Application of Machine Learning algorithms to evaluate the changes in energy consumption in the Leinster area and subsequently the impact on consumer behaviour in the commercial sector.

Maria Dominguez Alvarenga

A Thesis Submitted in Partial Fulfilment

of the requirements for the

Degree of

Master of Science in Data Analytics

Diagram

Description automatically generated with medium confidence

May 2024

Supervisor: Kislay Raj

**Abstract**

Table of Contents

[1. Topic: 2](#_Toc152532757)

[2. Title: 2](#_Toc152532758)

[3. Proposed Objectives. 2](#_Toc152532759)

[3.1. Research Objectives. 2](#_Toc152532760)

[3.2. Technical Objectives. 2](#_Toc152532761)

[4. Literature Review: 3](#_Toc152532762)

[4.1. Global Energy crisis – Volatile in the energy sector. 4](#_Toc152532763)

[4.2. Data Centres electricity consumption 4](#_Toc152532764)

[4.3. Data Analytics in Energy - Electricity prediction 6](#_Toc152532765)

[4.4. Conclusion. 7](#_Toc152532766)

[5. Sampling Strategy 7](#_Toc152532767)

[5.1. Population. 7](#_Toc152532768)

[5.2. Sampling Method. 7](#_Toc152532769)

[5.3. Sampling type. 8](#_Toc152532770)

[5.3.1. Sampling size. 8](#_Toc152532771)

[6. Research Methodology. 8](#_Toc152532772)

[6.1. Primary Research. 8](#_Toc152532773)

[6.1.1. Profiles of people for Depth Interviews per population. 9](#_Toc152532774)

[6.2. Secondary Research. 10](#_Toc152532775)

[7. Ethical and Risk considerations during the Data Analytics project. 10](#_Toc152532776)

[7.1. Data collection – Use of Open Data. 10](#_Toc152532777)

[7.2. Not obtaining enough data - Personal data issues. 11](#_Toc152532778)

[7.3. Literature review: 11](#_Toc152532779)

[7.4. Bias information: 11](#_Toc152532780)

[7.5. Voluntary participation in the depth interview: 12](#_Toc152532781)

[8. Further areas of study. 12](#_Toc152532782)

[9. References. 13](#_Toc152532784)

# **1. Topic:**

The energy sector has been experiencing volatile since winter 2021 due to different factors that had affected the supply of gas, which resulted in the sudden increase of prices of electricity, which is still an ongoing concern. Consequently, the constant fluctuations in energy prices are an area where research can be conducted. Therefore, it is intended to evaluate the electricity consumption of the commercial sector and Data Centres in Leinster area using Data Analytics algorithms and examine the reasons of the fluctuations in consumer behaviour.

# **2. Title:**

Application of Machine Learning algorithms to evaluate the changes in energy consumption in the Leinster area and subsequently the impact on consumer behaviour in the commercial sector.

# **3. Proposed Objectives.**

## **3.1. Research Objectives.**

1. Analyse the changes in energy, in terms of electricity consumption of the commercial users of Leinster area.
2. Investigate the reasons for the variations in the usage of electricity in the commercial sector and data centres recorded on the gathered datasets.
3. Use Data Analytics through deep learning ANN and SVR, RFR, machine learning models to obtain the most suitable proposed strategy to assist customers in Leinster area to manage energy consumption.

## **3.2. Technical Objectives.**

1. Train traditional machine learning models as Random Forest Regressor, Decision Tree Regressor, Support Vector Regressor and a Deep learning Artificial Neural Network model with data from meter readings for commercial and Data Centres users of Leinster area to analyse their performance in terms of energy (electricity) consumption.
2. Examine the features in the dataset that can affect energy usage through a correlation analysis of the extracted features from the data.
3. Validate the results obtained from the models prepared to compare their performance to offer better options to users about the managing of energy consumption.

# **4. Literature Review:**

According to the Sustainable Energy Authority of Ireland (SEAI) (2023), the sectors that consume more energy in Ireland are Transport, Residential, and Business sectors. The focus of this study will be concentrated in two groups of the Business sector, which are the commercial sector and Data Centres. This last one is part of the Information and Communication Technology sector (ICT). Hence, it is intended to document the reasons of the recent fluctuations of the electricity prices, the volatile in the energy sector and the increasing demand in electricity of Data Centres. As well as that, the application of Data Analytics in the research of electricity usage and how traditional machine learning techniques and deep learning models have been useful to measure the consumption of electricity and therefore to identify ways how to improve the energy efficiency through the example of different research studies.

The sources referenced below were obtain from different online sources such as the Irish Times, research papers, national websites (Central Statistics Office, Government of Ireland, Bord Gais, International Energy Agency, Sustainable Energy Authority of Ireland, Data Centre Journal and RTE News) It was decided to pay a subscription in the Irish Time as the main articles that I needed to have access to were only accessible to subscribers. Since this is a trustworthy national source, I considered this needed to complete the research proposal. Nevertheless, I already request a free subscription as a master student which will be very useful next year to prepare the capstone project.

## **4.1. Global Energy crisis – Volatile in the energy sector.**

As stated on the International Energy Agency site (2023), in 2021 the energy markets began to increase due to different factors, among them it can be listed the fast economic rebound after the covid-19 pandemic. However, the crisis was significantly intensified into a global crisis in the energy sector following the Ukraine invasion by Russia which occurred in February 2022. Similarity, on a different source (Bord Gais site, 2023) another factor that make a significant impact on energy prices was the sanctions imposed on Russia by the EU, which cause that Russia reduced its gas supply to other countries and cutting the supply to some countries in Europe. As a result of that, electricity prices increased as the prices of natural gas incremented severely. Hence, the highest level in oil prices were recorded since 2008 (IEA, 2023) as natural gas is accounted for 34% of the primary energy requirements in Ireland that is used for the generation of Electricity (Gov.ie, 2023)

As stated by O’Halloran (2023) electricity prices went up again in October this year due to the Israel-Hamas conflict which cause fossil fuel cost increased. As the same source went on (O’Halloran, 2023) Ireland power generation relied almost exclusively on fossil fuel, which wholesale electricity prices had an estimated price of € 125.52 a megawatt hour sold in October 2023, which was 12 per cent higher than the price for the previous month of September this year.

Pope (2023) states that the cost of energy increasing cost since winter 2021 has cause a shocking effect on the Irish households and the cost of light and heating were double in price. Despite the facts that the government implemented a series of energy credits, the impact on the increased in electricity prices was extreme. As the same source went on (Pope, 2023) households in Ireland pay including taxes 47.12c per kw hour, which is way higher in comparison with the average price in Europe of 26.34c.

## **4.2. Data Centres electricity consumption**

According to Data Centre Journal site (2023) there are 19 data centres located in Dublin area. Among those Digital Realty’s, Equinix DB1, Keppel, Servecentric, Amazon Data Centre can be listed. According to CSO site (2023) the data centres electricity consumption has increased between 2021 and 2022 by 31%. This steady increased can be compared with the total of 215 gigawatts hours expended by Data Centres between January to March of 2015 and the 1,450 gigawatts per hour utilized between October-December 2022, which represents an increase of 400%. In other words, this represents an increase from 5% to 18% of metered electricity used by data centres by the end of 2022. Similarly, as outlined by Seai site (2023), the information and communication technology sector (ICT), which includes the data centres was accounted for 3.9% of the total energy demand and16.5% of its total of electricity demand of Ireland in 2021.

Similarly, O’Sullivan outlines (2023) that data centres are accounted for 18 per cent of Ireland total consumption of electricity in 2022, in comparison with the reduction of house’s energy usage during the same period. There are more than 75 data centres in Ireland and most of them are concentrated in Dublin area. As the same source went on (O’Sullivan, 2023) the amount of electricity used in Kilkenny city could be compared with the total electricity consumption of one large data centre near the M50.

Lantry (2023) argues that data centres are essential due the digital connectivity enable by them, which helps to the diagnose and hospital equipment, transport systems, solar and wind energy storage innovations, which depend on the connectivity produced by data centres. Hence, Ireland is interested in continuing being the centre of the digital world as the data centres, which make sure to provide high-speed connectivity to users are located near the main cities (Lantry, 2023). In contrast, Bray and Curran (2023) agree with the fact that data centres are beneficial and important to Ireland as they have provided to the country with the advantage to have the digital industries operating here, but also stress out that is critical to find of source electricity to them in a more efficient way.

According to DCD site (2023) appeals have been filed with the planning regulator in Ireland to stop the building of Amazon new data centres in Dublin as the proposed development will represent a significant pressure on the decarbonisation of the electricity sector. Similarly, as stated on RTE news (2023) that it has been confirmed by EirGrid that it will not connect any new data centres in Dublin in future as the Dublin area is already limited. Therefore, any new data centre application will be only taken into consideration if they are planned to be built in other parts of the country. As the same source went on (RTE, 2023) there are concerns in terms of the large electricity usage and energy security of data centres as EirGrid has issued in the recent 12 months period seven amber warnings about the energy supply concerns.

However, as outlined by Corcoran and Andrae research (2013) data centres were less transparent to consumers as they infrastructures are energy cost, which expansion were expected to continue in the future as they were seen as critical element for the ICT industry. Similarly, Coyne and Denny (2018) carried out a study about the evaluation of the electricity use in the Data Centres in Ireland, which produced similar findings as their represented a significant electricity demand and there was a growing concern in terms of network structure and electricity generation.

## **4.3. Data Analytics in Energy - Electricity prediction**

As Vom et al. (2020) study outlines that factor as volatility in generation of electricity as a result of a raising share of sources of renewable energy, rise complexity and therefore, create new demand for Data Analytics. One of the findings of this study was the importance of electricity consumption in the topic Data Analytics in the electricity area as most of the literature review were allocated in that range, followed by generation and transmission of electricity. As the same source went on (Vom et al, 2020), outlines that the forecasting of consumption of electricity was the leading application of Data Analytics in terms of electricity area. The same study shown that consumption of electricity was often performed using Artificial Neural Networks, Autoregressive Integrated Moving Average (ARIMA) and hybrid approaches based on Support Vector Regressor (Vom et al., 2020)

On a different study conducted by Sarswatula et al. (2022) that aimed to analyse the effectiveness of machine learning models which were used to predict electricity consumption. They developed machine learning models such as Random Forest Regressor, Extreme Gradient Boost Regressor, Multiple Linear Regressor and Decision Tree Regressor to predict energy consumption (Sarswatula et al., 2022) As well as that, they developed classifiers as Randon Forest, Support Vector Machine, KNN and Deep Learning. The results of such study concluded that Random Forest Regressor was the best prediction model with R2 score of 0.869. Deep learning also yields an accuracy of 0.88 after 10 epochs in training and testing. As the same source went on (Sarswatula et al, 2022) the results of that research concluded that machine learning algorithms could be a helpful benchmark to measure consumption in factories and help to identify how to improve energy efficiency.

However, it has been pointed out by Guo et al. (2022) that there are some deficiencies in the research on household electricity consumption as most studies fail to explore in a comprehensive way the relationships between the interactions of time related factors and housing electricity patterns. They (Guo eta al., 2022) also outlined that researchers often examine energy patterns and usage from a static point of view when electricity consumption patterns have fluctuations through different time intervals as daytime during winter last less than in summer season, temperature area among others.

## **4.4. Conclusion.**

As stated above, the energy sector in Ireland is subjected to fluctuations caused by external factors as the supply of gas from other countries. Variations in the electricity prices will continue happening and sectors, particularly the commercial sector and ICT sub sector, where the Data Centres are included, will experience changes in consumer behaviour when it comes to usage of electricity. Hence, there is the need to continue carrying out research about the prediction of electricity consumption of the chosen sectors.

# **5. Sampling Strategy**

## **5.1. Population.**

Hence, the population chosen to conduct the sampling were selected within the business sector, particularly the commercial, services and the ICT sub sector, where the Data Centres belong and the reason why these have been selected as the datasets on meter readings consumption chosen with accessible data have non-residential client’s data (commercial customers) and Data Centres electricity usage. It has been identified three populations, which are going to represent the audience, which are the Electricity companies, Data Centres and Business users in Leinster area. The first two populations have been selected as they are represented in the available data from CSO site, which made them relevant and can provide with insight during a given period (2015-2022) about the electricity consumption in these sectors. The business users have been selected as a population as is aimed to get information from local business which could produce insight about the variations in their behaviour in terms of electricity usage in Leinster area.

## **5.2. Sampling Method.**

The proposed sampling methodology chosen will be non-probability sampling as not every person of the chosen populations will have an equal chance of participating in the research (QuestionPro, 2023). As it will be later explained in the research methodology section, the sampling chosen from the first two populations (Electricity companies and Data Centres), these people will be selected based on their expertise in the energy matter in Ireland as they can provide relevant information about the energy consumption in terms of electricity. Similarly, as explained above, the sampling of the third population (Business users), will be 2 companies in Dublin area.

## **5.3. Sampling type.**

This will be conducted by judgment or self-selection (Byrne, 2023), where it has been used my own judgment to select the person for sampling since that has the advantage that the time expend for its execution can be reduced, as well as that, it will be possible to reach out directly with the target audience with the intention of producing better results. Therefore, based on judgement, depth interviews will be carried out to people expert in the field of energy as it is expected to obtain the results rapidly as the members of the sample possess the expertise in the energy area of electricity (QuestionPro, 2023). The same situation is applicable to the third population, business users, depth interviews will be carried out to the sampling of this population.

### **5.3.1. Sampling size.**

The size of the sampling has been narrowed down to 7 individuals from the different populations. Depth interviews will be conducted to experts in the energy sector, three people from this population and two people from the Data Centre and Business users’ population. All these since the time for preparing the capstone project is limited and there will be time involved to carry out the interviews and summarize the results obtained.

# **6. Research Methodology.**

The proposed research methodology as below:

## **6.1. Primary Research.**

My choice of primary research will be data collection through depth interviews as that information is not already available (Byrne, 2023). As mentioned above, the reason why depth interviews are going to be conducted is to gather first-hand information from experts in the energy matter with the aim of collect new insight, get answer to questions that have not been answered before (Bouchirika, 2023) in relation on how commercial customers and data centres react to changes in the price of electricity since they are the ones that can provide with current and relevant information in terms of electricity consumption. All these is going to be supported with the data analysis of the raw data collected in the CSO site as secondary research.

### **6.1.1. Profiles of people for Depth Interviews per population.**

The roles of the people chosen to carry out dept interviews have been taken from their profiles in LinkedIn and are detailed per population as follows:

**Population 1:** Electricity companies

**Sampling:** 3 individuals from this population

[**Position:** Energy and Technology Manager – ESB Networks](https://www.linkedin.com/in/sinead-reilly-65323412/)

Profile: Wind energy engineer providing technical expertise in energy, turbine procurement and wind monitoring (LinkedIn, 2023)

[**Position:** Electrification Manager, Network Development & Electrification at ESB Networks](https://www.linkedin.com/in/emmasilke/)

Profile: In charge of managing electrification in the network development and network asset space (LinkedIn, 2023)

**Position:** System Operations Engineer at EirGrid

Profile: Electricity sector Engineer driving decarbonisation through power system operations. (LinkedIn, 2023)

**Population 2:** Data Centres

**Sampling:** 2 individuals from this population

[Position: Data Centre Engineering Operations - Amazon Web Services](https://www.linkedin.com/in/andy-kavanagh-71237760/)

[Position: Electrical Design Engineer for Data Centres](https://www.linkedin.com/in/pranil-patil-3250a6b9/)

**Population 3:** Business users

**Sampling:** 2 individuals from this population

[**Position:** Store Manager at Marks and Spencer, Liffey Valley, Dublin](https://www.linkedin.com/in/jonny-duffy-2996a8a3/)

Profile: Experienced Store Manager with a demonstrated history of working in the retail industry. (LinkedIn, 2023)

[**Position:** Store Manager at Lidl – Dublin area](https://www.linkedin.com/in/tais-barbosa-79608a196/)

## **6.2. Secondary Research.**

The data collected from meter readings for electricity consumption for non-residential customers 2015-2022 (CSO, 2023). As well as that, the meter readings for electricity usage from Data Centres 2015-2022 (CSO, 2023). It is considered secondary research as it has been carried out by the COS and therefore, it is already available. (Byrne, 2023). The datasets available on CSO site, which contains open data, but both data sets are licensed under [Creative Commons Attribution 4.0](https://creativecommons.org/licenses/by/4.0/). Additionally, there are also referenced articles from the Irish Times (2023), which are relevant to electricity consumption and data centres in Ireland. As well as that, I did use data from research papers in terms of Data Analytics in the electricity and energy topics. The reason why the datasets referenced above have been selected from the CSO site are due to different factors, where it can be mentioned that the data from meter readings is relevant to the topic and title, it provides with current data from 2015-2022. Another factor that has been taking in consideration is that the units of measurement are all in gigawatts, which made them comparable, and therefore, compatible. Finally, the CSO is a reliable source, which has been taking all the considerations to ensure data protection (CSO, 2023). Additionally, as it was shown on the literature review above, different online sources have been used as secondary research such as the Irish Times, RTE News, Government of Ireland among others.

# **7. Ethical and Risk considerations during the Data Analytics project.**

Since the proposed research could represent ethical issues, it has been identified five ethical challenges as follows:

## **7.1. Data collection – Use of Open Data.**

As mentioned above, the datasets “MECO3 – Metered Electricity Consumption” and “MECO2 – Data Centres Metered Electricity” were obtained from CSO site (2023), which both are licensed under [Creative Commons Attribution 4.0](https://creativecommons.org/licenses/by/4.0/), which allows me to use the datasets, adapt and remix the material for any purpose under the terms that the original source must be referenced in the report, provide a link to the licence, and also reference if any change has been made to the datasets. The original data from meter readings was provided by ESB networks and processed by CSO in aggregate form to comply with data protection (European Commission, 2023) as it will be impossible that business or individuals could be identified (CSO, 2023)

## **7.2. Not obtaining enough data - Personal data issues.**

Raw dataset has been gathered from CSO site. Though, it is intended to obtain other datasets for my project through different sources, where ESB Networks and CSO Environmental statistics departments are included. Hence, emails have been sent to these institutions to request access the data for electricity meter readings. All this with the aim to obtain a bigger dataset that can supplement the findings of my research. If this has a positive outcome, it will be essential to make sure that any possible information from smart readings will not be identified directly or indirectly in the dataset and meet the requirements stated on the personal data issues of the Ethics and Data Protection document of the European Commission (2023)

## **7.3. Literature review:**

I did rely on grey material for the literature review. I also depended on articles from the Irish Times site, which it is a reputable source. I did also used research papers about Data Analytics for the electricity consumption research. Even though there is plenty information about energy consumption available online, the most recent sources were used as they could add reliable and recent information. However, textbooks were not used to support the proposed research topic.

## **7.4. Bias information:**

There is the challenge of bias in the research methodology chosen, which is non probability. It was selected as I decided to conduct depth interviews with experts in the energy matter. However, I will be using my own judgment to choose those samples from the populations. I need to be careful to not structure the questions to encourage the people being interviewed to respond in a particular way. It will be important to avoid making questions which could be complex or too confusing that cannot be answered accurately for the participants as that is critical to ensure the validity of the responses. As outlined by Bouchirika (2023) if the questions are properly constructed, straightforward and clear it could help to avoid biased questions, which is the aim purposed.

## **7.5. Voluntary participation in the depth interview:**

The challenge of choosing specific experts from the populations for sampling implicate that these people are free to choose to participate in the interviews without any pressure and, they can decide to not proceed with that if that is their decision. It will be always the risk of them to not accept to participate if the interview or drop out from it after they confirm their involvement. Hence, if that was the case, I need to respect their decision to not continue with the interview (Bhandari, 2023). Another consideration that I must keep on mind regarding to conducting depth interviews is to get a consent form signed for their participation and there is the possibility to not get enough people willing to participate if the interviews. I have listed 7 potential profiles of people from my populations, but I have not contacted them yet and therefore, I cannot guarantee that they will be willing to participate in the proposed research.

# **8. Further areas of study.**

# Through the preparation of this research proposal, it has been learned about the factors that lead the energy crisis and consequently, the sudden increased in the electricity prices in Ireland during the last two years. It has been also possible to record the current spent of electricity of Data Centres in Ireland. Additionally, it has been shown that Data Analytics has been proved to be able to help to the prediction of energy usage. As energy prices are affected by external factors, there will be always fluctuations in the prices that could disturb consumer behaviour in the sectors listed in this academic paper. Thus, a study that could use traditional machine learning algorithms and deep learning models to evaluate the changes in energy consumption in the Leinster area could be beneficial and produce findings useful to manage energy consumption in the commercial sector and Data Centres.

# **9. References.**

Bhandari, P. (2023). Ethical Considerations in Research, Types & Examples. [online] Available at: <https://www.scribbr.com/methodology/research-ethics/> [Accessed 28 November 2023].

Byrne, R. (2023). Sampling Management. Research and Professional Ethics module. (Slides 4, 12) [Accessed 24 November 2023].

Byrne, R. (2023). Key Research Management Concepts. Research and Professional Ethics module. (Slides 4, 12) [Accessed 24 November 2023].

Bouchrika, I. (2023). Primary Research vs Secondary Research: Definitions, Differences, and Examples. <https://research.com/research/primary-research-vs-secondary-research> [Accessed 28 November 2023].

Bray, J. and Curran, I. (2023). Cap on data centres ruled out despite surge in energy use. [online] Available at: <https://www.irishtimes.com/environment/climate-crisis/2023/06/13/coalition-rules-out-cap-on-data-centres-despite-surge-in-energy-use/> [Accessed 23 November 2023].

Corcoran, P. and Andrae, A., 2013. Emerging trends in electricity consumption for consumer ICT. *National University of Ireland, Galway, Connacht, Ireland, Tech. Rep*.

Data Center Journal (2023). Dublin Data Center Facilities and Providers. [online] Available at: <https://www.datacenterjournal.com/data-centers/ireland/dublin/> [Accessed 30 November 2023].

Coyne, B. and Denny, E., 2018. *An economic evaluation of future electricity use in Irish data centres* (No. TRiSS-WPS-02-2018). TRiSS Working Paper Series.

CSO (2023). Data Centres Metered Electricity Consumption 2022. [online] Available at: <https://www.cso.ie/en/releasesandpublications/ep/p-dcmec/datacentresmeteredelectricityconsumption2022/keyfindings/#:~:text=Electricity%20consumption%20by%20data%20centres%20increased%20by%2031%25%20between%202021,2015%20to%2018%25%20in%202022>. [Accessed 24 November 2023].

CSO (2023). Metered Electricity Consumption [online] Available at: <https://data.cso.ie/table/MEC03> [Accessed 24 November 2023].

CSO (2023). Data Centres Metered Electricity Consumption [online] Available at: <https://data.cso.ie/table/MEC02> [Accessed 24 November 2023].

CSO (2023). Metered Electricity Consumption – Data Protection Transparency Notice [online] Available at: [Metered Electricity Consumption - CSO - Central Statistics Office](https://www.cso.ie/en/methods/tn/meteredelectricityconsumption/) [Accessed 28 November 2023].

DCD (2023. Appeals lodged against AWS data centers in Dublin. [online] Available at: https://www.datacenterdynamics.com/en/news/appeals-lodged-against-aws-data-centers-in-dublin/ [Accessed 28 November 2023].

European Commission (2023). Ethics and Data Protection [online] Available at: <https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/guidance/ethics-and-data-protection_he_en.pdf> [Accessed 28 November 2023].

EuroNews.Green (2023). Data Centres Gobble up 18 of Ireland electricity as country struggles with climate targets. [online] Available at: [Data centres gobble up 18% of Ireland’s electricity as country struggles with climate targets | Euronews](https://www.euronews.com/green/2023/06/13/data-centres-gobble-up-18-of-irelands-electricity-as-country-struggles-with-climate-target) [Accessed 24 November 2023].

Government of Ireland (2023). National Energy Security Framework [online] Available at: <https://assets.gov.ie/221399/86cb99f5-58e3-4821-bc4c-e1bb1fa706fb.pdf> [Accessed on 30 November 2023].

Guo, Z., O'Hanley, J.R. and Gibson, S., 2022. Predicting residential electricity consumption patterns based on smart meter and household data: A case study from the Republic of Ireland. *Utilities Policy*, *79*, p.101446.

IEA site (2023) Globally Energy Crisis. [online] Available at: <https://www.iea.org/topics/global-energy-crisis> [Accessed 30 November 2023]

Lantry, P. (2023). Data Centre moratorium could strangle digital growth and impact carbon targets [online] Available at: <https://www.irishtimes.com/business/2023/11/27/data-centre-moratorium-could-strangle-digital-growth-and-impact-carbon-targets/> [Accessed 24 November 2023].

LinkedIn (2023). Profile of Energy managers in Dublin area [online] Available at: <https://www.linkedin.com/search/results/people/?keywords=profile%20of%20energy%20managers%20in%20dublin&origin=SWITCH_SEARCH_VERTICAL&searchId=c8bf8623-1d6b-4ac3-98c4-3f0333499267&sid=Bxa> [Accessed 24 November 2023].

O’Halloran, B. (2023). Electricity prices rise in October [online] Available at: <https://www.irishtimes.com/business/2023/11/07/electricity-prices-rise-in-october/> [Accessed 24 November 2023].

O’Sullivan, K. (2023). Data Centres Q&A: How big a drain are they on Ireland’s energy grid? [online] Available at: <https://www.irishtimes.com/environment/2023/06/13/data-centres-qa-how-big-a-drain-are-they-on-irelands-energy-grid/> [Accessed 24 November 2023].

Pope, C., (2023). Pricewatch: Will energy prices remain high for the foreseeable future? [online] Available at: <https://www.irishtimes.com/your-money/2023/08/28/is-there-any-hope-of-cheaper-energy-for-irish-homes-this-winter/> [Accessed 24 November 2023].

QuestionPro Surver Software (2023). Judgmental Sampling: Definition, Examples and Advantages [online] Available at: <https://www.questionpro.com/blog/judgmental-sampling/> [Accessed 24 November 2023].

RTE News (2023) No new data centres for the capital for the foreseeable future, greater Dublin area “constrained” [online] Available at: <https://www.rte.ie/news/dublin/2022/0110/1272869-eirgrid-datacentres-dublin/> [Accessed 24 November 2023].

Sarswatula, S.A., Pugh, T. and Prabhu, V., 2022. Modeling energy consumption using machine learning. *Frontiers in Manufacturing Technology*, *2*, p.855208.

Seai.ie (2023). Energy in Ireland 2022 Report. [online] Available at: <https://www.seai.ie/publications/Energy-in-Ireland-2022.pdf> [Accessed 24 November 2022].

Seai.ie (2023). Energy in Ireland [online] Available at: <https://www.seai.ie/data-and-insights/seai-statistics/key-publications/energy-in-ireland/> [Accessed 30 November 2023].

Vom Scheidt, F., Medinová, H., Ludwig, N., Richter, B., Staudt, P. and Weinhardt, C., 2020. Data analytics in the electricity sector–A quantitative and qualitative literature review. *Energy and AI*, *1*, p.100009.

<https://towardsdatascience.com/neural-network-embeddings-explained-4d028e6f0526>