14]. The data for the average mean weather from the World Bank Climate Change Knowledge Portal [15]

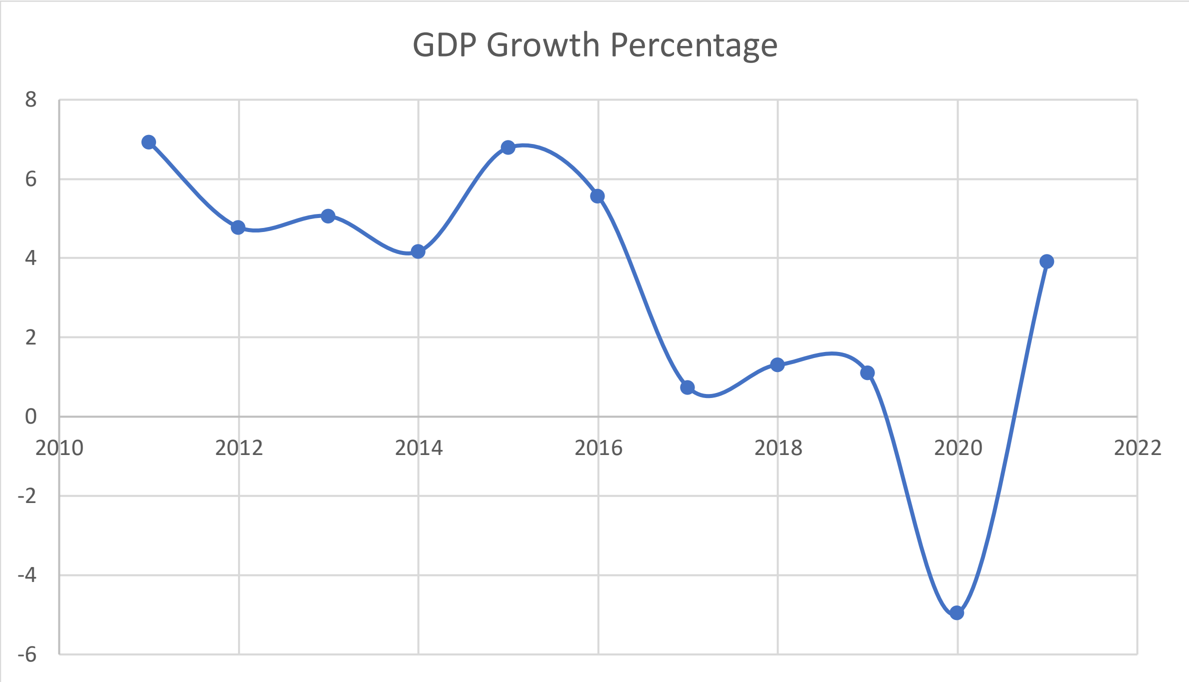


Figure 17: GDP Growth Percentage

Dubai is known for its rapidly growing and diverse economy, with a GDP that has consistently increased over the past few decades. In 2019, Dubai's GDP was estimated to be around $108 billion [16]. This growth has been attributed to various factors, including policies and strategies implemented by the government, investment in infrastructure and technology, and favourable economic conditions.

According to Elbadawi and Soto [17], Dubai's sources of economic growth and development strategy include its strategic location, favourable business environment, and investment in infrastructure. The authors argue that Dubai's government policies and investments in infrastructure have contributed significantly to the growth of the city's economy. In particular, they point to the development of Dubai's transportation and logistics sector as a key driver of economic growth. This sector has been able to take advantage of Dubai's location as a gateway to the Middle East, Africa, and Asia, as well as its world-class port and airport infrastructure.

Another factor that has contributed to Dubai's economic growth is foreign direct investment (FDI). According to Zebregs [18], FDI has been a significant source of capital and technology for many developing countries, and Dubai is no exception. The author argues that FDI can help drive economic growth by increasing productivity, creating jobs, and promoting technology transfer. This has been seen in Dubai, where FDI has played a significant role in the development of the city's infrastructure, real estate, and tourism sectors.

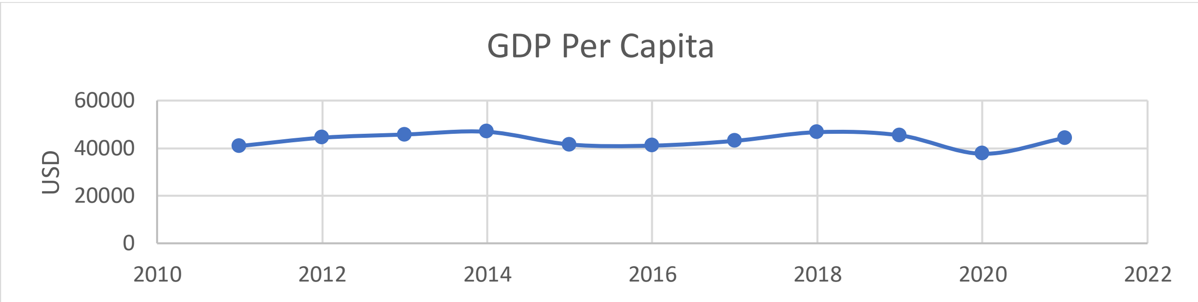


Figure 18 GDP Per Capita

The impact of the global financial crisis on Dubai's economy has been studied by various researchers, including the Dubai Economic Council (2009). The authors of this report argue that the global financial crisis had a significant impact on Dubai's economy, particularly on its real estate and financial sectors. The report highlights the need for the government to take action to address the consequences of the crisis and to anticipate post-crisis transformations. This has led to the implementation of various policies aimed at reducing the dependence on oil and diversifying the economy.

Overall, Dubai's economy has been driven by various factors, including government policies and investments in infrastructure, foreign direct investment, and favourable economic conditions. However, challenges such as the impact of the global financial crisis and inflation can have significant impacts on the economy. Understanding these factors and implementing appropriate policies and strategies can help to ensure the continued growth and success of Dubai's economy.

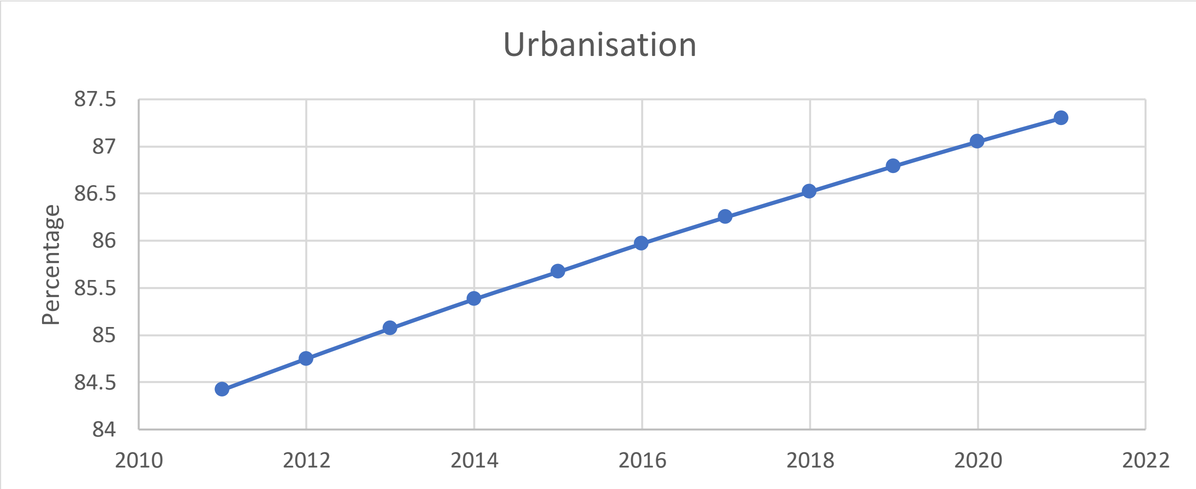


Figure 19 Urbanisation Percentage

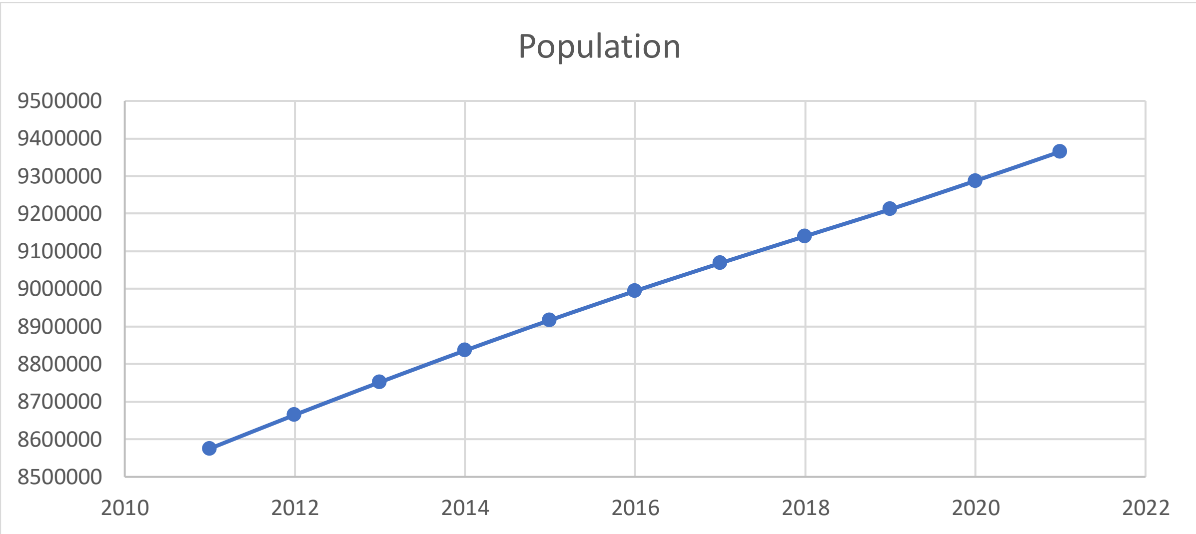


Figure 20 Annual Population

Free zones in Dubai are designated areas where foreign companies can establish a business without the need for a local partner or sponsor. These zones provide various incentives such as tax exemptions, 100% foreign ownership, and streamlined procedures for company setup and registration. This has attracted a large number of foreign investors, which has had a significant impact on the city's urbanization and population growth.

According to a report by the Dubai Statistics Centre, the population of Dubai increased from 1.5 million in 2011 to 3.3 million in 2019, with the majority of the growth coming from the influx of foreign workers and investors in the free zones. The report also highlights that the free zones have contributed significantly to the city's economy, accounting for around 33% of Dubai's GDP in 2019 [19].

Another study by Iriani et al [20] investigated the impact of free zones on the urbanization process in Dubai. The study found that the establishment of free zones has led to the creation of new urban centres, which have attracted a large number of foreign investors and workers. The authors note that this has resulted in the development of new infrastructure, such as transportation networks, housing, and commercial facilities, which has further fuelled the city's urbanization process.

Overall, it is clear that the establishment of free zones has had a significant impact on Dubai's urbanization and population growth. While these zones have contributed to the city's economic development, there is a need for careful consideration of their social and economic impacts to ensure the sustainability of the city's growth trajectory.

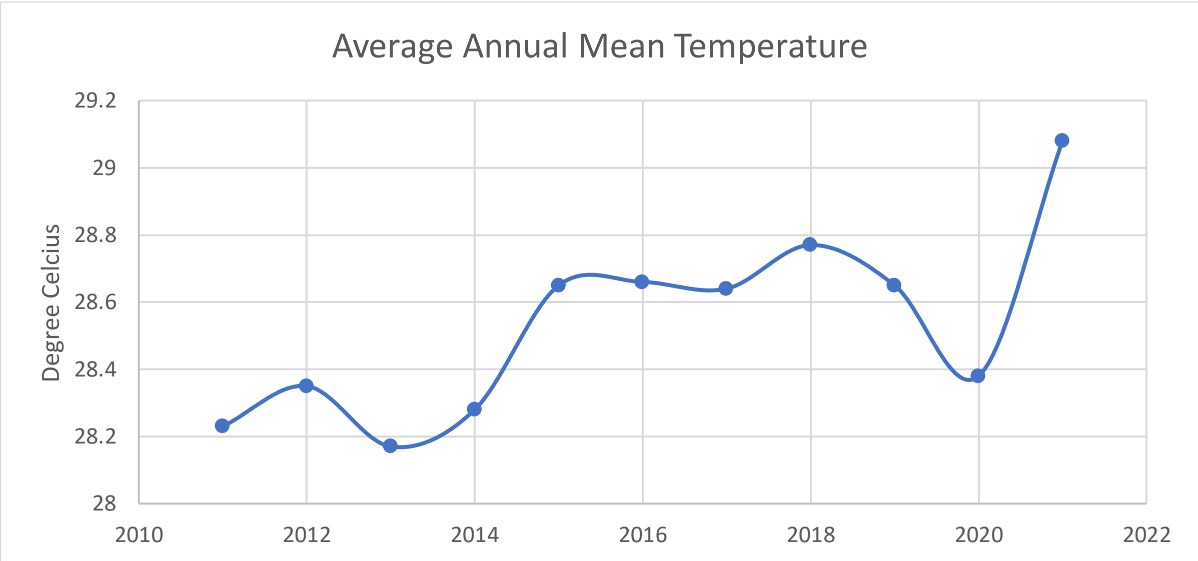


Figure 21 Average Annual Mean Temperature

Climate change is one of the most critical issues faced by our planet today, and understanding the trends in temperature over time is an essential aspect of this issue. The annual average mean temperature of Dubai from 2011 to 2021 has been shown in Figure 19.

According to the data obtained from the Climate Knowledge Portal [21], the annual average mean temperature of Dubai has been steadily increasing over the past decade. In 2011, the temperature was recorded at 28.23 degrees Celsius, and by 2021, it had risen to 29.08 degrees Celsius. This represents an increase of 0.85 degrees Celsius over the past ten years.

This upward trend in temperature is consistent with the broader global trend of rising temperatures due to climate change. The increase in temperature in Dubai can be attributed to various factors such as urbanization, industrialization, and population growth, which are known to contribute to higher temperatures in urban areas.

To mitigate the impact of climate change, it is essential to take immediate action to reduce greenhouse gas emissions and adopt sustainable practices that promote energy efficiency and conservation like the Demand Side Management programs. Furthermore, increasing public awareness and promoting education on the issue of climate change can help to drive meaningful change in the region and beyond.

Now let's discuss about the relation of Dubai Free Zone Council and Dubai electricity consumption

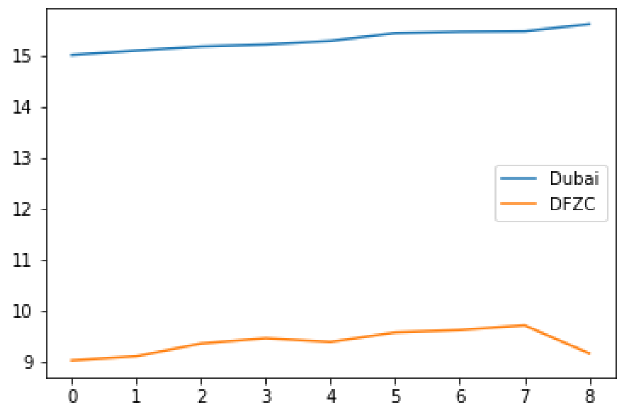


Figure 22 Correlation between the demand for power on the mainland and that in the free zones

The correlation coefficient, calculated using the Pearson correlation test, measures the strength and direction of the linear relationship between two variables. In this case, the two variables being compared are the Dubai Electricity Consumption and the Dubai free zones cumulative energy consumption.

To conduct the Pearson correlation test, one needs to calculate the correlation coefficient (r) and the associated p-value. The p-value is a measure of the probability that the observed correlation coefficient occurred by chance. If the p-value is less than a pre-determined significance level (alpha), it is considered statistically significant and indicates that there is evidence of a non-random relationship between the two variables.

The correlation coefficient is a value between -1 and 1, where a coefficient of 1 indicates a perfect positive correlation (i.e., as one variable increases, the other variable increases proportionally), a coefficient of -1 indicates a perfect negative correlation (i.e., as one variable increases, the other variable decreases proportionally), and a coefficient of 0 indicates no correlation (i.e., there is no linear relationship between the variables).

For the electricity consumption between Dubai and Dubai Free Zones from 2011 – 2021 the correlation coefficient is 0.506, which indicates a moderate positive correlation between the Dubai Electricity Consumption and the Dubai free zones cumulative energy consumption. This suggests that there is a tendency for the two variables to increase together, but there may be other factors that also contribute to their relationship.

The test for statistical significance using a significance level (alpha) of 0.165. The p-value obtained from the Pearson correlation test is compared to the significance level to determine whether the correlation is statistically significant. Since the p-value is less than the significance level, it is concluded that there is a statistically significant correlation between the two datasets.

Therefore, based on the results of the analysis, there is a moderate positive correlation between the Dubai Electricity Consumption and the Dubai free zones cumulative energy consumption, and this correlation is statistically significant

3.8 Results

The coefficients for the variables are obtained by multiple regression using previous decade data form 2011-2021 and the results are as follows:

y = -11901.92 + 0.00*Population + -18.29*Temperature + -0.82*Urbanization Percentage + 40.43*GDP Growth + 0.02*GDP Per Capita - 10.00*alpha

The given equation represents a ridge regression line, which is a regularized form of linear regression used to prevent overfitting of the model on the training data.

The coefficients (or weights) of the different independent variables in the model and their relation with the dependent variable which is the electricity consumption can be interpreted as follows:

1. Population: The coefficient for Population is 0.00, indicating that this variable has no effect on the dependent variable (i.e., it has a zero impact on the outcome).

2. Temperature: The coefficient for Temperature is -18.29, indicating that as Temperature increases by 1 unit, the dependent variable is expected to decrease by 18.29 units, all other variables being held constant.

3. Urbanization Percentage: The coefficient for Urbanization Percentage is -0.82, indicating that as Urbanization Percentage increases by 1 unit, the dependent variable is expected to decrease by 0.82 units, all other variables being held constant.

4. GDP Growth: The coefficient for GDP Growth is 40.43, indicating that as GDP Growth increases by 1 unit, the dependent variable is expected to increase by 40.43 units, all other variables being held constant.

5. GDP Per Capita: The coefficient for GDP Per Capita is 0.02, indicating that as GDP Per Capita increases by 1 unit, the dependent variable is expected to increase by 0.02 units, all other variables being held constant.

6. alpha: The coefficient for alpha is 10, which is the regularization parameter used in Ridge regression. This helps to prevent overfitting of the model on the training data by shrinking the coefficients towards zero.

Overall, the Ridge regression line suggests that the most important variables for predicting the dependent variable are GDP Growth and GDP Per Capita, followed by Temperature and Urbanization Percentage. The coefficient for Population is zero, indicating that it has no effect on the outcome. The Ridge regularization parameter (alpha) has been set to 10 so that the model is highly regularized and the coefficients have been heavily shrunk towards zero to prevent overfitting.

The dependency of the variables can be explained as follows:

GDP Growth: This variable is often used as a proxy for economic development and growth, and is expected to have a positive effect on the dependent variable which is the electricity consumption. A growing economy is likely to lead to an increase in demand for goods and services, which in turn can lead to an increase in the electricity consumption .

GDP Per Capita: This variable is often used as a proxy for the standard of living, and is expected to have a positive effect on the dependent variable. A higher GDP per capita is associated with higher levels of consumption and investment, which in turn can lead to an increase in the electricity consumption. The dependence on this variable is less as the free zone electricity consumption is mainly due to the increase in the economic development from the service sector and not from the residential sector.

There could be several reasons why urbanisation percentage annually and annual mean temperature average are negatively affecting electricity consumption in Dubai's free economic zone based on the regression model.

Energy-efficient buildings: As urbanisation increases, the construction of energy-efficient buildings also increases. These buildings are designed to conserve energy by reducing heat gain/loss through walls, windows, and roofs, and by using efficient lighting and cooling systems. This can result in lower electricity consumption.
Also, Dubai free economic zone has been primarily a service-based economy. Service-based businesses typically require less energy-intensive processes than manufacturing, resulting in lower electricity consumption.

Reduced need for cooling: The negative effect of annual mean temperature average on electricity consumption could be due to the fact that as temperatures rise, people tend to use less electricity for heating, and the need for cooling is reduced due to the efficiency of modern air conditioning systems.

The free zone council has implemented several energy-saving as mentioned earlier in recent years, such as promoting the use of energy-efficient appliances and increasing public awareness about energy conservation. These initiatives may have contributed to the negative effect of urbanisation and temperature on electricity consumption.

Overall, there could be several factors at play in the negative effect of urbanisation and temperature on electricity consumption in the Dubai free economic zone. It's important to conduct further research to understand the underlying causes and to identify potential solutions to mitigate any negative impacts on energy consumption.

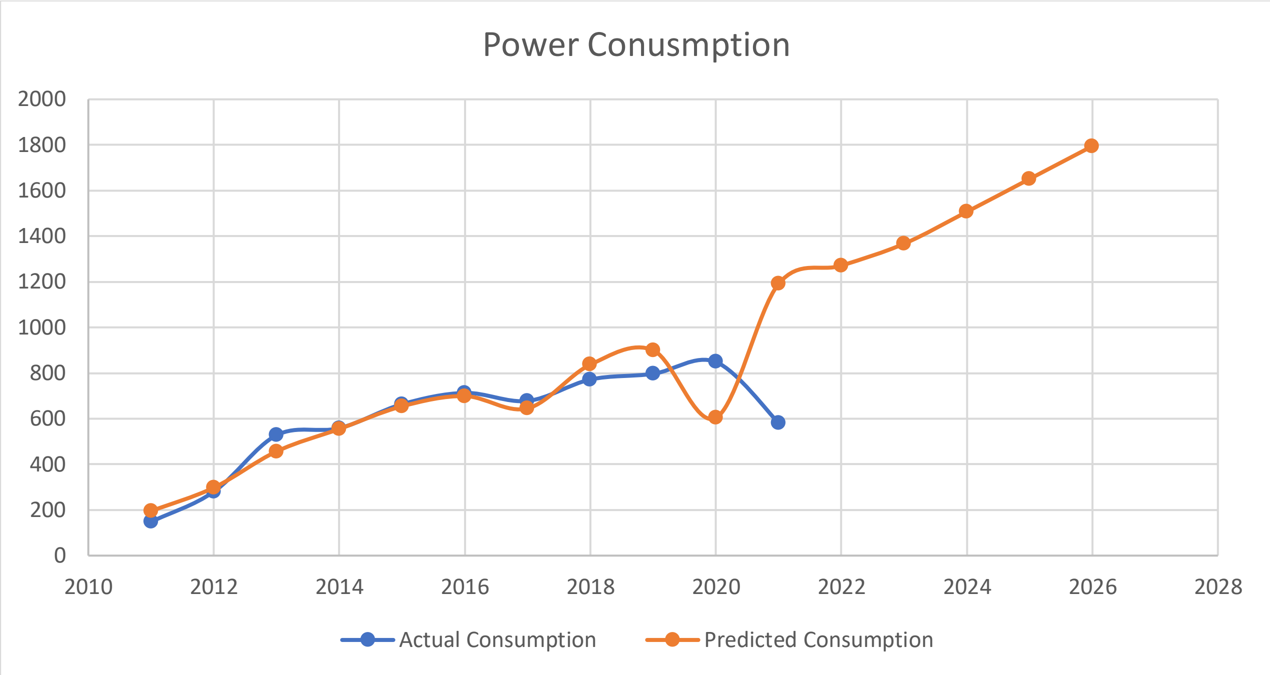


Figure 23 Actual and the Predicted Consumption results from the model

Year	Actual Consumption (GWh)	Predicted Consumption (GWh) (alpha=10)
2011	148.00	206.53
2012	280.02	313.58
2013	527.76	445.75
2014	558.54	542.41
2015	663.67	626.23
2016	713.13	683.18
2017	677.96	684.49
2018	771.79	838.70
2019	796.73	901.18
2020	848.73	732.22
2021	581.24	1139.93
2022	-	1271
2023	-	1367
2024	-	1507
2025	-	1651
2026	-	1795

Table 3 Actual and the Predicted Energy Consumption

The figure shows the actual electricity consumption with the estimated values using the models that we have developed. As seen from the figure an appropriate fit of the historical data is provided except for the anomaly in the year 2020 and 2021. For the year 2020 (due to the Global Pandemic) the dip in the predicted electricity consumption is due to the negative GDP growth and as seen from the equation the magnitude of coefficient for the GDP Growth variable is the highest.

Dubai's GDP growth over the past decade has been characterized by ups and downs. Between 2010 and 2015, Dubai experienced strong economic growth, with annual GDP growth rates averaging around 4.5%. This period of growth was driven by a number of factors, including rising oil prices, strong investment in the real estate sector, and the hosting of high-profile events like the Dubai World Expo in 2012.

However, in 2016, Dubai's GDP growth slowed down due to a combination of factors, including the global economic slowdown, low oil prices, and a slowdown in the real estate market. From 2016 to 2019, the annual GDP growth rate averaged around 2.5%, which was still relatively healthy compared to other global economies.

In 2020, the COVID-19 pandemic hit the global economy hard, and Dubai was no exception. The pandemic had a significant impact on Dubai's economy, particularly on the tourism and hospitality sectors. As a result, Dubai's GDP contracted by 6.1% in 2020, marking the first contraction in a decade.

As for the year 2021, the data reporting and collection from the Free Zones is not complete therefore it cannot be said that weather the electricity consumption in 2021 is closely fit to the point predicted by the model.

The Dubai Demand Side Management (DSM) Strategy 2030 is an important initiative for sustainable growth in Dubai, especially in light of the UAE's commitment to achieve Net Zero by 2050. The DSM Strategy aims to deliver 30% annual savings in electricity and water consumption by 2030 compared to the business as usual consumption. The implementation of the DSM Strategy in 2021 resulted in 6.4 TWh of annual electricity savings and 12.2 billion imperial gallons of annual water savings, which surpassed the set targets for the year.

To achieve the DSM Strategy goals, various programmes are rapidly expanding and the efforts of all programme owners are crucial. The ongoing support received from the Dubai leadership and institutions gives confidence that the ambitious goals of the DSM Strategy will be achieved. The DSM Strategy is generating real savings, improving awareness, building capabilities, and developing the energy efficiency market.

In line with the DSM Strategy, a Dubai Free Zone Savings Model was developed using a linear regression model and a ridge regression model. The model was trained from 2011 to 2018 and tested from 2018 till 2021. The ridge regression model performed better with a lower RMS error. The model used forecasted data for features such as GDP growth, GDP per capita, Population, and Urbanization from the World Bank, to forecast electricity consumption until the year 2026.

The predicted business as usual electricity consumption for the year 2026 is 1795 GWh. Therefore, the savings target was set at 30% of the business as usual consumption in line with the national policy.

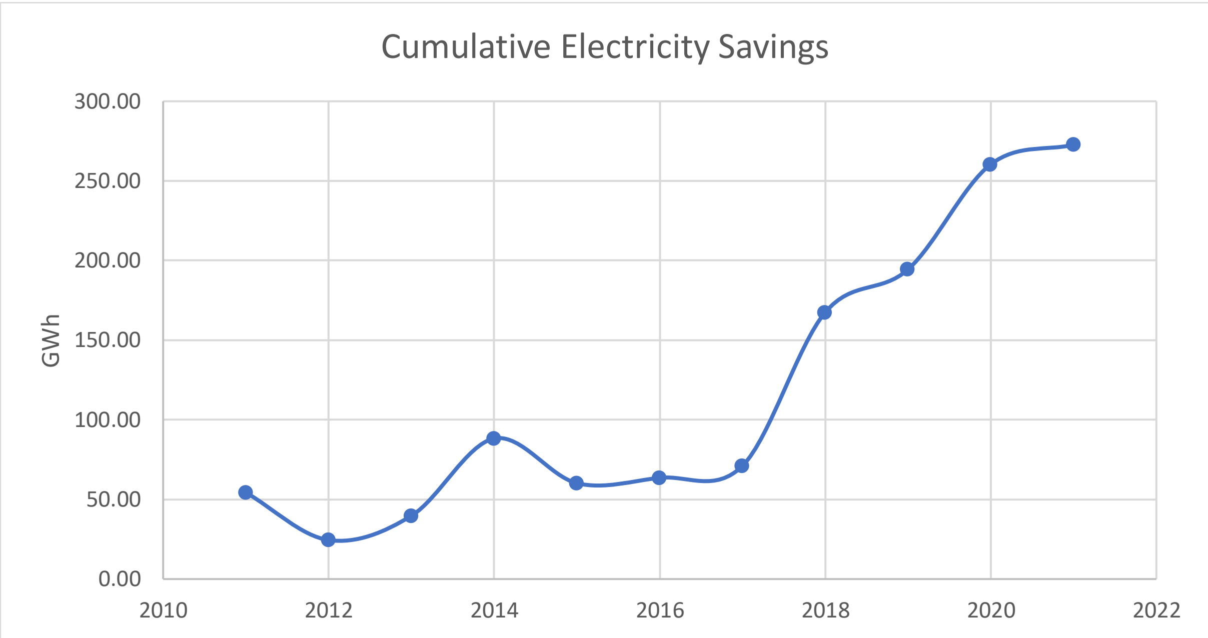


Figure 24 Cumulative Electricity Savings

Overall, the DSM Strategy and the Dubai Free Zone Savings Model demonstrate Dubai's commitment to achieving sustainable growth and reducing electricity and water consumption. The target seems achievable as the current savings is 30% of the total energy consumptions of all the zones. The electricity savings in the year 2021 are around 272 GWh.

4 Programs and Implementation Mechanism

4.1 Programs

The implementation mechanism and savings program can greatly help in achieving savings in electricity consumption. The initiatives and milestones developed can provide a structured approach to identify and prioritize energy-saving opportunities and to implement measures to reduce energy consumption.

1. Green Building Program

	Initiative	Milestones	Additional Implementation Details
1.1	Implementing a stringent building code that mandates a specific minimum efficiency level for all new buildings.	Impose a 20% efficiency minimum for all new buildings (compared to 2011 baseline)	"Conduct a study to identify a green building code which meets the requirement Apply to all new construction across free zones "
		Impose a 40% efficiency minimum for all new buildings (compared to 2011 baseline)	
1.2	Following a building rating system that reflects a building's level of efficiency and quality (e.g., Sa'fat).	Impose all undeveloped land to be developed as Gold Sa'fa (A local green building code)	Create a regulation around this and restricting building permits that do not support this.

2. Building Retrofits

	Initiative	Milestones	Additional Implementation Details
2.1	Building retrofits.	Conduct technical and commercial feasibility study to understand the potential to retrofit buildings	Conduct cost benefit analysis

2.1	Building retrofits.	Retrofits 50% of existing buildings indicated by the study	Raise funds from green finance by presenting the prospective savings through this initiative and determining the breakeven time of the raised investment or utilizing partnerships with Energy Service Companies (ESCOs)
2.1	Building retrofits.	Retrofits 100% of existing buildings indicated by the study	Raise funds from green finance by presenting the prospective savings through this initiative and determining the breakeven time of the raised investment or utilizing partnerships with ESCOs
2.2	Common areas retrofits.	Conduct retrofits on 50% of all common areas indicated by the study	Use of OpEx Model if CapEx is not available. Commercial feasibility study (of the model) should be conducted.
2.2	Common areas retrofits.	Extend latter milestone to reach 100% of all common areas indicated by the study	Conduct technical & commercial feasibility study to understand the business case for retrofitting common areas (at the areas controlled by the Free Zone)

3. Outdoor Lighting

	Initiative	Milestones	Additional Implementation Details
3.1	Increasing the minimum efficiency standard for new developments	Impose all new outdoor lighting to be fitted with LED.	Issue a requirement to the all zones to install LED lights through building codes and regulations.
3.2	Retrofitting the existing lighting	Conduct technical and commercial feasibility study to understand the potential to replace street lighting to high efficiency	Conduct cost benefit analysis

3.2	Retrofitting the existing lighting	Conduct LED retrofits on 50% of the outdoor lighting indicated by the study	Use of OpEx Model if CapEx is not available.
3.2	Retrofitting the existing lighting	Extend the former Milestone to Conduct LED retrofits on 100% of the outdoor lighting indicated by the study	Use of OpEx Model if CapEx is not available.
3.3	Install solar street lights	Replace 50% of street lights with solar street lights.	Raise funds from green finance by presenting the prospective savings through this initiative and determining the breakeven time of the raised investment or utilizing partnerships with ESCOs
3.3	Install solar street lights	Replace 100% of street lights with solar street light.	Raise funds from green finance by presenting the prospective savings through this initiative and determining the breakeven time of the raised investment or utilizing partnerships with ESCOs
3.4	Implement a switch-off initiative	Implement a switch-off policy for low-traffic residential areas of 40-50% of your street lights after 10 pm.	Install automatic lighting controls such as timers or motion sensors to ensure the lights are turned of at specified times

4. Efficient Cooling

	Initiative	Milestones	Additional Implementation Details
4.1	Implementing District Cooling Independently	Identify where independent District Cooling system can be implemented in a planned development that is in early stage design.	Conduct a feasibility study to rule out the uncertainty in the resistance of the chilled water network in the District Cooling
4.1	Implementing District Cooling Independently	Develop District Cooling Plants through financing and distribute to owned assets for lower energy costs and sold and leased assets by acting as a District Cooling operator.	Understanding the need for DC plants through a careful feasibility study proving the current efficiency of conventional cooling and the clear benefit of District Centralised Cooling in contrast.

5. Consumer Behaviour

Initiative	Milestones	Additional Implementation Details
Tenant engagement on DSM initiatives	Design engagement plan to educate tenants on DSM programs	Conduct Awareness and Training Programs
Tenant data submissions	Design program to allow for tenant data submission	Conduct Awareness and Training Programs

6. Solar Power Generation

	Initiative	Milestones	Additional Implementation Details
6.1	Increasing Solar PV generational efficiency	Implementing smart asset management software that allow for a better output from solar rooftops and parks.	Data platforms that monitor renewable asset activity can be used here.
6.2	Conducting a regulatory & commercial study to increase Solar PV Generation and Capacity Cap.	Engage with DEWA (Dubai Electricity and Water Authority)on solar PV regulations.	Understand the need for further uptake of PV in the Free zone and initiating discussion with DEWA.
6.2	Conducting a regulatory & commercial study to increase Solar PV Generation and Capacity Cap.	Develop a business case for a joint venture with DEWA and other energy developers to develop solar projects in the free zone.	Conduct a feasibility study to show the commercial benefit of developing solar installation in collaboration with DEWA.

6.2	Conducting a regulatory & commercial study to increase Solar PV Generation and Capacity Cap.	Enter a joint venture with DEWA and other energy developers to develop solar projects for the free zone.	Proving the feasibility of further uptake of PV in the Free zone and creating an agreement with DEWA.
6.3	I-REC purchasing scheme to be adopted by Zones having maximum solar capacity as per DEWA Cap	Purchasing the desired number of I-REC certificates through centralized platform or directly through the supplier.	I-REC program should have a robust monitoring and verification process in order to ensure they accurately represent the environmental benefits

7. Recycled and Ground Water Demand Management

	Initiative	Milestones	Additional Implementation Details
7.1	Increasing usage of Recycled Water.	Initiate discussions with District Cooling operators specific to your free zone regarding the usage of recycled water for efficient cooling.	Conduct a feasibility study to show the commercial benefit of using recycled ground water for District Cooling Plants.
7.1	Increasing usage of Recycled Water.	Implement the use of Recycled Water for District Cooling throughout the free zone by making it a requirement for operators to be able to sell cooling in your zone.	Guidelines for the use of the recycled water in DC by the DFZC

7.2	Using sensors and monitoring technologies	Implementing the technologies for leakage management, water quality monitoring, meter readings and water conservation through financing or OpEx model.	Retrofit technologies into equipment through certified products and services that allow for increased efficiency as well as monitoring of activity.
7.3	Promote the use of efficient irrigation practices	Implement 50% of your systems as drip irrigation.	To be applied for new landscape as well as existing.
7.3	Promote the use of efficient irrigation practices	Implement 100% of your systems as drip irrigation.	To be applied for new landscape as well as existing.

8. Efficient & Smart Charging

	Initiative	**Milestones**	**Additional Implementation Details**
8.1	Expand EV Charging Point Network	Create plan roll out of charging points in new and existing buildings & infrastructure.	Coordinate with DEWA to determine optimal installation location
8.2	Promote Adoption of Green Vehicle	Roll out EV fleets for free zone authorities, where existing, to reach a level of 10% penetration	

9. Smart Facility Management

	Initiative	Milestones	Additional Implementation Details
9.1	Capacity Building for Facility Management	Require accreditation from RSB for all senior facility management staff	Require accreditation from RSB for all senior facility management staff
9.1	Capacity Building for Facility Management	Create a sustainable facility management policy and guideline that will be applicable for all free zone authorities	With support from a sustainability consultant.
9.2	Sustainable Facility Management	Free zones implement the policy and guidelines within their operations	Awareness programs, workshops and trainings can be used to facilitate policy & guideline implementation.
9.2	Sustainable Facility Management	Create task force to perform site visits and energy audits	With support from an energy consultant or energy auditor.
9.3	Supporting Information Distribution	Implement platform for information sharing across free zones	Create a software architecture that links one main platform for the DFZC to individual software for each Free zone whilst taking into account compatibility across all platforms
9.3	Supporting Information Distribution	Implement champions program to highlight learning from high performers	Using platform created previously, creating a ranking system based on performance.
9.4	Create a set of procurement standards and guideline	Roll out implementation via free zone level standards and guidelines	Following these standards and guidelines, executing the purchases.
9.4	Create a set of procurement standards and guideline	Ensure procurement of data-friendly equipment that allow for easy data accessibility	Scouting the market for the most digital friendly equipment and understand how it can suit the need of the concerned Free zone, then putting in place a procurement system that ensures the purchase of said equipment.

4.2 Implementation Mechanism

Implementation mechanisms are important because they help ensure that energy-saving measures are implemented effectively and efficiently. They can also help track and measure the impact of these measures over time, providing feedback on their effectiveness and identifying areas for further improvement. Additionally, implementation mechanisms can help overcome barriers to energy savings, such as lack of awareness or funding, by providing a clear plan of action and resources for implementation.

	Initiative	**Milestones**	**Additional Implementation Details**
1	Digitalisation Across Free Zones	Prepare guidelines on digitalisation	Create step by step outline on how to digitalise in a manner adapted to each Free zone respectively.
2	Digitalisation Across Free Zones	Implement digitalisation for data collection with digital dashboard and standardized outputs	Use guidelines to understand the purpose of digitalisation and creating tools to answer this purpose.
3	Digitalisation Across Free Zones	Implement web portal for free zone data submissions	Work with supplier to develop a web portal for automatising DSM savings
4	Enhanced Data Collection	Set guidelines for submetering and implement procurement guidelines for connected equipment	Create a submeter system architecture to enhance efficiency and data accuracy.

5	Enhanced Data Collection	Provide structure for tenant data submissions	Create data collection platform using previous milestone.
6	Capacity Building	Development of training and guidelines targeted at members of the energy committee	Conduct trainings 2 times a year covering topics relevant to DSM, net zero, and sustainability
7	Capacity Building	Development of training and guidelines targeted at facility managers (project manager level)	Conduct trainings 2 times a year covering topics relevant to digitization, smart facility management, and responsibilities within DSM
8	Tenant Awareness	Development of training and guidelines targeted at tenants as well as consultants and vendors.	Conduct trainings seminars and workshops to upon enrolling new vendors / tenants as well as once / twice a year for old vendors/tenants.

5 Conclusion and future development

In the internship that I concluded with the AESG and we presented the final results and suggestion with the Dubai Free Zone Council.

The challenges faced by Free Zones in terms of energy and water reporting and savings are numerous and complex. The lack of visibility on electricity and water usage on buildings not owned by the authority, coupled with confusing billing procedures and metering issues, makes data collection and validation a significant challenge.

Additionally, regulations around solar PV which prevents any facility to install more than 2 MW of solar panels [22] and the need for sustainable facilities to cater to international agencies following sustainable development goals pose further obstacles.

Warehouses rented by Free Zones are often uninsulated and require significant cooling loads, which places a strain on DEWA connection and necessitates the use of diesel generators. Finally, value engineering and Empower's (District Cooling Provider) policies make it difficult to focus on sustainability initiatives, and Delta T challenges pose an ongoing issue. Even though some of the free zones have their own district cooling plants and are able to save a lot on energy but not every zone is has the resources to replicate that.

The presented energy savings target, derived through regression modelling, provides a preliminary indication of the desired outcome. Based on the regression model, the energy savings target has been proposed. However, it should be noted that these targets are subject to change with accurate and complete data reporting. The predicted business-as-usual energy consumption, which relies on factors such as GDP, weather, and population projections, may also vary based on future economic scenarios and political developments. Therefore, while these targets provide a sense of what can be achieved, it is important to consider the limitations and uncertainties associated with the underlying data and assumptions. Further research and analysis are needed to refine these targets and improve the accuracy of the predictions.

To overcome these challenges, it is recommended that Free Zones focus on finding a baseline for energy and water usage, using guidelines and case studies from international best practice, and developing a unified strategy across Dubai Free Zone Council. It is also important to ensure that new initiatives do not discourage developers and that the economic success of the Free Zone is not compromised. Centralizing data and implementing per-plot electricity metering can help address data collection issues, while regular equipment maintenance and proprietary protocols can improve energy efficiency. To address Delta T challenges, Free Zones should consider incorporating new technologies and adopting best practices from other industries.

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