Energy Master Plan

UCD Sustainable Energy Community

Dublin, 22nd of April 2021

Preface

Since we initiated the planning for this UCD Sustainable Energy Community, the idea was to provide a platform for academics, researchers, professionals and public stakeholders to exchange knowledge, expertise and the latest cutting-edge developments on future sustainable cities and communities with a focus on our campus.

Decarbonisation of cities is increasingly being seen as a key priority in addressing the challenge of achieving the level of sustainability we foresee. Supporting a sustainable living environment provides opportunities to develop a low carbon, efficient and reliable economy, which is an essential requirement for the next generation of communities.

Having such a shared platform in such an highly regarded forum, we think, is a paramount step to tackle the enormous number of multisectoral and multidisciplinary challenges we need to face to achieve the target of a more sustainable future society. This is what the UCD Sustainable Energy Community is intended for: a place where to stop, analyse, think, discuss and restart the pathway for designing our future urban environment.

The UCD SEC committee would like to thank UCD Energy Institute to host the activities, all participants such UCD Estates, IES Environmental and all the academics, as well as the University and the scientific committee for helping us to build this exciting and informative initiative.

We wish UCD management could support the initiative further, towards the full decarbonisation of the campus and its associated activities.

UCD SEC, April 2021

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Introduction

1.1. Objective

The Belfield Campus of University College Dublin (UCD) is an important centre of learning and innovation in Ireland. UCD is ranked in the top 1% of higher education institutions worldwide and has a renowned global reputation. With a growing number of students and increasing demand for services, development and expansion will be vital to UCD's future. The University recognises this unique opportunity, and responsibility, to ensure that this development is sustainable while also setting an example for institutions around the world.

At a community level, UCD comprises a diverse population engaging in a wide range of activities and services. The campus houses education and research facilities, offices, extensive sporting amenities and commercial properties. Like cities and countries worldwide, UCD is working towards achieving ambitious climate change targets in line with the public sector targets set out in the 2019 Climate Action Plan. UCD aims for a 50% improvement in energy efficiency and a reduction in CO_2 emissions of 30% by 2030 [8]. Achieving these targets will require an integrated, whole-system approach that considers all of the campus energy users and how they interact.

To aid in achieving the targets, the community in collaboration with UCD Estates has established the UCD Sustainable Energy Community (SEC). This allows stakeholders from various backgrounds to come together with the collective aim of improving campus sustainability. While a more sustainable campus is beneficial for reaching climate targets, it will bring additional benefits, such as improved air quality, thermal comfort and energy security along with the opportunity for economic savings. The main objective of the UCD SEC is to raise awareness and improve the energy efficiency and reduce the CO_2 emissions of the campus while also maintaining the current standard of service provided and facilitating future expansion. UCD recognises that improving sustainability at Belfield will require a multidisciplinary approach, tackling the campus energy networks, the existing building stock and the waste and water facilities, while also encouraging behavioural changes.

1.2. Analysis of the landscape

This preliminary analysis presents available measures for the decarbonisation of the electricity and heat sectors, with particular emphasis on reducing carbon dioxide (CO_2) emissions in urban areas, such as UCD. Decarbonisation of a district involves strategies to reduce the CO_2 emissions of the individual elements within the area and the development of district-wide, integrated systems. This review ensures that a range of measures are considered in the preparation of the campus action plan.The starting point for such measures are buildings. In general, buildings in Ireland account for 38% of the primary energy supply, broken down into 23.6% residential and 14.4% services [20]. Therefore, the decarbonisation of buildings will play a vital role in the achievement of Ireland's emission reduction targets, with the ultimate goal of full decarbonisation by 2050. The decarbonisation of buildings is technically viable with the current state-of-the-art technologies [23]. The economic viability relies on the selection of the optimal technologies and the creation of synergies between the building and the environment. In the next section we will explain the role of energy efficiency and passive energy savings.

1.2.1. Passive Energy Savings and Energy Efficiency

Passive energy saving strategies typically involve improving the building's thermal properties to reduce the electricity demand or limit the heating and cooling requirements [12]. In the design stage, this can involve careful selection of the building orientation, the use of shade, the optimisation of natural light and a reduction in window area [6]. A balance must be struck between the thermal losses and the solar gains of the building depending on the requirements. In heating dominated climates, the most effective passive measures are thermal insulation to reduce the rate of heat transfer through the structure, quantified by the U-value, and passive solar heating [3]. This approach can be combined with the use of phase change material (PCM) integrated into walls and floors, acting as a latent heat storage mechanism [6] [3]. Installing high energy efficiency appliances can greatly reduce the building energy demand. Lighting demand in particular can be reduced by installation of LED technologies, along with occupancy or daylight sensors.

1.2.2. Solar Energy

Solar photovoltaic (PV) panels can be employed for large and small scale electricity generation and can be ground-mounted, roof-mounted or integrated into building materials. The panels are made up of individual solar cells, with the technology divided into three generations. The first generation consists of crystalline silicon technologies (c-Sci) currently make up the greatest share of the global market due to their relative maturity and high efficiencies [22].

> Second generation solar PV cells are the thin-film technologies. The conversion efficiency is lower than that of c-Sci cells, however, they offer a number of distinct advantages such as reduced cost due to production requiring less energy and material. The thinness and flexibility of the cells make them suitable for a wider range of applications and make them visually superior to c-Sci cells. The third generation includes multi-junction cells and all of the latest emerging technologies. Multi-junction cells are composed of multiple layers of different thin-film technologies, allowing for a greater absorption of energy and conversion efficiencies of up to 47.1%. Their complex production process and high cost makes them unsuitable for general applications [16].

PV accounted for 0.03% of electricity generated in Ireland in 2017. This slow uptake relative to other European countries is in part due to the lack of a feed-in-tariff for solar PV installations. The Climate Action Plan 2019 set the intention of allowing electricity generated through micro-generation to be sold back to the grid from 2020, including the establishment of a feed-in-tariff [8]. In [8], it has been estimated for higher education campuses in Ireland that the utilisation factor for roof- mounted solar PV is between 0.3 and 0.4. Evidence can be found in recent systems on the roof of three buildings in UCD (Engineering, Ashfield Residences and Smurfit), which occupy 37% of the total space. Furthermore, the typical capacity factor associated with these installations is reported to be 0.102 kWp/m^2 [9].

A feasibility analysis was carried out on the suitability of solar PV for installation in Dublin given the Irish climatic and economic conditions [14]. The test case was the installation of 195 PV panels of mono-crystalline silicon cells on the roof of an industrial building in UCD. With a roof availability of 785 m^2, an average received global irradiation of 1040 kWh/m^2 per year and a panel efficiency of 16.5%, the installation would produce 43,537 kWh of electricity annually. With this generation rate, assuming the panels to have a thirty-year life and the inverter to have a fifteen-year life, the energy payback period for the entire life cycle of the system is 5.23 years [14]. The life cycle greenhouse gas (GHG) emissions for electricity generation from solar PV were found to be 69 g CO_2-eq per kWh generated. This can be compared to 457 g CO_2-eq per kWh generated for electricity from the national grid. Applying different feed-in-tariff rates resulted in a range of economic payback times from 19.3 to 34.4 years. It is expected that as economies of scale are developed, the economic payback period would be reduced. Furthermore, as production of the PV panels requires electricity and accounts for over 50% of the GHG emissions, the total GHG emissions will decrease as the share of renewables in the electricity supply increases [14].

1.2.3. Electricity Storage

One significant drawback associated with renewable energy, such as wind and solar PV, is that they are non-dispatchable methods of electricity generation. Furthermore, the generation profile does not always match that of demand as the output varies seasonally, daily and even hourly. Energy storage systems can be integrated into renewable energy systems to balance supply and demand and allow for excess generation when the resources are abundant which can be stored for later use during peak demand.

Grid-scale energy storage is available in the form of pumped hydroelectric storage and compressed air energy storage. Application of both methods is limited by the suitability of the geographical loca- tion. A more convenient and universally suitable method is battery energy storage (BES). BES can be categorised into lithium-, lead-, nickel- and sulphur-based batteries, as well as flow batteries.

Lithium-ion (Li-ion) batteries are the most common BES, accounting for 55% of the market [5]. They have the highest storage efficiency of the common BES technologies and have the advantage of a long life, with efficient charge and discharge [5]. The main disadvantage of Li-ion batteries is the high cost. Recently, Lithium-Sulphur (Li-S) batteries are gaining popularity and are expected to obtain a significant market share due to the abundance of Sulphur and their low cost.

Lead-acid (Pb-A) batteries are also available for energy storage applications. While more recent designs can reach up to 90% efficiency, they have a significantly lower energy density than Li-ion batteries and a poorer life cycle. Furthermore, there are environmental impacts of toxicity from the use of lead [7]. Nickel- and sodium-based batteries are also available. The main objectives with BES development is to achieve high energy densities at low cost, whilst reducing the use of toxic substances or unsustainable materials and practices.

1.2.4. Hybrid Systems

The use of hybrid systems for district energy demand is a common measure for the decentralisation of the energy generation. The most common form of hybrid system is combined heat and power (CHP), which is also known as cogeneration. Trigeneration can occur when cooling is also supplied, creating a combined cooling, heating and power (CCHP) system. CHP and CCHP are suitable for decentralised application, where they are used on site, or can be connected to the electricity grid and a district heating network.

The prime mover in the system generates electrical power, typically using an internal combustion engine, a gas or steam turbine or a Rankine system [1]. A suitable heat recovery unit is then put in place to recover the heat generated by the power system. If cooling is required, a refrigeration system can be installed. The main advantage of a CCHP is that a single fuel source can provide power, heat and cooling and reduce costs compared to separate generation. Furthermore, recovering the useful heat from the power system increases its efficiency. Most CCHP systems operate a topping cycle, where the main priority is the generation of power. In this case, the process produces heat as a by-product which is then utilized. A bottoming cycle is also possible, where the production of heat is the priority and the rejected heat is used to generate power [1].

CHP and CCHP units are commonly run on natural gas, however, investigations have been made into its co-firing with biomass and the use of biomass as a sole fuel supply in small-scale gasification plants [17]. It has been reported that 30% to 50% CO_2 removal can occur when a gas turbine plant is converted to co-fire 10% to 30% biomass. However, when natural gas is replaced completely by product gas, the result of biomass gasification, there is a 20% to 30% reduction in the achievable electricity [24].

To use biomass as a fuel source it must undergo gasification, purification and cooling. It can then be mixed with natural gas at different ratios to achieve the optimum performance. A ratio of 1:1 is often employed for co-firing CCHP plants [26]. Studies have reported an energy efficiency of 79.5% at this ratio, while a CCHP system fired solely by biomass has a reduced efficiency of 70% [24]. The availability of feedstock is an important consideration for biomass CHP and CCHP applications. Where there are local sources such as residue from forest thinning and trimming, biomass can be an economically viable option.

1.2.5. District Heating Network

Conventionally, heat for space and water is generated on-site using oil or gas boilers, solid fuels or heat pumps. An alternative method is a district heating network (DHN), in which heat is generated on a larger scale at a number of point sources and distributed to consumers through an underground pipe network. There are three main components; the heat source, the distribution network and the heat delivery system.

The main advantage of a DHN is the opportunity for waste heat recovery. Industrial processes and electricity generation typically result in the production of heat as a by-product which is usually left to dissipate, taking with it a significant amount of energy. A DHN collects this waste heat and distributes it to residential, commercial and industrial properties for use, thus increasing the efficiency of the plant in which it is generated. CHP plants are common sources of waste heat that can be connected to the network. A thermal storage system (TES) can be incorporated to balance the variation between supply and demand. Furthermore, there may be a need for a backup supply on-site [11].

The distribution system consists of a network of insulated underground pipes through which a heat carrier flows. As the technology advances, and more efficient insulation materials and generators are available the outlet temperature of the heat being distributed has been decreasing. This, combined with increased insulation of the pipes, reduces heat losses in the network. The aim for the next generation system is to reduce losses and exploit synergies to increase efficiency. By upgrading the thermal efficiency of buildings through insulation, heat can be supplied at a lower temperature and more properties can be connected to the same grid. Distribution temperatures on the supply side are likely to be halved to 50 degrees Celsius [13].

Substations are used to deliver the heat to properties and generate hot water. Where cooling is required, absorption chillers or heat pumps can be installed [19]. The cost of a DHN is greatly influenced by the demand. These systems require to run for at least 7000 hours per yearto be economically viable, therefore densely populated areas with concentrated heat demand are more ideal locations [11]. The extent of retrofit required also has a major impact on the financial viability of the system.

1.2.6. Energy Modelling

Efforts to develop models to determine optimal decarbonisation strategies have been extensively reported in literature and are often referred to as the practice of energy system analysis. The main element of this analysis is the energy system model, a simplified representation of the current or future system, used to investigate supply and demand [25]. Models to assess future pathways are typically designed to maximise a benefit or to minimise an objective function, such as the total cost over the lifetime of the simulation [4]. While cost and energy security have been the main focus of much research in the past, energy models are increasingly being used to plan for GHG emissions reductions in tackling climate change [25]. A baseline with the current conditions is established to act as a reference scenario, allowing for the impact of chosen measures to be quantified and compared. A scaling factor is typically used to apply historical or current data to future scenarios [2].

Of particular interest in the energy system analysis is scenario selection and investigation. In some studies, scenarios are used to represent different levels of decarbonisation [12]. Other models investigate scenarios that vary based on the main strategies implemented, driven by different policy measures, support schemes and technological advancements. A common application of recent scenario analysis is to compare centralised and decentralised energy systems, identifying the most appropriate approach for a given environment [10]. Kowalski et al. has defined three classifications of scenarios[10]:

- Extrapolatory investigations, or forecasting, are based on the assumption that the future is a continuation of the past and aim to identify the most likely projection given current trends.

- Normative scenarios are defined by a quantifiable future goal. The pathways to achieving this goal are then explored through the analysis.

- Exploratory scenarios investigate a range of possibilities, rather than attempting to predict the most likely future outcome.

In each case, there is a limit on the number of scenarios that can be tested, meaning that a methodology is required to identify the most relevant alternatives. Literature has highlighted the importance of a balanced and objective approach to scenario analysis. A systematic methodology allows for justification of decisions made and thus can increase stakeholder acceptance [25]. As energy systems are influenced by the complex interaction of internal and external factors, the scenarios chosen must be informed by a baseline analysis.

Scenario analysis is a useful tool to inform decision-making, however, there are associated internal and external uncertainties such that simulation results may not be fully achievable in practice. Internal uncertainties are those arising from the accuracy and reliability of the model itself and its inputs. External uncertainties, on the other hand, are uncontrollable or unpredictable factors that may influence future systems, for example, oil prices, the levelised cost of electricity or technological improvements [25].

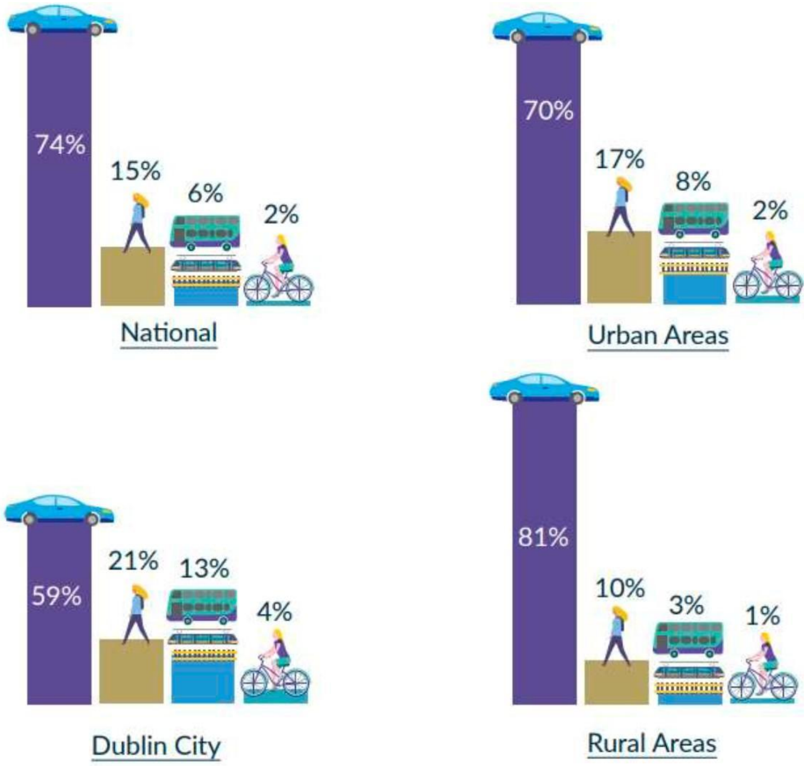


Figure 1.1: Commuter Trends by Area

1.2.7. Transport in Ireland

Ireland has one of the greatest expected population growth rates in the OECD, with 6.75 million expected to be living in the country by 2051. Allowing the rate of private vehicle ownership and fuel consumption to grow according to current trends will be unsustainable. Traditionally, private vehicles have often been the most used mode of transport given the infeasibility of providing public transport to those living in rural areas, displayed in Figure 1.1. As the population grows, it is expected that this proportion will shrink as most of this population growth will be in urban areas serviced by public transport. Figure 1.2 shows trends in commuter transport mode over thirty years, clearly highlighting the high rate of private vehicle ownership in Ireland. For sustainable electrification, the focus must be on this portion of the population, encouraging the switch to rechargeable electric vehicles (EVs). The electrification of buses and commercial fleets will also play into the increased charging load.

Predicting the trajectory of EV uptake in Ireland is a challenge given its dependency on government policies and economic performance. Currently, there are grants to incentivise the purchase of new EVs, however, the market is still relatively small, with the cost and lack of second-hand availability excluding many potential consumers. As of today, there are a number of different chargers connected to the Irish DS, from generic chargers installed over the last number of years by ESBN, to Tesla ‘fast chargers’, as well as lower powered ‘trickle-chargers’ connected to domestic LV connections.

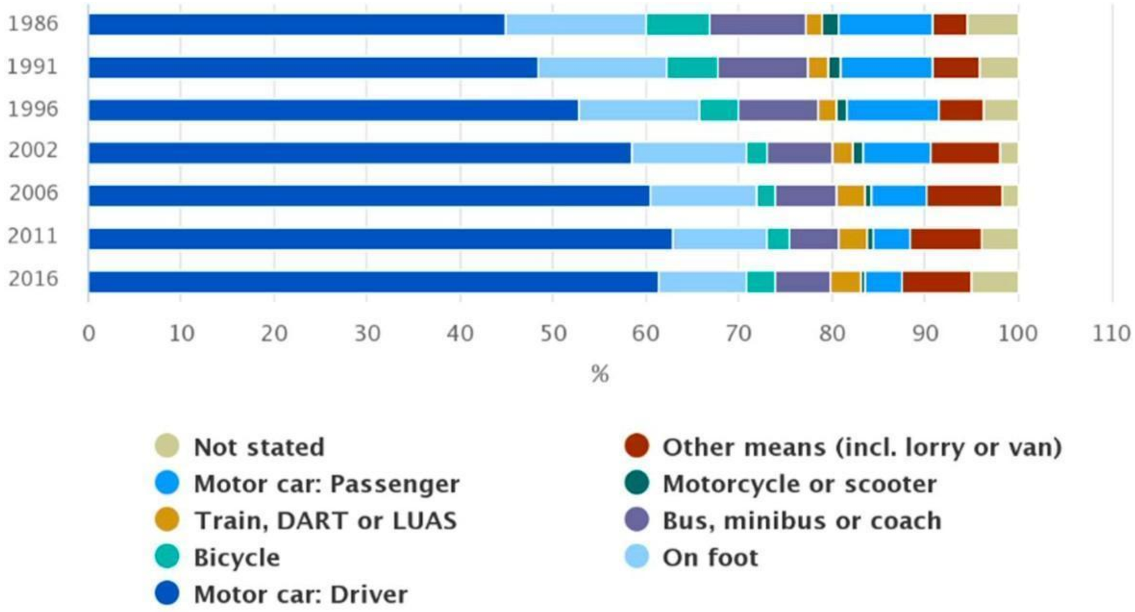


Figure 1.2: Means of Travel of Working Commuters Ireland

EVs are powered by batteries which store charge and release it as direct current which is either inverted or regulated to power the drivetrain. Most full EVs charge at a level of 400 V to 800 V or for Plug- in Hybrids 100 V to 200 V. The car's on-board Battery Management System (BMS) communicates this voltage as well as current flow and sometimes battery temperature to the charge point if it is DC. When using the AC charge socket on an EV, the EV takes the voltage at distribution level; 230 V single phase or 400V three phase and utilises the lower powered on-board charger.

In the early 2000s, the Irish government decided that ESB Networks would be best suited to install and manage public charge points. The first wave of these points is currently seeing upgrades from 3.7 kW and 22 kW chargers to 50 kW DC fast chargers. This upgrade has been further reinforced by the announcement by the government of a €20 million investment in a further 50 kW DC fast chargers.

As Ireland moves to meet its Paris Climate Change Agreement commitments, the transport system, private and public, constitutes scope for a 20% reduction in national carbon emissions. Due to the dispersed nature of the Irish population, the elective private vehicle will be a major additional load to the electricity distribution system as the country moves away from fossil fuels. Private EV charge trends have shown when uncontrolled, that they tend to compound the typical consumer electricity ramp in the evening time.

Understanding the impact of EV charging points on the campus networks will be vital for sustainable and secure development. The University recognises that the availability of charging points on the campus may be a factor in the decision-making of its population.

2

Local Infrastructure

2.1. Introduction

The UCD Belfield Campus significantly contributes to the quality of life in Ireland by acting as a hub for education, research and innovation. It is a large area in the centre of Dublin 4 where more than thirty thousands of people use to spend their working days. The area and associated activities, such students coming from abroad, events and accommodations have a major positive impact on the Irish economy. The campus contains publicly accessible sports and recreation facilities within its open landscape and hosts events throughout the year. A high volume of visitors occupy the campus year round, particularly from September to May. Extensive infrastructure is in place to meet the resulting energy demand for heat and electricity, and to facilitate commuters.

2.2. Heat

Integrated and localised energy systems are employed to supply heat to the Belfield Campus. The District Heating Network (DHN) connects sixteen of the campus buildings to a central Energy Centre, as shown in Figure 2.1. Heat is transported through the supply and return pipe networks. The buildings are connected in series, with a sub-network fed through the science district. The heat transported through the DHN is generated in a centralised Energy Centre. The Energy Centre contains six generation units, including two gas powered combined heat and power (CHP) units, three gas boilers and one biomass generator. At present, the biomass unit is not in operation. Table 2.1, presents a summary of the DHN Energy Centre generation units. The schedule position indicates how the generators are dispatched to meet the demand.

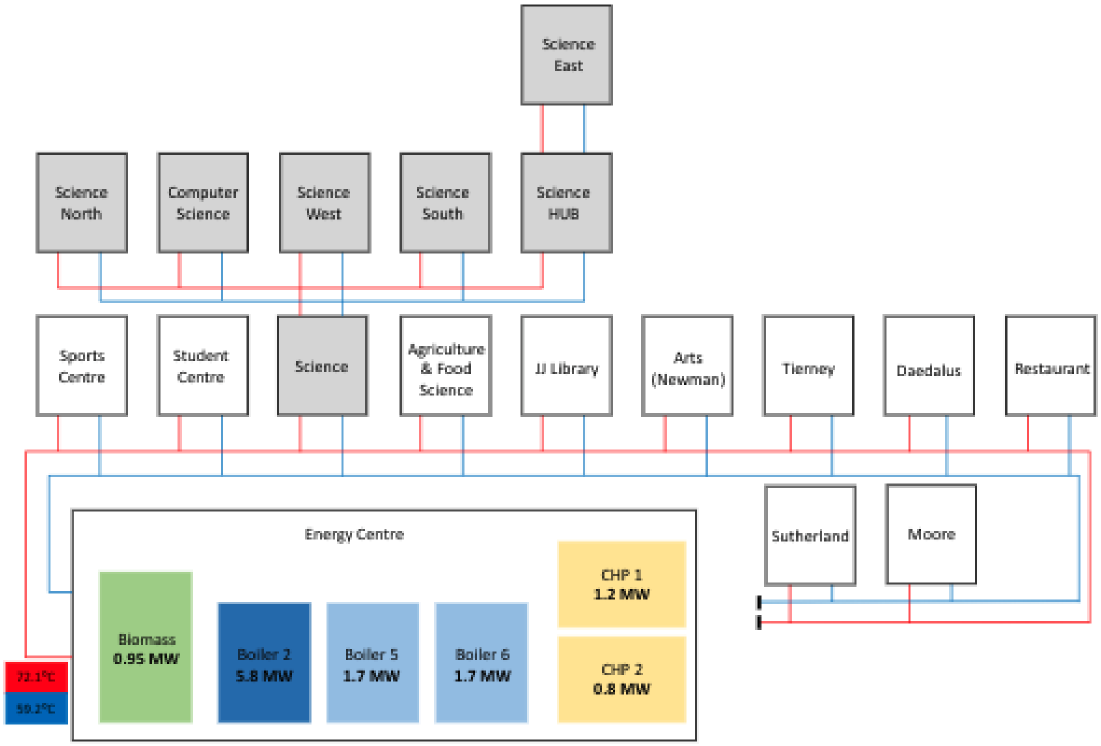


Figure 2.1: Schematic of Campus District Heating Network

Table 2.1: District Heating Network Energy Centre Generators

Name	**Capacity (MW)**	**Fuel**	**Electrical Effi-ciency (%)**	**Thermal Effi-ciency (%)**	**Schedule Position**	**Note**
CHP 1	1.2	Gas	43.6	43.3	1	Heat is the primary output
CHP 2	0.8	Gas	43.6	43.3	2	Heat is the primary output
Boiler 5	1.7	Gas	-	90	3	-
Boiler 6	1.7	Gas	-	90	4	-
Boiler 2	5.8	Gas	-	80	5	-
Biomass Boiler	0.95	Biomass	-	90	6	OFF currently

Localised heat generation, typically in the form of a gas boiler, supplies the remaining campus buildings. Two of the buildings have further heating capacity from local gas powered CHP units. Five of the buildings currently connected to the DHN have a share of their heat demand supplied by a local gas boiler.

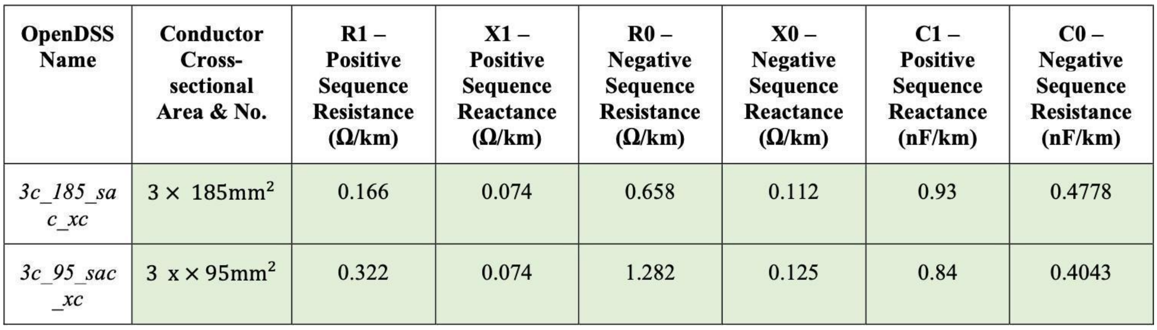
2.3. Electricity

The main source of electricity for the campus is the national electricity grid. The CHP units are primarily employed to provide heat, however, they produce some electricity. Two of the academic buildings have a roof-mounted solar PV array, with a capacity of 10 kW each that assists in meeting the electricity demand.

The UCD Belfield Campus has a 10 kV connection via an ESB 38 kV station to the Dublin MV Net- work. From the main switchgear at the ESB substation, four 10 kV radials distribute power throughout the campus. These can be meshed manually at various points in order to facilitate maintenance. Each distribution substation employs either ABB SafeRing, Moeller GAE or Merlin Gerin RN2 gas insulated switchgear which have a one fault lifespan. The cables used across campus for the 10 kV runs are un- derground 3-core with 185 mm^2 or 95 mm^2 conductors. Some runs are armoured, as they are directly buried, while others are unarmoured and run in the campus' service tunnels or dedicated cable ducting. The system has 31 MV buses including the ESB supply bus, of these 27 have step-down transformers connected to distribute three-phase 380V single-phase 230V to the buildings on campus. Not all buses are exclusively load buses, there is 3.4 MWe of CHP currently installed at three locations on campus. There is also 239 kW of solar PV installed across the academic and residential buildings.

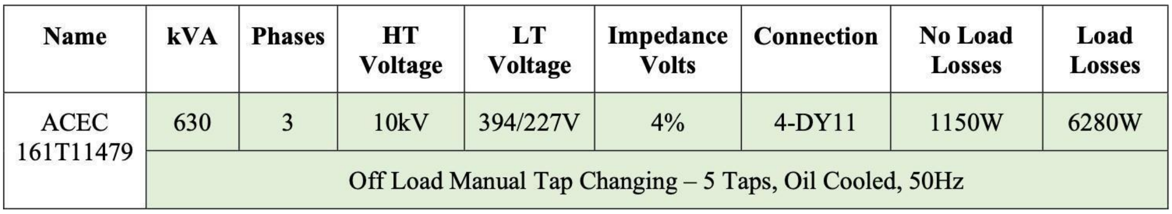
The Distribution System has been modelled using OpenDSS, a comprehensive electrical power system simulation tool primarily for electric utility power distribution systems developed by the EPRI. The two types of line used in the UCD MV network were modelled as in Figure 2.2. There are 63 lines in use in the campus on a daily basis, there are another four which are installed as redundancy to be manually switched in order to allow back-feeding from other feeders if an outage occurs or works are being carried out. The process of using these cables requires resetting of relay settings to account for power flow from a different direction.

Of the 63 lines modelled, 30 connect the busbars in the main substations to their adjacent substations and the other 33 connect the cabinet in the substation to the distribution transformer. Approximate line lengths for the main feeder were estimated using geographic locations of substations. It was assumed that the lines between the substations and distribution transformer were 15m, this was on the basis that all transformers on the campus are located in the substations and this was deemed a reasonable length to traverse the small substations.



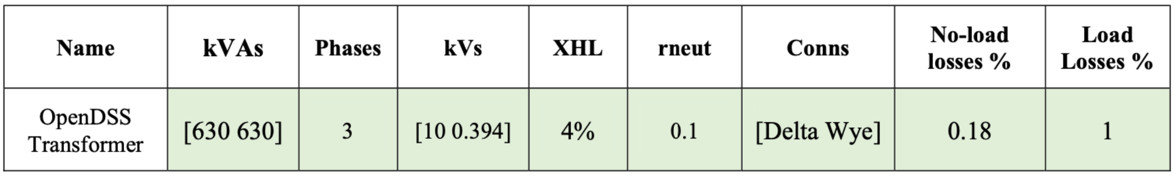
OpenDSS Name	Conductor Cross-sectional Area & No.	R1 – Positive Sequence Resistance (Ω/km)	X1 – Positive Sequence Reactance (Ω/km)	R0 – Negative Sequence Resistance (Ω/km)	X0 – Negative Sequence Reactance (Ω/km)	C1 – Positive Sequence Reactance (nF/km)	C0 – Negative Sequence Resistance (nF/km)
3c_185_sac_xc	$3 \times 185\text{mm}^2$	0.166	0.074	0.658	0.112	0.93	0.4778
3c_95_sac_xc	$3\ \text{x} \times 95\text{mm}^2$	0.322	0.074	1.282	0.125	0.84	0.4043

Figure 2.2: OpenDSS Line Definitions



Name	kVA	Phases	HT Voltage	LT Voltage	Impedance Volts	Connection	No Load Losses	Load Losses
ACEC 161T11479	630	3	10kV	394/227V	4%	4-DY11	1150W	6280W
	Off Load Manual Tap Changing – 5 Taps, Oil Cooled, 50Hz							

Figure 2.3: Transformer Specifications of Model Used



Name	kVAs	Phases	kVs	XHL	rneut	Conns	No-load losses %	Load Losses %
OpenDSS Transformer	[630 630]	3	[10 0.394]	4%	0.1	[Delta Wye]	0.18	1

Figure 2.4: Transformer Model Employed in OpenDSS

There are a number of different transformers in use across campus, varying in age from one to over fifty years old. Many of the older transformers were manufactured by ACEC in County Waterford who also manufactured for the ESB rural and urban electrification schemes from the 1950s. These transformers are located in the buildings built between 1962 and 1979 such as some of the Science Block, Newman Building, Main Restaurant, Tierney Building, Boiler house, Ardmore and James Joyce Library. The nameplate parameters for these are shown in Figure 2.3.

They vary in size from 200 kVA to 2,500 kVA and step-down from 10 kV to 394 V nominal at tap setting one. Given the large number of this type of transformer present on campus and that distribution transformer parameters have been relatively static for the last fifty years, an example of how the transformers were modelled in OpenDSS can be seen in Figure 2.4. The completed model of the electricity network can be found in Figure 2.5.

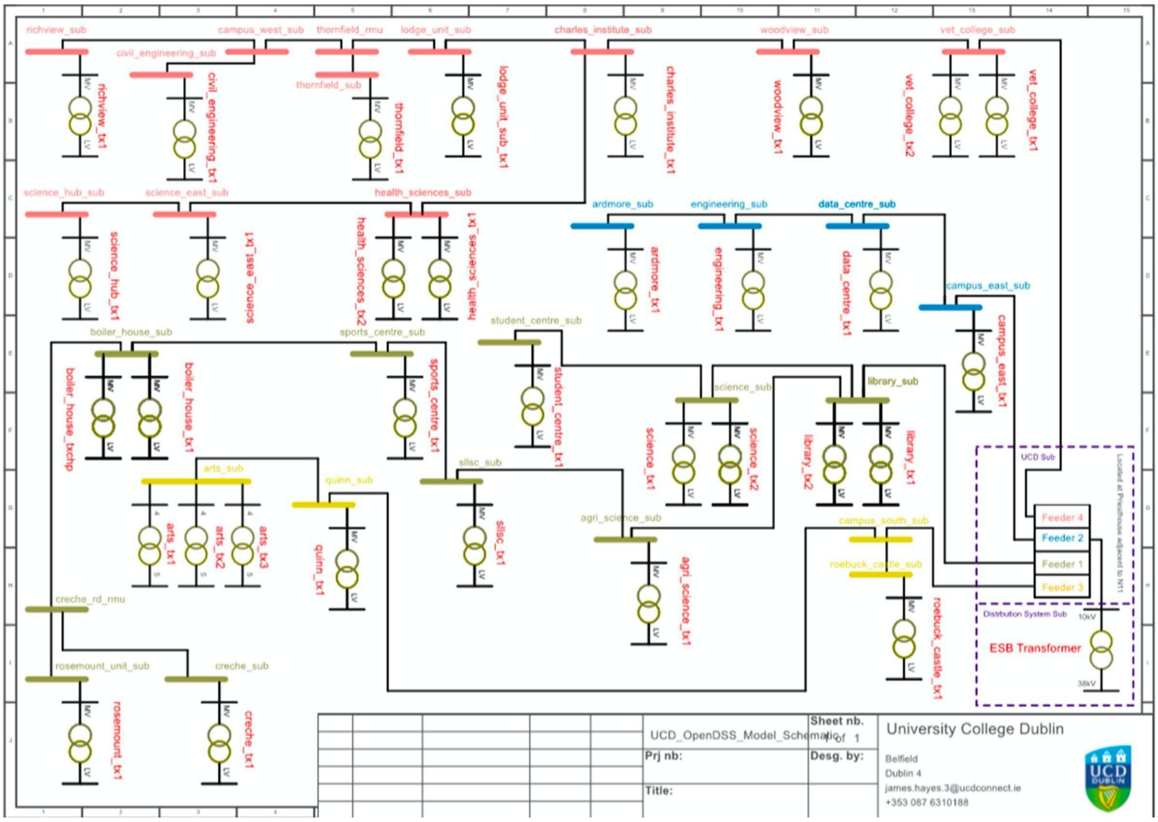


Figure 2.5: Electricity Model

2.4. Transport

Transport options within the core of the Belfield campus are limited to walking and cycling. Therefore, the major energy consumption in the transport sector is a result of the population commuting to the campus daily. Figure 2.6 highlights the pedestrian core of the campus, with the car parks located around the periphery. UCD continuously encourages the use of public transport, cycling and walking to access the campus, constructing a new bus terminus and parking facility and engaging in awareness campaigns. A survey carried out by University Estate in October 2019 found that over 22,000 pedestrian movements, two-way, and 6,000 cycle movements were recorded entering and exiting the campus between 07:00 and 19:00 hours. Approximately 55% of the pedestrian movements were through the main entrance on Stillorgan Road, a significant number of which were to and from the southbound and northbound bus stops.

There are 3,368 car parking spaces at the Belfield Campus, including both permit and visitor parking. Of these spaces, 7 are reserved as electric car charging points. During peak times, 08:00 to 09:00 hours, approximately 1,200 vehicles enter the campus, with 850 exiting between 17:00 and 18:00 hours. The survey from 2019 showed a decrease in private car traffic of 9% since 2015, despite the steadily growing population and the trend of increasing commuter distances. Cycling as a mode of transport to the campus has also decreased since 2015, while pedestrian access has seen an increase, likely due to a switch to public transport. Areas that have been investigated for the addition of EV charging points can be found in Figure 2.7

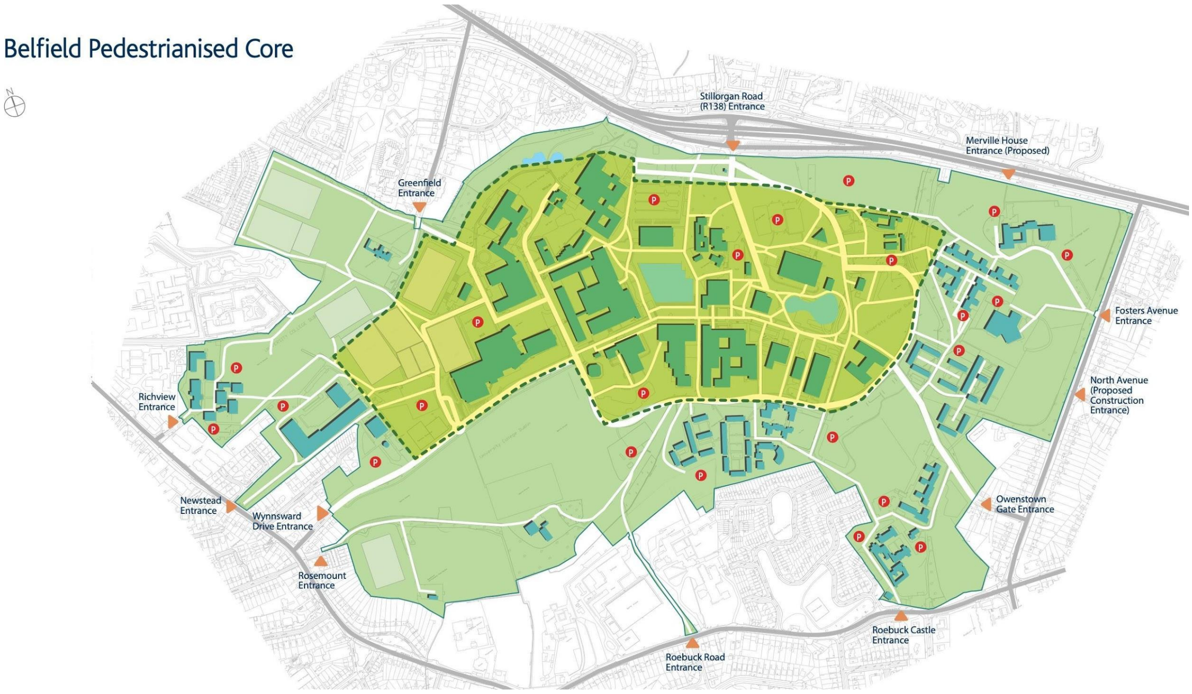


Figure 2.6: Pedestrian Core and Car Parks at Belfield

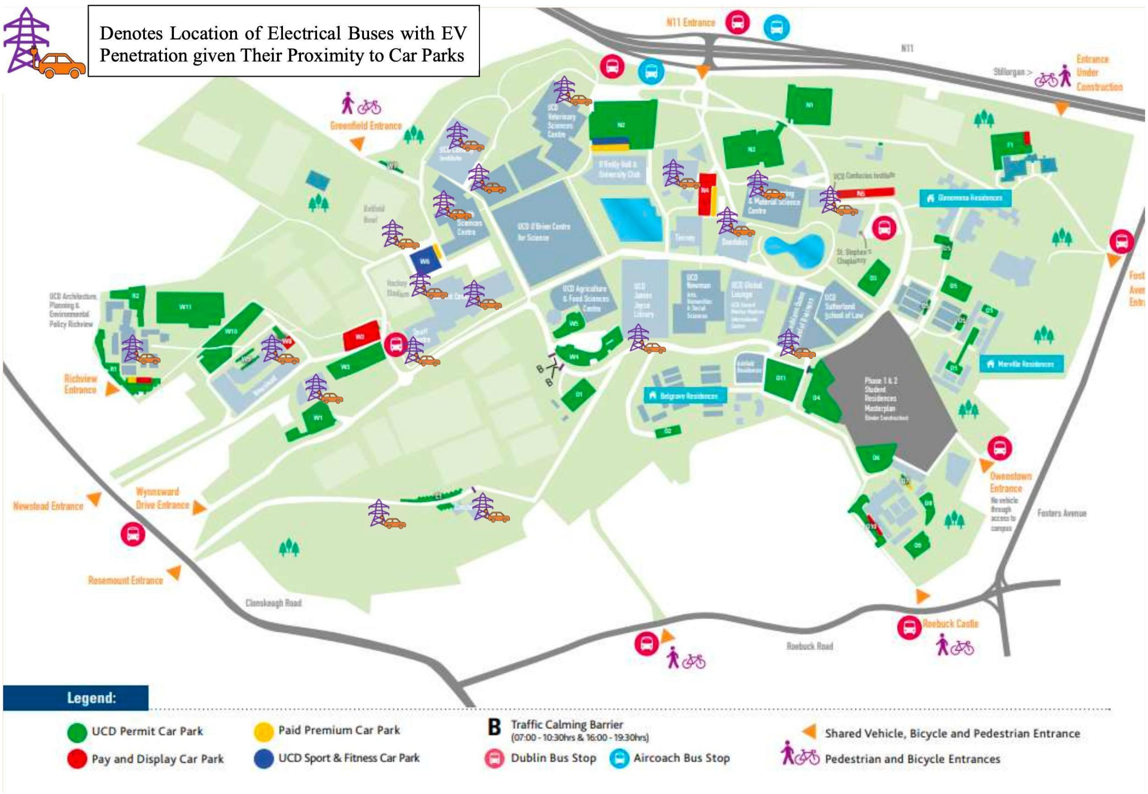


Figure 2.7: UCD Carparks

3

Characterisation of the Community

3.1. Overview

Before the pandemic, Belfield was experiencing a large number of visitors daily, particularly during the academic year. The high footfall experienced is not only attributed to academia, but also to sports, recreation and events. Three distinct character areas have been identified within the campus, shown in Figure 3.2. These areas include education, research and innovation; sports and recreation; and residential. Although these areas are interconnected, identifying the distinct zones allows the SEC to consider the unique identity and needs of each space. Each character area has a primary use, along with complementary and supporting uses as needed. These character areas are individually connected through walking and cycling green routes. The car parks are located at the periphery of the Belfield campus, leaving the core of the campus as a pedestrian and cycle zone only.

3.2. Population

The number of people attending the campus varies daily and includes students, staff, faculty and visitors. This number is expected to grow over the coming years. The campus population is diverse, with 136 nationalities within the student body, and changes every year. Therefore, it is vital that sustainability is embedded in the ethos of the university, ensuring that it is carried throughout the years.

The 2018/2019 academic year saw approximately 29,300 students enrolled in UCD, excluding those operating remotely or off-campus. The full-time equivalent academic staff reached approximately 1,700, with 1,900 additional support staff. While campus accommodation is available for a portion of the students,

Figure 3.1: University College Dublin, Belfield, Dublin 4

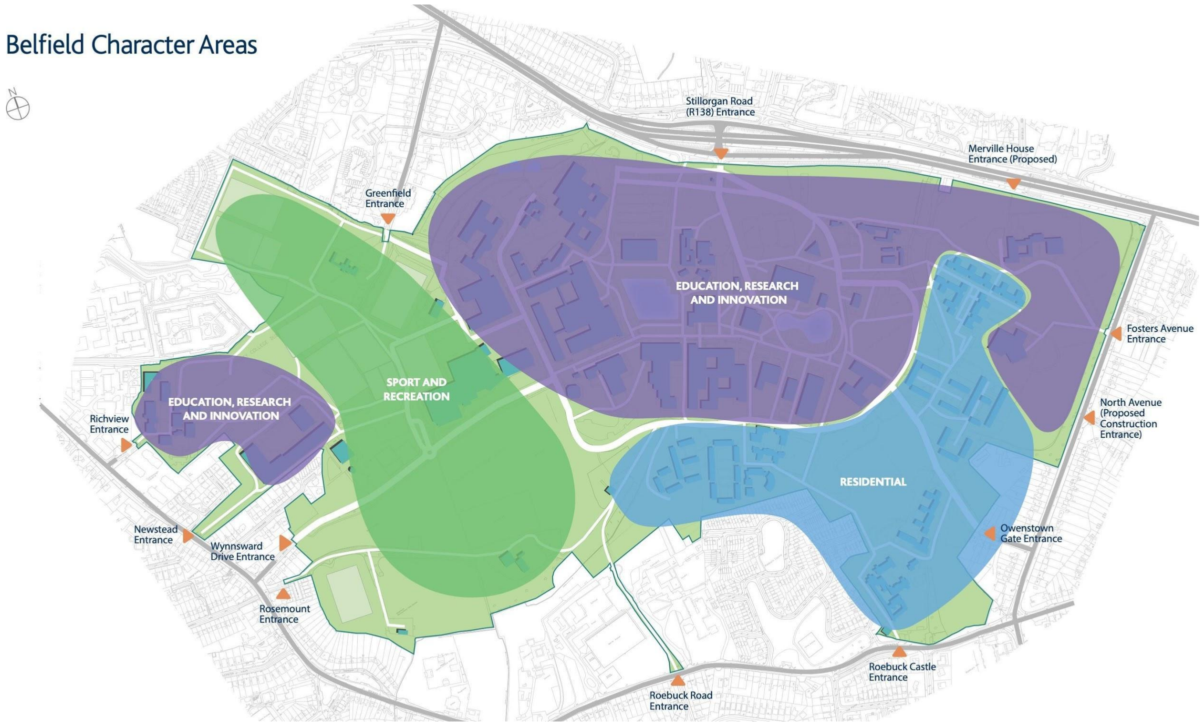


Figure 3.2: Character Areas, Belfield, Dublin 4

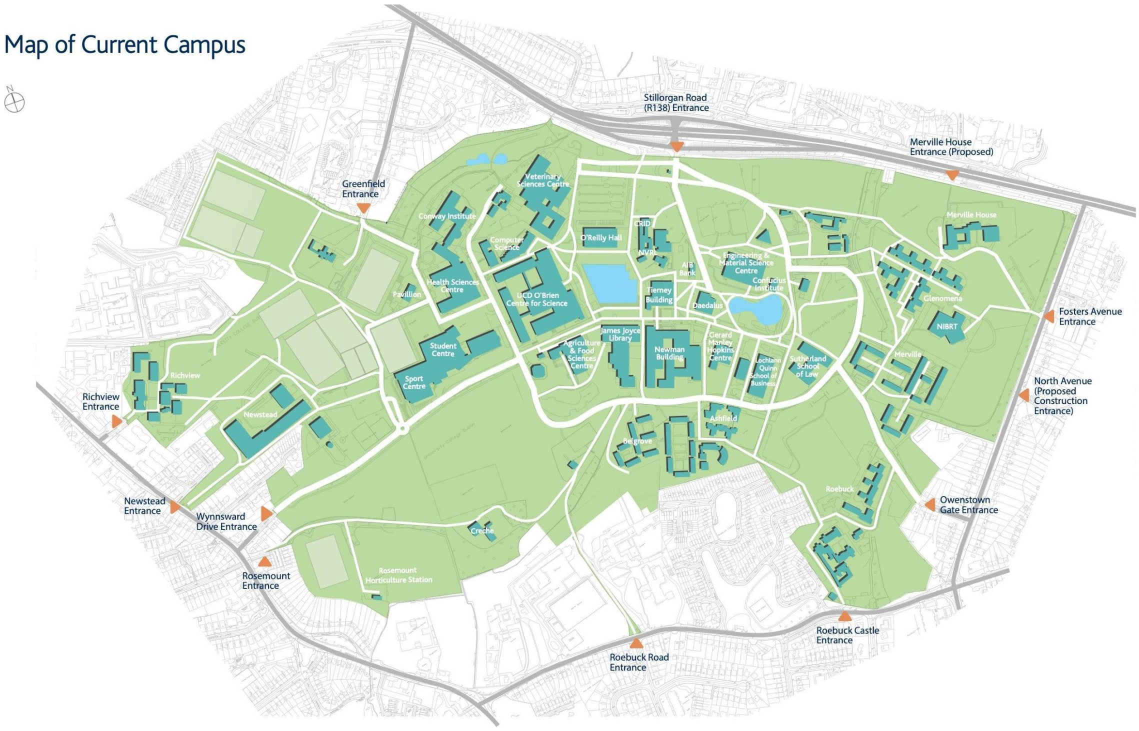


Figure 3.3: Belfield Campus Amenities

the majority of the population commute to and from Belfield daily, making it one of the largest originators of journeys in the Greater Dublin Area.

3.3. Amenities

The Belfield campus hosts a diverse range of publically accessible facilities for education, research, sports, recreation and cultural use. Figure 3.3 presents a map of the area. At the core of the campus are the academic buildings, shared among six colleges, including Arts and Humanities, Business, Engineering and Architecture, Health and Agriculture, Social Sciences and Law, and Science. Each college has dedicated lecture halls, offices, research facilities and recreation amenities. The Belfield Campus is unique in its range of services, offering gyms, a swimming pool, playing pitches, woodland walks, exhibitions and cultural facilities, along with shops, restaurants and coffee shops. The campus amenities are spread across 133 hectares of woodland, with the academic core surrounding two lakes. The buildings are connected through pedestrian and cycle paths, with the roads limited to the periphery of the area.

Over a third of the building stock in Belfield was constructed during the 1960s and 1970s, 34% of which are in need of major refurbishment. UCD faces the challenge of improving the sustainability of these buildings and accommodating the growing demand for campus services, while also working with limited space availability and the goal of preserving the existing green areas. A modernisation programme is under development to carry out the necessary refurbishments, aiming to utilise existing structures where possible and to minimise adding to the embodied energy of the building stock.

New builds will continue to be carried out to high standards of sustainability in terms of the entire life- cycle of the building. Most recently, the UCD O'Brien Centre of Science extension received a BREEAM Excellent award for sustainability and the new residences were constructed to Passivhaus standard. The Belfield campus is home to state-of-the-art sports and recreation amenities, centred around the new UCD Student Centre constructed in 2012. The centre contains a 50 metre Olympic swimming pool and gymnasium, along with cinema, drama and debate facilities. The surrounding area consists of multiple grass and all-weather playing pitches. The facilities are available to students and to club members, attracting a high volume of visitors daily.

3.4. Environment

The Belfield campus boasts a unique landscape with a woodland setting providing a site that is rich in biodiversity and is home to a wide variety of flora and fauna. UCD aims to seamlessly integrate the natural and built environments to create a campus that meets the needs of its population, while also retaining its open character and providing access to green spaces. There is active tree management underway at Belfield, more than doubling the number of trees on site since 1998.

4

Energy Modelling

4.1. Introduction

The SEC team has developed an extensive energy modelling of the campus area to extrapolate a baseline energy analysis and to investigate the impact of potential future scenarios on the campus CO_2 emissions. The Intelligent Virtual Network (iVN) from Integrated Environmental Solutions (IES) has been used to create a virtual representation of the UCD Belfield Campus, complete with both the heating and electricity networks. The logic employed in creating the model was to assign a heat and electricity demand profile to each of the campus energy users and to include the generation units based on their type, capacity, efficiency and the general dispatch priority list. For each simulation run, the model matches the generation to the demand. The aim for the baseline model was to achieve a generation profile that best replicates the running of the campus. Subsequently, network changes and optimised dispatch could be included in scenario investigations to highlight where energy or emissions savings could be made.

4.2. Campus Energy Model

The campus energy model has been developed and calibrated based on energy data provided through the Building Management System (BMS). The extensive metering system provides real time-series data, recorded in fifteen minute intervals and stored on an ESB dashboard. The data for 2019 has been used to assign heat and electricity demand profiles to each of the campus buildings. Figure 4.1 shows the three-dimensional (3D) model of the campus, with the buildings inside the UCD boundary shown in yellow. Both on-site heat and electricity genera- tors were added to the model as network assets based on their capacity and efficiency specifications. A two-dimensional (2D) view of the completed campus model can be seen in Figure 4.2.

Figure 4.1: Full Campus 3D Model

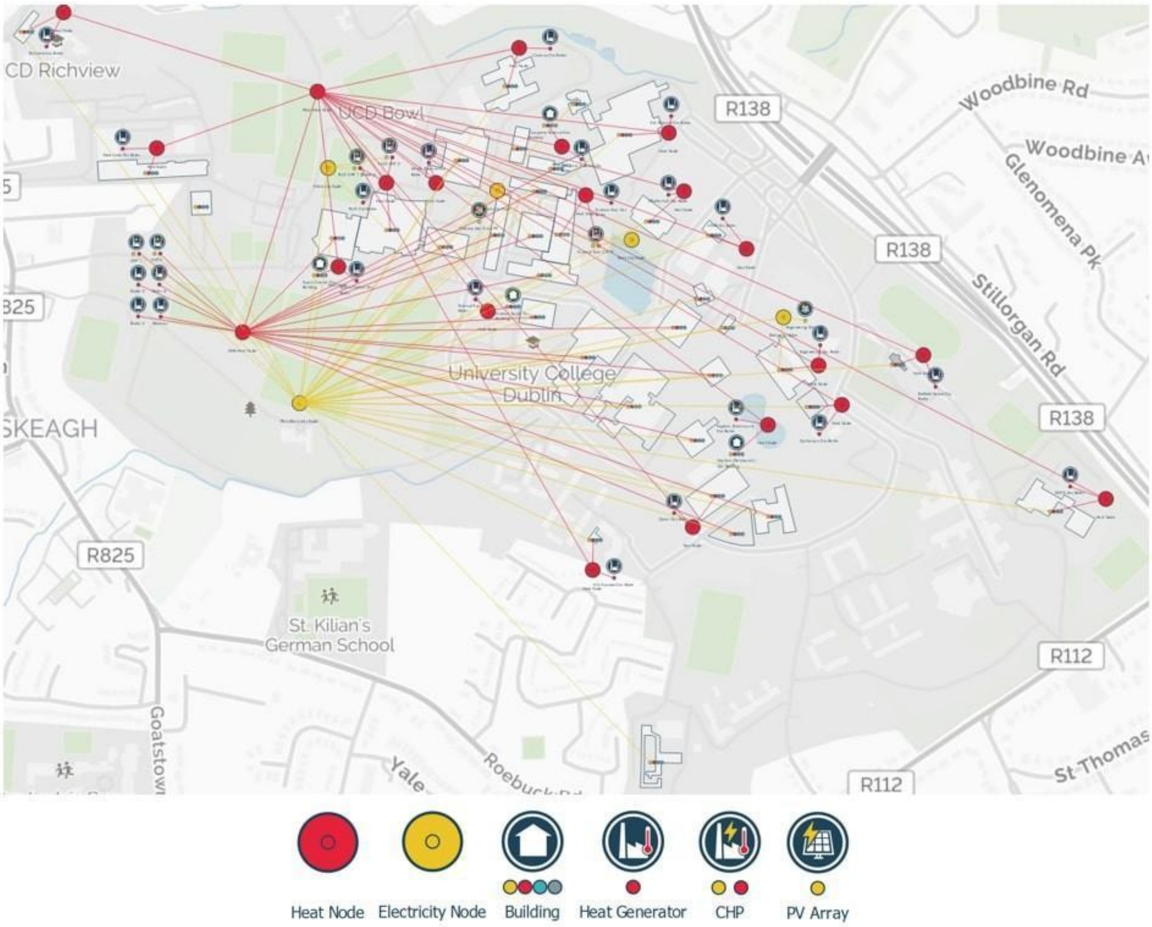


Figure 4.2: 2D Baseline Model of the UCD Belfield Campus

Each red asset in Figure 4.2 represents a heat node while electricity nodes are in yellow. Simulations in the iVN work by matching the supply to the demand at each node. The main heat node is considered to be the parent heat node and is the location where all of the child nodes, are those which have generators or consumers, or both, connected to them, meet.

Table 4.1: CO_2 Emissions Factors of Fuel Types

Fuel Type	**Emissions Factor kg CO_2/ kWh**
Natural Gas	0.203
Biomass	0.025
Electricity (Grid)	0.409

A schedule is required at each heat and electricity node to assign a priority list for generator dispatch. The generation units are also assigned a minimum load requirement, below which they will not turn on. They will then generate at any level required between this minimum and their rated power output. Solar PV panel electricity generation is calculated based on its specified capacity and the chosen weather file. If the connected generators do not have sufficient capacity to cover the load, the model can be instructed to do one of two things:

1. Acquire the remaining heat or electricity demand from an external source.
2. End the simulation with a shortfall in heat or electricity supply, meaning not all of the demand is met.

In the case of electricity, the first option is suitable as it is possible to import electricity from the grid. On the other hand, there is no external source of heat entering the campus and thus the second option was selected. Therefore, it is not possible for a simulation to present a shortfall in electricity, as the last source on the priority list is always the electricity grid. However, there is no such back-up source for heating and thus the balance of supply and demand must be checked.

The model calculates the CO_2 emissions produced by multiplying the energy used by the emissions factor for the fuel type. The CO_2 emissions factors of the fuel types have been reported in Table 4.1 [21]. Electricity generation from solar PV is considered to have no associated emissions factor in this analysis, as a full life-cycle analysis of all generators has not been undertaken.

4.3. Model Calibration

Calibration of the campus energy model was carried out using the metered energy data from the BMS. As the demand profiles were assigned directly from this data, only the supply side required calibration. This process focused on the CHP units in the DHN Energy Centre as they are the key sources of heat for the campus. Furthermore, as heat is the primary output of the CHP generators, the calibration process focused on matching this to the metered heat output. Combining the two CHP units, the comparison between the simulated and measured heat generation can be seen in Figure 4.3.

The simulation data follows more of a consistent pattern, while the metered data is clearly impacted by more than a set priority list. For example, April and May show the largest deviation from the actual

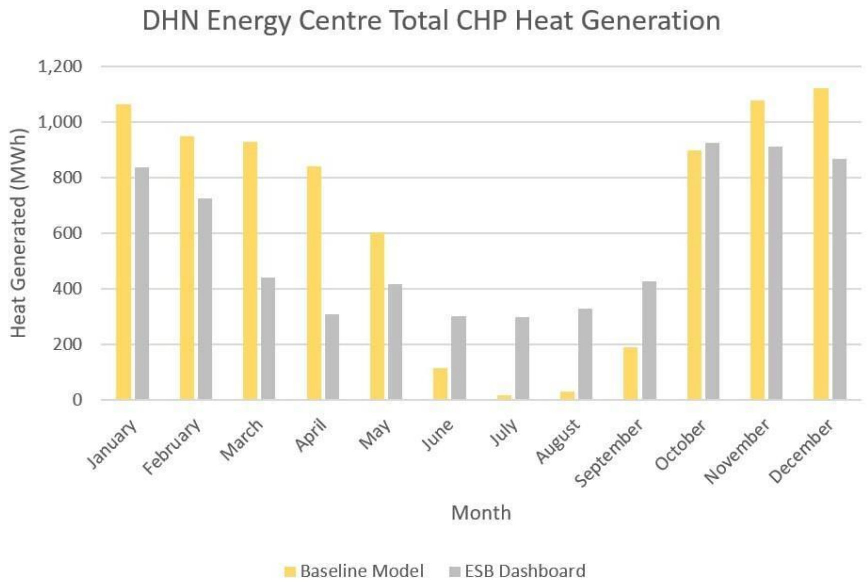


Figure 4.3: Calibration Results for DHN Energy Centre CHP Heat Generation 2019

heat generation. This is due to one of the CHP units being turned off for maintenance. Given the reliance on a set dispatch list for the duration of the simulation, it is impossible for the model to predict these times of unplanned shutdown. Furthermore, the BMS opts to rely solely on the second CHP unit during the summer, either searching for loads to supply or dumping excess heat where necessary. In the simulation, however, the CHP units will only turn on if the demand reaches their rated heat output. The summer load was often lower than required and the simulation dispatched the boilers to avoid running the CHP at part load.

ASHRAE acceptance criteria, typically employed for building models, was applied to the district model for calibration. In particular, the Mean Bias Error (MBE) was used, shown in Equation 4.1 [15].

$$MBE(\%) = \frac{\sum_{i=1}^{N}(m_i - s_i)}{\sum_{i=1}^{N} m_i} \qquad (4.1)$$

In this equation, m_i and s_i are the measured and simulated output respectively. The number of data points in the interval is denoted by N. A limit of 5% is considered to be acceptable. The totals for the year, both from the simulation and the metered data, have been included in Table 4.2. This table also shows the extent to which the modelled campus deviates from the actual performance. Using the ASHRAE criteria, Equation 4.1, the MBE for the DHN Energy Centre CHP units was calculated for the year. The total result can be seen in Table 4.3. The value for the MBE is within the specified range and therefore the model is calibrated and is considered to be suitably representative of the heat and electricity networks of the campus.

Table 4.2: DHN EC Total CHP Heat Output 2019

	ESB Dash- board (MWh)	**Baseline Model (MWh)**	**Difference (MWh)**	**Percentage Difference from Actual**	**MBE**
Heat	6782.59	7826.80	+1044.20	+15.40 %	-3.53 %

5

Energy Baseline

Introduction

The baseline analysis depicts the current energy demand which is the sum of electrical and thermal demand. In the baseline analysis, CO_2 emissions are categorised as being from heat generation using natural gas, or electricity sourced from the grid. This is due to the fact that all CO_2 emissions from the CHP units are considered to be associated with heat production, to avoid double counting, and that the biomass unit is currently off. Three levels of analysis were carried out on the baseline simulation; high-level, building-level and generator-level.

High-Level Analysis

The high-level analysis involved studying the campus as a whole and calculating the breakdown of energy consumption, energy generation and the associated CO_2 emissions. Figure 5.1 shows the total campus energy consumption for 2019 on a monthly basis, broken down into electricity and heat consumption, along with their total annual shares. Figure 5.1 shows the electricity consumption remains relatively stable throughout the year, decreasing slightly during the summer months. On the other hand, heating shows more seasonal variation which is to be expected. Heating accounts for just over half the total energy consumption of the campus. The corresponding CO_2 emissions can be seen in Figure 5.2.

Based on this analysis, the heating sector accounts for the greatest portion of the CO_2 emission produced on the campus and therefore would be targeted by reduction measures.

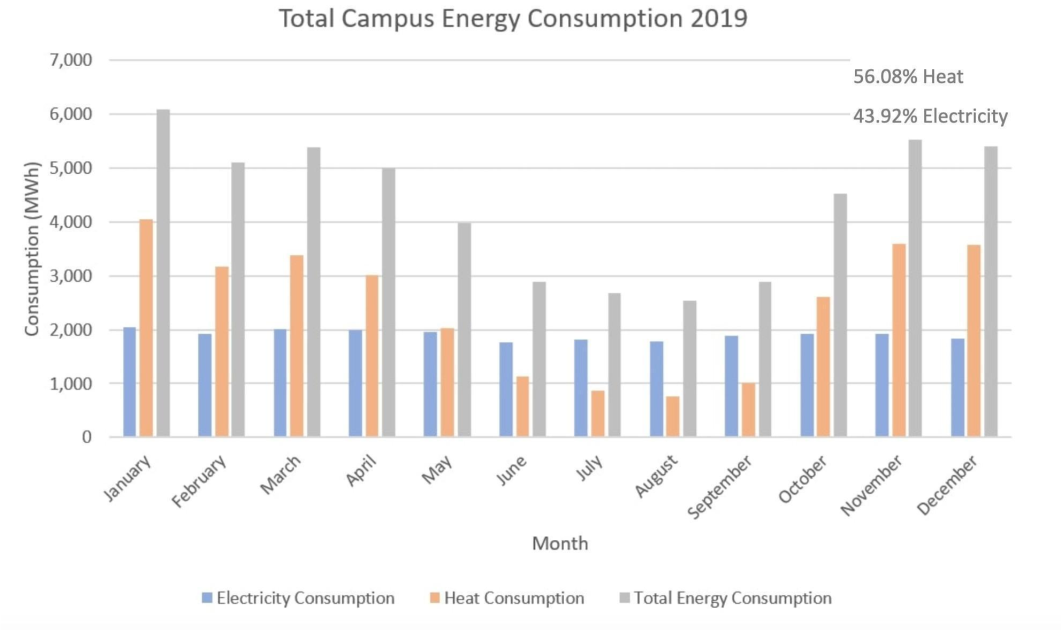


Figure 5.1: Total Campus Energy Consumption 2019

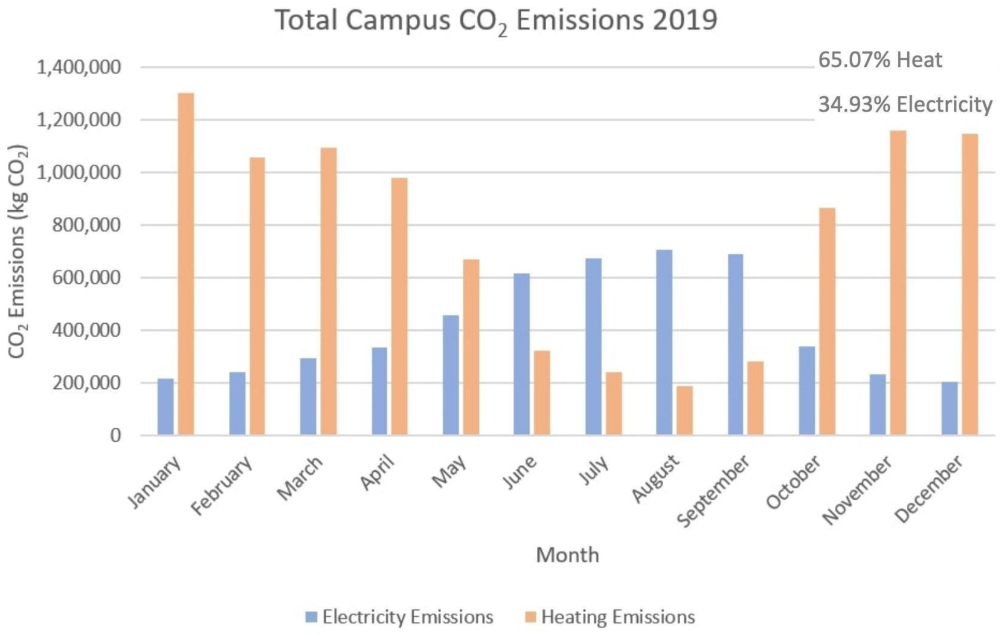


Figure 5.2: Total Campus CO_2 Emissions 2019

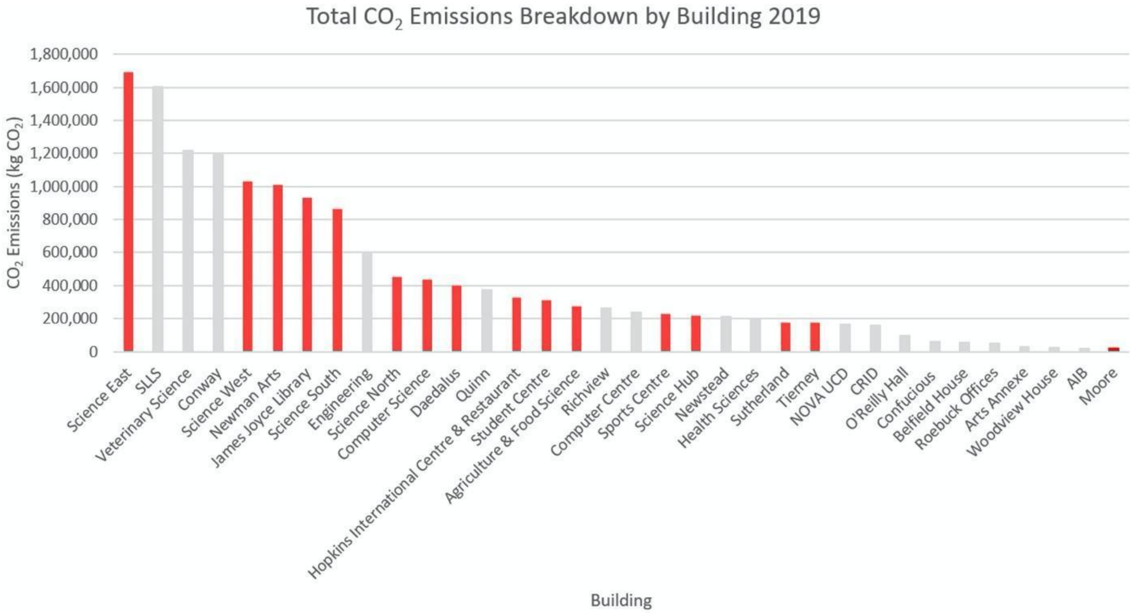


Figure 5.3: Building CO_2 Emissions 2019

5.3. Building-Level Analysis

The baseline analysis was extended to identify the key buildings responsible for the campus CO_2 emissions. The emissions are quantified based on the amount of CO_2 emitted to generate and supply the energy demand of the building. It was found that six of the top ten CO_2 producing buildings are currently connected to the DHN, shown as the red data in Figure 5.3. This indicates that decarbonising the DHN Energy Centre supply would result in widespread CO_2 emissions reductions. Furthermore, replacing or installing a system in the Energy Centre would be less disruptive than tackling individual buildings that are in use and must be less cost-intensive than adding multiple new units elsewhere. Therefore, a clear first step would be to improve the current DHN supply.

6

Options Appraisal

6.1. Scenario Development

The analysis of the baseline provided a breakdown of the campus CO_2 emissions. Each of the three levels of analyses informed the scenario selection process:

1. The breakdown of overall CO_2 emissions from the high-level analysis indicated whether the electricity or heating sector required the most attention.
2. The building-level analysis identified which buildings are currently generating the greatest CO_2 emissions, and therefore may achieve the most significant reduction if targeted for decarbonisation.
3. The generator-level analysis determined which form of generation contributed most to the CO_2 emissions, taking into account the level of production of useful energy.

Once the target areas had been identified, the scenarios were created. The aim was that each scenario would build on the previous, making changes to network configurations, generators installed or dispatch schedules. The scenario development process was based on a literature review, the baseline analysis and the information from UCD Estate Services to investigate the impact of realistic, achievable upgrades to the campus networks.

An overview of the baseline and the scenarios modelled can be seen in Figure 6.1. Five scenarios have been explored, two of which have sub-variations. The generators pictured are those which are operating from the DHN Energy Centre. The first measure chosen was to remove the local gas boilers from the buildings connected to the DHN and to allow the network to provide all of their heating requirements. UCD Estate Services have already agreed to this measure to improve efficiency in 2021 and move towards decarbonisation. This was maintained throughout subsequent variations. Scenarios two to four then vary based on generators installed and the dispatch schedule in the EC.

The fifth scenario investigates the potential for solar PV on the campus to increase the emissions reduction. The capacity of solar PV was calculated by using Google Earth to estimate the total roof area of the buildings involved in the analysis. Based on the literature review, an utilisation factor of 0.3 for the roof, and a capacity factor of 0.102 kWp/m^2 for the panels, were employed [9].

The scenarios were modelled by creating variants of the baseline in the iVN software and making the necessary changes to the networks. In each case, the demand was maintained at the current level to ensure a fair experiment. A check was carried out to confirm that the new configuration had sufficient capacity to meet the campus demand. A model variant was created for each scenario and the simulation results for 2019 compared based on the CO_2 emissions associated with electricity and heat consumption.

6.2. Detailed Scenario Analysis

6.2.1. Scenario 1

The change from the baseline in the first scenario is that the five local gas boilers in the buildings currently connected to the DHN have been removed. The full heat demand is now supplied through the DHN. Local CHP units in these buildings, where applicable, are still present. This measure was chosen as it has been agreed by UCD Estate Services to be one of their next steps towards decarbonisation.

6.2.2. Scenario 2

As in the first scenario, Scenario 2 has the local gas boilers in the DHN-connected buildings removed. Additionally, the current 0.95 MW biomass unit has been turned on. Two variations of the second scenario exist, which differ based on the priority schedule in the DHN EC.

- Scenario 2 has the biomass generator at the top of the dispatch order, followed by the two CHP units and the gas boilers.
- Scenario 2.A keeps the two CHP units at the top of the dispatch order, followed next by the biomass generator and finally by the gas boilers.

These two variants were chosen to investigate whether the lower emissions factor of the biomass unit or the dual production from the CHP units resulted in lower overall CO_2 emissions.

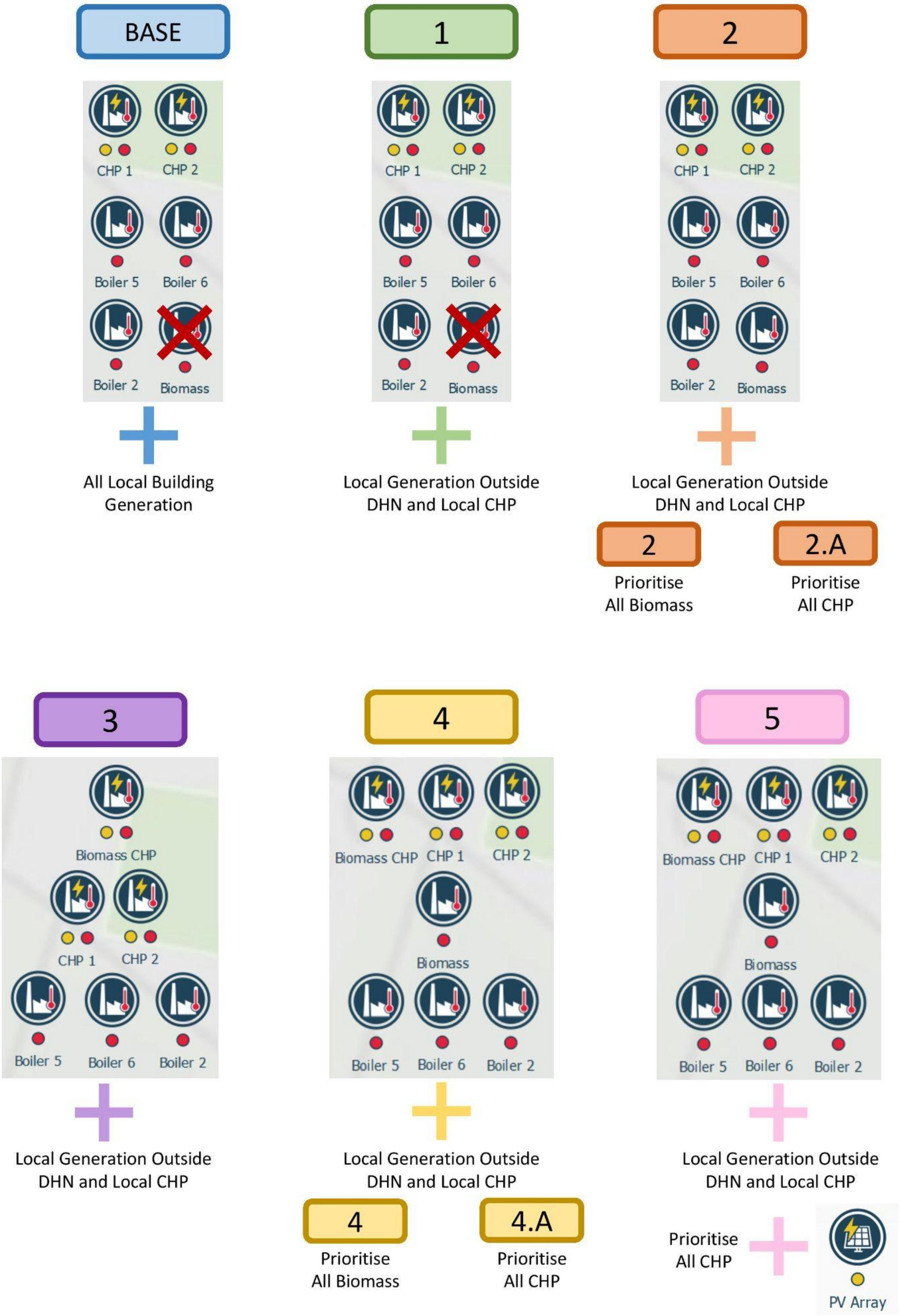


Figure 6.1: Summary of Scenarios Tested

Table 6.1: Biomass CHP Unit Efficiency Specifications

Parameter	Value
Electrical Efficiency Minimum Output	0.22
Electrical Efficiency Rated Output	0.22
Thermal Efficiency Rated Electricity Output	0.76
Thermal Efficiency Minimum Electricity Output	0.76

6.2.3. Scenario 3

As in the previous scenarios, the local gas boilers in the DHN-connected buildings have been removed in scenario 3. The current biomass boiler has been replaced by a biomass CHP unit with a rated heat output of 900 kW and a rated electricity output of 600 kW. This biomass CHP generator has been placed at the top of the priority dispatch list, followed by the current baseline sequence. The efficiency specifications for the biomass CHP unit can be found in Table 6.1, obtained from the supplier data sheet [18].

6.2.4. Scenario 4

Scenario 4 investigates the impact of adding the biomass CHP unit from scenario 3 while also keeping the current biomass unit in operation. There are two variations which differ based on the priority schedule in the DHN EC.

- Scenario 4 has the two biomass units at the top of the dispatch order, followed by the two gas CHP units and the gas boilers.
- Scenario 4.A has the three CHP units, one biomass and two gas, at the top of the dispatch order, followed next by the biomass generator and finally by the gas boilers.

These two variations were explored to determine which configuration offered the greatest emissions savings.

6.2.5. Scenario 5

Scenario 5 was developed following an analysis of the results of the previous scenarios. Scenarios 4 and 4.A resulted in the greatest reduction in overall campus CO_2 emissions. Both scenarios created significant savings in terms of heating but also caused an increase in electricity related emissions compared to the baseline. Thus, an investigation was carried out into the potential for solar PV integration and its impact on the CO_2 emissions.

As a result, scenario 4.A was chosen as the basis for the model. This was decided following a meeting with UCD Estate Services, where it was confirmed that their objective is to give CHP units priority where possible. The capacity of solar PV was calculated using a method described in literature [9]. As a result, 3 MW of solar PV was installed.

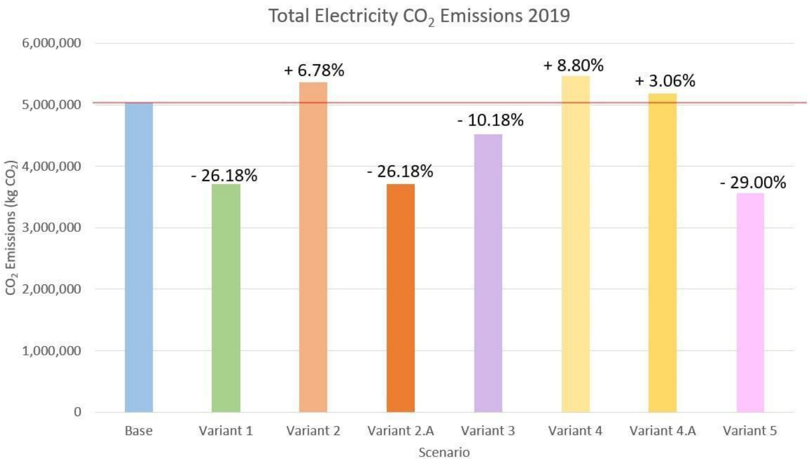


Figure 6.2: Comparison of Electricity CO_2 Emissions in All Scenarios 2019

6.2.6. Comparison

A simulation was run for each scenario for 2019 and the results compared in four areas:

1. The CO_2 emissions associated with electricity consumption.
2. The CO_2 emissions associated with gas consumption.
3. The CO_2 emissions from heat generation, including biomass and gas generators.
4. Total campus CO_2 emissions from meeting the electricity and heating demand.

Electricity Emissions

The CHP units, the solar PV installations and the grid supply electricity to the campus. As solar PV is considered to have no operational CO_2 emissions and those from the CHP units are considered to be for heat, the total electricity emissions are solely the CO_2 emissions of the imported electricity. A comparison of the emissions in each scenario can be seen in Figure 6.2. A common theme in the results is that the CO_2 emissions from electricity are lower when more CHP units are installed and used. This is due to the lower emission factor of gas and biomass, compared to the electricity on the grid.

Scenario 1 experienced a reduction in electricity emissions as the CHP units on the DHN were used to supply a portion of the heat previously generated by local gas boilers, thus simultaneously generating electricity. In the first variation of Scenario 2, prioritising the biomass generator pushed electricity imports above the base case, while dispatching the CHP units first in the second variation produced the same amount of electricity as in Scenario 1. From Scenario 3 onward, the biomass CHP unit was added to the DHN EC. While this generator uses fuel with a lower emission factor, it has approximately half the electrical efficiency of the gas CHP units. This, combined with the lower capacity compared to CHP 1, the former first preference, causes an increase in the need for imported electricity. However,

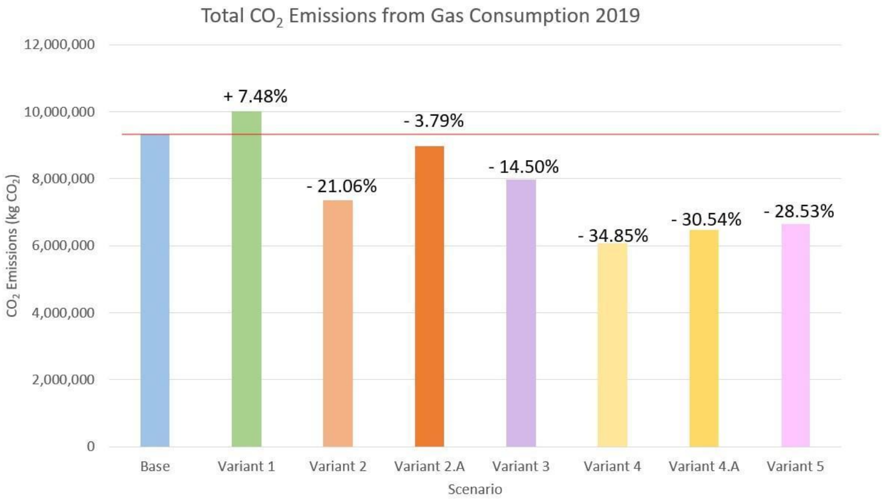


Figure 6.3: Comparison of Gas Consumption CO_2 Emissions in All Scenarios 2019

Scenario 5 shows that the addition of a local electricity source, in this case 3 MW of solar PV, can reduce this reliance on imports, achieving a 29% decrease from the baseline.

6.2.7. Gas Emissions

The changes in CO_2 emissions from gas consumption compared to the baseline can be seen in Fig 6.3. As expected, the introduction of a biomass generator reduces the CO_2 emissions associated with gas as its consumption is decreased. In contrast to the electricity emissions in Figure 6.2, the prioritisation of the biomass generator which produces only heat, has a positive impact. Clearly, any switch from gas will result in a reduction in gas-associated CO_2 emissions. The difference between the results in Figure 6.2 and Figure 6.3 highlights the need for an assessment of changes in total campus emissions.

6.2.8. Heating Emissions

Although the emission factor of biomass is lower than that of natural gas, it still produces carbon emissions and must be considered in the total heating emissions. Figure 6.4 shows the change in total CO_2 emissions resulting from heat production compared to the baseline. With the exception of Scenario 1, where the lower thermal efficiency of the CHP units in the DHN EC compared to that of the local boilers resulted in an overall increase in heating emissions, the scenarios each achieved a reduction. The greatest reductions were achieved where the biomass generator, which produces only heat, was placed above the gas CHP units in the priority schedule. However, it has been shown that this has the opposite impact on the emissions associated with the electricity supply. Again, the total emissions must be considered to identify the optimal solution.

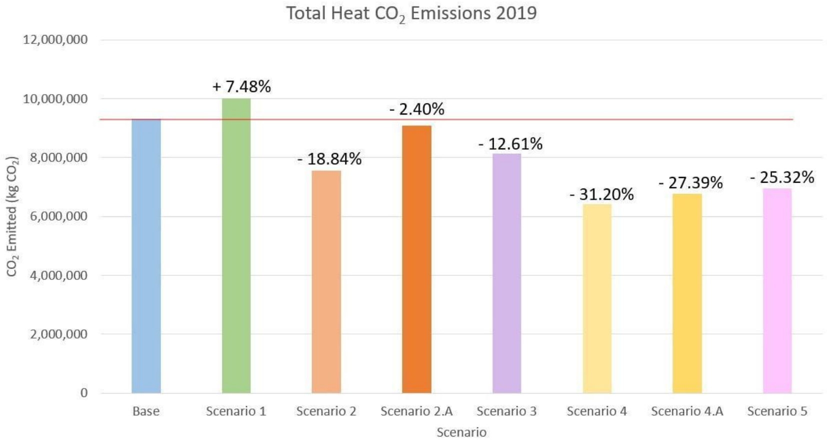


Figure 6.4: Comparison of Heating CO_2 Emissions in All Scenarios 2019

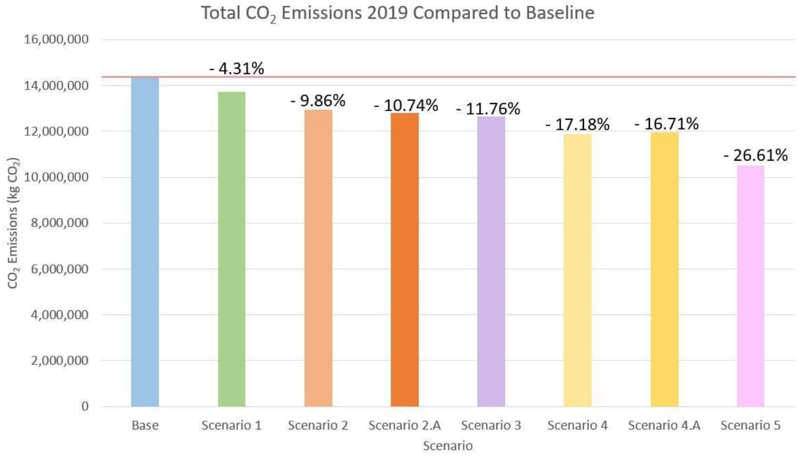


Figure 6.5: Comparison of Total CO_2 Emissions in All Scenarios 2019

6.2.9. Total Emissions

The total CO_2 emissions of the campus in each scenario can be seen in Figure 6.5 along with the percentage change relative to the baseline. In each case, an improvement on the current campus emissions was achieved. In cases where the electricity emissions increased, the reduction in emissions associated heating more than compensated for this rise. There is potential to reduce the total CO_2 emissions of the campus by up to 10.74% with the generation units currently available in the DHN EC. Should the opportunity arise to install an additional unit, this analysis recommends the use of a biomass CHP unit which can result in a CO_2 emissions reduction of approximately 17%. Consideration must be given to the source of the biomass. The recommendation would be to source the feedstock locally, including biomass collected from on-site maintenance of the grounds.

The majority of the CO_2 emissions reduction is a result of a change in the heating of the campus. An opportunity remains to tackle the electricity sector with renewable electricity generation. This the sis has identified the potential for 3 MW of solar PV on the campus, which would result in almost a 10% additional reduction in emissions. This would bring the total CO_2 emissions reduction to 26.61%, approximately a quarter of the way to full decarbonisation.

7

Action Plan

A number of actions have been identified for UCD Estate Services to undertake during the first year of the energy master plan. Over the coming years, UCD is expected to expand in terms of both building floor area and population. Thus, the action plan contains measures to improve the energy efficiency of the current campus, while also committing to sustainable growth.

The main objective over the coming years is to decarbonise the space heating of the Belfield campus, mainly through the district heating network. In the short-term, the removal of the local gas boilers in the DHN-connected buildings is planned, thus allowing the district heating network to supply the entire heat demand to those buildings. The impact of this measure has been assessed in Chapter 6. To support the increased demand on the DHN and to introduce a more sustainable heat source, it is planned to have the 0.95 MW biomass generator fully operational within the year. It is expected that the combined impact of these measures will be almost a 10% reduction in the total CO_2 emissions.

Throughout the next year, UCD Estate Services plans to make continuous energy management improvements, prioritising a reduction in emissions and optimisation in the control of campus systems and processes. In terms of new builds, steps will be taken to ensure that all new UCD buildings are of net-zero energy building (NZEB) standard. This will involve engagement in Energy Efficient Design (EED) and procurement, including a carbon life-cycle evaluation, for all projects.

The main aim for the first year of the UCD SEC Energy Master Plan is to lay the groundwork for future upgrades and new developments across the Belfield campus. It is expected that it will take a number of years to see the full impact of these measures and to reap the benefits in terms of CO_2 emissions reductions.

Long term plan

University College Dublin is strongly committed to the continued reduction of CO_2 emissions across the Belfield campus, with plans extending beyond the first year of the energy master plan.

The Belfield campus is already well developed, with a range of existing buildings and infrastructure. Thus, UCD is aware that upgrades and refurbishments will play an even greater role in decarbonisation than plans for new builds.

As previously discussed, almost a third of the building stock at Belfield was constructed in the 1960s and 1970s, many of which are now in need of major refurbishment. Given the embodied energy of these buildings, levelling the site and building an NZEB in its place is not a viable option. Currently, the Building Energy Rating (BER) of the buildings varies greatly across the campus, reaching as low as a G-rating. UCD Estate Services are planning to carry out widespread refurbishments to bring all existing buildings to a B-rating. These actions will greatly reduce the energy demand of the campus, particularly in terms of space heating.

The district heating network has been identified as having a key role in meeting the remaining heat demand of the campus and presents an opportunity for widespread decarbonisation. Over the coming years, UCD Estate Services are planning to install large scale heat pumps, starting with 1 MW to 2 MW on the district heating network. The network model of the campus has been used to quantify the impact that the B-rated refurbishment and the heat pump installation would have on the campus CO_2 emissions.

Figure 8.1 shows the reduction in CO_2 emissions from gas consumption over the range of possible interventions. The impact on the total CO_2 emissions of the campus can be seen in Figure 8.2.The introduction of the heat pump, with priority dispatch, in the DHN energy centre results in substantial emissions savings in terms of natural gas usage. However, when considering the total campus emissions, a 2 MW heat pump only achieves approximately a 4% reduction, while the 1 MW heat pump increases CO_2 emissions. This is due to the reduced output from the CHP units, which simultaneously generate heat and electricity. Therefore, the introduction of a heat pump would be best when there is an accompanying decarbonisation of the electricity supply

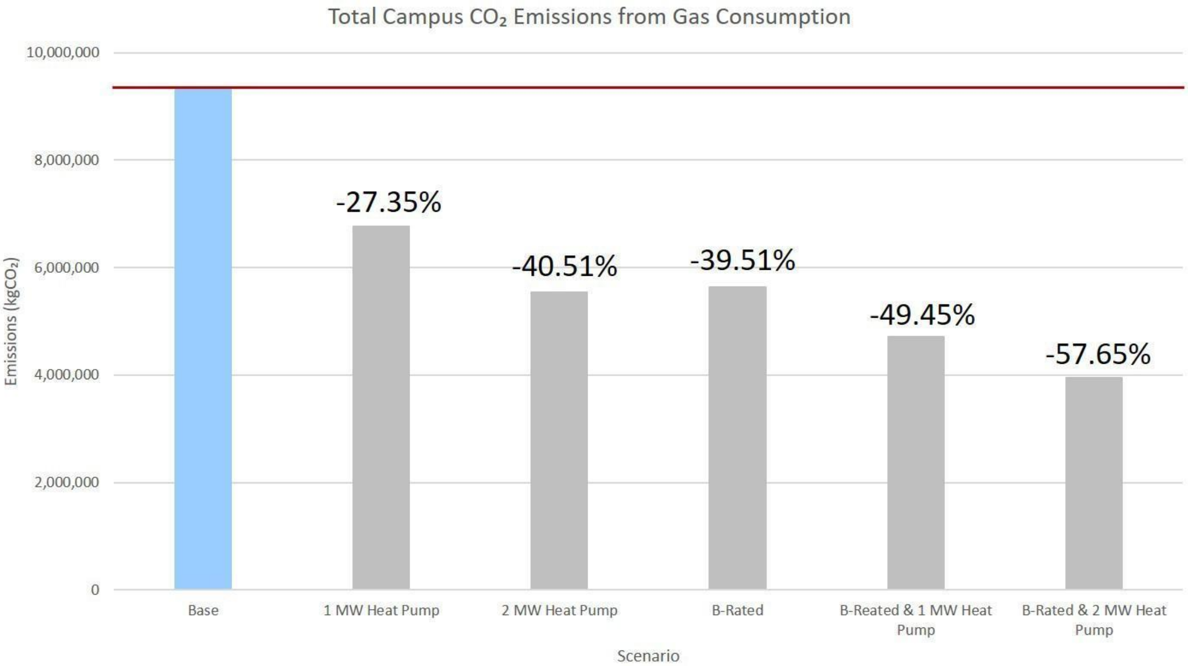


Figure 8.1: Comparison of Total Campus CO_2 Emissions from Gas Consumption

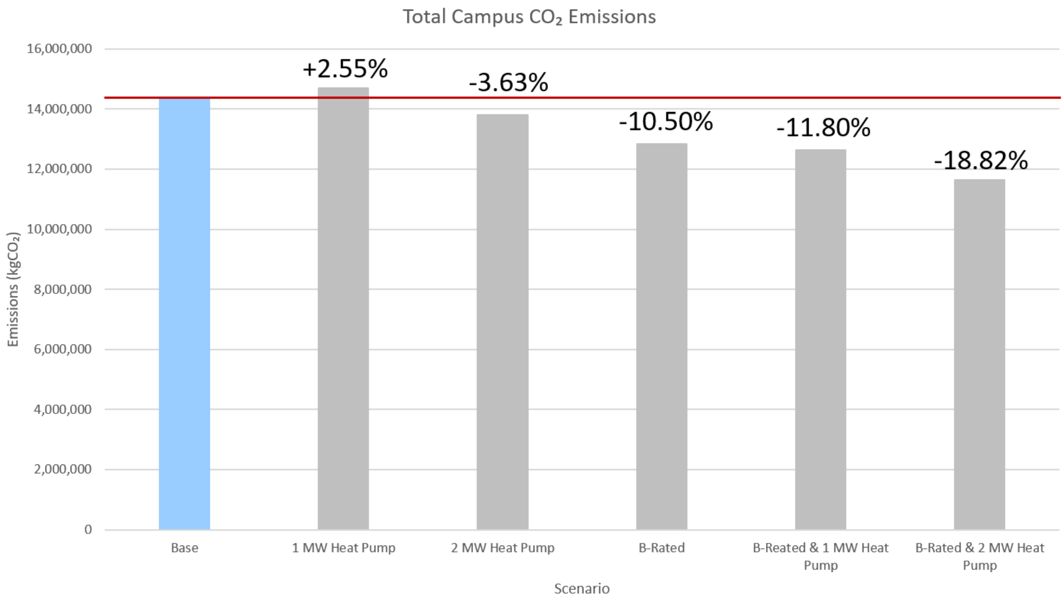


Figure 8.2: Comparison of Total Campus CO_2 Emissions

8

Final remarks

Since the establishment of the UCD Sustainable Energy Community, the team has faced several challenges in the planning and implementation of this project. However, the collaboration of the academic team with the input of the technical team of UCD Estates who face day-to-day operations resulted in a productive partnership with several lessons learned. This section analyses the path of the UCD SEC Community from different perspectives: raising awareness and community engagement, energy efficiency and sustainable energy production, commuting and transportation and future work.

Raising awareness

During the last few years, the UCD Sustainable Energy Community steering committee and volunteers members have participated and raised awareness with three main channels:

- Website for the community available at: https://sec.ucd.ie

  The website played an important role for our community because it provided an identity to a group of volunteers who wanted to impact such a large community and also it allowed us to advertise activities, social gatherings and discussion forums. It also helped to acknowledge the responsibility of members and facilitated the requests from the community.
- Public monthly events called CafeSEC

  The UCD Steering Committee has organised monthly meetings called CafeSEC where we gathered together as community members and discussed a topic or an event or a theme on sustainability, sustainable development goals
- Organisation of the first UCD Sustainable Energy Community and Cities Symposium. This Symposium was held 04 December 2019 and provided a vision of future sustainable cities and communities, where each component not only aims to maximise its efficiency, but it cooperates and interacts with the others as a whole. Topics for the symposium included Sustainable Energy Communities, Consumer and Prosumer Behaviour, Buildings, IoT, Data Analytics, Transport, Renewable Energies, Energy Generation and Management, Water Treatment and Recycling. All these areas are profoundly interconnected target areas of interventions and can lead to significant improvements to the city ecosystem and path towards decarbonisation and sustainability. The event was supported by private sponsorship and was divided into

three thematic areas: Sustainable Energy Communities in Ireland: present, impact and future, IoT and digitalisation of the power system, ASHRAE Smart Technologies in Buildings. The symposium was fully booked with more than 100 people attending the full day event. We established working collaboration with other Sustainable Energy Communities including the Dundrum community. At the event, other third level institutions were present such as the DCU Sustainable Campus Officer. The event was recorded by the media and reached a large audience.

During the pandemic, the activities on the campus have ceased. We have reduced the number of events and we decided to focus on delivering the UCD SEC Energy Master Plan while maintaining the initiative alive. A new engagement plan will be developed as soon as we will return back to the campus.

Energy efficiency and sustainable energy production

The work undertaken has focused on the application of district level energy modelling and stakeholder engagement in developing tailored and evidence-based decarbonisation strategies. The use of heterogeneous historical data from all the buildings in the district and the stakeholder consultation towards large-scale electrification of thermal loads and more sustainable energy systems has transformed a formal consultation into an innovative, collegial decision process. The innovative process led users, building managers, and policymakers to assess the analysis from the environmental, cost and energy perspective, participate in the discussion, and contribute as decision-makers, or just with sustainable behaviours to support the management.

The Energy Master Plan has demonstrated that allowing the current DHN to operate closer to its full potential would have almost the same impact on CO_2 emissions as carrying out a refurbishment to bring all buildings to a minimum B1 BER rating. Although improving the energy efficiency of the building stock will play a key role in achieving full decarbonisation, this investigation highlights the need for optimisation of existing systems and networks. In this way, significant emissions savings can be made with low or no cost and disruption to services.

Through improved use of the DHN and the installation of a new biomass CHP, emissions could be reduced by up to 17%. When coupled with a solar PV installation to tackle electricity emissions directly, the savings would increase to 26%. An alternative strategy of widespread retrofit and a heat pump installation on the current DHN would achieve a 19% emissions reduction.

A fundamental requirement for the decarbonisation process is the availability of detailed historical energy consumption and occupants behaviour data. The centralised data repository available for the UCD Campus has facilitated the carbon footprint analysis and detailed model development. Additional data on staff and students commuting, parking occupancy and internal working schedules have been essential for calibrating the model and exploring the impact of different measures. It should be noted that some of the decarbonisation measures have been selected and analysed after consultation with the UCD Estates team responsible for the campus facilities and after the evaluation of specific Irish policies for the public sector. As such an endeavour towards a more sustainable future, a lesson learned is the importance of discerning and evaluating different perspectives: occupants, user behaviour, policies and local community guidelines.

The technology used to enable this cooperation has led to a holistic approach where different stakeholders could, directly or indirectly, collaborate to enrich the model, aimed at creating a unique digital twin of the university, with the potential of predicting the campus behaviour over time and under different possible scenarios. This was made possible also by the use of beta-versions of the simulation tools, thanks to a bi-directional feedback process aimed at fulfilling the project scope while also integrating the broader stakeholders perspective into possible considerations for future software development.

The exploitable results of the work performed were the development of a detailed energy system model using a commercial software solution for the economic and environmental analysis of the decarbonisation measures and the development of a common strategy among academics, UCD Estate Services and community towards the full decarbonisation of the UCD Campus.

The model is available here:

https://www.dropbox.com/s/j5g85a41si6unkn/ucd%20model%20with%20variants.zip?dl=0

And further analysis on the decarbonisation strategy are available here:

https://www.dropbox.com/s/6nfkovyxwc14u0e/UCD%20Campus%20Full%20Decarbonisation%20Analysis.pdf?dl=0

Commuting and transportation

According to research, in the UK only 10 percent of people share their journey while the average worker will spend 400 days of their lives commuting. University College Dublin (UCD) is attracting more than 30,000 students from across the country and more than 3,000 staff members. Each year, commuting to UCD amounts to more than 7 million journeys. This makes UCD the largest commuting destination in Ireland. In partnership with the National Transportation Authority (NTA) and thanks to the UCD Sustainable Energy Community and the Smart Travel Initiative, UCD has committed to increase the sustainability of the commuting journeys via a detailed travel plan. The plan allocates resources to promote cycling, public transport, and funding initiatives that can make UCD an example in sustainable transportation.

For some of the commuters, the car is the only viable option to access the campus, therefore car parking is available for employees and students. However, especially during the academic semester and peak times, the car parks can be fully occupied causing an overspill of parking into the neighbouring community and can adversely affect the university’s relationship with its neighbours. Therefore it is of paramount importance to promote and foster sustainable solutions that can help to reduce the total number of cars used for commuting. Carpooling is one of such solutions, potentially providing a feasible, sustainable and ready to be implemented.

The UCD Sustainable Energy Community has proposed a full rollout of a carpooling solution for University College Dublin, estimating the resources and recommending the available technologies on the market. Additionally, a full rollout of a carpooling service for the campus can provide answers to research questions advancing our shared knowledge on how to promote social sustainable behaviours on large communities/cities.

The proposal was approved, the UCD Steering committee and the UCD Smart Travel Initiative have selected the technology and UCD Estates has allocated a budget for it. Unfortunately, the pandemic has affected such innovative initiatives postponing the carpool commuting scheme to undefined future date.

Another strand of work of the SEC has been the evaluation of the impact of EV charging points on the campus premises in collaboration with a research project associated with the UCD Energy Institute. A first version of the campus electricity model was developed in 2020. This model contained an interface to access building energy data from the UCD Estates Services platform and an electric model of the campus electrical distribution grid (modelled using an open-software power flow simulator. The building data and electrical model were combined to perform an impact analysis of EVs on the campus grid at different penetration levels using a simple charging pattern characterization. This study revealed that there could be negative technical impacts in the form of transformer and line overloading (i.e., their transferred power would exceed nominal specifications).

As exploitable result here is available the electric model of the campus for the analysis of EV penetration, developed in OpenDSS:

https://github.com/hayesjj/EV_Load_OpenDSS/tree/draft_0

Another exploitable result available is carpooling project proposal approved by UCD Smart Travel Initiative:

https://www.dropbox.com/s/i83cu4b05w0s41j/ucd-sec-carpooling%20initiative.pdf?dl=0

Future Work

Future work will involve further improvements to the UCD SEC Energy Master Plan and include details of the current campus community, along with the energy demand and generation, a register of opportunities containing the results of further scenario analysis, and a list of the suitable projects selected for the campus. A key attribute of the SEC programme and the Energy Master Plan is that the objectives set are feasible and agreed among the stakeholders. Therefore, stakeholder engagement and involvement of the community throughout the process is vital to implement interventions and improve their energy efficiency. The work undertaken has provided UCD with the means to explore a variety of decarbonisation strategies at district level and at community level. It has been a pleasure to work with the steering committee and all the people involved in the Sustainable Energy Community. It is paramount for the UCD Sustainable Energy Community keep enrolling new volunteers and blending its activities with other campus wide activities such as the Green Campus or Green Young Society. This is just the beginning, the priorities have been defined, different energy models have been developed and they are publicly available, but the pandemic has partially affected the engagement between different stakeholders.

Acknowledgements

The work has been undertaken through collaboration and engagement with UCD Energy Institute, Integrated Environmental Solutions (IES) Ltd., University College Dublin (UCD) Sustainable Energy Community, UCD Estate Services, SEAI Sustainable Energy Authority of Ireland. Thank you to all the people involved, especially to Prof Andrew Keane, Dr Mattia De Rosa, Dr Patricia Walker, Dr Pallonetto Fabiano, Dr Mohammad Saffari, Dr Anjukan Kathirgamanathan, Guneet Kaur, Cathy Quinn, Adamantios K. Bampoulas, Devasanthini Devaraj, Páraic Carrol, Paul Noonan, Kieran Brassil and all UCD SEC Steering Committee members and students involved in the activities.

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