Final Year Project

Energy demands' trends during COVID-19

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A thesis submitted in part fulfilment of the degree of

BSc. (Hons.) in Computer Science

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Details

- Gitlab - FYP

Note

Chapters 1-4 and the Abstract were completed in the previous semester as part of the initial report. Chapter 4 was extended as the implementation process went on and Chapters 5-8 were added on to the initial report as part of the Thesis write-up.

Due to the nature of the data source that was used, the student used data visualisation and analysis alone to discuss the energy demands' and trends. The data source only provided two main schemas which were

- Carbon Intensity
- Energy generation mix

In the student's opinion more data such as how the energy was consumed and in what manner it was consumed (different sectors) was needed to make any useful predictions. Since this data was not available, the student was only left with the breakdown of energy sources and their % contribution to the overall energy generation in the UK.

Abstract

The focus of this project is to research and summarise the impact of COVID-19 on energy consumption, retrieve publicly available data and develop a post-COVID-19 predictive algorithm in energy consumption. The Coronavirus lock-downs have led to the biggest fall in energy demand in over 70 years while also having an immense effect on the current energy mix. Renewable energy sources have increased while non-renewable energy sources such as fossil fuels have decreased worldwide. Due to this, we will see a record decline in CO2 emissions. The global energy market is experiencing its biggest shock in 70 years. A review of trends and energy consumption before and during COVID-19 at a national/international level will provide an analysis of where the energy market will go from here. There will be a focus on countries within Europe, specifically regions within the United Kingdom. Literature and related works will be studied and summarised to comprehend the effects of energy consumption during COVID-19. Alongside this, data relating to the different aspects of energy demands and trends' provides an insight into the full effects of COVID-19.

Chapter 1: **Introduction**

Over the past two decades, energy consumption has been at the forefront of most conversations. There has been a constant need to change our global energy mix and move towards energy neutrality. In 2008, the EU came together and set targets for 2020 and 2030 regarding energy and climate change. The 2020 climate and energy packet states that there is to be a 20% reduction in greenhouse gases, 20% increase improvement in energy efficiency and 20% of the energy mix was to come from renewable energy sources.[1] In 2019 an article was published stating that in 2017, for the third consecutive year energy consumption had increased in the EU.[2] Figures from 2017 stated that "the EU was 5.3% above the efficiency target for 2020". As global warming continues to affect the world around us, the time-frame in which we can reverse the damages continues to decrease. We must find a way to implement permanent changes to the global energy mix and energy consumption before it is too late.

The purpose of this project is to look at the effects that COVID-19 has had on the global energy market. There will be a focus on the demands' and trends of energy consumption during COVID-19. While looking at specific regions, the student will identify the different aspects that have caused changes to occur within the energy market. This will allow the student to fully grasp the situation at hand and identify improvements that can be made to deal with future lock-downs. There will also be a focus on the contingency plans that were implemented which led to reductions in CO2 emissions and changes in energy consumption. The systems that are currently put in place to deal with the pandemic have a massive effect on a country's energy consumption, and it is these systems that we must investigate to understand the direction that the global energy market will be heading towards.

The student will research and summarise literature relating to this project. Looking at the different aspects contributing to the changes in energy demands and trends at a national/regional level will provide an understanding of the effects of COVID-19. The most important part of this research is summarising the different aspects of energy consumption which were affected by COVID-19 and understanding the causes behind them.

From this the student will gather data relating to energy consumption during COVID-19 in preparation for the design and implementation of a predictive algorithm. The data will be specific to different regions and this will allow the student to make predictions for that region or country. Using the data, the student will train the model to produce accurate predictions relating to future energy demands and trends. These predictions will help to improve upon the contingent policies implemented by a region and lead to improved overall energy efficiency. Looking at the different aspects of these predictions will lead to a better understanding of how to deal with future lock-downs more efficiently. The effects of the pandemic have led to an improved environmental situation. Therefore it is necessary to study these impacts and act upon the current situation. Using this predictive algorithm, it will be possible for different countries and regions to adjust their lockdown implementations to lead to smoother and more energy efficient systems.

Chapter 2: **Related Work and Ideas**

2.1 Lock-downs and Restrictions

As COVID-19 tightened it's grips around the world, the effects were evident. Governments around the world implemented lockdown measures in an attempt to stop the spread of the virus. Due to this, businesses and societies were forced to follow guidelines and restrictions set out as safety measures. Energy demands dropped significantly as travel restrictions and border closures came into effect. The effect of lock-downs showed a shift in energy consumption within sectors. As cities and countries enforced strict measures relating to physical contact and closures of businesses, energy demand shifted from industries and businesses to residential sectors.

Looking at the Sustainable Energy Authority of Ireland's (SEAI) latest publication relating to COVID-19 [3], there was an immediate reduction to the daily energy demand when the first full lockdown came into effect, as seen in Fig 3.1. The energy demand from Wk13-Wk27 for 2020 was much lower than the energy demand from the same period during 2019. This period represents Level 1 to Level 3 restrictions and around Wk 16 the energy demand was roughly 11.5GWh lower than 2019.

The daily demand did not reach 2019 levels until the Level 3 reopening. We can see that due to COVID-19 the electricity demand graph for 2020 had much higher peaks and troughs. This was most likely due to businesses and services preparing for lockdown and the effects of lockdown. Following on from the Level 3 reopening we can see that energy demands return to 2019 averages briefly before increasing as businesses and services reopened. The graph in **Figure 3.1** shows a correlation with the reopening of the country and the loosening of restrictions. There is a clear increase in energy demand as the society returns to a sense of normality.

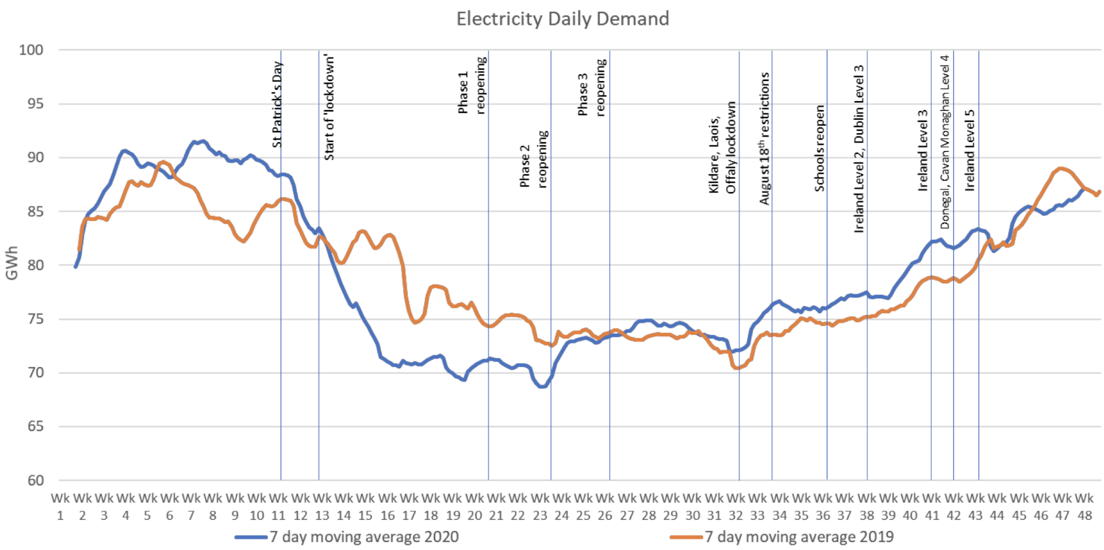


Figure 2.1: Irish Energy Demand 2020 vs 2019. Sourced from [3]

A workshop hosted by CIGRE Ireland NGN [4] discussed the effects of COVID-19 on the direction of the power industry. There was a constant referral to the changes in the graphs produced by electricity demand in Ireland. As society continued to follow lockdown measures, it was observed that the longer we stayed in lockdown, the more electricity demand dropped week by week the energy demand reached around 500GWh. Comparing the energy demand to 2019, from Week 14 to Week 19 there was a decrease of 8-11%, which again implies the direct correlation between energy demand and lockdown measures.

In [5], the severity of the lockdown measures being imposed had a direct effect on energy consumption within different sectors. Using Lagos, Nigeria as a case study, the authors showed how different situations and restrictions caused changes in behaviour which then lead to varying demands for energy consumption. Looking at **Figure 3.2** the figures for the Industrial and Commercial sectors showed a reduction from peak energy consumption to Full Lockdown energy consumption. Reductions of 0.44MW and 1.13MW in the Commercial and Industrial sectors respectively were observed.

Electricity consumer categories	Ave Week 1 - Business as usual (MW)	Ave Week 2 - Business as usual (MW)	Ave Week 3 - Business as usual (MW)	Ave Week 4 - Partial lockdown (MW)	Ave Week 5 - Total lockdown (MW)
Commercial	2.81	2.98	3.07	2.81	2.63
Industrial	2.47	2.49	2.54	2.02	1.41
Residential	3.59	3.66	3.72	3.72	3.87
Grand Total	**3.37**	**3.44**	**3.50**	**3.40**	**3.42**

Figure 2.2: Energy demand in Lagos over 5 week period. Sourced from [5]

The closure of businesses and non-essential services in a full lockdown immediately reduced demands. One interesting aspect viewed in the paper was that energy consumption actually increased in the 3 weeks leading up to partial lockdown as businesses and manufacturers prepared for lockdown measures, as observed in **Figure 3.2**. The authors showed that there was a clear shift in demands for energy consumption due to the behavioural changes being enforced by the government. From looking at these shifts it is evident that the behavioural changes responsible for these shifts can be made permanent. The reduction and increase in energy consumption within Commercial/Industrial and Residential sectors was due to people working from home as opposed to in offices or public buildings. Temporary changes such as these during a pandemic can be viewed as ways that energy consumption could be effectively reduced within all sectors if companies and businesses were to make adjustments to their energy and working policies.

The unprecedented changes due to COVID-19 shows that energy demand needs to be actively monitored. The data gathered from the moment COVID-19 forced countries into closure can help to push towards a more energy efficient future through energy monitoring and management. Being energy efficient does not solely rely on renewable energy resources, it also requires that the energy being generated is used up and that over-generation does not occur. With situations such as COVID-19 it presents a problem as energy generation is estimated as we cannot predict energy demand. This is where predictive algorithms and machine learning can improve energy systems around the world.

2.2 CO2 emission reductions

In [6], the authors talks about temporary reductions in CO2 emissions due to the changes in energy consumption, it then continues to go on and compare the differences in CO2 emissions during COVID-19 in April and pre-COVID-19 in April 2019. The most significant reduction in emissions occurred in the Aviation sector with reductions of 60%, while the public transport sector also saw massive reductions in CO2 emissions of 36%, as people stayed confined to their homes and restricted surrounding areas. Overall the authors found that there was a 17% reduction between all sectors with the Residential sector being the only one which saw a slight increase of 2.8%.

The effects of forced confinement are evident from these figures alone, as the level of CO2 emissions being shown here were last seen in late 2006. These temporary reductions have led to the largest decline seen in over 70 years.[7] This only scratches the surface of what is happening as we continue to deal with COVID-19 on a global scale.

The absence of a real-time CO2 emission tracking/monitoring system means we can only attempt to predict or forecast these emissions based on our energy consumption and the changes in demands. In [8] the authors presented estimates of CO2 emissions using "near-real-time activity data, results of the international research initiative Carbon Monitor". These predictions and assumptions vary based on what figures we are given from different databases and are not in real-time. Due to this, we struggle to grasp the effects of our energy consumption until it is too late. Figures published for CO2 emissions do not allow us to view our current situation in real-time. By the time these figures are released, we have already moved past the time-frame that those figures represented.

The Global Carbon Project (GCP) is mostly responsible for releasing estimates and exact figures for CO2 emissions. The problem with this is the time-frame between the release of these estimates and the confirmed figures is roughly 3-5 months.[9] There needs to be a system in place where we can actively track the CO2 emissions as this provides us with a much clearer insight on the current situation. Temporary reductions do not change the overall trajectory of CO2 emissions as there is a rapid increase once we are on the road to recovery, as shown below in **Figure 3.3**.

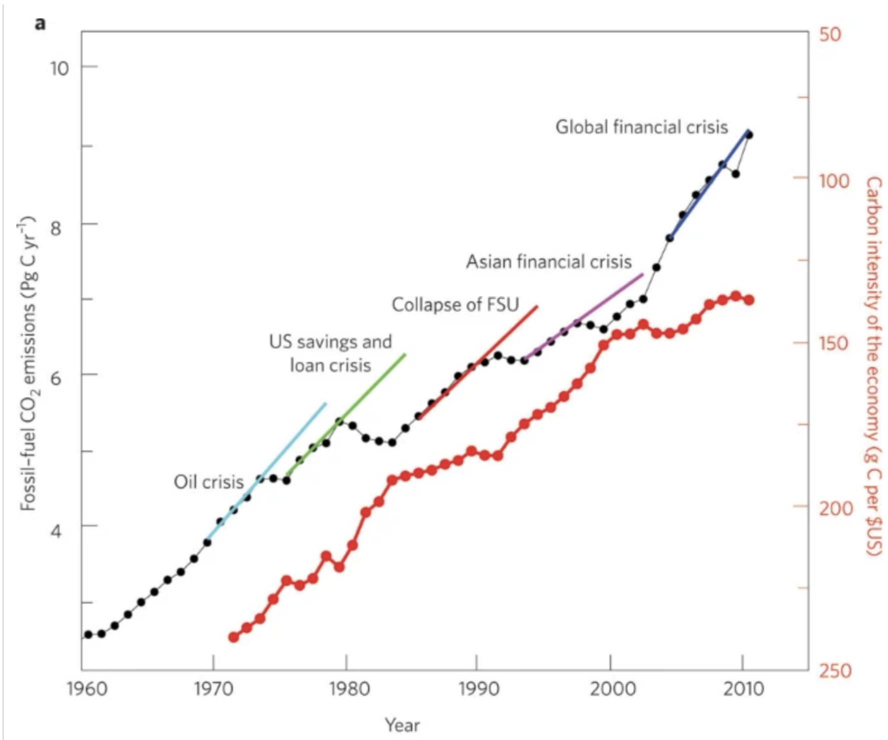


Figure 2.3: CO2 emissions returned to normal after each temporary reduction. Sourced from [10]

There was no attempt made to implement the positive changes that led to these reductions. Sectors such as Industry and Transport reverted to higher CO2 emissions. If we are to base post-COVID-19 energy consumption and CO2 emissions off of the 2008-2009 figures, we are looking at a massive increase in emissions once we manage to find a way to beat COVID-19. There should be an analysis of the different aspects that have contributed to these reductions in energy consumption and CO2 emissions. From this, we can then devise policies and plans to try to sustain the positive changes and integrate them into our current systemic policies. [11]

There needs to be a global action plan when dealing with global pandemics and not individual regional/national plans. Looking at the countries which effectively dealt with COVID-19, others can then make adjustments to their contingency plans. Practices such as working from home, reduced business hours and reduction in public transport can lead to improved policies paving the way for a cleaner and more energy-efficient future. [12]

Due to the decline in energy demand globally, the percentage share of renewable energy sources has increased. This is most likely due to the fact that renewable energy sources are prioritised over fossil fuels and other energy sources when it comes to times of low energy demand.[13] Looking at the graph below we can see that there is a sudden increase in renewable energy source contribution to each countries energy mix.

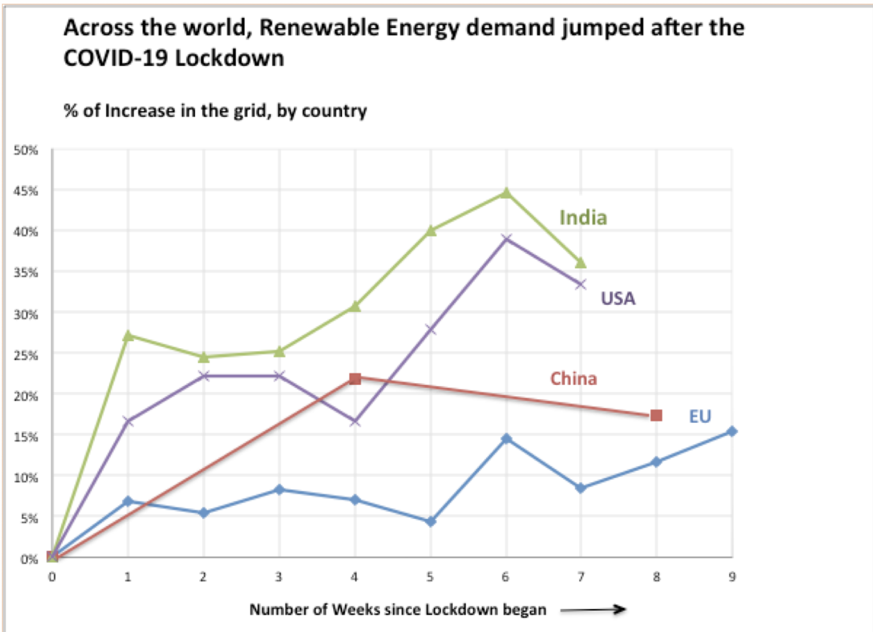


Figure 2.4: Increase in Renewable energy source contribution. Sourced from [14]

2.3 Energy consumption prediction

Energy Forecasting and Energy Management Systems (EMS) are areas where Machine Learning is very much relevant in today's world. These systems are put in place to monitor energy consumption for appliances and households. The importance of these systems continues to grow as countries around the world move towards zero-carbon goals and energy efficiency goals. In [15] the authors assess an energy forecasting model using a combination of smart-grid technology and predictive data-mining techniques. Using energy production and consumption data, the model is trained. Following the process presented in this paper, we can see that the data is gathered and pre-processed, then split into training and testing sets. The student will follow a process similar to this as outlined in the Project Workplan. ML models are suitable for prediction algorithms as they use historical known data to train a model in making predictions on unknown data. In [16] the author uses ANN to predict the effects of COVID-19 on power systems in Northern Italy. Mean Squared Error (MSE) and Mean Absolute Error (MAE) were used as measures of performance for 10 different configurations of ANN. This is a good way to find the best possible configuration for the data being used. In the paper the 'Net05' ANN configuration was selected as it had values of 0.5311 and 1.0281 for MAE and MSE respectively. What the author found using the 'Net05' configuration was that there was a direct correlation between societal behavioural changes and the power system infrastructure in Northern Italy due to COVID-19. The affected mobility had strong inter-dependencies with the power systems, which led to shifts in loads (measured in GWh) between sectors such as Residential and Industrial.

In [17] the authors develop "day-ahead local wind power forecasting models" using ML models. Again different variations Neural Networks are used along with other ML models such as Random Forests, Gradient Boosting Decision Trees and Bi-directional Long Short Term Memory network. One of the key features in this paper was the use of Ensemble methods. These methods allow the user to aggregate different ML models together and use the average performance of all models. This is proven to be a much more accurate model especially in terms of prediction. [18] The authors made use of the Ensemble models and attained the average of all the ML models used above, which improved the prediction accuracy/forecasting performance as shown in **Figure 2.4** below.

Table 3. Forecasting performance in terms of Root Mean Square Error (RMSE), for the five local day-ahead wind power forecast models (Random Forest—RF, Gradient Boosting Decision Tree—GBDT, MultiLayer Percpetron—MLP, Bi-LSTM—BLSTM, and ENSEMBLE.

	RF	GBDT	MLP	Bi-LSTM	Ensemble (Average)
RMSE [kW]	2347	2387	2338	2389	2327

Figure 2.5: Sourced from [17]

Another prediction model was developed to project the impact of COVID-19. Using the Pandemic Oil Demand Analysis (PODA) model [19], the authors projected Oil demand in America. This PODA model is interesting as it uses different modules within the model to predict and detect different aspects that would be related to US Gasoline demand. Within the PODA model a Neural Network is used to detect differences in mobility through input data. This is the "Mobility Dynamic Index Forecast Module". Another aspect of the model is the "Motor Gasoline Demand Estimation Module", this module is tasked with taking input data relating to trip activity, as it was shown that increases or decreases in "out-of-home trips during the pandemic" had a direct effect on the motor gasoline demand.

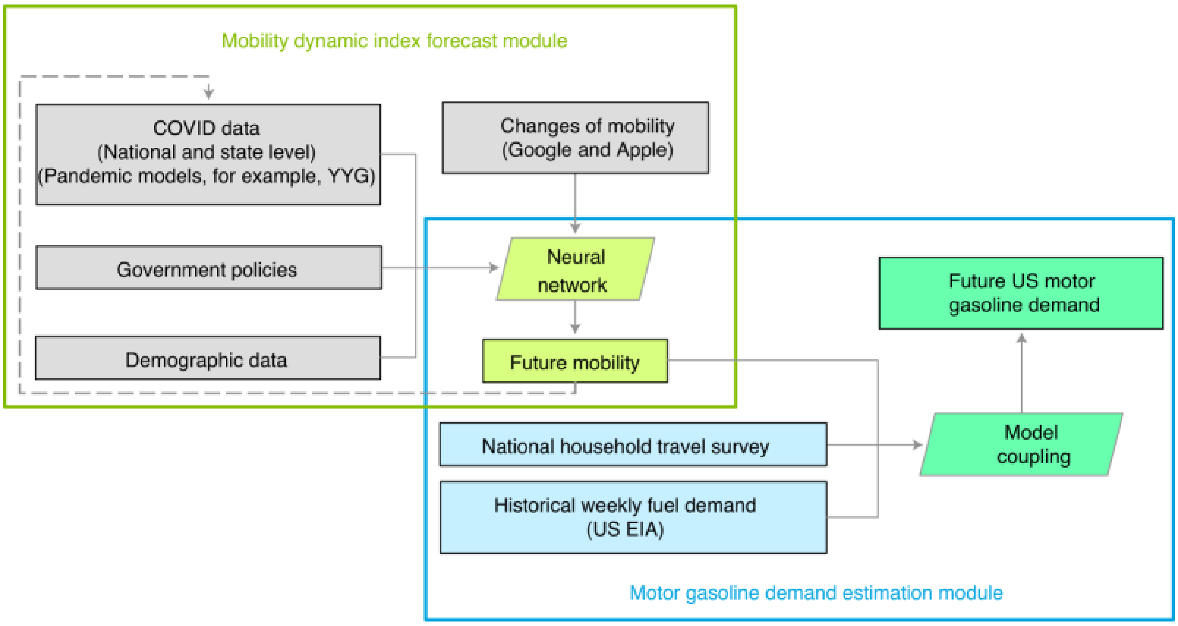
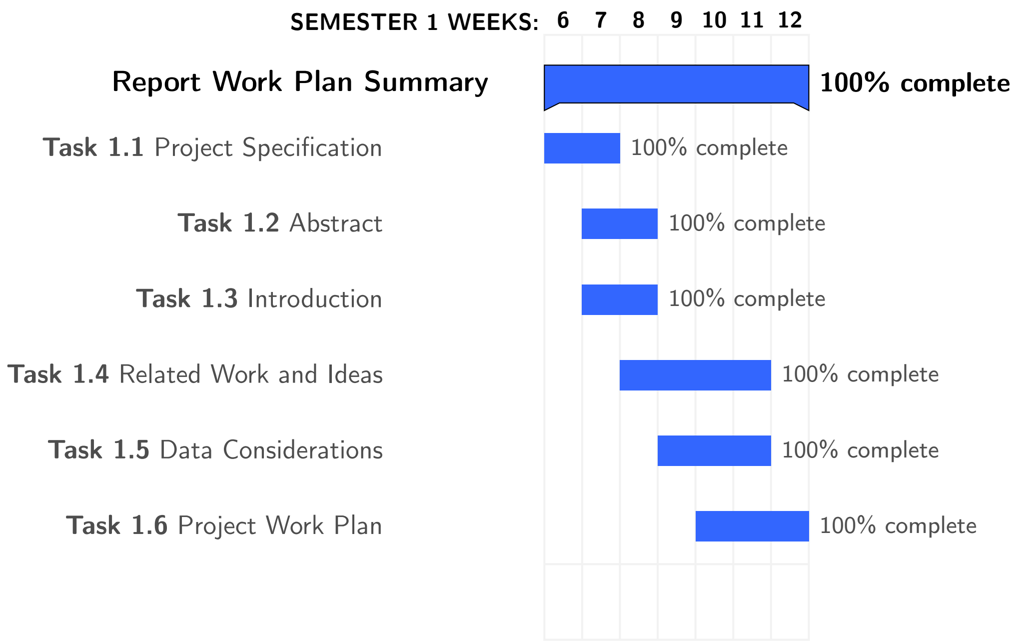


Figure 2.6: PODA model. Sourced from [19]

Chapter 3: **Project Workplan**

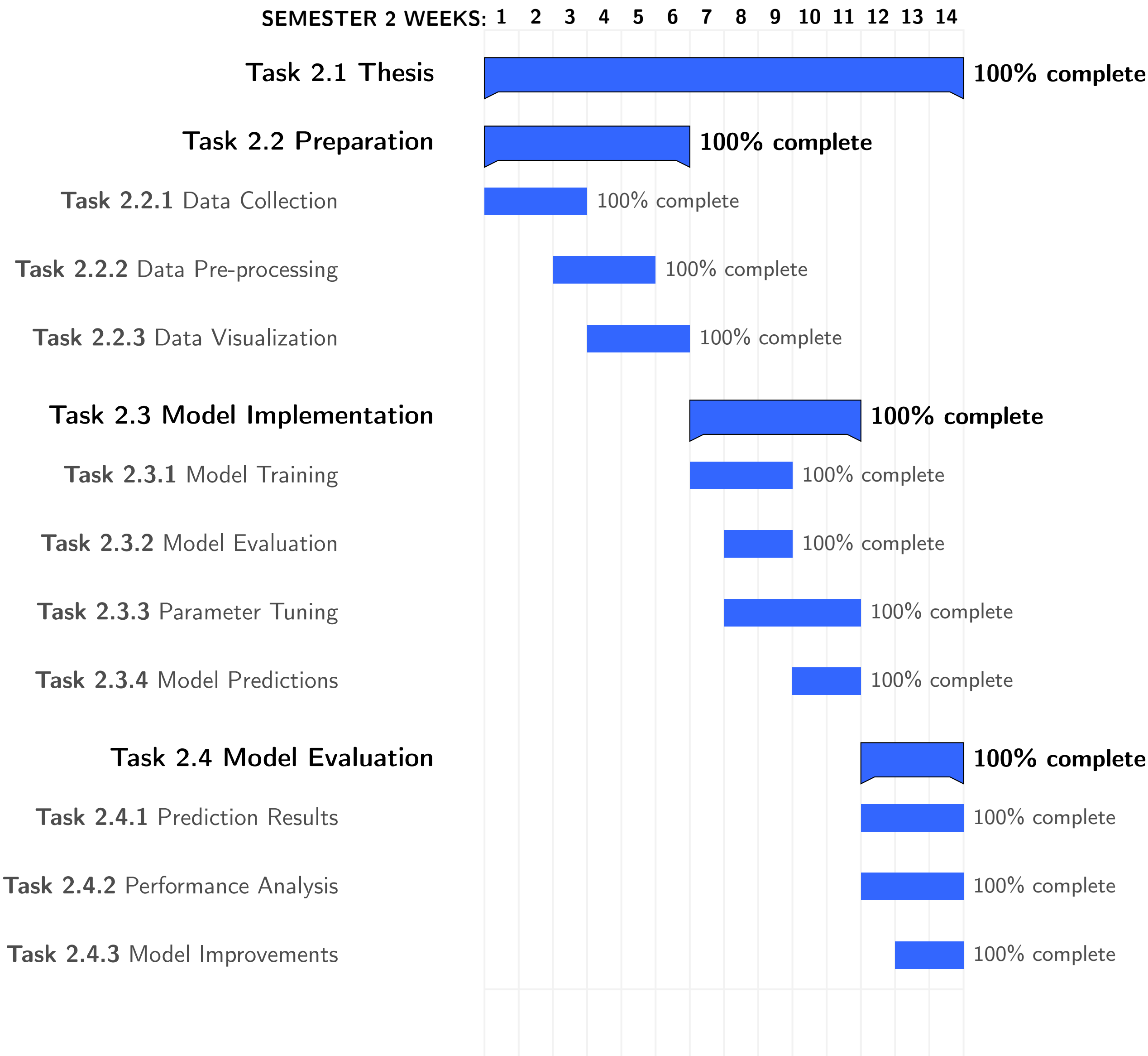
3.1 Project Plan - Semester I

In order to achieve the desirable result for this project, the work-plan is outlined as in the Gantt charts provided below for each semester. The first stage of the project started in Semester I where the Foundations report was produced and the second stage of this project will take place in Semester II where the remaining components of the full report will be produced along with the application being fully implemented.



3.2 Project Plan Semester II

For this report the work plan was linear. The sections are structured to be completed in order. As seen below in the chart, certain sub-sections were scheduled concurrently as it was possible to make a start on more than one topic before completing the sub-sections before it. Since most of the report work was completed in Semester I, this left only two main sections for the rest of the full report.



3.2.1 Thesis (Task 2.1)

The first half of the Thesis started in Semester 1 as part of the initial Final year project report. The full Thesis will be completed along with the implementation of the project. Content will be added as the student works through the project plan. Changes and adjustments will be made when necessary and the final summary section will be completed once the implementation is fully complete.

3.2.2 Preparation (Task 2.2)

The Preparation task describes the entire initial process of data collection, data pre-processing and data visualisation. This has been split into 3 main sprints, where each sprint is based on some part of initial process. The goal of this task is collect the data sets which will then be cleaned and pre-processed to fit the structure required for the Model's input data. The data will be split and prepared for training and testing. The tasks have been ordered in a logical manner in terms of Machine Learning methodologies.

3.2.3 Model Implementation (Task 2.3)

The model implementation will consist of 4 main sprints. This task will focus on training the model using the data prepared from Task 2.2, evaluating it and continuously tuning the parameters to improve the accuracy of the model, and finally using the model to make predictions.

3.2.4 Model Evaluation (Task 2.4)

For the model evaluation, the student will evaluate the accuracy of the model's predictions and performance by using different evaluation metrics. Through this evaluation the student will then be able to discuss any future improvements to the model and the effects of any parameter tuning from Task 2.3.3.

Chapter 4: **Data Considerations**

For this project the student will be using the Carbon Intensity API for the United Kingdom.[20] The API provides estimated and forecast data regarding carbon intensity nationally, and across different regions in Great Britain. The data is dynamic and constantly being updated as the API uses Machine Learning techniques to forecast data.[21] The API provides data regarding the Carbon Intensity Nationally and Regionally. It also provides data regarding the mix of different energy sources (Hydro, Wind, Coal, etc.). The data provided relates to the energy generation and unfortunately does not relate to energy consumption.

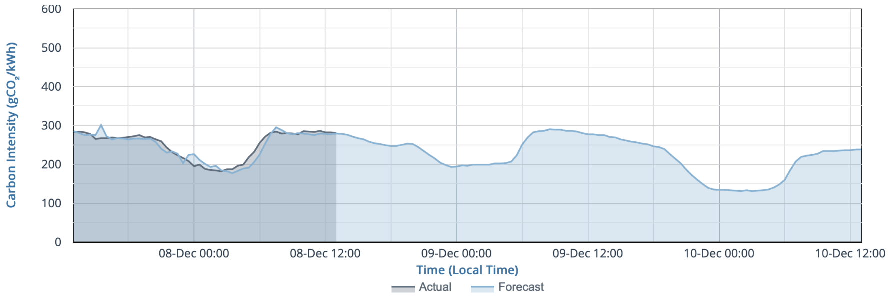


Figure 4.1: National Carbon Intensity Forecasts -24hrs to +48hrs

The data can be remotely obtained using the commands provided in the API documentation, and depending on the student's needs for the project data can be retrieved for specific time frames or regions. The reason for using this specific data relating to the United Kingdom. is due to the fact that there were no readily available Irish data sources. There were not any other databases available that provided the data in as much detail as this API. The data that can obtained from this API is publicly available while also fulfilling the needs of the project.

#	Region	Forecast Carbon Intensity (gCO_2/kWh)	Index
1	South Scotland	42	very low
2	North West England	81	low
3	North East England	86	low
4	North Scotland	180	moderate
5	North Wales & Merseyside	236	moderate
6	South East England	271	high
7	West Midlands	284	high
8	South West England	307	high
9	London	309	high
10	East England	321	high
11	South Wales	349	high
12	Yorkshire	355	high
13	South England	378	very high
14	East Midlands	492	very high

Figure 4.2: Carbon Intensity Forecast for regions within UK.

The data being retrieved was in the form of JSON responses which needed to be converted to data frames that the student could then pre-process and analyse. The data was structured as follows

- Timestamp - From and To
- Name of schema
- Names of energy sources
- Energy source % contribution

The API where the data was being retrieved only allowed a maximum given period of 1 month. Due to this limitation the student needed to create a function which could retrieve the data for a specified period of time while adhering to the limitation of the API. So for example, to retrieve the data for 2019, the function would store 12 months worth of data into 12 separate .csv files as this was the only way to retrieve all the data for 2019.

All the monthly data was then compounded into one single data frame so that the data could be worked on easily. Due to the fact that there were several different sources of Renewable energies, they were all stored as one single entry in the new data frame under the name "Renewables". This entry consisted of

- Hydro
- Solar
- Wind
- Biomass

The "Fossil_Fuels" entry in the new data frame consisted

- Natural Gas
- Coal

Chapter 5: **Results**

From looking at the Data analysis and visualisation, we can see that the changes in lockdown and restrictions throughout 2020 had a huge effect on the energy generation mix. Looking at Figure 5.1, we can see there are huge fluctuations corresponding to when lockdown measures were strengthened or loosened. The sudden increase in Fossil Fuel contribution to energy generation in May-Jun relates to the increase in energy demand from transport and business sectors as lockdown restrictions were lifted, while the sudden decrease in Fossil Fuel contribution from Sept-Oct relates to the introduction of a new 3-tier lockdown system to combat the increase in cases. Comparing the ratio of Clean energy to Dirty energy in the Pre-COVID graph to the During-COVID graph, there is a drastic increase. For a total of 5 months in 2020, the energy being generated was mainly from Renewable energy sources. If lockdown measures had not been loosened in June, there is no doubt that Renewable energy sources would have continued to contribute more on average to the national energy generation for the UK.

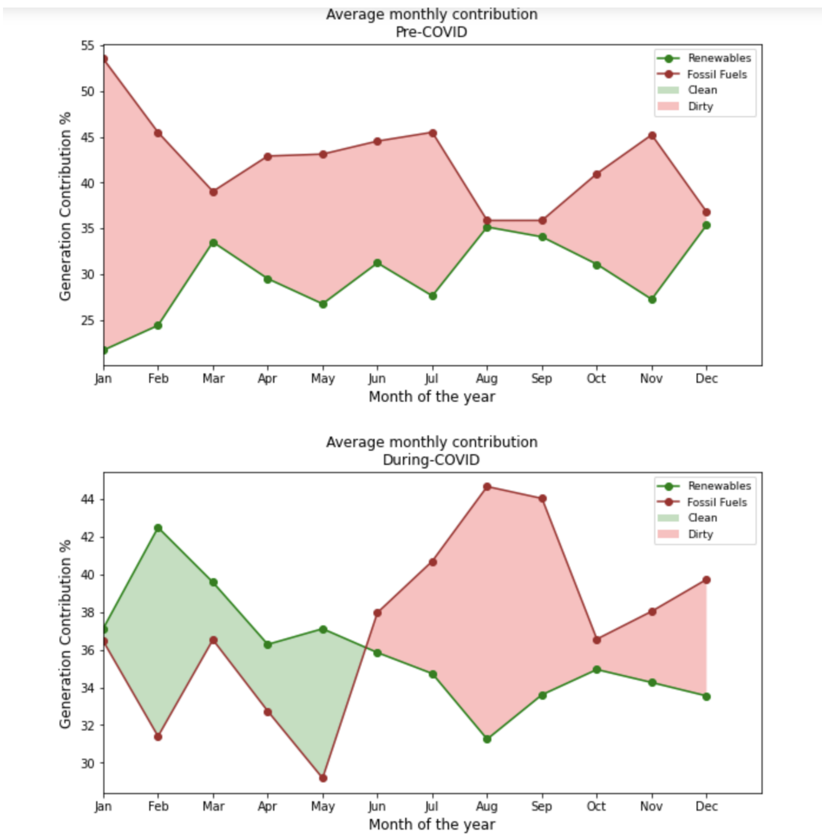


Figure 5.1: Monthly average contribution of Fossil Fuels and Renewables

It is interesting to note that when comparing the above Figure to a timeline of the UK's lockdown restrictions it is easy to pinpoint why the contribution for either energy source goes up or down.

The conclusion can be drawn that restricting how a population has to work or go about their daily lives has a huge effect on the energy demand. The closure of businesses and reductions in demand for transport had huge implications on the Fossil Fuel and Renewable energy contribution.

Certain aspects of everyday life such as transport and work currently demand such high levels of energy that the Renewable energy sources available cannot fully provide all the energy needed thus leading to Fossil Fuels contributing more. This shows that the renewable energy sources are still a behind in terms of being able to generate readily available and on-demand energy. This is clearly an aspect of the current energy systems in place that need to be looked at, especially in the case of a global pandemic.

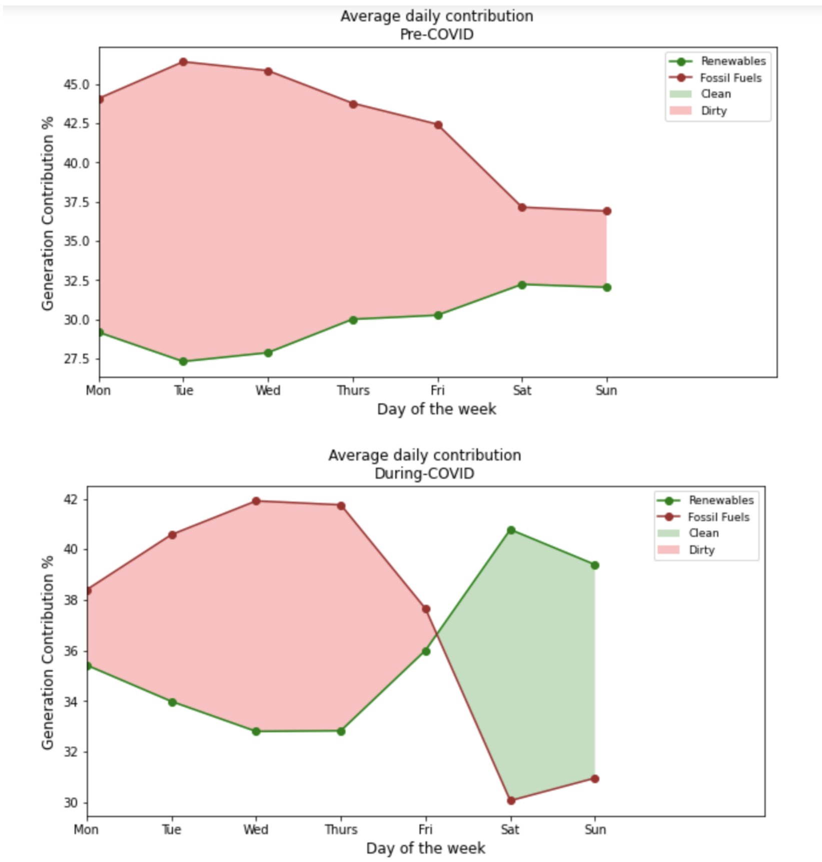


Figure 5.2: Energy generation contribution - Daily timeframe

Inverse relationship between Fossil Fuels and Renewable energy source contribution to energy generation. This was due to the fact that energy generated from Renewable energy sources are purchased with priority, meaning that during lockdown, as much of the energy requirements needed for consumption were purchased through Renewable energy sources and then Fossil Fuels. This led to an overall percentage increase in Renewable sources contributing to energy generation. The most obvious example of this is in Figure 5.2 where the two plots in the bottom graph move in opposite directions and the shaded area almost looks like a mirror image when split horizontally. This shows us that if we can focus on a directly increasing Renewable energy source contribution during periods of higher energy demand we can decrease the energy contribution of Fossil Fuels.

We can see that periods of strict lockdown measures led to periods on the daily, weekly and monthly scales where the energy being generated was clean energy rather than Fossil Fuel heavy energy. This was down to the changes in behaviour such as working from home and drastic drops in public transport and transportation overall, which is a huge contributor to Fossil Fuel generated energy.

Looking at Figure 5.3 below, we can see that there is a 6.1% increase in Renewable energy source contribution and a 5% decrease in Fossil Fuel contribution. This is most likely due to the priority given to Renewable energy sources during periods of low energy demand as discussed in Section

2.2. Since the two of these energy sources had huge changes due to COVID-19 while the likes of nuclear, imports and other energy sources did not change significantly. The student decided to focus on these two energy sources in more detail on a daily, weekly and monthly time frame. From the in-depth data visualisation, there is an obvious inverse relationship between the two main energy sources contribution to United Kingdom's energy generation.

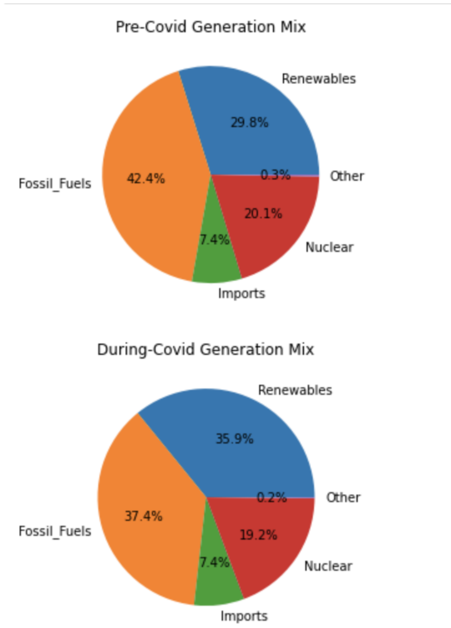


Figure 5.3: Breakdown of Energy Generation source % contribution - 2019 vs 2020

Chapter 6: Summary and Conclusions

Co2 emissions and energy consumption continues to increase all over the world. The threat of global warming and irreversible damage continues to loom large. The longer it takes for us to make positive and effective changes that can significantly and continuously reduce Co2 emissions and limit energy consumption in a way that helps us to achieve our environmental goals, the lower the chances we have of reversing the damage that has already been done. To do this however, we must understand what the causes of the current problems are and how we can make changes. The effects of COVID-19 have had temporary positive changes to energy consumption and Co2 emissions as discussed in this report, however temporary changes are not enough and before we know it, Co2 emissions will climb back to pre-COVID-19 rates. This is where a study of the trends and demands of energy during COVID-19 is essential. It allows us to understand why lock-downs and restrictions had such a drastic effect on Co2 emissions and how we can then look at these enforced temporary changes and see what can be done to implement better systems in place for the future in a post-COVID-19 world.

Throughout the entirety of this project and the research involved, it is obvious that the way in which people live their lives and how businesses are run has a huge effect on energy demand. We can also see that the level of energy demand needs to be controlled to allow Renewable energy sources to contribute more to the overall energy generation for a country. Sectors such as transport, businesses and tourism increase Fossil Fuel contribution and therefore increase Co2 emissions due to the lack of energy systems in place that can actively handle the energy demand required by these sectors. There are plenty of new ideas and changes being implemented but we are running out of time.

A definite way in which we can monitor the energy demand and prepare for situations that may effect energy consumption which in turn effects energy generation is the implementation of predictive energy systems. Systems such as smart-grids and smart-energy systems are a step in the right direction. This however is only possible if there is more readily available data relating to consumption and generation. As shown in this project, there is currently a lack of readily-available data that can be easily accessed by researchers. The data that is available is not enough to implement predictive models which can then provide insight into the trends and habits that can positively or negatively affect our future.

This project is far from perfect and can be extended in several ways. The project only focuses on the UK and energy generation. Further implementation and research could include energy consumption and it's relationship to how much energy is wasted. Another aspect that is definitely worth looking into is how different energy sources are used in energy generation from country to country and how we might change this to combat rising Co2 emissions.

This project is more relevant than ever today. In a world where countries and nations are racing to combat problems relating to Co2 emissions and increasing energy consumption. New and innovative ways to make permanent changes to negative trends in energy consumption are needed, and this can only happen with further research on this topic.

Reflection

This project involved Data Science methodologies as well as report writing and project management/planning, therefore the learning process was continuous. The project began with an initial report writing and learning how to write a report using Overleaf and LaTex. Aspects such as referencing and researching were new concepts that the student had not previously encountered before.

Due to the student being from a Computer Science background, a lot of the methodologies and technologies used in this project had to be learnt. Understanding the problem and the background and related works behind it was essential in mapping out a work-plan and planning the different tasks needed to produce useful results.

The student realised the importance of finding a data source that met the demands of the project and understanding the data. The data pre-processing and collection was especially difficult as the student struggled to produce a data set that would be suitable for the models. This was due to the fact that the student did not select a model before attempting to pre-process the data and structure it to meet the needs of the model. Another aspect that the student came to realise the importance of was the data visualisation. This was the task that provided insights into the data and allowed the student to discuss the data in detail and explain the patterns and trends present within the data.

The student's understanding and grasp of data analysis and visualisation has vastly improved along with research and report writing skills. This came down to the fact that the student knew was aspects of the data set were important and this allowed him to focus on the useful elements of the data set which could the be discussed.

Lastly the experience gained from this project has vastly improve all the skills mentioned above and the interest for the project continued to grow as the project went on. The time and resource limitations did prevent the student from going into a lot more detail and this is discussed in Chapter 8 of this report.

Chapter 7: Future Works

For the data pre-processing, the student chose to group the different sources of Renewables and Fossil Fuels together respectively, as discussed in Chapter 4. This made the training of the model a lot easier and more efficient. If there was more time available the student would have avoided this and this would have provided more insight into how COVID-19 affected different individual energy sources such as Natural gas, Coal, Wind energy, etc.

Due to the limitations relating to readily available data, the student was only able to focus on the changes in trends relating to energy generation instead of energy consumption. Energy consumption despite having a close correlation with energy generation is a completely different aspect. The student would have liked to been able to analyse and predict energy consumption trends within the UK and Ireland. Any results and conclusions discussed above only relate to the changes in demands of energy and not how energy was consumed or the breakdown of where the energy was being consumed.

Finding readily available data for energy consumption would allow us to look at how social practices and different regions within a country determine how energy is consumed and how a national or global pandemic then affects that. Another aspect that the student would have liked to discuss and analyse is the % of energy being wasted after it has been generated. For example a study in 2018 showed that the United States wastes 68% of the energy being generated. [22] If the student were to look at the energy wastage during COVID-19 there is no doubt that the figure would be significantly lower, and that is due to the changes in social practices.

The student would have liked to use K-means Clustering using the Regional data within the API. This would have provided an insight into whether or not relocation affected the energy demands for different regions by looking for any anomalies within the data.

The data source could be utilised more as there were several schemas that the student did not use. This was due to time and workload restraints and this is an aspect of the project that could be worked on in the future as an extension and improvement of the project.

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