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Assessing and Reducing the Environmental Impact of the English Premier League

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Abstract

Football in England is a growing industry with the top tier, the English Premier League (EPL), being a global product of immense popularity. The operations of the league have grown in size as the EPL itself grows and this comes with an associated environmental impact. This study has assessed this environmental impact in terms of Carbon Dioxide equivalent (CO_2e) emissions across a number of sectors involved with how the clubs operate over a season. Using this assessment, a number of emission reduction measures were suggested and the effect of these were calculated in order to identify ways in which the clubs in the EPL can limit the negative effects their operation have on the environment. It was found that across club travel and accommodation, fan travel and electricity and gas consumption CO_2e emissions totalled 80,651 tonnes, with the greatest contributor fan travel to home and away matches (44%). The value found is an estimation of emissions and it is acknowledged that it is likely an underestimate of the EPLs emissions, given there are many other sources of emissions that are not considered here.

The reduction measures suggested varied across limiting numbers of club staff and away fans, changing travel patterns of fans and installing solar panels to generate electricity to offset emissions. Overall, these measures achieved a decrease in CO_2e emissions of 31.05% with the most effective being limiting the number of away fans to 1,500 at all matches. All suggested measures were considered feasible and largely effective in reducing total emissions. It was also found low carbon transport, such as Electric Vehicles (EVs), could be effective in reducing emissions, potentially by a further 18.2%, but this is outside the EPL clubs' control but could change as EVs becomes more prevalent in wider society. It was seen that the different measures may be more effective at different clubs and should be evaluated on a club-by-club basis, but reducing the EPLs environmental impact could be achieved fairly simply. The league could also have a wider impact on society, as climate targets are attempted to be attained, by influencing the millions of fans to reduce their individual emissions by the clubs setting a leading example through their own actions.

Acknowledgements

I would like to thank my supervisor, Daniel Cóstola, for his great advice and support throughout the completion of this project. I also appreciate the support from my family and friends, who have helped me throughout my MSc and my many years at university.

Table of Contents

List of Figures

List of Tables

1.0. Introduction

1.1. Problem Definition

The modern game of football is the world's most popular sport with the Fédération Internationale de Football Association (FIFA) estimating that 3.5 billion fans watched the 2018 World Cup in Russia (FIFA.com, 2018) and there are around 265 million active players (FIFA, 2006). Football has its roots in England from where the game has spread across the globe. The first professional league, made up of 12 teams, was formed in Manchester in 1888 (Goldblatt, 2006) and the game and league pyramid expanded from there. By 1992 the game was a global force, with English teams being the grandest and most renowned sporting institutions in the world. At this point, football was about to become revolutionised and monetised to an extent never seen before with the birth of the English Premier League (EPL).

The EPL is now a global product with a cumulative audience of 3.2 billion people watching some part of the 2018/19 season remotely (Premier League, 2019a) and 14.5 million people attending games at the 20 stadiums (worldfootball.net, 2019). Fans travel to watch games from far and wide, utilising public and private forms of transport such as bus, car, train and planes. As much as 60% of a football clubs carbon footprint is attributable to fan mobility (VfL Wolfsburg, 2020b). The players and staff also travel via bus, train and planes to matches but in far fewer numbers.

Each of the 20 teams in the EPL play in a home stadium which have become huge infrastructure developments in the respective geographical areas. The stadiums on match day can have peak electrical consumption of over 3 MW (The Engineering ToolBox, 2004; Wilson, 2019) and over a year can consume 4.99 GWh of electricity (Chilvers, Chaer and Ford, 2015). All top-flight clubs have training grounds and offices where club employees work throughout the week. An estimate of the electricity consumption of all facilities of a top-flight football club is 6.74 GWh (VfL Wolfsburg, 2020b).

The rise of the EPL as a global spectacle has meant a rise in energy consumption across the facilities, fans and player transport which comes with associated greenhouse gas (GHG) emissions to power this growing industry. It is within the leagues interest to be a leading example in minimising its environmental impact and it can play a role in motivating the collective wider society to reach net zero targets. Once the environmental impact of the EPL has been assessed it allows a clearer understanding of which areas are most GHG emitting. This allows measures to be identified and implemented to reduce the environmental impact of the EPL and to be done so in the most effective way.

The environmental impact of fan mobility is required to be understood to find how most emissions are generated for an EPL football club. This will require an understanding of how fans get to matches and what fuel is used (if any) for travel. Primarily, it would be expected to be fossil fuel based, but initiatives for fans to use low-carbon transport are prevalent. Large proportions of fans using public transport would reduce the impact each fan has. This assessment allows a calculation of Carbon Dioxide equivalent (CO_2e) emissions and can allow an appraisal of ways to reduce this. A similar process can be undertaken for travel of players and staff across the country to matches.

Understanding the energy consumption of football clubs' facilities may provide a challenge due to a lack of data but some studies have already undertaken research (Chilvers, Chaer and Ford, 2015; Katsaprakakis *et al.*, 2019; VfL Wolfsburg, 2020b; Berg *et al.*, 2021). This work can be built on to calculate energy consumption across the EPL and effective ways to reduce this can be analysed.

Sport Positive outlined the sustainability of the 20 clubs in the EPL. It was found that 13 out of 20 EPL clubs get 100% of their energy from suppliers that say it is clean or from renewable sources (*EPL Sustainability Table 2020*, 2021). This can be from suppliers such as Octopus Energy (Octopus Energy, 2018) but only 3 out of the 20 clubs generate some energy on their own which seems an opportunity for many clubs given the property and resources they have. This opportunity can be exploited using renewable sources of electricity generation using solar photovoltaic (PV) panels or installing heat pumps, hence reducing reliance on suppliers, reducing cost and for reduce GHG emissions.

Some football clubs already point the way for the EPL to a more sustainable future. Forest Green Rovers (FGR) in the English Football League Two are the world's only UN certified carbon-neutral football club (Morris, 2018). FGR serve only plant-based food at the stadium and training ground, have shirts made from coffee waste and recycled plastic bottles, have an organic pitch and plan to build a new wooden stadium (Forest Green Rovers, 2021b). AFC Ajax in Amsterdam play in the Johan Cruyff Arena where a PV-battery system is used to provide the stadium with renewable electricity (Vo and Nguyen, 2018). VfL Wolfsburg similarly use PVs to generate electricity for their training ground. Most EPL teams have sustainability initiatives and some employ technologies like PVs to generate electricity, but measures like at FGR and Ajax are not ubiquitous, leaving room for development to reduce the environmental impact of the EPL as a whole.

Currently no studies have analysed the EPL as a whole to find the environmental impact of all aspects of the clubs that compete. It is a relevant problem where the league is looking to present itself as sustainable and forward thinking in relation to climate change and sustainability initiatives.

1.2. Aims and Objectives

The initial aim of this study is to evaluate the environmental impact of the English Premier League. This assessment will allow the secondary aim to be undertaken where ways in which to reduce this impact are to be determined. This may be through changing logistics, investigating low carbon means of transport and finding ways in which EPL clubs could generate their own electricity from renewable sources.

The objectives of this project include:

- Determine what factors contribute most to the environmental impact of the EPL and calculate the CO_2e emissions of each – to then find the overall emissions for the EPL.
- Investigate ways that the emissions from the EPL could be reduced and the magnitude various measures, technologies and changes could result in – for both fans, players and club facilities.
- Identify suitable renewable energy technologies that could be employed at EPL facilities to generate electricity that could be used by the clubs.
- Consider whether the EPL has a social responsibility to promote sustainability and if it has an influence on wider society's role in meeting climate targets.

The problem of assessing and then reducing the environmental impact of the EPL is wide ranging and complex, with many aspects of the league that require varying levels of detail when considering. It is difficult to tackle all aspects, especially for a project like this where resources and access to data can be limited. Therefore, the tools utilised are not overly complex but the study will provide a useful and relevant assessment of the emissions of an organisation that is prevalent in the public eye and aims to suggest feasible and effective ways to reduce the environmental impact of the EPL.

1.3. Outline of Dissertation

1. Introduction

The project is introduced with a description of the problem and the relevance it has. Aims and objectives of the study have been laid out with the objectives defining the general steps that will allow the aims to be achieved.

2. Literature Review

The literature review gives an idea as to what research has been done and where there is a gap in the work in which this study fits. Firstly, studies that have assessed aspects of the EPLs carbon footprint are analysed and these are then evaluated as to whether they can be built on or similar methodology can be used to find a more current appraisal. Previous studies that have analysed renewables that are suitable for electricity generation are reviewed and these give an idea to how EPL clubs could integrate technologies into their facilities.

3. Assessing the Environmental Impact of the English Premier League

This section addresses the first aim of the project. A methodology for determining the environmental impact of the EPL is followed to find sources and magnitude of GHG emissions. This takes into account direct emissions from burning fossil fuel for transport and heating as well as emissions associated with electricity consumption.

4. Reducing the Environmental Impact of the English Premier League

This section analyses the sources of GHG emissions associated with the EPL and identifies the most effective ways to reduce them. This includes looking at changing the travel patterns of both club delegations and fans, limiting numbers attending matches and also investigate the potential for EPL clubs to generate their own electricity using renewable sources of power.

5. Discussion

This section will discuss the environmental impact the EPL has and discuss the results found from the analysis of both the assessment of emissions and effect of the reduction measures carried out. The most effective measures to reduce the GHG emissions associated with the league are outlined and the extent to which the environmental impact can be reduced is presented. The limitations of the study will be discussed as well as potential work that could be carried out to build on results found.

6. Conclusions

The project is concluded with the key findings of the study in answering the aims and objectives.

2.0. Literature Review

The literature review aims to place the project definition into the existing field of study and amongst research that has been done. Firstly, literature describing the English Premier Leagues (EPL) place and prominence in the world will be outlined, setting the context why it is important to be able to evaluate and reduce the environmental impact of a football league. Literature describing the impact the effects of climate change are having on global sport and the EPL will be identified, illustrating the threat it poses to the future of the industry. Studies that have attempted to assess the environmental impact of the different sectors of the EPL will be discussed, as well as those that have looked at other sporting events or clubs. This could give a possible basis for this project to build on or outline methodology suitable to follow in an independent assessment of GHG emissions of the EPL.

The final section of the literature review will look at research that has suggested ways to reduce GHG emissions from transport and from energy consumption. Studies carrying out similar analyse to this project will also be used as validation for results of an evaluation of GHG emissions from the EPL and effective ways in which to reduce this.

2.1. Football in the UK

Association Football is the most popular sport in the UK (Johnes, 2005), historically playing a role in society and the community, contributing to both the cultural heritage and economic background of the country. It generates great moments of drama and creates memories that live in the memory of a nation for years. The English Premier League (EPL) is the top tier football division in England, showcasing the 20 best football teams in the country. In the UK, the audience for the EPL is of all ages**,** across all sectors of society and across the globe the EPL is shown in a 188 of the world’s 193 countries officially recognised by the UN (Premier League, 2019a).

The EPL product can be considered one of the UKs most beneficial exports and as such contributes significantly to the economy, adding £7.6bn (billion) to the Gross Domestic Product (GDP) (Ernst & Young, 2019). The league supports 100,000 jobs with £1.1bn paid in taxes by the players alone. It has become a global brand attracting 686,000 international visitors in the 2016/17 season, spending £555m (million) and the overseas broadcast deals for the same season cost £1.1bn as millions of people watch worldwide (Ernst & Young, 2019). The economic impact of the EPL clubs has risen from £0.7bn in 1999 to £7.6bn in 2017, an increase of over 800% in cash terms (Ernst & Young, 2019), compared to a 40% increase in GDP for the UK over the same period (Office for National Statistics, 2017). With the dramatic scale of the fiscal growth of the EPL and rise in international interest in the league, it would be expected the environmental impact will increase correspondingly as it is clear from history that greater economic impact results in greater GHG emissions (EPOC, 2016).

2.2. Impact of the Changing Climate on Sport

Although this project will primarily analyse the environmental impact of sport which contributes to the overall climate crisis, it is important to understand how sporting competitions, clubs and facilities will be, and in fact are already being, affected by climate change. This should generate even more of a driver for a reduction in GHG emissions due to leagues such as the EPL and provides a clear premise to carry out the analysis that follows in this project.

In Paris in 2015, 196 UN countries entered into a legally binding international treaty to limit global warming to below 2°C by limiting the emission of GHG into the atmosphere (United Nations, 2015). Even with this magnitude of global temperature rise, sport will be seriously impacted upon. Of 21 past Winter Olympic Games locations, 38% will no longer be viable options to host the various winter sports by 2050 due to changes to the climate (Scott *et al.*, 2019). The marathon at the 2020 Tokyo Olympics was moved 800 km north to Sapporo (BBC Sport, 2019) due to temperatures commonly exceeding 40°C when the athletes' health could be endangered. This is in contrast to the previous Tokyo Olympics in 1964 where the climate was considered ideal for endurance events (Goldblatt, 2020).

Taking part in vigorous exercise in temperatures above 33°C can firstly affect performance and then result in serious illness such as heat stroke and in some cases fatalities (Fortington *et al.*, 2021). This is especially prevalent in Australia, where temperatures are consistently above 40°C in summer. The England Test Cricket Captain, Joe Root, was hospitalised with heat stroke in a match in Sydney in 2018 (Gibson, 2018) and 243 members of the crowd suffered heat exhaustion at the Australian Tennis Open in 2014 (Bishop, 2014). With global temperatures continuing to rise, more geographical areas will be unable to host sporting events at certain times in the calendar because of concerns for the health and wellbeing of the athletes taking part.

Climate-related disasters have increased 83% between the periods 1980-1999 to 2000-2019 (Yale E360, 2020). These include floods, severe storms, wildfires and droughts. Typhoon Hagibis caused the cancellation of 3 games at the Rugby World Cup in Japan in 2019 (de Menezes, 2019) and Storm Ciara resulted in the cancellation of the EPL match between Manchester City v West Ham United in February 2020 (BBC Sport, 2020). In 2016, in Maharashtra in India 13 Indian Premier League cricket matches were relocated because of the worst drought in over 100 years (BBC News, 2016).

Breathing in air of poor quality can increase the likelihood of heart disease, strokes, asthma and lung cancers (Pope III *et al.*, 2002) and air pollution has increased significantly in many of the largest cities in the world. This is due to a high density of vehicles that tend to burn fossil fuels. When partaking in heavy exercise, ventilation of air into the body can increase from 5 litres a minute to over 100 litres a minute (Burton, Stokes and Hall, 2004). In megacities of poor air quality, an increase in consumption of poor air quality can instigate negative health impacts. For example in 2017 in Delhi, cricketers required oxygen cylinders and suffered episodes of vomiting during a match between India and Sri Lanka as the city experienced air pollution levels 15 times the specified World Health Organisation (WHO) limits (Safi, 2017).

One of the key aspects of 2^{o}C of global warming is the rising sea levels and the resulting threat to low lying coastlines and countries. This poses a risk of annual flooding and/or full submersion to 2% of world's land area but 10% of the world's population if global temperatures continue to rise at a similar rate (McGranahan, Balk and Anderson, 2007). The risk this poses is significant even for the mega-rich football clubs of the EPL. Using data mapping how sea levels may rise and floods may regularly impact on land mass in 2050, it was found that from clubs competing in the 2020/21 EPL season: St Marys Stadium in Southampton and West Ham's London stadium would be partially flooded from rising sea levels, Fulham's ground, Craven Cottage, and St Marys would be completely flooded annually and Chelsea's ground, Stamford Bridge, would be partially flooded on an annual basis as rivers burst their banks (Goldblatt, 2020). A figure of 20% of all EPL stadiums being affected by flooding or submersion is significant for a global product with a huge audience.

2.3. Studies on the Environmental Impact of Sport

The next section of the literature review will analyse studies that have previously calculated GHG emissions and environmental impact of sport clubs, tournaments and leagues across the world. This will give a basis of study to work from, values to use as validation and provide an outline of methodology to carry out analysis for this project.

2.3.1. Greenhouse Gas Reporting and Accounting

When reporting GHG emissions for tournaments and within clubs, it is common to see authors define scopes to set out boundaries for the research or reporting. The emissions are separated into either direct or indirect emissions which is consistent with GHG accounting protocol (WBCSD and WRI, 2004). An example of this is in the GHG accounting report for the 2018 FIFA World Cup where the scopes are set out as follows (FIFA and South Pole Group, 2016):

> *Scope 1: All direct greenhouse gas emissions, such as emissions from combustion in owned or controlled boilers and vehicles.*
>
> *Scope 2: Indirect greenhouse gas emissions from the generation of purchased electricity, heat or steam consumed by the company.*
>
> *Scope 3: Other indirect emissions, such as emissions from the extraction and production of purchased materials and fuels, vehicles not owned or controlled by the reporting entity, outsourced activities and waste disposal.*

These scopes are consistent with other reports concerning sports (Norwegian Govt, SA Department of Environmental Affairs and Tourism and Econ Pöyry, 2009; FIFA and MGM Innova Group, 2013; Fluminense FC, 2014; VfL Wolfsburg, 2020b) and allows an understanding of where a company is responsible for the emissions. Fan travel is consistently considered in Scope 3 i.e. Other indirect emissions where the company or club is unable to take direct action to reduce. These scopes will form the boundaries for the assessment of emissions of the EPL in this study.

Also frequently seen in emission accounting is the term Carbon Dioxide equivalent (CO_2e) which is a typical measure of reporting the amount of GHG emitted into the atmosphere. This is used as GHG consist of more gases than just CO_2. These all have varying global-warming potential (GWP) (Table 1) but by converting amounts of other gases into the equivalent amount of CO_2 with the same GWP, CO_2e can be used as an overall metric to measure emissions from various GHG (Brander, 2012). The GWP of a GHG is a measure of the amount of warming a given mass of gas causes over 100 years, where CO_2 has the index value of 1 and the GWP of other gases is the number of times more warming they cause in comparison to CO_2. This project will use the CO_2e metric to ensure consistency throughout the report and to maintain consistency with other literature.

Table 1: Global-warming potential of a number of gases considered Greenhouse Gases under the Kyoto Protocol (IPCC, 2007)

Greenhouse Gas (GHG)	**Global-Warming Potential (GWP)**
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
Hydrofluorocarbons (HFCs)	124 – 14,800
Perfluorocarbons (PFCs)	7,390 – 12,200
Sulfur Hexafluoride (SF_6)	22,800
Nitrogen Trifluoride (NF_3)	17,200

German Bundesliga football club VfL Wolfsburg are one of very few clubs to publish an energy audit as part of a club-wide sustainability report (VfL Wolfsburg, 2020b). Wolfsburg are a large club from Lower Saxony, often playing in European competitions and the home stadium, the Volkswagen Arena, holds 30,000 people. As Wolfsburg play in the top German division, the club can be considered similar to a number of EPL clubs and values can be used as benchmarks when evaluating environmental impact of other clubs. For the 2019/20 season, the total GHG emitted were found to be 9,461 tonnes CO_2e with 59.46% coming from fan mobility to home and away games (Figure 1). The next greatest contributors are heating energy (17.98%) and team travel (5.98%), meaning travel accounts for over 65%. As Wolfsburg procure electricity from LSW Energie supplying power from 100% renewable sources, it does not appear on the breakdown as no emissions are considered to be attributable to electricity usage.

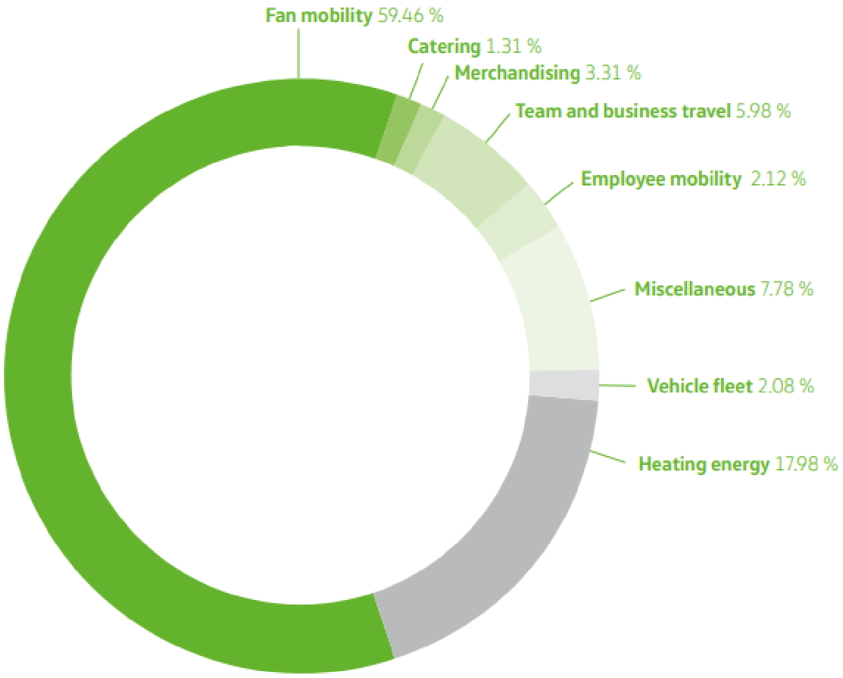

Figure 1: Breakdown of sources of CO_2e emissions across VfL Wolfsburg for the 2019/20 season; where the total emissions equals 9,461 tonnes CO_2e (VfL Wolfsburg, 2020b)

Previous literature has estimated the CO_2e emissions of the last 3 FIFA World Cups; 2010 in South Africa (Norwegian Govt, SA Department of Environmental Affairs and Tourism and Econ Pöyry, 2009), 2014 in Brazil (FIFA and MGM Innova Group, 2013) and 2018 in Russia (FIFA and South Pole Group, 2016). The total CO_2e emissions for the tournaments (Figure 2) included transport, facility construction, heating, electricity and accommodation of players, staff and visitors. International, intra-city and inter-city transport accounts for the majority of emissions; 86.4% in 2010, 83.7% in 2014 and 73.8% in 2018. This is a greater proportion than the values found in the Wolfsburg energy audit due to the international transport involved in travelling to the countries for a World Cup. In South Africa in 2010, international travel accounts for 67.4% of GHG emissions alone. In Brazil in 2014, electricity usage at the tournament venues accounted for emissions of 55,680 tonnes of CO_2e emissions which could be reduced by integrating renewable technologies into the facilities as demonstrated by VfL Wolfsburg.

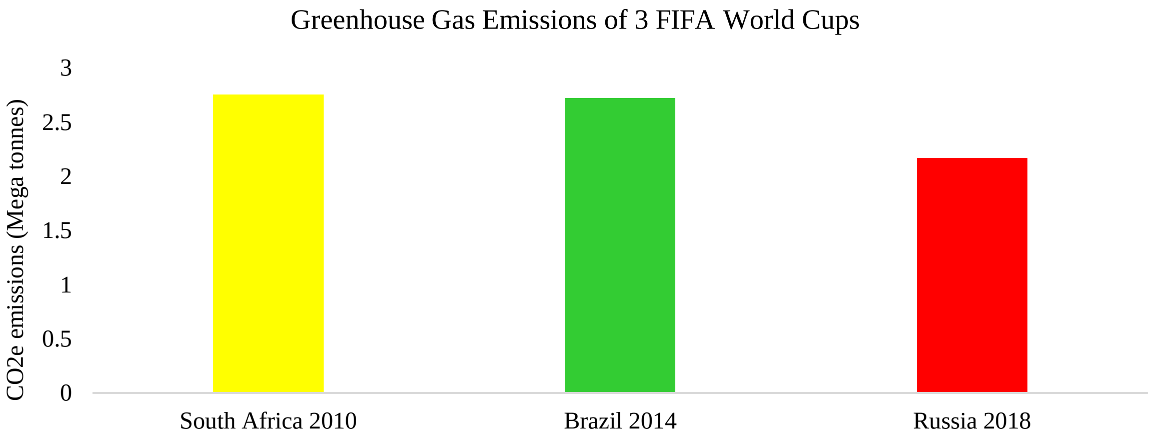

Figure 2: Total CO_2e emissions of the last 3 FIFA World Cups (Norwegian Govt, SA Department of Environmental Affairs and Tourism and Econ Pöyry, 2009; FIFA and MGM Innova Group, 2013; FIFA and South Pole Group, 2016)

A breakdown of the sources of the GHG emissions due to the 2018 FIFA World Cup in Russia highlights the high proportion that is due to travel (Figure 3). Clearly, there are numerous sources of emissions for such a large event and mitigating this is a challenge as a result. Accommodation accounts for 11.7% of all emissions, a high proportion, and this will be due to the number of attendees at a World Cup including players, officials and fans. Consideration should be made that in general, players and fans stay at different standard of hotels, where more luxury hotels result in greater emissions. It should also be noted, this GHG accounting report is from 2016 – prior to the actual event. The values given are expected emissions for the 2018 World Cup and are based on assumptions of travel patterns, expected number of attendees and many other estimations.

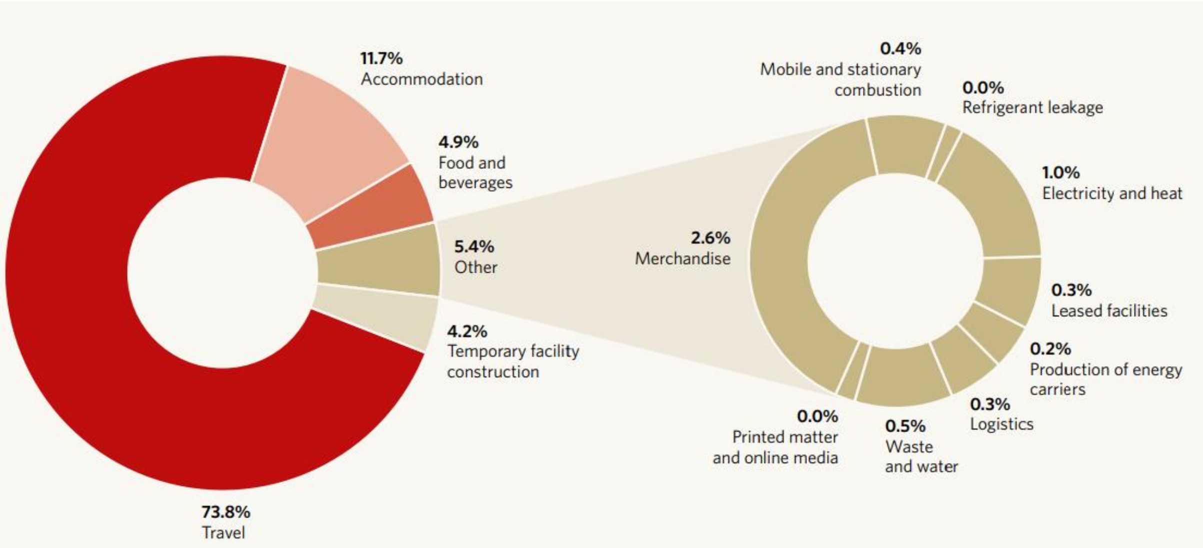

Figure 3: Breakdown of sources of GHG emissions for the 2018 FIFA World Cup in Russia - where total CO_2e emissions equals 2.17 mega tonnes (FIFA and South Pole Group, 2016)

2.3.2. Club Travel

The transport of players and staff also contributes significantly to a football club's carbon footprint. In most studies, travel by fans is considered indirect emissions (Scope 3) that the club is not responsible for, whilst player and staff travel is direct emissions (Scope 1) which also includes energy use, merchandise and catering (VfL Wolfsburg, 2020b). The total emissions for the player and staff travel for all 20 clubs for the season was estimated to be 697 tonnes CO_2e. This is only 131 tonnes greater than the value found for just VfL Wolfsburg which suggests either the distances travelled in Germany between clubs in the Bundesliga is far greater or there is inconsistency in emissions accounting methods. The average emissions for an EPL clubs travel over the 2016/17 season was 34.8 tonnes CO_2e with the average size of a clubs' delegation being 39 people. This results an average emissions per member of each delegation of 891.6 kg CO_2e (Pereira, Filimonau and Ribeiro, 2019).

The study found that per person, travelling by coach is the most carbon efficient which is consistent with other research (Brand and Boardman, 2008; Filimonau *et al.*, 2013). Air travel is most carbon intense, with the study identifying possible strategies to eliminate air travel from the EPL clubs scheduling could reduce the carbon footprint of the league (Pereira, Filimonau and Ribeiro, 2019). The paper suggest hosting EPL matches in 'neutral' venues so that neither club requires to use air travel to get there but is able to travel by bus or by train. This is a similar conclusion to analysis of small-scale sports events held in Canada where 52% of emissions were found to result from the 4% of fans travelling by air, highlighting the far greater emissions resulting from air travel than other means of transport (Dolf and Teehan, 2015).

The accommodation of players and staff whilst travelling to away matches is also estimated to contribute to emissions of 439 tonnes of CO_2e over the 2016/17 season (Pereira, Filimonau and Ribeiro, 2019). Accommodation is estimated to account for 11.7% of emissions at the 2018 World Cup which is line with estimates for other sectors such as tourism, which is estimated to be between 10-20% (Becken, Simmons and Frampton, 2003; FIFA and South Pole Group, 2016). The clubs usually use luxury hotels for the players and staff which are more carbon intense than budget hotels (Xuchao, Priyadarsini and Eang, 2010), where emissions are assumed to be 34.32 kg CO_2e per person per night (Chenoweth, 2009). However, it is acknowledged that players and staff do not get to use facilities in luxury hotels such as spas so the value of 34.32 kg CO_2e may not be representative. In 4 cases, accommodation of players and staff over the season was found to result in more carbon emissions than the transport. This is at clubs like West Bromwich Albion, Stoke City and Leicester City in the middle of England where journey distances are shortest. To reduce the carbon footprint from accommodation of EPL players and staff, the study suggests utilising budget hotels with lower associated CO_2e emissions.

When comparing the travel emissions found for 1 season per delegate for the players and staff and per fan it is most suitable to compare the value found for the average Bundesliga fan (Loewen and Wicker, 2021) and the average EPL delegate (Pereira, Filimonau and Ribeiro, 2019) which are 311.2 kg CO_2e and 891.6 kg CO_2e respectively. It is a valid comparison as both studies consider top flight leagues. Per person club travel to matches is almost 3 times greater than per fan and this does not take into account overnight accommodation, which contributes 562.9 kg CO_2e per club delegate over a season.

2.3.3. Fan Travel

It is clear from GHG reporting that the majority of emissions attributable to sport clubs and tournaments is from transport of fans. This is seen at club level (Figure 1) and at global football tournaments (Figure 3). As a basic overall figure for a top-flight club, the VfL Wolfsburg fans contributed 5,625 tonnes CO_2e in the 2019/20 season due to mobility to and from home and away matches, amounting to almost 60% of emissions for that year.

Fluminense FC from Brazil carried out a similar analysis, accounting and reporting GHG emissions across a season and finding a contribution of fan mobility to club CO_2e emissions of 43.9%. The Fluminense stadium holds 16,274 people and therefore fewer fans travel to home games leading to a reduction in contribution to overall emissions. Total GHG emissions across the whole club were found to be 2,580 tonnes CO_2e reflecting the size of the club in comparison to Wolfsburg (Fluminense FC, 2014). However, the Fluminense GHG report for the 2012 season has been seen as potentially a gross underestimate of emissions (Goldblatt, 2020). The club played in the Copa Libertadores, the South American inter-continental club competition, that season where they travelled to Buenos Aires in Argentina 3 times, Venezuela and southern Brazil (transfermarkt, 2012). For just the 3 away games in Buenos Aires, if they took 1,000 fans on each trip that would account for CO_2e emissions of 1,300 tonnes, 50.3% of the clubs supposed emissions for that season (Fluminense FC, 2014; ICAO, 2016). This undermines the validity of the report.

The travel patterns of fans attending matches of 47 clubs in the 3rd to 10th tiers of English football have been analysed and the results extrapolated out to all clubs in the 8 tiers (Figure 4) (Dosumu, Bragg and Colbeck, 2017). Modes of transport of the fans included car, taxi, buses, trains, cycling and on foot, clearly all with varying environmental impact. Distance travelled varied between 80 m to 612 km, with the average distance travelled to a home game 15.55 km and average distance to an away games 114.12 km. This resulted in average GHG emissions of 1.70 kg CO_2e for home spectators and 13.71 kg CO_2e for away spectators, with an overall average of 4.74 kg CO_2e for any given fan travelling to a single match. Emissions increased for fans in higher tiers of the football pyramid, where those in tier 3 was over 3 times that of those in tier 6 and below. This could be an important factor in assessing CO_2e emissions of spectators at EPL matches (tier 1 in the pyramid) (Figure 4).

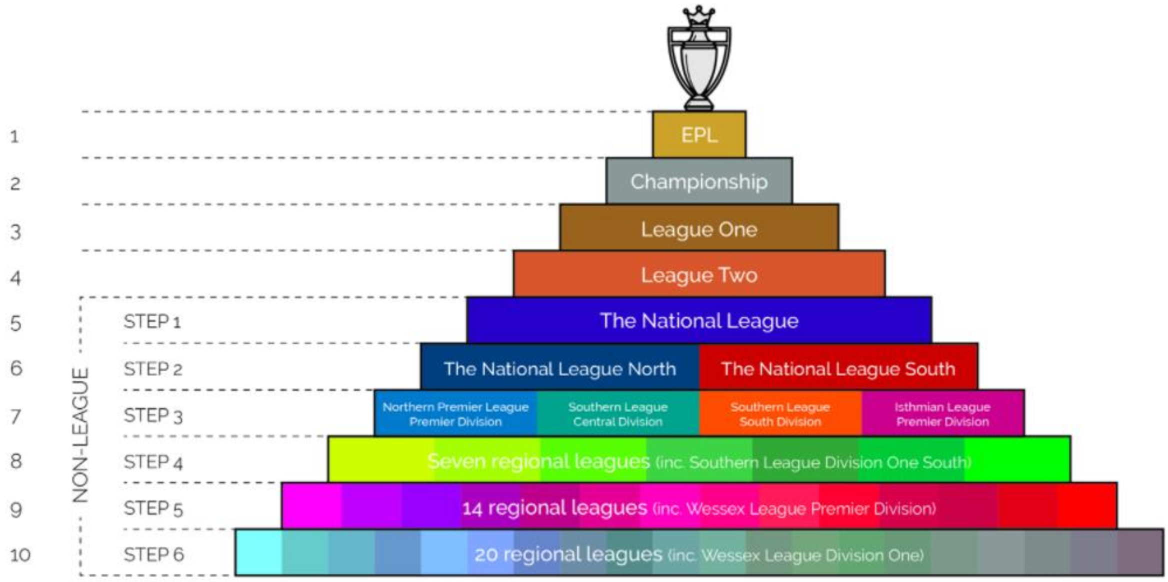

Figure 4: English football league pyramid, where the EPL is tier 1. 47 clubs from tier 3 to 10 are involved in the study of travel patterns of English football fans (Smith and Hardcastle, 2021)

Analysis of travel patterns of fans of the German Bundesliga found an average seasonal carbon footprint of 311.1. kg CO_2e (Loewen and Wicker, 2021). Given there are 36 matches per team in a season, the average emissions of a fan travelling to a Bundesliga match was found to be 8.64 kg CO_2e – around double that found for spectators attending 8 tiers of English football (Dosumu, Bragg and Colbeck, 2017). The difference is due to greater travelling distances involved in attending games across Germany. Although the study did not outline mean CO_2e emissions of home and away fans over a season, it did describe how more dedicated or fans who hold 'memberships' are associated with 4 times the CO_2e emissions as they tend to travel further to away games more often.

2.3.4. Electricity and Heating Energy Consumption

VfL Wolfsburg found heating energy accounted for 17.98% of CO_2e emissions (Figure 1) as the club maintains thermal comfort across their facilities. These include the men's stadium, the women's stadium, employee offices and the training complex. The club also reported total electricity consumption of 6.74 GWh for the 2019/20 season across all facilities, but as LSW Energie supply them with '100% renewable' power it is not considered to contribute to CO_2e emissions (Figure 1). Wolfsburg can be used as a valid benchmark for EPL clubs due to its similar size, stature and top-flight facilities.

Fluminense FC reported total electricity consumption over 2 sites of 0.596 GWh for the 2012 season, which potentially seems an underestimate compared to Wolfsburg. However, they have fewer sites, more basic facilities and utilise floodlights less frequently (Fluminense FC, 2014). The method used to find 0.596 GWh was based on the electricity consumption of a district divided by a percentage of how much of the district Fluminense own. This is not a robust way to find electricity consumption as it does not account for energy intense facilities like heated swimming pools and gyms, commonly present at training grounds and stadia.

The 12 stadia used for the 2006 World Cup in Germany were found to have an average annual electricity consumption of 3.5 GWh and average annual consumption of 4.0 GWh of heating energy. These vary in size from capacities of 42,000 to 74,000 and this is reflected in consumption of double the average in the larger stadiums such as the Allianz Arena in Munich (Dolles and Soderman, 2010).

The Aviva Stadium is a multi-purpose venue in Dublin, Ireland with a capacity of 51,700 used for rugby matches, football matches and events across the year. Data collection (Table 2) was carried out over a year for the Aviva and Wembley as well as for an un-named 'Stadium A' (Chilvers, Chaer and Ford, 2015). Stadium A is described as a recently built Premier League Stadium with a capacity of 31,000. The only stadium that fits this would be the Amex Stadium where Brighton and Hove Albion FC (BHAFC) play, which was completed in 2011. BHAFC was identified as the joint 2nd most 'sustainable' club in the EPL (*EPL Sustainability Table 2020*, 2021) with initiatives such as zero-waste, 100% 'green electricity' and offsetting gas usage (Brighton and Hove Albion FC, 2021).

Table 2: Electricity consumption of the Aviva, Wembley and Amex stadiums and how that compares to each stadiums capacity, internal area and hospitality areas (Chilvers, Chaer and Ford, 2015).

	Aviva	**Wembley**	**The Amex**
Capacity (seats)	51,700	90,000	31,000
Gross Internal Area (GIA) (m^2)	66,460	174,000	21,000
Hospitality Area (m^2)	6,160	8,905	3,650
Annual Electricity Consumption (GWh)	8.21	22.19	4.99
Electricity Consumption per seat (kWh/seat)	158.85	246.57	161.03
Electricity Consumption per m^2 (kWh/m^2) GIA	123.57	127.54	237.71
Electricity Consumption per m^2 of Hospitality (kWh/m^2)	1,333.18	2,492.02	1,367.63

It is acknowledged that the data for Wembley is perhaps not useful as the value for GIA appears to relate to the concourse rather than the 'thermal envelope' of the stadium (Chilvers, Chaer and Ford, 2015). Also, Wembley has a retractable roof which means, alongside its operational electrical usage, growth lamps are required for the grass on the pitch all year round leading to an unrepresentatively high electricity consumption. Only one other ground in the UK has a retractable roof, the Millennium

Stadium in Cardiff which currently plays host to the Welsh National Rugby Team, so the electricity consumption data for Wembley is not representative for the EPL.

When analysing the results for the Aviva and the Amex, the percentage difference for values for electricity consumption per seat and per m^2 of hospitality are 1.36% and 2.55% respectively. This suggest the values of 161.03 kWh/seat and 1,367 kWh/m^2 of hospitality could be utilised for further analysis of other EPL stadia. The values found for the Aviva and the Amex also reasonably reflect values found for the 2006 World Cup in Germany suggesting a benchmark for electricity consumption of football stadia of between 3.5 GWh and 8.2 GWh depending on size and capacity.

The basic number for the annual electricity consumption for a stadium does not take into account the spikes in demand, mainly on match day events. On a match day at an EPL stadium such as Old Trafford, electricity load can jump to over 3 times the normal load on a given non match day (Wilson, 2019). The main reason for this is floodlights that are turned on regardless of if kick-off is at 3pm or 7:45pm due to the EPL season being played through the winter. The data for EPL demand profiles of a given time step are not widely available, but the Skagarek Arena in Norway was the basis of a study where the hourly electricity demand profile (Figure 5) was published (Berg *et al.*, 2021).

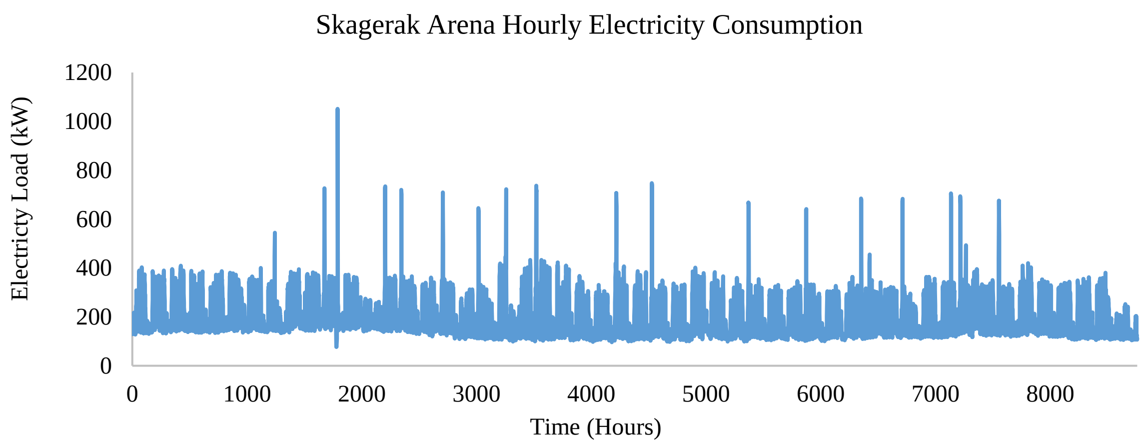

Figure 5: Hourly electricity demand profile for the Skagerak Arena in Norway (Berg et al., 2021)

The peaks reflect when the stadium owners, Odds Ballklubb, play at home and last for around 3 hours and are between 2.5 and 3.5 times the normal load for that time of day. The annual electricity consumption for the Skagarek Arena is 1.75 GWh, which for a 13,500-person capacity stadium is 129.77 kWh/seat. This is a 21.5% difference to the Amex Stadium (Table 2) but as it is an EPL stadium with high specification facilities and likely more hospitality resulting in greater electricity consumption, the value for kWh consumption per m^2 reflects a reasonable degree of similarity.

Data collection across numerous sources has been carried out to attain annual electricity consumption of sport stadia across the globe and establish a relationship between electricity consumption and stadium size (Figure 6). The results of the data collection show a clear correlation between capacity and electricity consumption and suggest a numerical relationship between the two, shown by the trend line. It also potentially shows some outliers where the relationship is not as strong, such as the average for the stadia used for the 2006 World Cup in Germany, but generally shows a distinct correlation. The consumption of electricity at stadia will result in CO_2e emissions in correlation with the magnitude of the consumption. The associated emissions depends on the GHG conversion factor of each kWh consumed from the electrical grid in the given geographical location of the stadium.

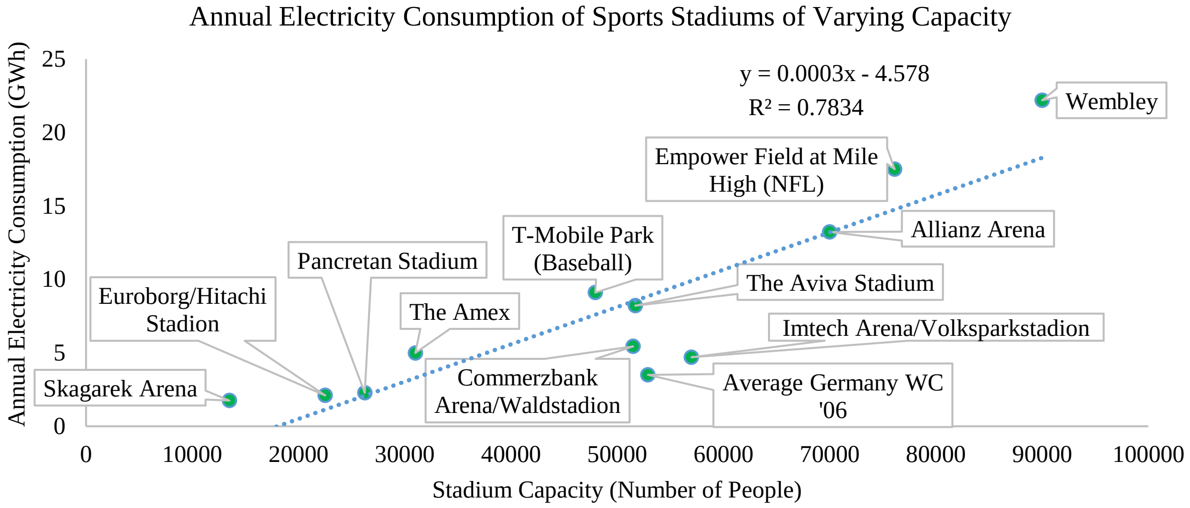

Figure 6: Annual electricity consumption of various sport stadia across the globe of varying capacity, where data is taken from literature (Dolles and Soderman, 2010; Dietrich and Melville, 2011; Smulders, 2012; Chilvers, Chaer and Ford, 2015; Katsaprakakis et al., 2019; Berg et al., 2021)

2.4. Studies on Reducing the Environmental Impact of Sport

The first step in mitigating the environmental impact of a system or organisation is accounting and reporting GHG emissions**.** The next section of the literature review will discuss previous studies that have looked to build on GHG reporting and analyse ways in which to reduce the associated environmental impact. This may be through changing travel patterns of players, staff and fans, introducing energy saving measures into sports facilities or integrating renewable technologies to reduce the energy intensity of running sports facilities.

2.4.1. Club Travel

Player and staff travel has also seen to be more carbon intensive per person and this is partly due to the clubs frequent use of air travel. Reducing this has, again, been identified as a prime strategy for limiting CO_2e emissions (Dolf and Teehan, 2015; Pereira, Filimonau and Ribeiro, 2019). Also discussed is the possibility for EPL clubs to choose to fly on services using biofuels but this is a future eventuality and beyond the scope of this project.

Changing the scheduling of the EPL may help to mitigate the need for clubs to travel by air. This could be done by utilising ‘neutral’ venues which would eliminate the need for air travel. By staging the games between Newcastle United and Brighton and Hove Albion at Aston Villa's ground in Birmingham, neither team would need to fly, and both could opt to travel by coach. Coach travel has been seen to release over 5 times less CO_2e emissions than air travel, hence reducing the environmental impact of that game. Extending this practice out to the whole league could prove to an effective strategy in reducing the emissions due to club travel by as much as 50% (Pereira, Filimonau and Ribeiro, 2019).

2.4.2. Fan Travel

Fan mobility has consistently been seen to contribute most CO_2e emissions but is also typically considered within Scope 3 in reports. This means the club or organisation may consider it indirect emissions and not something they can directly reduce. However, various football clubs have looked to provide incentives to fans to use methods of transport that minimises the associated CO_2e emissions with the journey to the match. The 'KombiTicket' was first introduced by FC Schalke 04 and is now commonplace in the German Bundesliga where fans can utilise public transport for free with their match ticket (Yates *et al.*, 2013). The system was also introduced in Germany for the 2006 World Cup as well as at the 2008 European Championships hosted in Austria and Switzerland (Dolles and Soderman, 2010; Horne, 2010). In Germany in 2006, 57% of supporters used public transport to travel to and from matches which was greater than the 40% expected, highlighting the popularity of the KombiTicket. It was estimated the cleaner travel initiatives introduced at the 2006 World Cup saved around 18,000 tonnes of CO_2e emissions showing how effective something like the KombiTicket can be.

SV Werder Bremen have been more forceful in encouraging fans to use public transport by banning car parking around the stadium on match days (Goldblatt, 2020). Forest Green Rovers FC have installed 7 electric car charging points that are available to fans and plan to significantly increase the number of installations at the Eco Park, their new stadium due to be developed by 2023 (Forest Green Rovers, 2021b; Zap Map, 2021). Many NFL teams in America have introduced electric car charging points at the stadiums, however it is noted that this was without considering the travel patterns of fans and how these could be altered (Reiche, 2013).

It is now widely acknowledged that football clubs and authorities should engage with fans to increase use of low-carbon travel to and from matches and this could be through a range of initiatives. Firstly, by introducing a comprehensive network of public transport at an affordable price for the ordinary fan (Dosumu, Bragg and Colbeck, 2017). This could be achieved in the EPL with the introduction of the KombiTicket or similar, as is in place in the Bundesliga. Potential benefits would reflect wider society where improved public transport networks can lead to increased usage and hence reductions in CO_2e emissions associated with surface transport (Climate Change Committee, 2020).

Increasing vehicle occupancy when travelling to and from matches can also help reduce emissions. This could be achieved by offering improved coach services or promoting car-pooling for travelling to and from games (Dolf and Teehan, 2015; Dosumu, Bragg and Colbeck, 2017). The English Football League have introduced a Football Car Share community where fans can offer or look for people to share a car journey to the matches with (liftshare.com, 2021).

In summary, the main theme amongst literature is that engaging with spectators to change their behaviour will instigate the greatest reduction in environmental impact. Also, as fan mobility account for so much of footballs emissions, fan engagement where clubs take a pro-active role in potentially offering incentives is important in reducing emissions from the sport.

2.4.3. Reducing Electricity Consumption and Renewable Generation

Reducing energy consumption of club owned facilities is provides a two-fold benefit, saving money that can be invested elsewhere whilst also reducing CO_2e emissions for those looking to present themselves as a sustainable organisation. As a result, numerous clubs, organisation and many studies have investigated or even already implemented ways in which to introduce energy saving measures or generate renewable energy.

At the Johan Cruyff Arena where Ajax play in Amsterdam, electrical demand can increase from 200 kW to 3,000 kW during an event. To supply emission free power to the stadium, a battery energy storage system (BESS) has been installed featuring 4,200 photovoltaic (PV) modules and a battery bank with capacity of 2.8 MWh (Pagliaro and Meneguzzo, 2019). The system uses solar energy to charge the batteries, which is then discharged during stadium events, such as football matches, to reduce the electrical demand from the grid. The system is used for ‘peak shaving’ (Figure 7) where the energy stored in the battery system is discharged to reduce the magnitude of the peaks of electricity required to be drawn from the grid, both helping to limit emissions and save money (Vo and Nguyen, 2018).

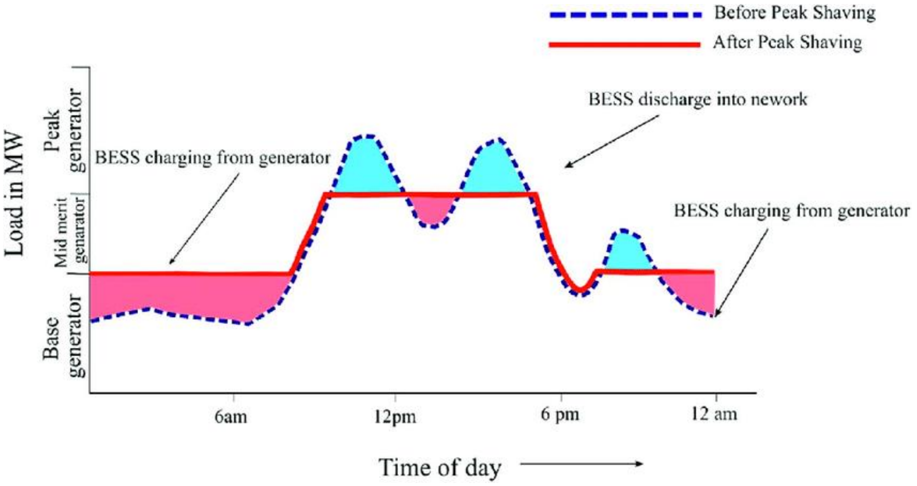

Figure 7: An example of 'peak shaving' of an electrical load using a BESS (Uddin et al., 2017)

A similar system to at the Johan Cruyff Arena has been suggested as feasible to replace back-up diesel generators used at football stadia in Norway. This is present at the Skagarek Arena, where a coupled

PV-battery system operates with capacity of 1.1 MWh. The system is most effective when combining peak shaving, energy arbitrage and using the electricity at the stadium when the electrical load is greatest and the floodlights are in operation. A BESS in a sports stadium is described has having ‘great potential’ and could be integrated into other European stadiums currently using back-up diesel generators (Berg *et al.*, 2021).

Multiple clubs in the EPL and other leagues have installed PVs to generate electricity across club owned facilities. Brighton and Newcastle United have PVs installed at the training grounds (*EPL Sustainability Table 2020*, 2021) , as do Forest Green Rovers which is just one of many initiatives at the world’s first UN certified carbon-neutral football club (Forest Green Rovers, 2021b). Arsenal have a battery system of 2.5 MWh capacity installed at the Emirates Stadium, which discharges over a match day, cutting electricity costs (Arsenal, 2018). Many EPL clubs are provided with ‘100% renewable’ or ‘clean’ energy from suppliers hence reducing carbon emissions but this is difficult to verify and ensure it is as emission free as the energy companies claim.

Research into the potential of installing PV arrays onto the roofs of Australian sports stadia found generation potential of an estimated 20 GWh a year from solar energy. This includes football, cricket and Australian Rules football grounds, identifying that these buildings have plenty of unused roof space capable of hosting 77,000 m^2 of PV panels. The study does not assess the possibility of installing a BESS system, instead generated electricity is exported to the grid and emissions are considered as offset. Spatial imagery of stadia roof space is used alongside solar irradiance data to determine potential generation using PVs, taking into account shading and tilt (University of New South Wales and Australian Photovoltaic Institute, 2021c).

Electricity generated from a PV array could be used to power other systems installed into a stadium. This possibility was investigated in two scenarios where the PV plant is coupled with a Ground Source Heat Pump (GSHP) and where the plant is coupled with a biomass plant and an absorption chiller used for heating and cooling. This study was for the Dacia Arena in Udine, Italy where the PVs could generate 0.815 GWh annually, which is entirely consumed for the biomass plant system, but almost 0.5 GWh is wasted with the GSHP system. Both systems are viewed as feasible to be replicated in other facilities (Manni *et al.*, 2018).

The economics of installing a PV plant is compared to applying highly-reflective (HR) surface coating to the Dacia Arena which would increase solar reflectance. No other system is coupled with the PV plant meaning it would not provide power elsewhere and it may not be able to cover the 60 MWh annual load of floodlights, due to the peaks on match days throughout the year. HR paint can mitigate against global warming effects by modifying the Earth Thermal Balance (Akbari, Matthews and Seto, 2012) and in this study, in Italy, 720 tonnes CO_2e emissions were offset over 20 years. It was concluded using the HR surface coating has lower cost and a shorter payback time and results in greater CO_2e savings (Manni *et al.*, 2020).

Highly-reflective paint can also be effective in reflecting solar heat and hence reduce the required cooling load in the built environment (Zinzi and Fasano, 2009). This could be considered an energy saving measure and other strategies can be applied to sport stadia. Implementing effective energy saving measures for outdoor arenas does pose a challenge due to the open-air nature of the buildings.

A number of passive and active measures were modelled for the Pancretan Stadium in Greece (Katsaprakakis *et al.*, 2019) including replacing openings in the stadium's thermal envelope, heating and cooling systems of greater efficiency, energy-efficient lighting and a building energy management system (BEMS). Also, to produce thermal energy for use in the swimming pool facility, for example, a coupled solar collector and biomass system was implemented as well as integrating PVs able to generate around 0.2 GWh of electricity. These measures save 83% of energy use and the renewable energy technologies can contribute to 82% of the energy demand for the stadium. These are impressive results but represent a stadium in a very different climate to England and of different architectural style to those in the EPL.

Introducing improved lighting technologies, such as LED floodlights and stadium lights, can reduce electricity demand significantly. Results in US stadia show this can reduce demand by as much as 30% for the Safeco Field, 8% at the Toyota Centre and 15% at the Sports Authority Field, when used in tandem with other measures such as BEMS for lighting and heating and cooling systems (Dietrich and Melville, 2011). Better efficiency lighting is commonplace in the EPL already, with most clubs using LED bulbs in stadia, which can save up to 90% energy consumption compared to a traditional, fluorescent bulb with a similar output (Phillips, 2021). Introducing BEMS has been seen consistently to be an effective energy saving measure (Chard and Mallen, 2013).

Other notable technologies installed in global stadia include a cooling system installed at the Air Canada Centre in Toronto where deep-lake cold water is drawn from Lake Ontario, hence reducing air conditioning load. At the Bank of Montreal Field, also in Toronto, a wind turbine produces around 1 GWh of electricity annually on site that is fed into the local electricity grid (Chard and Mallen, 2013). Electricity generated by wind turbines off site feeds into the BESS installed at the Johan Cruyff Arena in Amsterdam. The O2 Arena in London is planning to install vertical wind turbines that can generate electricity even when wind speeds are low (Ambrose, 2021). A Combined Heat and Power (CHP) system installed at St. James' Park, home of Newcastle United, is estimated to reduce CO_2 emissions by 390 tonnes annually (ENER-G, 2016).

As discussed, Forest Green Rovers are leading innovators in football in reducing the clubs' environmental impact. The pitch is free from pesticides, the rainwater is collected so water from the mains is not required, the lawnmower is electric and solar powered and all food and drink offered at the stadium and training ground is plant-based (Forest Green Rovers, 2021c). The club are also set to build a new stadium (Figure 8), which will be made entirely from wood, in an effort to avoid locking in carbon emissions during construction. Stadiums are usually made from concrete and steel where 75% of CO_2e can be considered to be locked in from day 1 of construction, so eliminating this in new stadiums by using different materials can be significant in reducing emissions (Gustavsson, Pingoud and Sathre, 2006; Rushden *et al.*, 2021).

Figure 8: Artists Impression of Forest Green Rovers planned new all wooden, low carbon stadium - the Eco Park (Forest Green Rovers, 2021a)

2.5. Policy and Framework

The UN have outlined a Sports for Climate Action framework where sports related organisations are invited to pledge, firstly, to measure, report and reduce environmental impact, and secondly, to use the platform the sporting world has to encourage wider society to take climate action. The framework is simply a set of 5 principles to adhere to, where the overall aim is ensuring global warming is limited to below 2ºC, in line with the Paris Agreement (United Nations, 2021b). However, it is encouraging to see sports organisations taking proactive steps to reduce emissions with 238 signatories to the framework including EPL clubs Arsenal, Liverpool, Southampton and Tottenham Hotspur (United Nations, 2021a).

There are clear protocols for organisations looking to measure and report GHG emissions. This results in consistency in methodology and hence, validity when comparing emissions from different sources and organisations. Managing and reducing emissions is also more effective as a result of a clear protocol, allowing the most carbon intense sectors to be identified and emissions mitigated (Greenhouse Gas Protocol, 2021). Environmental Reporting Guidelines for the UK are based from the protocols and feature 5 key steps (HM Government, 2019).

1. *Determine the boundaries of the organisation*
2. *Determine the period for which you should collect data*

3. *Determine the key environmental impacts for your organisation*
4. *Measure*
5. *Report*

Literature which has been discussed in this review can be seen to follow the guidelines and protocol. An example of following steps 1 and 3, where the boundaries of a club are defined and each scope finds emissions from key impacts such as fan mobility and energy usage (Fluminense FC, 2014; VfL Wolfsburg, 2020b). Step 2 is followed by reporting emissions for a season or for a tournament, which are defined periods of time (FIFA and South Pole Group, 2016; Forest Green Rovers, 2021c). Steps 4 and 5 are the technical aspect of the accounting and reporting seen in many studies discussed in the literature review. The steps outlined provide an overall methodology for finding the environmental impact of the EPL for this project.

2.6. Conclusions from the Literature Review

The literature review has been successful in identifying a wide range of studies, reports and articles that have discussed many aspects of the relationship between climate change and sport. It is clear literature exists which has attempted to evaluate the environmental impact of different football competitions and clubs and the breakdown of the sources of these emissions. Several key conclusions from existing literature can be drawn:

- Sports clubs, tournaments and leagues will be a victim of the effects of global warming, with stadiums becoming flooded, temperatures too hot to play in and increasing number of sporting events being cancelled due to climatic weather events.
- Fan and club transport to matches is the main contributor to CO_2e emissions of football clubs, leagues and tournaments; for clubs, such as VfL Wolfsburg, this is as much as 60% and at tournaments, like FIFA World Cups, figures range from 74% up to 87%.
- Suggested strategies to reduce transport emissions, from both fans and clubs include changing scheduling and venues, reducing air travel and introducing greater incentives to use public transport.
- Heating of sports facilities can also be carbon intensive, 18% at VfL Wolfsburg and electricity usage at football stadiums increases with capacity, ranging between annual consumption of 1.5 GWh and 22 GWh (Figure 6).
- Football clubs often use electricity suppliers that provide ‘100% renewable’ or ‘green’ energy where they can claim it has no associated CO_2e emissions.
- Energy saving measures have been considered such as at the Pancretan Stadium in Crete where introducing changes to the stadium saved 83% of consumption.

- Studies have investigated the use of technologies such as PV panels to generate renewable electricity for sport club facilities in Australia, Crete and Italy and finding it is a feasible option in globally. Technologies exploiting renewable energy sources have been seen to generate as much as 82% of the Pancretan Stadiums electricity load.
- Some clubs already have integrated renewable technologies – such as a coupled PV-battery system at Ajax and PV panels on the FGR training ground roof – which can be used as models for this project.

In summary, there has not yet been a wide-ranging calculation of the emissions attributable to the EPL, but it is clear this would be a relevant project to various stakeholders. Methodology of accounting GHG emissions has also been reviewed in relation to football and sport, and also overall methodology outlined as protocol for GHG reporting. This gives convention for GHG reporting that this project can follow to ensure the results presented can be as accurate and valid as possible. Assessing the emissions of an industry or sectors of it, such as the EPL, will allow the most effective mitigation strategies of emissions to be determined and again gives drive to carrying out the initial aim of the project, so that the secondary aim can also be achieved.

3.0. Assessing the Environmental Impact of the EPL

3.1. Methodology

The literature review outlined convention when reporting and accounting GHG emissions from an organisation such as the EPL and the 20 clubs it comprises of each season, and this structure was adhered to in the following assessment.

Firstly, it was established that the most appropriate season to guarantee a comprehensive assessment of EPL emissions was the 2018/19 season. This was due to the fact both the 2019/20 and 2020/21 seasons were impacted by the COVID-19 pandemic, where fans were unable to attend for large parts of both seasons. As shown by the literature review, fan travel has been seen to account for the majority of emissions, so the value for the overall emissions from the league over those 2 seasons would be low and not representative of a typical EPL season.

3.1.1. Club Travel

Emissions as a result of players and staff delegations travelling to away games can be considered within Scope 2 of the GHG reporting protocol. The steps carried out to find the CO_2e emissions of club travel will be outlined here.

The first step was to find the clubs competing in the 2018/19 season, each clubs' home stadium and the location of each stadium that would host matches across the season (Figure 9). Each of the 20 clubs has a home ground where they play each of the other 19 teams once. This results in the EPL season comprising of 380 matches in total. The travel of club players and staff to home matches was not considered to contribute to CO_2e emissions of the EPL. This is due to players and staff travelling to home games using private means from private accommodation, so this information is not widely available to assess the resulting emissions. It is also reasonable to assume it is negligible in comparison to travel to away matches as it would be expected that club players and staff live within close proximity to home stadia.

To assess emissions as a result of club travel, the means of transport for each club's respective away matches must be found. Clearly, the distances between different clubs varies and hence the mode of transport is different. It was found through a survey of EPL clubs that coach, train and airplane are the chosen modes of transport for EPL clubs travel to away fixtures (Pereira, Filimonau and Ribeiro, 2019). The survey also found that there are certain distance thresholds and conditions where clubs will choose to travel by varying means of transport. For one-way trips under 257.49 km or for journeys under 3 hours, the coach is utilised as it is most flexible. Distances above 257.49 km are travelled by train or airplane depending on what suits the clubs most, with a maximum distance of 344 km for train travel.

This seems to result in a small window where train travel is preferred, however, often clubs travel in and out of London on trains to avoid traffic congestion around a big city. The main consideration in club travel is players comfort, where journeys over 3 hours are avoided so that players do not cramp up. It should also be noted for away matches over 64.37 km away, overnight accommodation is required for all EPL clubs. The conditions for EPL clubs travel found in literature were applied for this assessment of CO_2e emissions as these limits were provided from a survey of the participants themselves.

Figure 9: EPL clubs and location of stadia in the 2018/19 season (Wikipedia, 2021)

The nearest major train stations and major airports to each club was found and the distance by road to each transport hub found (Table 3), so that this short leg of the journey was also accounted for. The distance between each clubs by road was calculated (The AA, 2021) and using this the different thresholds were applied for each clubs 19 away trips to determine if each trip was taken by road, train or air. The home ground of the EPL clubs was assumed to be the start or end point of the journeys. For train journeys distance was calculated between the train stations closest to each club being considered (RailMiles, 2021) and the coach journey at either end was added. This was also carried out for air travel, where the distance between the airports closest to each club was found (Air Miles Calculator, 2021) alongside the coach journey at either end. The distance travelled by each club via each mode of transport was determined so that the associated emissions could be calculated for each trip as well as for each means of transport overall. The number of people travelling in each clubs delegation was assumed to be 39, an average for the EPL found in literature (Pereira, Filimonau and Ribeiro, 2019). The size of delegations is variable, and information is not widely available, so it is reasonable to use an average value from previous studies.

Table 3: Twenty clubs competing in the 2018/19 EPL season, the location within the UK, the host stadia and nearest major transport hub to each club. The distance by road between the stadia and each transport hub is shown.

Club	City	Stadia	Nearest Airport - Distance (km)	Nearest Train Station - Distance (km)
Arsenal	London	Emirates Stadium	London City Airport – 15.7	London Euston – 4.9
AFC Bournemouth	Bournemouth	Vitality Stadium	Bournemouth Airport – 8.3	Bournemouth Station – 3.4
Brighton and Hove Albion	Brighton	Amex	Gatwick Airport – 48.4	Brighton Train Station – 13.1
Burnley	Burnley	Turf Moor	Leeds Bradford International Airport – 56.9	Burnley Central – 1.98
Cardiff City	Cardiff	Cardiff City Stadium	Cardiff Airport – 17.8	Cardiff Central Station – 3.89
Chelsea	London	Stamford Bridge	Heathrow Airport – 23.7	London Euston – 10.5
Crystal Palace	London	Selhurst Park	London City Airport – 25.5	London Euston – 16.7
Everton	Liverpool	Goodison Park	John Lennon Airport – 17.1	Liverpool Lime Street – 4.39
Fulham	London	Craven Cottage	Heathrow Airport – 22.1	London Euston – 13.2
Huddersfield Town	Huddersfield	The John Smith's Stadium	Leeds Bradford International Airport - 32	Huddersfield Station – 1.5
Leicester City	Leicester	King Power Stadium	East Midlands Airport – 36.3	Leicester Station – 2.48
Liverpool	Liverpool	Anfield	John Lennon Airport – 16.5	Liverpool Lime Street – 4.3
Manchester United	Manchester	Old Trafford	Manchester Airport – 18.9	Manchester Piccadilly – 6.5
Manchester City	Manchester	Etihad Stadium	Manchester Airport – 17.9	Manchester Piccadilly – 2.8
Newcastle United	Newcastle	St. James' Park	Newcastle International Airport – 10.8	Newcastle Central – 2.32
Southampton	Southampton	St. Mary's Stadium	Southampton Airport – 8.1	Southampton Station – 2.65
Tottenham Hotspur	London	Tottenham Hotspur Stadium	London City Airport – 23	London Euston – 11.5
		Wembley	London City Airport – 42	London Euston – 17.6

Watford	London	Vicarage Road	London Luton Airport – 30.9	Watford Junction – 2.11
West Ham United	London	London Stadium	London City Airport – 8.4	London Euston – 10.5
Wolves	Wolverhampton	Molineux	Birmingham Airport – 45.4	Wolverhampton Train Station – 1.6

The next step was to find the associated emissions with the travel and accommodation of club delegations travelling to away fixtures using GHG conversion factors for each of the means of transport as well as for overnight hotel stays in luxury hotels. The conversion factors are determined by the UK Governments' Department of the Environment, Food and Rural Affairs (DEFRA) and this study will use the values in the units of Carbon Dioxide equivalent emissions (CO_2e). It is standard practice to utilise these conversion factors when assessing the carbon footprint of an organisation. For the 3 means of transport the values are kg CO_2e per passenger per km (Table 4), so emissions will be dependent on the delegation size and the distance travelled to away fixtures by each mode of transport. The values are taken as an average for a passenger on each means of transport. This means it has been considered that planes, trains and coaches are not always at capacity and hence emissions per passenger are not always the same for a journey of the same distance if the transport is at varying capacity. However, the average conversion factor takes this into account.

Table 4: DEFRA's GHG conversion factors for travelling by coach, train and air, per passenger per km travelled. (BEIS, 2021b)

Mode of Transport	GHG Emissions Conversion Factor (kg CO_2e)
Coach	0.02732
Train (National Rail)	0.03694
Airplane (Domestic)	0.2443

The CO_2e emissions due to travel are calculated by multiplying the distance travelled by each means of transport by the number of people and then by the relevant conversion factors (Equation 1).

$$CO_2e\ Emissions\ (kg) = Distance\ travelled\ by\ given\ transport (km) \times No.of\ people\ travelling \times GHG\ Conversion\ Factor\ (\frac{kg}{km}) \quad (1)$$

For the overnight accommodation, the EPL club delegations were assumed to stay in luxury hotels where the associated emissions were assumed to be 34.32 kg CO_2e per person per night. This value is taken for the emissions associated with stays in luxury UK hotels (Chenoweth, 2009). As discussed, overnight stays were required where the distance away from the clubs' home ground was greater than 64.37 km and the emissions is found by multiplying the number of nights stayed by the number of people and then by the conversion factor outlined (Equation 2). The emissions as a result of accommodation were added to the travel emissions to find total club travel emissions.

$$CO_2e\ Emissions\ (kg) = No.of\ people\ \times No.of\ nights\ stayed\ \times GHG\ Conversion\ factor\ (kg) \qquad (2)$$

3.1.2. Fan Travel

Emissions as a result of EPL club fans travelling to away games can be considered within Scope 3 within the GHG reporting structure, where they are indirect emissions, and the organisation is not the direct source of the emissions, but they do come as a consequence of the organisations actions. The steps carried out to find the CO_2e emissions of fan travel will be outlined here.

Similarly to club travel, the location of matches and the distance fans travel to matches was found based on the distance by road. This distance varies dependant on the fixture and this information was collated to utilise in the calculation of emissions due to fan travel, alongside number of fans and associated emissions with modes of transport used.

Both home and away fixtures were considered for fan travel, due to the large number of fans that attend home fixtures and the significant distances involved in travel to away fixtures, even where numbers travelling is lower. Each home ground hosts 19 matches a year where attendances vary with a set number of away fans allocated tickets at each stadia (Table 5) (awaygames.co.uk, 2019). The published attendances for every match in 2018/19 season are on record on the Premier League website (Premier League, 2019b). The away fan allocation was assumed to be full at each game, as data regarding exact numbers of away fans at matches is unavailable, except at Wolves where exact numbers of away fans at each game was published. The number of home fans at each game was found by subtracting the away fan allocation from the published attendance, allowing the total number of fans, home and away, to be aggregated for each club and at each stadium across the 2018/19 season (Figure 10).

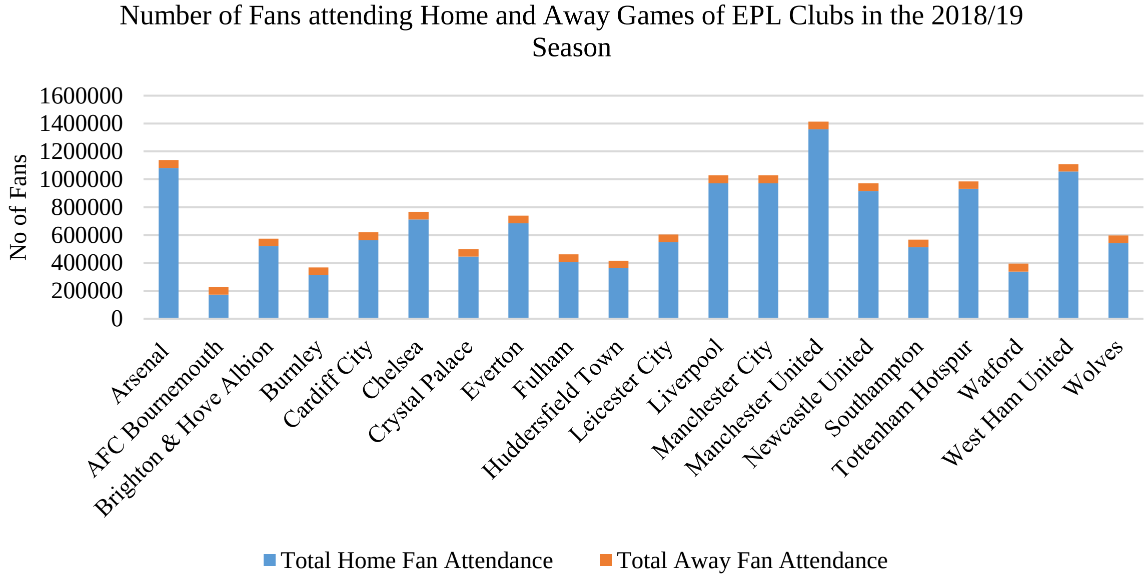

Figure 10: Total fan attendance of each club competing in the 2018/19 EPL season (Premier League, 2019b).

The distance away fans travel for each away fixture clearly varies depending on the opponent, where Arsenal travel a far shorter distance for an away game to Chelsea than they do for an away game against Newcastle United (Figure 9). However, for home games fans were assumed to all travel the same distance from a geographical location relevant to the home ground (Table 5). It is assumed this distance is an average of what home fans travel to matches. This is simple for cities like Newcastle, where fans travel from the city centre to the ground, whereas in a much larger city like London, the centre of London would not be a suitable location for all the clubs. Therefore, the centre of different areas of London boroughs were chosen as the relevant location in relation to the home ground based on concentrations of each clubs fans across London (Malinowski, 2011).

Table 5: Participants of the 2018/19 EPL season, the home stadia, the city centre relevant to each club and distance to it and details of fan capacities of each ground.

Club	Stadia	Geographical Centre Relevant to Stadia	Distance to Centre (km)	Capacity	Away Fan Allocation
Arsenal	Emirates Stadium	London (Highbury)	2.48	60,704	3,000
AFC Bournemouth	Vitality Stadium	Bournemouth	4.96	11,329	1,500
Brighton and Hove Albion	Amex	Brighton	9.08	31,000	3,000
Burnley	Turf Moor	Burnley	0.68	21,944	4,000
Cardiff City	Cardiff City Stadium	Cardiff	9.77	33,316	1,800

Chelsea	Stamford Bridge	London (Chelsea)	2.04	40,834	3,000
Crystal Palace	Selhurst Park	London (Croydon)	3.21	25,486	2,000
Everton	Goodison Park	Liverpool	4.27	39,414	3,000
Fulham	Craven Cottage	London (Fulham)	2.09	25,700	3,000
Huddersfield Town	The John Smith's Stadium	Huddersfield	2.87	24,500	4,000
Leicester City	King Power Stadium	Leicester	3.11	32,312	3,000
Liverpool	Anfield	Liverpool	4.26	53,394	2,000
Manchester City	Etihad Stadium	Manchester	3.58	55,017	3,000
Manchester United	Old Trafford	Manchester	5.94	74,190	3,000
Newcastle United	St. James' Park	Newcastle	0.36	52,305	3,000
Southampton	St. Mary's Stadium	Southampton	1.93	32,384	3,200
Tottenham Hotspur	Tottenham Hotspur Stadium	London (Tottenham)	0.14	62,303	3,000
	Wembley		19.75	90,000	6,000
Watford	Vicarage Road	London (Watford)	1.84	22,200	2,200
West Ham United	London Stadium	London (West Ham)	4.05	60,000	2,800
Wolves	Molineux	Wolverhampton	1.20	32,050	3,000

The next step was to find how fans travel to football matches in England. This was determined using values from literature where a wide survey had been carried out to find travel patterns of EPL fans travelling to both home and away games (Yates *et al.*, 2013). This was the most suitable way to find the numbers of fans that travel to matches by different means of transport due to a lack of data and the scale of a survey that would be required if this project were to find a breakdown of travel patterns independently. The survey adopted was carried out as a national campaign to improve travel options for football fans, in terms of the environment and individual finances, and was done in cooperation with the Football Supporters Federation. It provides a valid representation of means of transport used by fans in England travelling to games. The breakdown of modes of transport used includes fans travelling by car, train, tram, tube, bus, coach, walking and cycling and varies for home (Figure 11) and away (Figure 12) fan travel.

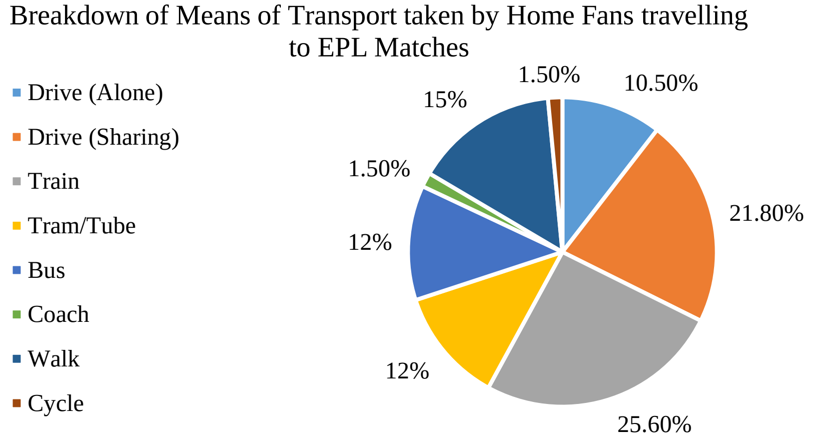

Figure 11: Breakdown of travel patterns of home fans travelling to EPL matches (Yates *et al.*, 2013)

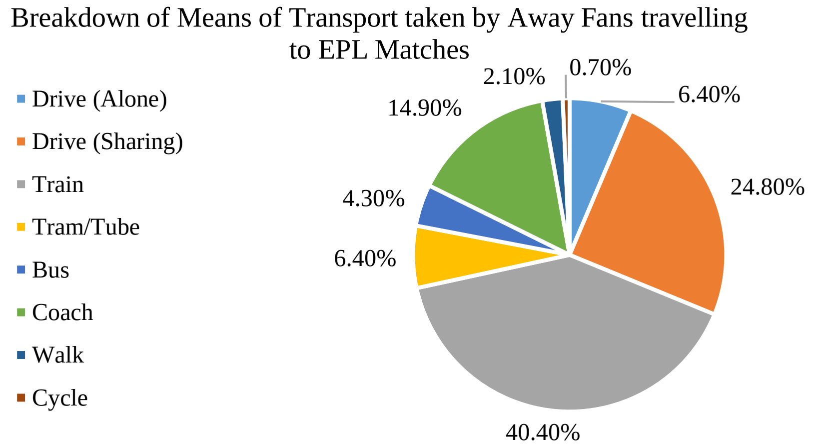

Figure 12: Breakdown of travel patterns of away fans travelling to EPL matches (Yates *et al.*, 2013)

A significant number of fans travel to both home and away games by car sharing, which reduces the emissions attributable to the car journey by a factor of the number of people in the car. So, if there is 4 in the car, the emissions per passenger per km is divided by 4. The occupancy rate of cars of fans travelling to lower league football matches in England was found to be an average of 2.26 people per car (Dosumu, Bragg and Colbeck, 2017), so this value was suitable to be applied to this study as it relates to shared car journeys to football matches in England. The breakdown of the mode of transport used is the same for all clubs, realistically this would not be the case, with fans of London clubs utilising public transport more often, but the survey provides an average able to be applied across the whole EPL.

The final consideration in the assessment of the carbon footprint of EPL fans is the CO_2e emissions associated with each means of transport. Some of these are the same as the values used for club travel, as the DEFRA GHG conversion factors for transportation are used again (Table 6). Within the DEFRA conversion factors there are different values for London buses to the rest of the country and there is a difference between values for the tram/tube used outside of London and the London Underground and this is reflected in the values used depending on the fans journey. Walking and cycling have no associated CO_2e emissions. Similarly to club travel, these conversion factors are average values for emissions per passenger per km and consider the varying capacity of the vehicles of each mode of transport.

Table 6: DEFRA conversion factors for various means of transport used by fans (BEIS, 2021b)

Mode of Transport	**GHG Emissions Conversion Factor (kg CO_2e)**
Drive (Alone)	0.1714
Drive (Sharing – Occupancy Rate = 2.26)	0.07584
Train (National Rail)	0.03694
Tram	0.02991
London Underground	0.0275
Average National Bus	0.10312
London Bus	0.07586
Coach	0.02732

The final step in finding CO_2e emissions of fans travelling to each match is to multiply the number of people travelling by each mode of transport by the relevant conversion factor and the distance the fans travel utilising each mode of transport (Equation 1). The number of home and away fans at each match is found using the published attendances for each match and the away allocation for that match. The number of fans is broken down into means of transport using the percentages found in the survey of EPL fans (Figures 11 and 12). The distance stays the same for a club's home games but varies for away games dependant on location.

Carrying out this process allows a number of different aspects of fan travel to be analysed. The overall CO_2e emissions each clubs' fans can be found as well as emissions as a result of travelling to a certain stadium over 1 season or 1 match. It can show whether home or away fans travel results in most emissions and which clubs' fans result in the most emissions. Also, the most emitting mode of transport can be identified and a relationship between number of fans, distance travelled, and mode of transport can be found. This is similar to analysis that can be carried out from finding emissions attributable to club travel, where clubs and modes of transport which contribute most to emissions can be identified. This results in a simpler and clearer identification of where the carbon footprint of football clubs and fans can be reduced and the best strategies for doing that.

3.1.3. Electricity and Heating Energy Consumption

Under the GHG accounting and reporting protocol outlined in the literature review, electricity and heating energy provided by burning natural gas fall under different reporting scopes. Emissions resulting from heating of stadia and the facilities within utilising gas-powered boilers and heating systems are considered as Scope 1 due to the direct burning if fuels resulting in GHG emissions. Emissions resulting from electricity usage at club stadia is considered an indirect emission and hence Scope 2. This is because the electricity is acquired from the grid and the emissions resulting from the production of electricity aren't directly attributable to the organisation, such as a football club. It should also be noted that a number of EPL clubs are supplied with electricity from companies claiming to provide 100% clean or green energy. However, electricity is supplied from the same National Grid regardless of the supplier, so the associated emissions are the same across the board. Companies such as Octopus Energy can claim to supply 100% green energy as the company invests in technology to supply the grid with electricity generated from renewable sources, with lower carbon emissions, in order to match the electricity supplied to customers by the company from the grid (Bunney, 2019). In this study, the emissions resulting from electricity usage will be considered the same, regardless of the clubs supplier, as emissions from electricity supplied from the National Grid is considered the same nationwide by GHG reporting procedure and the DEFRA conversion factor (BEIS, 2021b).

Data concerning electricity and gas consumption of EPL clubs is not widely available information and hence the methodology outlines an estimation of the emissions. All 20 clubs that participated in the 2018/19 season were contacted regarding consumption data, but no data was obtained as part of that data collection attempt. As a result, the values found in literature will be utilised to give an estimation of CO_2e emissions where values will be based on electricity and gas consumption per seat over 1 year, which can be assumed to be equivalent to 1 season. Therefore, the capacity of each stadium is important in assessing the consumption over a season and this data was collected previously for the assessment of fan travel emissions (Table 5).

For electricity consumption, data collection across a number of stadia was carried out as part of the literature review to determine a relationship between stadium capacity and its annual electricity consumption (Figure 6). This graph shows the stadiums average electricity consumption, in kWh, per seat over a year and provides an average which was found to be 144.89 kWh/seat per year. This value will be useful in providing an estimate of electricity consumption and then CO_2e emissions for an EPL stadium of a given seat capacity (Equation 3).

$$Annual\ Electricity\ Consumption\ (kWh) = 144.89\ \left(\frac{kWh}{seat}\right) \times Stadium\ Capacity\ (No.of\ seats) \quad (3)$$

To then find CO_2e emissions, the electricity consumption in kWh is multiplied by the DEFRA conversion factor (Equation 4), similarly to previous parts of this study. The value for CO_2e emissions per kWh of electricity usage from the UK National Grid is 0.23314 kg CO_2e/kWh.

$$CO_2e\ Emissions\ (kg) = Electricity\ Consumption\ (kWh) \times GHG\ Conversion\ Factor\ (\frac{kg}{kWh}) \qquad (4)$$

Data regarding gas consumption for heating of sport stadia is even less widely published. Only values for Wembley and the Aviva Stadium were found (Chilvers, Chaer and Ford, 2015) and an average of 114.38 kWh/seat per year, was utilised in this assessment of emissions. This value was used for all EPL stadia used by the 20 clubs in the 2018/19 season (Equation 5).

$$Annual\ Gas\ Consumption\ (kWh) = 114.38\ \left(\frac{kWh}{seat}\right) \times Stadium\ Capacity\ (No.of\ seats) \qquad (5)$$

Similarly to electricity consumption, to then find CO_2e emissions, the gas consumption in kWh is multiplied by the DEFRA conversion factor (Equation 6). The value for CO_2e emissions per kWh of gas usage from the UK National Grid is 0.18387 kg CO_2e/kWh.

$$CO_2e\ Emissions\ (kg) = Gas\ Consumption\ (kWh) \times GHG\ Conversion\ Factor\ (\frac{kg}{kWh}) \qquad (6)$$

This method of finding associated emissions with electricity and gas consumption aligns with GHG accounting and reporting procedure by using the published conversion factors. However, by simply using averages for consumption per seat over a year the results will certainly have limitations and be directly proportional to the seat capacity of each stadium.

3.2. Results

3.2.1. Club Travel

The distance travelled by EPL clubs depends on the geographical location of the club and the proximity in relation to other clubs' home grounds. This results in the London clubs travelling the least distance and Newcastle United, which is furthest north and not close to any other clubs (Figure 9), travelling by far the furthest distance (Figure 13).

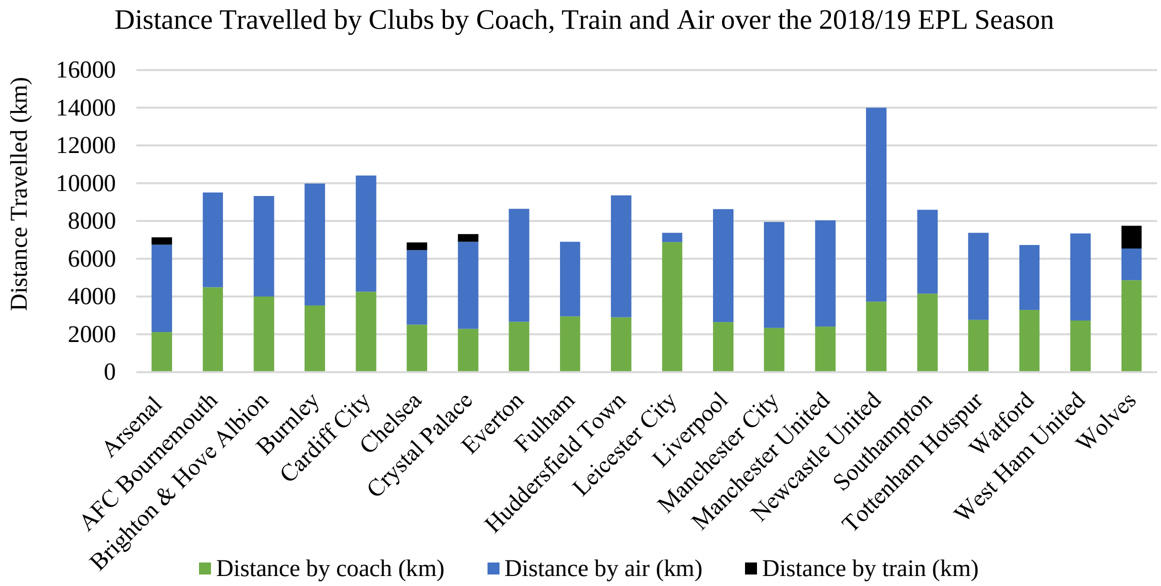

Figure 13: Distance travelled by EPL clubs by coach, train and air over the 2018/19 season.

The midlands clubs, like Leicester City and Wolves, tend to travel further than the London clubs, but as these are in the middle of England, the majority of distance is travelled by coach as individual distances are below the threshold of 257.49 km. Leicester City travel only 6.7% of the distance by air, which is in contrast to an average of 59% for the whole league (Figure 14). The total distance travelled by all 20 EPL clubs over the season was found to be 169,354 km, with 59% travelled by air, 40% travelled by coach and 1% by train, illustrating the importance clubs stress in player comfort and a preference for quickest and flexible modes of transport.

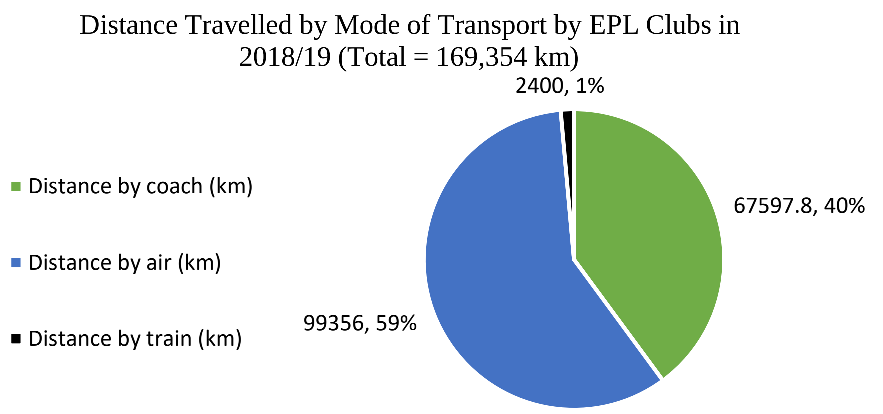

Figure 14: Breakdown of distance travelled by all 20 EPL clubs over the 2018/19 season.

The effects of the midlands clubs utilising air travel far less than average, shown by far less CO_2e emissions resulting from travel which results in the travel of these clubs having the smallest carbon footprint (Figure 15). However, the location of Leicester and Wolves means accommodation is required for all away trips resulting in accommodation emissions being greater than travel emissions for these 2 clubs, where the opposite is true for the rest of the league. Newcastle United is by far the greatest contributor to emissions, which is in correlation with distance travelled. This pattern continues with clubs in more isolated locations like Cardiff City, Burnley, Huddersfield and Brighton travelling long distances and requiring many overnight stays resulting in significant CO_2e emissions.

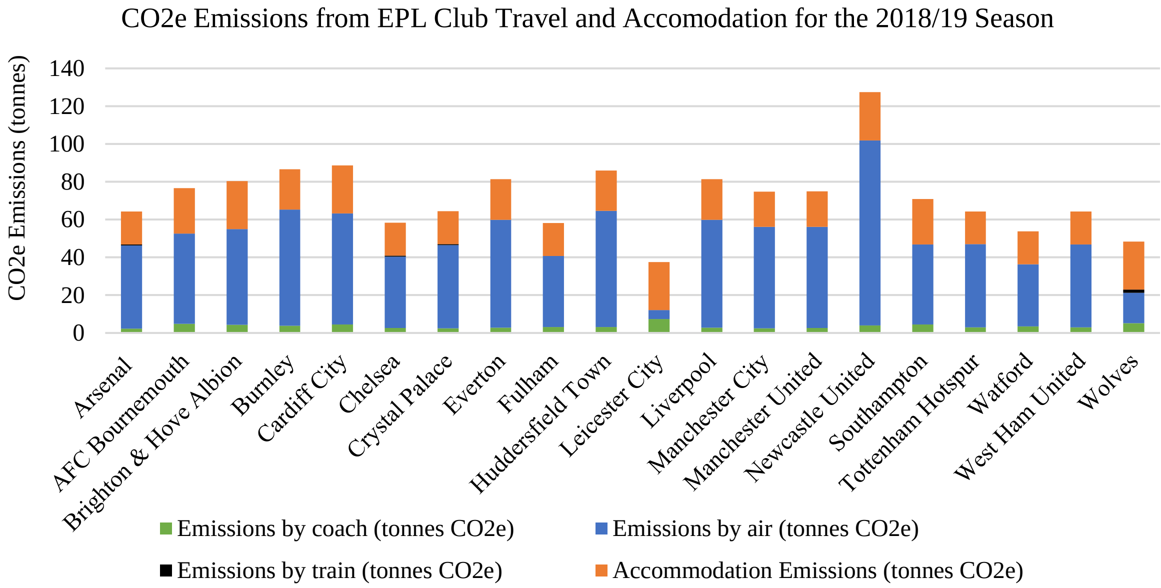

Figure 15: Sources of emissions from club travel and accommodation of EPL clubs over the 2018/19 season.

The total CO_2e emissions from club travel and accommodation to away matches for all 20 EPL teams is 1,442.4 tonnes CO_2e. This shows a 23.9% difference to value found for the 2016/17 season (Pereira, Filimonau and Ribeiro, 2019), perhaps due to the different composition of the teams that make up the league between the 2 seasons. The majority of emissions is from air travel, where it accounts for 93% of travel emissions for the whole league (Figure 16), despite only accounting for 59% of the distance travelled. This shows the difference in environmental impact travelling by coach, train and air has, with coach travel resulting in far less CO_2e emissions, which is reflected in the DEFRA GHG conversion factors.

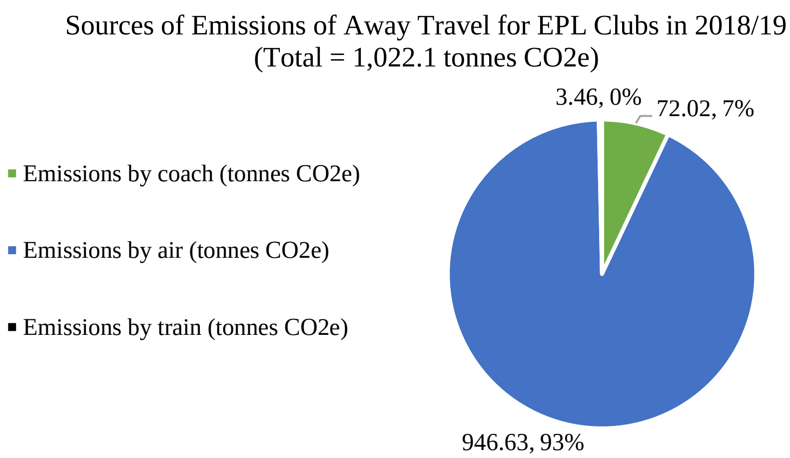

Figure 16: Sources of emissions of club away travel for the 20 EPL clubs in the 2018/19 season.

Accommodation emissions account for 420.3 tonnes CO_2e with 5 clubs requiring accommodations for all 19 away trips, 29% of total emissions over the season (Figure 17). All 7 London clubs only required accommodation for 13 of the 19 away trips over the season, reflecting the proximity to each other, and this is the smallest number of overnight stays required, with every club requiring overnight stays for between 13 and 19 away trips over the season. For clubs requiring accommodation for every away trip, this results in emissions of 25.4 tonnes CO_2e over the season for each club and this could be reduced by utilising budget hotels.

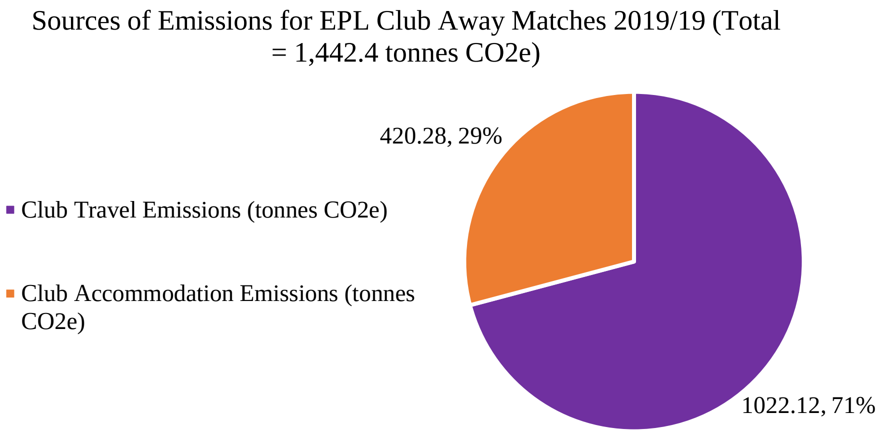

Figure 17: Breakdown of emissions of EPL clubs over the 2018/19 season, between travel and accommodation.

The away travel involved for the 2 matches between Bournemouth and Newcastle United were the greatest single match contributors to CO_2e emissions over the season. This is due to this being the largest distance between any 2 clubs – 560 km one-way. The travel involved two 474 km airplane journeys for the 39 delegates for each club's away trip and 19.1 km by coach to transport the delegates from the airports to the stadiums. This resulted in emissions of 9.07 tonnes CO_2e per round trip for the travel in addition to 1.34 tonnes CO_2e emissions due to 1 nights stay, total emissions of 10.41 tonnes CO_2e for the away trip. This is in comparison to the Liverpool and Everton matches, where the 2 stadiums are 1.4 km away from each other. This distance can be covered by coach, with no requirement for overnight accommodation, resulting in total club travel emissions of 2.98 kg CO_2e for each away trip. The average emissions for an EPL clubs away travel and accommodation to 1 match is 3.80 tonnes CO_2e with average emissions of the 20 clubs over 1 season of 72.12 tonnes CO_2e.

3.2.2. Fan Travel

Data collection carried out across attendances at EPL matches in the 2018/19 season found a total 14.5 million spectators attended the 380 matches. This varies across each of the clubs, with the majority being home fans (Figure 10). The total number of each clubs' fans attending the matches depends heavily on the stadium capacity (Table 5) with the clubs with the largest stadia, such as Arsenal and Manchester United, able to host the largest number of fans across the season. Home fans account for

92% of attendees across all matches in the EPL season, with 8% of fans travelling further to support the away team.

The distance travelled by 1 fan if they were to go to all 19 home games and all 19 away games is dependent on the location in England of the club in relation to others as well as the distance from the relevant geographical centre and the home ground. Similarly to the club travel, Newcastle United fans travel the furthest distances (Figure 18), due to the isolation of Newcastle compared to the rest of clubs, in terms of the geography of England. This is slightly mitigated against due to the fact home fans are considered to travel the shortest distance to the stadium for all home games (Table 5). Fans of London clubs travel the shortest distance due to close proximity to other clubs' stadia for away games. It should be noted that Tottenham Hotspur moved stadium after 14 home games from Wembley to the new Tottenham Hotspur Stadium, where they played the last 5 home games of the season. This is significant as Wembley is 19.61 km further from the centre of Tottenham than the new stadium. This results in the distance 1 fan travelling over a season to be greater than expected when compared to other London clubs.

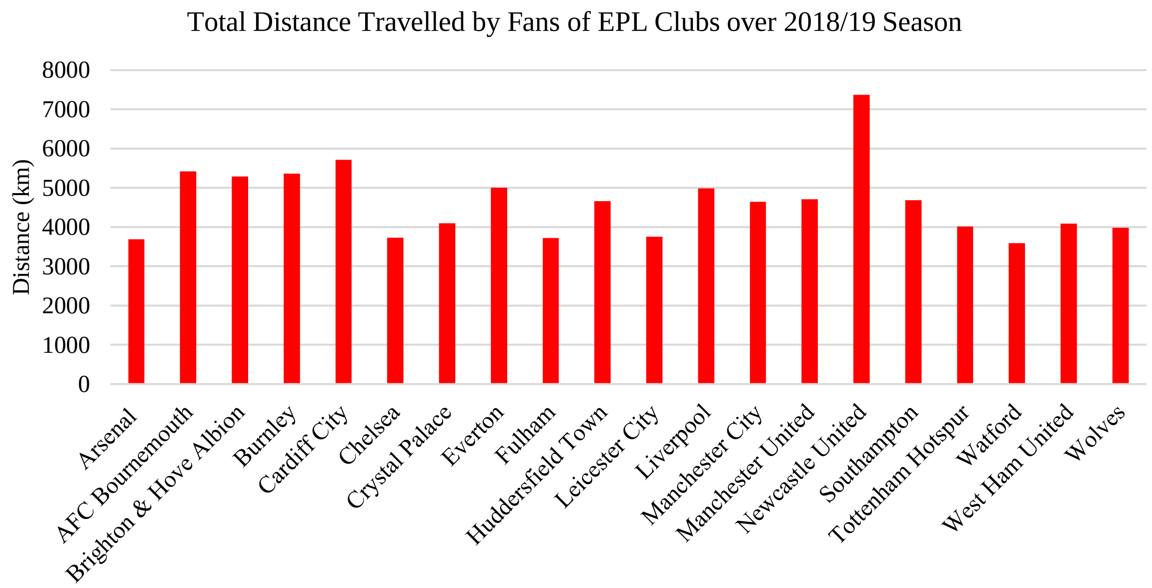

Figure 18: Distance travelled by 1 fan when attending all 38 games of a EPL clubs' season.

When applying the breakdown of means of transport taken by home and away fans and the GHG conversion factors to raw numbers of fans attending and the distance they travelled (Equation 1), the resulting emissions of each match, each club and total for the season was found (Figure 19).

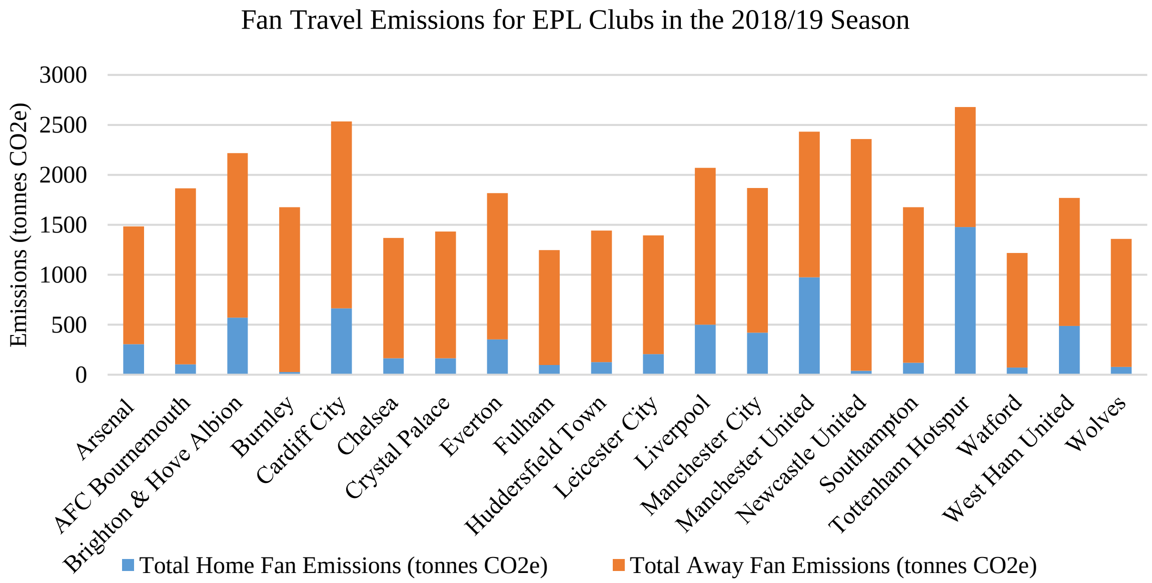

Figure 19: Emissions resulting from EPL clubs' fan travel to home and away games over the 2018/19 season.

The total emissions due to fans travelling to EPL games over the 2018/19 season was calculated to be 35,904 tonnes CO_2e; 6,947 tonnes CO_2e due to home fans travel and 28,957 tonnes CO_2e due to away fans travel. This is far greater emissions than found for club travel, which was 1,442.4 tonnes CO_2e. Tottenham fans contribute most to emissions, and this is due to a large number of home fans who were required to travel 19.75 km to home games at Wembley, hence 55% of emissions are due to home fans with more emissions due to home fans than away – something unique to the rest of the league. This is in stark contrast to clubs like Burnley and Newcastle where home fans travel small distance to games but long distance to away games. As a result, only 1.53% of fan travel emissions of Newcastle are attributable to home fans and similarly only 1.54% to Burnley home fans. Newcastle and Tottenham have fairly similar number of fans travelling to games showing the impact a longer distance having to travel to home games has on resulting emissions. The clubs with least emissions are Fulham and Watford where attendances are lower, distance travelled to home and away games are lower and the conversion factors for London transport are lower.

The greatest emissions resulting from fan travel to a single match was for Tottenham Hotspur v Liverpool at Wembley where 388.8 tonnes CO_2e emissions resulted from 80,188 fans attending the match. As discussed, this is due to the overall large number of fans, where the majority travel a relatively long way to a Tottenham home game at Wembley as well as 6,000 away fans travelling 334.7 km from Liverpool. The least emissions resulting from a match was Fulham v Chelsea at Craven Cottage in London – 6.32 tonnes CO_2e. This was the opposite to the largest emitter where a smaller home crowd of 21,900 travelled only 2.09 km to the match alongside the 3,000 away fans who travelled only 3.3 km to the match. The average emissions from fan travel to any given EPL match during the 2018/19 season was 94.5 tonnes CO_2e and the average emissions from the fan travel of an EPL club over the entire season was 1,795 tonnes CO_2e.

The average emissions for 1 home fan travelling to attend an EPL match in the 2018/19 season was found to be 0.486 kg CO_2e whereas for 1 away fan travelling to an EPL match emissions were found to be 26.315 kg CO_2e. This is a huge difference reflected in the fewer away fans travelling to matches resulting in far greater emissions. Just 8% of EPL fans, the away supporters, account for 81% of emissions, highlighting a possibility of how to reduce emissions due to fan travel to football matches. The overall average emissions for any 1 fan travelling to an EPL match was 2.834 kg CO_2e, where the greater number of home fans reduces the average despite the significantly higher average for an away fan.

Home fans driving to matches accounts for 57% of emissions from travelling (Figure 20), despite only making up 32.3% of the means in which fans travel (Figure 10). This is due to the carbon intensity of driving compared to other forms of transport (Table 6). Driving alone contributes 30% to the carbon footprint of home fans where only 10.5% of fans drive alone to matches, showing the negative impact of travelling this way. Travelling to matches by train, tube or tram contributes 22% in total to emissions, where 37.6% of fans travel this way, showing this mode of transport results in less emissions than road transport. Clearly, walking and cycling to matches produces zero emissions, reflected by the GHG conversion factors equalling 0 kg, despite 16.5% of fans travelling these ways and this highlights a way to reduce emissions from home fan travel. Bus travel results in 20% of the emissions of home fans, perhaps showing it is not a low-carbon way to travel, as only 12% of fans travel this way.

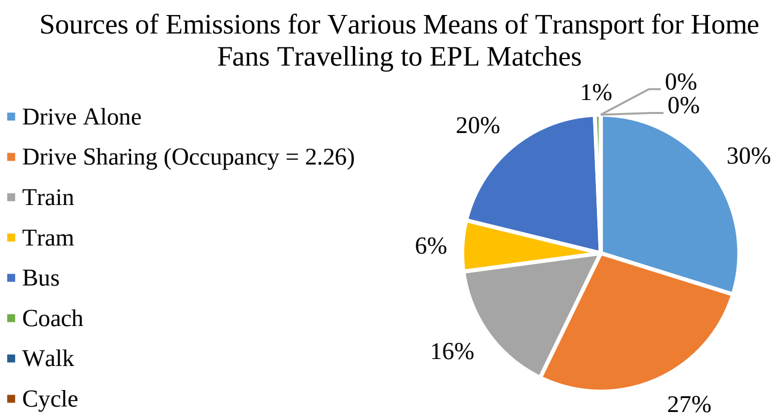

Figure 20: Sources of emissions from modes of transport used by home EPL fans in the 2018/19 season.

The majority of emissions for away travel are also due to driving to the matches, 54% of CO_2e emissions attributable to driving along and sharing in total (Figure 21). This is in spite of a reduced proportion of fans travelling this way compared to home fans, again highlighting the high emissions of travelling to matches by car, especially alone. Over 40% of fans travel to away games by train (Figure 11), contributing to 27% of emissions, showing this as low emission mode of transport which is effective and popular for away fans travelling greater distances. Also notable for away fans is the greater proportion travelling by coach (14.9%), compared to just 1.5% for home fans. Emissions resulting from away coach travel accounts for 7% of the total, showing this is also a low emission mode of transport which is more popular with away fans.

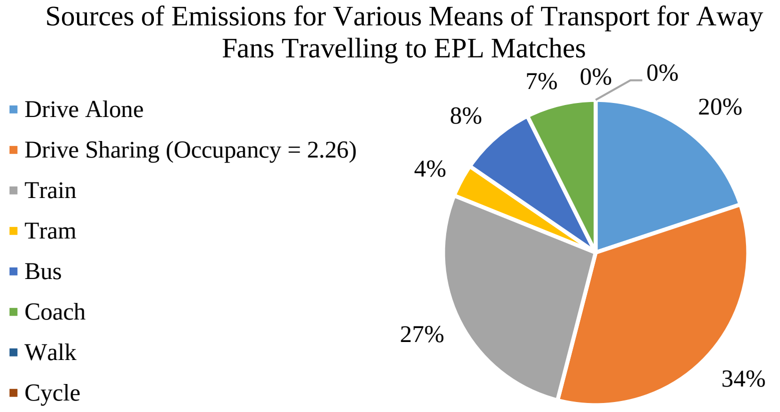

Figure 21: Sources of emissions from modes of transport used by away EPL fans in the 2018/19 season.

It is clear that for both home and away fans that travelling by car results in high emissions, especially when driving alone. Driving does provide a quick and flexible mode of transport for fans, so if it is required fans should be encouraged to share where emissions can be slightly reduced. Travelling to games by train, tube, tram and coach have been identified as low emission modes of transport, with greater number of away fans already utilising some of these ways of travelling. Walking and cycling offer zero-carbon travel and therefore is the best option to reduce emissions of fans however this is less feasible where fans have to travel long distances to away games.

The emissions resulting from fan travel are far greater than that for club travel and accommodation. The total emissions from both over the 2018/19 season were found to be 37,347 tonnes CO_2e, with 96.1% of that attributable to fan travel. This suggests it is far more important to reduce the environmental impact of EPL fans, rather than the clubs themselves. The far greater percentage of emissions resulting from fan travel seems to line up with previous reports and literature. Fan travel comes under Scope 3 in GHG reporting where the club is indirectly responsible for emissions, so it is more difficult for them to take direct action to limit emissions from this source. Club travel and accommodation is directly the responsibility of the club and hence direct actions can be taken to reduce emissions coming from this aspect of the organisation of the league.

When considering just the club and fan travel, not accommodation emissions, total emissions for the EPL season amount to 36,927 tonnes CO_2e all attributable to travel of fans, players and staff. This value is equivalent to 0.031% of total transport CO_2e emissions in the UK for the year 2019 (BEIS, 2021a). When considering the number of motorists and the extent of public transport and air travel in the UK, this is a reasonably high percentage coming from a section of the sports industry. This shows how a high proportion of emissions result from industries with greater economic worth, such as the EPL.

3.2.3. Electricity and Heating Energy Consumption

The total calculated emissions from both electricity and gas consumption of the EPL clubs stadia over the 2018/19 season was found to be 43,304 tonnes CO_2e, with the majority coming from electricity usage (Figure 22). Emissions resulting from electricity consumption are greater due to the greater kWh consumption per seat over a year and the greater associated GHG conversion factor, for every kWh of consumption.

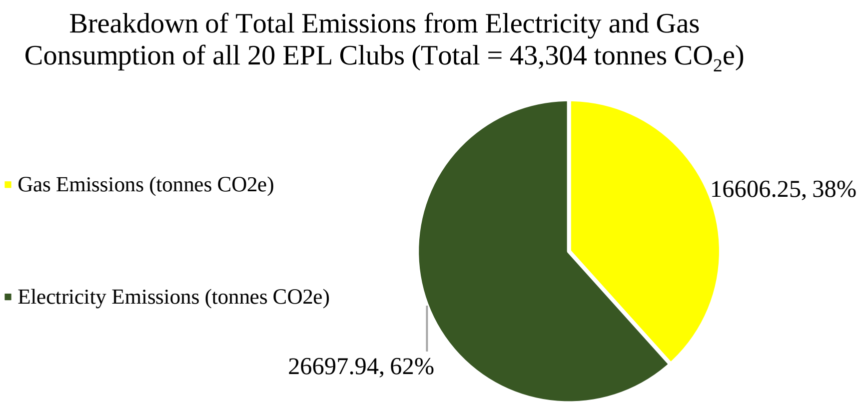

Figure 22: Estimated emissions resulting from electricity and gas consumption at 20 EPL stadia over the 2018/19 season.

As expected, the electricity and gas consumption and resulting CO_2e emissions of each club are directly proportional to the size of each given stadium. This highlights the limitations of the method used for the estimation, as energy saving measures such as LED lighting at some stadia are not taken into account. As Old Trafford is the stadium with the largest capacity, Manchester United have the greatest associated CO_2e emissions and, by contrast, Bournemouth have the smallest emissions with the Vitality Stadium being the smallest ground in the league that season (Figure 23). The average emissions from electricity and gas consumption at an EPL stadium over the 2018/19 season is 2,165 tonnes CO_2e. Given there is 19 matches hosted at each ground over the season, the average emissions at an EPL match were 113.96 tonnes CO_2e. As discussed, this clearly varies with the stadium capacity of each club's home ground. At Bournemouth's home stadium, the emissions per match is 32.67 tonnes CO_2e compared to 213.81 tonnes CO_2e at Old Trafford for each of Manchester United's home matches. This is clearly a large difference and highlights the challenges clubs with larger home grounds face in reducing emissions when they play at home.

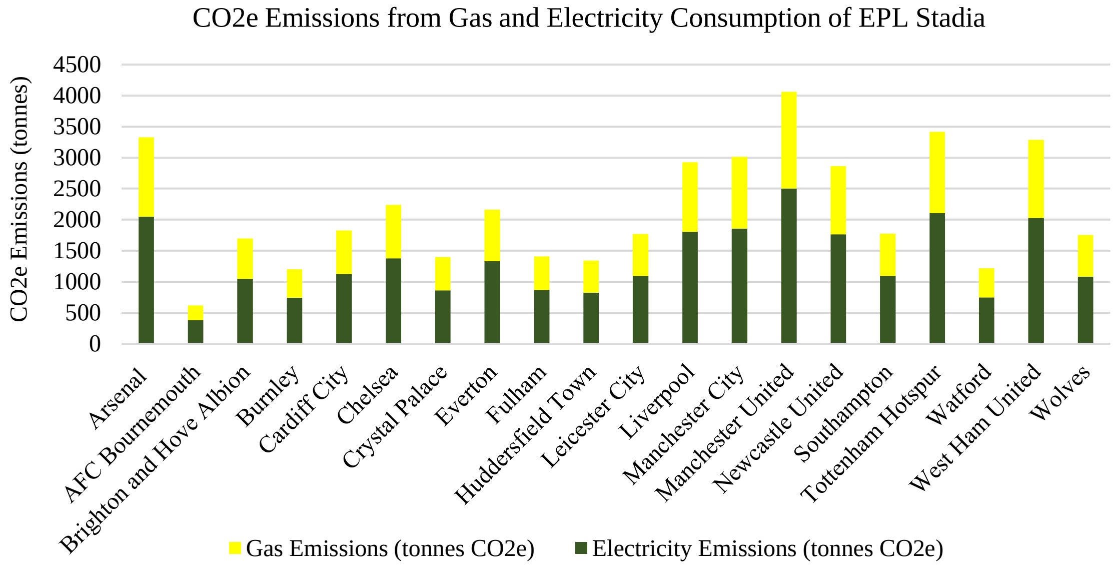

Figure 23: Emissions resulting from electricity and gas consumption at each EPL clubs' stadium in the 2018/19 season.

3.2.4. Total Emissions

Total emissions aggregated across the sectors of club travel and accommodation, fan travel and electricity and gas consumption for all 20 clubs over the 2018/19 season equal 80,651 tonnes CO_2e. The breakdown shows most emissions resulting from fan travel, which was expected following the literature review, and then electricity and gas consumption, with least emissions as a result of club travel to away matches (Figure 24).

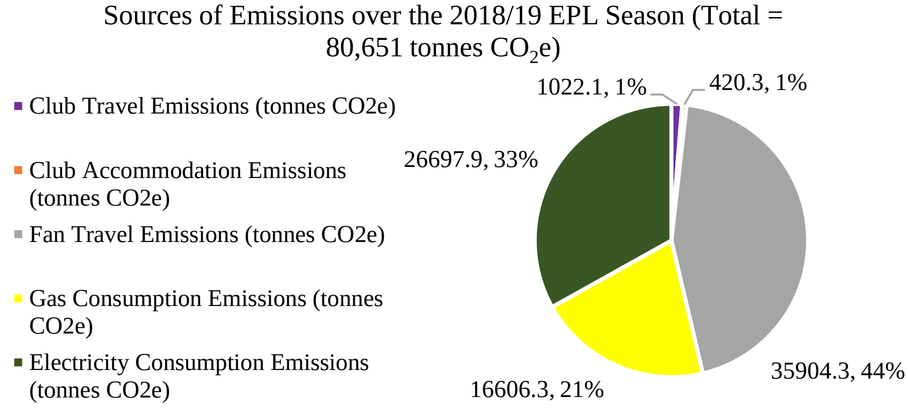

Figure 24: Breakdown of sources of emissions from sectors of operations of the 20 clubs competing in the 2018/19 EPL season.

However, if the contribution of electricity and gas consumption to emissions are combined, this is greater than for fan travel. This contrasts with examples found in literature and is perhaps down to the role electricity from '100% clean energy' suppliers plays when companies and organisations are reporting GHG emissions. This is shown by the VfL Wolfsburg energy audit (Figure 1), where emissions from electricity consumption do not appear as the supplier claims to be a 100% clean energy supplier. The contribution of club travel and accommodation is around 2% of total emissions. This is less than the 6% found by Wolfsburg but this perhaps due to the greater area of Germany, the country they play in, resulting in more air travel and overnight stays in hotels.

It should also be noted not all sectors of club operations are considered for this assessment of the environmental impact and as such percentages of total emissions may be skewed. For a more comprehensive assessment of emissions of the EPL clubs' aspects of operations like catering, merchandising, building and pitch maintenance, all club owned buildings and mobility of administrative staff should be considered, similarly to the VfL Wolfsburg report. However, this was out of this projects scope with not much relevant available data.

The single club responsible for most emissions over the 2018/19 season were Manchester United with a total of 6,569 tonnes CO_2e (Figure 25). This is primarily down to the fact their home ground holds the largest capacity, which greatly increases the emissions resulting from electricity and gas consumption. Tottenham Hotspur is the second most emitting due to the significant emissions resulting from home fan travel to matches when they were playing at Wembley for the majority of season, further away from where most home fans are based. Newcastle United away fan travel resulted in the most emissions of any club and this results in the overall emissions being 3rd highest in the league. Both Tottenham and Newcastle also have relatively large stadiums, like Manchester United, and this contributes to the high overall emissions when aggregating each considered sector.

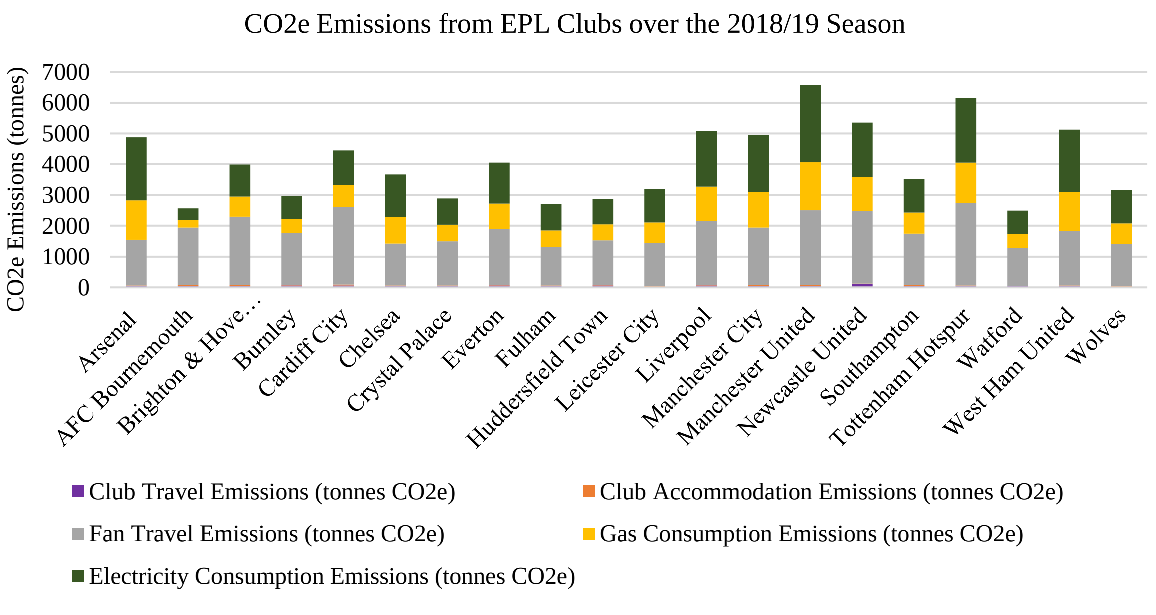

Figure 25: Aggregated emissions of each club competing in the 2018/19 EPL season.

The clubs with the least emissions like Watford and Bournemouth have the smaller stadiums. This results in less emissions coming from electricity and gas consumption as well as fewer home fans travelling to matches. Watford has the least total emissions of any club in the EPL over the 2018/19 season with 2,490 tonnes CO_2e and this is due to the smaller stadium and the geographical location of the club in London, resulting in smaller distances with less emissions for both players and fans. It is clear that the number of people at football matches is the principal driver in creating emissions from the EPL and hence this may offer a route to an overall reduction in the environmental impact of the league. Even the football operations of Watford, with the smallest contribution to emissions, results in significant emissions with a damaging warming effect on the planet. Therefore, this highlights the importance reducing this impact is and the role the clubs of the EPL can play in limiting emissions resulting from their operation.

4.0. Reducing the Environmental Impact of the EPL

4.1. Methodology

The aim of the next part of the study is to use the assessment of the environmental impact of the EPL to identify ways in which to reduce the emissions that are attributable to the clubs that compete in the league. This will be achieved by employing some measures discussed in the literature review as well as finding the effect of measures unique to this project. The methodology applied to find a percentage decrease in emissions from applying the various measures will be outlined in the next section.

4.1.1. Club Travel

A simple initial step to take to reduce emissions is to reduce the actual number of people contributing to emissions through travel and accommodation to away matches. Therefore, the size of each EPL clubs' delegation needs to be limited. In the assessment of club travel emissions, the club's delegation was assumed to be 39, as per literature, which comprised of players, coaches, medical staff, physios, performance analysts and recruitment staff. The assumed number of staff can be limited to those crucial to match day performance and wellbeing (LCFC, 2021), which amounts to 14 coaches, medical staff and physios such that the total delegation equals 32. This is a 17.95% decrease in the total number of people travelling to away matches as part of EPL club delegations so it would be expected the same decrease in emissions occurs as a result of the reduction.

It is stated that EPL clubs don't use high emitting facilities at luxury hotels such as spas, saunas and swimming pools when staying in overnight accommodation for away matches (Pereira, Filimonau and Ribeiro, 2019). Therefore, the hotels EPL clubs utilise can be budget hotels with lower associated CO_2e emissions per person per nights stay, as per the DEFRA GHG conversion factors. The new value for emissions due to a hotel stay is assumed to be 13.9 kg CO_2e per person per night (BEIS, 2021b), which is to be applied to all clubs where each require an overnight stay for their delegation on an away trip (Equation 2).

It is well established in literature and from the results of the assessment of emissions from EPL club travel that most emissions are due to air travel (Figure 15). It is clear, as a result, that distance travelled by air should be reduced to instigate an overall reduction of CO_2e emissions due to club travel. A measure to do this is by increase the distance and length of time clubs are willing to utilise coach travel for. The limit at which clubs would then utilise air travel at was 257.49 km or any journey time over 3 hours on a coach. This is due to the players physical wellbeing where their muscles would cramp up (Andrews, 2002). However, English clubs competing in European competitions often travel by air for matches in countries such as Turkey, Russia and Greece, spending over 4 hours on planes (Air Miles Calculator, 2021), so this limit is not absolute. Therefore, to reduce air travel emissions of EPL clubs the limit to which players can spend travelling on coaches is increased by 33% to 343.32 km or 4 hours. This new limit is applied across all EPL clubs travel to away matches, such that the distance travelled by air will be significantly reduced and overall emissions will decrease as a result.

A similar measure was employed where the distance from each club's home ground where overnight accommodation is required was increased by 33%. This increases the distance from 64.37 km to 85.82 km, which typically amounts to travelling time of about 20 minutes and a small change to the clubs' travel schedule would be required. The change cannot be too extreme as for early kick-offs, at around 12pm or 1pm, clubs need plenty of time to arrive before the match starts to be able to prepare effectively and as such likely will not travel for periods longer than 90 minutes from their home stadia on the morning of the game. This new limit is applied across all EPL clubs away trips, where some overnight stays would no longer be required.

4.1.2. Fan Travel

Driving accounts for most emissions from fan travel to both home and away matches, due to the higher emissions per passenger per km driven in cars than public modes of transport. Where 21.8% of home fans travelled in cars with others, this accounted for 27% of total home fan emissions and similar results were seen for away travel. Increasing the occupancy rate where more fans are in each car driving to the game would decrease the individual emissions of each person and therefore total emissions as well. The occupancy rate previously employed was 2.26, which was an average found from literature (Dosumu, Bragg and Colbeck, 2017). Initiatives have been introduced in the lower English leagues, such as liftshare.com, where fans can offer or take up lifts to matches and hence increase occupancy rate. Introducing something similar into the EPL could increase occupancy rate for fans driving to matches and so it is assumed the effect of a similar scheme could result in an occupancy rate of 4, where most cars have a minimum of 4 seats. The new occupancy rate was applied to the associated GHG conversion factor such that it is reduced from 0.07584 kg CO_2e to 0.04285 kg CO_2e per person per km for fans driving sharing.

A similar step taken to reduce club travel emissions can be applied to reduce fan travel emissions, which is to limit the number of fans attending EPL matches. This would not be a popular measure with fans and would be seen to be damaging to the game, but certain measures will have to be employed to reduce overall emissions from the EPL if it is to be seen to be reducing the environmental impact of the league. It is clear from the assessment of fan travel emissions, away fans contribute far more to emissions due to the greater distances involved in travelling to the matches (Figure 19). Therefore, only the numbers of away fans will be limited. This will be achieved in 2 ways, with the more realistic taken forward in terms of how popular and likely to be employed it would be with fans and the league organisers.

Firstly, the number of away fans at any given EPL match will be limited to 1,500. This is the lowest away fan allocation of clubs that competed in the 2018/19 EPL season, where it was at Bournemouth's Vitality Stadium (Table 5). This would ensure all matches would have the same number of away fans and hence would provide an equal level of away support at away matches. This value was applied to all EPL matches in the 2018/19 season to find the emissions resulting from this number of travelling away fans. Note that the number of fans was not increased, where there would now be extra capacity available to home fans at most stadia, as this would be an assumption of how many extra fans would turn up and could not be guaranteed to be accurate.

The second method to limit the number of away fans was to create a standard limit by proportion of each stadium that is allocated to away fans. The limit was set to 2.5% of capacity allocated to away fans and therefore the ratio of home to away fans would be the same at all EPL matches. This value was chosen to ensure the new away fan allocation did not exceed the current allocation at all stadia. This clearly meant the away fan allocation ranges significantly, where the largest stadiums have the largest away allocations and the smallest allocation is as low as 300 away fans, at Bournemouth again (Table 7). These limited values were applied to the away fans at each 2018/19 EPL match to find the resulting emissions from the new allocation and the home fans were not increased despite the extra possible home fan capacity.

Table 7: Away fan allocation at each EPL stadium to be used for finding reduction in away fan travel emissions by reducing number of away fans to 2.5% of capacity.

Club	Stadia	Capacity	Away Fan Allocation (2.5% of Capacity)
Arsenal	Emirates Stadium	60,704	1,511
AFC Bournemouth	Vitality Stadium	11,329	300
Brighton and Hove Albion	Amex	31,000	765
Burnley	Turf Moor	21,944	564
Cardiff City	Cardiff City Stadium	33,316	833
Chelsea	Stamford Bridge	40,834	1,042
Crystal Palace	Selhurst Park	25,486	658
Everton	Goodison Park	39,414	1,014
Fulham	Craven Cottage	25,700	642
Huddersfield Town	The John Smith's Stadium	24,500	613
Leicester City	King Power Stadium	32,312	813
Liverpool	Anfield	53,394	1,352
Manchester City	Etihad Stadium	55,017	1,377
Manchester United	Old Trafford	74,190	1,893

Newcastle United	St. James' Park	52,305	1,310
Southampton	St. Mary's Stadium	32,384	817
Tottenham Hotspur	Tottenham Hotspur Stadium	62,303	1,552
	Wembley	90,000	2,250
Watford	Vicarage Road	22,200	539
West Ham United	London Stadium	60,000	1,500
Wolves	Molineux	32,050	793

The first method of reducing away fan allocation seems more reasonable given the variance in the size between different stadiums using the 2.5% limit. A limit of 1,500 at all matches would allow more fans over a season, be fairer and more popular as the spectacle of the game would not be as impacted but also reduce the number of away fans significantly.

The final step to reduce fan travel emissions was to implement measures that would reduce the number of people driving alone and encourage the use of public transport. Increasing the percentage of fans utilising public transport could be achieved by offering a 'KombiTicket' where travel is included in the match ticket, offering free buses from the town centre to stadiums, scheduling dedicated transport to align with kick off times and discounting travel prices across all public modes of transport for fans. It tends to come down to the economics of each fan, where the cheapest option is most popular. It was found that 50% of those that drive to matches alone would rather take the train, 20% would rather travel by bus and 13% by coach (Yates *et al.*, 2013). These percentage values were applied to the number of fans travelling by each mode of transport in this study (Figures 10 and 11) such that a new breakdown of fan travel was found for both home and away fans (Figures 26 and 27). This new breakdown of fan travel was applied to find the resulting emissions from a significantly increased number of fans utilising public transport. The effect should be pronounced as the number of fans driving along has reduced from 10.5% to 2% for home fans and 6.4% to 0.4% for away fans, and this was the greatest source of emissions.

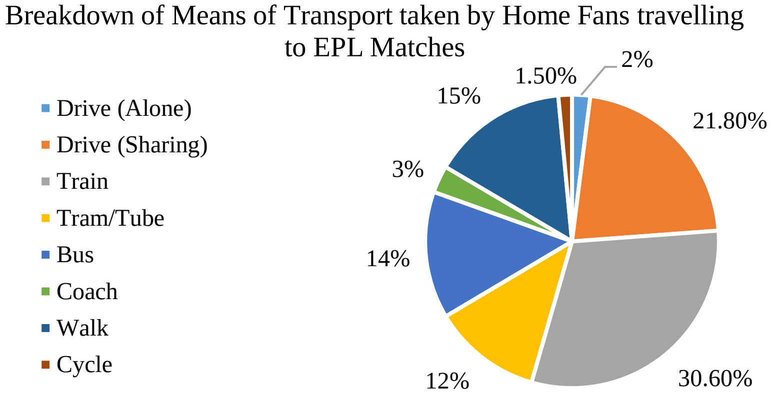

Figure 26: Breakdown of travel patterns of home fans travelling to EPL matches with increased proportion utilising public transport.

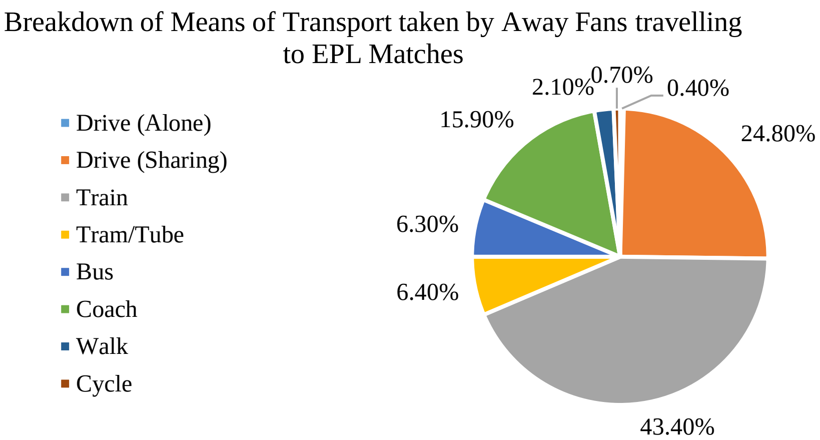

Figure 27: Breakdown of travel patterns of away fans travelling to EPL matches with increased proportion utilising public transport.

4.1.3. Renewable Energy Generation

It was observed in the literature review that many football clubs, including some in the EPL, have begun to integrate renewable energy technologies in and around club facilities. These include CHP plants, biomass boilers and, perhaps most prominently, PV panels to exploit the significant solar energy resource and produce emissions free electricity. Electricity is generated using solar energy using panels on the roof of the Johan Cruyff Arena in Amsterdam as well as at the training grounds of Brighton, Newcastle United and Forest Green Rovers. Studies regarding potential solar generation on the rooftops of Australian sport stadia have also been carried out using spatial imagery to model PV arrays to assess the magnitude of electricity that could be generated. A similar assessment will be carried out in this study, this time of the rooftops of EPL stadia, to determine what proportion of electricity consumed at the clubs' stadia could be generated utilising PV panels installed at each ground. This would therefore reduce the emissions associated with electricity consumption, which were determined in the initial assessment of the environmental impact of the EPL, by offsetting by feeding electricity back into the grid.

The first step required was to determine the viable roof-space of each ground that would be able to accommodate PV panels which would be productive in generating electricity. This means discounting areas inhibited by structural aspects of the stadium or areas in shade, where the solar resource would be minimised. An example of this would be at Liverpool's stadium, Anfield, where the structural supports would make it difficult to install PV panels as well as significantly shading panels from the sun, if they were to be installed (Figure 28). This makes the area marked by the green box as feasible to accommodate a PV array, whereas the red box as not feasible to host an installation. The structural integrity of stands after installing a large number of PV panels is not considered but panels are currently lightweight and can be adapted to a given application. The study of solar generation on Australian sport stadia envisages advancements in lightweight solar technology and considers it likely when making an assessment of potential PV arrays being installed on grounds such as the Melbourne Cricket Ground (University of New South Wales and Australian Photovoltaic Institute, 2021b). However, for this study stadium rooftops that incorporate transparent glass sections have not been considered suitable to accommodate PV panels. These areas often overhang the pitch, as at Anfield, in order to allow more light onto the pitch and so would be able to hold less weight as well as any panels obstructing the light accessing the pitch. The assessment of the measured area suitable to install PV panels on stadium rooftops was achieved using spatial imagery available on Google Earth (Google, 2021). This process was carried out across all 20 EPL clubs home grounds.

Figure 28: Aerial view of Anfield, home ground of Liverpool FC, with areas of the stadium roof suitable to hold PV panels shown in green and unsuitable areas shown in red.

It can be observed that stadia of certain design can accommodate a greater number of panels, due to more smooth roof surfaces and limited presence of metal structures on the roof, like at Anfield, which would prevent the integration of a PV array. These tend to be stadiums built more recently, such as the Tottenham Hotspur Stadium (Figure 29) and the London Stadium, home ground of West Ham United which were both completed in the last 10 years. It was also decided to just consider the Tottenham Hotspur Stadium, rather than Wembley where Tottenham also played during the 2018/19 season. This is because Wembley is not owned by Tottenham and was temporarily used by the club, whereas the new stadium is, and any future installation and generation would be only possible at the Tottenham Hotspur Stadium if the club were to install any magnitude of PV capacity.

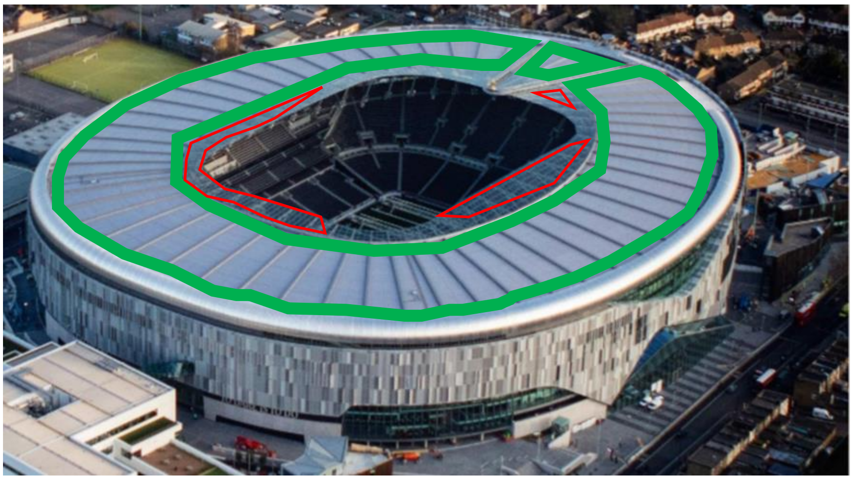

Figure 29: Aerial view of The Tottenham Hotspur Stadium, with areas of the stadium roof suitable to hold PV panels shown in green and unsuitable areas shown in red.

To determine the number of panels that can fit on a given roof space, the actual size of the PV panel is required. The PV module to be used in the modelling is the BP 380 (Figure 30). It is suitable as the manufacturer claims it to be robust, durable and perform reliably over a long period. These are all useful for the rooftop environment, which could be subject to high winds, all kinds of weather and would be pragmatic to have as few maintenance and replacement issues for the panels if they are mounted on the roof. Each module is made up of 36 polycrystalline cells connected in series with a rated power of 80 W, nominal voltage of 12 V and weight of 7.7 kg (BP Solar, 2008). The front side dimensions of the module result in a total panel area of 0.649233 m^2 which will define how many panels can fit into the viable roof space found previously. The capacity of a given PV array mounted on a stadium roof is found by multiplying the number of panels that can fit on the roof space by the rated power of each panel.

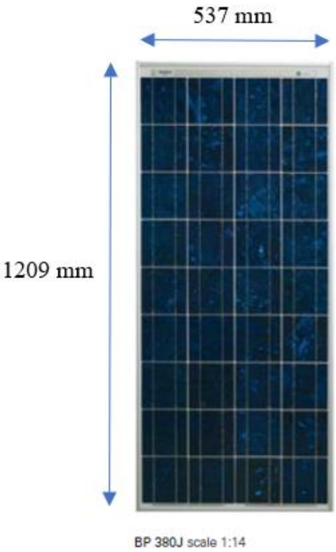

Figure 30: A single BP 380 photovoltaic module, made up of 36 polycrystalline cells with the resulting dimensions shown (BP Solar, 2008).

The stadia rooftops all have tilt, with different structures at varying angles. However, it was assumed all arrays at all stadia were installed at a tilt of 10^o (University of New South Wales and Australian Photovoltaic Institute, 2021a), which could be due to the natural angle of the roof or be instigated by installing the panel at the required angle. All the EPL grounds are in England but are orientated in different directions in relation to the sun and this compass direction is taken into account depending on the direction each stands roof faces. The system losses were assumed to be 10%, through transmission and distribution through wires and transformers to the grid or a BESS if that were to be installed by the club. This information, alongside the relevant location of each stadium and the capacity of PV array to be installed there, was inputted into the Renewables.ninja platform (Pfenninger and Staffell, 2021). This platform utilises weather data to simulate PV installations across the globe, with a greater detail available in Europe and it has been seen to produce high quality renewable energy simulation data with accurate results. The application was developed for studies, like this one, to be able to replicate a large-scale study of PV installations at over 1000 sites for any given application that the study requires (Pfenninger and Staffell, 2016).

The Renewables.ninja application produces an hourly electricity generation profile based on the direct and diffuse irradiance at each site and the electricity produced over the year is totalled. This value can be used to determine the percentage of electricity consumption that can be generated at each club's stadium by integrating PV panels onto the roof.

4.1.4. List of Emission Reduction Measures and Expected Results

- Assumed size of club delegation reduced from 39 to 32, to just include those critical to matchday operations and performance (LCFC, 2021). This is a 17.95% reduction in the number of people travelling and staying overnight in hotels, so would expect 17.95% decrease in total club CO_2e emissions.

- EPL club delegations stay overnight in budget hotels rather than luxury hotels (Pereira, Filimonau and Ribeiro, 2019), with a 59.5% decrease in associated GHG conversion factor from 34.32 kg CO_2e to 13.9 kg CO_2e per person per night. Expect to observe a 59.5% reduction in accommodation emissions as a result.

- Reduce the need for clubs to fly to matches (Dolf and Teehan, 2015; Pereira, Filimonau and Ribeiro, 2019), by increasing the distance clubs use coach travel for. Would expect significant decrease in club travel emissions, as England is not a huge country and most away club journeys should be completed in under 4 hours.

- Reduce the need for clubs to utilise overnight accommodation, by increasing the limit by 33%. This is measure unique to this study and effects may be minimal, as the increase in distance likely will not result in large decrease in overnight stays as many clubs will still not be in close enough proximity.

- Increase the assumed occupancy rate from 2.26 to 4, to reduce fan emissions from car sharing to matches (Dosumu, Bragg and Colbeck, 2017; liftshare.com, 2021). This is a 43.5% decrease in emissions per fan travelling to matches in a shared car, which initially is 21.8% and 24.8% for home and away fans respectively. Would expect total fan travel emissions to reduce by between 12% and 15%, given the decrease per car sharer and the proportion of fans travel by this means to EPL matches.

- Reduction in away fans is not suggested in literature so effects are unique to this study, but clearly will reduce environmental impact as away fans contribute 35.9% of total emissions of the EPL. The methods of reducing the number of away fans saw a 64.8% (Limit to 2.5% of capacity) and 48.5% (Limit to 1,500 at all matches), so would expect the same reduction in away fan emissions and a significant effect on total emissions.

- Encourage fans that drive alone to utilise public transport, as many fans want to (Yates *et al.*, 2013) and it can reduce emissions by as much as 19% (Dolles and Soderman, 2010). Public transport is far lower emissions than driving alone and driving alone contributes significantly to total emissions, so greater use of public transport should see fan emissions reduce considerably.

- The final measure suggested installing solar PV arrays on EPL stadia roof as present and studied at other grounds (Warmerdam, Hoogt and Kotter, 2020; University of New South Wales and Australian Photovoltaic Institute, 2021c). The potential generation will vary from ground to ground, but emissions will be offset by emissions free electricity being fed back into the grid and should result in a decrease in emissions at each ground dependant on the viable roof space.

4.2. Results

The results of the effects of the measures outlined in the methodology taken to reduce the environmental impact of the EPL will be presented in the next section. Individual and overall percentage decrease of emissions will be calculated to determine how effective each measure was and how this impacted the total emissions found in the initial assessment of the environmental impact of the EPL.

4.2.1. Club Travel

The first step taken was to reduce the club delegation from 39 to 32. This resulted in club travel emissions decreasing by 17.95% from 1,442.4 tonnes CO_2e to 1,183.5 tonnes CO_2e. This was expected as it is the same decrease as in the size of the club delegation. The same percentage decrease is seen across all teams, all modes of transport and accommodation. It is a simple but effective measure in reducing emissions by limiting those in club delegations travelling to matches to those who are vital for the football game.

EPL clubs utilising budget hotels, with lower associated CO_2e emissions per person per night, resulted in a further decrease in total emissions by 17.33% from 1,183.5 tonnes CO_2e to 978.3 tonnes CO_2e. The reduction in emissions was entirely through accommodation which decreased by 59.50% from 344.9 tonnes CO_2e to 139.7 tonnes CO_2e. This percentage decrease is the same as the decrease in value of the conversion factor used for luxury and budget hotels, from 34.32 kg CO_2e to 13.9 kg CO_2e. The proportion of emissions from accommodation therefore decreased, such that 14% came from accommodation and 86% from the travel of club delegations.

The next measure introduced was to increase the distance and time for which coach travel was allowed for players to travel for, hence reducing the requirement for extensive air travel. This resulted in a further percentage decrease of 29.6% from the previous step, as emissions decreased from 978.3 tonnes CO_2e to 688.6 tonnes CO_2e. This measure effected travel only and as such travel emissions only reduced from 838.7 tonnes CO_2e to 548.9 tonnes CO_2e, a 34.6% decrease. The changes to emissions were caused by the change in how clubs travelled to matches. The increased coach travel caused an overall increase in distance travelled to a total of 173,468 km, 66% of which is covered by coach travel and 33% by air, in contrast to before any changes being made, where 40% was coach travel and 59% air travel. However, air travel still makes up the majority of total emissions at this stage in the implementation of measures (Figure 31), so the distance and time threshold could be increased to further decrease air travel and hence total club emissions.

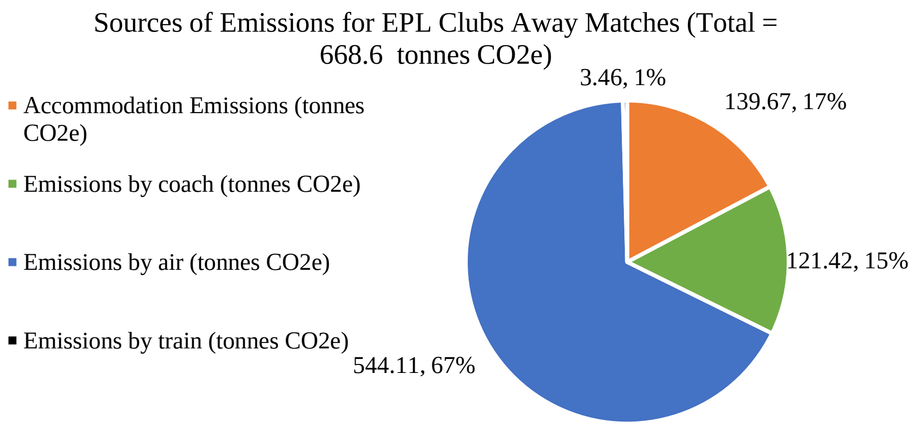

Figure 31: Sources of emissions due to club travel and accommodation, after 3 emissions reduction measures have been implemented.

The final measure implemented increased the distance for which accommodation was required by 33%. The effects of this were limited as only 6 nights stays for EPL clubs were no longer required. As a result, accommodation emissions reduced by only 1.93%, from 139.7 tonnes CO_2e to 137.0 tonnes CO_2e, an overall further decrease of total club emissions by 0.39%. From the initial assessment of club travel emissions, the measures resulted in an overall percentage decrease of 52.4%, from the initial value of 1442.4 tonnes CO_2e to 685.9 tonnes CO_2e. The breakdown between the 20 EPL clubs shows how some clubs were affected by the measures more than others (Figure 32).

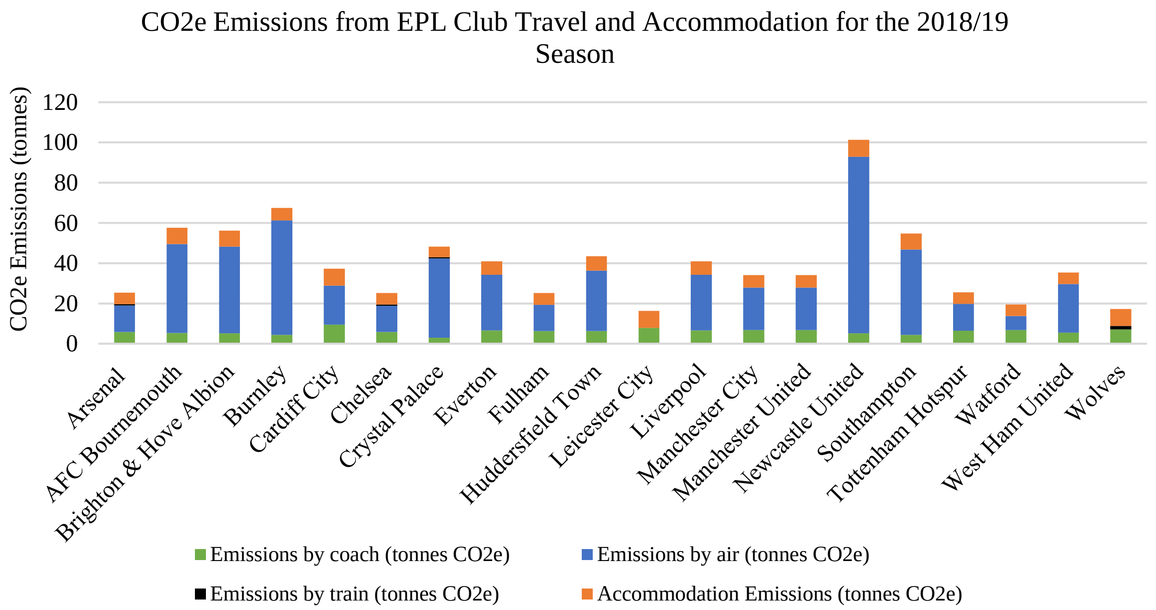

Figure 32: Sources of emissions for each EPL clubs away travel and accommodation over the 2018/19 season.

The percentage decrease of the emissions from the initial value of individual clubs varied from 33.6% to 68.4%, where the measures were most effective. The lowest reduction in emissions was at Newcastle United, as it is still too isolated and far away from other clubs, so measures to decrease air travel and accommodation are not effective as coach trips are still often above 4 hours and overnight accommodation is still always necessary. The greatest decrease in emissions was at Watford. This is due to a high number of airplane trips no longer being required to clubs in and around Manchester and Liverpool. This was a pattern seen for many London clubs, but as Watford is the furthest north London club, club travel to the north was lowest in terms of distance and therefore emissions. Overall, these simple measures showed to be effective in reducing emissions due to EPL club travel and accommodation and would not be difficult to implement and follow.

4.2.2. Fan Travel

The first step taken to reduce fan travel emissions was to increase the occupancy rate of those that travel by car sharing. Initially, an average of 2.26 travelling per car was taken but this was increased to 4 to reflect greater encouragement by clubs for fans to use lift sharing initiatives. The result of this caused the emissions per passenger per km travelled in a shared car to reduce from 0.07584 kg CO_2e to 0.04285 kg CO_2e. Overall, total fan emissions decreased by 14.3% from 35,904 tonnes CO_2e to 30,760 tonnes

CO_2e with the same percentage decrease seen all clubs, home and away fans and therefore all averages. The increase in occupancy rate causes a change proportion of sources of emissions for both home and away fans as less emissions result from shared car journeys (Figures 33 and 34). This further highlights the need to reduce the number of people driving to matches alone, as it makes up an even greater percentage of emissions.

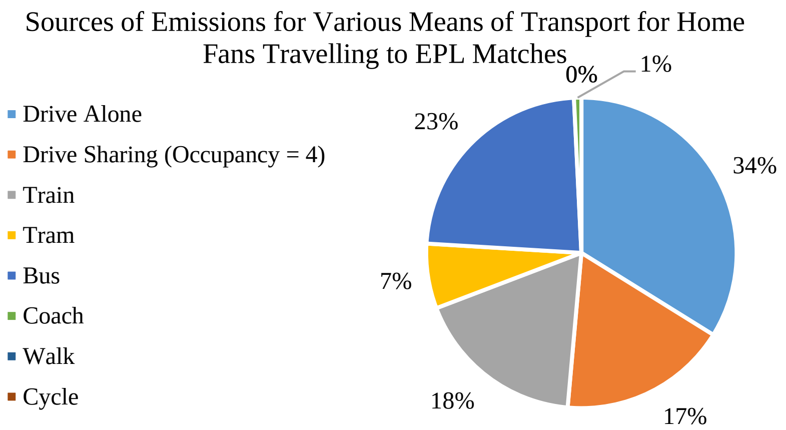

Figure 33: Breakdown of sources of emissions across various means of transport for home fans, where Driving Shared occupancy rate is increased to 4.

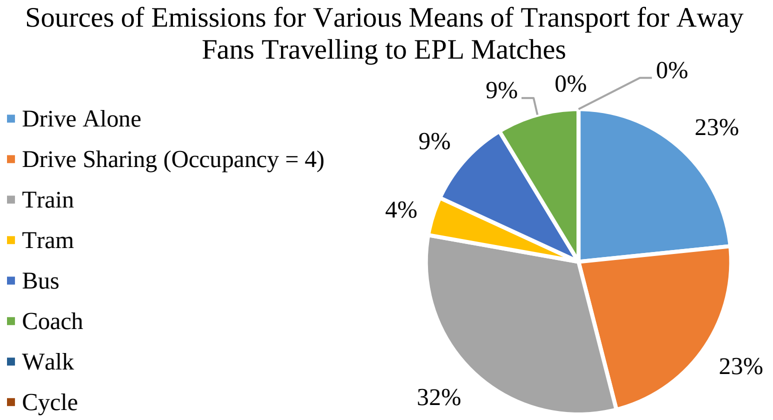

Figure 34: Breakdown of emissions across various means of transport for away fans, where Driving Sharing occupancy rate is increased to 4.

The next step was to limit the number of away fans travelling to EPL matches. This was primarily due to the fact that despite making up only 8% of the number of fans, away fans account for 81% of emissions. The reduction was applied in 2 ways, as described in the methodology. Firstly, the number of away fans at all EPL matches was limited to 1,500, which resulted in a 38.5% further decrease in total emissions from 30,760 tonnes CO_2e to 18,907 tonnes CO_2e. The average emissions from fan travel at any given EPL match reduced to 49.76 tonnes CO_2e due to a decrease in emissions attributable to away fans. The reduction in emissions comes entirely from away fan travel, where it now accounts for 67.7% of emissions but this is because away fans now only make up 4% of total fans at EPL matches, showing how emissions per fan is unchanged by this measure.

The second method was to limit the away allocation to 2.5% of the stadium capacity at all EPL matches. This resulted in a far greater reduction in the number of away fans and, therefore, a greater reduction in emissions from fan travel as away fans make up 3% of total attendees at EPL matches with this limit to away allocation. This decrease in away fans resulted in a further 51.9% decrease from the previous step, where fan travel emissions equal 14,799 tonnes CO_2e. The average emissions from fan travel to any given EPL match are 38.94 tonnes CO_2e for this method and away fan travel accounts for 58.8% of fan emissions. Clearly, this method of reducing the number of away fans results in greater reductions in emissions but as discussed, it is unlikely EPL clubs and fan will find this a popular solution and would not be in favour of its implementation. Therefore, it is the first method that will be worked with further, where total emissions are 18,907 tonnes CO_2e, with a further step outlined to reduce emissions from fan travel to EPL matches to a greater extent.

The final measure implemented to reduce the emissions resulting from fan travel to EPL matches was to increase the percentage of fans utilising public transport to travel to matches. The number of fans driving alone was reduced based on a survey of EPL clubs' fans and more fans were assumed to take the train, bus and coach (Figures 26 and 27). The result was a further 16.4% decrease in total emissions, from 18,907 tonnes CO_2e to 15,811 tonnes CO_2e. The average emissions resulting from fan travel to any given EPL match decreased to 41.61 tonnes CO_2e, where the emissions per home and away fan also decreased, as lower carbon modes of transport were more prevalent. Average emissions per home fan travelling to any given match were 0.342 kg CO_2e, representing an overall decrease from the initial assessment of fan travel emissions of 29.6%. A similar decrease of 27.1% was found for away fan travel, which now equals an average of 19.194 kg CO_2e for an away fan travelling to a EPL match. The total decrease in emissions from the initial assessment was from 35,904 tonnes CO_2e to 15,811 tonnes CO_2e, a 55.96% decrease coming from the implementation of various measures as described.

Overall, the measures introduced across both club and fan travel have proved effective in decreasing the environmental impact of the EPL. Total emissions from both club and fan travel over 1 season decreased by 55.8% from the initial assessment of 37,347 tonnes CO_2e to 16,497 tonnes CO_2e, with the added measures.

4.2.3. Renewable Energy Generation

The capacity of the PV arrays at each ground (Figure 35) varied depending on the size of the viable area on the roof and this will heavily influence the potential for electricity generation at each stadium. As discussed, it is the stadia with greater areas of smooth rooftop and limited metal structural supports that can accommodate the greater number of PV panels. This is a result of more modern architectural techniques and shows that, in this case, the stadium seat capacity does not necessarily result in a greater size of potential PV panel array. The average size of a potential PV array at an EPL stadium was found to be 875.2 kW, which is fairly similar to the 1134 kW array present at the Johan Cruyff Arena (Warmerdam, Hoogt and Kotter, 2020). This suggests the method of finding potential PV array capacity is valid in the real world and can produce useful and accurate results.

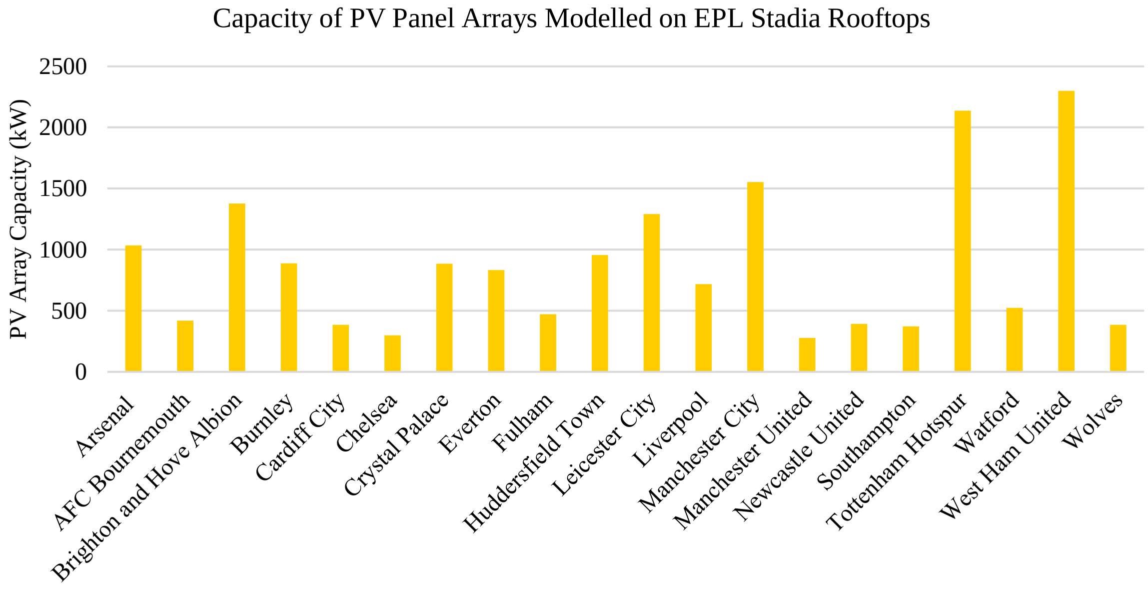

Figure 35: The potential capacity of solar PV arrays at each EPL clubs' home stadium.

The total potential annual electricity generation across PV panels mounted on all 20 EPL stadia roofs of the clubs competing in the 2018/19 season was calculated to be 17.98 GWh. This amounts to 15.7% of the electricity consumption calculated across the same stadia previously, hence, giving the potential to save the same percentage of CO_2e emissions over a season, without accounting for transmission and distribution back to the grid or the losses that would occur if a BESS was employed.

This is quite a simple calculation of potential electricity generation, and it is assumed it is wholly transmitted straight back into the National Grid rather than being directly utilised at the stadium. It is assumed that in this way it reduces emissions by offsetting overall electricity usage, rather than stadiums directly using emissions free electricity generated by the PV panels. A more detailed analysis could look at the potential to incorporate storage systems such that the peaks of electricity consumption could be matched by dispatching stored electricity as required. This would be similar to the system present at the John Cruyff Arena or modelled at the Skagerak Arena in Norway.

As expected, the stadiums with the greatest potential to accommodate PV panels generate the most electricity (Figure 36). However, the different weather data at the 20 stadium locations means generation is not directly proportional to array capacity with generation per panel varying from 70.7 kWh/panel in Burnley to 90.2 kWh/panel in Bournemouth. Generally, the further south the stadium is the greater the value for generation per panel, which is expected with these locations closer to the equator and exposed to more sun. The generation is also dependant on the compass direction of the arrays on each stand at each ground, but the tilt should be useful in ensuring each panel generates as much electricity as possible.

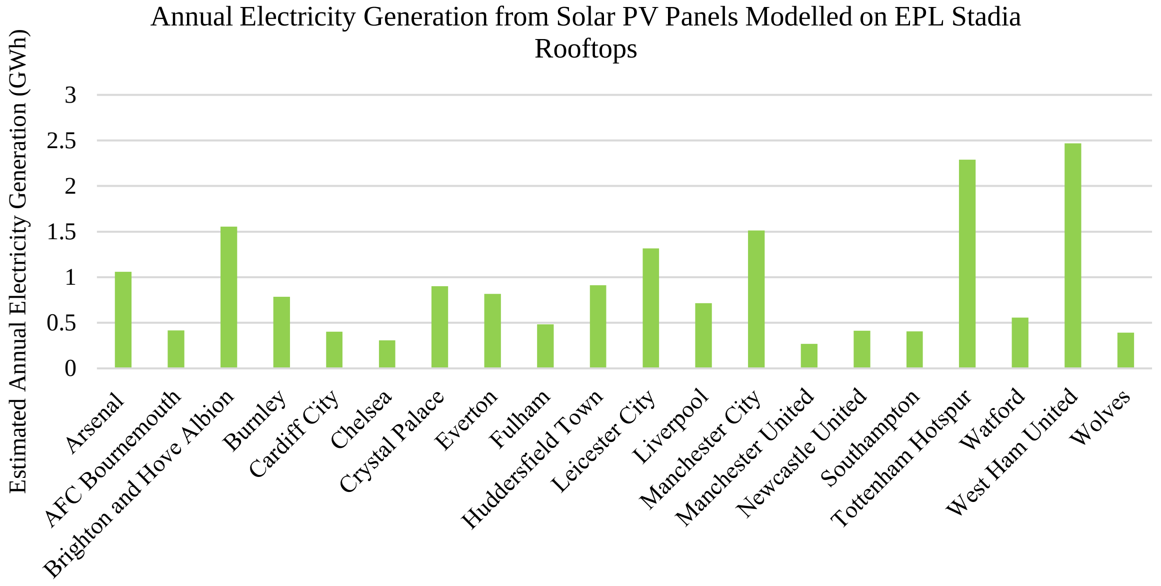

Figure 36: Potential annual electricity generation from PV panels on the roofs at 20 EPL stadia competing in the 2018/19 season.

The resulting CO_2e savings from the annual electricity generation using PV arrays clearly varies from club to club (Figure 37). The emissions, similarly to the electricity itself, are assumed to be offset by zero-emission electricity being fed back into the grid from the rooftop PVs and, in this way, reducing emissions attributable to electricity consumption at EPL stadia. The reduction in emissions correlates to the potential generation at each stadium. At stadia like Old Trafford, where viable roof space for PV panels is limited, and the electricity consumption is high the reduction in emissions is small. This would highlight whether it is worth installing PVs at all and if other measures to reduce to emissions would be more suitable.

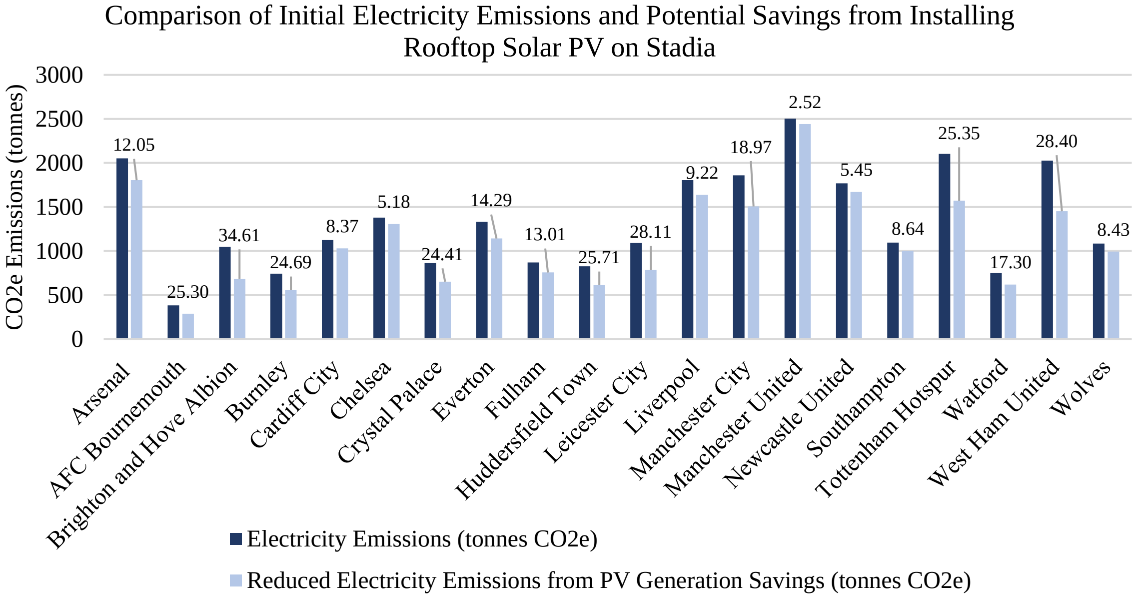

Figure 37: Comparison of the initial assessment of CO2e emissions and potential savings where rooftop solar PV generation offsets electricity consumption at each EPL club stadium. Also shown is the magnitude of percentage decrease at each stadium.

The potential for a decrease in emissions ranges from 2.5% at Old Trafford to as much as 28.4% at the London Stadium, where West Ham United play at home. The average decrease in emissions from electricity consumption is 17.0%. Total emissions from electricity consumption of all 20 EPL clubs' stadia reduces by 15.7% from 26,697.9 tonnes CO_2e to 22,507.0 tonnes CO_2e. When combining with emissions resulting from gas consumption at stadiums, there is a reduction of 9.7% from the initial value of 43,304.2 tonnes CO_2e to 39,113.3 tonnes CO_2e. The combined results across all sectors will be discussed in the next section and will highlight the effect installing PV panels has on total emissions.

5.0. Discussion

5.1. Combined Results

5.1.1. Assessing the Environmental Impact of the EPL

The assessment of the environmental impact of the EPL employed standard GHG accounting and reporting procedures to determine the Carbon Dioxide equivalent emissions attributable to certain operations of the 20 clubs competing in the 2018/19 season. The operations considered stretched across club travel and accommodation to away games, fan travel to each clubs 38 fixtures over 1 season and the electricity and gas consumption at each clubs home stadium. The environmental impact of an organisation such as the EPL is a complex issue and as such many aspects were unable to be considered for this study and certain areas were examined at a high level due to a lack of data available.

Despite this, an estimation was found for the emissions of the considered sectors of the EPL of 80,651 tonnes CO_2e over the course of the 2018/19 season. A large majority of 44% of emissions stems from fan travel to matches (Figure 24), with 81% of fan travel emissions attributable to away supporters. Electricity consumption accounted for 33% of emissions. However, many EPL clubs consider the electricity supplied to facilities as emissions free, but this was discounted due to the fact suppliers state the electricity comes from the grid, so has an associated emissions factor for every kWh consumed. Within club travel and accommodation, air travel accounts for 93% of emissions attributable to clubs across the league (Figure 16). Although the sector itself accounts for very little emissions compared to other operations, just 2% (Figure 24). These sources of emissions were especially identified as targets to implement reduction measures to given that they contribute most to the leagues environmental impact and actions could be seen to have the greatest impact.

The emissions found for the EPL are comparable in magnitude to the Aluminium production industry in the UK (BEIS, 2021a), showing it is not a huge contributor to the emissions from the country as a whole. However, to meet climate targets all sources of emissions should be mitigated and the highly visible nature of the EPL suggests actions to reduce emissions would go further than reducing the environmental impact of the league, encouraging wider change in the publics behaviour to reduce emissions.

5.1.2. Reducing the Environmental Impact of the EPL

The assessment of the emissions of the EPL over a season allowed identification of specific areas and challenges in reducing the environmental impact the league has. As such, various emission reduction measures were considered and modelled to find effective ways to reduce emissions, especially from those areas which contributed most overall and also within a given sector, such as away fan travel, electricity consumption and club air travel.

The overall reduction in emissions following the implementation of the outlined measures was found to be 25,040.5 tonnes CO_2e, from 80,651 tonnes CO_2e to 55,610.5 tonnes CO_2e. This is an overall decrease of 31.05%. These were high level measures that are simple to implement, highlighting the possibilities the EPL has to reduce the environmental impact of the league's operations. It is without doubt there are more detailed opportunities to further reduce emissions from the league.

The measures were implemented in the order in which they were outlined in the methodology and the percentage decrease was found from the emissions resulting from the previous step. This allowed a comparison of how effective each measure was, firstly, within the sector the measure applies to and then the overall effect on the total emissions found for the EPL in the initial assessment (Table 8).

Table 8: Implemented measures to reduce EPL emissions and the percentage decrease of each.

Sector	Measure	Percentage Decrease to Sector Emissions (%)	Percentage Decrease effected by Measure on Total Emissions (%)
Club Travel and Accommodation	Reduced Delegation Size	17.95	0.321
	Budget Hotels	17.33	0.255
	Increase Coach Travel Limits to 4 hours or 343.32 km	29.61	0.361
	Increase Accommodation Distance limit to 85.82 km	0.39	0.003
Fan Travel	Increase Occupancy Rate of Car Shares	14.33	6.438
	Limit Number of Away Fans to 1,500	38.53	15.857
	Increased Prevalence of Fans Utilising Public Transport	16.37	4.922
Renewable Energy Generation	Integrating PV Panels to Generate Electricity to Offset Emissions from Consumption	15.70	7.008

The results show clearly what the most effective measures were. Away fans were seen to be a significant source of emissions for the EPL and so it is logical that reducing number of away fans would be effective in reducing emissions. It is interesting to observe that despite the significant reductions the measures effecting club travel and accommodation have on that sectors emissions, the effect on total emissions is not considerable. This shows how club travel and accommodation emissions are comparatively small and these measures should not be a priority. The 4 measures implemented for fan travel and renewable generation contribute most to reducing emissions and it would be recommended to look at the possibilities to introduce these first. However, the effect each measure has will likely vary on a club-by-club basis and to reduce emissions in the most efficient way, each clubs' operations should be analysed in more detail to limit environmental impact as much as possible.

5.2. Comparison to Literature

Previous studies have assessed and looked at ways to reduce emissions from sports clubs, tournaments and leagues and these were discussed in the literature review. No previous study has attempted such a wide-ranging assessment of emissions from a league such as the EPL. Fan travel emissions have been analysed in England and Germany (Dosumu, Bragg and Colbeck, 2017; Loewen and Wicker, 2021) and some clubs have assessed their own fan bases contribution to club emissions over a given season (Fluminense FC, 2014; VfL Wolfsburg, 2020b). The same football clubs published GHG reports, identifying areas where most emissions came from, and this included club travel and accommodation and energy resource consumption. Club travel and accommodation of the EPL clubs in the 2016/17 season have been calculated (Pereira, Filimonau and Ribeiro, 2019), giving a good benchmark and procedure this study was able to utilise. Little was done in the research to identify ways to reduce emissions giving room to build on the work for this project. Electricity and gas consumption figures were largely unavailable, giving little opportunity to compare results, rather simply utilise literature values to estimate emissions resulting from energy consumption at EPL club facilities.

5.2.1. Assessing the Environmental Impact of the EPL

The results found for club travel and accommodation saw a 23.9% difference to the emissions found for the 2016/17 season (Pereira, Filimonau and Ribeiro, 2019), the large majority of which were from transportation, which was also found here. It was also found that 85% of club emissions resulted from transport, similar to the 93% found for the 2018/19 season. It should be noted that, due to the promotion and relegation aspects of the competition, 3 different teams play in the league from season to season, perhaps offering reasons for variations in results. The emissions resulting from the club travel of VfL Wolfsburg was found to be 565.76 tonnes CO_2e, which would be 39.2% of emissions found for all 20 EPL clubs for the 2018/19 season. However, this study only analysed domestic club games whereas Wolfsburg considered the men's teams participation in the Europa League, where emissions would be considerable due to trips from Germany to France, Sweden and the Ukraine (VfL Wolfsburg, 2020a). This would explain the difference in results and perhaps highlights a possibility to continue this study, where the EPL clubs competing in Europe could have emissions assessed from these trips abroad and aggregated with domestic travel emissions. Fluminense found away club travel emissions of 248.25 tonnes CO_2e, which would be 17.21% of emissions found for the full EPL. The reliability of this assessment of Fluminense's GHG emissions has been discussed in the literature review, but the differences could be accounted for by the size of Brazil, where they play, resulting in considerably longer distances for clubs to travel to away matches.

The results of the assessment of fan travel emissions were variable in comparison to values found in previous studies. The average emissions for any given fan, home or away, travelling to a EPL match was found to be 2.834 kg CO_2e, which is in the same order and similar to the value of 4.74 kg CO_2e found for the English lower leagues (Dosumu, Bragg and Colbeck, 2017). However, it was discussed that the emissions per fan would be expected to be greater for higher tiers of the football pyramid and this pattern was observed in literature. The average emissions for a fan attending a German Bundesliga match were found to be greater as well, an average of 8.64 kg CO_2e per fan per match (Loewen and Wicker, 2021) and this difference is likely due to the greater size of Germany in comparison to England resulting in longer journeys. However, this difference in average results in a total fan travel emissions being over 10 times that found in this study. This seems quite a considerable difference, given the Bundesliga has 2 fewer teams and a similar number of attendees.

VfL Wolfsburg found almost 60% of emissions were attributable to fan travel, a value of 5,625.5 tonnes CO_2e, this is in comparison to an average per club of 1,795 tonnes CO_2e found for the EPL. Similarly to club travel, this could be due to European fan travel, not considered here, and the comparative size of Germany. However, Wolfsburg found the majority of emissions resulted from home fans which contrasts results here and in existing literature, where lower league away fans in England had average emissions 8 times greater than home fans. This is less than found here for the EPL, where away fans emissions were 54 times greater than home fans on average. This again is quite a considerable difference, perhaps due to the more local nature of the English lower leagues where away fans travel shorter distances than those in the EPL.

The assessment of emissions resulting from electricity and gas consumption in this study were principally based on existing literature, so comparisons are hard to make, given the values were used in the assessment. The average emissions from gas consumption for an EPL club over 1 season were found to be 830 tonnes CO_2e, which is around half the value found by Wolfsburg of 1,701 tonnes CO_2e. However, Wolfsburg considered all club facilities and had access to exact readings, perhaps making it a more accurate value. The average electricity consumption found for EPL stadia was found to be 5.73 GWh, similar to Wolfsburg's consumption, who consider electricity as 100% emissions free, of 6.73 GWh. All facilities are considered again, accounting for the greater electricity consumption at Wolfsburg despite the stadium capacity being 28.3% smaller than the average EPL stadium. The electricity and gas consumption, both across all club facilities and at just stadiums, is an extensive problem and as such this study provides an estimate of resulting emissions from consumption values based on literature.

The greatest source of emissions was found to be from fan travel (Figure 24), and this is consistent with clubs, like Wolfsburg and Fluminense, and at football tournaments, such as recent FIFA World Cups (Figure 3). Total emissions were estimated at 80,651 tonnes CO_2e, giving an average for a EPL club of 4,033 tonnes CO_2e. Compared to VfL Wolfsburg, this is around 42.6% of the value and around 1.5 times that of the value found for Fluminense. Firstly, this difference may be due to the club and fan travel variances in distance and considerations, as discussed. Also, many aspects were not considered in this study that were by Wolfsburg, such as catering, merchandising and a 'miscellaneous' sector, accounting for nearly 8% of emissions (Figure 1). As mentioned, no studies have assessed the emissions of the EPL in great detail but a 'back of the envelope' calculation estimated a value of 185,000 tonnes CO_2e (Goldblatt, 2020) having extrapolated from the Fluminense study. Clearly, this is greater than 80,651 tonnes found in this study, but, again, more aspects are considered in the calculation of 185,000 tonnes.

5.2.2. Reducing the Environmental Impact of the EPL

In terms of reducing emissions, limited studies have demonstrated what different actions could achieve and this is the gap this project has aimed to fill. As such, there are a number of measures unique to this study and have no literature to compare to. Some measures were suggested or implemented in the literature and the effect of this, in comparison to this study, will be analysed.

Air travel has been identified as the major source of emissions from club travel (Dolf and Teehan, 2015; Pereira, Filimonau and Ribeiro, 2019) and implementing measures to reduce this saw a near 30% reduction in emissions within the sector for the 2018/19 season. These studies suggested this as a way to reduce emissions and the results saw it would be effective in doing so.

Initiatives encouraging fans to utilise public and low emission transport, such as the 'KombiTicket', introduced at the 2006 World Cup in Germany saw an estimated 18,000 tonnes CO_2e saved within the transport sector (Dolles and Soderman, 2010). This is a saving of 19% within transport which compared to EPL fan travel, where emissions reduced by 16.4% within the sector, is a very similar saving to what was seen at the 2006 World Cup. As discussed, no previous studies have analysed the effect of limiting away fans or increasing occupancy rate of car shares so no comparisons can be made.

An assessment of rooftop solar PV generation on Australian sports facilities, including stadiums and offices, found viable roof space of 77,000 m^2 with the potential to generate around 20 GWh of electricity annually (University of New South Wales and Australian Photovoltaic Institute, 2021c). This study found 142,052 m^2 of viable roof space, almost double, across the 20 EPL stadia, with the potential to generated 17.98 GWh of electricity. This reflects the difference in solar resource in Australia compared to England, but the generation potential is very similar. The average generation at a given EPL stadium equals 0.899 GWh from an average PV array capacity of 875 kW. This capacity is similar to that present at the Johan Cruyff Arena in Amsterdam (Warmerdam, Hoogt and Kotter, 2020), showing the real possibility of this kind of installation at EPL stadia.

A 778 kW solar PV installation modelled at the Dacia Arena in Udine, Italy, found potential electricity generation of 0.815 GWh annually, showing a similarity in generation to rooftop PV on EPL stadia. A 1 MW solar PV installation at the Bentegodi Arena in Verona, also in Italy, saw potential CO_2e savings of 550 tonnes (Manni *et al.*, 2018). To see this magnitude of emissions savings in England, an array of over 2,139 kW capacity is required, like possible at the Tottenham Hotspur Stadium, illustrating again the limited solar resource in England. PV arrays installed on EPL stadia could potentially save 4,191 tonnes CO_2e emissions from the electricity generation of 17.98 GWh and this compares well to literature and existing installations where similar findings have been observed.

5.3. Feasibility of Reduction Measures

The feasibility of the suggested measures (Table 8) is important in assessing the likelihood they could be implemented by the EPL and the 20 clubs that make up the league. Considerations EPL clubs could take into account include economic factors, athletic performance, social impact and popularity with the fan base and simply ease of implementation for a given club. The factors will be discussed in the next section.

Firstly, delegation size of clubs was suggested to be reduced. All staff considered to be relevant to match day performance will still be in attendance, just analysts and recruitment staff will no longer travel. This could affect scouting and post-match analysis as it is no longer done live. However, most football, especially top level like the EPL, is televised so analysts can access match footage very easily without having to attend matches. Scouting of professional football is often carried out online anyway (wyscout, 2021), as clubs look to analyse specific players, so it is unlikely this part of a clubs' operations would be greatly affected. Overall, the reduced delegation may not be universally popular and convenient, but it reduces club emissions to such an extent that is a reasonable measure to introduce.

Budget hotels are an easy measure to introduce as it is stated EPL clubs do not use the facilities specific to luxury hotels (Pereira, Filimonau and Ribeiro, 2019), so it is not necessary for clubs to stay overnight there. It would also be feasible for clubs to stay in hotels trying to limit GHG emissions (Salehi *et al.*, 2021), with the industry identifying disproportionate emissions attributable to hotels and the resulting need to reduce them.

An increase in the limit that clubs use coach travel for is likely to be unpopular with players and performance coaches as the reason to limit travel in any 1 seat to 3 hours is to prevent muscle cramps from prolonged sitting (Andrews, 2002). Cramps can be painful for players and inhibit the ability for them to continue in a match. So, increasing the likelihood of cramps occurring is unlikely to be an attractive option for players, coaches and fans as the players struggle, potentially lose games and the quality of football decreases. However, as discussed, players often travel for European fixtures on airplanes for 4 hours so it is not unreasonable to suggest the same could be done on coaches for domestic games. The decrease in total emissions of this measure was only found to be 0.361%, a small decrease to the overall environmental impact of the league. It is likely that such a small decrease in emissions may not be considered worthwhile if negative impacts on players, fans and the overall football product are significant.

The final measure applied to clubs was an increase in the accommodation distance. The feasibility of this is likely to depend on the time of kick off and the effect the increased travelling directly prior to the match has on scheduling. Kick off times vary between 12pm and 8pm, so it would vary whether the team would require overnight accommodation on a match-by-match basis. Also, the decrease in total emissions was minimal, just 0.003%, so it is questionable if the measure is worth implementing at all.

The fan travel measures will require a degree of engagement with supporters to encourage fans to car share, in order to increase the occupancy rate, as well as increase the use of public transport. Initiatives such as liftshare.com (liftshare.com, 2021) have been introduced in the English lower leagues and in wider society, popular applications like BlaBlaCar (BlaBlaCar, 2021) exist that encourage people to reduce emissions by increasing occupancy rate of cars on journeys. It is definitely feasible to promote these platforms and the emission savings, of 6.438% of total emissions, show it would be worth investment required.

It has been seen in literature that incentives such as the ‘KombiTicket’ in Germany encourage fans to utilise public transport by including the fare in the match ticket and the resulting emissions savings can be significant (Dolles and Soderman, 2010). So similar initiatives can be introduced for EPL fans, who already are eager to increase their public transport usage but see the economic factors of public transport as the main barrier to using it more (Yates *et al.*, 2013). An initiative is already in place at Newcastle United, called the ‘Magpie Mover’ where season ticket holders can travel to and from home games for free on public transport (Newcastle United FC, 2021). This can be a model for other clubs alongside the KombiTicket initiative by relieving the economic stress for fans, by making public transport to EPL matches cheaper. The results found here, of a reduction of fan travel emissions of 16.4%, are similar to found from introducing the KombiTicket so the incentives clearly work and could lead to a significant decrease in emissions.

A less popular measure would be limiting the number of away fans able to attend matches in order to reduce emissions, despite this being the most effective measure in doing so (Table 8). Away fans in England contribute greatly to the atmosphere of the games, providing a loud and entertaining presence that encourages the away team and creating a theatre to every occasion. Limiting away fans would reduce this effect, potentially damage the product and upset fans who wish to support their team. It was seen that through the COVID-19 pandemic, where matches were played in empty stadiums, the game of football was not the same, so reducing away fans would similarly reduce the spectacle. However, to reduce emissions in such an effective way, as seen by limiting away fans to 1,500 at all matches, is perhaps the fairest way where compromises need to be made to reduce emissions as a society as a whole.

Introducing PV panels onto stadia roof is certainly feasible, as many examples are in practice in Amsterdam and Verona amongst others. There is a solar resource available in England that rooftop solar PV on football stadia can utilise but structural factors of the roofs themselves should be considered, which is beyond the scope of this project. However, installing PV panels at EPL stadia should again be considered on a club-by-club basis, as although potential electricity emissions decrease by an average of 17%, this is not seen across the whole league. At grounds like Old Trafford where emissions from electricity are offset by PV generation only decrease emissions by 2.5% (Figure 36), it is unlikely clubs will see that as a worthwhile investment and find different solutions to reduce emissions. It is also true that reducing emissions requires contributions from as many sources as possible, so any decrease, even as small as 2.5%, should be considered as building a system that operates with the minimum emissions possible. This principal should be carried through when looking at all suggested measures, as the EPL looks to reduce its environmental impact.

5.4. Low Carbon Transport

Low or zero carbon transport is a very important factor for society if climate targets are intended to be met and emissions are to reduce significantly and the EPL is no different. The measures introduced to reduce club travel emissions from air travel were effective but utilising low carbon fuels instead of kerosene, the current aviation fuel, could see a further decrease. Biofuels called biokerosene, produced from vegetable and animal fats for the aviation industry, have the potential to reduce emissions by between 50-95% (DHL, 2019) and these would not require significant mechanical modifications to the aircraft. Synthetic kerosene is developed from the electrolysis of water, which would be powered by renewably sourced electricity and represents the leading edge in decarbonising aviation (Drünert *et al.*, 2020). However, extensive development is still required for these fuels, requiring time and money. This could certainly be a project the EPL clubs help support to reduce club travel emissions, given their economic power and also the connections many clubs have to the aviation and fossil fuel industries (Ronay, 2019).

Electric vehicles (EVs) offer an opportunity to decarbonise many forms of transport by the electrification of the propulsion mechanism, where the charge is supplied by renewably generated electricity. Electric cars, HGVs, buses, coaches and trains all are in development or a large part of the transport network, whereas electrified airplanes are a significant challenge due to the thrust requirements to power flight. This therefore gives an opportunity to use EVs for the various journeys of both EPL club delegations and fans and reduce the associated CO_2e emissions with the league.

Battery electric vehicles use electricity procured from the National Grid to charge an auxiliary battery pack which provides power, as required, to an electric motor for propulsion. There are also hybrid electric vehicles, which involve a combustion engine and electric motor working in tandem to provide propulsion, but emissions are greater for hybrids and, so, will not be considered here. However, as EVs rely on electricity supply from the grid, it is acknowledged that the decarbonisation of the electricity mix up is as important as improvements in low emission transport technology. For this study, GHG conversion factors for EVs have been found (Table 9) and applied to evaluate the effect using these vehicles in place of fossil fuel equivalent have on the environmental impact of the EPL.

For electric cars, the conversion factor is available from the DEFRA GHG reporting procedures (BEIS, 2021b). Associated GHG conversion factors are not widely available for buses, coaches and trains. However, studies have been carried out which found an associated emissions per person per km (Lie *et al.*, 2021). For electric coaches, which would be most important for club travel, various travel companies offer a zero-emissions coach (Westway, 2021). These can travel up to 2 hours on 1 charge, so this limit will be applied to each journey of given length. It is noted that these vehicles still need to charge from the grid, but an associated GHG conversion factor is not available, so it is assumed the emissions factor is zero as stated by the travel company. This is unlikely and partially limits the study.

Trams and the tube in the UK are widely already electrified so the DEFRA values are used, but conventionally fossil fuelled trains still make up 60% of the national rail network (Royston *et al.*, 2019). Conversion factors are taken from research regarding low emission train travel (Logan *et al.*, 2020), where the trains are assumed to be 'regional' and 50% full, representing that EPL clubs are likely to book out entire train carriages. It is also assumed that introducing EVs is the final measure to reduce emissions, so, for example, coach travel limits for clubs are 4 hours, occupancy rate of shared cars is 4 and public transport usage is more prevalent. To find the CO_2e emissions associated with club and fan travel to each match using EVs, the number of people travelling by each mode of transport is multiplied by the relevant conversion factor and the distance travelled utilising each mode of transport (Equation 1).

Table 9: GHG conversion factors of EVs and some conventionally fuelled vehicles, per person per km travelled (Logan *et al.*, 2020; BEIS, 2021b; Lie *et al.*, 2021; Westway, 2021)

Mode of Transport	**GHG Emissions Conversion Factor (kg CO_2e)**
Domestic Air Travel	0.2443
Drive (Alone) - EV	0.05274

Drive (Sharing – Occupancy Rate = 4) - EV	0.01319
Train (National Rail) - EV	0.0052
Tram	0.02991
London Underground	0.0275
Bus - EV	0.049
Coach – EV (Under 2 hours journey time)	0
Coach	0.02732

Introducing EVs to club travel, primarily effected the coach travel emissions, where emissions decreased by 2.3% from 686 tonnes CO_2e to 670 tonnes CO_2e. This shows still how air travel makes up most of club travel and accommodation emissions, increasing to 68% from the last step (Figure 31), so measures effecting coach and train travel will only have a minimal effect on total emissions.

More means of transport utilised by fans are affected by introducing EVs and hence decreasing the GHG emissions factor. This results in a significant decrease in fan travel emissions by 63.7%, from 15,811 tonnes CO_2e to 5,734 tonnes CO_2e. Overall, combined emissions decrease by 18.2%, from 55,610 tonnes CO_2e to 45,517 tonnes CO_2e. From the initial assessment of EPL emissions, introducing all measures as well as EVs, a 43.6% decrease in emissions is observed.

This is an impressive outcome, indicating the effect introducing EVs could have on emissions. However, introducing EVs for fans to utilise would be a public expense and may take time to implement on a national basis as these vehicles are brought in across society anyway. It is possible that the EPL clubs, who could use significant resources to invest in low carbon transport, could help to reduce both their fans and club emissions by introducing specialised vehicles to be used for travelling to EPL matches. It is likely that over time, as the UK looks to meet climate targets, EVs will be introduced anyway, and this will instigate a reduction in EPL emissions as well.

5.5. Other Considerations

Many aspects of a football clubs' operations have not been analysed to assess emissions from these sources and these have been addressed through the project. These include catering, merchandising, administrative staff travel emissions, water usage, waste management and all club facilities energy consumption. These lead to limitations of the study however, it was acknowledged that this is a high level assessment of emissions, with certain aspects unable to be considered due to the complex nature of the issue. Beyond this, there are further considerations that could be studied in future to potentially find greater reductions in the emissions of the EPL.

Firstly, a measure suggested in literature to reduce club travel and accommodation emissions was to use neutral venues, where emissions could potentially reduce by 50% (Pereira, Filimonau and Ribeiro, 2019). This was tested in this study for the 2 matches leading to most club emissions which was Newcastle v Bournemouth and the reverse fixture in Bournemouth. A neutral venue was identified as Molineux, which is the EPL stadium most equidistant between Newcastle and Bournemouth and club travel emissions would decrease by 74.8%, as both teams could travel by coach now. However, the study does not consider fan travel emissions when finding emissions reduction of 50%. The neutral venue would lead to large numbers of 'home' fans travelling a far greater distance and in practice becoming away fans, with greater associated emissions. It was calculated that for the fixture where Newcastle were considered the home team, fan travel emissions increase by 560%, hence cancelling out any decrease in club travel emissions and showing neutral venues as being ineffective in reducing emissions.

In the literature review, different technologies, other than solar PVs, were identified as being able to reduce footballs environmental impact. These include wind, biomass, absorption chillers, heat pumps, LED lighting and highly-reflective paint. None of these were considered for this study, although LED lighting is prominent at EPL stadia which reduces electricity consumption at these grounds. It would be interesting to see if different technologies could help generate electricity or reduce emissions and potentially be more suitable at certain grounds than installing PV arrays.

At certain stadia, such as the Johan Cruyff Arena, battery storage works in tandem with PV arrays to match electricity consumption peaks, like when football matches are played. This requires a more detailed analysis of electricity generation and storage potential and how the stored electricity could be dispatched as required. This would be an interesting study to see how this could work in the EPL and with battery storage already in existence at Arsenal, it could build on the potential solar generation at the Emirates Stadium found in this study to investigate the feasibility of introducing a BESS there. This would require access to hourly electricity consumption profiles at EPL stadia, which was not available for this study, limiting the possibilities of modelling a BESS.

Another aspect is the social responsibility such a public facing organisation like the EPL has in reducing its environmental impact and leading by example to wider society. The EPL has many community-based initiatives based around youth development, racial justice and national health and given the climate emergency, it would make sense for greater initiative to be shown in this field. The league could encourage the public to change habits, both whilst engaging with football and in life in general, in order for people to reduce their individual environmental impact. The league has both the outreach, through its fan base, as well as the financial resources to make a real difference in this regard.

6.0. Conclusions

The main aim of this study was to initially assess the environmental impact, in terms of CO_2e emissions, of the English Premier League and identify effective ways to reduce these emissions. From the early research, it was apparent the issue of the emissions attributable to such an extensive organisation, with many elements and different operations such as the EPL, is highly complex. This perhaps inhibited this study in preventing detailed analysis into all sectors of the league which contribute emissions. However, it was possible to carry out a wide-ranging study into certain areas that were identified as contributing most to emissions, including club travel, fan travel and stadia energy usage, and calculate the magnitude of emissions from these sectors. The EPL has been acknowledged to be a global organisation, with extreme popularity and economic weight with most clubs desiring to reduce emissions and display themselves as promoting sustainability to millions of fans. This gave good premise for this study to be carried out and can help the clubs and the league identify ways in which to reduce emissions and play a part in meeting climate goals.

The total emissions found for the EPL over the 2018/19 season were 80,651 tonnes CO_2e, which is likely to be an underestimate given this value only considers emissions from club travel and accommodation, fan travel and electricity and gas consumption at each stadium. There are many aspects not researched in this study and these have been outlined in the discussion section. Most emissions (44%) originated from fan travel, which is consistent with observations from the literature, and club travel and accommodation contributing least to emissions (2%).

The suggested reduction measures saw emissions decrease by 31.05% and these measures have been discussed, finding varying feasibility, suitability and effectiveness. Most of the measures are all relatively simple and quick to implement and would to see a significant reduction in emissions. It was found that limiting the number of away fans, to 1,500 at all EPL matches, was the most effective measure in reducing the overall emissions of the league. This was followed by installing solar PV panels on stadia rooftop to feeding emissions free electricity back to the grid and then changing the travel patterns of EPL fans. Renewable electricity generation using solar is certainly a possibility for EPL grounds, given PV arrays exist on other stadia rooftop and the possibility for electricity generation offsetting significant CO_2e emissions. However, the size of the array and therefore magnitude of the decrease in emissions varies from ground to ground and the suitability for installations on each EPL stadium should be considered on an individual basis.

Introducing low carbon transport saw a further 18.2% decrease in CO_2e emissions but with less certainty about the results and feasibility of implementation by the clubs. However, EVs and low emission fuels offer an option for the future and will be important in both EPL clubs becoming more sustainable and wider society meeting climate goals.

The least effective measures in decreasing total EPL emissions were those implemented to club travel and accommodation specifically. This was primarily due to this sector amounting to the least emissions anyway. However, such a small decrease in the environmental impact may not be considered worthwhile if the performance of the players suffers, due to greater coach travel, disrupted scheduling and lack of support staff, and the product of the EPL declines.

Future work has been discussed in the other considerations section, but the main aspects that could be built on from this study would be considering more sectors when assessing CO_2e emissions, calculating the effect of more low carbon transport and sustainable fuels and investigating further suitable renewable technologies to reduce emissions of each club.

7.0. References

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