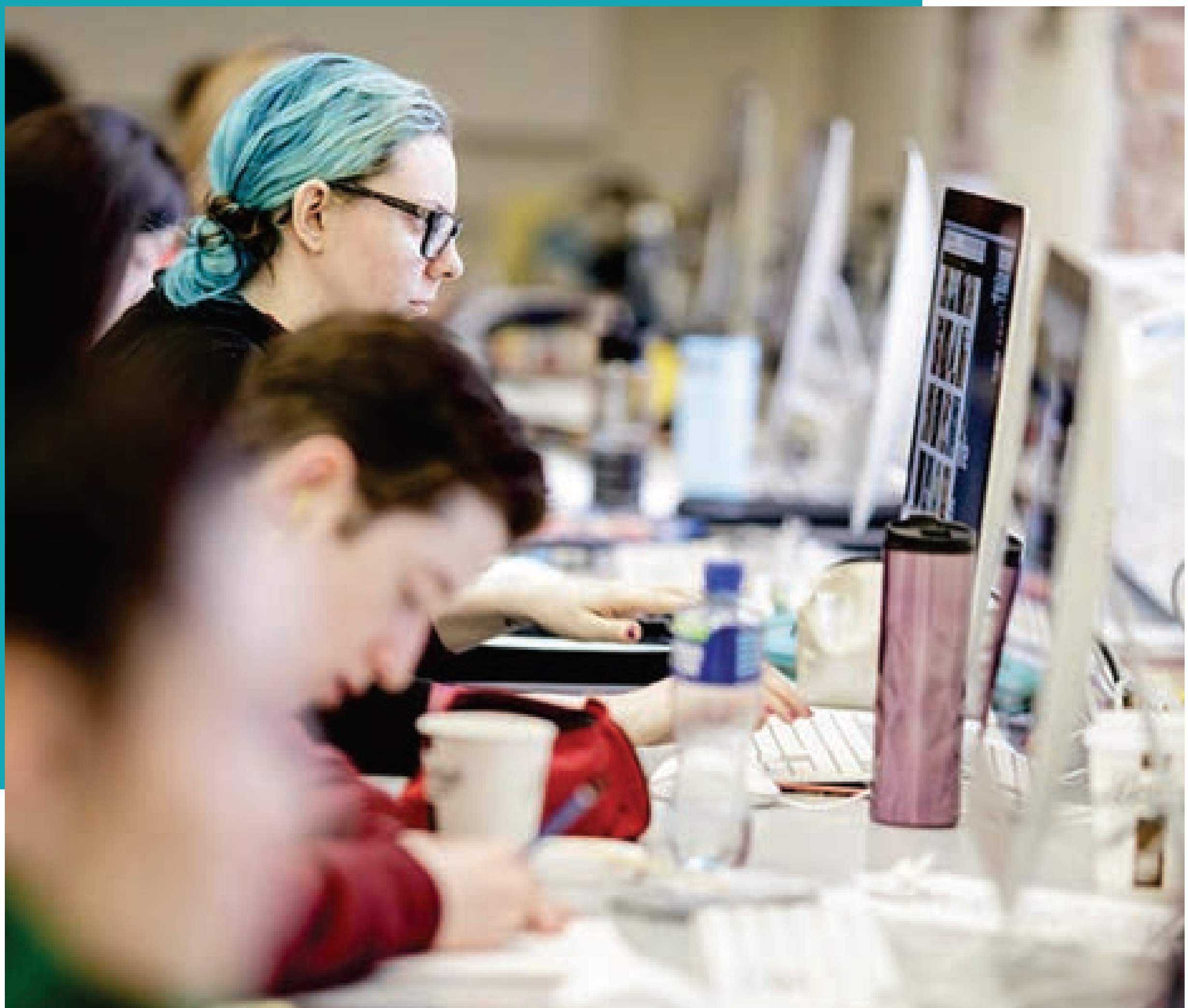

Sustainable Energy Action Plan

April 2025

TU DUBLIN
OLLSCOIL TEICNEOLAÍOCHTA BHAILE ÁTHA CLIATH
TECHNOLOGICAL UNIVERSITY DUBLIN

Codema
Dublin's Energy Agency

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ABBREVIATIONS

AHU Air Handling Unit
ASHP Air Source Heat Pump
BDHS Blanchardstown District Heating System
BER Building Energy Rating
BESS Battery Energy Storage System
BMS Building Management System
CAPEX Capital Expenditure
CO_2 Carbon Dioxide
COVID Coronavirus
DH District Heating
EEOS Energy Efficiency Obligation Scheme
EnMS Energy Management System
EPC Energy Performance Contracting
ESB Electricity Supply Board
ESCO Energy Service Company
EU European Union
EV Electric Vehicle
GHG Greenhouse Gas
HVAC Heating Ventilation & Cooling
LED Light Emitting Diode
MIC Maximum Import Capacity
MW Megawatt
OPEX Operational Expenditure
PI Project Implementation
PPA Power Purchase Agreement
PV Photovoltaic
SEAI Sustainable Energy Authority of Ireland
SEC Sustainable Energy Community
SRESS Small Scale Renewable Energy Support Scheme
SSRH Support Scheme for Renewable Heat
TDHS Tallaght District Heating Scheme
TES Thermal Energy Storage
TU Technological University

1. EXECUTIVE SUMMARY

1.1. Purpose

This report outlines a sustainable energy action plan for advancing Technological University Dublin's (TU Dublin) energy decarbonisation strategy across its five campus locations: Aungier Street, Blanchardstown, Bolton Street, Grangegorman, and Tallaght, building on the analysis and findings from previous tasks. TU Dublin has several buildings at other sites including the Broombridge Design and Construct Centre, FOCAS, Synergy Centre and CASH (Centre of Applied Science for Health). The assessment process involved a thorough review of progress to date, including an evaluation of existing energy initiatives, current emissions baselines, and energy management practices. It also included an opportunity evaluation to identify and prioritise high-impact projects that can support TU Dublin's energy and emissions reduction goals.

1.2. Key Findings

Progress to Date: TU Dublin has achieved a 26% improvement in energy efficiency relative to its 2009 baseline (1996 kWh/student in 2023). The university's Scope 1 and Scope 2 emissions in 2023 were 8,901 tCO_2e, reduced from a baseline of 10,947 tCO_2e (2016–2018 average). This represents a 19% reduction. While progress has been made, challenges remain due to increased energy demand from new facilities and the resumption of pre-COVID-19 activity levels.

Opportunity Evaluation: A detailed evaluation of energy and emission reduction opportunities identified a range of impactful measures across TU Dublin's campuses. These include larger capital projects, such as district heating, solar PV, and energy storage. A separate load profile analysis highlighted the benefits of improved energy metering, optimising building management systems (BMS), upgrading internal and external lighting to LEDs, medium and shallow retrofits to existing buildings, space optimisation and behavioural change campaigns. The evaluation does not consider deep retrofit projects as these are more complex projects that have been identified in the Climate Action Roadmap as a programme of work to be completed post 2030.

Project Prioritisation: A workshop held with relevant key TU Dublin staff helped identify high, medium, and low-priority projects, which were then organised into short-, medium-, and long-term timelines. The prioritisation process was informed by a €/tCO_2 analysis derived from energy models, highlighting the cost-effectiveness of emissions reduction projects over their lifetimes relative to the shadow cost of carbon.

Next Steps: Based on the project prioritisation, TU Dublin will progress short-term actions, including improved metering, district heating expansion, BMS optimisation, lighting upgrades, medium retrofit measures and behavioural change. Medium-term actions include implementing decarbonised district heating in Blanchardstown campus, onsite solar PV installations, geothermal exploration and production in Grangegorman campus, an energy storage assessment, decanting Aungier Street, and enhanced behavioural campaigns.

Long-term efforts will focus on microgrid development, geothermal energy integration, and a lifecycle assessment of new versus existing buildings to inform developing Building Stock Plans and ensuring alignment with 2050 targets.

Strategic Considerations: Key decisions will need to be made regarding large infrastructure projects and cross-campus energy initiatives to ensure alignment with TU Dublin's long-term decarbonisation goals. These decisions will be informed by factors such as CAPEX and OPEX funding availability, payback periods, site constraints, campus masterplans, regulatory and policy changes, and TU Dublin's internal resource capacity.

2. INTRODUCTION

2.1. Context

TU Dublin is committed to advancing its energy transition and sustainability goals, with the overarching ambition of achieving net-zero across its campus locations. In alignment with Ireland's national climate targets, TU Dublin is striving to reduce its greenhouse gas (GHG) emissions by 51% by 2030 and reach net-zero emissions by 2050. Additionally, TU Dublin is committed to fully decarbonising Scope 1 & 2 emissions by 2040. This commitment requires a comprehensive approach that addresses energy efficiency, decarbonisation of heat and electricity supply, and improves energy management practices.

TU Dublin is actively pursuing strategies to decarbonise its energy systems, enhance energy efficiency, and integrate renewable energy sources. However, to achieve these ambitious goals, a clear and strategic approach is required—one that identifies high-impact projects, optimises resource allocation, and addresses potential risks and challenges. This report provides such a pathway, guiding TU Dublin through the next stages of its energy transition.

2.2. Scope & Methodology

This Sustainable Energy Action Plan Report builds on the outcomes of previous tasks conducted for TU Dublin's energy transition analysis. The reports for these tasks are included in the appendices.

- **Task 2.1: Review of Progress** — Provided a detailed evaluation of TU Dublin's existing energy-related emissions, reviewed current projects and initiatives, and established a baseline for emissions reduction efforts.
- **Task 2.2: Energy Management Review** — Identified strengths and areas for improvement in TU Dublin's Energy Management System (EnMS), providing mentoring support to enhance internal practices and capabilities.
- **Task 2.3: Opportunity Evaluation** — Assessed a range of potential projects and opportunities, including district heating expansions, solar PV potential, offsite power purchase agreements (PPAs), electricity grid flexibility, and demand reduction initiatives.

The primary focus of this report is to synthesise these findings into a cohesive action plan that outlines the next steps and strategic considerations for TU Dublin's energy transition. This document presents a prioritised list of projects that have been evaluated based on their impact on energy efficiency, emissions reduction, and cost-effectiveness. Additionally, it provides a high-level list of strategic considerations to support decision-making, resource allocation, and risk management.

The report is structured to provide a suite of high-priority projects, set a clear decarbonisation pathway, and establish a timeline for action, ensuring the university is well-positioned to meet its sustainability objectives and contribute to national and global climate targets.

3. CURRENT STATUS

3.1. Progress to Date

As a public body, TU Dublin is required to comply with the Public Sector Climate Action Mandate, which outlines specific targets for energy efficiency and greenhouse gas (GHG) emissions reductions. TU Dublin must achieve a 51% reduction in GHG emissions and a 50% improvement in energy efficiency by 2030, relative to the baseline periods set for each target. These commitments align with national climate action objectives and are reported annually through the SEAI's Monitoring and Reporting (M&R) system. TU Dublin's progress towards these targets is driven by campus-specific initiatives as well as cross-campus projects focused on energy efficiency, renewable energy integration, and sustainable infrastructure development. Following is a comparison of each campus factoring in energy related emissions and large energy consumers. A full comparison of each campus is included in the 'Review of Progress to Date'.

Tallaght Campus:

- In 2023, the Tallaght campus accounted for 12% of TU Dublin's total emissions (1,099 tCO_2e), with a total floor area of 29,478 m².
- Energy efficiency measures, such as connecting the Main Building and the Sport Science, Health and Recreation Building to the Tallaght District Heating Scheme, have helped reduce reliance on gas-fired heating systems. This shift has contributed to the campus achieving lower-than-average emissions per m² (37.3 $kgCO_2e/m^2$ compared to the University average of 42.2 $kgCO_2e/m^2$)
- The Main Building remains the largest energy consumer at the campus, responsible for 67% and 77% of electrical and non-electricity energy consumption respectively. Efforts to optimise this building's energy use will be critical in further reducing campus emissions.

Grangegorman Campus:

- The Grangegorman campus is the largest of TU Dublin's campuses, both in terms of size (85,252 m²) and emissions (3,935 tCO_2e), accounting for 44% of the University's total emissions in 2023.
- Energy consumption at Grangegorman has increased significantly due to the addition of large, energy-intensive buildings, such as the Central Quad and East Quad, which are connected to the gas fired district heating network. However, ongoing efforts to decarbonise this system, including exploration of geothermal energy, are expected to significantly lower emissions in the coming years.
- The campus's emissions per m² are currently higher than the university average (46.2 $kgCO_2e/m^2$), indicating a need for targeted energy efficiency and emissions reduction measures, particularly for high-energy use buildings like the Central and East Quads.
- The Grangegorman campus is projected to increase student numbers and expand with four new buildings by 2030, followed by University Accommodation and possible additional teaching and research facilities by 2050. Despite these expansions, TU Dublin must achieve its energy efficiency and emissions targets, ensuring sustainability regardless of the growth in buildings or student population.

Aungier Street Location:

- In 2023, Aungier Street accounted for 16% of TU Dublin's total emissions (1,432 tCO_2e) across a total floor area of 23,920 m², resulting in a $kgCO_2e/m^2$ of 59.9, above the University average.
- The main building is the largest energy consumer, accounting for 92% of the location's non-electrical energy consumption and 84% of electrical energy consumption. The FOCAS building accounts for the remainder.
- Planned relocation to the Grangegorman campus is expected to reduce emissions as more energy-efficient facilities become operational. For this reason, no significant energy efficiency improvements of emissions reduction measures are anticipated.

Bolton Street

- In 2023, Bolton Street contributed 13% of total emissions (1,148 tCO_2e) over a total floor area of 32,075 m², resulting in a $kgCO_2e/m^2$ of 35.8, the lowest among TU Dublin campuses and locations.
- The Main Building is the largest energy consumer, responsible for 66% of the campus's non-electrical energy consumption and 58% of electrical energy consumption.
- A decision is yet to be made on whether Bolton St operations will be transitioned to the expanded Grangegorman campus, however as one of the best performing buildings from a $kgCO_2e/m^2$ perspective, the divestment of Aungier Street is anticipated to be given priority.
- A comparative assessment of Bolton Street's operational emissions versus the lifecycle emissions of new builds on the Grangegorman campus will be necessary to ensure an optimal sustainability outcome.

Blanchardstown Campus:

- The Blanchardstown campus, with a total floor area of 25,573 m², accounted for 14% of TU Dublin's total emissions (1,285 tCO_2e) in 2023.
- The campus has a higher emissions intensity compared to other campuses, with 50.3 tCO_2e/m^2, largely due to the age and condition of its building stock. Electrical and non-electrical energy consumption is more evenly spread between building which highlights the need for comprehensive approach to energy retrofits and upgrades to heating systems.
- Deep retrofit plans for the Aras Fíos building, which are expected to improve its Building Energy Rating (BER) from D1 to A3, will serve as a blueprint for similar projects at the campus. This retrofit is projected to substantially reduce energy consumption and emissions for the building.

Cross Campus Initiatives

TU Dublin has launched several impactful initiatives that span across its campuses, focusing on enhancing energy efficiency, reducing emissions, and fostering sustainability. The development of district heating systems is a major initiative, with Tallaght and Grangegorman campuses already connected and plans underway for Blanchardstown to develop a network in the near future. The University has also transitioned its vehicle fleet from diesel to electric, reducing Scope 1 emissions.

The Green Labs Programme, which encourages energy-efficient practices in research settings, has been introduced across multiple campuses to minimise the environmental impact of laboratory operations. A submetering programme is being implemented to improve energy monitoring and management at the building level, enabling more precise tracking of energy consumption and identification of efficiency opportunities. Additionally, TU Dublin has invested in educational and awareness campaigns, including Climate Leadership Training, Green Public Procurement Training and Sustainability Training for Researchers, to build capacity for sustainability among staff and students. These initiatives collectively contribute to the University's progress towards achieving its 2030 targets.

Overall University Performance

Energy Efficiency: TU Dublin has achieved a 26% improvement in energy efficiency relative to its 2008 - 2009 baseline, with an Energy Performance Indicator (EnPI)[1] of 1,996 kWh/student as of 2023. While this marks positive progress, the University must continue to implement energy-saving measures to meet the 50% improvement target by 2030. An additional 8% improvement would be required to be in line with the glidepath trajectory to 50% as shown in Figure 1[2].

GHG Emissions Reduction: TU Dublin's baseline emissions for Scope 1 and Scope 2, using a 2016-2018 average, were 10,947 tCO_2e, with a target of 3,637 tCO_2e by 2030 (51% reduction). To reach this goal, the focus needs to be on reducing Scope 1 emissions, primarily from on-site fossil fuel use. This can be achieved by transitioning to renewable energy sources, like district and geothermal heating, and optimising current systems. While recent reductions have been observed, new building additions and a return to pre-COVID activity levels present ongoing challenges, emphasising the need for targeted actions to achieve the 2030 goal as shown in Figure 2. A full definition of Scope 1 and Scope 2 emissions is included in the appendices of this report.

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[1] An Energy Performance Indicator is a measure that is used to determine energy intensity/ efficiency. Energy consumption is attributed on a pro rata basis across a separate measurement such as cost, floor area, number of students etc. This allows an organisation to track progress made towards achieving energy efficiencies. TU Dublin measures EnPI on a Student Number basis (kWh/student).

[2] Figure 1 illustrates TU Dublin's normalised annual energy performance compared to the 50% glidepath to 2030. The glidepath shows the average annual energy reduction required to meet the 50% Energy Efficiency target

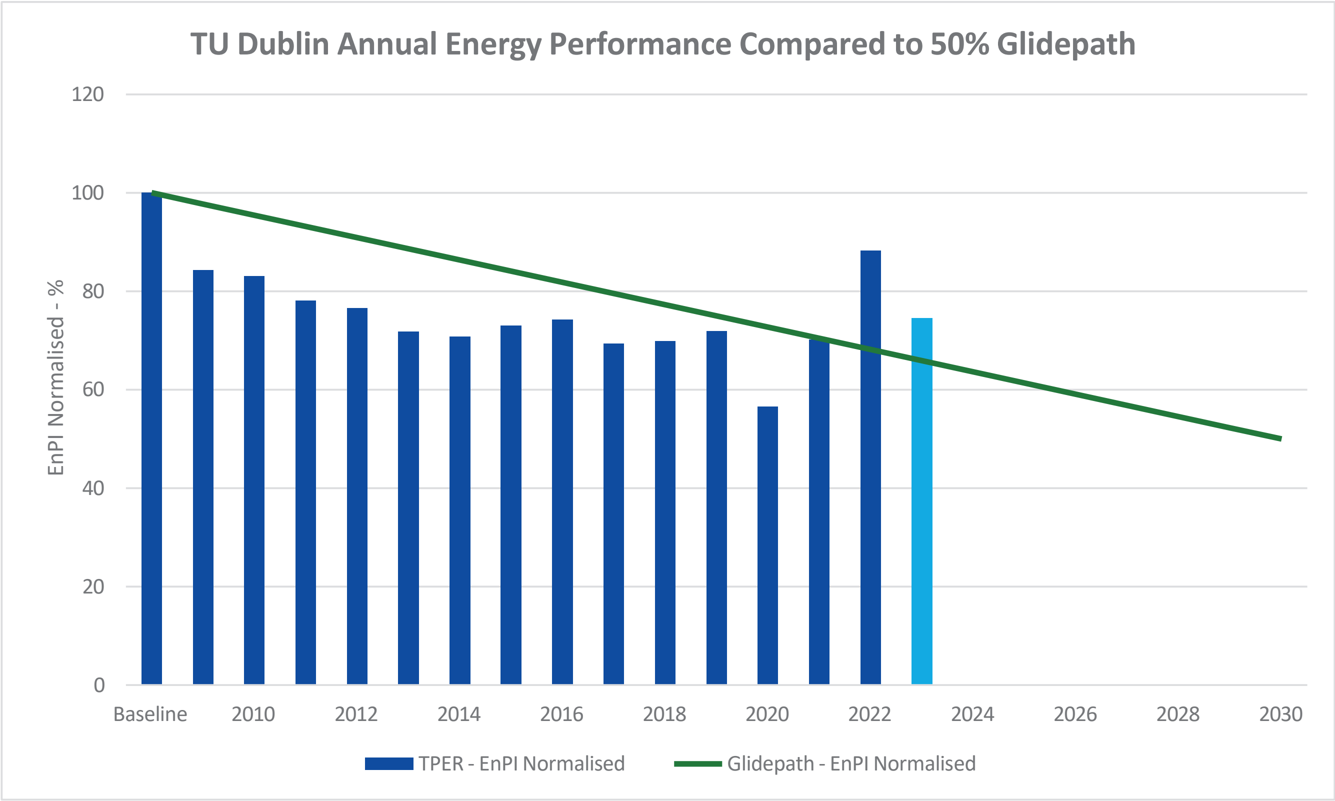


Figure 1: TU Dublin’s Normalised Energy Efficiency Performance Glidepath

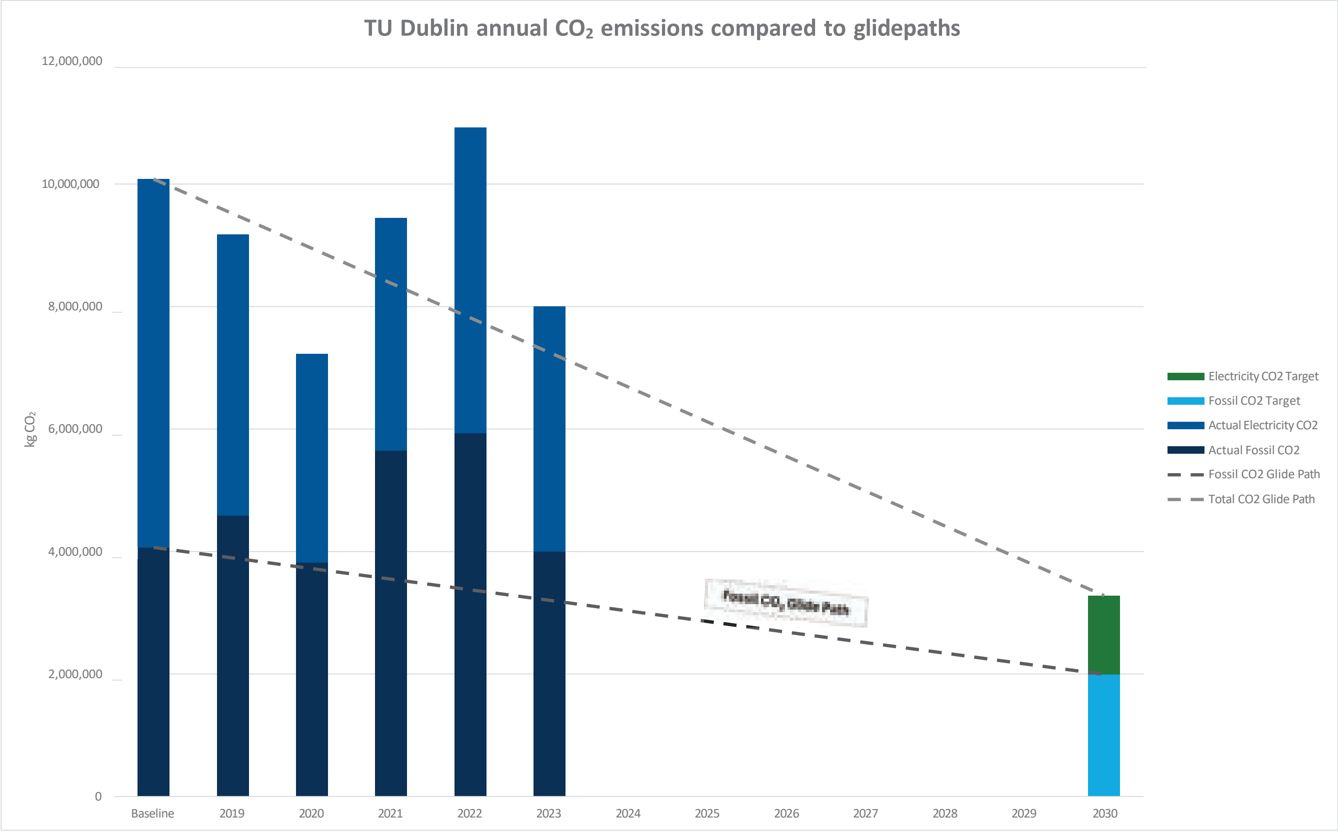


Figure 2: TU Dublin's CO2 Emissions Performance Glidepath (segregated into purchased electricity and fossil fuel combustion).

4. NEXT STEPS

4.1. Opportunity Evaluation Findings

The Opportunity Evaluation Report identified several key energy opportunities across TU Dublin campuses, focusing on strategies to decarbonise energy use, increase energy efficiency, and integrate renewable energy technologies. The findings are categorised into five main areas: Heat Energy Analysis, Solar PV Evaluation, Power Purchase Agreements (PPAs), Electricity Flexibility, and Demand Reduction.

Heat Energy Analysis

This evaluation identified opportunities to expand or improve district heating (DH) networks across the Grangegorman, Tallaght, and Blanchardstown campuses. The existing DH system at Tallaght is already contributing to a reduction in Scope 1 emissions. At Grangegorman, the transition to a low-carbon geothermal energy source is expected to significantly reduce thermal emissions, with potential savings of up to 90% if the system is implemented by 2030. Similarly, the Tallaght District Heating Scheme (TDHS), which utilises waste heat from a nearby data centre, offers a scalable solution for further expansion to the Tallaght North (CAET) and Synergy/CASH buildings. For Blanchardstown, TU Dublin can develop a campus network, enabling efficient integration with the proposed Blanchardstown District Heating Scheme (BDHS) as it becomes operational. Collectively, district heating expansion projects could reduce thermal emissions (Scope 1) by 57% compared to 2022 levels.

Solar PV Evaluation

The solar photovoltaic (PV) evaluation identified suitable roof spaces on the Blanchardstown, Grangegorman, and Tallaght campuses for potential solar installations. The Blanchardstown campus has the greatest potential, with a total capacity of circa 1 MW, which could meet approximately 34% of its electricity demand. At Grangegorman, a large-scale installation of up to ~900 kW at the Broombridge site could be installed to support the proposed facility's electricity demand. Limited roof space and planning constraints at the Tallaght campus reduce its solar potential, but an installation of up to 180 kW is still feasible. If fully implemented, these solar PV systems could significantly support TU Dublin's energy efficiency targets.

Power Purchase Agreements (PPAs)

This analysis explored both physical and virtual PPAs as mechanisms for procuring renewable electricity. Due to regulatory constraints on private wires in Ireland, direct-line PPAs are largely unfeasible. However, TU Dublin could explore on-site physical PPAs for future solar installations, allowing an external operator to install, own, and maintain the system, selling electricity to TU Dublin at a fixed price. While virtual PPAs can provide long-term price stability, they do not contribute to emissions reductions under SEAI's M&R system. Direct procurement and ownership of on-site solar installations remain the most cost-effective option to meet sustainability goals.

Electricity Flexibility Analysis

Incorporating electricity flexibility solutions, such as Thermal Energy Storage (TES) and Battery Energy Storage Systems (BESS), could support increased electrification and renewable energy integration at TU Dublin. TES, often included in modern district heating systems, is cost-effective due to reduced additional costs. While BESS has historically been more expensive, recent significant price reductions and anticipated further declines improve their business case. BESS remains viable in specific cases, such as at the proposed Broombridge facility, to enhance self-sufficiency and energy efficiency. However, the financial viability is strongly influenced by feed-in tariffs. In some cases, feeding excess electricity back into the grid may be more economical than storage. Additional analysis is needed to determine the most cost-effective option for each campus, especially given that the Small-Scale Renewable Electricity Generation scheme[3] may dictate tariffs for organisations like TU Dublin. There is also potential to work with the local SECs to become a renewable energy community which can be eligible to compete for more favourable feed in rates.

Demand Reduction (Load Profile) Analysis

This evaluation identified several opportunities to reduce energy consumption across TU Dublin's campuses. These include optimising building management systems, enhancing lighting efficiency, medium retrofit measures, and promoting behaviour change. The main opportunities identified are:

1. Building Management Systems (BMS) and Metering Improvements: Enhancing BMS and metering capabilities, with a focus on installing main incomer meters initially, will provide a comprehensive overview of campus energy consumption. This will enable better tracking of overall energy use, and associated emissions. Once main incomers are in place, additional submeters can be deployed to provide detailed tracking and identify inefficiencies at the building and equipment level.

2. External Lighting Upgrades: A full inventory of external lighting assets is recommended, followed by an LED retrofit plan. Upgrading to LEDs and adding control measures (e.g., dimming during low-activity hours) will reduce energy demand, particularly at the Blanchardstown campus.

3. Internal Lighting Upgrades: Many buildings, especially at Tallaght, still use outdated T8 fluorescent lamps. Replacing these with LED fixtures and reducing over-lit areas could lower lighting loads by up to 50%. A full lighting redesign should be considered for the Tallaght Main Building.

4. Addressing Out-of-Hours Loads: Significant baseloads were observed during out-of-hours periods, especially at Grangegorman. Installing meters on essential equipment will help identify non-essential loads that can be reduced or shut off to minimise overnight energy consumption.

[3] Small Scale Renewable Electricity Generation Scheme

5. Equipment Scheduling: Equipment at some campuses operates outside necessary hours. Reviewing start-up and shut-down schedules will ensure alignment with building occupancy and reduce energy waste during early mornings and late evenings.

6. Space Optimisation: During low-occupancy periods, such as summer, some buildings can be temporarily closed to reduce operational costs. Consolidating students ans staff into fewer buildings will reduce energy use in unoccupied spaces.

7. Occupancy Sensors for Lighting and Ventilation: Installing occupancy sensors in lecture halls and hallways, particularly at Tallaght, will ensure automatic shutoff of lighting and ventilation when spaces are not in use. Combining these sensors with daylight controls will further enhance energy savings.

8. Communication and Behavioural Change Campaigns: Previous campaigns like “Reduce Your Use” and “TU Dublin is Switching Off” had limited success due to insufficient metering. Improved metering and real-time displays in key buildings will better communicate campaign results and drive behaviour change. Streamlining the campaigns and providing feedback opportunities will further increase engagement.

4.2. Project Prioritisation

The identified opportunities have been evaluated and prioritised based on their cost, potential energy and emissions impact, feasibility, and alignment with TU Dublin’s strategic energy goals. The prioritisation is divided into two main approaches:

1. Cost per Tonne of CO_2 Saved Analysis for major capital-intensive projects such as district heating, solar PV installations, and energy storage. This was developed using outputs from the nPro energy models.

2. Workshop-Based Prioritisation: A workshop involving relevant key TU Dublin staff was also held to determine the prioritisation of all opportunities, including BMS enhancements, lighting upgrades, scheduling optimisations, space utilisation strategies, and behavioural change campaigns. The outputs of the workshops will help to inform the decarbonisation pathway included in section 5 below.

Figure 3 on the next page presents a comparative analysis of energy projects at TU Dublin based on their cost-effectiveness, measured in €/tonne of CO_2 saved over the technology lifetime. The shadow cost of carbon, which represents the estimated economic cost of emitting one additional tonne of CO_2 into the atmosphere, is set at €322/tCO_2 in line with government infrastructure guidelines[4].

[4] Shadow Cost of Carbon (Infrastructure Guidelines)

The shadow cost of carbon is used as a benchmark to evaluate the cost-effectiveness of emissions reduction projects and policies. By applying this cost to emissions, decision-makers can assess the value of carbon abatement efforts relative to their impact on society, guiding investments toward projects that provide significant carbon reductions at or below this cost.

It is worth noting that technologies like district heating (DH) have lifetimes of 40 to 50 years, whereas battery storage systems may require replacement after 10 to 15 years, influencing the cost effectiveness of the carbon reduction. This is evident in the graph below.

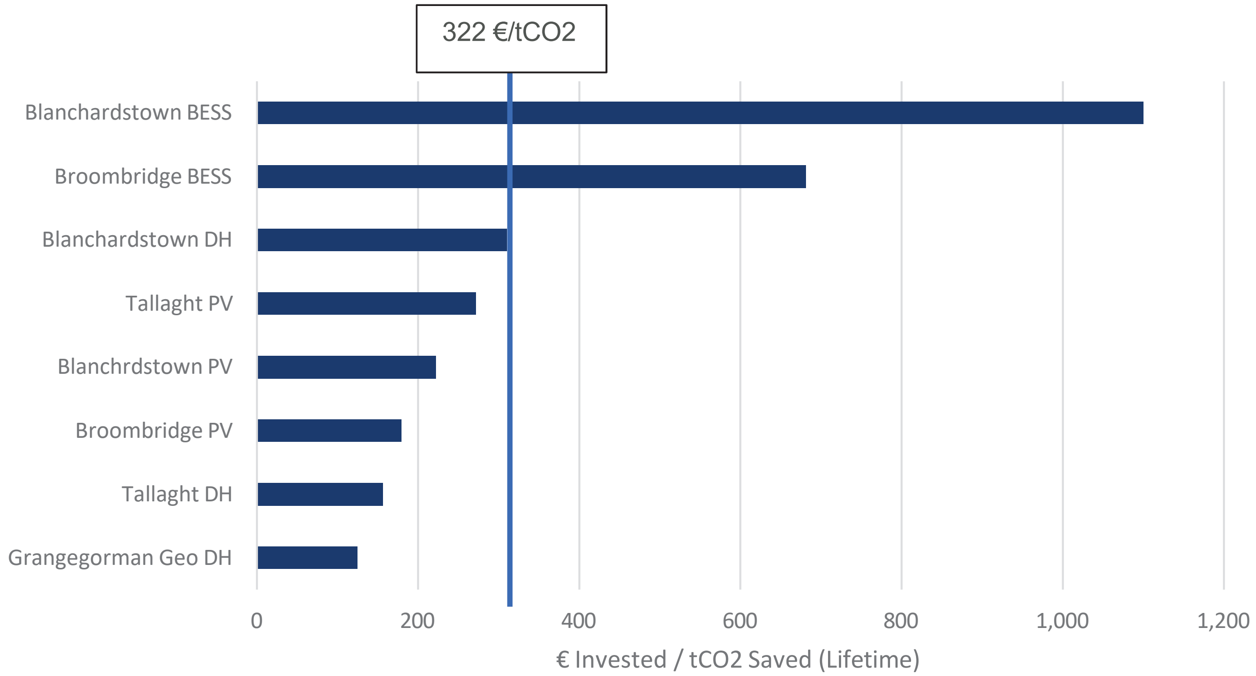


Figure 3: Capital Cost (€) vs tonne of CO_2 saved from nPro energy model outputs

District Heating (DH) Projects

Grangegorman Geothermal District Heating: The Grangegorman project is the most cost-effective district heating option due to economies of scale and the presence of an existing heating network. The main costs are associated with converting the current gas-based district heating system to a low-carbon geothermal energy source. The large scale of the campus and existing infrastructure significantly reduce the €/tCO2 compared to building a new network, making this a favourable project for reducing emissions. There is, however, uncertainty around the geothermal resource which may affect the timeline and complexity of delivery, cost, and impact.

Tallaght District Heating: The Tallaght project involves expanding the existing TDHS to connect two additional buildings (Synergy CASH and Tallaght North CAET). The smaller scale of this project results in higher costs per tonne of CO_2 saved compared to Grangegorman. However, it remains a valuable addition, as it will further decarbonise the campus's heating demand using low-carbon heat.

Blanchardstown District Heating: The Blanchardstown DH scheme has the highest cost per tonne of CO_2 saved among district heating options due to the need to construct the entire system, including a distribution network, a new energy centre, and heat production equipment, resulting in higher CAPEX. Connecting to the wider Blanchardstown District Heating Scheme (BDHS), if operational by 2030, could be a more cost-effective solution for decarbonising campus heating systems as a separate energy centre would not be required. However, this approach carries higher risks due to reliance on external stakeholders and uncertain timelines. At €310/tCO_2, this project is approaching the shadow cost of carbon.

Solar PV Projects

Blanchardstown Solar PV: The Blanchardstown PV project is the most viable near-term option for solar installations at TU Dublin. With suitable roof space available on existing buildings and minimal planning constraints, this project offers cost-effective CO_2 savings at around €250/tCO_2 saved. Blanchardstown's PV array would support the campus's energy self-sufficiency and contribute to reducing Scope 2 emissions.

Broombridge Solar PV: The Broombridge PV project, while cost-effective in terms of €/tCO_2 saved, should not be considered a near-term option, as the facility is not yet constructed. Efforts should focus on engaging with design teams early in the development phase to incorporate solar PV into the final design and ensure compliance with regulations such as solar safeguarding zones. This proactive approach will maximise the potential for PV adoption and avoid retrofitting costs once the building is operational.

Tallaght Solar PV: The Tallaght PV project has a higher cost per tonne of CO_2 saved due to its smaller scale. The campus's roof space is limited, and its location within a solar safeguarding zone imposes additional planning restrictions. As a result, only a small PV array is feasible, making this a lower-impact option for emissions reductions.

Energy Storage Systems

Thermal Energy Storage (TES): TES is generally more cost-effective compared to BESS due to lower CAPEX when integrated with a DH network. TES also has a smaller spatial footprint, making it suitable for urban campuses where space is limited. However, the feasibility of TES is contingent on the presence of a DH network to supply and distribute stored thermal energy. For campuses with a DH network, TES can also support peak load management and enhance the efficiency of heating systems. TES is not considered a project in its own right as it will be part of a DH network.

Battery Energy Storage Systems (BESS): The BESS projects at Blanchardstown and Broombridge currently exceed the shadow cost of carbon (€322/tCO_2) based on today's battery costs. However, this may change as the shadow cost of carbon rises yearly per infrastructure guidelines and as battery costs decrease. Unlike Thermal Energy Storage (TES), which provides thermal flexibility, BESS offers electricity flexibility, enhancing grid integration and energy self-sufficiency. Reassessing the business case for BESS as costs decline may reveal improved cost-effectiveness, making it a more competitive option for energy storage.

5. DECARBONISATION PATHWAY

5.1. Proposed Decarbonisation Pathway

This decarbonisation pathway was developed based on a workshop held on 04.11.24 and a follow up session 17.12.24 with key TU Dublin staff specialising in energy management and sustainability. The interactive session allowed participants to influence project prioritisation, ensuring alignment with University goals. Projects were categorised into high, medium, and low priorities, and further broken down into short-, medium-, and long-term timelines. Medium-term initiatives were selected based on their potential to significantly impact 2030 targets, while long-term initiatives were geared towards achieving 2050 targets. The €/tCO_2 graph from the previous section was used to guide decisions and assess cost-effectiveness. The results have been summarised in the bullet points below.

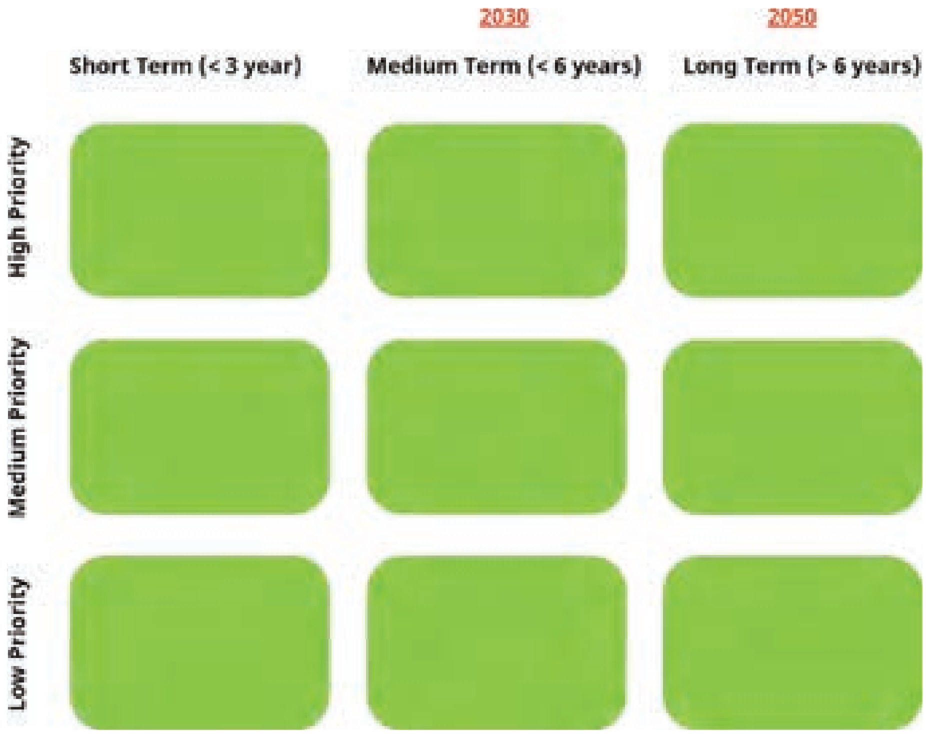


Figure 4: Prioritisation Framework (Miro Workshop)

Short Term (1 – 3 years)

- **High Priority**:
  - Install main incomer meters in all buildings to enable accurate energy measurement at the building level.
  - Assess out-of-hours energy loads and optimise equipment scheduling to ensure buildings operate only, when necessary, supported by effective BMS operations.
  - Focus on reducing energy usage in leased buildings, which may currently be operating inefficiently.

  - Connect remaining buildings on the Tallaght campus to the Tallaght District Heating Scheme (TDHS).
  - Evaluate the feasibility of developing a district heating network at the Blanchardstown campus including identification of the most cost-effective heat source for Blanchardstown (e.g., geothermal, waste heat, or bioenergy).
  - Carry out the design of the full geothermal production system to decarbonise district heating on the Grangegorman campus

- **Medium Priority**:
  - Conduct comprehensive reviews of internal and external lighting across all campuses, with a focus on the Tallaght campus due to inefficient T8 lighting and over-lit spaces.
  - Assess external lighting schedules, particularly during winter months, to identify optimisation opportunities.
  - Launch energy campaigns to communicate the energy action plan effectively and engage students and staff in energy-saving initiatives.
  - Consider decanting operations from the FOCAS building to Grangegorman as a key step toward meeting net-zero goals.
  - Development of strategic assessment report for Bolton Street.

Medium Term (3 – 6 years)

- **High Priority:**
  - Once main incomer meters and BMS improvements are operational, implement a detailed metering strategy, including sub-metering for renewable energy systems and occupancy sensors, to support space optimisation studies.
  - Transition the Grangegorman campus from gas to geothermal energy to reduce emissions given its high energy consumption.
  - Implement district heating at Blanchardstown using a renewable heat source, either on-site or by integrating with available district heating in Blanchardstown.
  - Install solar PV on all suitable buildings at Blanchardstown
  - Brief design team for the Broombridge facility to ensure PV is incorporated.
  - Carry out a study to evaluate the feasibility and effectiveness of energy storage systems (TES or BESS) at each campus.
  - Decant Aungier Street to align with 2030 carbon reduction targets.

- **Medium Priority:**
  - With adequate metering and sub-metering in place, revitalise behavioural energy campaigns like “Reduce Your Use” by leveraging real energy data to communicate localised results to academic departments and professional service areas.

- Use data-driven insights to better engage students and staff, fostering a sense of ownership in energy- saving efforts.
- Launch targeted campaigns aimed at specific high-energy users, such as laboratories and workshops, to encourage competition and promote sustainable practices across the campus community.
- Initiate selected option from Bolton Street Strategic Assessment Report. Decide on whether to decant operations from Bolton Street, based on a comparative assessment of operational emissions from the existing campus versus the lifecycle emissions of constructing new buildings at Grangegorman.
- Enhance the Building Stock Plan to evaluate the relative merits and investment costs for deep retrofit opportunities, ensuring progress toward 2050 targets.

- **Low Priority:**
  - Install PV panels on suitable buildings at the Tallaght and Grangegorman campuses that currently lack PV systems, ensuring compliance with solar safeguarding zones to maximise renewable energy generation potential.

Long Term (6+ years)

- **High Priority:**
  - Assess any expansions to the Tallaght and Blanchardstown campuses for their capacity to deliver low- carbon energy, with a focus on low-carbon heat solutions.
  - Conduct a study informed by Grangegorman's geothermal viability to evaluate the cost-effectiveness of
  - drilling a production well at Tallaght and Blanchardstown to support network expansion.
  - Establish an additional heat source in Tallaght as waste heat from the Amazon data centre is likely to be fully utilised by this stage.
  - Establish an additional heat source in Blanchardstown to diversify heat source options.

- **Medium Priority:**
  - Deliver the Bolton Street solution and embed consequences in overall lifecycle emissions and reporting as part of the building stock plan.
  - Ensure that any transition aligns with TU Dublin’s long-term net-zero carbon targets and strategic goals.
  - Develop a comprehensive Building Stock Plan to evaluate the relative merits and investment costs for deep retrofit opportunities, ensuring progress toward 2050 targets.

6. STRATEGIC CONSIDERATIONS

6.1. Decision Points

A variety of considerations are relevant to determine what the most effective, realistic, and financially advantageous options are to implement the opportunities identified in the 'Opportunity Evaluation' report. The considerations that are relevant to a project depend on the specifics of each project including the capital investment required, complexity of the project, and the risk associated with the project. Based on the findings of the 'Review of Progress to Date' (Appendix B), the 'Opportunity Evaluation' report (Appendix C), and discussions with the TU Dublin Energy Management Team, six specific decisions have been identified to enable TU Dublin to meet its 2030- and 2050 energy and emissions targets.

- **District Heating at the Blanchardstown campus**
  TU Dublin is committed to implementing district heating at the Blanchardstown campus. A campus-level district heating network will be developed to ensure the site is 'district heating ready' and prepared to connect to an available renewable heat source, ideally, the wider Blanchardstown district heating scheme as soon as it becomes operational. Timelines for an external network must be established in time to determine whether an on-campus energy centre will be required to meet the 2030 GHG emission reduction targets. Further analysis is needed to identify the most cost-effective heat source and the requirement for an on-campus energy centre.

- **Solar PV at the Blanchardstown campus**
  The Opportunity Evaluation report highlights the significant potential for development of solar PV arrays on buildings at the Blanchardstown campus. TU Dublin will now decide the delivery approach and timeline to implement the technology to avail of the cost and carbon reduction benefits.

- **Metering**
  Improved metering will play a key enabling role in the delivery and the effectiveness of various other energy and emission reducing actions. TU Dublin will develop a metering plan and determine how this plan will be delivered. Based on discissions with the TU Dublin Energy Management Team, installing building level electricity and heat meters across all campuses is the preferred option. This action should be considered urgent and treated as a high priority. TU Dublin will then decide the suitable approach to developing sub-building level metering once building level metering has been installed across all campuses.

- **Divestment and new buildings**
  Greater clarity is needed regarding the future plans for buildings across TU Dublin campuses. Ongoing review is required into the divestment or decanting of certain buildings, their interrelationship to new build proposals, and the timeframe for these changes.

Confirmation is required on which buildings will be divested, how this aligns with the new build programme, and when these facilities will cease contributing to TU Dublin's recorded energy consumption and emissions.

- **Geothermal District Heating at Grangegorman**
  Decarbonisation of the district heating system at the Grangegorman campus using geothermal energy is the optimal route to reducing thermal emissions and is the option TU Dublin is actively progressing. It is important however for TU Dublin to decide the next steps they will take dependent on the findings of the GEMINI project. The results of the GEMINI project are expected in 2027. TU Dublin will now begin planning for the three identified scenarios of the deep geothermal drilling (i.e., identify a course of action for the scenarios of 3 MW, 6 MW, or 10 MW of heat being available for use in a district heating network). This will include a design for additional systems that can provide heat if insufficient capacity is available.

  Opportunity to Engage with Energy Communities at the Proposed D+C Centre
  TU Dublin will explore the benefit of implementing community energy projects in tandem with the energy plan developments at our locations. There is a particular opportunity for an exemplar large-scale solar PV community project in conjunction with the proposed Broombridge (D+C) Design + Construct Project. The Opportunity Evaluation report outlines how entry into the Small-Scale Renewable Energy Support Scheme (SRESS) may be an option at the site thereby strengthening the business case for the project. Eligibility for this scheme requires community involvement and there may be an opportunity to collaborate with the existing SECs in the area to develop a strong community component to the project. To progress this, the aims/ objectives of the project will need to be agreed collaboratively. Installing solar PV panels to meet the electricity demand of the building as part of the redesign process will have the benefit of minimising the Scope 2 emissions that the building would add to TU Dublin's total emissions once operational.

CAPEX and OPEX

Identification and comparison of the upfront and lifetime investment required for each project is necessary to determine the most appropriate delivery approach. For example, the Opportunity Evaluation Report (appendix C) identifies two ways that solar PV could be installed on TU Dublin campuses. The first option is to provide the upfront investment costs required to purchase and install the relevant solar equipment.

The other option is to engage in a PPA contract with a solar operator who would pay for the installation of the solar equipment and TU Dublin would buy the electricity generated from the solar operator. The first option requires very high upfront investment but would likely be more profitable over its lifetime. The second option offers an alternative if the upfront investment requirements are not available in the short term. TU Dublin will assess which is the most viable route, considering the availability of upfront capital when the project is being progressed.

Payback period

Findings from analysis on the payback period of each of the opportunities identified will be an influencing factor on the decision to pursue the opportunities identified. Additionally, the risk associated with the payback period will likely influence the amount of capital investment in a project. Installation of solar PV for example is a low-risk project that has a predictable outcome and minimal need for involvement with external stakeholders. Development of a geothermal district heating system comparatively is reliant on further exploration to determine if useable temperatures are available and is part of a wider project that will involve various stakeholders. The risk, level of outcome certainty, and confidence in investment payback will therefore likely influence investment in different projects.

Trajectory and changes in relevant sectors

It should be noted that the findings and opportunities identified in the Opportunity Evaluation Report are based on current market, regulatory, and policy landscapes, each of which are liable to change in the coming years. It is important to consider the implications changes may have on feasibility of projects identified in the report. Continued trends of falling battery prices for example may influence the financial viability of installation of battery energy storage system at the campuses. Changes to Private Wire legislation may make Power Purchase Agreements a more attractive option in the coming years. Introduction of flexible grid connections and increased Time-of-Use tariffs may justify larger investment in energy storage systems across the campuses. Changes in feed-in-tariff rates for renewable energy may impact the payback period of solar PV installations. These are just some examples of the many external factors that will influence the technical and financial viability of opportunities identified. Changes in European and national policy may also have an influence on the priority in which actions are taken. For example, the expected addition of a requirement that public buildings install solar technologies on the majority of existing buildings to the Energy Performance of Buildings Directive in the near future will likely accelerate the delivery of the opportunities identified for solar PV in order to comply with this requirement. All of these factors point to the need to regularly update this Energy Action Plan. For these reasons, this Energy Action Plan will be updated annually in line with updates to the Climate Action Roadmap.

Energy infrastructure requirements

The majority of opportunities identified involve installation of technologies across various campuses. Depending on the equipment required, this may have a major impact on the space requirement. It is important to consider the impact this may have on wider operations at the campus, and this has been and must continue to be reflected in the various master planning documents produced/ currently in development to ensure that the space requirement does not negatively impact other infrastructure or developments at the campuses. Additionally, upgrading electrical connections may be required in many buildings when replacing energy systems. In the case of installing heat pumps the Maximum Import Capacity (MIC) of the building/ relevant meter may also need to be increased and this may be a barrier if there is limited electrical capacity available in the area. The ESB will therefore be engaged with an early stage of developing projects to determine if this will be a barrier.

Building plans

Space optimisation analysis to be conducted in the coming years will highlight opportunities to use buildings more efficiently. This may include decanting older or less efficient buildings. It is therefore important to consider the long-term plans for each building before investing in solar, retrofit measures etc. as this will impact the payback period. Additionally, any plans to change the use of buildings (particularly as a result of the optimisation study) should be considered as this will impact the electricity/ heat requirements of the building

6.2. Capability and Knowledge Development:

Delivering most projects identified in the Opportunity Evaluation Report will require many hours of TU Dublin staff time. Resourcing across areas of project management, procurement, maintenance, etc., will be required to install and then maintain the various technologies outlined. In many cases TU Dublin staff already have the skills and knowledge to install and manage the technologies identified in this report, particularly relating to opportunities to optimise energy management across the campuses. Up-skilling of staff may be required in other areas. For some technologies, the installation/ management can be outsourced to specialized companies and the TU Dublin role can be primarily based on project management and coordination.

District heating

One of the primary benefits of a customer who is connected to a district heating system is that the centralised nature of the system minimises the responsibility of the customer to maintain, service, and repair the system. At the Tallaght campus, TU Dublin is a customer of the Tallaght District Heating Scheme and therefore are not involved in maintenance of the energy centre as this is the responsibility of Heat Works. The training, expertise, and management required by TU Dublin at the Tallaght campus is therefore limited mainly to managing the heat exchangers located within buildings at the Tallaght campus. This is an important consideration when deciding the approach to delivering and managing the district heating systems at the Blanchardstown campus.

There is a requirement to build a campus-level district heating network to enable TU Dublin to connect to a wider Blanchardstown scheme. It may be required to install and manage an interim energy centre for the campus in advance of a wider system being available. Outsourcing of this role and responsibilities to a specialized operator in the sector or insourcing and upskilling our Campus & Estates Management Team will be required and this potential cost and the resourcing required to manage this will be factored into the decision-making process.

Geothermal systems

As outlined above, TU Dublin is involved in the GEMINI project which will determine the deep geothermal potential at the Grangegorman campus. TU Dublin will therefore develop their geothermal knowledge base through this project in both the professional and academic departments of the organization. This knowledge and experience will be useful for TU Dublin to also examine the geothermal potential at its Tallaght and Blanchardstown campus.

The findings of the GEMINI project will determine how the existing district heating system at the Grangegorman campus will be decarbonised. The development of a geothermal based district heating system will likely require a highly specialised team of professionals. TU Dublin will have an important project management role in decarbonising the district heating system at the Grangegorman campus, and a large majority of the design, installation, and operation will require external expertise. The long-term operating arrangements for the Grangegorman District Heating Scheme as it extends to other users will require the establishment of an operating and governance structure with these other users. It will be important to determine this at the earliest opportunity so that resource requirements can be factored in. There will also be an opportunity to build internal skills within the institution for both students and staff via undergraduate and postgraduate courses in the areas of geothermal and district heating technologies.

Solar PV

As previously outlined, the most financially advantageous option to install solar PV across the TU Dublin campuses is to procure it directly. If this route is progressed, a specialised solar installer will be required to carry out detailed design array plans, roof surveys, and to install the solar PV panels. TU Dublin's role in delivering solar PV in this approach is in project management and procurement. TU Dublin would then be responsible for basic maintenance and monitoring of the performance of installed solar arrays once operational.

Power Purchase Agreements

The Opportunities Evaluation Report outlines the various options for TU Dublin to enter a PPA. There are currently limited benefits for TU Dublin to enter a PPA with an independent energy generator. However, if capital is not available to install energy infrastructure to comply with statutory timeframes, PPAs may need to be considered. There may be potential to use PPAs to develop a solar PV community project at the Broombridge site and expanding the knowledge base of how PPAs function within TU Dublin staff may be necessary if this is to be progressed. There will also be an opportunity to build internal skills within the organisation for both students and staff via undergraduate and postgraduate courses in the areas of financial mechanisms to enable the energy transition.

6.3. Resource and Funding Considerations

Energy Performance Contracting

TU Dublin is actively exploring the benefits of using Energy Performance Contracting (EPC) as a mechanism to achieve its climate action targets. Energy Performance Contracting (EPC) is a form of Design, Build, Operate, Finance and Maintain contracting. EPC can be used to guarantee the outcome of an energy/ emission saving project as the structure of the contract ensures that the Energy Services Company (ESCo) is financially incentivised to meet the agreed cost/ carbon savings. In an EPC, the payments to the ESCo are directly linked to the effectiveness of the cost/ carbon savings measures implemented.

EPCs are typically most suited to building level projects rather than larger, campus wide projects. Lighting upgrades, building management systems optimisation, and plantroom upgrades at a building level are generally well suited to an EPC. Examples of actions that are suited to EPC are provided below.

Measures suited to EPC

- LED lighting upgrades at a building level
- Boiler upgrades/ replacement to improve efficiency/ installation of heat pumps
- Mechanical and electrical upgrades/ replacements
- Upgrading of building controls including installation of occupancy sensors, replacement of AHUs with more efficient models, installation of new pumps, HVAC design/controls upgrade
- Installation of solar PV on an individual building level
- Installation and management of building level equipment that offtakes heat from a district heating scheme. An EPC can be used for the installation, maintenance, and optimisation of heat exchangers.
- Installation of electricity and heat meters

EPC provides an alternative to traditional deep retrofit projects for improving building efficiency. EPC allows buildings to remain operational during upgrades, avoiding the significant disruption and costs associated with vacating buildings for deep retrofits. Deep retrofits, while impactful, often incur high carbon savings costs and require careful, time-intensive planning. These projects must align with changes in building use to support evolving teaching and working methods. Retrofitting decisions across TU Dublin campuses should account for both operational impact and cost-effectiveness, prioritising approaches that balance efficiency with practicality.

Figure 5 on the next page shows a comparison of the EPC approach and a traditional retrofit contract. EPC generally focuses on decarbonisation and cost savings and actions can be carried out over an extended period of time. A deep retrofit comparatively involves extensive refurbishment to a building's fabric. Deep retrofit may be a more advantageous option for buildings that require construction work independently of energy upgrades (generally to improve comfort in the building, refurbish a building for a new use etc.).

If a deep retrofit project can be carried out in tandem with other construction works this may be a preferrable option, as the costs and disruption of emptying the building is occurring anyway. However, in the majority of instances an EPC approach to decarbonise and improve the operational efficiency of a building is a more cost-effective method of achieving guaranteed carbon and cost savings.

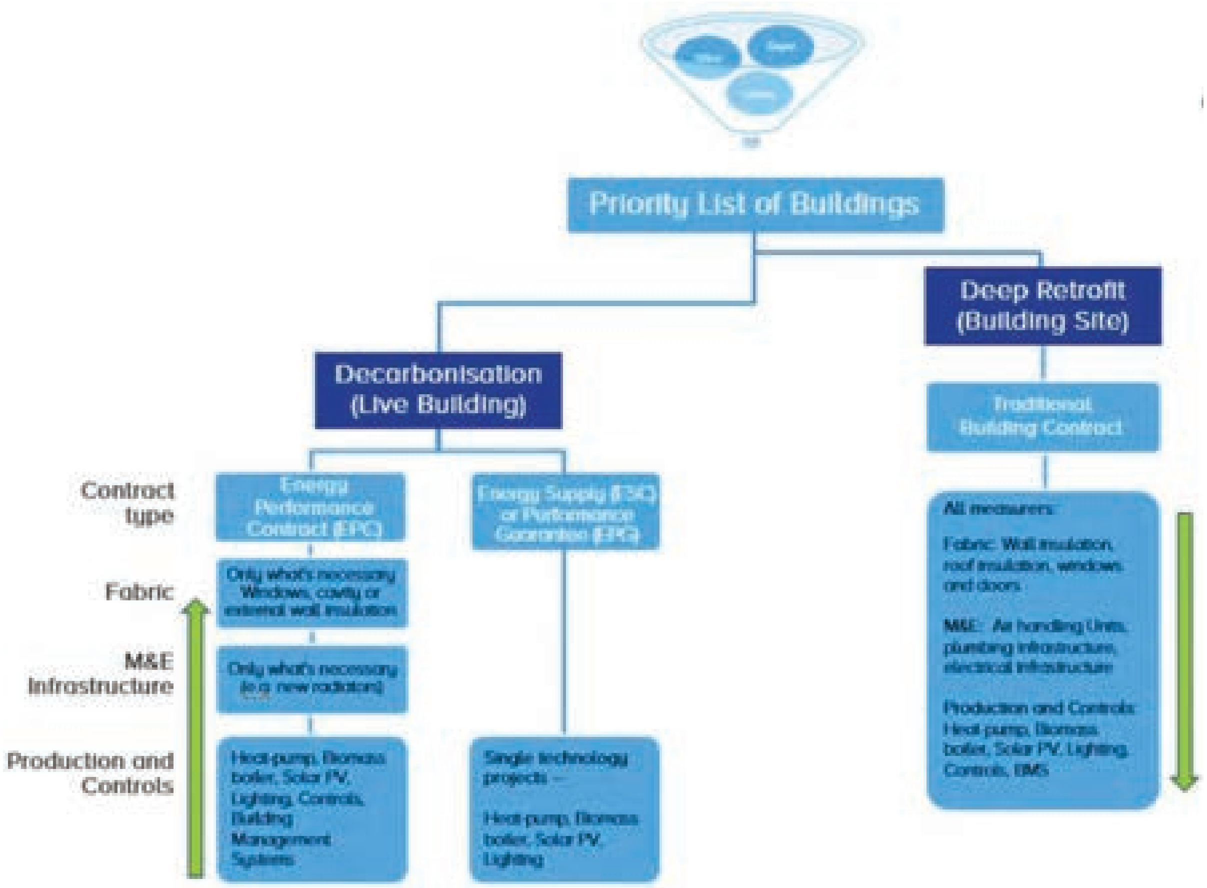


Figure 5: Graphic comparing the decarbonisation and deep retrofit approach for improving building operations.

There are various factors to consider when determining if EPC is a suited approach for delivering carbon/ cost saving actions. These considerations include the annual energy spend of a building, existing upgrade works that the building has undergone, and the energy management structure of the building. Codema has prepared a guide *"A Guide to Energy Performance Contracting in Public Buildings"* that provides additional information on how an EPC works. The "*EPC pre-assessment tool*" allows for a high level assessment of whether an EPC is suitable for a building.

Metering

Installation of electricity and/or heat meters is identified as a measure to include in an EPC. It should be noted however that the current lack of building level metering across the TU Dublin campuses may be a barrier to EPC development as the lack of building level consumption profile presents challenges to identify measures that will effectively reduce the energy consumption/ emissions of a building. Therefore, TU Dublin is prioritising installing building-level meters across each campus. This will enable more effective EPCs to be developed and there is potential to then include further metering within buildings in EPCs once this consistent base of building-level metering has been achieved.

Pathfinder

The Pathfinder programme is a funding programme provided by the SEAI. The aim of the programme is to build capacity and knowledge within public sector bodies to enable them to achieve their retrofit goals. One of the partners with the SEAI in the Pathfinder programme is the Higher Education Authority. A significant portion of the Pathfinder funding has been allocated to supporting third level institutions to meet their 2030 energy efficiency and greenhouse gas emissions reduction targets. TU Dublin is already in the process of obtaining funding from this programme for the deep retrofit of the Aras Fíos building at the Blanchardstown campus and to support the installation of a geothermal source for the district heating system in Grangegorman campus. There may be additional opportunities to obtain funding from this programme for some of the opportunities identified in the coming years.

SEAI Support Scheme for Renewable Heat (SSRH)

The SEAIs SSRH offers financial support for organisations that are developing renewable based heating systems. The scheme aims to bridge the gap between the installation and operating costs of renewable systems when compared to fossil fuel-based heating systems. The scheme can provide up to 40% of the costs of installation of a heat pump. Although TU Dublin is committed to developing district heating networks at their main campuses rather than individual building level heat pumps, this scheme may be relevant for funding heat pumps for these centralised district heating systems. Additionally, there are various buildings that are not located at the main campuses. Building level solutions (likely heat pumps) will be required to decarbonise the heating system of these buildings. This scheme can also support district heating network pipes and other infrastructure in some instances. Consideration of the eligibility criteria of this scheme should therefore be given when planning building level retrofits and to support campus level transition to renewable heat sources. The eligibility criteria of the scheme are outlined in the Grant Scheme Operating Rules and Guidelines.

Energy credits – Energy Efficiency Obligation Scheme

The Energy Efficiency Obligation Scheme (EEOS) was set up to incentivise taking actions to achieve sustained energy efficiencies across various sectors. Under the scheme large energy suppliers (the Obligated Parties) are required to financially support customers who have made progress in improving their energy efficiency. Each Obligated Party has a specific efficiency target to achieve based on their market share within the energy industry. Energy suppliers therefore offer compensation to customers to buy the 'energy credits' they have earned through efficiency measures. Obligated parties can also provide services through this scheme to assist clients to develop projects that will yield energy savings credits. TU Dublin is actively engaged with Obligated Parties to use this as an income stream when electricity and gas consumption is reduced through efficiency measures. The SEAI provide details as to how public bodies can engage in this process.

Energy credits – Energy Efficiency Obligation Scheme

The Business Energy Upgrades Scheme is open for all types of businesses, including Universities, to partially fund small and medium sized projects. Eligibility is based on the area of the building. There is a suite of nine measures supported including automatic controls installation, design assistance, BMS optimisation and AHU upgrades and heat pump installation. It also supports fabric upgrades to roofs and walls. Grants are provided for support up to 30% and 50% for design assistance and BMS optimisation. TU Dublin may be able to use this fund to partially support smaller upgrade projects for maintaining existing stock of buildings.

Community Energy Grant / Better Energy Communities Scheme

The Community Energy Grant Scheme supports sustainable energy across the community in the domestic, commercial, public and not-for-profit areas. Public sector and commercial applicants can receive up to 30% funding for community- oriented projects with a cross-sectoral approach. A project coordinator can be supported to develop sustainably financed projects. TU Dublin may be able to use this fund to support Community Energy Projects.

EU Funding

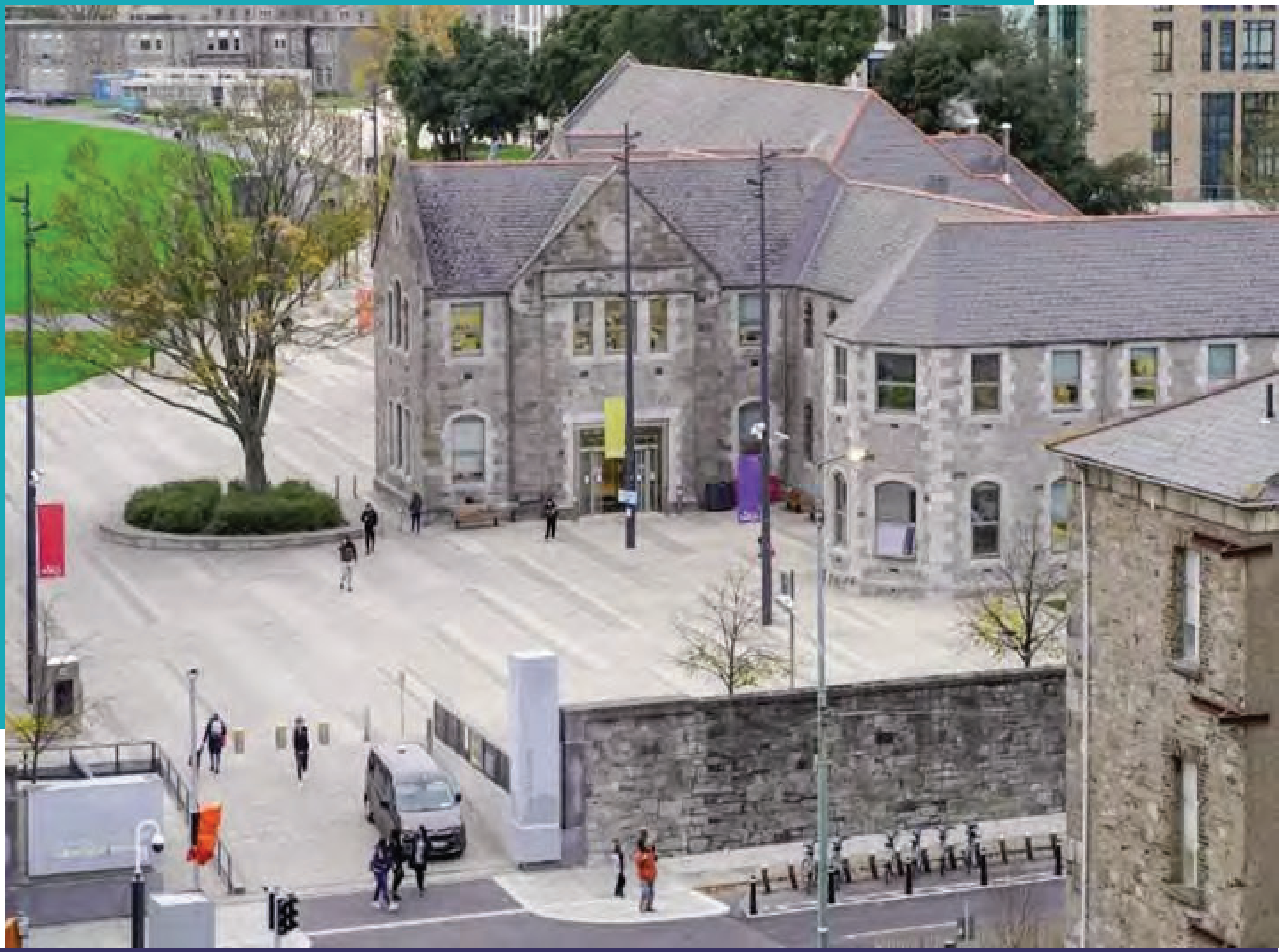
European Union funding programmes are available for projects under a variety of topics and TU Dublin has/is currently reviewing the opportunities to avail of funding from these programmes such as ELENA and PEACEPLUS to support energy and climate related actions across the organisation. Horizon Europe is another example of a funding stream for projects in the area of research and innovation. The EU LIFE funding stream offers funding specifically for projects in the areas of climate change mitigation, adaption, governance and information. Regularly reviewing the funding opportunities and mechanisms available at a European level may help identify relevant funding streams to deliver some of the opportunities identified.

Small-Scale Renewable Electricity Support Scheme

The Small-scale Renewable Electricity Support Scheme (SRESS) offers a fixed tariff for renewable energy projects that are owned by a small-medium enterprise or a community. As previously outlined, there may be potential to develop a SRESS project at the Broombridge building that would act as an investment with annual revenues to finance other projects.

Climate Action Funding

Funding was obtained from the Climate Action Fund for development of the Tallaght District Heating Scheme. Funding streams of a similar nature may be available in the coming years for district heating developments. The Infrastructure, Climate and Nature Fund is expected to provide the capital investment required for various climate related projects including district heating in the coming years.



APPENDIX A - Emission Types

APPENDIX A – EMISSION TYPES

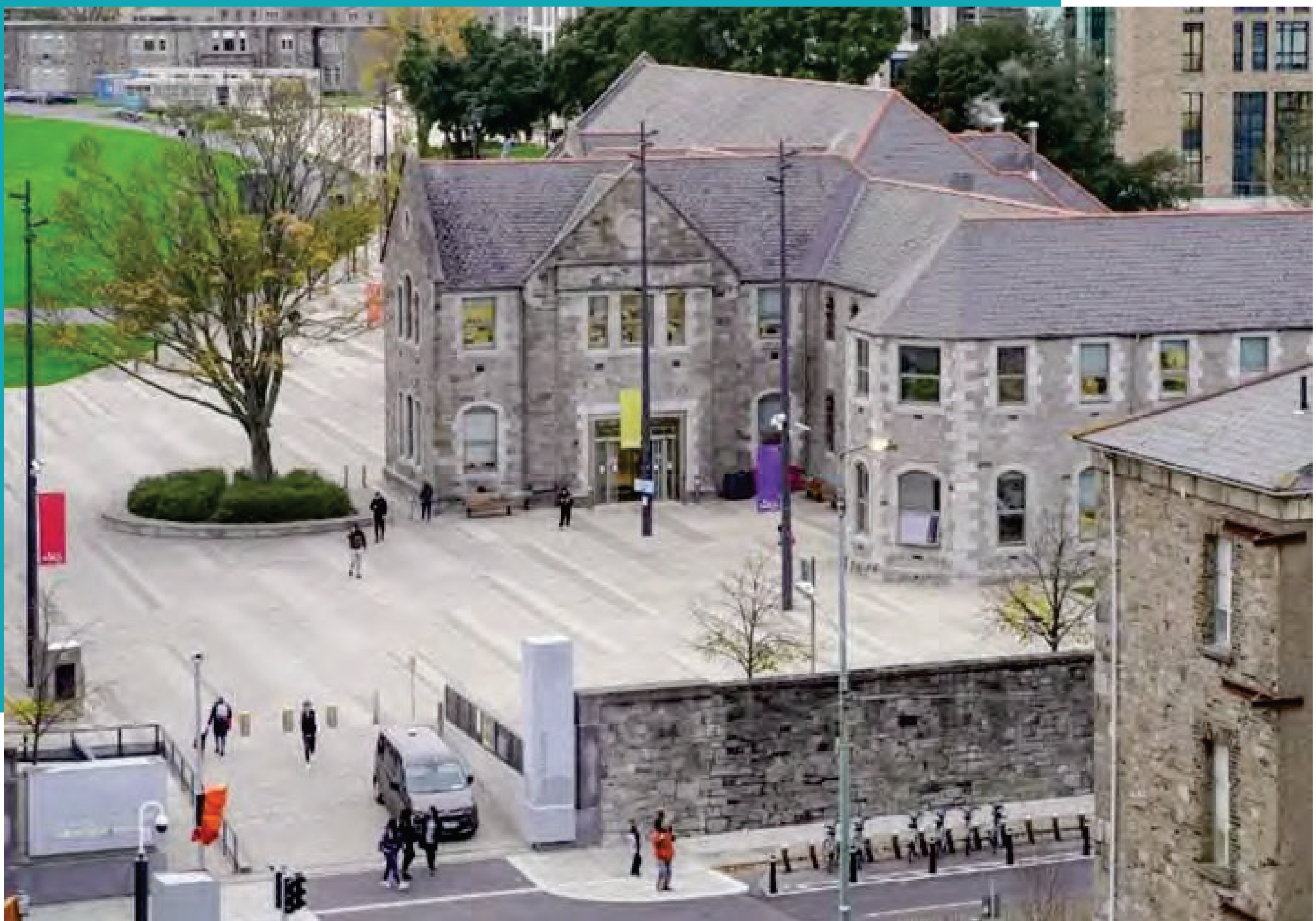
Figure 6: Scope 1, 2, and 3 Emissions

Scope 1, Scope 2, and Scope 3 emissions are categorizations used to classify and account for different sources of greenhouse gas (GHG) emissions.

1. Scope 1 emissions represent direct GHG emissions that originate from sources owned or controlled by the reporting entity. These emissions are typically generated from activities such as combustion of fossil fuels within company-owned facilities, vehicles, or equipment. Examples include emissions from on-site power generation, company-owned vehicles, and the heating, cooling, and lighting of buildings. Scope 1 emissions are considered direct because they occur directly from the entity's operations.

2. Scope 2 emissions refer to indirect GHG emissions associated with the consumption of purchased or imported electricity, or heat by the reporting entity. These emissions are generated off-site, but they are a consequence of the energy consumed by the reporting entity. Scope 2 emissions are typically produced by fossil fuel combustion at power plants that generate electricity or heat, which is then purchased and used by the reporting entity. Examples include emissions from grid electricity or off-site district heating systems. Scope 2 emissions are considered indirect because they result from the consumption of energy by the entity.

3. Scope 3 emissions cover all other indirect GHG emissions that occur because of the reporting entity's activities but are not included in Scope 1 or Scope 2. These emissions are generally a consequence of the entity's value chain, including both upstream and downstream activities. Scope 3 emissions can result from activities such as the transportation of goods and services, employee commuting, waste disposal, land use. Scope 3 emissions are the most comprehensive and often the largest portion of an entity's carbon footprint, as they encompass a broader range of activities beyond the direct operations.



APPENDIX B - Review of Progress to Date

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ABBREVIATIONS

AWS	Amazon Web Services
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DH	District heating
EED	Energy Efficiency Directive
EnPI	Energy Performance Indicator
EPBD	Energy Performance of Buildings Directive
EV	Electric vehicle
GDA	Grangegorman Development Agency
GPRN	Gas Point Reference Number
MPRN	Meter Point Reference Number
M&R	Monitoring and Reporting
OBC	Outline Business Case
PPP	Public Private Partnership
PSO	Public Sector Organisations
PV	Photovoltaic
SDG	Sustainable Development Goal
SEAI	Sustainable Energy Authority Ireland
TFC	Total Final Consumption
TPER	Total Primary Energy Requirement
TU Dublin	Technological University Dublin
UN	United Nations
VRV	Variable Refrigerant Volume

1. INTRODUCTION

This chapter provides a comprehensive overview of the current operations, management, and plans relating to energy across the TU Dublin campuses and buildings. The mandatory emissions reduction and energy efficiency targets set out for public bodies will be challenging for TU Dublin to meet as the University is continuing to expand in both physical size, and number of students/staff. The continued development of low carbon district heating systems at the main campuses will therefore be intrinsic to decoupling the expansion of the universities activities and greenhouse gas emissions.

The various mandatory targets TU Dublin must meet as a public body are outlined and analysis is provided on progress made to-date towards achieving these targets. As a major third level education institution, TU Dublin has a far-reaching influence across the activities and behaviour of students, staff, researchers, and surrounding communities. Education, training, and energy saving campaigns are therefore an important tool in promoting energy awareness and a description of some of the most notable initiatives taking place across the TU Dublin campuses are included in this chapter.

2. OBLIGATIONS AND PROGRESS

The Public Sector Climate Action Mandate outlines the targets which public sector bodies such as TU Dublin have a statutory obligation to comply with. The main requirements of the Public Sector Climate Action Madate are that public bodies must reduce greenhouse gas emissions by 51% by 2030 and achieve an energy efficiency improvement of 50% by 2030. The SEAI operates a monitoring and reporting platform (the M&R system), where PSOs (Public Sector Organisations) are required to upload various data sets that shows their yearly progress towards achieving each target. TU Dublin has been reporting its energy performance since 2021, when TU Dublin was established. Prior to this, the three institutions reported their energy performance individually and the baseline figures below are the amalgamated baselines of the three institutions that formed TU Dublin.

Energy Efficiency

This 50% energy efficiency target is relative to an average 2006-2008 baseline. TU Dublin recorded a baseline Total Final Consumption (TFC) of 36,983,394 kWh/year and an Energy Performance Indicator[1] (EnPI) of 2,633.84 for this baseline period. To meet the target TU Dublin must achieve an EnPI of 1,316.92 by 2030. The TFC recorded in 2023 was 36,538,693 kWh which represents a 1.2% reduction in TFC when compared to the 2006-2008 baseline. The EnPI recorded in 2023 was 1,996.41.

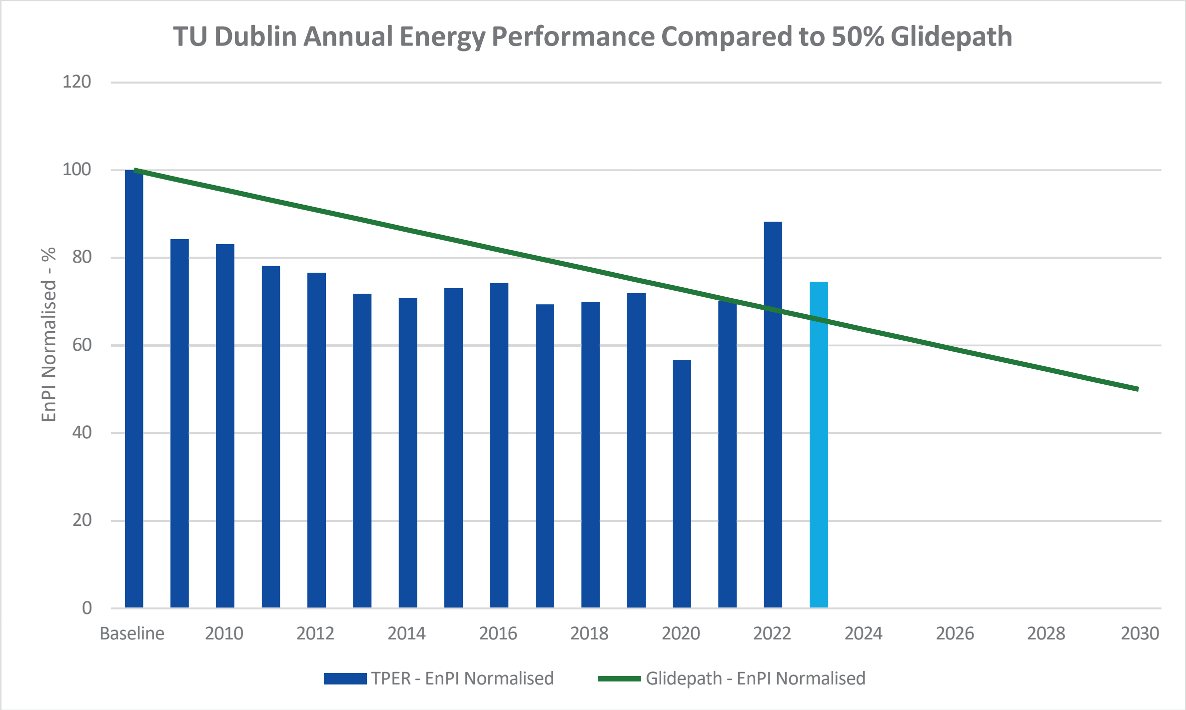

Figure 1: TU Dublin’s annual normalised energy performance compared to a 50% glidepath

[1] An Energy Performance Indicator is a measure that is used to determine energy intensity/ efficiency. Energy consumption is attributed on a pro rata basis across a separate measurement such as cost, floor area, number of students etc. This allows an organisation to track progress made towards achieving energy efficiencies. TU Dublin measures EnPI on a Student Number basis.

Figure 1 illustrates TU Dublin’s normalised annual energy performance compared to the 50% glidepath to 2030. The glidepath shows the average annual energy reduction required to meet the 50% Energy Efficiency target. TU Dublin managed to achieve a 44% improvement in energy performance in 2020 meaning that they had almost achieved their 50% energy efficiency target in that year. A large portion of this however was due to reduced levels of in-person teaching/activities provided in 2020 and 2021 due to Covid-19, and a bounce-back of usage occurred in 2021 and 2022. Additionally, various new buildings with large heating demands and electricity loads (notably Central and East Quad) came into use between 2020 and 2022 and this increased energy usage which likely contributed to the sharp decline in energy efficiency (relative to the university level baseline) shown from 2020 to 2022.

A significant improvement in energy efficiency occurred between 2022 and 2023, likely due to a combination of actions taken across the university such as the connection of buildings at the Tallaght Campus to a district heating scheme and energy management improvements achieved through shallow retrofits and control/ operation efficiencies. A 26% improvement in energy efficiency, relative to the baseline was therefore recorded in 2023. An additional 8% improvement would be required to be in line with the glidepath trajectory to 50% shown in Figure 1.

Greenhouse Gas Emissions

This 51% emissions reduction target is relative to a 2016-2018 average baseline and includes only Scope 1 and 2 emissions[2] . TU Dublin’s baseline emissions for this period are recorded as 10,063 tCO2e/year (2023 amended figure). To meet the target TU Dublin must therefore decrease emissions to 3,343 tCO2e/year by 2030. This reduction is greater than 51% when projected national grid decarbonisation levels are taken into account.

[2] Scope 1, Scope 2, and Scope 3 emissions are categorisations used to classify and account for different sources of greenhouse gas (GHG) emissions. Broadly speaking, Scope 1 emissions are from direct combustion of fossil fuels, Scope 2 emissions are from the indirect emissions associated with purchased electricity, and Scope 3 emissions are from an organisations entire value chain. A detailed description of this categorisation is provided in Appendix A.

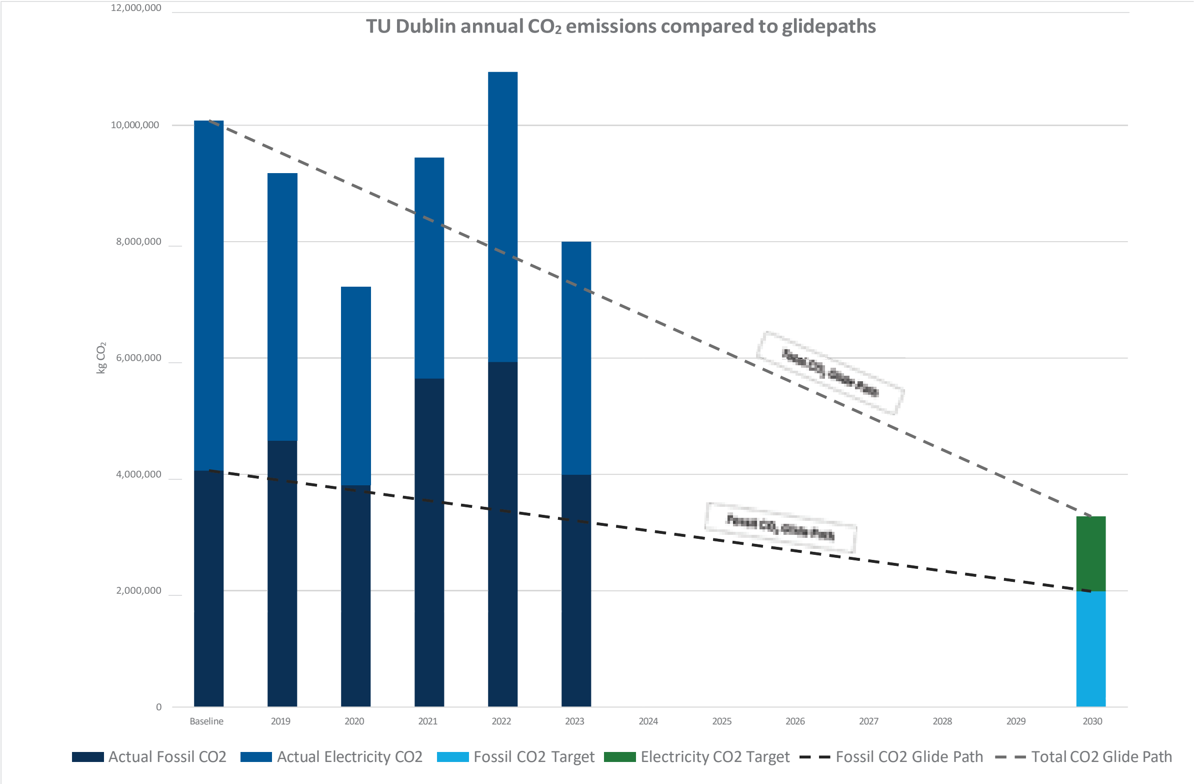

Figure 2: Annual carbon dioxide emissions of TU Dublin (segregated into emissions from purchased electricity and from fossil fuel combustion) compared to a glidepath reductive to meet 2030 targets.

Figure 2 above illustrates TU Dublin's annual carbon emissions from both on-site fuel combustion, and the carbon emissions associated with purchased electricity (i.e. Scope 1 and Scope 2 emissions). TU Dublin recorded total emission reductions between the baseline and 2019, and between 2019 and 2020, as shown above. However, emissions increased significantly between 2020 and 2021, and between 2021 and 2022. The reduction recorded between 2019 and 2020 was likely caused primarily by the impacts of the COVID-19 lockdowns in 2020 that significantly reduced the use and occupancy of buildings across all campuses. The fluctuations across 2020, 2021, and 2022 are therefore likely influenced by the absence, and then return to in-person teaching across the campuses. However, the addition of various new buildings at the Grangegorman Campus that are particularly high energy users (such as Central Quad) since 2020 has also likely had a major impact on the increase in energy consumption and associated emissions. The significant reduction in total emissions between 2022 and 2023 is a positive finding and highlights the impact of emission reducing actions being taken across the campuses.

ISO 50001

ISO 5001 is an international standard for energy management and includes requirements relating to achieving continuous energy efficiencies and the development of energy policies. The Public Sector Climate Action Mandate also requires "All public sector bodies with an energy spend greater than €2 million per annum to achieve ISO 50001 certification by end-2024". This energy spend applies to TU Dublin and TU Dublin have been awarded accreditation of ISO50001 in both 2023 and 2024 An Energy Management Team has been established in TU Dublin as part of the ISO50001 process.

European Directives

The Public Sector Climate Action Mandate also includes various other requirements that are informed by European Directives, the most notable of which are listed below. Compliance with these regulations is generally outlined in the Climate Action Roadmap that public organisations are required to prepare.

- The public sector will not install heating systems that use fossil fuels after 2023, in 1) new buildings, and 2) “major renovation” retrofit projects, (exceptions apply) (Energy Performance of Buildings Directive).
- Large Public Sector bodies will upgrade their building stock to NZEB/ZEB in line with the requirements of the Energy Performance of Buildings Directive and the Energy Efficiency Directive.
- Public bodies will procure only zero-emission vehicles from the end of 2022 which will enable Ireland to surpass the requirements of the Clean Vehicles Directive.

The Energy Efficiency Directive sets binding targets member states must achieve. One of the key aspects of this directive is public sector leadership in adopting efficiency measures. Some of the other noteworthy requirements of the EED include but are not limited to:

- Achieving a 1.9% reduction in absolute energy consumption annually.
- Renovation of at least 3% of the total floor area to NZEB per year (/equivalent retrofit actions).
- New public buildings must be NZEB.
- Consideration of energy efficiency in contracts and tenders.

Amendments to the Energy Performance of Builds Directive in recent years have set regulations for both new and existing buildings to reduce both energy consumption and greenhouse gas emissions. Some of the most noteworthy requirements of the EPBD include but are not limited to:

- New buildings owned by public bodies must be zero emission buildings
- The SEAI have indicated in webinar sessions that additional requirements to install solar on all new and existing public buildings. For existing public buildings, the requirement is that buildings over 2000m2 must install solar by 2028, buildings over 750m2 by 2029, and buildings over 250m2 by 2030. It should be noted however that this has not been formally announced, and the details of the implementation of this requirement are yet to be provided.
- Provision of sustainable mobility infrastructure. In particular, the 2021 Energy Performance of Building Regulations requires the provision of electric vehicle charging points and ducting infrastructure in new buildings and existing buildings that are undergoing major renovation (where the building has associated vehicular parking).

3. CROSS CAMPUS INITATIVES

A campus level review of energy performance to date is provided later in this chapter and this includes building and campus level actions and progress in reducing greenhouse gas emissions and promoting energy efficiency. The following are projects and initiatives that have, or are currently, taking place at a multi-disciplinary and whole university level.

District Heating

TU Dublin is committed to continuing participation in the development of low-carbon district heating systems across its campuses. The use of waste heat from other industries in district heating systems is an extremely energy efficient method of providing space and water heating and is encouraged across various European and national policies, including the national Climate Action Plan. Replacing gas boilers across the campuses of TU Dublin with district heating connections improves energy efficiency and is a low-carbon alternative to fossil fuel heating systems. The Tallaght and Grangegorman campuses are both connected to district heating systems. Expansion and improvement of these systems is ongoing. Development of a district heating system at the Blanchardstown campus is at early stages and TU Dublin have engaged with Fingal County Council and Codema to express their interest in being involved with the development of this district heating system. Each system is detailed further in the campus level review and hat energy analysis contained in the Opportunities Evaluation chapter.

Electric Vehicles

TU Dublin has replaced its fleet of 2 no. diesel vehicles with electric vehicles. This action contributes to both greenhouse gas reductions and improved energy efficiency. Fully electric vehicles do not create any Scope 1 emissions; however, Scope 2 emissions may increase slightly due to the charging of the vehicles. As electric vehicles are significantly more energy efficient than diesel vehicles, this replacement will result in a decrease in absolute energy consumption, and a reduction in the release of the greenhouse gases carbon dioxide and nitrous oxide. This is in line with the requirements of the Public Sector Climate Action Mandate and the Clean Vehicles Directive.

Submetering Programme

Many buildings across the campuses of TU Dublin are grouped to share electricity and gas meters. In some instances, the entire campus is sharing a single MPRN. A submetering programme is therefore currently underway across the university so that accurate building level energy consumption and performance data can be obtained. This will allow for more detailed analysis and identification of efficiency and optimisation opportunities.

Towards a Sustainable University Campus

TU Dublin was awarded €1 million of the HEA €5.5 million in Performance Funding in 2023. This funding is awarded to higher education institutions in recognition of their contribution to national strategic priorities and policies. TU Dublin is using this €1 million funding to develop a pilot smart monitoring and reporting project that will upgrade and digitise the existing monitoring and control systems of three buildings across the university. The data sets that will be gathered from this digitisation and monitoring will provide an evidence base to develop strategies to optimise energy usage. The pilot project seeks to promote active user involvement so that the three buildings will operate as living laboratories that will be based on a user-centric approach where users of the buildings have an understanding and awareness of the energy consumption of the building.

Green Labs

The Green Labs Programme operates across the Tallaght, Grangegorman, and Aungier Steet Campuses of TU Dublin. The Green Labs programme encourages adoption of sustainable practices in laboratory spaces as these facilities are typically highly energy and resource intensive. The Green Labs programme addresses 14 topics of sustainability, 6 of which are directly related to energy usage (plug load, infrastructure energy, cold storage, travel, large equipment, and fume hoods). TU Dublin has achieved certification for various labs across the University and intends to continue implementing actions that will improve the performance of labs.

		Campus	School/Research Hub	Lab Name	Date	Assessment Type	Overall Score	AWARD	Location
Faculty of Sciences & Health	1	Tallaght	School of Chemical & BioPharmaceutical Sciences	Chemistry Lab Suite	Jun-21	Baseline	51	Platinum	111, 113/115, 119/121, 129
					Dec-22	Certification	74		
	2	Tallaght	School of Chemical & BioPharmaceutical Sciences	Biological Sciences Lab	Mar-23	Baseline	55	Platinum	131, 149, 151
					Dec-23	Certification	74		
	3	Tallaght	School of Chemical & BioPharmaceutical Sciences	Apprenticeship Lab	Nov-23	Baseline	85	In Progress	127
					TBD	Certification			
	4	Grangegorman	School of Chemical & BioPharmaceutical Sciences	Chemical Sciences	Mar-23	Baseline	80	Gold	All UG labs in CQ (CQ-415, CQ-416, CQ-418, CQ-420, CQ-422, CQ-423, CQ-424, CQ-426)
					Dec-23	Certification	64		
	5	Grangegorman	School of Biological, Health and Sports Sciences	Biological Sciences Lab	Mar-23	Baseline	59	Gold	CQ-217, CQ-218
					Dec-23	Certification	68		
	6	Grangegorman	School of Physics, Clinical & Optometric Sciences	Junior Lab Suite	Mar-21	Baseline	44	Silver	CQ-117, CQ-118, CQ-120
					Dec-23	Certification	58		
	7	Grangegorman	School of Food Science and Environmental Health	Biology Lab Suite	Mar-23	Baseline	39	Platinum	CQ-226, CQ-333, CQ-335
					Dec-23	Certification	79		
	8	Grangegorman	School of Food Science and Environmental Health	Chemistry Lab Suite	Mar-23	Baseline	52	Gold	CQ-113, CQ-114, CQ-115
					Dec-23	Certification	62		
Research & Innovation	1	Grangegorman	Environmental Sustainability and Health Institute (ESHI)	Core Lab Area	Mar-23	Baseline	52	Silver	Core
					Dec-23	Certification	53		
	2	Aungier Street	Facility for Optical Characterisation and Spectroscopy (FOCAS)	Core Lab Area	Mar-23	Baseline	38	Platinum	Core
					Dec-23	Certification	79		

Table 1: Labs across the University that have been awarded Green Labs certifications.

Training and Education

The use of information, education, and awareness campaigns plays a pivotal role in achieving both emission reductions and energy efficiency across the TU Dublin campuses. Significant energy savings can be made through behavioural change and optimisation of existing facilities, space, and systems. Educating and training staff and students on the energy impact of their actions is an integral part of achieving energy savings that are consistent and long-term. TU Dublin was awarded Green Campus status by An Taisce in December 2023 and TU Dublin is the first multi-campus university in Ireland to be awarded this Green Flag. The green campus programme seeks to educate and spread awareness among students and staff across a variety of environmental topics, including energy.

Staff:

- TU Dublin hosts Senior Management Climate Leadership Training in which colleagues and representative from various other Higher Education Institutions attend a workshop to encourage peer-learning and adaption of best practice climate action.
- The TU Dublin Procurement team completed certified Green Public Procurement Training in 2023.
- Various members of TU Dublin staff have undertaken training in the EU Levels Framework that is run by the Irish Green Building Council. This training relates to Life Cycle Assessment for buildings and embeds circularity into the design process.
- TU Dublin runs Employee Induction Training in Sustainability for new and existing staff. This training consists of a module in Sustainability that introduces staff to the SDGs and climate change. This training was introduced in 2023 and is run twice a year. This training has been delivered to over 80 senior and managerial staff members as part of the Senior Leaders Development Programme.
- The University Executive team of TU Dublin have undertaken workshops on topics related to energy and climate action more broadly.

Students and researchers:

- Researchers in TU Dublin are required to participate in Sustainability Training for Researchers which includes taking two modules to train researchers to align research outputs with various relevant policies, most notably the UNs Sustainable Development Goals.
- As a third level institution, TU Dublin has the potential to greatly impact the skillsets, perspective, and experiences graduates leaving the colleges will have. Ensuring modules in the various courses offered in TU Dublin equip students with the knowledge and skills to work in fields related to climate action and the energy transition is an important role of third-level institution to ensure energy and climate skills gaps can be met. Embedding climate action and awareness in course material is important across all disciplines, and in particular in courses related to construction, the built environment, and engineering as this is where many current green skills gaps currently exist. An example of where TU Dublin is addressing this gap is through the creation of a new Modern Methods of Construction programme to upskill construction workers.
- The University Sustainability Council and the TU Dublin Green Team work to promote awareness of various climate related issues and to accelerate the delivery of many energy and climate initiatives taking place at TU Dublin. Both groups include various student representatives from across the University.

4. TALLAGHT CAMPUS

Overview

The Tallaght Campus is located on the southwestern edge of Dublin, within the Local Authority area of South Dublin County Council. The Tallaght Campus consists of 10 buildings, 6 of which are located on the 18-hectare main campus. The remaining 4 buildings are located within the Tallaght general area, as shown below. The TU Dublin Tallaght buildings vary in age from early 1990s buildings to recently completed new builds. Construction of the final building on the main campus (North Block) is close to completion. There are currently approximately 5,000 TU Dublin students based at the Tallaght campus.

TU Dublin Tallaght Map

The map below map shows the buildings that constitute the TU Dublin Tallaght Campus. A more detailed map of the buildings at the Tallaght Main Campus is provided below.

Figure 3: Map of the buildings of the TU Dublin Tallaght Campus.

Synergy Global

The Synergy Global building is located in the Citywest Business Park. This building is owned by TU Dublin and is one of the top three non-electrical energy users at the Tallaght Campus. This building is considered a potential future divestment opportunity; however, no decision has been made in relation to this. Space heating and domestic hot water are supplied by 1 no. gas boiler.

Technical Development Centre

The Technical Development Centre is a leased building that is used for energy and environmental teaching programmes. Divestment of the building is currently under live review. If this divestment occurs the functions of the building will be consolidated to the Tallaght Main Campus. The building is heated by a gas system.

Premier House

Premier House is owned by TU Dublin. The building has been recently refurbished and now contains lecture theatres and computer laboratories. The building is considered a potential future divestment opportunity; however, no decision has been made in relation to this. The building contains 2 no. gas boilers that provide space heating and domestic hot water.

Priorsgate Apt

TU Dublin leases space in an apartment building in Tallaght.

Tallaght Main Campus

Figure 4: Buildings located at the Tallaght Main Campus

Airton Close

Airton Close is a leased building. The building is not connected to the district heating system and instead uses a Variable Refrigerant Volume (VRV) electric heating system. Electricity at Airton Close is metered separately to the rest of the main campus.

Tallaght Main

The Main Building is the largest energy user at the Tallaght campus by a significant margin. The building is owned by TU Dublin and is connected to the district heating system. The district heating system supplies both space heating and hot water to the building through heat exchangers that are located in the building. The Main Building was the second highest energy user across TU Dublin in 2022, with this moving to the third highest user in 2023 as the full benefits of connecting this building to the district heating system came into effect. Gas is still used at the main building in the teaching kitchens for programmes in the Culinary Arts and Food Technology School.

Tallaght North

The North Block is a new building, and the final stages of construction are nearing completion. This building is owned by TU Dublin (Public Private Partnership)[3] and it is connected to the district heating system. The building is expected to come into operation in 2024 and will accommodate Engineering, Culinary Arts, Hospitality, and Apprenticeship courses.

Tallaght Sports, Science & Health

The Sport Science and Health building is a recently completed building that began operating in 2023. The building is owned by TU Dublin it is connected to the district heating system. The building includes a solar PV array of 130 panels (35 kW) and solar thermal panels on the roof of the building.

Tallaght Creche

There is a creche at the Tallaght Campus that is owned by TU Dublin. The creche however is operated by a separate entity who are responsible for energy management at this building.

Synergy CASH

The Synergy Centre consists of two parts. The first part of the building (Synergy) was constructed in 1999, while the newer extension (CASH) was added in 2016. The building is used primarily for meeting spaces and research facilities by both TU Dublin and external agencies. The building is owned by TU Dublin, and it is the second largest consumer of electricity at the Tallaght campus. The older Synergy building is currently heated by 2 no. gas boilers, while the newer CASH building is heated by 3 no. gas boilers. These gas boilers provide space and water heating to the building.

Tallaght Student Hub

The Student Hub is the smallest building at the Tallaght campus. The building is owned by TU Dublin and is used by the Student's Union. The building is heated by a gas-fired burner.

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[3] A Public Private Partnership is a method of procuring public services where the relevant public bodies work with private companies to provide services.

Energy Usage and Emissions

In 2023, the Tallaght Campus accounted for 12% of the carbon emissions of TU Dublin (1,098.93 tCO2e). As such, the impact of emission reduction measures at the Tallaght Campus will have a significant but not defining impact on the success of university wide emission reductions. The emissions of the Tallaght Campus on a kgCO2e per m2 floor area basis is currently lower than the average across the TU Dublin campuses.

2023 estimated total emissions (electrical + non electrical)	tCO_2e
Tallaght Campus	1,099
TU Dublin total	8,901
Tallaght as % of total	**12%**

Table 2: Total emissions of the Tallaght Campus (2023)

Floor area (2023)	m^2
Tallaght Campus total floor area	29,478
Tallaght $kgCO_2e/m^2$	37.3
TU Dublin average $kgCO_2e/m^2$	42.2

Table 3: Emissions per m^2 at the Tallaght Campus compared to the TU Dublin campus average.

Electrical

Top 3 electrical energy users (tCO_2e)		
1	Main Building	514
2	Synergy CASH	83
3	Airton Close	55
		652
% of total campus		85%

Table 4: Top three electricity users at the Tallaght campus.

The three largest electricity users at the Tallaght Campus account for 85% of electricity usage at the campus and actions should therefore be prioritised and concentrated on these three buildings for the most impactful emission reductions.

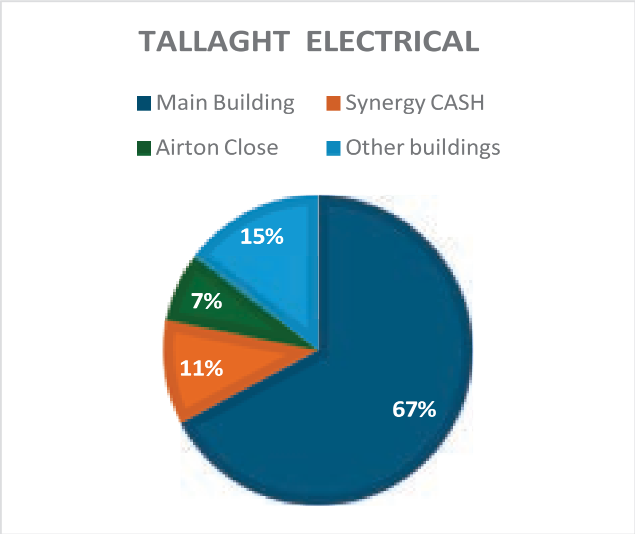


Figure 5: Graphic showing the portion of electricity usage of buildings at the Tallaght campus.

Non-Electrical

Top 3 non-electrical energy users (tCO_2e)		
1	Main Building	258
2	Synergy Global CW	30
3	Sports Science	27
		315
% of total campus		94%

Table 5: The three largest non-electrical energy users at the Tallaght campus.

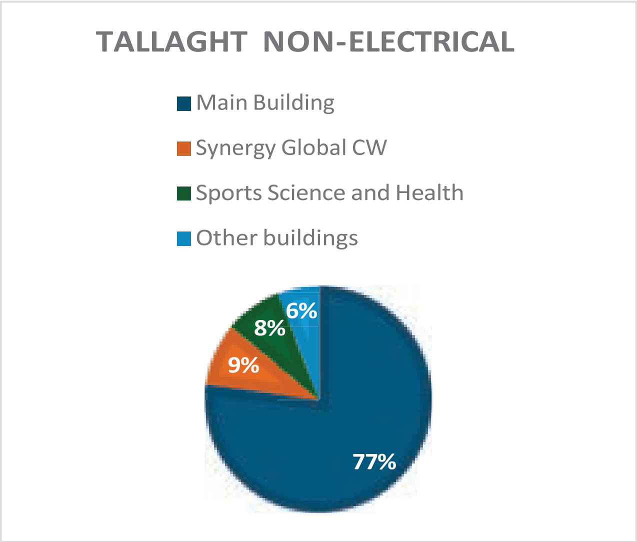


Figure 6: Graphic showing the proportion if non-electricity energy use at buildings at the Tallaght campus.

The three largest non-electricity users at the Tallaght Campus account for nearly all non-electrical energy usage at 94% of usage of the campus. The Main Building alone accounts for 77%. Although the Main Building is connected to the district heating system, the thermal emissions associated with the building are still considerable as the emissions factor for this accounts for the electricity usage of the district heating energy centre. This emission factor is beyond the control of TU Dublin; however, it is expected that this emission factor will decrease substantially in the coming years as the national grid is increasingly decarbonised. A significant portion of the non-electrical emissions of the Main Building however come from gas used in the three teaching kitchens at the Main Building and there is not currently a clear pathway to decarbonise this gas use.

Tallaght Microgrid study

Programmes related to Electric and Electronic Engineering are located at the Tallaght Campus. A microgrid has been developed at the campus as part of these teaching programmes. The microgrid is based on the Tallaght Main building and is connected to a 34 kW peak array of solar PV panels and a 6.5 kW wind turbine. The energy produced in the microgrid is not currently used and is purely for teaching purposes. However, it is possible, and it is the intention of the academic staff involved and TU Dublin Energy Management team that the energy produced will be consumed by the Tallaght Main building. The microgrid was originally connected to the Main Building, however one of the key concepts of a microgrid is that the building (or network if the microgrid is across multiple buildings) in question can operate independently of the main grid. An electric vehicle charger was installed at the Main Building and is connected to the microgrid to use the energy produced. However, a battery storage system is required to facilitate use of this EV charger from the microgrid, and for the system to operate independently of the main grid. A battery system has been obtained for the microgrid, however the batteries suffered degradation, and the academic staff involved in the project are therefore currently sourcing funding to replace the necessary components of the battery system.

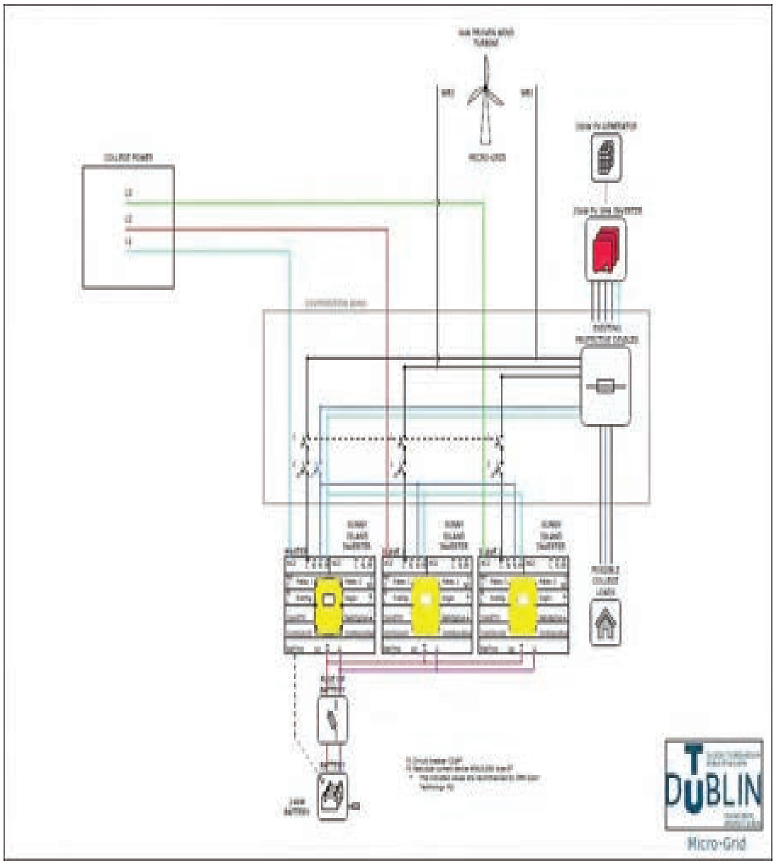


Figure 7: Schematic drawing of the Microgrid system at the Tallaght Campus

District Heating

The Tallaght District Heating Scheme began construction in 2021 and has been providing heat to TU Dublin since 2022. The district heating system at Tallaght uses waste heat from an AWS data centre located close to the Tallaght Campus. The system is managed by Heat Works, a not-for-profit energy utility that was set-up, and is owned by South Dublin County Council. TU Dublin is one of the anchor customers for this district heating system and as such is a member of the Heat Works company board. 3 buildings at the TU Dublin Tallaght main campus are currently connected to this district heating system (Main Building, Sports Science and Health, North Block). The Synergy CASH building is planned to be connected to the system in 2026. It is not currently feasible to connect any of the other existing building to the district heating system due to the consolidation plans for these buildings, and as TU Dublin does not own some of these buildings. Any new buildings at the Tallaght Campus will be connected to the district heating system if technically feasible.

Future Campus Development and Priorities

TU Dublin is currently developing an Opportunities Framework for the Tallaght Campus which will inform future development of the Tallaght campus. One of the aims of this Framework is to consolidate the buildings that are not at the main campus to the main campus. TU Dublin will prioritise using existing spaces and services to accommodate this consolidation. This optimisation of space represents an opportunity to reassess available space at the Tallaght Campus and ensure that a demand exists for any new buildings that cannot be met with the existing stock. The Opportunities Framework also identifies a demand for student accommodation at the Tallaght Campus and identifies lands for potential development of student accommodation in the coming years. Construction of additional buildings at the Tallaght Campus if therefore likely in the future due to demand for additional teaching buildings and student accommodation. The image below shows potential development areas at the Tallaght Main Campus that are considered in the Tallaght Campus Opportunities Framework.

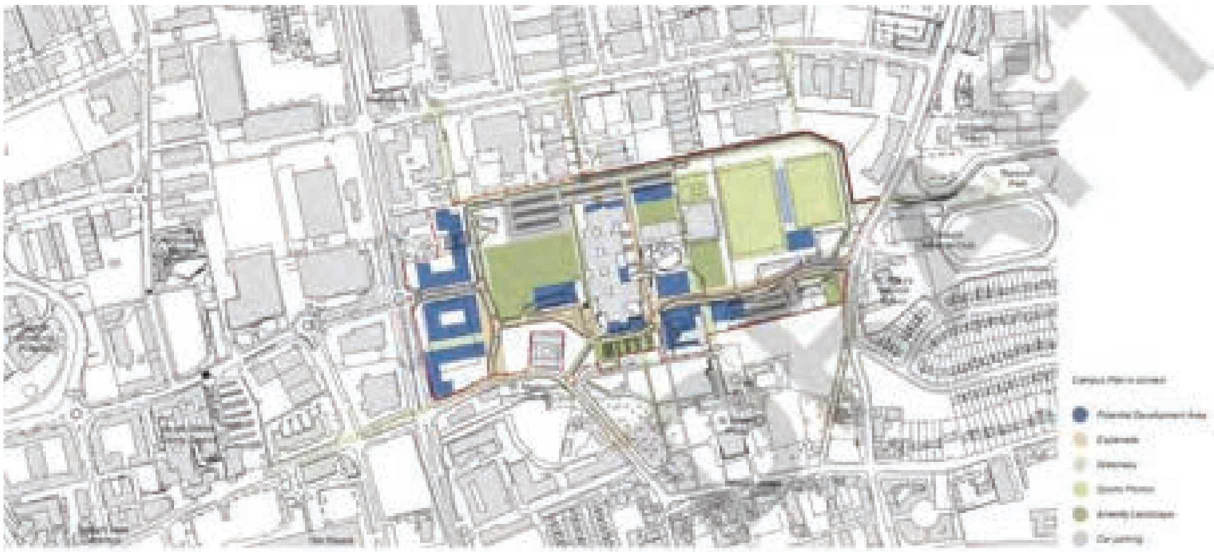


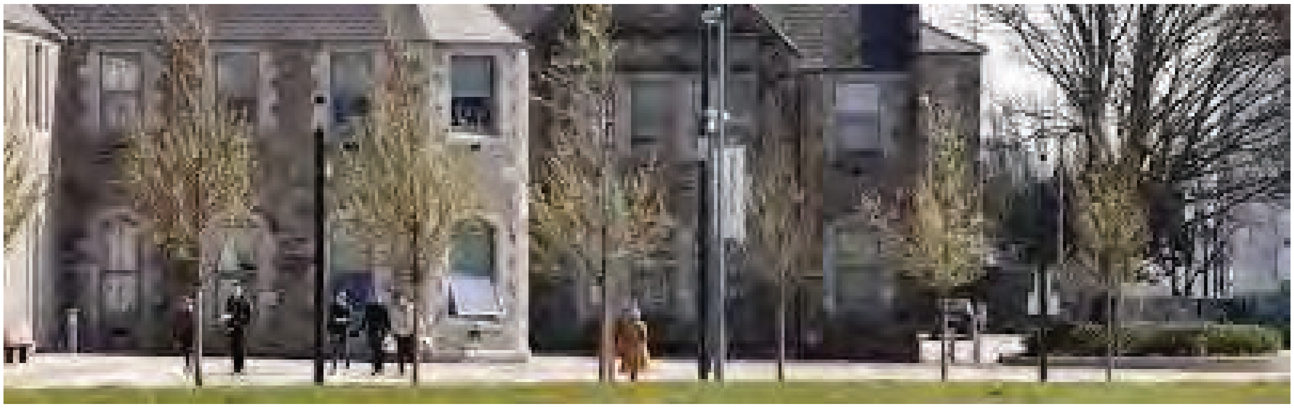
Figure 8: Extract of the Tallaght Campus Opportunities Framework showing potential areas for development at the Tallaght Main Campus

The Tallaght district heating system is continuing to expand in line with the development plan for the network. TU Dublin has conducted geothermal exploration works at the Tallaght Campus with a view to potentially providing a geothermal connection to the existing district heating system. TU Dublin is currently conducting technical assessments of the geothermal potential at the Tallaght Campus and are exploring the potential for geothermal energy to connect to the existing district heating system at the campus.

SWOT Analysis of the Tallaght Campus

Figure 9: SWOT analysis of the Tallaght Campus

5. GRANGEGORMAN CAMPUS



Overview

The TU Dublin Grangegorman Campus is located in the northwest inner city, within the Local Authority area of Dublin City Council. The Grangegorman Campus is the largest of the three major TU Dublin campuses, and construction of the campus is ongoing. TU Dublin work closely with the Grangegorman Development Agency who are responsible for overseeing the redevelopment of the wider Grangegorman Strategic Development Zone in which the Grangegorman TU Dubin Campus is located. The entire area of redevelopment is approximately 29 hectares, the majority of which is occupied by TU Dublin. The other main occupants include a HSE Primary Care Centre, and a primary school.

The TU Dublin Grangegorman Campus began welcoming students in 2021 as part of plans to consolidate the various locations of then Dublin Institute of Technology across the city into one campus. This consolidation is ongoing, and when completed may allow for the divestment of some of the buildings of the city campuses. Currently, approximately 10,000 TU Dublin students are based at the Grangegorman Campus. There are 19 buildings owned/operated by TU Dublin and a further six are currently at various stages of construction/ design stage (Academic Hub, Research Hub 2, West Quad, Design & Construct, Indoor Sports, and University Accommodation Phase 1 GG). When the Masterplan is fully completed TU Dublin will own and/or occupy 29 buildings at the Grangegorman Campus. TU Dublin has recently acquired a building in Broombridge, approximately 2 kilometres from the main campus, that is considered part of the Grangegorman Campus. The Grangegorman Campus includes various historical buildings that were constructed in the early to mid-1800s. These buildings have undergone refurbishment in recent years. The majority of buildingsat the campus , and notably the largest buildings, are new-builds that are built to recent building regulations.

TU Dublin Grangegorman Map (Existing Buildings)

Figure 10: Map of TU Dublin existing buildings at the Grangegorman Campus

Central Quad

Central Quad is the largest building across the entire TU Dublin University by a significant margin, consequently, it also has high levels of energy usage. As the building is a new building (built to NZEB standards) it should operate at a high level of efficiency. However, the energy management of this building is not operated efficiently, and TU Dublin have limited influence into this management as the building operates under a Public-Private Partnership. The structure of this arrangement does not incentivise the efficient operation and management of the energy systems of the building.

The building is used for teaching and research and contains a variety of specialised labs and teaching spaces. The building is connected to the district heating system which provides space and hot water heating to the building. The building is owned by TU Dublin (Public-Private Partnership).

East Quad

East Quad is the second largest building at the campus and is used for Arts and Humanities Programmes. The building contains various teaching spaces including lecture theatres and classrooms, as well as a large concert hall, a theatre, and studios. The building is connected to the district heating system which provides space and hot water heating to the building. The building is owned by TU Dublin but faces the same restrictions and issues relating to energy management as it operates under a Public-Private Partnership.

Lower House

Lower House is the oldest building at the Grangegorman Campus. TU Dublin carried out a deep renovation of the building in 2017 to bring it into useable condition. The building is now used to provide a variety of student facilities including a gym, student union space, and music rooms. The building is connected to the district heating system.

Historical Cluster

The historical cluster consists of four buildings that were built during the 1850's. These buildings underwent significant renovation in 2014/15 to bring them into useable condition. Rathdown House is the largest of these buildings and is used for student administrative and registration services. The building also contains a large canteen and a health/wellness centre. Glassmanogue is a smaller building in the historical cluster that is used as a gym space. Bradogue is used as office and administration space. St. Laurence's Church is used as a events space. Rathdown House, St Laurence's Church, Bradogue, and Glassmanogue are connected to the district heating system. These four buildings are served by one heat exchanger that is located in Rathdown House.

Orchard House

Orchard House is used as an office and administrative space. The building was constructed in 1894, and major refurbishment was carried out in 2014 to bring it into useable condition. This is a leased building and is therefore not connected to the district heating system. The building is heated by 1 no. gas boiler.

Clocktower

The Clocktower building is a large building that is used as an office and administrative space. The building was constructed in 1816 and has undergone major refurbishment in recent years This is a leased building and is therefore not connected to the district heating system. The building is heated by gas boilers.

Greenway Hub

Greenway Hub was built in 2016. The building is used mainly for research and innovation facilities including lab and incubation spaces, and also contains some meeting rooms. The building is connected to the district heating system which provides space and hot water heating to the building.

Park House and Kirwan House

Park House is located adjacent to the north of the main campus along North Circular Road. The building is owned by TU Dublin and the library for the Grangegorman campus, as well as various student services are currently located there. These services however will be moved to the main campus in the coming years upon completion of new buildings there. A significant portion of the building is occupied by office space that is rented to other organisations. The electricity used by TU Dublin is metered separately to the electricity used by the other occupants of the building. The building was constructed in the early 1970s. The building is currently heated by 5 no. gas boilers. Kirwan House is a separate building that is located beside Park House and is also in the ownership of TU Dublin. Kirwan House is not currently in use.

Hub 2

Hub 2 is a data centre building that stores the hardware equipment to support and store the various computing processes that take place across the campus.

Energy Centre 1

The energy centre is the centralised heat source for the district heating system that extends across the campus. The energy centre contains 5 x 2.9MW gas boilers that are used to heat water that is distributed through the district heating pipe network to 8 buildings across the campus.

Printmaking Workshop

The Printmaking Workshop is a small, leased building that was constructed in 2021. The building is used as a printing studio space. A solar PV array has been installed on the roof of this building and this is connected to the electric heating system of the building.

Estates Yard and Store

The Estates Yard and Store building is a small building that was constructed in 2021. This building is owned by TU Dublin and is used as a storage area for the Estates services teams at the campus.

Field Sports Changing and Estates 1

The Field Sports Changing and Estates building is a temporary structure that is leased by TU Dublin. TU Dublin intends to build a new permanent sports changing building in the medium term.

Broombridge Warehouse and Broombridge Sports Changing

TU Dublin recently acquired building in Broombridge where it intends to develop a Design and Construct Programme that will upskill construction workers in modern methods of construction. This is expected to be completed in 2026. The warehouse type building is not currently in use, however a small changing facility (Broombridge Sports Changing) next to the building that is also owned by TU Dublin is in use by teams that use the sports pitch beside the building. This is used mainly in the evenings.

Energy Usage and Emissions

In 2023, the Grangegorman Campus accounted for **44%** of the carbon emissions of TU Dublin (3,935 tCO_2e). This can be expected to increase significantly in the coming years as new buildings at the Grangegorman Campus come into operation. The impact of emission reduction measures at the Grangegorman Campus will therefore have a major impact on the success of university level emission reductions in line with obligations and targets. The emissions of the Grangegorman Campus on a $kgCO_2e$ per m^2 floor area basis is currently slightly higher than the average across the campuses. This can be expected to decrease substantially however if the district heating system is connected to geothermal energy, and as new NZEB buildings come into operation at the campus.

2023 estimated total emissions (electrical + non electrical)	tCO_2e
Grangegorman Campus	3,935
TU Dublin total	8,901
Grangegorman as % of total	44%

Table 7: Total emissions of the Grangegorman Campus in 2023

Floor area (2023)	m^2
Grangegorman Campus total floor area	85,252
Grangegorman $kgCO_2e/m^2$	46.2
TU Dublin average $kgCO_2e/m^2$	42.2

Table 6: Emissions of the Grangegorman campus per m^2 compared to the TU Dublin campus average

Electrical

Top 3 electrical energy users (tCO_2e)		
1	Central Quad	1243
2	East Quad	562
3	Lower House	151
		1956
% of total campus		79%

Table 8: Top three electricity users at the Grangegorman campus

The three largest electricity users at the Grangegorman Campus account for close to 80% of usage at the campus and actions to relating to energy efficiency and sourcing renewable electricity should be concentrated on these three buildings for maximum impact. As noted previously, a significant portion of the electricity usage of Central and East Quad can be attributed to the inefficient energy management of the two buildings under PPP operating agreements.

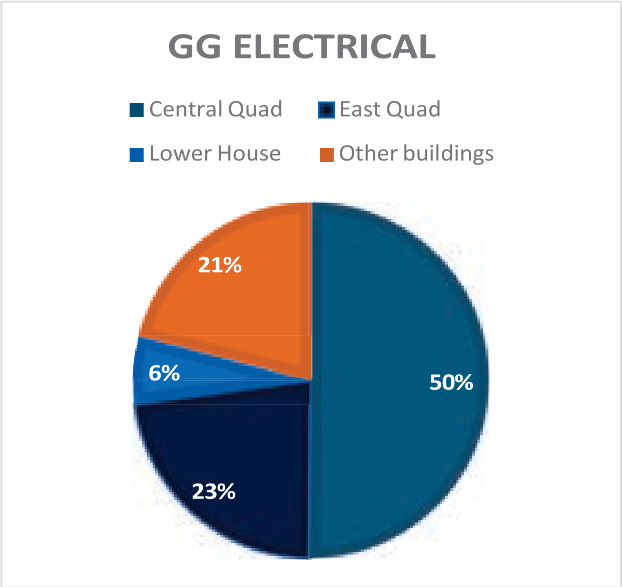


Figure 11: Graphic showing the proportion of electricity usage of buildings at the Grangegorman campus.

Non-Electrical

Top 3 non-electrical energy users (tCO_2e)		
1	Central Quad	884
2	Park House	231
3	Lower House	174
		1288
% of total campus		88%

Table 9: Top three non-electricity energy users at the Grangegorman campus

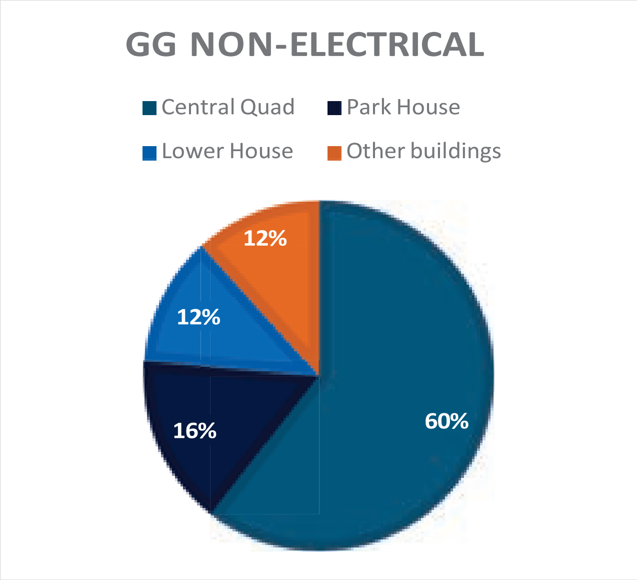


Figure 12: Graphic of the proportion of non-electrical energy usage of buildings at the Grangegorman campus.

The three largest non-electricity users at the Grangegorman Campus account for the majority of non-electrical energy at the campus.[4] Central Quad and Lower House are connected to the district heating system. This will likely be decarbonised in the coming years, pending positive results from geothermal exploration works. Efforts should therefore be focused mainly on formulating a decarbonisation plan for Park House as decarbonisation of heating at these three buildings alone will have a high impact on reducing emissions at the Grangegorman Campus. Non-electrical energy generally relates primarily to heating uses; however, it is worth noting that Central Quad contains various lab spaces that may contribute to non-electrical energy usage that is not related to heating.

District Heating

Deep geothermal drilling and exploration is currently underway at the Grangegorman Campus and it is envisioned that geothermal heat will connect to the existing district heating system at Grangegorman and will provide renewable, low carbon heat for space and water heating. TU Dublin researchers in partnership with Geological Survey Ireland have previously drilled a 1 kilometre bore hole that revealed positive results and an indication that it is worthwhile to continue this drilling to 2.5 kilometres. TU Dublin have secured funding from the SEAIs Pathfinder project to partially fund the deep borehole drilling at Grangegorman. This deep geothermal drilling is the first of its kind project in Ireland and will provide valuable data and insight for deep geothermal research and the geothermal industry in Ireland. Codema conducted an Outline Business Case (OBC) for the Grangegorman Development Agency (GDA) in 2024 and this details how a deep geothermal system is the most attractive option to replace the current gas-fired system from an environmental and economic perspective. However, as this will not be delivered in the immediate future an interim shallow geothermal system may be pursued to enable TU Dublin to meet its 2030 targets.

[4] Metered, granular data has been used in energy analysis wherever possible. However, it should be noted that in many instances energy usage has been attributed across buildings on a floor area basis which may result in inaccuracies in the results presented.

A district heating system was installed at the early stages of the redevelopment of Grangegorman as part of a vision for the wider Strategic Development Zone to maximise energy efficiency and reduce carbon emissions of the zone. The district heating system is currently connected to 8 TU Dublin buildings and supplies space and water heating to these buildings through the underground pipe network. The district heating system is currently fuelled by gas. Studies have been conducted to determine potential alternative fuel sources for the district heating system in the interim to geothermal heat. The use of biomass fuel was considered, however issues relating to sourcing and on-site storage presented complications. The map below shows the buildings that are currently connected to the district heating system. The centralised energy centre of the district heating system where the gas boilers are contained is shown in red.

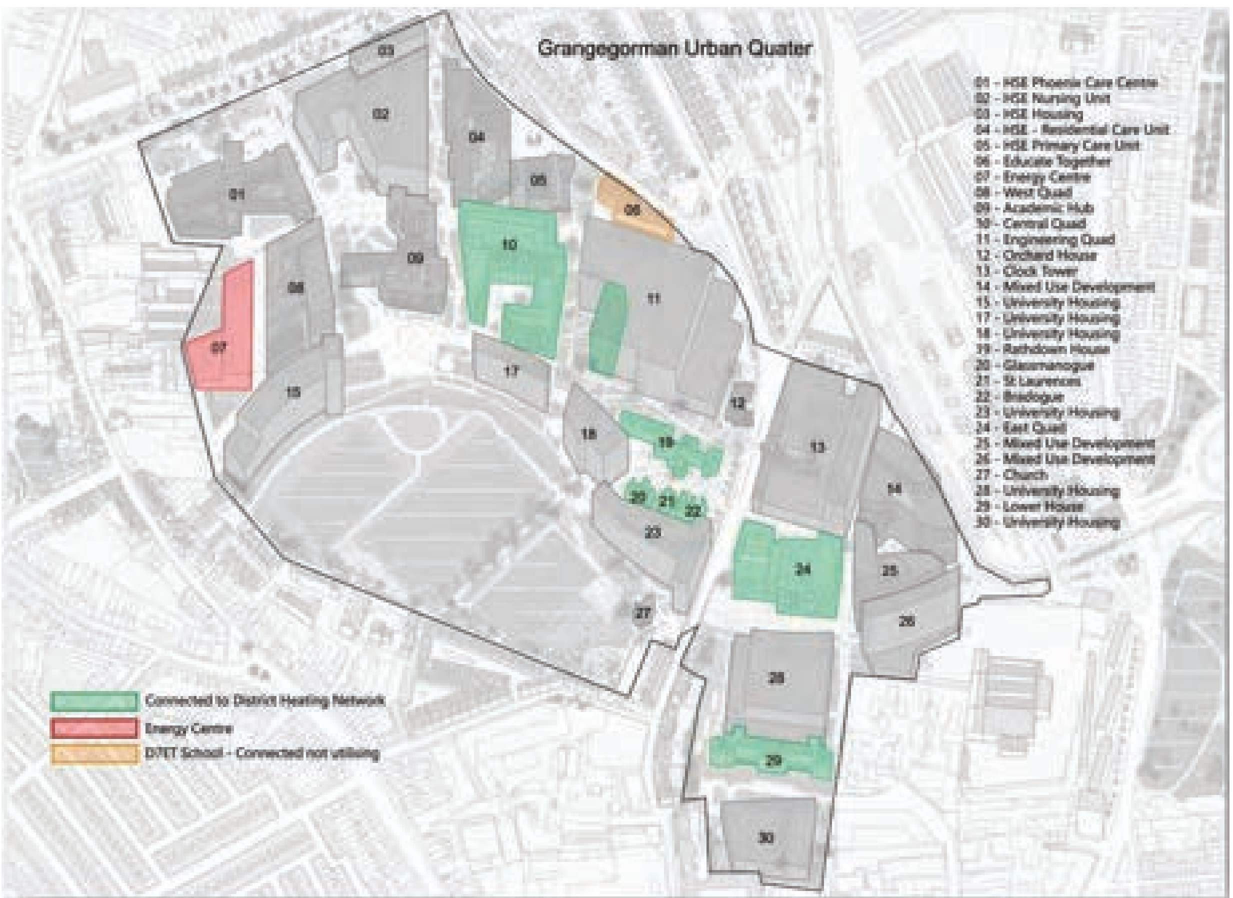


Figure 13: The district heating system at the Grangegorman Campus.

Future Campus Development and Priorities

Delivery of 6 new TU Dublin buildings at the Grangegorman Campus are at various stages of construction or design. These buildings are part of the overall Masterplan for the Grangegorman Strategic Development Zone. In the short term, the Academic Hub is currently under construction and expected to become operational in 2024/25. West Quad, Design and Construct (Broombridge), Research Hub 2, Indoor Sports, and University Accommodation Phase 1 are all live projects and TU Dublin have secured funding to advance these projects towards construction stage.

SWOT Analysis of the Grangegorman Campus

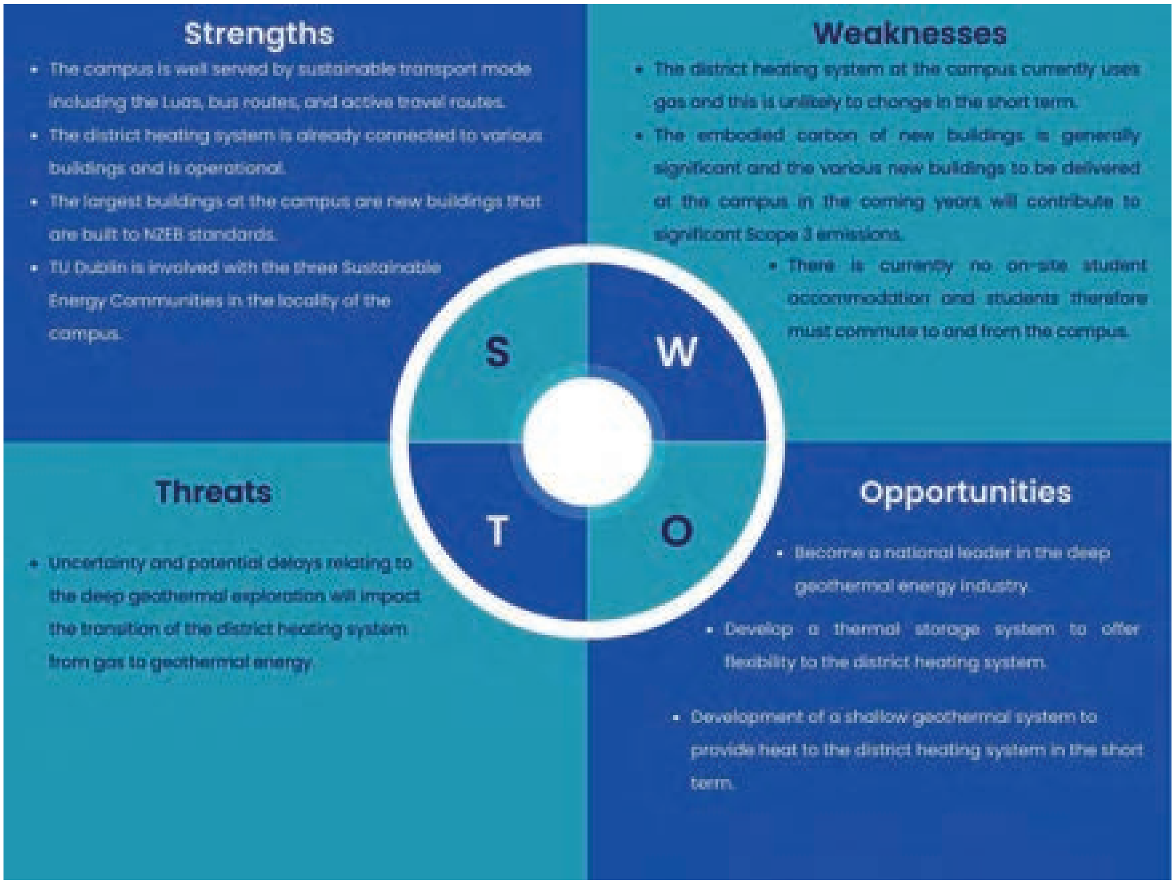


Figure 14: SWOT analysis of the Grangegorman Campus

6. BOLTON STREET CAMPUS

Overview

The TU Dublin Bolton Street Campus is located in Dublin city centre, primarily along Bolton Street and Kings Inn Street. The Campus consists of 6 buildings, 5 of which are located on Bolton Street and the adjacent streets. The other building (Aviation Technical Centre) is located outside of the city at Dublin Airport but is considered a part of the Bolton Street Campus for administrative and reporting purposes. The two largest buildings (Bolton Street Main and Linenhall) constitute the vast majority of the floorspace of the campus. These buildings are used primarily as teaching space for disciplines relating to the built environment. Architecture, Mechanical and Civil Engineering, Environmental Planning, and various Construction courses are based at the Bolton Street Campus. The buildings across the campus are historical buildings with construction dating back to 1911. Refurbishment and extension works have taken place across the buildings to keep them in useable condition.

TU Dublin Bolton Street Map

Figure 15: Map of buildings at the Bolton Stret Campus (Aviation Technical Centre not included)

Bolton Street Main

The Bolton Street Main building is the largest building at the Bolton Street Campus by a significant margin. The street facing portion of the building is a historical building that was constructed in 1911. Major extensions were added in 1961, and 1987. The building is used as a teaching space for programmes relating to architecture, engineering, and construction. Movement of these programmes to the new buildings at the Grangegorman Campus over the coming years however is actively being reviewed. The building is heated by 3 no. gas boilers that provide space and water heating to the building.

81 Capel Street

The Capel Street building is a small building that is used as office space. Space and water heating are provided by electric systems.

E Block

The E-block building is used as office and administrative space. The building is heated by 1 no. gas boiler that provides space and water heating to the building.

Linenhall

The Linenhall building is located opposite the Bolton Street Main building. The building was constructed in 1963. The building is used primarily as a teaching space for programmes relating to construction. The building contains various workshops which contribute to a high electricity consumption due to the equipment used in these workshops. The building is heated by a gas system.

Beresford Street

The Beresford Street building was constructed in 1950. The building is heated by 2 no. gas boilers that space and hot water heating.

Aviation Technology Centre

Unlike the other five buildings that constitute the Bolton Street Campus, the Aviation Technology Centre is not located in the city centre. The building is instead located at Dublin Airport and this building is leased by TU Dublin. The building is used as teaching space for programmes relating to Aviation. The building is heated by 1 no. gas boiler that provides space and water heating to the building.

Energy Usage and Emissions

In 2023, the Bolton Street Campus accounted for **13%** of the carbon emissions of TU Dublin (1,148 tCO_2e). The emissions of the Bolton Street Campus on a $kgCO_2e$ per m^2 floor area basis is the lowest of the 5 campuses and significantly below the campus average. It is clear therefore that Bolton Street is currently performing efficiently relative to the other campuses.

2023 estimated total emissions (electrical + non electrical)	tCO_2e
Bolton Street Campus	1,148
TU Dublin total	8,901
Bolton Street as % of total	13%

Table 10: Total emissions of the Bolton Street campus in 2023.

Floor area (2023)	m^2
Bolton Street Campus total floor area	41,519
Bolton Street $kgCO_2e/m^2$	27.7
TU Dublin average $kgCO_2e/m^2$	42.2

Table 11: Emissions of the Bolton Street campus per m^2 compared to the TU Dublin campus average.

Electrical

Top 3 electrical energy users (tCO_2e)		
1	Bolton Street Main	262
2	Linenhall	132
3	Beresford Street	201
		414
% of total campus		92%

Table 12: Top three electricity users at the Bolton Street campus.

The three largest electricity users at the Bolton Street Campus account for 92% of usage at the campus. Investment in energy efficiency and decarbonisation at the three buildings should therefore be prioritised if use and/or ownership of these buildings is anticipated to continue in the medium to long term.

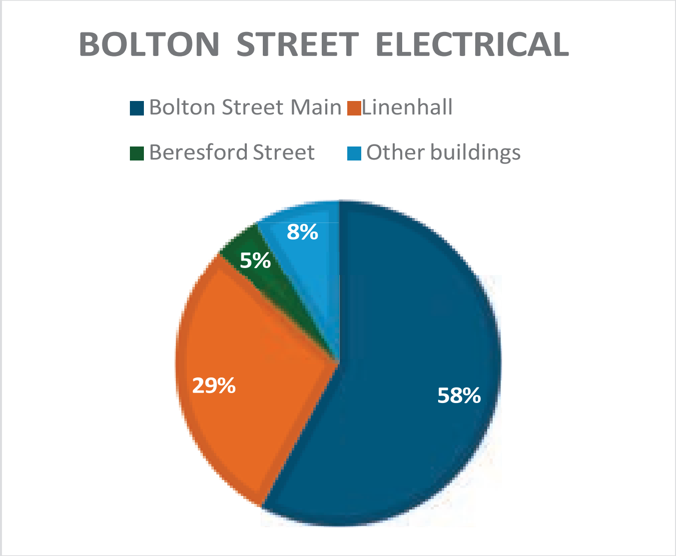


Figure 16: Graphic of the proportion of electricity use by building at the Bolton Street campus.

Non-Electrical

Top 3 non-electrical energy users (tCO_2e)		
1	Bolton Street Main	459
2	Linenhall	163
3	Beresford Street	49
		672
% of total campus		97%

Table 13: Top three non-electricity energy users at the Bolton Street campus.

The three largest non-electricity users at the Bolton Street Campus account for close to the entire emissions from non-electrical energy at the campus. If these buildings are being retained by TU Dublin, decarbonisation pathways for the heating systems of these three buildings will be required.

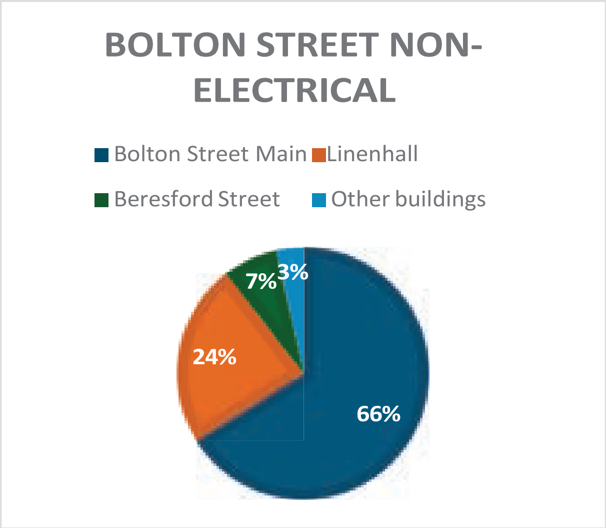


Figure 17: Graphic of the proportion of non-electricity energy usage by building at the Bolton Street campus.

Future Campus Development and Priorities

The future of the Bolton Street Campus is currently being considered. Forward planning for the needs of the university as a whole is being considered when reviewing the functions of the buildings that make up the Bolton Street Campus. As new buildings at the Grangegorman Campus come on stream, there is an opportunity to potentially move activities currently taking place at the Bolton Street Campus to the Grangegorman Campus. From an energy and emissions perspective, there are various considerations to be taken into account when reviewing the opportunities available. Of particular note is comparison of operational performance of buildings and lifecycle emissions of new builds. Although the reporting of Scope 3 emissions is not currently required by public sector organisations, TU Dublin intends to consider the embodied carbon associated with new buildings. Analysis is therefore ongoing to determine the role building optimisation will play in using existing buildings efficiently. An important consideration however is that the Bolton Street Main building and the Linenhall building are both heated by gas systems, and there are currently no plans to change this. As outlined, the Grangegorman district heating system currently also uses gas, however a clearer decarbonisation pathway for this system exists. This may be deciding factor for the movement of functions currently at the Bolton Street Campus to the Grangegorman Campus in the medium term.

SWOT Analysis of the Bolton Street Campus

Figure 18: SWOT analysis of the Bolton Street Campus.

7. AUNGIER STREET CAMPUS

Overview

The TU Dublin Aungier Street Campus is located in the city centre, close to St Stephens Green. The Campus consists of just two buildings – Aungier Street building and the FOCAS building. There are currently approximately 5,000 students based at the Aungier Street Campus, however these students are gradually being transferred to the Grangegorman Campus as the functions of the Aungier Street Campus are being moved to the existing and planned buildings at the Grangegorman Campus. The buildings at the Aungier Street Campus will be divested once this move has been completed.

TU Dubin Aungier Street Map

Figure 19; Map of the two buildings of the Aungier Street Campus

Aungier Street

The Aungier Street building was constructed in 1994 and is the third largest building across the entire TU Dublin university. The building is located between Peter Row and Bishop Street. The TU Dublin College of Business is located in the building and occupies the majority of this large building. The building is heated by 4 no. gas boilers that provide space and hot water heating.

FOCAS

The FOCAS building was constructed in 2001. The building is located on Camden Row in the city centre. The building is used as for research is the area of physical life sciences. The functions of this building will be relocated to the future Research Hub 2 building at the Grangegorman Campus and this building on Camden Row will be divested. The current building is heated by 2 no. gas boilers that provide space and hot water heating.

Energy Usage and Emissions

In 2023, the Aungier Street Campus accounted for **16%** of the carbon emissions of TU Dublin (1,433 tCO_2e). As both buildings at the Aungier Street Campus will be divested in the coming years a reduction in emissions is anticipated at the functions of these existing buildings will be moved to newer buildings at the Grangegorman Campus that will likely connect to the (planned) low carbon district heating network there which will reduce (as opposed to displace) the majority of the non-electrical emissions of the Aungier Street Campus.

The emissions of the Aungier Street Campus on a $kgCO_2e$ per m^2 floor area basis is the second highest across the five campuses and significant investment and refurbishment works would likely be required to improve this performance.

2023 estimated total emissions (electrical + non electrical)	tCO_2e
Aungier Street Campus	1,432
TU Dublin total	8,901
Bolton Street as % of total	16%

Table 15: Total emissions of the Aungier Street campus in 2023.

Floor area (2023)	m^2
Aungier Street Campus total floor area	29,065
Aungier Street $kgCO_2e/m^2$	49.3
TU Dublin average $kgCO_2e/m^2$	42.2

Table 14: Emissions per m2 of the Aungier Street campus compared to the TU Dublin campus average.

Electrical

Electrical energy emissions (tCO_2e)		
1	Aungier Street	464
2	FOCAS	91
		555

Table 16: Electricity emissions of the two buildings at the Aungier Street campus.

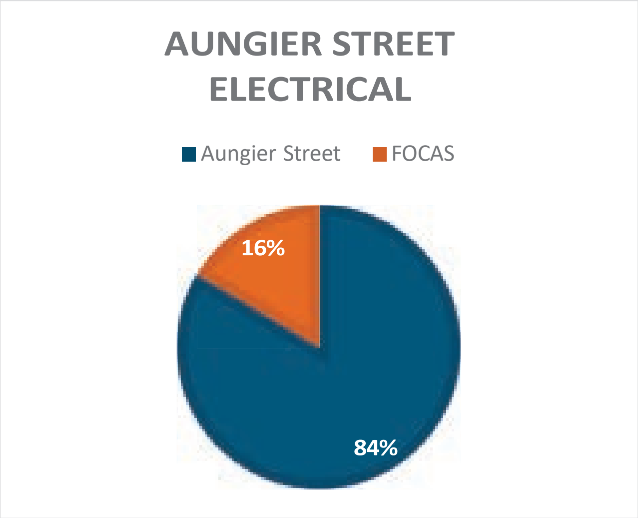


Figure 20: Graphic showing the proportion of electricity emissions from the Aungier Street campus buildings.

Non-Electrical

Non-electrical energy emissions (tCO_2e)		
1	Aungier Street	810
2	FOCAS	67
		877

Table 17: Non-electrical emissions of the two buildings at the Aungier Street campus.

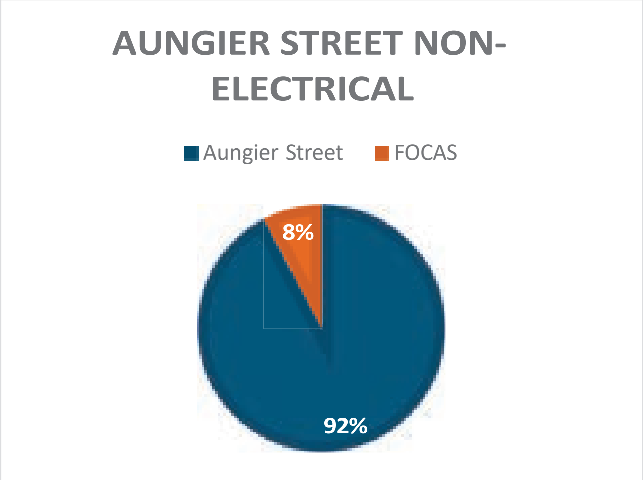


Figure 21: Graphic showing the proportion of non-electrical energy emissions from the Aungier Street buildings.

Future Campus Development and priorities

Divestment of the two buildings that make up the Aungier Street Campus is underway as the function of these buildings is moving to the Grangegorman Campus. Once completed, this will result in the reduction of approximately 1,432.33 tCO_2e (electrical and non-electrical emissions of the campus recorded in the 2023 Climate Action Roadmap). A subsequent increase in emissions at the Grangegorman Campus is anticipated as the functions of the campus are moved there.

8. BLANCHARDSTOWN CAMPUS

Overview

The TU Dublin Blanchardstown Campus is located on the northwestern edge of Dublin, approximately 2 kilometres from the centre of Blanchardstown. The campus is within the Local Authority area of Fingal County Council. The Blanchardstown Campus consists of 10 buildings, all of which are located on the same site of 22.5 hectares. The buildings are relatively modern with construction spanning 1999-2024. The Blanchardstown Campus is close to completion as the final building (Aras Geal) is at the final stages of construction. The Blanchardstown Campus participated in the Optimising Power at Work programme that encourages behavioural change to reduce energy wastage. Various buildings at the Blanchardstown Campus were fitted with gas and electrical meters as part of this programme and this has provided granular data relating to gas and electrical consumption of buildings.

TU Dublin Blanchardstown Map

Figure 22: Map of the buildings at the Blanchardstown Campus

Aontas

Aontas is the oldest building at the Blanchardstown campus (1999). The building is a single storey semi-permanent prefabricated building that is made of a metal clad material. The building contains lecture theatres, classrooms, a recording studio, server room, and offices. The building is heated by two gas boilers which were replaced in 2023.

LINC/ Buntús

The LINC building (Learning and Innovation Centre/ Buntús) was built in 2000. The building contains computer labs that are used for cyber security teaching programmes, a large lecture theatre, a café, and meeting rooms/ spaces that are used by both TU Dublin and by external organisations. The building is heated by 2 no. gas boilers.

Croí

Aras Croí is the largest building at the Blanchardstown campus. The building is used for student services and includes a restaurant, sports hall, offices, and a kitchen area. The building was constructed in 2002 and has not since undergone any major retrofit actions. The building is heated by 2 no. gas boilers and domestic hot water is provided by gas fired water heaters.

Doras

Doras was built in 2002. The building contains computer engineering labs, classrooms, and workshop spaces for welding classes. The building is heated by 2 no. gas boilers and domestic hot water is provided by gas fired water heaters.

Eolas

Eolas was built in 2002 and is a multi-use building that includes classrooms and lab spaces. Aras Eolas, Aras Fíos and Aras Doras were all built at the same time and are of a similar style and material. Eolas and Fíos are close to exact replicas of each other and the planned deep retrofit of Fíos will help form plans for retrofit actions in Eolas and Doras. Eolas is heated by 2 no. gas boilers which were replaced by more efficient models in 2023.

Fíos

Fíos is a multi-purpose building that includes the main campus library, student services, a lecture theatre, and computer labs. The building is heated by 2 no. gas boilers. TU Dublin has secured funding from the Higher Education Authority through the Pathfinder programme for a deep fabric retrofit of the Fíos building. The energy management team has carried out thermal imaging analysis to determine the extent of deep fabric works needed to have a meaningful impact on the efficiency of the building. Insulation, window replacement, and outer cladding replacements will be carried out in the coming months.

TU Dublin will provide financing to carry out mechanical and electrical improvement works. Combined, it is expected these works will improve the performance of the building from a BER of D1 to a BER of A3. This retrofit is providing valuable learnings on determining the most effective and realistic approach to retrofitting buildings across the campus.The approach being taken addresses both the administrative logistics of securing financing for retrofits and accommodating staff and students in other buildings while the retrofit works take place.

Connect

The Connect building was completed in 2019 and is used primarily for administrative and management services. This electrical system of the building is fitted to be able to incorporate solar electricity and installation of solar PV panels on this buildingmaking the incorporation of on-site renewables easier. The building is heated by 2 no. gas boilers.

Spraoí

Aras Spraoi is one of the most recently constructed buildings at the Blanchardstown campus (2016). The building is used mainly in the evenings as sport teams rent out pitches and use this building for changing room and gym facilities. Energy usage is therefore concentrated in the evening hours. The floodlights of the adjacent sports pitches are also connected to these building and new, more efficient floodlights were installed at the pitches in recent years. The building is heated by 2 no. gas boilers.

Horticulture

The Horticulture building is the smallest building and energy consumer at the Blanchardstown campus. The building was constructed in 2014 and includes a workshop building and various greenhouses and tunnels. Two of these greenhouse structures are heated with underfloor heating (though it is not used often) and the main workshop building is heated by a gas-fired heater as the building was originally designed as a potting shed. The roof of the building contains a sedum rainwater capture system.

Geal

Construction of Aras Geal is close to completion and expected to become operational in 2024. The building is owned by TU Dublin (Public Private Partnership). A heat pump will be used to heat the building. This will likely cause an increase in electricity consumption at the Blanchardstown Campus.

Energy usage and emissions

In 2023, the Blanchardstown Campus accounted for **14%** of the carbon emissions of TU Dublin (1,285.23 tCO_2e). Similar to the Tallaght Campus, emission reduction actions will therefore have a significant but not defining impact on the Universities overall ability to meet emission reduction targets. The Blanchardstown Campus is however the highest emitter on a $kgCO_2e$ per m^2 floor area basis and is significantly above the campus average across the university. It should be noted that the additional electrical load from Aras Geal will likely have a significant impact on electricity consumption when it becomes operational.

2023 estimated total emissions (electrical + non electrical)	tCO_2e
Blanchardstown Campus	1,285
TU Dublin total	8,901
Blanchardstown as % of total	14%

Table 18: Total emissions of the Blanchardstown campus (2023).

Floor area (2023)	m^2
Blanchardstown Campus total floor area	25,573
Blanchardstown $kgCO_2e/m^2$	50.3
TU Dublin average $kgCO_2e/m^2$	42.2

Table 19: Emissions of the Blanchardstown campus per m^2 compared to the TU Dublin campus average.

Electrical

Top 3 electrical energy users (tCO_2e)		
1	Croí	134
2	Doras	88
3	Fíos	74
		297
% of total campus		53%

Table 20: Top three electricity users at the Blanchardstown campus.

Electricity usage at the Blanchardstown Campus is more evenly spread between buildings than it is at the Tallaght or Grangegorman buildings. However, the three highest electricity users still account for over half of the electricity usage of the campus and efficiency measures should be prioritised at these buildings to maximise electricity efficiencies.

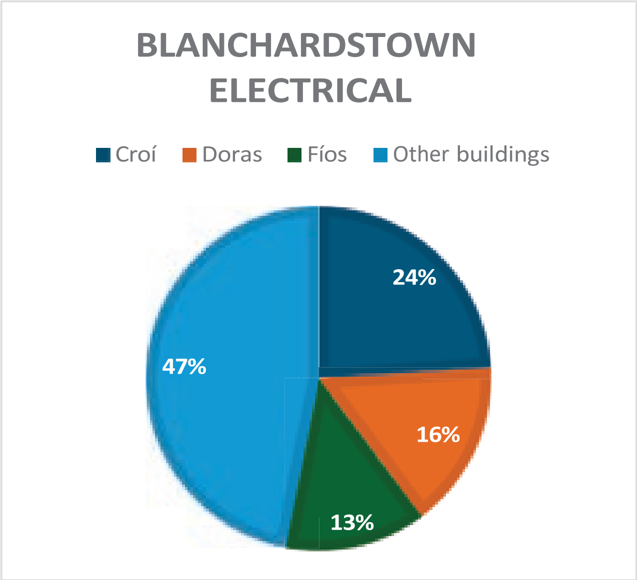


Figure 23: Graphic of the proportion of electricity emissions of buildings at the Blanchardstown campus.

Non-Electrical

Top 3 non-electrical energy users (tco2e)		
1	Croí	185
2	Doras	122
3	Fíos	103
		410
% of total campus		56%

Table 21: Top three non-electricity users at the Blanchardstown campus.

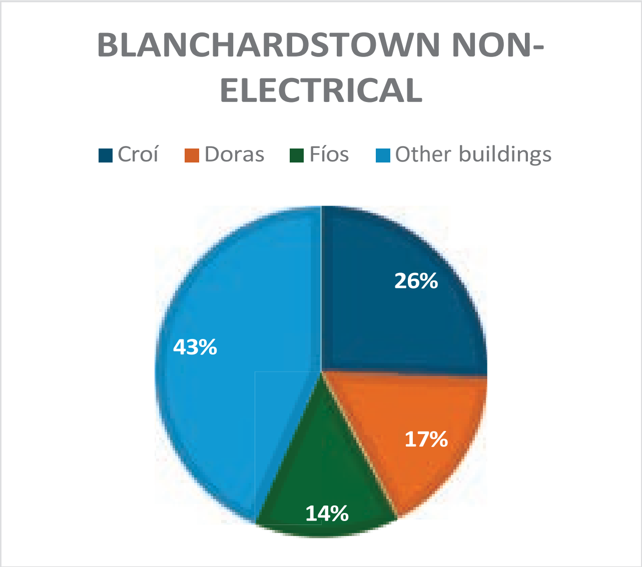


Figure 24: Graphic of the proportion of emissions from non-electricity energy usage at the Blanchardstown campus.

Similar to electricity usage, the non-electricity usage is more evenly spread between buildings at the Blanchardstown Campus compared to the other campuses, largely because the buildings are relatively close in size.

District heating

A district heating network at Blanchardstown that TU Dublin will connect to is currently at the assessment, planning, and design stage. Codema, as energy adviser to Fingal County Council (FCC), was appointed to develop an Outline Business Case (OBC) for a district heating system in the Blanchardstown area. The purpose of the OBC is to outline the justification of public expenditure to support the development of the scheme. The results of this feasibility study indicate that the scheme is both technically and economically viable and provides more benefits than the counterfactual (individual air-source heat pumps). This study delivers a high-level strategy. A technical detailed design would need to be completed before the recommendations are implemented. The Blanchardstown District Heating System is now being actively progressed by FCC. Codema and the NDFA are on board to assist FCC in developing the project, and a Project Board is to be established. The project is at the business case development stage, and a detailed case must be made for public sector funding and/or grant support. The proposed district heating system will utilise waste heat from data centres that are located in the area, similar to the operational district heating scheme that various buildings at the TU Dublin Tallaght Campus are connected to.

Figure 25: One of the three potential routes considered in the Outline Business Case of the Blanchardstown district heating system showing the pipe network between the data centre and the TU Dublin Blanchardstown Campus.

Future Campus Development and priorities

TU Dublin does not currently plan on building any additional teaching or administrative buildings at the Blanchardstown Campus. TU Dublin is however considering the suitability of the Blanchardstown Campus for providing student accommodation and whether there is sufficient demand for accommodation at this location. Additionally, the existing building stock at the Blanchardstown Campus will be refurbished and retrofitted over the coming years and will incorporate the learning from the Aras Fíos retrofit into future plans. These retrofit actions aimed towards achieving decarbonisation will prioritise decarbonising thermal systems as the first point of action. The TU Dublin Campus Planning Team is currently developing a masterplan for the Blanchardstown Campus that will layout the long-term plans and functions of each of the Blanchardstown buildings and determine if additional buildings are required.

From an energy perspective, TU Dublin is actively engaging with Codema and Fingal County Council to progress the development of a district heating system in Blanchardstown that the campus can connect to. Similar to the Tallaght Campus, a district heating system at Blanchardstown would allow the campus to significantly reduce their gas consumption and contribute to enabling the University to meet its emission reduction targets.

SWOT analysis of the Blanchardstown campus

Figure 26: SWOT analysis of the Blanchardstown Campus

APPENDIX C OPPORTUNITY EVALUATION

TABLE OF CONTENTS

ABBREVIATIONS

BDHS	Blanchardstown District Heating Scheme
BESS	Battery Energy Storage System
BMS	Building Management System
CAET	Culinary Arts, Engineering and Teaching
CAP	Climate Action Plan
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
DH	District Heating
FCC	Fingal County Council
GHG	Greenhouse Gas
GSI	Geological Survey Ireland
GRT	Geothermal Response Testing
HSE	Health Service Executive
IDA	Irish Foreign Direct Investment Agency
IRR	Internal Rate of Return
kWp	Kilowatt peak
NFDA	National Finance Development Agency
NHS	National Heat Study
NPV	Net Present Value
OBC	Outline Business Case
OPW	Office of Public Works
PPA	Power Purchase Agreement
PTES	Pit Thermal Energy Storage
PV	Photovoltaic
QH	Quarter Hourly
REFIT	Renewable Energy Feed-in Tariff
ReSS	Renewable Electricity Support Scheme
RYU	Reduce Your Use
SDCC	South Dublin County Council
SEAI	Sustainable Energy Authority of Ireland
SRESS	Small-Scale Renewable Electricity Support Scheme
SSRH	Sports Science Recreation and Health (Tallaght North building)
tCO2e	Tonne of Carbon Dioxide Equivalent
TDHS	Tallaght District Heating Scheme
TES	Thermal Energy Storage
TTES	Tank Thermal Energy Storage

1. EXECUTIVE SUMMARY

This report has been prepared by Codema to identify, explore, and evaluate various options and opportunities for TU Dublin to improve its energy systems and management across the campuses and activities of the organisation. These opportunities have been assessed using a variety of criteria, most notably the cost-effectiveness of the carbon savings and the technical viability of each option. The identification of opportunities has been informed by discussions between TU Dublin and Codema, site visits to the TU Dublin campuses, energy modelling, and various regulatory requirements relevant to energy and building management at TU Dublin. The opportunities identified in this report are categorised into five sections.

Chapter 3, Heat Energy Analysis, explores the potential of district heating (DH) systems to decarbonise the heating systems at TU Dublin's Grangegorman, Tallaght, and Blanchardstown campuses. District heating offers a cost-effective and scalable solution to reduce heat-related CO_2 emissions, which account for 44% of total energy-related emissions for the organisation. The Grangegorman campus already has a DH system in place, and plans are underway to transition from the existing gas-fired supply to a low-carbon geothermal energy source. In Tallaght, the campus is connected to the Tallaght District Heating System (TDHS), which utilises waste heat from a nearby data centre. Future expansion plans include connecting more buildings and incorporating geothermal energy. For Blanchardstown, a new district heating system, like the TDHS, is being developed using waste heat from a local data centre. This system could decarbonise the campus' thermal emissions and provide connections to surrounding facilities. There is also an opportunity to develop a campus DH network while the wider scheme is being built. If implemented as planned, district heating systems at all three campuses could reduce TU Dublin's thermal emissions by 57% compared to 2022 levels. Further reductions are achievable through additional building optimisation and retrofits to reach 2030 targets.

Chapter 4, Solar PV Evaluation, explores the feasibility of installing rooftop solar photovoltaic (PV) panels across TU Dublin's Blanchardstown, Grangegorman, and Tallaght campuses. This will support renewable electricity generation and enable TU Dublin to meet upcoming regulatory requirements. After assessing technical and regulatory constraints, several buildings were identified as suitable for solar installations. The Blanchardstown campus has the greatest potential, with up to 1,086 kWp of capacity, which could meet 34% of its electricity demand and reduce campus CO_2 emissions by 50%. The Tallaght campus is more constrained by limited roof space and planning regulations, with a maximum capacity of 186 kWp, which could reduce emissions by 15%. At the Grangegorman campus, the largest opportunity is at the proposed Broombridge Warehouse, which could produce 820 MWh annually with a 937 kWp system meeting a significant portion of the campus's demand. Overall, implementing these systems could significantly support TU Dublin's sustainability targets, but further planning is needed at Grangegorman and Tallaght due to regulatory constraints.

Chapter 5, Power Purchase Agreements (PPAs), explores the feasibility of PPAs for TU Dublin to procure renewable electricity. PPAs can be structured as physical or virtual agreements. While physical PPAs involve a direct line connection between a generator and consumer, this is largely not feasible in Ireland due to regulatory restrictions on private wires. Virtual PPAs, where the agreement is purely financial without physical electricity delivery, are currently the most common type in Ireland but do not contribute to TU Dublin's emissions reductions under SEAI guidelines. For on-site generation, such as rooftop solar PV at TU Dublin campuses, a physical PPA could allow an external operator to install, own, and maintain the system, selling electricity to TU Dublin at a fixed price. While this option reduces upfront costs, direct procurement and ownership of solar systems is more cost-effective in the long-term. Given current constraints, a direct line PPA is only feasible within a single campus, while a virtual PPA could stabilise electricity prices but would not impact emissions targets. Developing and owning solar installations remains the most favourable option for meeting TU Dublin's sustainability goals.

Chapter 6, Electricity Flexibility Analysis, emphasises the importance of electricity demand flexibility for TU Dublin. In particular, its transition to decarbonised heating systems, such as district heating and heat pumps, will increase its reliance on the national electricity grid. Several flexibility solutions are explored, including Battery Energy Storage Systems (BESS), Thermal Energy Storage (TES), and electric boilers, which can store or utilise excess renewable energy. TES is identified as the more cost-effective storage option for the university's energy profile, offering enhanced self-sufficiency and increased renewable energy usage with less spatial requirement compared to BESS. While BESS is less financially favourable due to high upfront costs and limited financial return, it may still be viable for specific applications. For instance, the proposed Broombridge facility is identified as suitable for a BESS installation, as it lacks a district heating system and is located far from the main Grangegorman campus. Additionally, a microgrid system integrating TES, BESS, and geothermal energy is proposed for the Blanchardstown campus. This would potentially allow it to operate independently of the national grid for periods and support TU Dublin's goal of carbon neutrality by 2050.

Chapter 6, Demand Reduction Analysis, examines the electrical and gas consumption profiles for TU Dublin's main campuses—Grangegorman, Tallaght, and Blanchardstown—using quarter-hourly data up to June 2024 to identify patterns and areas for reducing energy demand. Grangegorman showed high baseloads throughout the year, with peak electricity loads occurring during the winter months. Similarly, Tallaght and Blanchardstown exhibited seasonal variations, with winter peaks and lower baseloads in the summer. To reduce energy demand, the chapter suggests improvements in metering and building management systems (BMS), external and internal lighting upgrades, addressing out-of-hours energy loads, optimising equipment scheduling, and utilising space more efficiently during low-occupancy periods. Behavioural campaigns, such as TU Dublin's Reduce Your Use and TU Dublin is Switching Off initiatives, have previously shown success but could benefit from enhanced metering and communication pathways for better impact assessment. Enhanced engagement and collaboration between students, academic staff, and professional staff are key to optimising energy usage and achieving TU Dublin's energy efficiency goals.

2. INTRODUCTION

2.1. Objective

The objective of this Opportunities Evaluation Report is to provide an evidence base and key findings that will inform the Sustainable Energy Action Plan (Task 2.4). A summary of the key findings of the analysis contained in this report will be included in the final report. This report will serve as a reference if further detail is required on how the findings presented in the final report were reached. It should be noted that an in-depth and detailed analysis of each of the topics in this report may be projects in their own right. This opportunity evaluation seeks to size, profile and evaluate the high-level potential and feasibility of each of these opportunities. This will help to identify the prioritisation of these opportunities for further exploration as part of the delivery of TU Dublin's energy transition ambitions.

2.2. Scope & Methodology

As per the requirements of Task 2.3 Opportunity Evaluation outlined in the agreed Scope of Works, this report contains a high-level evaluation of a range of potential projects and opportunities that can contribute to TU Dublin's energy transition and emissions reduction targets. The methodology of the evaluation for each topic contained in this report is outlined below.

Heat Energy Analysis

The scope of this analysis is to evaluate the existing and any planned district heating systems at the Grangegorman, Tallaght, and Blanchardstown campuses. This evaluation includes considerations relating to expected timelines for expansion/delivery of systems, changes to energy sources of systems, the potential to grow systems beyond the campuses, emissions implications of options, and financial analysis.

The information presented in this chapter has been sourced from a variety of documents including publicly accessible reference documents, information provided by TU Dublin, and information sourced internally within Codema based on work on district heating across overlapping projects.

- Information relating to the Grangegorman district heating system has been sourced primarily from the Outline Business Case prepared recently for the Grangegorman Development Agency.
- Information relating to the Tallaght district heating system has been sourced from both TU Dublin and from Codema. This includes heat consumption profiles, performance of the system, and planned expansion.
- Information relating to the planned Blanchardstown system has been sourced primarily from the Outline Business Case document recently prepared by Codema for Fingal County Council.

Various software programmes have been used to create the information presented on this topic **including nPro, THERMOS**, and **QGIS.** An overview of these programmes is included in the appendices below.

Solar PV Evaluation

The scope of this analysis is to profile the opportunity for installation of solar PV panels on both existing and planned buildings at the Grangegorman, Tallaght, and Blanchardstown campuses. Analysis of the regulatory environment was carried out to inform requirements for installation of solar PV on planned buildings. For existing buildings, an analysis of each building's suitability for installation of solar PV panels was first carried out. The software **Open Solar** was used to model arrays on roof tops of buildings to determine the potential generation at each suitable building. Electricity consumption data was entered into Open Solar to determine the levels of self-sufficiency possible for each building for the proposed solar PV arrays. The results from this analysis were then added to the campus energy models in nPro to generate detailed financial analyses and payback of investment.

Campus Level Energy Models

Energy models were prepared for each of the campuses using the nPro software. The information obtained from the heat and solar analysis was entered into these models to simulate various scenarios based on actions considered feasible. Electricity and heat consumption data was also entered into these models. Granular metered data was used wherever possible, with billing data used to supplement this where hourly, building level consumption data was not available. These energy models were then used to evaluate the effectiveness of a variety of potential actions relating to district heating, installation of solar PV panels, and comparison of battery and thermal energy storage systems. nPro also provides detailed financial analysis that has been used to evaluate the cost-effectiveness of some of the opportunities identified in this report.

Offsite Power Purchase Agreements

The scope of this analysis included assessing the options that exist for TU Dublin to enter into a Power Purchase Agreement, and to evaluate the implications this agreement would have. This evaluation included a desktop analysis of the types of PPAs that are possible in Ireland, and an evaluation of the benefits and limitations of each type in the context of TU Dublin's operations.

Electricity Grid Flexibility Analysis

The scope of this analysis includes identifying and evaluating the opportunities for both thermal and electricity storage at each of the campuses. This analysis was carried out using the energy models in nPro by running various scenarios to evaluate the carbon and cost implications of thermal and battery energy storage systems.

Demand Reduction Analysis

The scope of this analysis includes profiling the opportunities for reducing thermal and electrical demand through a load profile assessment. The opportunities identified are also based on site-visits to the campuses and the outcomes of Task 2.2 Provision of peer review/mentoring services for internal TU Dublin energy team which included conducting a desktop review of energy management practices and procedures.

3. HEAT ENERGY ANALYSIS

3.1. District Heating Overview

Heat emissions arise from the combustion of fossil fuels in homes, businesses, and industry, as well as indirectly from electricity use. According to the SEAI National Heat Study (NHS)[1] these emissions account for 38% of total energy-related CO_2 emissions and 24% of total national greenhouse gas emissions in Ireland. Despite efforts like government grants to reduce emissions, heat emissions have increased by 12% since 2014.

District heating (DH) is a system that distributes heat generated from a central source (such as waste heat recovery, geothermal, biomass, or other energy sources) through a network of insulated pipes to provide space heating and hot water to residential, commercial, and public buildings. According to the NHS, up to 54% of building heat demand is suitable for DH in Ireland. This technology is a proven and competitive option that can be widely deployed to decarbonise the heat sector. In response to this, the Irish Government has set a target of 2.7 TWh to be met by DH by 2030 (10% of commercial and residential heat demand), with an interim target of 0.8 TWh to be met by 2025.

District Heating at TU Dublin

TU Dublin has become a leader in implementing district heating in Ireland. A DH network was installed at the Grangegorman campus in 2014. The system is powered by an interim energy centre utilising gas boilers and became operational in 2019, it currently serves 8 TU Dublin buildings. The potential for a deep-bore geothermal energy supply is being explored in partnership with Geological Survey Ireland (GSI) to transition away from the gas fired supply and decarbonise this network.

The Tallaght campus is connected to Ireland's first low-carbon district heating system. The Tallaght District Heating System (TDHS), which was developed by South Dublin County Council (SDCC) and is operated by HeatWorks[2], utilises waste heat from the Amazon Web Services (AWS) data centre located in South Dublin. The system, which became operational in 2023, currently serves the Tallaght Main and the new SSHR buildings with plans to connect further buildings on campus. The system also serves the SDCC County Hall & Innovation Centre buildings.

A DH system is also being actively developed by Fingal County Council (FCC) in Blanchardstown, which if implemented, will connect the TU Dublin campus nearby. The Blanchardstown District Heating System (BDHS) will be a technical replica of the TDHS, using waste heat from a nearby data centre. The scheme plans to connect a nearby hospital and sports campus in the first phase of its development. TU Dublin is exploring options for developing a campus DH network on the Blanchardstown campus which could connect to the wider scheme when it is operational.

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[1] SEAI National Heat Study
[2] Heatworks

Thermal Emissions at TU Dublin

The Climate Action Plan 2024[3] (CAP24), reaffirmed two high-level targets for public bodies that had been originally introduced in previous iterations of the plan:

- The public sector must improve its energy efficiency by 50% by 2030.
- The public sector must reduce its GHG emissions by 51% by 2030. The target will be a 51% reduction of direct energy-related emissions (thermal and transport consumption), plus projected supply side reductions in indirect energy-related emissions from electricity. The baseline for the methodology is the period 2016 to 2018.

According to the TU Dublin Climate Action Roadmap[4], energy related greenhouse gas emissions accounted for 11,076 tCO2e[5] in 2022. Of this total, thermal emissions accounted for 44% as shown in Figure 1, with transport and fugitive emissions accounting for less than 1% on the basis that TU Dublin only has 2 vehicles in its fleet. TU Dublin increased its thermal emissions by 49% between its baseline (2016-2018) and 2022. Due to this increase, to meet the GHG target for 2030, TU Dublin must now reduce thermal emissions by 67%.

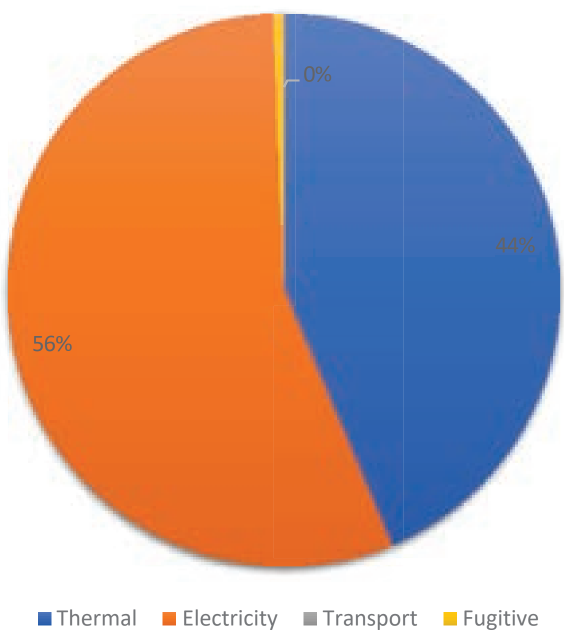

Figure 1: TU Dublin Energy-related GHG Emissions, 2022

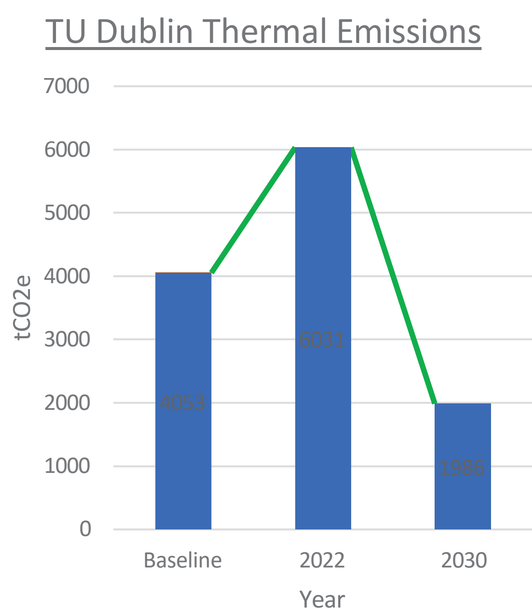

Figure 2: TU Dublin Thermal Emission Reduction Targets

[3] CAP24
[4] TU Dublin Climate Action Roadmap v3 June 2024
[5] Tonnes of CO2 equivalent

3.2. Tallaght Campus

Current System Overview

The Tallaght Campus consists of 10 buildings, 6 of which are located on the main campus. The Main Building and the Sports Science & Health (SSRH) Building are currently being supplied by the TDHS. The Tallaght North (CAET) and Synergy/CASH buildings will be supplied in the next phase of the DH system expansion. The Student Hub, Creche, and other buildings outside of the main campus are not being considered at present for connection to the network. An individual low carbon heating system is being considered for the Student Hub, and TU Dublin does not operate the Creche so has no incentive to prioritise its connection to the DH network.

Table 1 and

Table 2 below show the heat delivered to current and planned connections, along with tCO2 saved vs. traditional gas fired heating systems. The heat demand for each building was obtained using the results of the nPro energy model developed during Task 2.3.2, and the tCO2 saved was calculated as follows:

$$tCO2\ saved = (\frac{Heat\ Demand * g}{Boiler\ Efficiency}) - (Heat\ Demand * d)$$

Where g = emission factor for natural gas[6] (tCO2/MWh)

d = emission factor for TDHS[7] (tCO2/MWh)

Boiler efficiency is assumed to be 85%

Table 1: Current TU Dublin Connections to the Tallaght DH System (Phase 1)

Building	Supply	m²	Heat Demand (MWh)	tCO2 Saved
Main Building	2023	15,620	2,627	420
SSRH	2023	3,093	776	124
Total		**18,713**	**3,403**	**544**

Table 2: Future TU Dublin Connections to the Tallaght DH System (Phase 2)

Building	Supply	m²	Heat Demand (MWh)	tCO2 Saved
North (CAET)	2025	5,211	1,653	264
Synergy Cash	2025	3,861	1,049	168
Total		**9,072**	**2,702**	**432**

[6] SEAI Fuel Conversion Factors
[7] District Heating Carbon Factors

System Potential

The TDHS energy centre consists of two heat production elements, the water-to-water heat pump, and the backup electric boiler. The heat pump upgrades the waste heat from the data centre (~25°C) to a usable building temperature (60 - 85°C) while the electric boiler provides redundancy for the heat pump. Planning approval has also been granted for 2 no. thermal storage tanks (200m^3 each). The installation of the thermal stores will support the connection of future customers and improve the operation of the system. Table 3 shows the current and planned production capacity of the TDHS.

Table 3: TDHS Production Capacity

Production Unit	Installed	Efficiency	Capacity
Heat Pumps	2022	320%	3 MWth
Electric Boiler	2022	96%	3 MWth
Thermal Storage	TBC	2,702	2 x 200m^3

The footprint of the energy centre is 491m^2. There is also an additional 6 MWs of recyclable heat available from the nearby Amazon data centre. Design advances in heat pump technology have resulted in smaller sized heat pumps with higher production capacities. Based on this, it is anticipated that there is enough space for an additional 6-7 MW of heat pumps within the existing energy centre. A test borehole has also been drilled on the Tallaght campus to a depth of 1km to establish the geothermal resource in the area. The results of the borehole indicated a bottom temperature of 32.5°C. Geothermal energy could be an additional source for the network and increase system capacity, pending further exploration.

System Expansion

The TDHS currently supplies the TU Dublin Main and SSRH buildings, the SDCC County Hall and Library Building, and the SDCC Innovation Centre. The TU Dublin North Building (CAET) and SDCC Affordable Apartments (133 Units) are also connected to the system but are not yet receiving heat. The next customers to be connected to the scheme (1st phase) will be the Synergy / CASH building and a planned multi-apartment residential development. This will require system optimisation through the addition of the thermal storage tanks.

An additional 6-7MWs of heat pumps will be required to facilitate the 2nd phase of system expansion, where it is anticipated that the Tallaght hospital and nearby training centre will be connected. Once the 2nd phase has been supplied, it is estimated that the full waste heat resource from the Amazon data centre will be utilised. Therefore, the 3rd phase of the TDHS will require an additional heat source. It is possible that further geothermal exploration, justifying the drilling of a production borehole could provide the additional capacity required. An indicative timeline for the proposed expansion of the network is shown in Table 4:

Table 4: Indicative TDHS Expansion Timeline

No.	Building	Supplied
1	TU Dublin Main Building	2023
2	SDCC County Hall & Library	2023
3	TU Dublin SSHR Building	2023
4	SDCC Innovation Centre	2023
5	TU Dublin North Building (CAET)	2025
6	SDCC Affordable Apartments	2025
Phase 1		
7	TU Dublin Synergy/CASH Building	2026
8	Multi-apartment Development*	2026
Phase 2		
9	Tallaght Hospital*	2026+
10	Training Centre*	2026+
Phase 3		
11+	Future Connections*	2026+
	***TBC**	

Beyond the expansion proposed in Table 4, and in a scenario that geothermal energy proves to be a viable source of heat, the system has the also has potential to connect customers in the wider Tallaght area. Figure 4 maps the heat demand and shows the areas that meet the threshold demand densities set out in Figure 3.

	Band [TJ/km²year]
Not Feasible	<20
Future Potential	20-50
Feasible with Supporting Regulation	50-120
Feasible	120-300
Very Feasible	>300

Figure 3: DH Viability (TJ / km2)

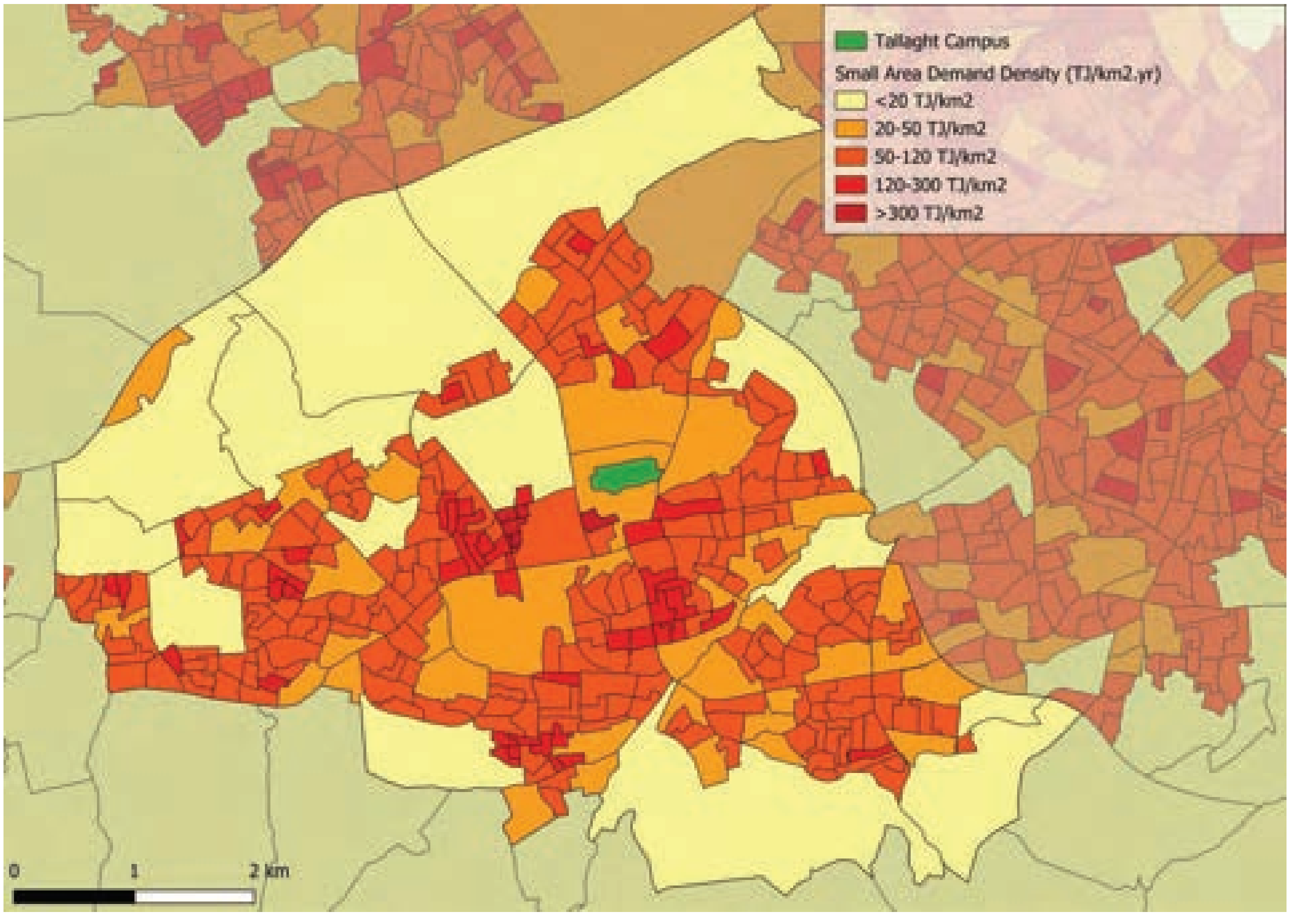

Figure 4: Tallaght Heat Demand Mapping

3.3. Grangegorman Campus

Current System Overview

The Grangegorman Urban Quarter is set to undergo substantial expansion in the next phase of its masterplan[8], including the construction or expansion of 11 buildings by 2030, followed by a further 10 mixed-use buildings by 2050. There are currently 9 buildings operational, 8 of which are owned or leased by TU Dublin. Details of the TU Dublin buildings which are operational are included in Figure 82 in the appendices below.

The Grangegorman DH system was installed as part of the first phase of the site's re-development works in 2014. The underground pipework is in place, with connection points and capacity for all existing and proposed buildings as per the masterplan. The system is powered by an interim energy centre supplied by gas fired boilers as shown in Table 5 which became operational in 2019. To ensure all buildings connected to the system achieve compliance with energy related building regulations (Building Control Part L), this source must be transitioned to a low-carbon solution. At present, the system serves 8 TU Dublin buildings as shown in Table 6, with plans to connect all remaining buildings once constructed.

[8] Grangegorman Urban Quarter Masterplan

Table 5: Grangegorman DH System Production Capacity

Production Unit	Installed	Efficiency	Capacity
Gas Boiler (5 x 2.9 MWth)	2019	Unknown	14.5 MWth

Table 6: Current TU Dublin Connections to the Grangegorman DH System (Phase 1)

Building	Supply	m^2	Demand (MWh)	tCO2[9]
Central Quad	2019	36,044	7,662	1,563
Rathdown House	2019	2,114	396	81
Glassmanogue	2019	374	28	6
St Lawrence's	2019	287	22	4
Bradogue	2019	511	39	8
Greenway Hub	2019	4,270	908	185
East Quad	2019	16,300	3,465	707
Lower House	2019	4,392	934	190
Total		**64,292**	**13,454**	**2,745**

System Potential

In 2021, TU Dublin together with GSI commissioned an exploration project to drill the first urban geothermal test borehole in Ireland to obtain high-quality information about deep subsurface data at the Grangegorman site. It was the first trial borehole of 1 km carried out by the GSI to assess geothermal potential in Ireland. The initial trial borehole showed promising results, with a temperature of 38.5°C at 1 km depth as shown in the figure below. It has been assumed that a geothermal gradient of approximately 28°C/km is realistic for the site. This has highlighted favorable subsurface temperatures to support further investigation of deep resources at Grangegorman.

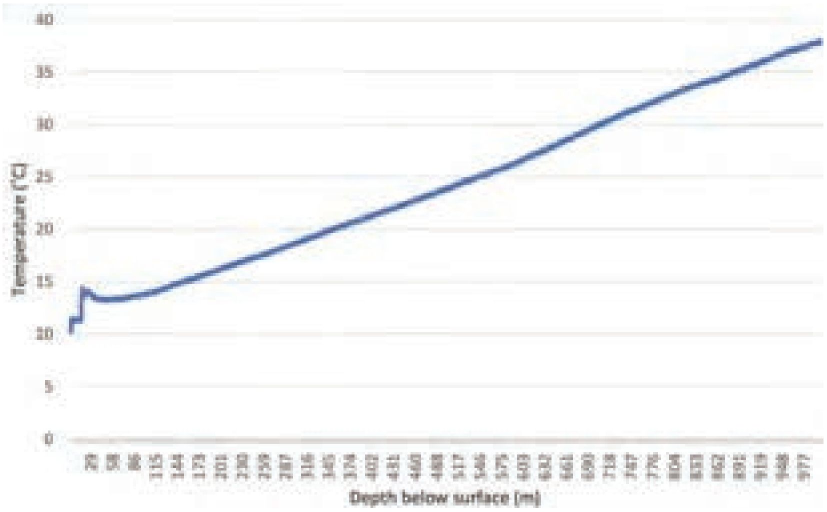

Figure 5: Temperature results from 1km borehole at Grangegorman

[9] Uses SEAI Conversion Factor for Natural Gas (0.204 tCO2/MWh)

The interim energy centre is intended to provide heat to the DH system until a suitable low carbon alternative is established. As part of the GEMINI project[10], further geothermal exploration will take place facilitated by the drilling of a 2.5km borehole on the Grangegorman site. It is anticipated that deep geothermal energy from this source could decarbonise the existing district heating network and provide low carbon heat to all connected buildings. Based on the established geothermal gradient, it is also likely that 70+°C could be produced, which would allow it to be injected directly into the network, without needing heat pumps to upgrade it.

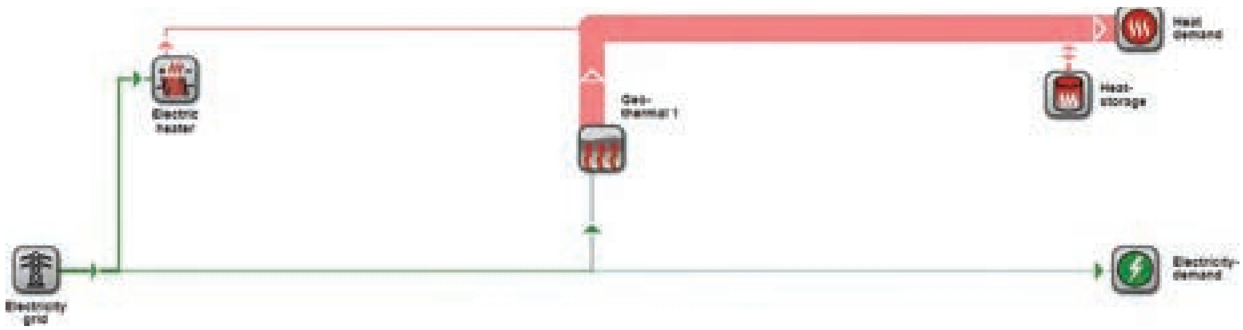

Figure 6: Indicative Geothermal DH Schematic

The geothermal source for the DH system could also incorporate thermal storage and a backup electric boiler as shown in the indicative schematic in Figure 6 above. The benefit of this arrangement is that the thermal storage can be charged during the night when electricity rates are cheap and discharged during the day to reduce energy costs. This approach also facilitates demand flexibility, where electrical consumption can be moderated on site to mitigate electricity grid constraints or utilise curtailed wind electricity when demand is low on the electricity grid.

System Expansion

The Grangegorman masterplan is a comprehensive development of 30 buildings which include academic, residential, mixed-use, sports, and healthcare buildings and facilities when fully built. TU Dublin will own, manage, or operate 24 of these buildings. The DH system will connect all buildings in the Urban Quarter once constructed. The phased building schedule is included in Figure 83 in the appendices below.

It is anticipated that transitioning the existing gas fired DH supply to geothermal energy source could reduce emissions by up to 90% if it's installed by 2030. This is derived from the campus energy model and based from projected supply side emissions reductions in electricity as shown in Figure 84, and a scenario where the 2.5 km borehole produces temperatures of 70+°C and enough heat to supply the entire urban quarter. At present, it is uncertain what amount of heat the borehole will produce. Codema engaged with Geological Survey Ireland (GSI) to ascertain likely heat capacities from a borehole at this depth on the Grangegorman site. Assuming an open-loop geothermal system, the total capacity for borehole on this site could range between 3.08MW (90% probability) and 15.61MW (10% probability) as shown in Figure 7.

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[10] GEMINI Geothermal Energy

The results of the GEMINI project will confirm the expected geothermal temperature and capacity at 2.5km, which is at present uncertain. A separate Pathfinder[11] project is also being explored to further utilise the 2.5km borehole to deliver heat to the campus.

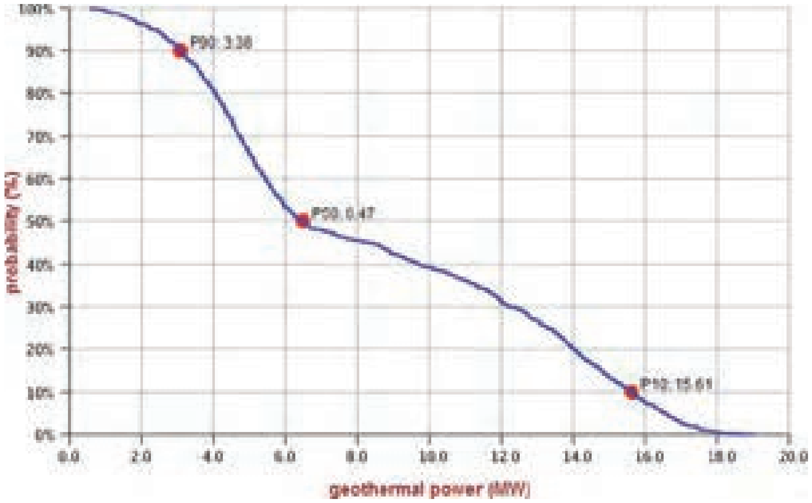


Figure 7: Deep Geothermal Capacity Probability Graph (2.5km)

Table 7: Current & Future TU Dublin connections to the Grangegorman District Heating System

Phase	Plot	Building	m²	Demand (MWh)	tCO2 Saved
2025	9	Academic Hub	12,600	189	35
	10	Central Quad	36,044	7,662	1,407
	11	Greenway Hub	4,270	908	167
	24	East Quad	16,300	3,465	636
	19-22	Historical Cluster	3,488	741	136
	29	Lower House	4,392	934	171
			77,094	13,899	2,552
2030	8	West Quad	20,730	311	57
	13	Clock Tower	23,000	345	63
	28	Indoor Sports	6,940	104	19
			50,670	760	140
2050	11	Mid Quad	29,730	446	82
	13	Clock Tower	2,500	38	7
	15 - 23	University Accommodation	65,237	7,373	1,354
		Park House	9,836	1,229	226
			107,303	9,086	1,668
Total			**235,067**	**23,745**	**4,360**

[11] SEAI Pathfinder Programme

Table 7 above details the planned TU Dublin connections to the system, and the carbon emissions savings based on connecting to the geothermal energy source. The system also has provisions to connect current and planned HSE owned buildings on the site, and an Educate Together school, both of which have not pursued a connection to date. Table 8 below shows all potential Urban Quarter connections to the DH scheme. The plots in both tables relate to the Phased Building Schedule shown in Figure 83 in the appendices.

Table 8: Current & Future connections to the Grangegorman District Heating System

Phase	Plot	Building	m^2	Demand (MWh)	tCO2 Saved
2025	9	Academic Hub	12,600	189	35
	10	Central Quad	36,044	7,662	1,407
	11	Greenway Hub	4,270	908	167
	24	East Quad	16,300	3,465	636
	19-22	Historical Cluster	3,488	741	136
	29	Lower House	4,392	934	171
			77,094	13,899	2,552
2030	1	Phoenix Care Centre	7,100	2,632	483
	4	Residential Care Unit	1,248	463	85
	5	Primary Care Unit	2,378	881	162
	6	Educate Together	4,436	589	108
	8	West Quad	20,730	311	57
	13	Clock Tower	23,000	345	63
	14	Mixed Use Development	27,500	413	76
	25	Mixed Use Development	21,500	323	59
	28	Indoor Sports	6,940	104	19
			114,832	6,060	1,113
2050	2	Nursing Unit	20,020	7,421	1,362
	3	HSE Housing	6,500	1,784	328
	13	Clock Tower	2,500	38	7
	11	Mid Quad	29,730	446	82
	15 - 23	University Accommodation	65,300	7,373	1,354
		Park House	9,836	1,045	192
			133,886	18,107	3,324
Total			**325,812**	**38,066**	**6,989**

In a scenario where excess geothermal heat is produced at the Grangegorman site, there is also potential for the system to expand beyond the connections detailed in Table 8. Figure 9 maps the heat demand and shows the areas that meet the threshold demand densities set out in Figure 8. The Urban Quarter is in a dense urban environment which is feasible for DH expansion. The campus is also located near three active Sustainable Energy Communities (SECs): Connecting Cabra, Cosybatter, and Phibsboro Village.

	Band [TJ/km²year]
Not Feasible	<20
Future Potential	20-50
Feasible with Supporting Regulation	50-120
Feasible	120-300
Very Feasible	>300

Figure 8: DH Viability (TJ / km2)

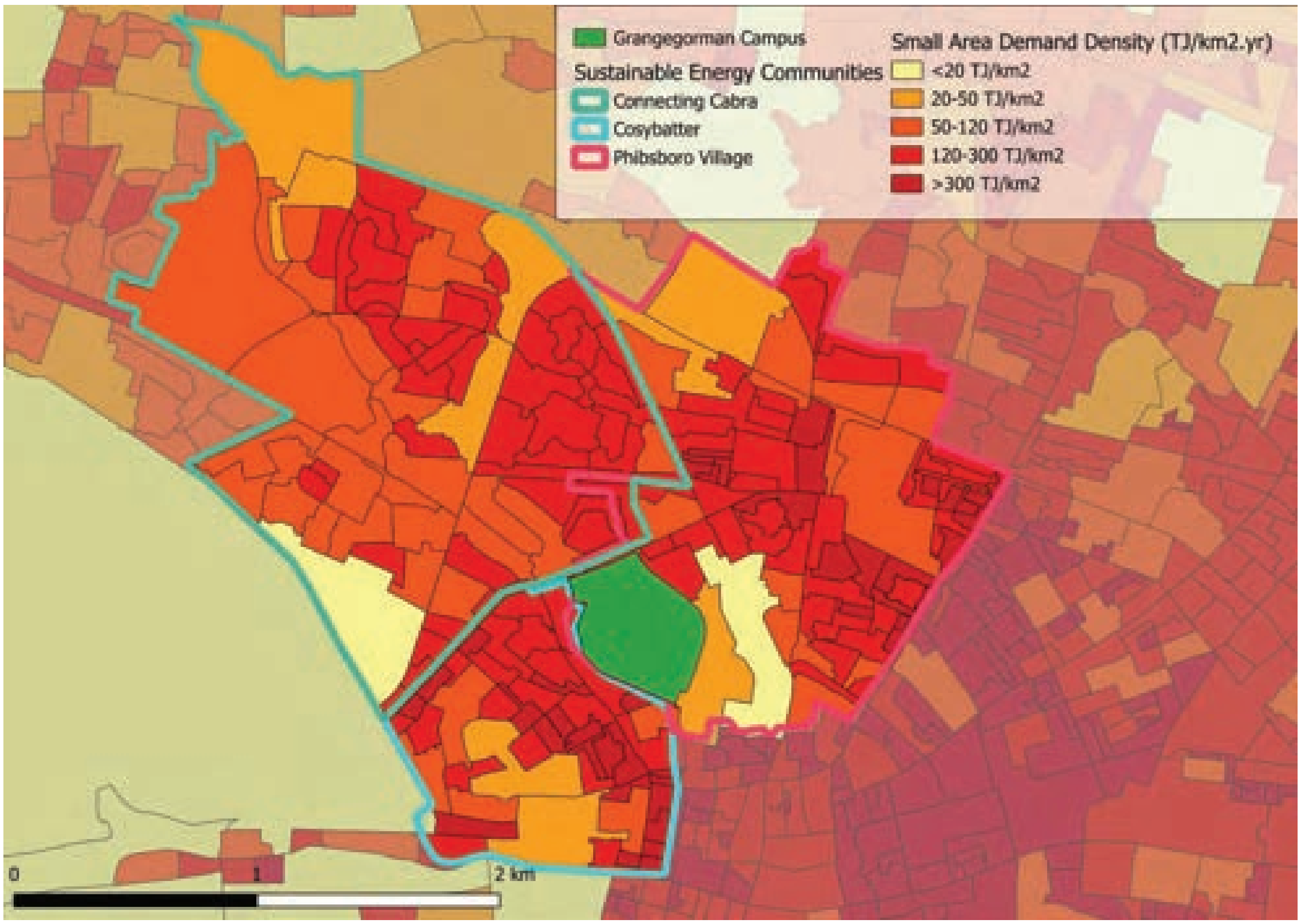


Figure 9: Grangegorman Heat Demand Mapping

3.4. Blanchardstown Campus

The TU Dublin Blanchardstown campus does not have a district heating system, and instead relies primarily on gas boilers to provide heat to university buildings. Given TU Dublin's position as a pioneer of DH development in Ireland, implementing a DH network at Blanchardstown is one of the primary decarbonization objectives for the university. TU Dublin aims to assess the thermal capacity of the ground conditions through geothermal response testing (GRT) at the campus. The results of this testing could establish the viability of using geothermal as an energy source for a network. A wider scheme is also being developed by Fingal County Council (FCC) which intends to use waste heat from a nearby data centre and could connect to the campus once operational.

Blanchardstown District Heating

Codema, as energy adviser to FCC, was appointed to develop an Outline Business Case (OBC) for a district heating system in the Blanchardstown area. The purpose of the OBC is to outline the justification of public expenditure to support the development of the scheme. The results of this feasibility study indicate that the scheme is both technically and economically viable and provides more benefits than the counterfactual (individual air-source heat pumps). The Blanchardstown District Heating System (BDHS) is now being actively progressed by FCC. Codema and the National Finance Development Agency (NDFA) are on board to assist FCC in developing the project, and a Project Board is to be established. The project is at the business case development stage, and a detailed case must be made for public sector funding and/or grant support.

The BDHS energy centre will consist of three elements, a water-to-water heat pump, a backup electric boiler, and thermal storage. The heat pump upgrades the waste heat from a nearby data centre (~25°C) to a usable building temperature (60 - 85°C) while the electric boiler provides redundancy for the heat pump. The thermal stores can be charged at nighttime and discharged during the day to avail of cheap electricity rates and reduce system costs.

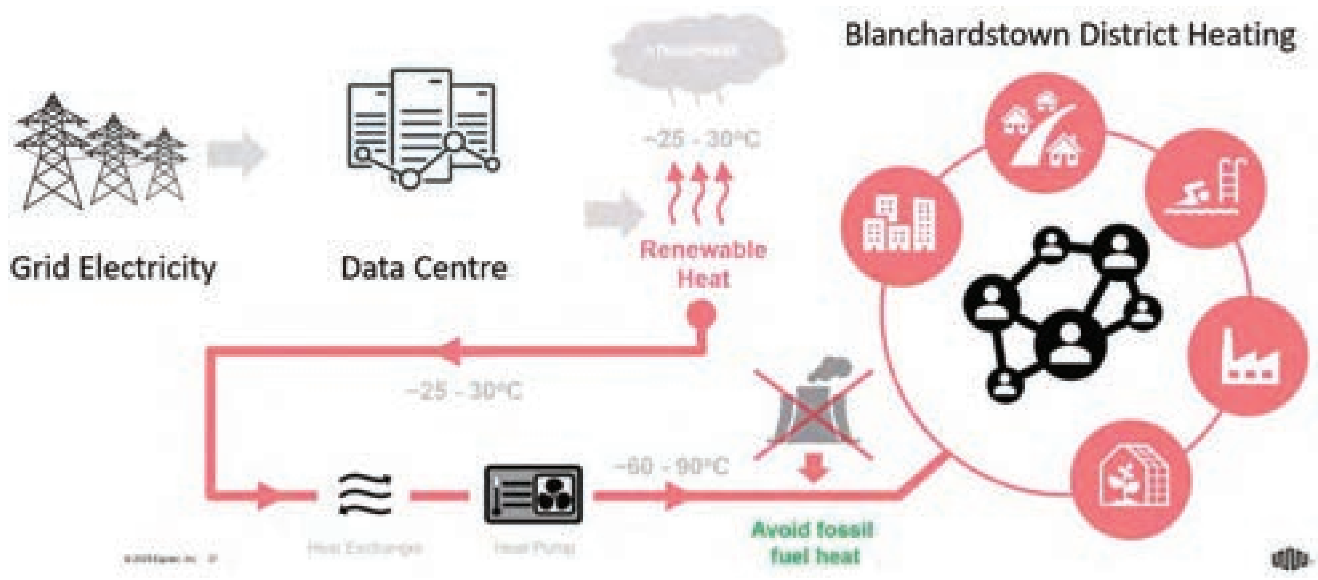


Figure 10: Indicative Schematic for the BDHS

Expected Timeline and Energy & Emissions Impact

One of the anchor tenants for the proposed scheme is the TU Dublin Blanchardstown campus which has been included in the first phase of the systems development. The scheme will be a technical replica of the TDHS, using waste heat from a nearby data centre. The scale of the initial phase of the BDHS however will be 5 times that of the Tallaght scheme. Once the project board has been established, and a suitable business model has been selected for the project it is expected that the council will proceed to procurement. Figure 11 depicts an indicative timeline from the decision to proceed to procurement, to heat on for the customers of the first phase.

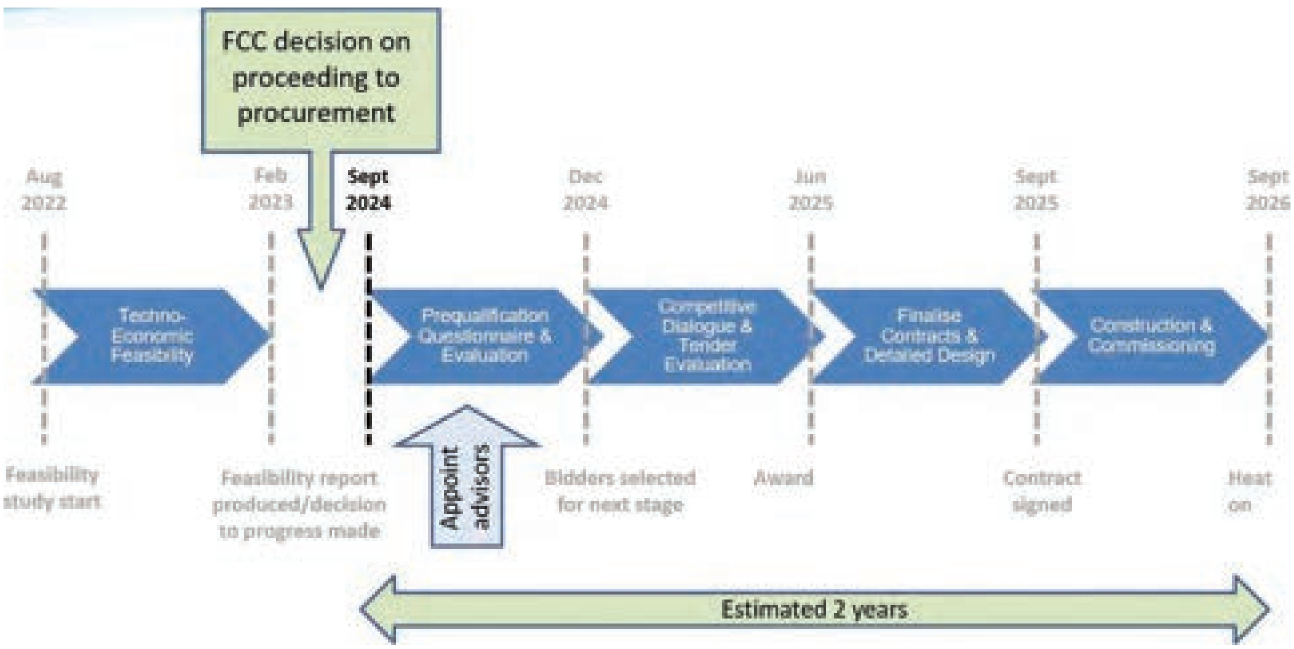


Figure 11: Indicative Timeline for Blanchardstown DH

If implemented, all buildings on the TU Dublin Blanchardstown campus could be connected, including Aras Geal which is currently under construction. To estimate the potential emission reduction impacts, the same methodology used for the TDHS can be used again as follows:

$$tCO2\ saved = \left(\frac{Heat\ Demand * g}{Boiler\ Efficiency}\right) - (Heat\ Demand * d)$$

Where g = emission factor for natural gas[12] (tCO2/MWh)

d = emission factor for TDHS[13] (tCO2/MWh)

Boiler efficiency is assumed to be 85%

[12] SEAI Fuel Conversion Factors
[13] District Heating Carbon Factors

Table 9: TU Dublin Connections to the Blanchardstown DH System (Phase 1)

Building	Supply	m^2	Heat Demand (MWh)	tCO2 Saved
Aontas	2026+	3,254	367	59
Buntus	2026+	2,282	169	27
Croi	2026+	3,490	834	133
Doras	2026+	4,584	681	109
Eolas	2026+	3,821	567	91
Fios	2026+	3,862	494	79
Horticulture	2026+	910	117	19
Spraoi	2026+	1,570	116	19
Ceangal	2026+	1,800	231	37
Geal (Future)	2026+	4,040	419	67
Total		**29,613**	**3,995**	**580**

Campus District Heating

Given that there are already district heating networks that serve the Tallaght and Grangegorman campuses, installing a campus wide system in Blanchardstown will enable TU Dublin to decarbonise thermal emissions at this site. This campus network could be installed while the BDHS network is in development and connect to the wider scheme once it is available.

To assess the viability of building a network on the Blanchardstown campus a DH options analysis software was used. THERMOS is designed to optimise local district energy network planning processes and sustainable energy master planning to facilitate the deployment of new low-carbon heating and cooling systems[14]. In particular, the software will be used to carry out the following analysis:

- Identification of optimal paths and connections for the Blanchardstown campus.
- Identification of local heat demand and network paths to match a known energy source.

To build an independent network, an energy centre location is required. It is anticipated that the energy centre could be located next to the Aontas building, which is located at the northeast end of the campus. The possibility of decanting this building may also free up further space that could house additional energy infrastructure. This is also the optimal location for connecting to the wider network if it is implemented. The optimal route and associated costs are shown in Figure 12 and Table 10 below, a full breakdown of the pipe sizes and costs are included in Figure 81 in the appendices below. These are network costs only and do not account for the heat production equipment or energy centre build costs.

[14] THERMOS

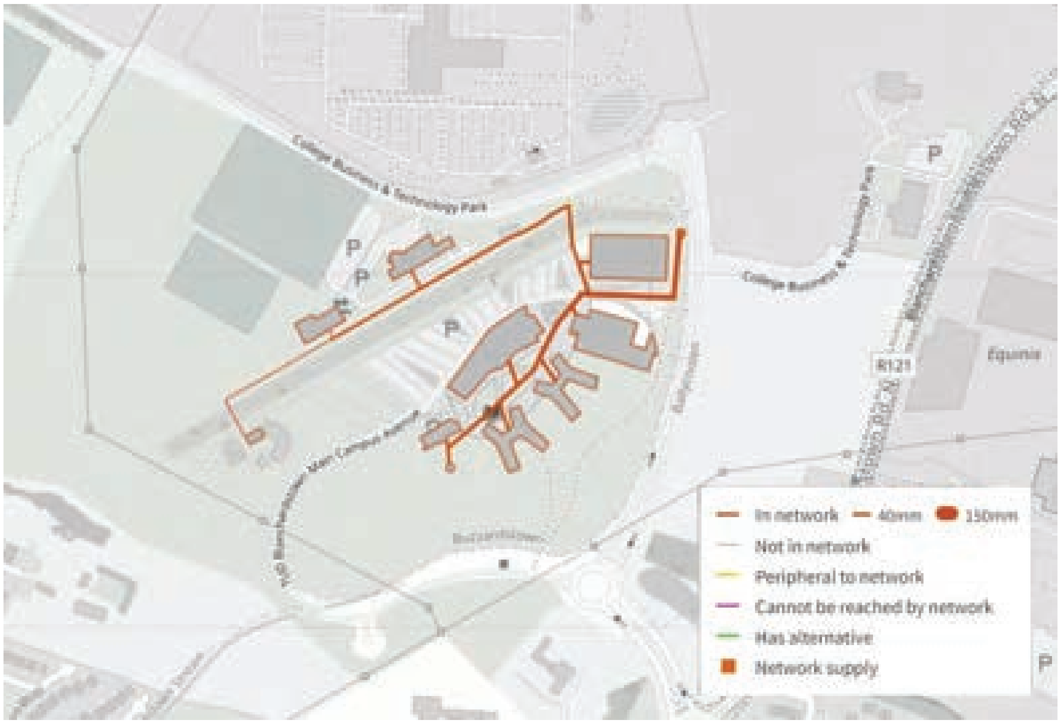


Figure 12: Proposed Blanchardstown Network Route, THERMOS

Table 10: Blanchardstown Pipe Network and Costs

	Length (m)	Cost (€)
Pipe Network	1,100	881,650
Contingency Costs (+35%)		419,350
Total	**1,100**	**1,310,000**

To estimate the remaining costs, the nPro energy model was used. Using the model, heat production equipment was sized. A deep geothermal energy source, backup electric boiler, and thermal storage arrangement was selected to estimate these costs, Figure 13 shows an indicative schematic for this system.

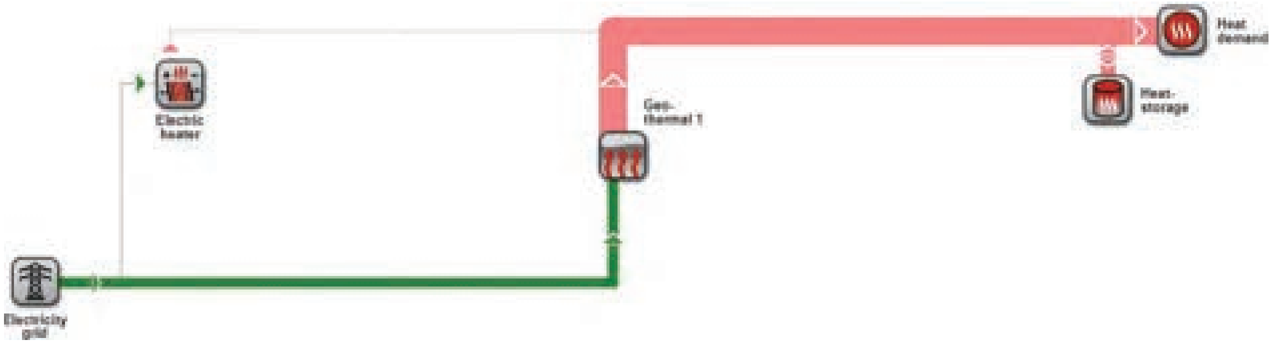
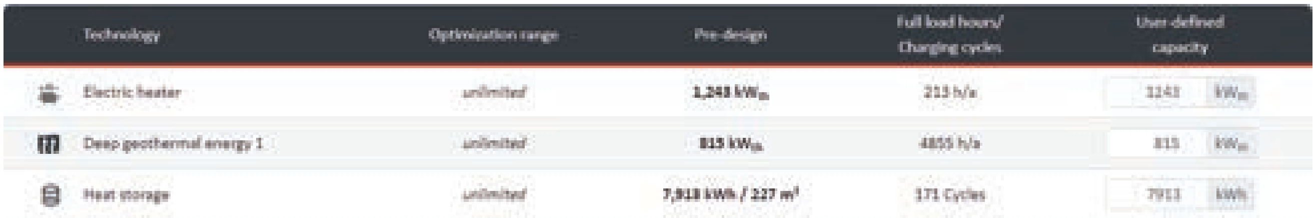


Figure 13: Blanchardstown Indicative DH Schematic

The equipment sizes selected by the model are shown in Figure 14. The total cost of the system is estimated to be ~ €9.7m, which accounts for contingency costs (+35%). The capital costs are estimated using the nPro model using costs from Table 41 from the appendices below.



Technology	Optimization range	Pre-design	Full load hours/ Charging cycles	User-defined capacity
Electric heater	unlimited	1,243 kW_{th}	213 h/a	1243 kW_{th}
Deep geothermal energy 1	unlimited	815 kW_{th}	4855 h/a	815 kW_{th}
Heat storage	unlimited	7,913 kWh / 227 m^3	171 Cycles	7913 kWh

Figure 14: Blanchardstown DH System Sizing, nPro

Table 11: Blanchardstown DH system total costs, nPro

Investments		Investment (€)	Annuity (€/a)
Building energy systems		88,508	4,869
Heat network		1,309,680	72,042
Heat production		3,361,787	177,669
Energy Centre		2,452,000	156,957
	Sum	**7,211,875**	**411,537**
Contingency (+35%)		2,524,191	161,578
	Total	**9,736,166**	**573,115**

System Expansion

The initial phases of the BDHS plan to connect the Sports Ireland campus, Connolly Hospital, IDA Business & Technology Park, nearby social housing, and industrial facilities Alexion & Bristol Myers Squibb as shown in Figure 15 above. This will require over 15km of pipework to be built as shown in Figure 15 below. The total heat demand that is anticipated to be delivered is over 50 GWh, with waste heat from the data centre expected to provide 68% of the heat required, thus reducing carbon emissions of the heat supplied by over 50% based on current national electricity grid carbon intensity figures[15]. As the national grid decarbonises, so will the BDHS which is intended to be a fully electrified system.

The Sports Ireland campus is also set to expand as part of the Sport Ireland Campus Masterplan Vision[16], which is an "ambitious blueprint which proposes a vision and framework for the growth of the Sport Ireland Campus and the long-term development of associated sporting facilities over the next 15–20 years". There are several data centres in the Blanchardstown area as shown in Figure 16 which could provide additional waste heat to the scheme to include this development, along with any suitable heat demand in the vicinity.

[15] SEAI Carbon Emission Factors
[16] Sports Ireland Masterplan

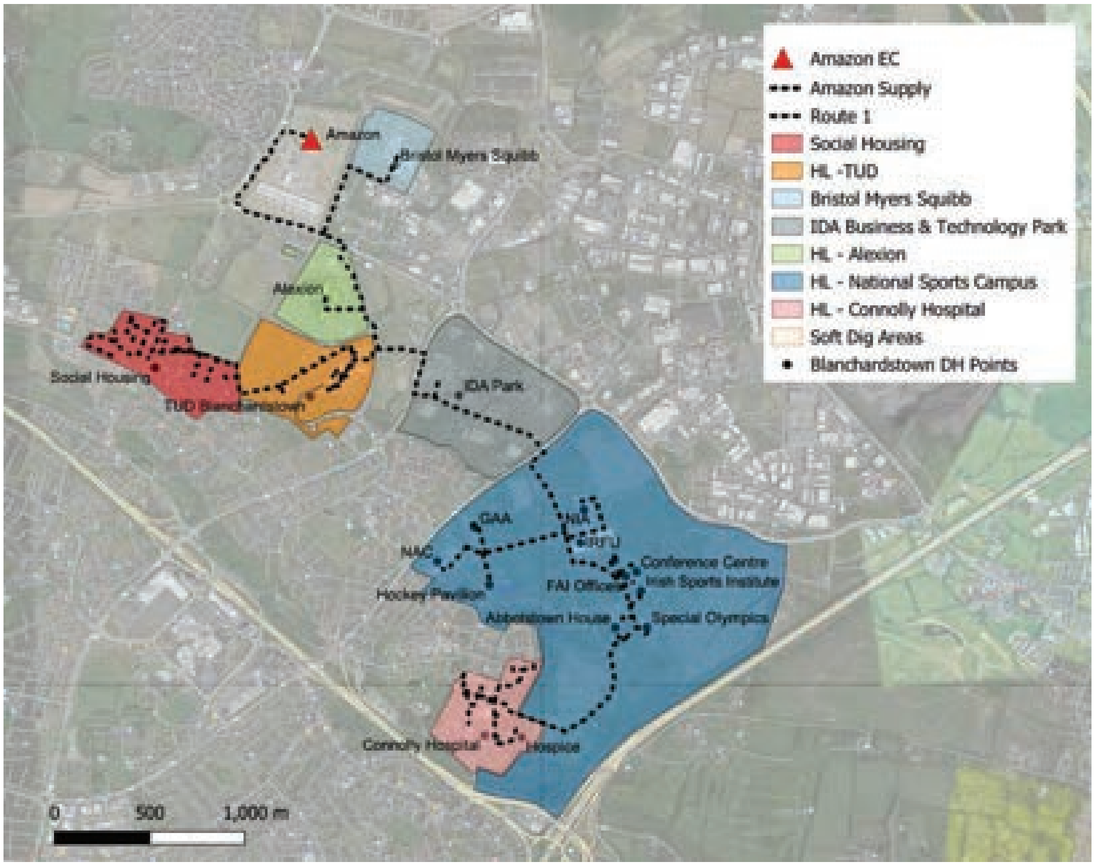


Figure 15: Potential Route for the Blanchardstown District Heating System

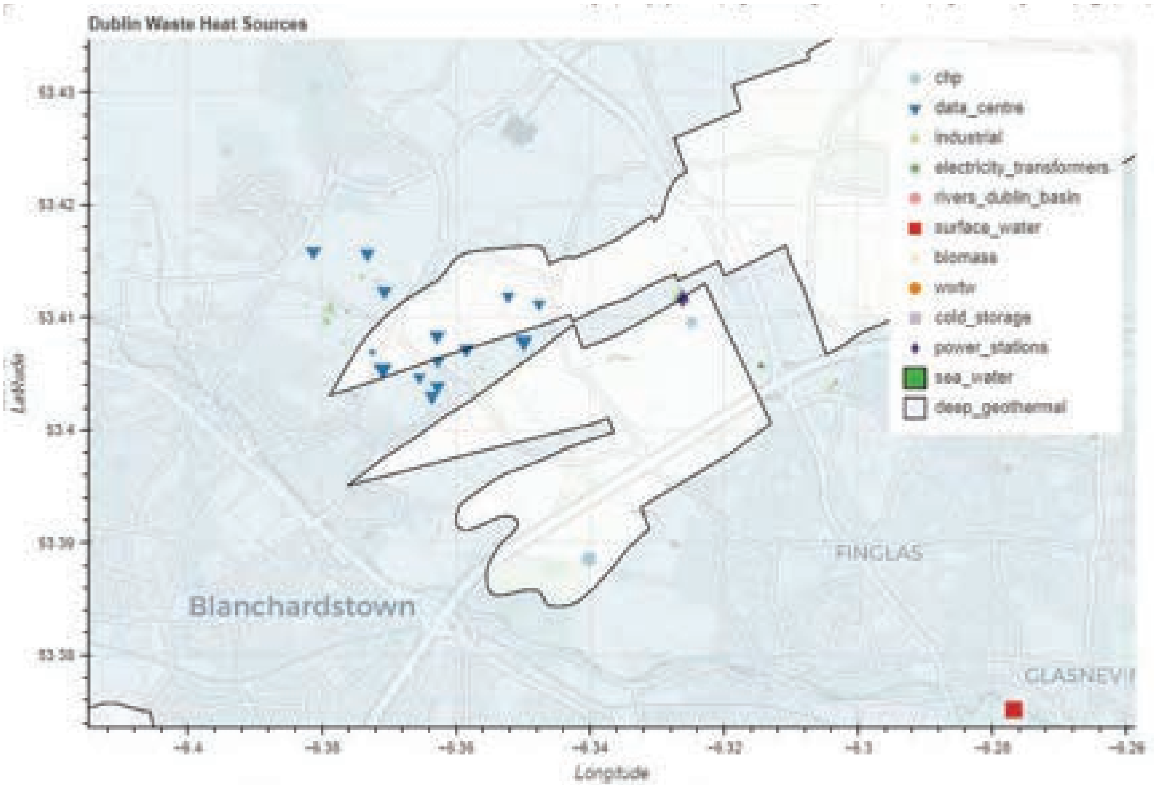


Figure 16: Waste heat source potential in Dublin

In a scenario where excess heat from all the data centres is utilised, or geothermal energy is proven to be a viable heat source for the network, there is also potential for the system to expand beyond the connections detailed in Figure 15. Figure 18 maps the heat demand and shows the areas that meet the threshold demand densities set out in Figure 17. There is a natural boundary to the scheme in the M3/N3 motorway, however, if roadworks were to be undertaken the scheme could expand to the southwest and connect nearby customers in Blanchardstown town centre.

	Band [TJ/km²year]
Not Feasible	<20
Future Potential	20-50
Feasible with Supporting Regulation	50-120
Feasible	120-300
Very Feasible	>300

Figure 17: DH Viability (TJ / km2)

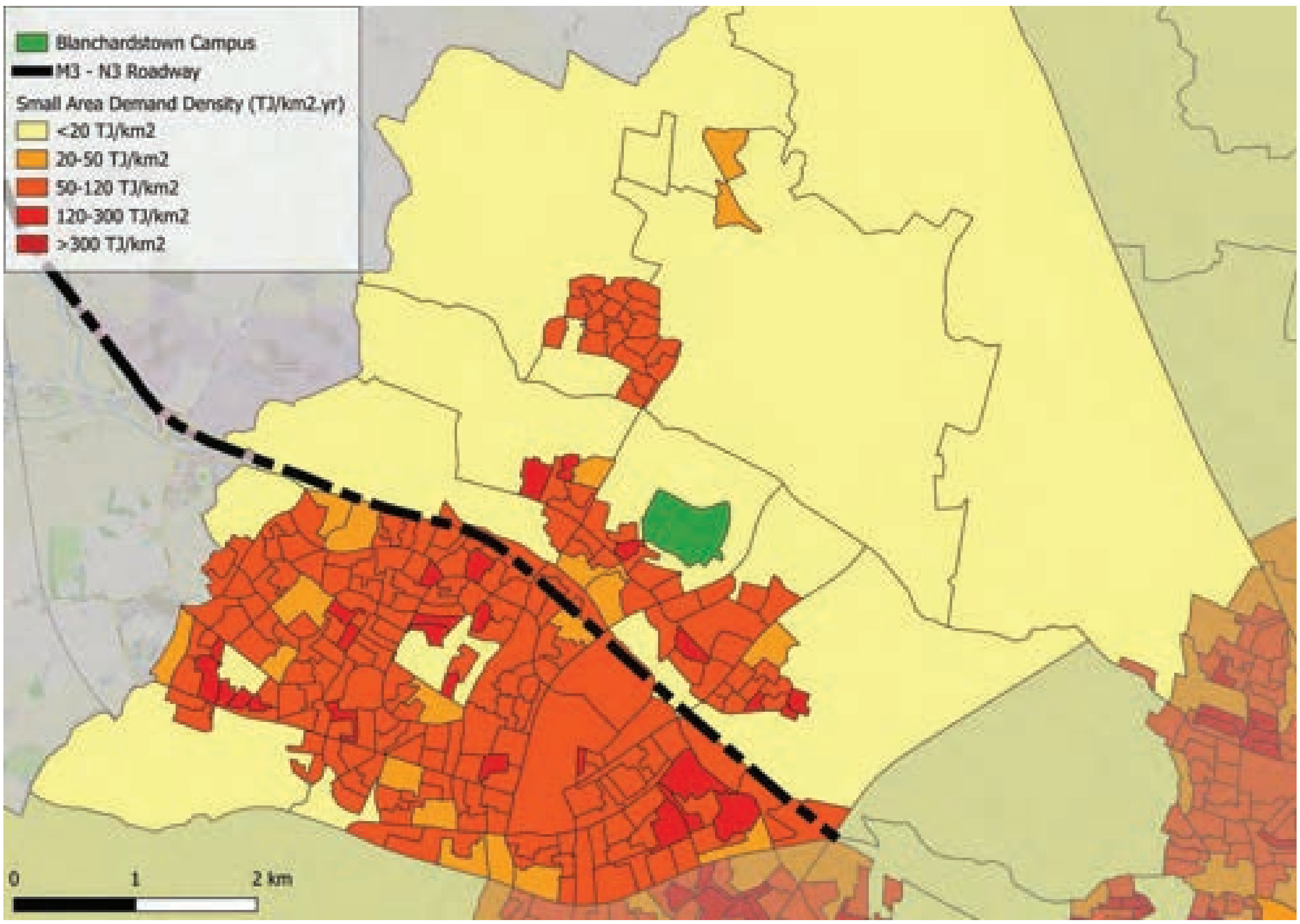


Figure 18: Grangegorman Heat Demand Mapping

3.5. Emission Reduction Potential

Table 12 shows the total emissions reduction potential for DH across the three main campuses, Tallaght, Grangegorman, and Blanchardstown. The reductions associated with the Tallaght campus consist of connecting the CAET and Synergy Cash buildings to the TDHS. The reductions associated with the Grangegorman campus are based on connecting the existing DH network to a geothermal energy source and connecting existing TU Dublin buildings to the system. The reductions associated with the Blanchardstown campus are based on all existing buildings connecting to the proposed BDHS system.

Table 12: Total DH Emission Reduction Potential

Campus	m^2	Demand (MWh)	tCO2 Saved
Tallaght	9,072	2,702	432
Grangegorman	127,764	14,659	2,517
Blanchardstown	29,613	3,995	513
Total	**166,449**	**21,356**	**3,463**

DH has the potential to reduce total TU Dublin thermal emissions by 57% compared to 2022 as shown in Figure 19. To reach the public sector target for 2030, a further reduction of 10% is required. It is anticipated that improvements in building space optimisation, controls and operation, and building retrofit will enable TU Dublin to further reduce thermal emissions to meet this target. It should be noted that all additional buildings added to TU Dublin campuses will increase consumption and emissions unless they are connected to low carbon energy systems such as DH. One method of negating this increase could be to review operations at the Aungier St, and Bolton St campuses, which at present do not have plans to implement DH and instead rely solely on gas to supply heat demand.

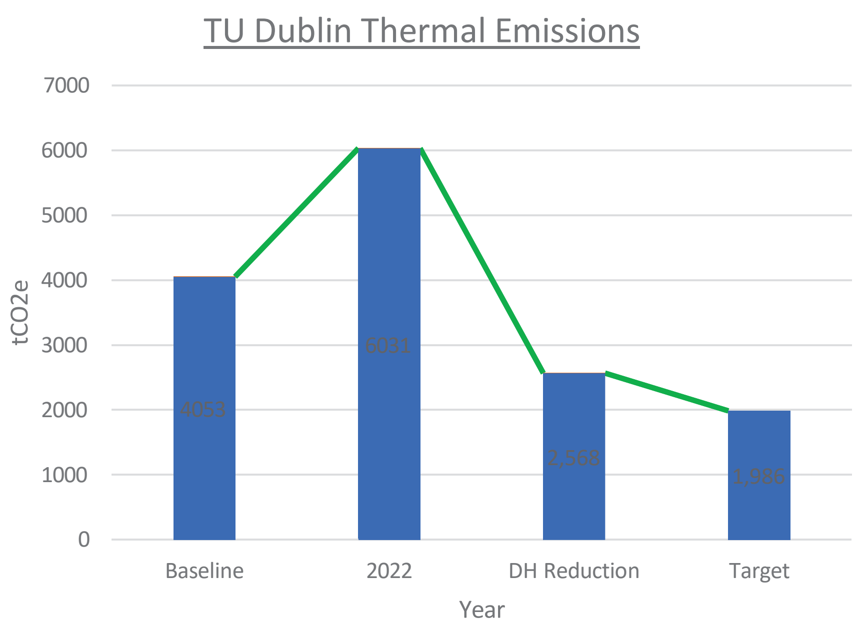


Figure 19: DH Emission Reduction Potential and TU Dublin Targets

4. SOLAR PV EVALUATION

4.1. Overview

Codema has carried out an evaluation of the potential for onsite solar photovoltaic panels to provide renewable electricity across the Blanchardstown, Grangegorman, and Tallaght campuses of TU Dublin. The City Campuses (Aungier Street and Bolton Street) have not been considered in this analysis as review of the use of various buildings that make up the City Campuses is ongoing, and this presents uncertainty when calculating the financial viability of solar PV installations on these buildings. Additionally, many of the largest buildings at these campuses are historic buildings that may not be suitable for the installation of solar PV equipment.

Initial assessment and evaluation included conducting site visits to each of the three campuses being considered and examining aerial imagery of the campuses. From this exercise, a number of buildings were identified as being unsuitable for rooftop solar due to various reasons including unsuitable roof material/ building structure that would not support the additional weight of a solar PV array, insufficient roof space as it is already being occupied by equipment from HVAC systems and other equipment, shading of the building from surrounding buildings and/or trees, and the historical nature of the building. The remaining buildings that were considered suitable for the installation of solar PV panels were then modelled on the solar design software Open Solar (a detailed description of the Open Solar software is provided below).

4.2. Regulatory Environment

New buildings

The Energy Performance of Buildings Directive (EPBD) requires all new buildings to be built to Nearly Zero Energy Buildings specifications (NZEB). The NZEB standard requires buildings to operate at a very high level of energy performance that promotes energy efficiency and includes energy sourced from renewable sources. For non-domestic buildings, an NZEB standard building is required to be equivalent to a 60% improvement in performance relative to the 2008 building regulations. This is reflected in the current building regulations relating to energy (Building Regulations 2022, Part L – Conservation of Fuel and Energy) and these regulations require that 20% of energy usage is from renewables produced onsite or nearby. As such, many new buildings include solar PV, and/or solar thermal panels to enable them to meet the requirements of these regulations. Recently built and future buildings at the TU Dublin campuses are/ will be required to be built to this standard. Many recent builds at TU Dublin therefore already include rooftop solar panels, such as the Tallaght Sports Science and Health, and Tallaght North buildings.

Existing buildings

The Energy Performance of Buildings Directive also includes requirements that any buildings that are undergoing major renovations (where over 25% of the fabric of the building is included for renovation) reach "Cost-Optimal level". Factors including capital investment, operational, maintenance costs, and the carbon costs associated with various energy efficient solutions and renewable technologies are considered when determining this "Cost-Optimal" level.

Energy Performance of Buildings Directive

The SEAI have provided information relating to upcoming requirements for installation of solar energy in buildings, in line with implementation of the requirements of the Energy Performance of Buildings Directive. This will require installation of equipment/technologies that capture solar irradiance on the site of the buildings, for example solar PV panels. This will be required on all existing buildings over 2000m^2 by 2028, on existing buildings over 750m^2 by 2029, and on existing buildings over 250m^2 by 2031, as shown below. A comprehensive guide on the details of these requirements is not yet publicly available.

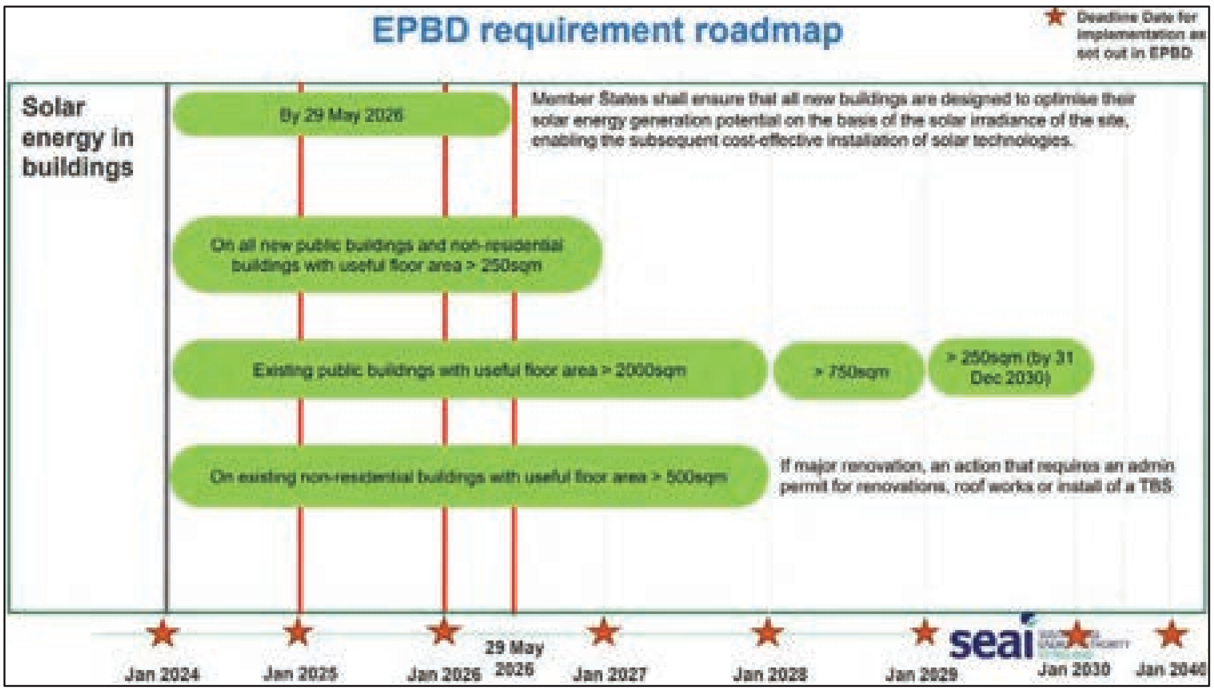


Figure 20: Extract from a SEAI presentation showing the requirements for installation of solar energy technologies in new and existing buildings in the coming years. (Source: SEAI webinar that took place on the 10/07/2024 titled "Decarbonising existing buildings)

Implementation of these requirements across the TU Dublin campuses will require installation of solar panels on many existing buildings. It is not currently clear what exemptions to the requirement will apply for buildings where it is not technically possible or permissible to install rooftop solar panels. The tables below show the buildings that will require solar installation at each of the three milestones identified above. In summary, 17 buildings across the campuses are over 2000m^2 and will require installation by 2028. 8 additional buildings are over 750m^2 and will require installation by 2029, and 10 additional buildings are over 250m^2 and will require installation by 2031.

Campus	Installation by 2028 (> 2000 m2)	Floor area (m2)
B	Aras Aontas	3,254
B	Aras Croí	3,490
B	Aras Doras	4,584
B	Aras Eolas	3,821
B	Aras Fíos	3,862
B	LINC Buntus	2,282
T	Tallaght Main	15,620
T	Synergy CASH	2,519
T	Airton Close	3,179
T	Tallaght Sports, Science and Health	3,093
T	Lower House	4,392
G	Rathdown House	2,314
G	Park House	9,836
G	Broombridge Warehouse	6,200
G	Greenway Hub	4,270
G	East Quad	16,300
G	Central Quad	36,044

Campus	Installation by 2029 (> 750 m2)	Floor area (m2)
B	Aras Ceangal/Connect	1,800
B	Aras Spraoí	1,570
B	Horticulture building	910
T	Technical Development Centre	1,209
T	Premier House	1,808
T	Synergy Global	1,341
G	Clocktower	1,488
G	Estates Yard and Store	850

Campus	Installation by 2030 (> 250 m2)	Floor area (m2)
T	Student Hub	290
G	St Laurences Church	287
G	Glassmanogue	374
G	Bradogue	511
G	Orchard House	269
G	Broombridge Sports Changing	440
G	Energy Centre 1	290
G	Hub 2	285
G	Printmaking Workshop	315
G	Field Sports Changing	616

Table 13: Tables showing what buildings at the Blanchardstown, Tallaght, and Grangegorman campuses will require installation of solar panels (based on floor area) at each of the three milestone years indicated by the SEAI.

Planning exemptions for solar installations

Amendments to the Planning and Development Act 2000 to provide planning exemptions for solar PV and solar thermal installations on a variety of buildings came into effect in 2022. The Planning and Development Act 2000 (Exempted Development) (No. 3) Regulations 2022, and the supporting Planning and Development (Solar Safeguarding Zone) Regulations 2022 sets out the classes, conditions and limitations to which planning exemptions apply. Class 61 of the Regulation outlines the relevant conditions for exemptions on educational buildings. The most relevant points of this relating to buildings across the TU Dublin Campuses include:

- Installation of solar panels on, and in the curtilage of, educational buildings is exempted development. There is no limit to the amount of rooftop solar that can be installed on buildings.

- However, if the building is located within a Solar Safeguarding Zone (explained below), a limit of 300m^2 applies to installation of rooftop solar on educational buildings. Additionally, the relevant planning authority must be notified of any solar panels that have been installed in a Solar Safeguarding Zone. Installation of larger solar arrays may be permitted, however anything larger than 300m^2 is not considered exempted development and planning permission must therefore first be obtained from the relevant Local Authority. A Glint and Glare Assessment will be required as part of this planning application.

- This exemption applies only where the primary function of the solar energy installation is for self-consumption of electricity / heat.

- The exemption includes technical specifications, notably that panels must be fixed a minimum of 2m on flat roofs, and 15cm on other roofs from the roof edge. Ancillary equipment can only be placed on a flat roof. Panels on a flat root must not exceed 1.6m above the roof level.

- For free-standing (ground-mounted) solar panels must not exceed an area of 75m^2 or exceed a height of 2.5 m.

Solar Safeguarding Zones

The regulation for exempted solar installations outlines restrictions to exemption for areas within Solar Safeguarding zones. A Solar Safeguarding Zone is a buffer area that is located around airports/airfields and helipads due to concerns that a glare from a high concentration of solar panels may have a blinding effect on pilots of low-flying aircrafts (buffer of 5 kilometres around airports and 3 kilometres around helipads -both public and private). Blanchardstown Campus is not located within one of these zones, however both the Grangegorman and the Tallaght Campuses are located within Solar Safeguarding Zones. The Grangegorman Campus is within both the Phoenix Park and the Kilmainham Solar Safeguarding Zones. The Tallaght Campus is within the Tallaght University Hospital Solar Safeguarding Zone.

This does not mean that a solar array over 300 m^2 cannot be installed at the Tallaght or Grangegorman campus, just that planning permission must first be obtained from the relevant Local Authority, and this would add costs and complexity to the process in comparison to locations where installation is exempted development. It is therefore advisable to first take the opportunity to avail of installing solar panels at the Blanchardstown Campus, and smaller installations (less than 300 square metres) at Grangegorman and Tallaght.

4.3. Technical Analysis

The solar arrays modelled on various buildings shown below were created using Open Solar[17]. Open Solar is a solar design software that allows a user to analyse the optimal size of a solar array on a building by inputting electricity consumption data of the building and then modelling a solar PV array on the rooftop of the building. Open Solar is programmed to calculate the projected irradiance of the proposed array based on the location and orientation of the building and the system being modelled. Comparison of the daily/monthly solar electricity generation and the electricity consumption for the same period can then be carried out to determine the optimal array size, location and orientation to maximise self-consumption of electricity.

The electricity consumption data that was input into Open Solar during this exercise is from various sources. For the Blanchardstown Campus the consumption data is from the meters that were installed as part of the Optimising Power at Work programme at the Blanchardstown Campus. Hourly consumption data from January 2023 to December 2023 was used to provide a full year of granular data. In a small number of cases there were gaps in the consumption data and figures were interpolated in Open Solar to account for these gaps. For the Tallaght and Grangegorman Campus it was more difficult to source granular electricity consumption data as many buildings at these campuses are grouped on shared meters and do not have building level sub-meters. Quarter-hourly and hourly data was used where available for these buildings, however for some buildings billing data was used which may not accurately reflect hours of consumption.

The costs provided below for each proposed solar PV array are high-level estimations that are based on a cost assumption of €1200/kW of solar PV installed. The Danish Energy Agency which identifies a price of €870/ kW for the solar equipment, most notably solar PV panels and inverters. A 35% margin of contingency was then added to this to cover soft costs associated with solar PV installation including surveys, labour etc. The €1200/kW installed assumption does not include VAT.

The seasonal generation profile of solar PV is somewhat mismatched with the electricity consumption of academic buildings. It is therefore expected that many of the solar PV arrays proposed below would generate excess electricity at certain times of the year and this would be sold back to the national grid when TU Dublin cannot use or store it. It is important to note that the Maximum Export Capacity cannot exceed the Maximum Import Capacity for small scale generation, and this may limit the amount of excess electricity that can be sold back to the grid. Further details relating to the Maximum Export Capacities of small-scale generations is available form ESBN - *Conditions Governing the Connection and Operation of Mini-Generation*.

[17] Open Solar

Optimising PV Tilt Angle for Maximum Self-Consumption

Your optimal year-round tilt angle:
36.7°

Your optimal tilt angles by season:
Spring: 36.7°
Summer: 21.7°
Fall: 36.7°
Winter: 51.7°

Your optimal tilt angles by month:
January: 46.7°
February: 41.7°
March: 36.7°
April: 31.7°
May: 26.7°
June: 21.7°
July: 26.7°
August: 31.7°
September: 36.7°
October: 41.7°
November: 46.7°
December: 51.7°

The usage profile of educational buildings that typically demand most energy during winter and spring months, and least during summer months when output from panels is at its highest presents a challenge to appropriately size solar systems of buildings to maximise self-consumption of on-site energy production. One way to address this is to choose a tilt for the panels that is optimal for the months that the buildings are in operation, rather than the annual optimal tilt. For example, the optimal annual tilt for the Blanchardstown Campus is 36.7°, however, the average optimal tilt from September to May (typical months of third level semester calendar) is 40°, and this tilt has therefore been input in the solar models shown below where technically possible.

Figure 21: Optimal tilt of solar panels by month and season. (Example for Blanchardstown Campus, Eircode: D15 YV78. Source: sunsolartilt.com)

4.4. Blanchardstown Campus

The Blanchardstown Campus is not located within a Solar Safeguarding Zone and as such installation of rooftop solar at the campus can be considered exempted development (if consistent with the technical requirements outlined).

Figure 22: TU Dublin Blanchardstown Campus relative to surrounding Solar Safeguarding Zones.

The majority of buildings at the campus have flat roofs that are particularly suited to installation of solar PV panels. Additionally, many of these roofs are unoccupied and there is ample space for installation of solar panels.

Figure 23: Aerial image of the Blanchardstown Campus showing the roof space available for installation of solar panels.

Some of the roof space however is unsuitable for installation of solar panels due to considerations such as the roof material and space availability (Aontas, Horticulture, Geal, Doras). The suitability of each of the 10 buildings at the Blanchardstown Campus is outlined below. In summary, the greatest potential for installation of rooftop solar panels is on the Connect, Croí, Spraoí, and LINC buildings. These buildings have been modelled using Open Solar software and the results of this modelling are provided below. There is also potential to install solar panels on the Eolas, and Fíos buildings, however these are considered less optimal as these roofs are tilted, half of which is largely north facing. These buildings have also been modelled in Open Solar and are included below.

Solar already installed	Very suitable	Potentially suitable	Not suitable

Building	Suitability	Proposed array (kWp)	Annual production (MWh)
Aras Aontas	There is some unoccupied space on the Aontas building that may be suitable for installing solar PV, however there is some building service equipment on the roof that will limit this availability. Additionally, the prefabricated material of Aontas may not support the weight of a large array.		
Aras Ceangal/Connect	There is potential to install rooftop solar PV on the Connect building, particularly as the electric system of the building is already fitted to incorporate solar energy. Most of the roof however is already occupied with other equipment and there is just approximately 200m2 of available roof space.	**26**	**22.163**
Aras Croí	The Croí building appears to be very well suited to installation of rooftop solar PV. The large roof (approximately 3,350 m2) is flat and largely unoccupied. There does not appear to be major shading from surrounding buildings or trees.	**537.6/ 366.8**	**477 / 326**
Aras Doras	There may be some potential for roof mounted solar PV on the Doras building, however, there appears to be various building servicing equipment/lighting across the entire roof. Additionally, a large portion of the roof is at a slight north facing tilt.		
Aras Eolas	There is potential for roof mounted solar PV on the Eolas building. The roof is slightly tilted (NE and SW) and is largely unoccupied. There is approximately 1,200m2 of available roof space, however half of this is slightly north facing.	**162**	**141**
Aras Fíos	Same shape and orientation as Eolas - slightly smaller. Potential for roof-mounted solar PV.	**156**	**136**
Aras Spraoí	The Spaoí building appears to be very well suited to the installation of solar PV. The roof is orientated southeast with a slight north-south tilt. There does not appear to be any shading from surrounding buildings. The roof is approximately 860m2.	**114.4 / 35.2**	**99.176 / 30.218**
Horticulture	The roof of the Horticulture building is a sedum roof and installation of solar panels may interfere with the design of this system.		
LINC/ Buntús	There is potential for roof mounted solar PV on the LINC building, particularly on the larger south facing side of the building (approximately 800m2) which is gently sloped. There does not appear to be any major shading issues from surrounding buildings or trees.	**90.8**	**73.666**
Aras Geal	The roof of Aras Geal is already occupied with building service equipment and there is little to no room to install solar PV panels.		
TOTAL		**1086.4 / 836.8**	**949.005 / 729.047**

Table 14: Analysis of building suitability for installation of rooftop solar PV panels at the Blanchardstown Campus.

Aras Ceangal / Connect

A 26 kWp solar array is proposed for the Connect building as shown. There may be potential to fit some additional solar panels on the building, however there is limited space for this due to the presence of roof windows. This building is relatively recently built (2019), and electrical works to incorporate electricity generated from on-site solar PV panels were included in the construction of the building. Open Solar modelling anticipates that the 26 kWp array proposed would meet approximately 20% of the annual electricity demand of the building, all of which can be consumed by the building as shown. The investment cost of the proposed 26 kWp array is estimated at €31,200.

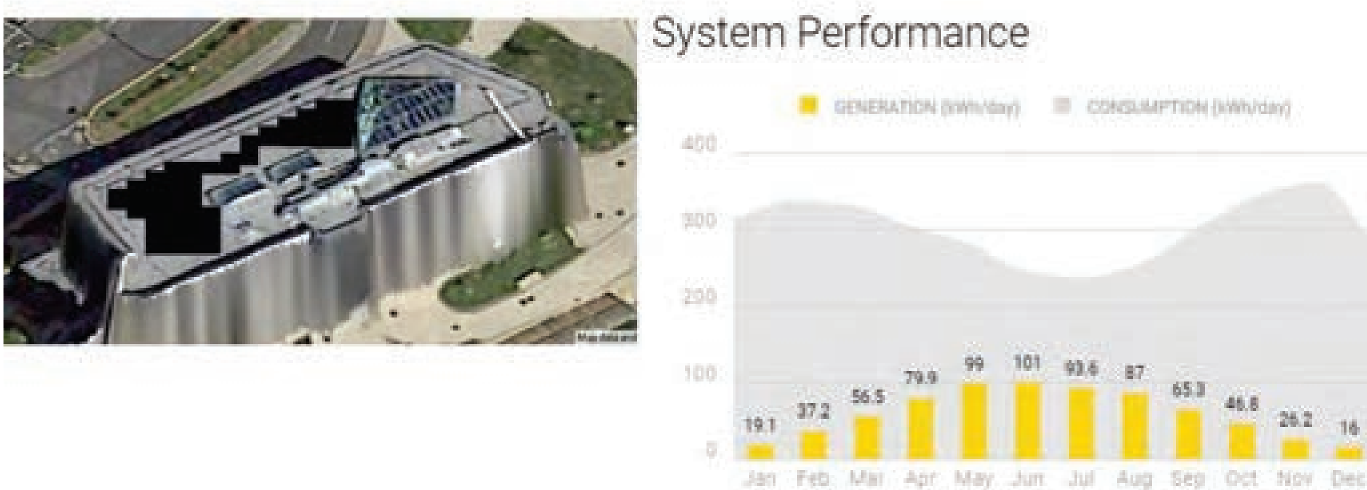


Figure 24: Aras Ceangal / Connect PV Array Installation & System Performance, Open Solar

Aras Croí

The Aras Croí building is suitable for the installation of a very large rooftop solar PV array. Two scenarios are outlined below based on whether it is technically and financially feasible to install the electrical infrastructure to allow solar PV panels on the Croí building to supply electricity to surrounding buildings at the Blanchardstown Campus. Scenario 1 assumes that this is possible. In this scenario the excess electricity generated from the large solar PV array is distributed to Aras Aontas and/or Aras Doras. Both buildings have been considered unsuitable for the installation of rooftop PV and the spatial layout of the campus indicates providing electricity to these buildings would minimise the distance of trenching required if new electrical wiring is required between the buildings in this scenario. Private Wire is not considered an issue in this scenario as the entire campus is within the ownership of TU Dublin.

Scenario 2 assumes that the electricity generated from rooftop solar PV panels on the Aras Croí building can only be consumed by the Aras Croí building. This scenario is included as further technical investigation is required to determine if the installation of the necessary electrical infrastructure to transfer electricity from the Croí building to the Aras Aontas and Aras Doras building (Scenario 1) is possible, and if the associated electrical works would have prohibitively expensive costs associated with it. Additionally, the age of the buildings in question (approximately 20 years old) may require expensive rewiring/ electrical upgrades to connect the buildings for the transfer of electricity. Therefore, although Scenario 1 would be optimal from a self-consumption and reduction of Scope 2 emissions point of view, Scenario 2 has been considered as an alternative if Scenario 1 is not possible. This scenario proposes a significantly smaller array of solar PV panels. Any excess electricity generated by the panels cannot be distributed to other buildings at the campus. Excess electricity would be sold to the national grid or connected to a solar water diverter to provide hot water for the building.

Scenario 1:

Scenario 1 maximises the available roof space of the Croí building and proposes a panel array of 537.6 kWp, as shown. Open Solar modelling of the array shown below would minimise imports of electricity for the Croí building across the year with just a small amount of electricity import required in December and January. Significant excess electricity would be generated between February and October that would be distributed to Aras Aontas and Aras Doras. The investment cost of the proposed 537.6 kWp array is estimated at €645,120.

Figure 25: Aras Croí (Scenario 1) PV Array Installation & System Performance, Open Solar

Scenario 2:

Scenario 2 proposes a 366.8 kWp array. This is significantly smaller than Scenario 1 but still a very large installation that would require major investment. This array would meet most of the electrical load of the Croí building between February and October (approximately), as shown below. Significant amounts of excess electricity would be generated however between April and September and the same options of selling to the grid or thermal storage are possible. The size of this array could be reduced to reduce the amount of excess electricity produced and to reduce the investment cost of installation. This, however, would also result in a need for additional electricity imports from the grid and the associated cost and carbon recording implications. The investment cost of the proposed 366.8 kWp array is estimated at €440,160.

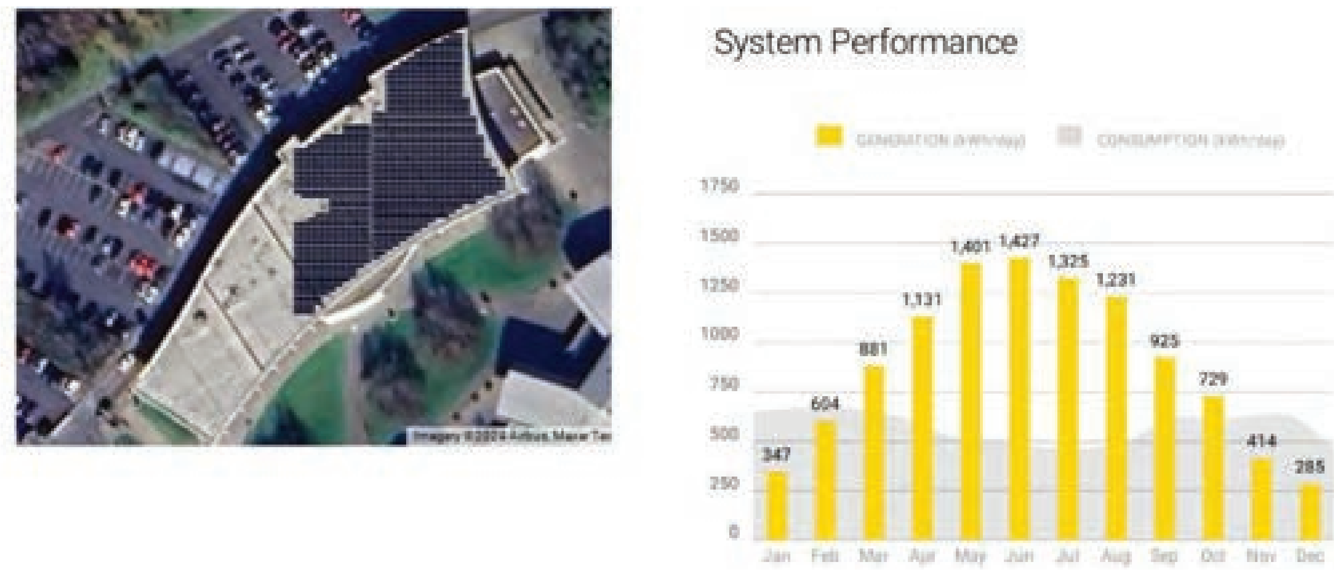


Figure 26: Aras Croí (Scenario 2) PV Array Installation & System Performance, Open Solar

Aras Spraoí

Like Aras Croí, Aras Spraoí has the potential to generate more electricity from rooftop solar PV than it can consume. Therefore, two scenarios have also been considered for this building based on the same principle as the Croí scenarios. If distribution of electricity from the Aras Spraoí solar PV system is possible then maximisation of the roof space available is advisable. Excess electricity could then be distributed to the Horticulture building and/ or Aras Geal.

Scenario 1: Scenario 1 assumes distribution of electricity generated from rooftop solar PV on Aras Spraoí to the Horticulture and/or Aras Geal is possible. Scenario 1 proposes a 114.4 kWp system, as shown below. This proposal would meet the daylight electrical demand of the Spraoí buildings at all points throughout the year. Excess electricity would be distributed to the Horticulture and Aras Geal building. The investment cost of the proposed 114.4 kWp array is estimated at €137,280.

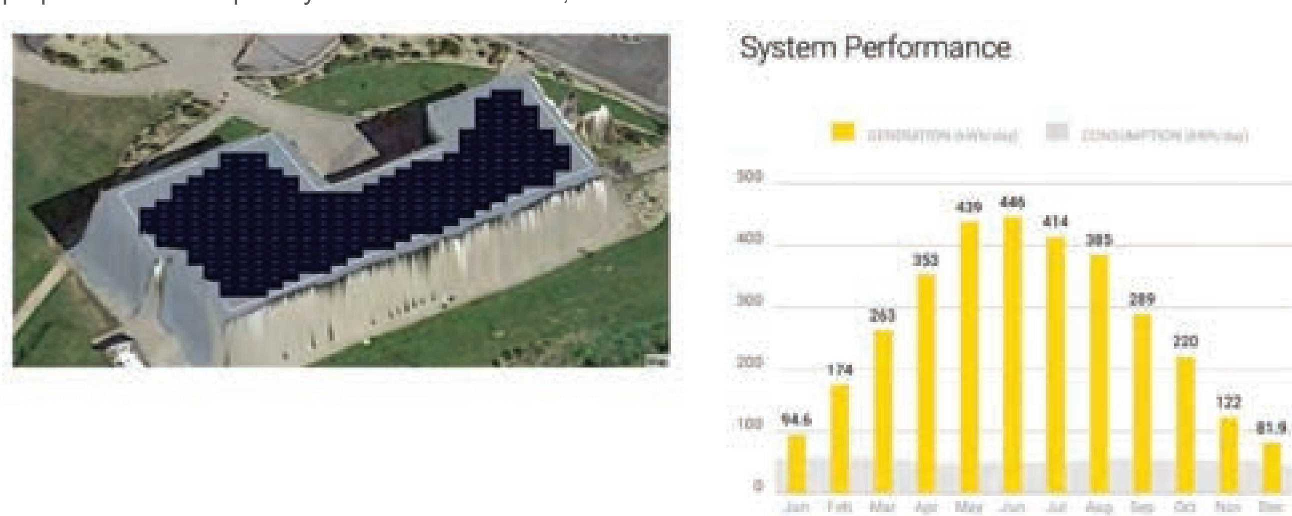


Figure 27: Aras Spraoí (Scenario 1) PV Array Installation & System Performance, Open Solar

Scenario 2:

Scenario 2 proposes a 35.2 kWp array which would meet the daytime electrical load of the building between February and October (approximately). Significant amounts of excess electricity would be generated between March and September with the same options outlined previously of selling to the grid or using for hot water heating. A smaller array can be considered to reduce installation costs and export of excess electricity. However, this will result in increased import of electricity from the national grid in Winter months. The investment cost of the proposed 35.2 kWp array is estimated at €42,240.

Figure 28: Aras Spraoí (Scenario 2) PV Array Installation & System Performance, Open Solar

LINC/ Buntus

A 90.8 kWp solar array is proposed for the LINC building. There is space to also add panels on the northern portion of the building, however as this part of the roof is tilted North the solar radiance received will be considerably less than the southern part of the building. The proposed array will not meet the electricity demand of the building at any point during the year and electricity imports from the national grid will therefore still be required, particularly during winter months. Self-consumption, however, will likely be possible for most of the electricity generated from the proposed array and exports of electricity to the grid would be minimal. The proposed array is expected to provide approximately 47% of the annual electricity demand of the LINC building. Installation of solar PV panels is particularly suited to this building as the consumption profile of the building shows a relatively stable consumption across the year with significant demand in the summer months (unlike other buildings at the campus) when solar PV panels would operate at their maximum capacity. The investment cost of the proposed 90.8 kWp array is estimated at €108,960.

Figure 29: LINC/ Buntus PV Array Installation & System Performance, Open Solar

Aras Eolas

A 162 kWp array is proposed for the Aras Eolas building, as shown below. A significant portion of the proposed array is on the North-East facing part of the building which will not perform as productively as the South-West facing array. The eastern and western orientation, however, will also offer extended hours of solar production without the need for battery storage. The proposed array would not meet the electrical demand of the building during most of the academic year. Generation would peak between May and August and would generate excess electricity. The investment cost of the proposed 162 kWp array is estimated at €194,400.

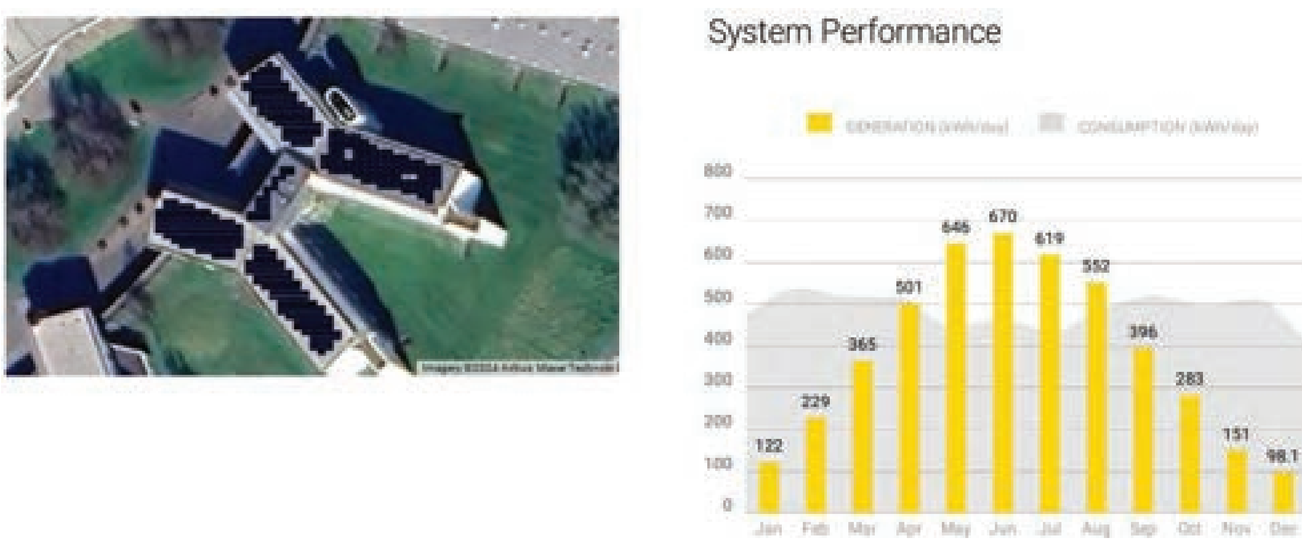


Figure 30: Aras Eolas PV Array Installation & System Performance, Open Solar

Aras Fíos

A 156 kWp array is proposed for the Aras Fíos building, as shown below. Similar considerations relating to the orientation of the tilted roofs as outlined for Aras Eolas also apply to the Aras Fíos building. Similarly, the proposed array would not meet the electricity demand of the building for most of the semester year and would generate excess electricity during the summer months. The investment cost of the proposed 156 kWp array is estimated at €187,200.

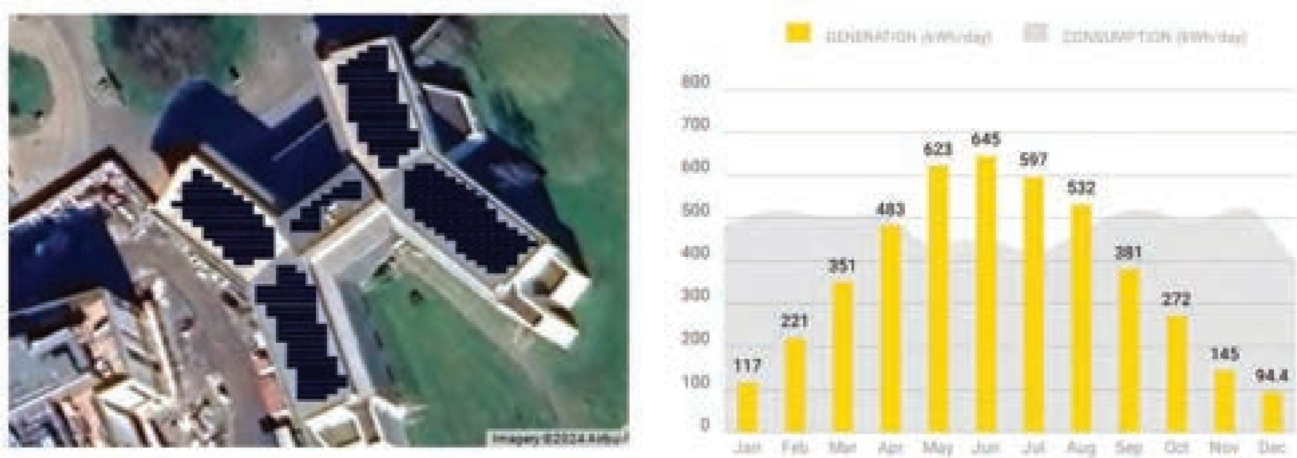


Figure 31: Aras Fíos PV Array Installation & System Performance, Open Solar

Campus summary

Energy import		PV Trial (Scenario 1)	PV Trial (Scenario 2)
Electricity import from grid	MWh	849	898
PV electricity generation	MWh	437	388
Self-sufficiency	%	34%	30%

Table 15: Campus level impact of implementing the above proposed solar arrays on electricity self-sufficiency of the Blanchardstown Campus.

The table above shows the impact that installation of the solar arrays proposed above would have on the campus wide electricity imports. A total annual requirement of 1,286 MWh for the campus is assumed. In Scenario 1, where electricity generated from solar PV panels can be distributed between buildings, solar PV would provide 34% (437 MWh) of the electricity demand of the campus. This decreases to 30% (388 MWh) in Scenario 2 where it is assumed electricity generated on a building can only be consumed by that building. The investment cost difference between Scenario 1 and Scenario 2 is €300,000 to achieve a 4% improvement in self-sufficiency.

Emissions and primary energy		PV Trial (BAU)	PV Trial (Scenario 1)	PV Trial (Scenario 2)
Electrical CO_2 emissions	t	328	164	200
Electrical CO_2 savings	%	0%	50%	39%
Primary energy	MWh	2,429	1,215	1,484
Primary energy savings	%	0%	50%	39%

Table 16: CO2 savings comparison between a 'do-nothing' scenario (BAU), Scenario 1, and Scenario 2.

Figure 30 shows a comparison of the expected CO_2 savings associated with both scenarios, as well as a trajectory of current operations in a 'Business as Usual' scenario. These results show that Scenario 1 is the optimal course of action to achieve major CO_2 savings.

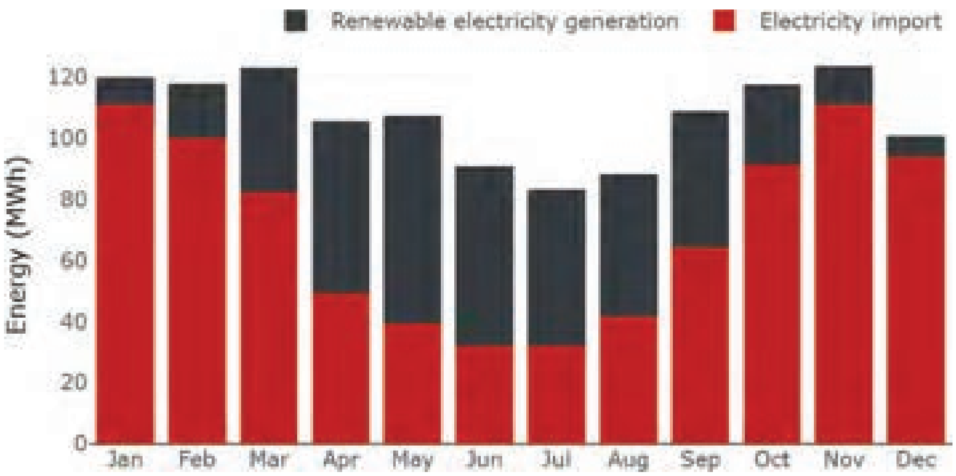


Figure 32: Monthly electricity generation from proposed solar PV and imported from the national grid.

The graph above shows monthly electricity consumption of the Blanchardstown Campus and this consumption is divided into electricity that can be generated from solar PV at the campus in Scenario 1, with the remaining demand being met by electricity imported from the grid. As outlined previously, electricity consumption at a campus level notably decreases between May and September in line with the college semester calendar. This is typically when solar PV panels can produce most electricity. For these reasons, the proposed solar PV systems would:

- Meet most of the electricity demand between April and August,
- Meet a significant portion of electricity demand during the months March, September, and October
- Meet a low portion of electricity demand during the months January, February, November, and December.

This same information is presented below and more clearly shows the curve of solar production across the year, with a noticeable peak during the summer months.

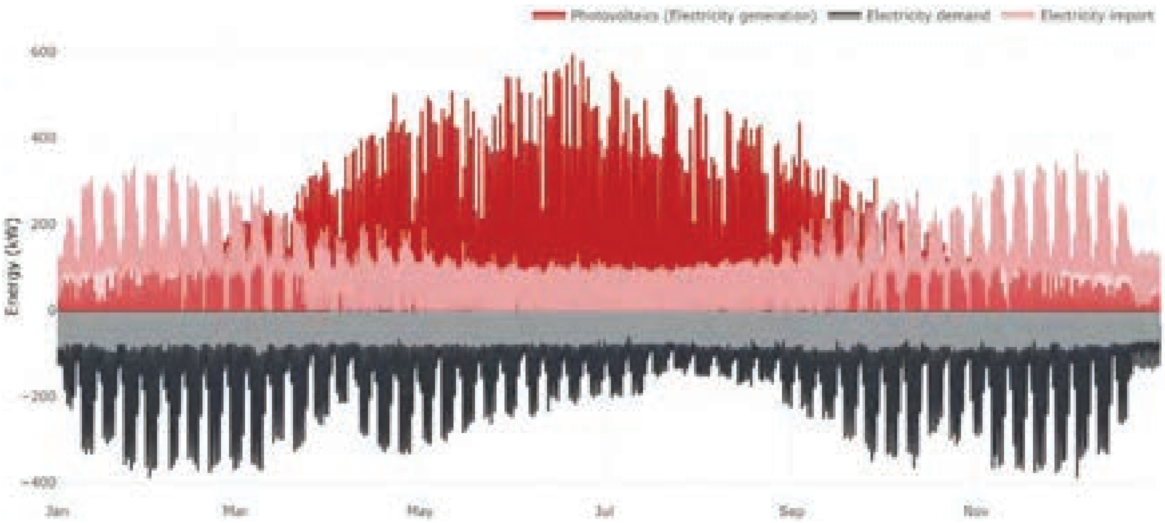


Figure 33: Electricity generation from proposed solar PV arrays and subsequent requirement for grid electricity relative to campus demand.

4.5. Tallaght Campus

The Tallaght main campus is located within the Tallaght University Hospital Solar Safeguarding Zone as shown below. Installation of solar panel arrays greater than 300m² is therefore not exempted development and planning permission must be obtained for any larger installations.

Figure 34: TU Dublin Tallaght Campus relative to surrounding Solar Safeguarding Zones.

There is overall limited scope to install rooftop solar panels at the Tallaght Campus. The roofs of the buildings at the Main Campus are largely occupied with various equipment and there is limited space to install large solar panel arrays. There are already solar panels on 3 buildings at the Main Campus. The following buildings on the Tallaght campus have been assessed for PV suitability and are included in the table below.

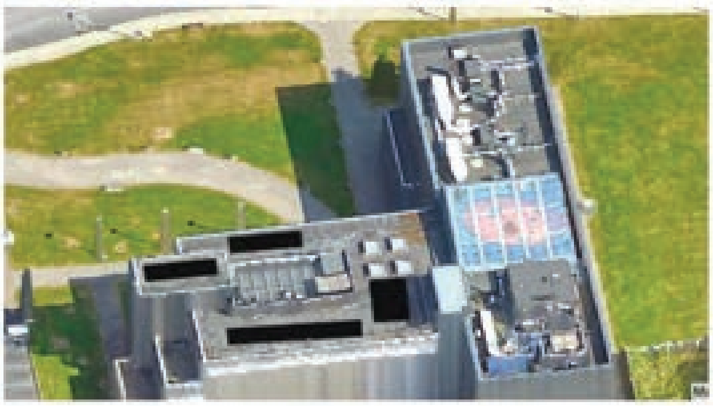
Solar already installed	Very suitable	Potentially suitable	Not suitable

Building	Suitability	Proposed array (kWp)	Annual production (MWh)	Considerations
Tallaght Main	There is an existing solar array of 34kW on the Tallaght Main building but this is part of a research project and not currently used by the building. There is some space for additional PV arrays on the main building, however the roof space is limited by various building equipment that occupy a significant portion of the roof and may require access and cause shading of panels. The existing space occupied by the solar PV panels is approximately 250 square metres meaning only an additional 50 square metres can be added without applying for planning permission.			* SOLAR SAFEGUARDING ZONE
Synergy CASH	There is limited space for installation of roof mounted solar panels on the Synergy CASH building. The roof of the newer part of the building is occupied with building service systems. There is space for a small solar PV array on the roof of the older part of the building.	**12.8**	**1.0447**	* SOLAR SAFEGUARDING ZONE
Tallaght Student Hub	The student hub is a single-story building and there are high trees located along the south facing side of the building. This would likely cause significant shading.			* SOLAR SAFEGUARDING ZONE
Technical Development Centre	LEASED BUILDING			* SOLAR SAFEGUARDING ZONE
Premier House	Ther is space to install rooftop solar PV on Premier House. Half of the roof is facing largely north however and this limits the size of array that should be installed.	**50.4**	**43.321**	* SOLAR SAFEGUARDING ZONE
Synergy Global	There is space on the Synergy Global building for installation of a large array of solar panels.	**122.8**	**109**	* SOLAR SAFEGUARDING ZONE
Airton Close	LEASED BUILDING.			* SOLAR SAFEGUARDING ZONE
Priorsgate Apartments	LEASED BUILDING.			* SOLAR SAFEGUARDING ZONE
Sports, Science and Health	The Sport Science and Health building is fitted with three panels that are used for solar thermal heating for hot water in the building. There is not sufficient space for additional panels to be added on the roof of this building. The Sports Science and Health building already has approximately 290 square metres of solar panels on the roof of the building.			* SOLAR SAFEGUARDING ZONE
Tallaght North	The North building is currently under construction and will include an array of solar PV panels when completed.			* SOLAR SAFEGUARDING ZONE
TOTAL		**186.00**	**153.3657**	

Table 17: Analysis of building suitability for installation of rooftop solar PV panels at the Blanchardstown Campus.

Synergy CASH

A 12.8 kWp array is proposed for the Synergy CASH building (on the older Synergy part of the building), as shown below. There may be space for a small number of additional panels however roof space is overall very limited on this building. The Synergy CASH building has a relatively high level of electricity consumption, and the proposed array would provide approximately just 4% of the electricity demand of the Synergy CASH building. The investment cost of the proposed 12.8 kWp array is estimated at €15,360.



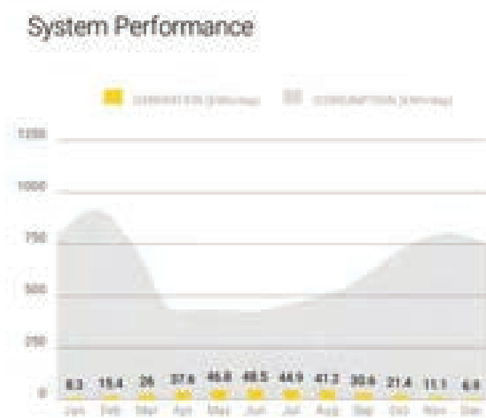


Figure 35: Synergy CASH PV Array Installation & System Performance, Open Solar

Premier House

A 50.4 kWp array is proposed for the Premier House building, as shown below. It should be noted that electricity consumption data available for this building was limited and the consumption levels shown on the graph below contains a high level of extrapolated data that may not be accurate. From this extrapolated consumption data, it can be expected that the proposed solar array would meet most of the electricity demand of the building between March and September and that grid import would be required between October and February. As this building is an individual building that is not located on the main campus, excess electricity produced during the summer months would likely be sold back to the grid. A smaller installation may therefore also be suitable to reduce the investment required. The investment cost of the proposed 50.4 kWp array is estimated at €60,480.

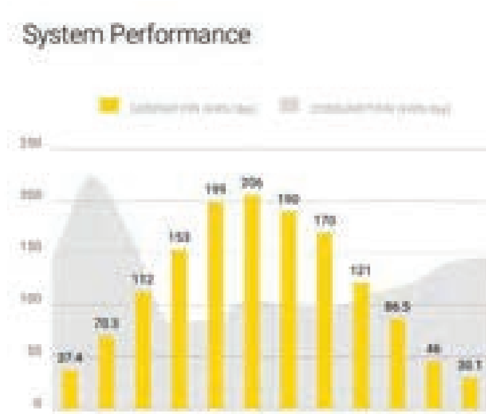


Figure 36: Premier House PV Array Installation & System Performance, Open Solar

Synergy Global

A 122.8 kWp array is proposed for the Synergy Global building located in the Citywest Business Park. The electricity consumption data shown below is based on monthly consumption from bills. It should be noted therefore that the self-consumption anticipated in the graph below may not be accurate as consumption and generation hours may not match and no battery storage system is proposed. The proposed array is very large and would meet or exceed the majority of electricity consumption of the building between April and August. Significant import of electricity would be required between August and March. The investment cost of the proposed 122.8 kWp array is estimated at €147,360.

Figure 37: Synergy Global PV Array Installation & System Performance, Open Solar

Campus summary

Energy import		Grid only	PV Trial
Electricity import from grid	MWh	591	510
PV electricity generation	MWh	0	81
Self sufficiency	%	0%	14%

Table 18: Campus level impact of implementing the above proposed solar arrays on electricity self-sufficiency of the Tallaght Campus.

The table above shows the impact that installation of the three solar arrays proposed above would have on the campus wide electricity imports. A total annual requirement of 591 MWh for the campus is assumed. The proposed solar PV arrays would meet 14% of this demand (81 MWh). This is equivalent to CO_2 savings of 15% as shown in Figure 38 below (15% savings are relative to current/ BAU operations).

Emissions and primary energy		Grid only	PV Trial
CO_2 emissions	t	151	128
CO_2 emissions savings	%	0%	15%
Primary energy	MWh	1,116	947
Primary energy savings	%	0%	15%

Table 19: CO2 savings comparison between a ‘do-nothing’ scenario (Grid only), and the proposed solar PV installations.

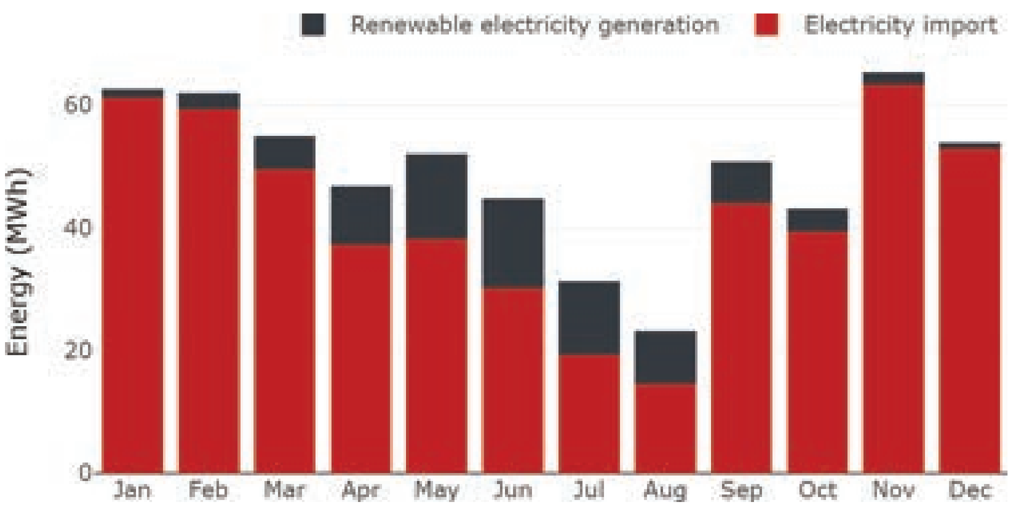


Figure 38: Monthly electricity generation from proposed solar PV and imported from the national grid.

The graph above shows the monthly electricity consumption of the Tallaght Campus, and this consumption is divided into electricity that can be generated from solar PV at the campus and the remaining majority that would come from electricity grid imports. In summary:

- A noticeable portion of electricity across the campus would be generated from the proposed solar PV arrays during the months of May to August.
- A small portion of electricity would be generated by the proposed solar PV arrays during the months March, April, September, and October.
- A very low portion of electricity consumption would be from the proposed solar PV arrays during the months January, February, November and December.

4.6. Grangegorman Campus

The Grangegorman campus is located within both the Kilmainham Solar Safeguarding Zone and the Phoenix Park Solar Safeguarding Zone, as shown below. Installation of solar panel arrays greater than 300m^2 is therefore not exempted development and planning permission must be obtained for any larger installations.

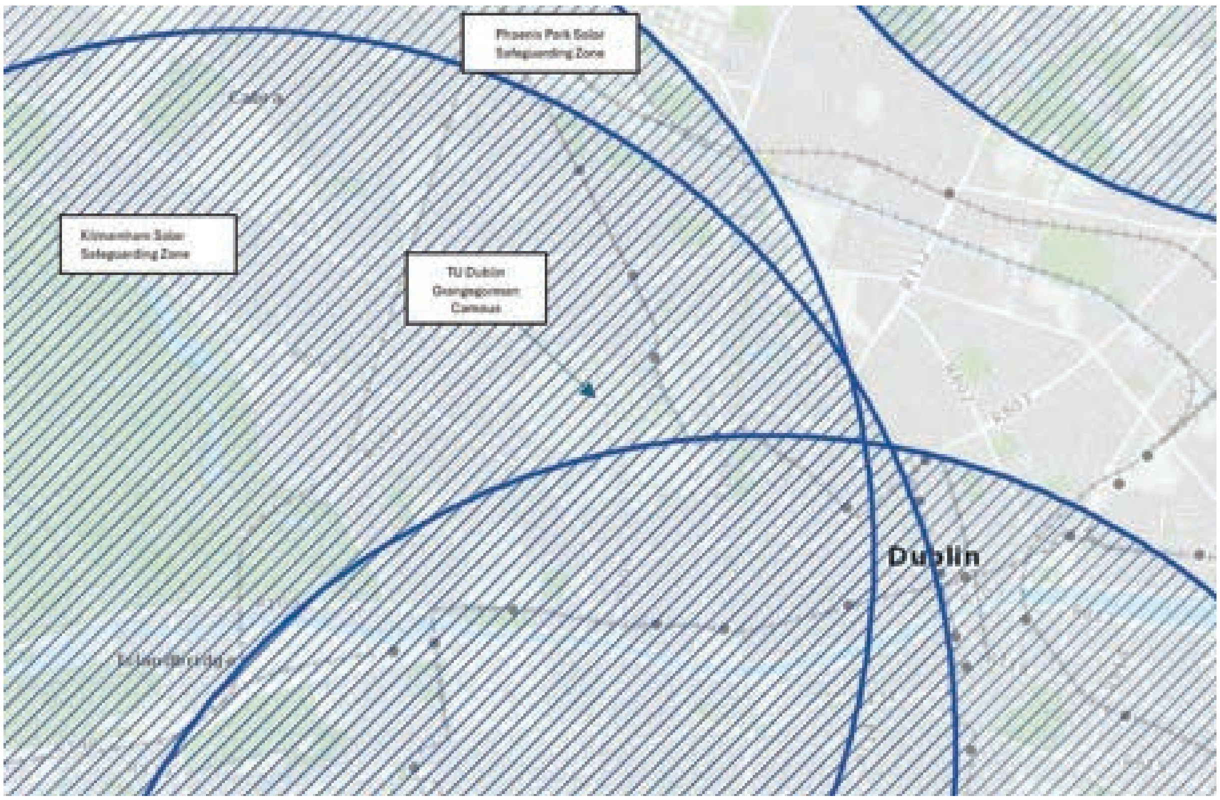


Figure 39: TU Dublin Grangegorman Campus relative to surrounding Solar Safeguarding Zones.

The Grangegorman Campus contains 11 Protected Structures. The installation of solar panels on Protected Structures is a somewhat grey area and is vaguely addressed in a letter sent from the Department of Housing, Local Government and Heritage to Local Authorities regarding the exemption regulations. The letter references section 57 and 82 of the Planning and Development Act 2000 which outlines that “development shall not be exempted development if it would materially affect the character of a protected structure or a building in an Architectural Conservation Area”. TU Dublin own/ occupy 8 of the Protected Structures at the Grangegorman Campus (Lower House, Clocktower building, Rathdown House, St. Laurence’s Church, Glassmanogue, Bradogue, Orchard House, and North House which will be part of the Academic Hub building).

There is space for installation of moderately sized solar PV arrays at some buildings at the Main Campus, the largest potential for solar PV however is at the Broombridge warehouse building recently acquired by TU Dublin. Central and East Quad are not considered suitable as they are owned under Public Private Partnerships and energy management is not directly controlled by TU Dublin. The following buildings on the Grangegorman campus have been assessed for PV suitability and are included in the table below.

Solar already installed	Very suitable	Potentially suitable	Not suitable

Building	Suitability	Proposed array (kWp)	Annual production (MWh)	Considerations
Lower House	PROTECTED STRUCTURE			* SOLAR SAFEGUARDING ZONE
Clocktower	PROTECTED STRUCTURE			* SOLAR SAFEGUARDING ZONE
Rathdown House	PROTECTED STRUCTURE			* SOLAR SAFEGUARDING ZONE
St Laurences Church	PROTECTED STRUCTURE			* SOLAR SAFEGUARDING ZONE
Glassmanogue	PROTECTED STRUCTURE			* SOLAR SAFEGUARDING ZONE
Bradogue	PROTECTED STRUCTURE			* SOLAR SAFEGUARDING ZONE
Orchard House	PROTECTED STRUCTURE			* SOLAR SAFEGUARDING ZONE
Park House	Space for a small-moderate sized array of panels	**20**	**16.052**	* SOLAR SAFEGUARDING ZONE
Kirwan House	This building is not currently in use and therefore has no electricity demand.			* SOLAR SAFEGUARDING ZONE
Broombridge Warehouse (/Sports Changing)	Significant opportunity for a large-scale solar PV installation. There is space for a very large array which will likely be greater than the demand of this building when operational as Design and Construct building.	**937**	**820**	* SOLAR SAFEGUARDING ZONE
Energy Centre	Unoccupied flat roof. Suitable for solar PV.	**38**	**28.775**	* SOLAR SAFEGUARDING ZONE
Hub 2	Roof is largely occupied			* SOLAR SAFEGUARDING ZONE
Greenway Hub	Limited space. Installation of a small array possible.	**12**	**9.907**	* SOLAR SAFEGUARDING ZONE
East Quad	PPP contract does not facilitate installation of PV panels by TU Dublin.			* SOLAR SAFEGUARDING ZONE
Central Quad	Very limited space for PV panels and PPP contract.			* SOLAR SAFEGUARDING ZONE
Estates Yard and Store	Space for only a very small array (2-3 kWp)			* SOLAR SAFEGUARDING ZONE
Printmaking Workshop	Already 80 square metres of panels on this building which is used to heat the building. There is space for additional panels if there is demand.			* SOLAR SAFEGUARDING ZONE
Academic Hub	Currently under construction - assumably solar PV panels are included in the design.			* SOLAR SAFEGUARDING ZONE
TOTAL		**1,007.00**	**874.734**	

Table 20: Analysis of building suitability for installation of rooftop solar PV panels at the Grangegorman Campus.

Park House

A 20 kWp array is proposed for the Park House building, as shown below. This is a relatively small sized array and there may be space for additional panels however most of the remaining roof space is already occupied or is likely to be shaded by higher parts of the building. The investment cost of the proposed 20 kWp array is estimated at €24,000.

Figure 40: Proposed solar PV array for the Park House building.

Broombridge Warehouse

There is potential to install a very large solar array at the Broombridge Warehouse building that is planned to be used as a Design and Construct training centre for Modern Methods of Construction. The array proposed below maximises the roof space available at the building and this assumes that the project would be development as a medium scale renewable energy or community project as it is highly unlikely that the building would have an electricity demand anywhere near what would be generated in the proposal below. It should be noted however that the array shown here is based on the existing warehouse buildings at the site and the array size possible for installation may vary significantly if the quantity of roof space in the new building proposed for this site is greater or less than the current building.

Further consideration of the options to develop a project at this building are examined in section 5 of this report on Power Purchase Agreements. The array modelled below is for a 937.6 kW peak array and this is anticipated to produce 820 MWh of electricity annually. The investment cost of this proposed array is estimated at €1,125,120. This cost, however, does not include additional administrative and consulting fees that may be required in a renewable energy project of this scale.

Figure 41: Proposed solar PV array for the Broombridge Warehouse building.

Energy Centre

There is roof space to install a 38 kWp solar array on the Energy Centre building, as shown below. It should be noted however that electricity consumption data for the building is not available as the building is metered with a group of other buildings and this building may not have a high level of electricity demand that would require a solar array of this size. Further investigation is therefore required to determine what the electricity demand of the building is, and if this demand is low whether it is possible to distribute electricity generated from a solar array on the Energy Centre building to other buildings at the Grangegorman campus. The investment cost of the proposed array is estimated at €45,600.

Figure 42: Proposed solar PV array for the Energy Centre building

Greenway Hub

A 12 kWp array is proposed for the Greenway Hub building, as shown below. This is a relatively small sized array and there may be space for a very small number of additional panels however, most of the remaining roof space is already occupied. Like the Energy Centre, this building is grouped on an electricity meter with several other buildings, and it is therefore difficult to determine the electricity consumption of the building. Given the small size of the array proposed however it is highly likely that the proposed array would provide a very low percentage of the electricity requirement of the building and all electricity generated throughout the year would be consumed by the building. The investment cost of the proposed array is estimated at €13,920.

Figure 43: Proposed solar PV array for the Greenway Hub building

Table 21: Campus level impact of implementing the above proposed solar arrays on electricity self-sufficiency of the Grangegorman Campus (*including the Broombridge Warehouse system).

Energy import		Solar PV Trial (BAU)	Solar PV Trial
Electricity import from grid	MWh	309	137
PV electricity generation	MWh	0	171
Self-sufficiency	%	0%	55%

The table above shows the impact that installation of the solar arrays proposed above would have on the campus wide electricity imports. It is important to note however that this includes the very large installation on the Broombridge Warehouse building that is located off the main campus. Therefore, unless this large renewable energy project was developed at the Broombridge site and distributed to the main campus (potentially requiring private wire), this level of self-sufficiency would not be achieved as the proposed installations at the main campus are modest in size. The options for developing a large-scale renewable energy project at Broombridge are examined in more detail in section 5 Power Purchase Agreements below.

Table 22: CO2 savings comparison between a 'do-nothing' scenario (BAU), and the proposed solar PV installations (Solar PV Trial).

Emissions and primary energy		Solar PV Trial (BAU)	Solar PV Trial
CO_2 emissions	t	79	-97
CO_2 emissions savings	%	0%	223%
Primary energy	MWh	583	-719
Primary energy savings	%	0%	223%

The table above shows the CO2 savings associated with installation of the solar PV arrays proposed above. Similarly, these results are at a campus wide level and the impact of the large installation on the Broombridge building is highly skewing the results if it is not possible to distribute electricity generated here to the main campus.

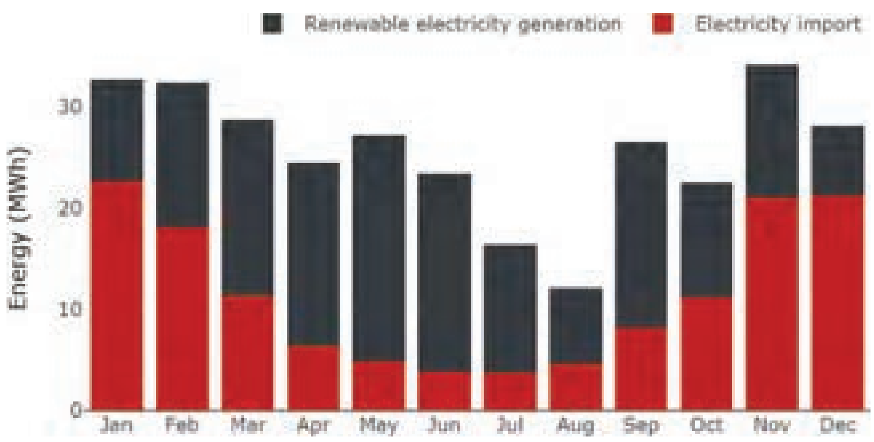


Figure 44: Monthly electricity generation from proposed solar PV and imported from the national grid.

As outlined, the above graph showing electricity generation from the proposed solar PV arrays and the remaining demand being imported from the electricity grid may not be accurate due to inclusion of the large-scale array proposed for the Broombridge building. The graph below presents the same information and more clearly shows the curve of solar production across the year, with a noticeable peak during the summer months and subsequent reduction in imported electricity.

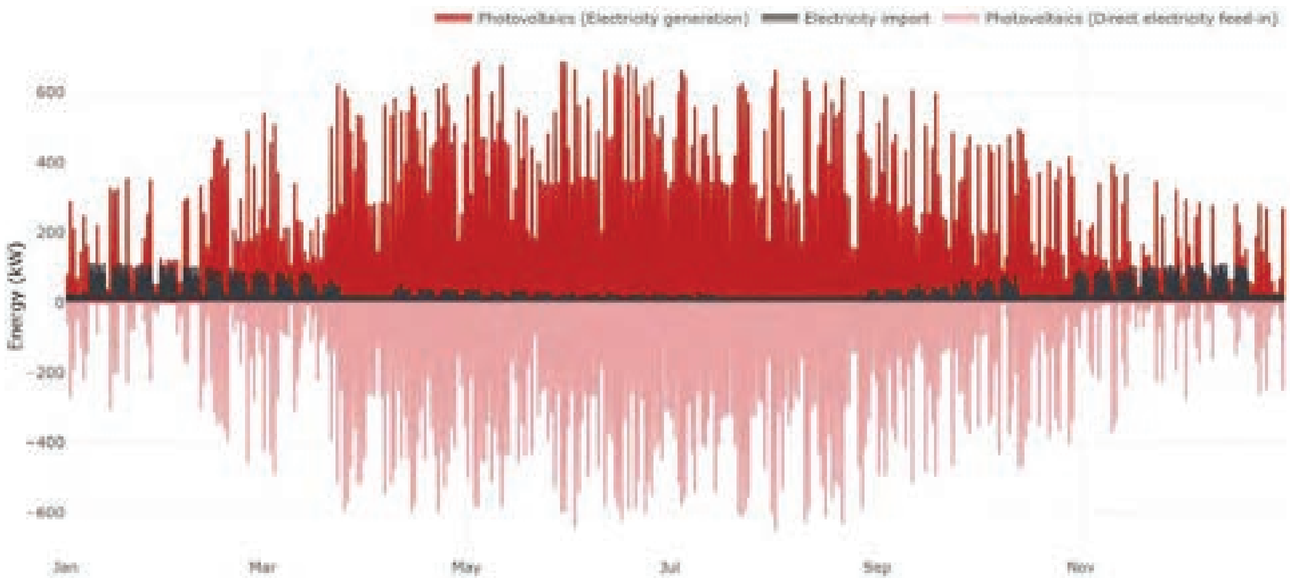


Figure 45: Electricity generation from proposed solar PV arrays and subsequent requirement for grid electricity relative to campus demand.

4.7. Solar PV Financial Analysis

In addition to assessing the technical suitability of solar PV for TU Dublin buildings, a financial analysis was undertaken to understand the capital costs, operational costs, and payback periods associated with installing the technology. The results of the open solar analysis were fed into the nPro energy models developed for each of the TU Dublin campuses. The full methodology used to model the financial elements of this study is described in Appendix B below which sets out the key assumptions and variables. The financial analysis is done on a campus-by-campus basis and is derived using the results of the technical analysis above.

Blanchardstown Campus

There are 6 buildings out of 10 which are deemed to be suitable for rooftop solar PV as per section 4.4 above and shown in Figure 49 below. The solar potential for the campus is described in two scenarios, one where PV solar is maximised on the basis that excess solar electricity generated can be shared between buildings (scenario 1), and another where solar PV is sized based on each individual building's requirements only (scenario 2).

Table 23: Blanchardstown Solar PV Potential

Building	Scenario 1 (kWp)	Scenario 2 (kWp)
Aras Ceangal/Connect	26	26
Aras Croí	537	367
Aras Eolas	162	162
Aras Fíos	156	156
Aras Spraoí	114	35
LINC/ Buntús	91	74
TOTAL	**1,086**	**837**

The results from the nPro model are shown in the tables and figures below. Table 24 and Table 25 below show the expected capital investment (€) and annual savings (€/a) for the two scenarios. The nPro model uses a discounted cashflow analysis to generate a net present value (NPV) and internal rate of return (IRR) for the PV installation. A full description of the methodology can be found on the nPro website[18].

Table 24: Solar PV Capital Investment, Blanchardstown Campus

Investments	Scenario 1 (€)	Scenario 2 (€)
Solar PV Installation	944,820	728,190
Contingency Costs (+35%)	330,687	254,866
Sum	**1,275,500**	**983,100**

Table 25: Solar PV Savings, Blanchardstown Campus Scenario Comparison

Savings		PV Trial (Scenario 1)	PV Trial (Scenario 2)
Photovoltaics (direct feed-in)	€/a	47,880	26,040
Photovoltaics (self-use)	€/a	122,273	108,562
Sum	**€/a**	**170,153**	**134,602**

The results above of the financial model for scenario 1 show that the capital investment (CAPEX) is €1,275,500 accounting for lump sum costs (+35%) and achieves an NPV of €1,336,300 after 25 years. This option has a payback of 10 years and an IRR of 7.7% as shown below in Figure 49.

[18] nPro Economic Calculation

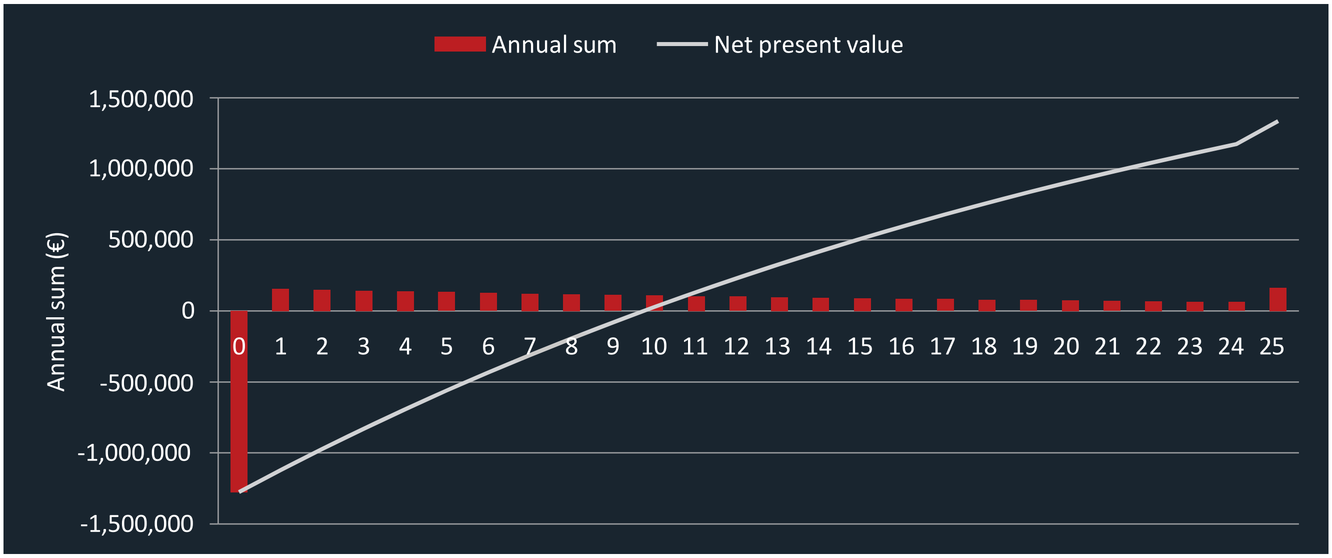


Figure 46: NPV Chart, Blanchardstown PV Scenario 1.

The results of the financial model for scenario 2 show that the capital investment (CAPEX) is €983,100 accounting for lump sum costs (+35%) and achieves an NPV of €1,084,000 after 25 years. This option has a payback of 10 years and an IRR of 8.1% as shown in Figure 50 below.

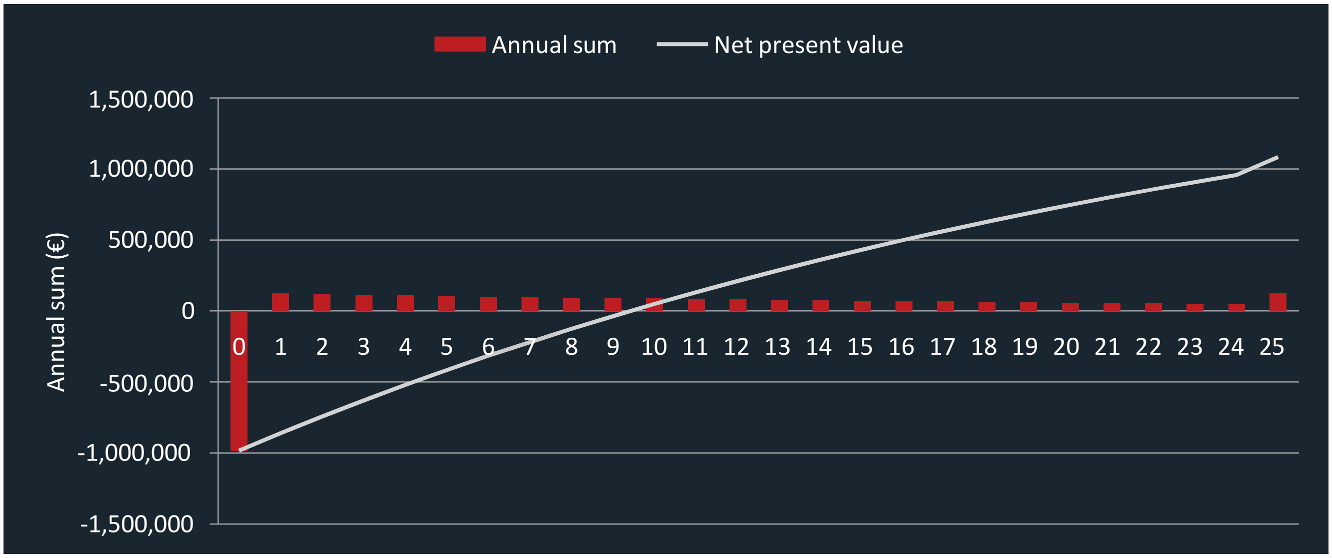


Figure 47: NPV Chart, Blanchardstown PV Scenario 2

The results from the financial model indicate that it is financially feasible to install rooftop solar PV at the Blanchardstown campus. The two scenarios outlined above have identical payback periods (~ 10 years). Scenario 1 has a higher upfront capital investment based on the larger combined array installed across the 6 buildings. The annual savings generated by the larger PV installation are approximately €170k per annum based on a combination of self-consumption (avoided electricity imports) and direct feed-in to the national grid. A component of self-consumption in this scenario is dependent on sharing excess electricity between buildings or storing it via electrical or thermal storage.

Tallaght Campus

There are 3 buildings out of 10 which are deemed to be suitable for rooftop solar PV as per section 4.5 above and shown in Table 26 below. This is primarily due to the unsuitability of many roofs at the Tallaght Campus for installation of rooftop solar panels. The results from the nPro model are shown in the tables and figures below. Table 27 and Table 28 show the expected capital investment (€) and annual savings (€/a).

Table 26: Tallaght Campus Solar PV Potential

Building	Scenario 1 (kWp)
Synergy CASH	13
Premier House	50
Synergy Global	123
Total	**186**

Table 27: Solar PV Capital Investment, Tallaght Campus

Investments		Scenario 1 (€)
Solar PV Installation		161,820
Contingency Costs (+35%)		56,637
	Sum	**218,500**

Table 28: Solar PV Savings, Tallaght Campus

Savings	Compensation (€/kWh)	Quantity (MWh)	Savings (€/a)
Photovoltaics (direct feed-in)	0.21	9	1,953
Photovoltaics (self-use)	0.28	81	22,664
		Sum	**24,617**

The results of the financial model for the Tallaght campus show that the capital investment (CAPEX) is €218,500 accounting for lump sum costs (+35%) and achieves an NPV of €158,200 after 25 years. This option has a payback of 13 years and an IRR of 5.5% as shown in Figure 51 below.

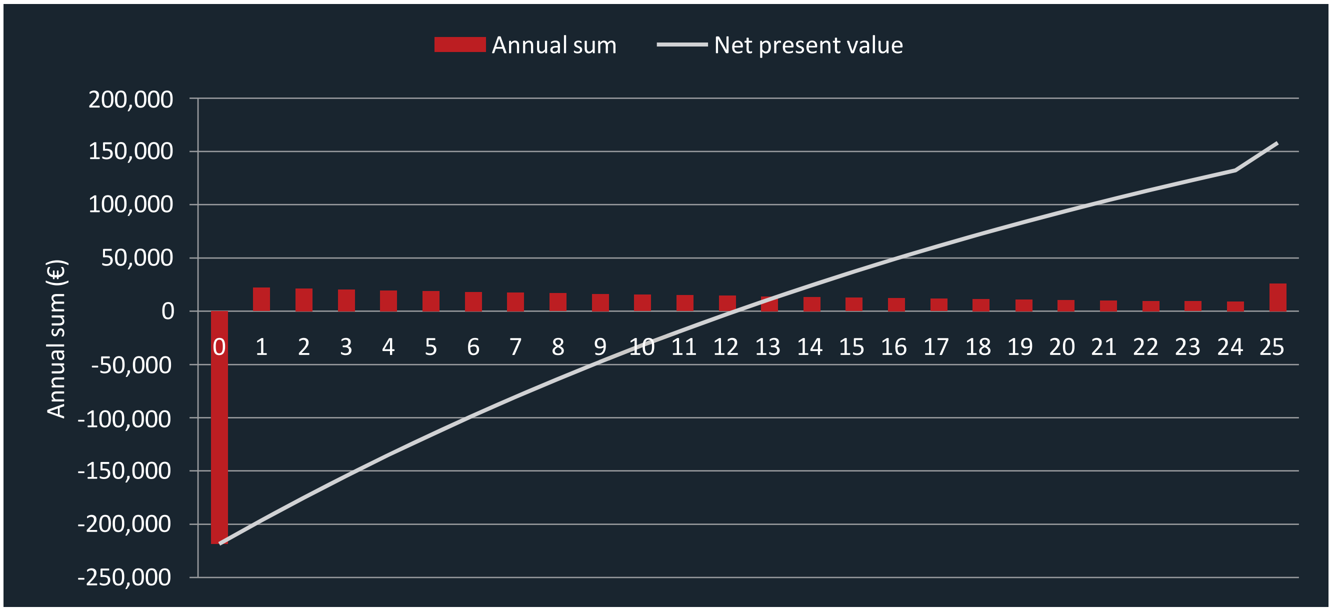


Figure 48: NPV Chart, Tallaght Campus PV

Grangegorman Campus

There are 4 buildings out of 18 which are deemed to be suitable for rooftop solar PV as per section 4.6 above and shown in Table 29 below. This is primarily due to the unsuitability of many roofs at the Grangegorman Campus for installation of rooftop solar panels. The Broombridge Warehouse building accounts for 93% of the solar potential identified at the Grangegorman Campus and the focus of the financial analysis below is therefore on this building. The results from the nPro model are shown in the tables and figures below and show the expected capital investment (€) and annual savings (€/a).

Table 29: Grangegorman Campus PV Potential

Building	Scenario 1 (kWp)
Park House	20
Broombridge Warehouse	937
Energy Centre	38
Greenway Hub	12
Total	**1,007**

Investments	Scenario 1 (€)
Solar PV Installation	816,060
Contingency Costs (+35%)	285,621
Sum	**1,101,700**

Table 30: Solar PV Capital Investment, Broombridge Warehouse

Savings	Compensation (€/kWh)	Quantity (MWh)	Savings (€/a)
Photovoltaics (direct feed-in)	0.21	573	120,330
Photovoltaics (self-use)	0.28	171	47,846
		Sum	**168,176**

Table 31: Solar PV Savings, Broombridge Warehouse

The results of the financial model for the Broombridge Warehouse show that the capital investment (CAPEX) is €1,101,700 accounting for lump sum costs (+35%) and achieves an NPV of € 1,485,500 after 25 years. This option has a payback of 9 years and an IRR of 9.7% as shown in Figure 52 below.

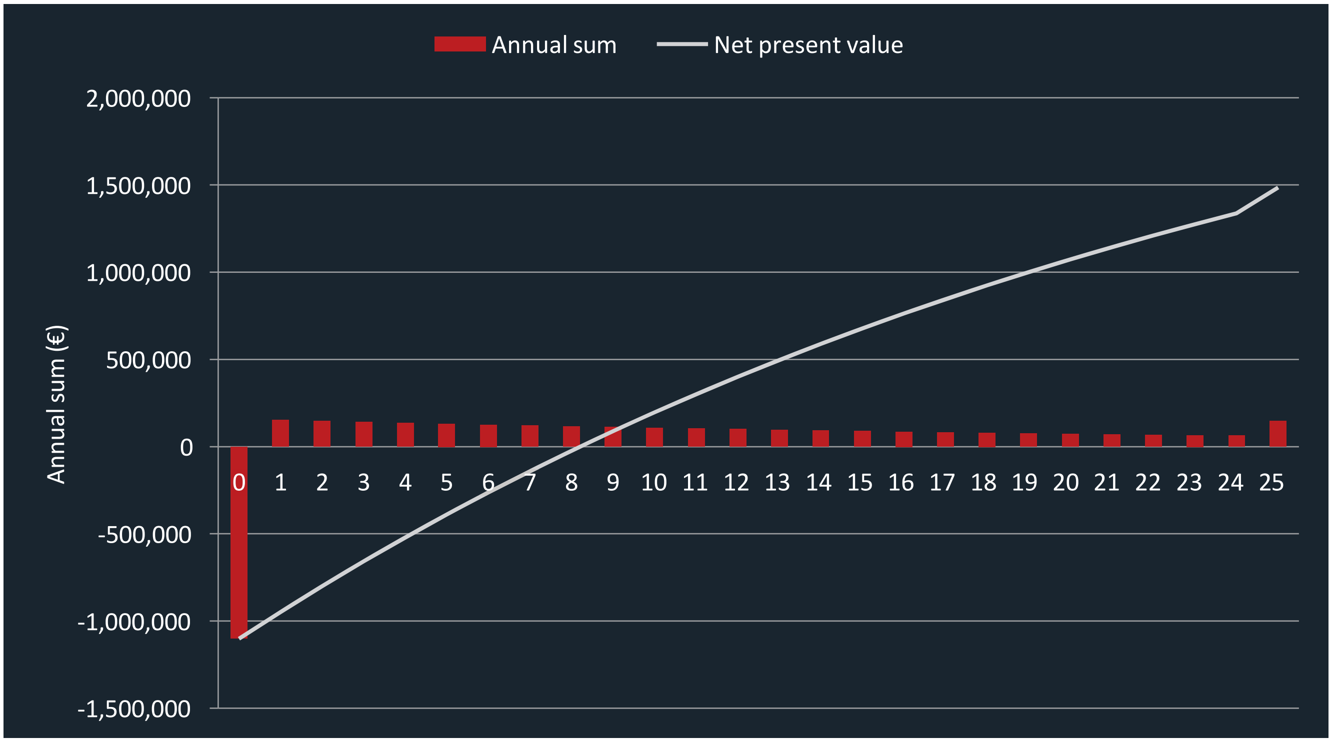


Figure 49: NPV Chart, Broombridge Warehouse PV

4.8 Alternative Renewable Electricity Generation

Wind Energy Opportunity Evaluation

A high-level analysis of the opportunities for installation of on-site electricity generation using wind turbines at the Grangegorman, Tallaght, and Blanchardstown Campus was conducted. From early analysis, the Grangegorman and Tallaght Campuses were identified as being unsuitable due largely to the urban surroundings of these campuses. The Blanchardstown Campus was considered to have some potential for on-site wind energy generation. Detailed further investigation however is required to determine if this is a realistic option for consideration.

Wind energy generation typically complements the generation profile of solar energy. Consideration of the opportunity to develop on-site wind energy production at the Blanchardstown Campus is therefore fitting as this would allow the campus to improve energy self-sufficiency if the solar PV arrays identified above were also installed. Installation of a wind turbine, however, is a more complex process and has significantly greater potential to have physical impacts on the surrounding area. Consequently, obtaining planning permission for installation of a large wind turbine at the Blanchardstown Campus may present challenges.

Dundalk IT, Co Louth is an example of a third level institution that has installed a wind turbine on-site at the campus. Dundalk IT installed an 850 kW wind turbine in 2005[19]. The turbine has undergone extensive refurbishment works in recent years and continues to be operational, supplying between 1.3 and 1.6 million kWh of electricity to the university campus annually.

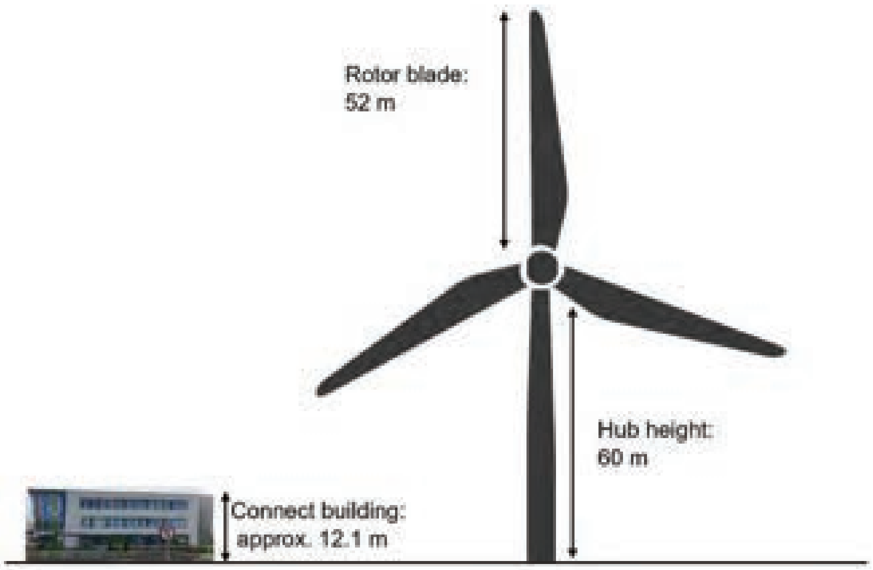


Figure 50: Graphic of the Connect building Blanchardstown in comparison to the size of wind turbine installed at Dundalk IT

[19] DkIT Wind Turbine

This turbine however is very large for a non-utility scale development. The turbine has a hub height of 60m and a rotor diameter of 52m. Figure 50 above shows a rough illustration of a replica of this size turbine compared to the Connect building at the Blanchardstown Campus to give a sense of the scale of this turbine and how it may interact with the landscape and existing built environment at the campus.

Figure 51 below shows the surroundings of Dundalk IT compared to the Blanchardstown Campus. From these images it is noticeable that the Blanchardstown Campus has significantly higher levels of residential development in the immediate surrounding area. The Wind Energy Development Guidelines (2006) are currently the main guiding document for Local Authorities to consider when reviewing proposals for wind turbines. The Draft Revised Wind Energy Development Guidelines were published by the Department of Housing, Planning and Local Government in 2019 and are intended to overhaul the 2006 Guidelines. Review of the consultation held on the draft Guidelines is ongoing and the publication and adoption of the finalised guidelines is expected in 2024/25. It is worth noting however that both the current 2006 Guidelines and the draft document includes a requirement that proposed wind turbines would have a minimum setback distance of 500 metres from existing residential properties. Further investigation is therefore required to determine if the flicker, noise etc. associated with wind turbines would have negative impacts on surrounding residents and businesses, and to identify an appropriately sized turbine.

Figure 51: TU Dublin Blanchardstown Campus (left) compared to Dundalk IT Campus (right).

Technical considerations

- **Topography**

The height and surrounding height of land has a significant impact on the amount of wind an area receives. Areas of land that are higher than their surroundings typically receive high levels of wind. The topography map below shows that land height increases in a north easterly direction. The TU Dublin Blanchardstown campus is therefore higher than its southwest surroundings and this is positive for wind generation at the campus as the prevailing wind in Ireland is a south westerly wind.

Figure 52: Topography map of the area surrounding the TU Dublin Blanchardstown Campus (Source: Ireland topographic map)

- **Wind speed**

The SEAIs Wind Atlas map provides details relating to wind resources across the country. The image below shows the wind speed available at the TU Dublin Blanchardstown Campus. The image shows that most of the campus experiences average annual wind speeds of 7.8 -7.9 metres/second. This is considered a moderate wind speed that would sufficiently power a medium-large sized turbine.

Figure 53: SEAIs Wind Atlas wind speed maps focused on the TU Dublin Blanchardstown Campus (Source: Wind Atlas)

5. POWER PURCHASE AGREEMENTS

5.1. Overview

A Power Purchase Agreement (PPA) is a contract between an energy generator and an energy purchaser / consumer. The contract specifies details including the amount of energy / electricity to be transferred, the price to be paid for the energy, and the duration of the contract[20]. In Ireland, PPAs have been used for many years, particularly by very large energy users as the structure of a PPA allows a large energy user to protect themselves against electricity price fluctuations by agreeing a long-term fixed price for the electricity. In recent years, smaller companies and energy community groups have begun using PPAs to also avail of these stable, and generally lower than wholesale market, electricity prices.

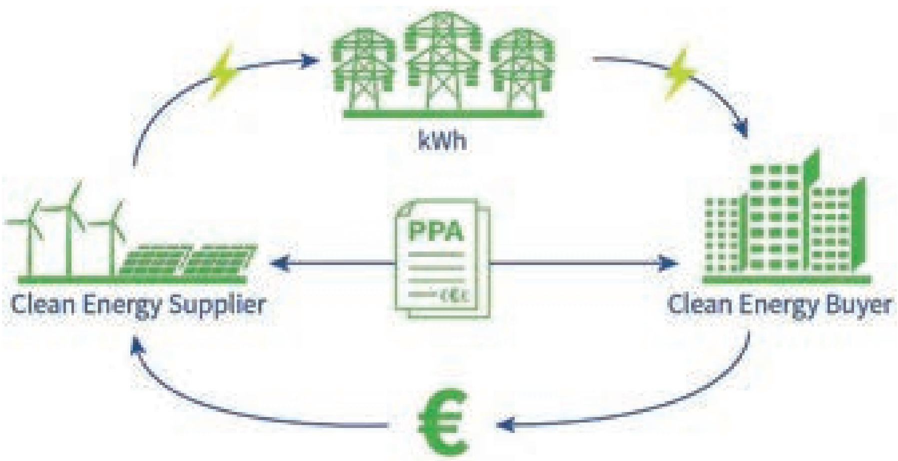


Figure 54: Graphic illustrating the basic structure of a Power Purchase Agreement.(Source: ReSource[21]).

5.2. Types of Power Purchase Agreements

PPAs can be categorised in different ways (e.g. renewable or non-renewable energy PPA, Corporate PPA or Community PPA), however the broadest and most common classification is physical PPAs and virtual PPAs.

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[20] PPAs are generally associated with the sale and purchase of electricity, however the same structure can/ is used for trading other forms of energy, such as renewable gases. In this evaluation we consider the use of PPAs by TU Dublin in the context of electricity use only.

[21] ReSource European platform for corporate renewable energy sourcing[21].

Physical PPAs

In a physical PPA there is a wired connection between the site of electricity generation and the consumer / off taker and electricity is physically transferred through this connection independently of the national electricity grid. These PPAs are also known as direct line PPAs. As modern PPAs generally use renewable energy which includes many sources that provide intermittent energy, notably wind and solar, the off taker will likely also have a connection to the national electricity grid that is used when electricity is not being supplied by the generator in the PPA. Alternatively, there may be some form of energy storage at either the generation or consumer site that is used when electricity is not being generated. This form of PPA is the most common type in many countries, however it is largely not possible in Ireland currently as regulations on Private Wires exist and this prohibits the laying of wires across public land for electricity distribution by anyone other than ESB Networks.

A public consultation on Private Wires was held in 2023 and it is anticipated that reforms to this regulation will take place in the coming years to facilitate private wires in some instances. The Department of the Environment, Climate and Communications released a brief document identifying the Guiding Principles for Policy Formation[22] in July 2024 that outlines an intention to permit Private Wires in the future as this will result in *"an accelerated investment in new electricity infrastructure to include renewable generation and storage, which will ultimately benefit the whole electricity system".* The details or potential timeline for when changes to this regulation may occur are not currently available.

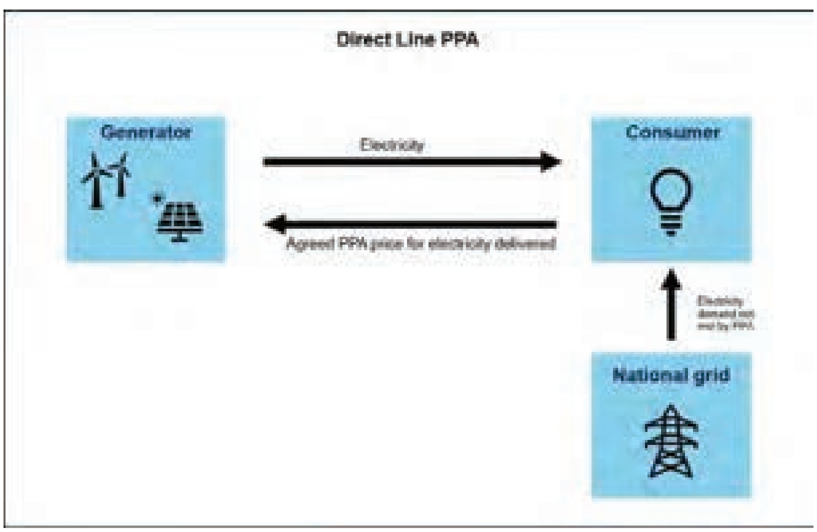

Figure 55: Graphic of a direct line physical PPA where the consumer is physically connected to the generator and also has a connection to the electricity grid.

A variation of physical PPAs includes Sleeved PPAs. In these PPAs electricity is physically delivered from the site of generation to the consumer, however the electricity passes through an electricity grid where balancing occurs, and the consumer is charged a "sleeving fee" on top of the electricity price to account for grid and balancing costs.

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[22] Private Wire Guiding Principles for Policy Formation

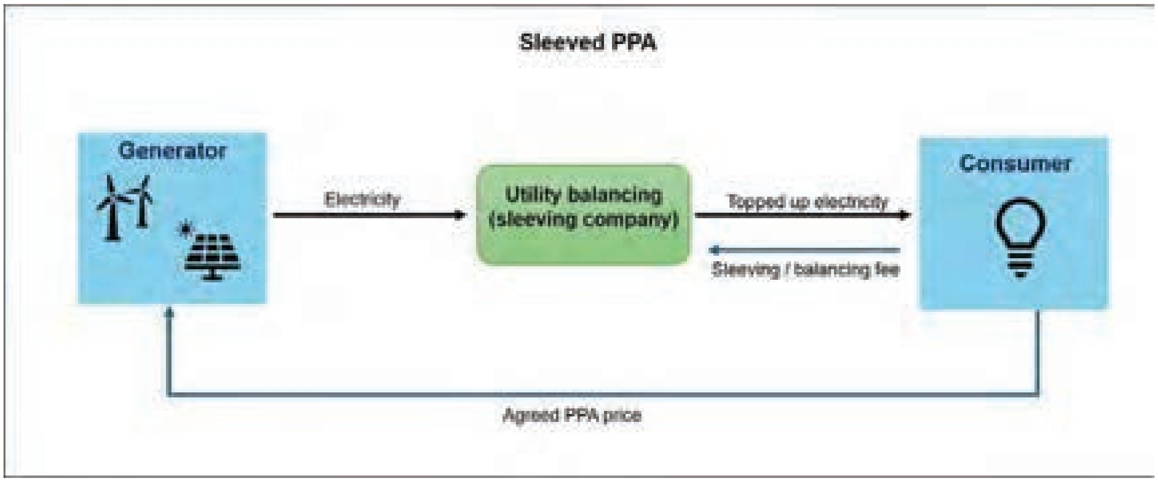

Figure 56: Graphic of a sleeved PPA where the consumer and generator are on the same grid and electricity generated is passed through a wider network where a utility company is responsible for balancing to meet the demand of the consumer.

There are currently limited instances however when a physical PPA can be used if Private Wire is not required. This generally involves an energy consumer contracting an energy generation company to install a generation system on the land that is in the ownership of the consumer and where the energy consumption takes place. The energy generation company generally installs, manages, and owns the generation equipment and then sells the energy to the landowner/ energy consumer through a contract that contains the details of how much energy, price, duration etc. For example, TU Dublin would be able to enter a physical PPA if an energy generation contractor was engaged to install, maintain, and own solar array(s) at one / all the campuses. The energy generation company would then sell electricity that has been produced on the campus to TU Dublin, the details of which would be laid out in the contract. As the entire campus is within the ownership of TU Dublin, Private Wire is not an issue and electricity generated can be distributed between buildings. The benefit for TU Dublin is that the upfront investment costs of installing a large solar system are avoided, however these arrangements typically result in higher electricity costs over the lifetime of the contract when compared to investing in and owning the same system. This arrangement is therefore a good option if a consumer seeks a hands-off, minimal involvement solution, however if the consumer has the resources to invest in and own their own system this is generally a more financially advantageous option.

Virtual PPAs

Virtual PPAs (also known as financial or synthetic PPAs) are the most common type of PPA in Ireland. This PPA is essentially a financial contract and there is no physical delivery of electricity from the generator in the PPA to the off taker. In these PPAs the generator and consumer agree a “strike price” for electricity and enter a Contract for Difference. When the market price of electricity is above the agreed strike price the consumer receives a reimbursement form the generator. If the market price of electricity is below the strike price the consumer pays the reimbursement to the generator. In this way, the consumer always pays the same agreed price for electricity per kWh.

These PPAs are therefore entirely paper based and the consumer in the PPA has a standard grid connection that draws electricity from the national grid. In many instances these virtual PPAs operate across different countries or electricity grids as no physical delivery of electricity is required, which may then offer economic advantages. These PPAs are most used by private corporations as a method of hedging against electricity price fluctuation and to obtain Certificates of Origin that are required for ESG reporting for various industries. It should be noted that the SEAI M&R system does not currently allow for virtual PPAs to be used to meet emission reductions for Scope 2 emissions. Although TU Dublin could enter into a virtual PPA with a renewable energy generator, the low carbon impact of this renewable electricity usage will not be reflected in the M&R system. Entering a virtual PPA would, however, offer TU Dublin long-term electricity price certainty and protection against electricity price fluctuation.

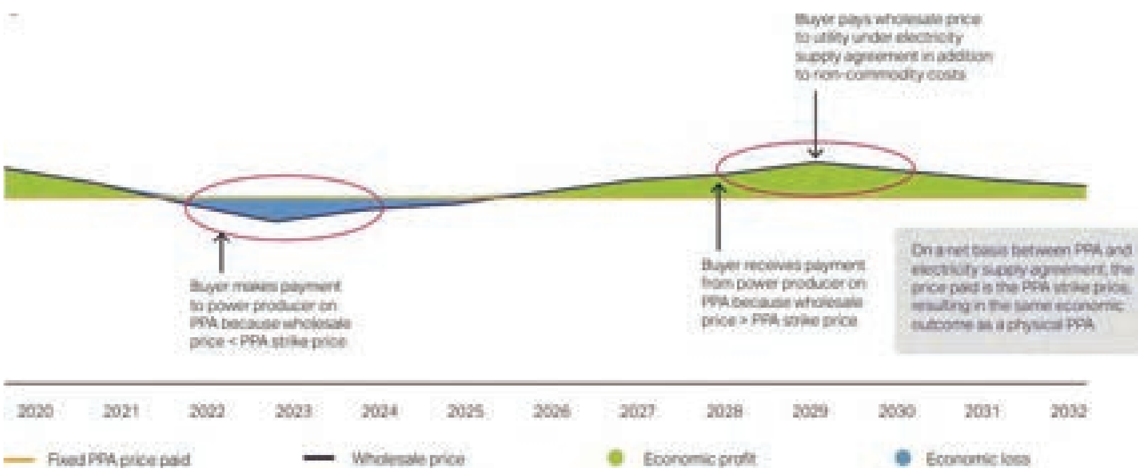

Figure 57: Virtual PPA (VPPA) - fixed strike price visualization

5.3. Considerations

There are various considerations to be aware of when determining if, and what type of, PPA may be suitable for an organisation to enter into. The points below are some of the considerations that are of relevance for TU Dublin. The chart below shows a hierarchy for selecting a source of renewable electricity for large users such as Universities.

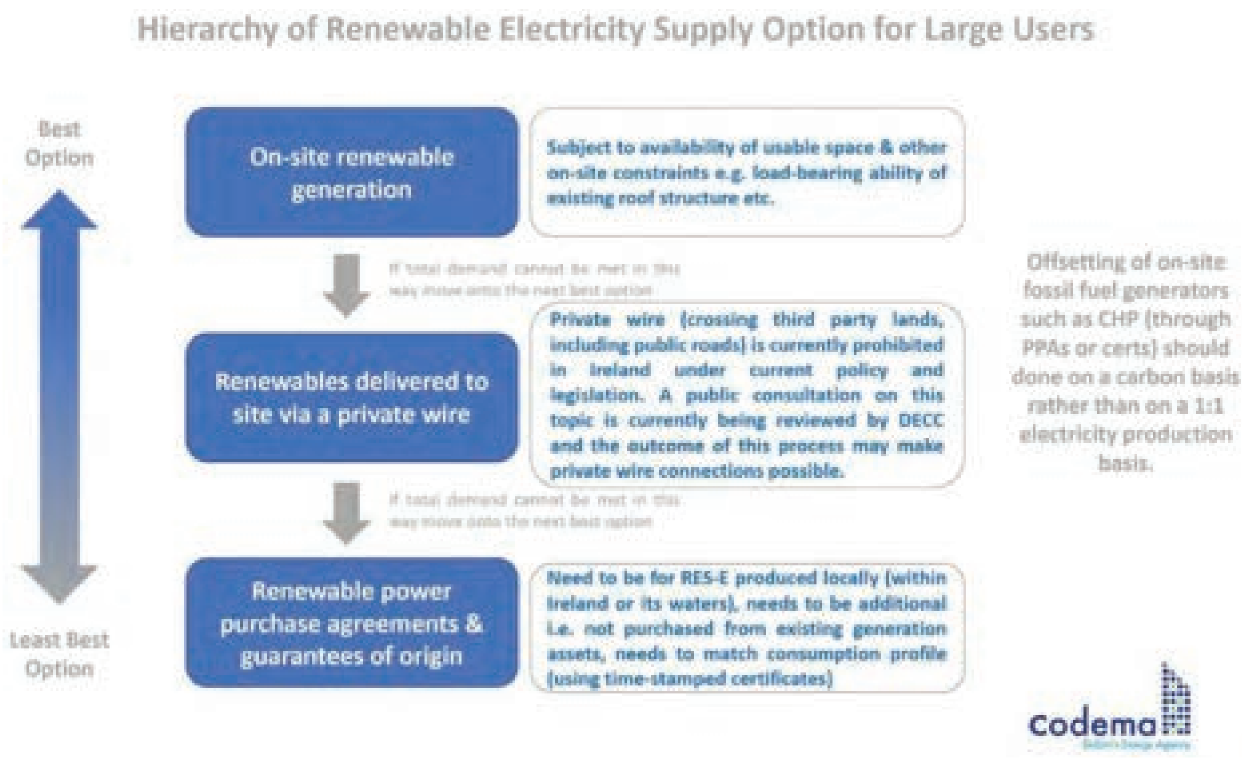

Figure 58: Hierarchy for sourcing renewable electricity for large-scale users on a carbon basis.

This preference is reflective of actual emission savings and shows that on-site generation should be prioritised where possible in the first instance. For many large-users, on-site generation is not possible at the scale required and delivery of renewable electricity produced on a different site via a private wire is the next best option for sourcing renewable electricity. The least preferential method is sourcing renewable electricity through a virtual PPA and obtaining guarantees of origin certificates. Entering into a renewable virtual PPA is still a positive action that can be taken by an organisation and in many instances is the only realistic option in Ireland currently. However, given the lack of regulation and requirement for these virtual PPAs to be time or carbon matched, the effectiveness of this structure to accurately displace the carbon associated with an organisation's electricity consumption is questionable. Many of these virtual PPAs are structured on a 1:1 electricity production basis rather than on a carbon basis. Some energy trading companies working within the virtual PPA sector, however, offer hourly matched/real-time PPAs whereby certificates of origin are provided on a granular level that is matched to the time of electricity consumption. This is a more accurate method of obtaining electricity that is renewable on a carbon intensity basis.

It should be noted that for the reasons outlined above (particularly the lack of accuracy of virtual PPAs in relation to carbon intensity of electricity usage), the SEAI does not allow for virtual PPAs to count towards an organisation's energy efficiency or carbon reduction targets. Therefore, entering into a virtual PPA would not have any impact on the emissions of TU Dublin in comparison to using grid electricity on the SEAI M&R system.

5.4. Options and Opportunities

On-site direct line PPA

This option includes entering into a physical PPA where electricity is generated on-site (most likely using rooftop solar PV panels) by an operator who would install, own, operate and maintain the system.

Advantages:

- Removes the requirement for major upfront installation costs.
- Maintenance is the responsibility of the owner and operator.
- A price per kWh can be agreed, and this offers protection from wholesale market price volatility.
- CO2 savings would be recognised in emissions reporting and contribute to reaching reduction targets.

Disadvantages:

- Directly procuring and owning solar PV systems is likely a more financially advantageous option to achieve the same emission reductions.
- The owner/ operator of the system may require that they retain profits arising from feed-in tariffs when excess electricity is exported to the national grid rather than passing this profit on to TU Dublin.
- This PPA would likely not meet the entire electricity demand of the campuses and electricity would still have to be purchased from the electricity grid at wholesale prices to supplement this.

Virtual PPA

TU Dublin could enter into a virtual PPA with a renewable energy generator. This process would not involve any physical work but would instead be an administrative, ‘paper-based’ process.

Advantages:

- This agreement would provide a stable price of electricity that would minimise exposure to electricity price fluctuations on the wholesale market.
- Agreed ‘strike price’ is generally lower than the wholesale market prices.

Disadvantages:

- This option will not have any impact on the emissions reduction targets of TU Dublin that are reported to the SEAI.

The set-up process can be administratively heavy

PPA with the Broombridge building

This option involves developing the large solar array that is proposed in Chapter 4 above (Solar PV evaluation) and entering into a PPA with whoever is the owner of this solar PV installation. This would currently only be possible as a virtual PPA and the same advantages and disadvantages as outlined above would apply to this PPA.

There is a scenario where the owner and consumer can be the same company, and this is known as the 'Supplier Lite' model. This energy trading structure is not technically a PPA as the electricity generated enters the wholesale market and benefits from renewable electricity support schemes such as RESS (and previously REFIT). In this structure TU Dublin would have to set up what is called a 'Supply Company'. This Supply Company is essentially a small utility company that enters into a RESS (previously REFIT) agreement. This structure is typically used for large renewable energy generation projects and the significantly smaller scale of the Broombridge project may make this option unfeasible for a variety of reasons, as outlined below.

Advantages:

- The renewable energy project would be owned and controlled by TU Dublin.
- The Supplier Lite structure benefits from renewable electricity support schemes, as well as potential electricity market uplift in prices.

Disadvantages:

- This option will not have any impact on the emissions of TU Dublin that are reported to the SEAI.
- The set-up process can be extremely administratively heavy and complex. TU Dublin would likely have to outsource the set-up and management of this structure of project to a specialised energy trading company. These administrative costs may outweigh the potential savings of developing this project.

Direct Line alternative

The distance between the Broombridge building and the main campus is approximately 2km (as the crow flies), and approximately 3km if following roads where laying of wire would likely take place. Considering the current lack of clarity relating to the likely changes to private wire regulations, as well as the costs and general disruption to laying a physical wire connection in a densely populated area, there is a high probability that the option to create a direct line between the Broombridge building and the Grangegorman main campus will not be feasible in the medium term.

Broombridge building – Community Energy project through PPA

It may be an option to develop a small-scale renewable energy project using the roof of the Broombridge building for the installation of the large solar PV array outlined previously. The financing of this option could be structured in various ways, depending on the desired outcomes, investment required, and returns required from the project. Options include availing of the Small-Scale Renewable Electricity Support Scheme (SRESS). This support scheme is designed specifically for "*small-scale (above 50kW and up to 6MW in capacity size) community, farm, and SME projects … and offers such projects a simpler, non-competitive, route to market*". This support scheme includes a 15-year tariff support. To develop it as a community scheme it may be possible to allow members of the community to 'buy into' the scheme. In this structure some of the investment cost of installation is provided by individuals / groups in the community who then are essentially shareholders in the project and receive a return proportionate to their investment. There may also be an opportunity to work in partnership with the existing Sustainable Energy Communities in the area in Stoneybatter, Phibsborough, and Cabra to provide low cost, renewable energy to these community groups.

5.5 Conclusion

There are a variety of PPA structures that exist, and TU Dublin has the option to enter into many of these structures. A direct line / private wire PPA is not currently permittable, unless the source of electricity generation is co-located on lands within the ownership of TU Dublin. TU Dublin may also enter into a virtual PPA with a renewable energy producer; however, the primary advantage of this option would be to lock-in a low-price rate of electricity for an extended period of time and this structure would have no impact on the emissions reporting of TU Dublin or its ability to meet 2030 emission reduction targets. Although it has significantly higher upfront investment costs, directly procuring and installing solar PV panels wherever possible across the three campuses is likely a more cost-effective option than entering into a PPA in the long-term.

6. ELECTRICITY FLEXIBILITY ANALYSIS

Figure 59: Clyde Bank Energy Centre and Thermal Storage Tank, Heat Networks Industry Council[23]

6.1. Electricity Flexibility Overview

Electricity demand flexibility refers to the ability of consumers to adjust their electricity usage in response to external signals, such as changes in electricity prices or incentives provided by grid operators. This concept plays a critical role in balancing supply and demand on the electricity grid, especially with the increasing share of renewable energy sources like solar and wind, which are intermittent.

Electricity demand flexibility is crucial for TU Dublin as the university transitions to meeting its thermal energy needs through district heating and heat pumps, both of which will rely heavily on the national electricity grid. As these systems are deployed, TU Dublin's electricity consumption will increase, particularly during peak heating periods. By incorporating demand flexibility, the university can adjust its electricity usage to align with grid availability, especially when renewable energy generation is high, ensuring more sustainable and cost-effective operations. This flexibility will help reduce reliance on fossil-fuel backup power, minimise strain on the grid, and optimise the integration of renewable electricity, ultimately supporting TU Dublin's decarbonisation and energy efficiency goals. To facilitate electricity demand flexibility, several solutions can be employed:

[23] Queens Quay Heat Pump Heat Network Scheme

- **Thermal Energy Storage (TES)**: Thermal energy storage used with DH systems, such as water tanks or phase change materials, can store heat generated during times of low electricity demand or when renewable energy supply is abundant. Heat pumps, for example, can operate during off-peak hours to produce and store thermal energy, which can be used later when heating demand is high. This reduces the need for real-time electricity consumption during peak periods, alleviating strain on the grid.

- **Battery Energy Storage Systems (BESS)**: Battery storage systems store electricity during periods of low demand or when renewable energy production is high (e.g., from on-site solar PV). This stored energy can then be used during peak demand periods or when the grid is under stress. Batteries enable load shifting, allowing TU Dublin to optimise its electricity consumption patterns, reduce peak load costs, and enhance grid stability.

- **Electric Boilers:** Electric boilers offer rapid demand response capabilities, allowing TU Dublin to quickly absorb surplus electricity, particularly when renewable energy is curtailed. They can convert excess electricity into heat for immediate use or store it in thermal storage systems. This flexibility supports grid stability, maximises the use of renewable electricity, and reduces the reliance on fossil fuels during peak demand periods.

- **Smart Control Systems:** Integrated energy management systems optimise the operation of thermal and battery storage, as well as electric boilers, by automating the use of stored energy or switching to electric boilers during peak demand times. These systems enable TU Dublin to balance electricity consumption, thermal storage, and battery storage in real time, responding to dynamic grid pricing signals or renewable energy availability.

- **Demand Response Programs**: By participating in demand response programs, TU Dublin can receive financial incentives for reducing or shifting electricity usage during peak times. With thermal and battery storage, as well as electric boilers, the university can strategically draw from these resources to curtail grid dependency without affecting critical services like heating.

6.2. Energy Storage Opportunity

Energy storage will be a crucial element of TU Dublin's ability to facilitate demand flexibility. Energy storage comes in many forms, however the energy storage solutions that are available to university campuses can largely be split into two distinct groups, thermal energy storage (TES), and battery energy storage systems (BESS). Deciding on whether TES, BESS, or a combination of both should be incorporated in TU Dublin energy systems is an important decision. Table 32 and Table 33 show the different forms of TES and BESS respectively.

Table 32: Different types of thermal energy storage (TES), Araner[24]

Type	Key Features	Applications
Sensible Heat Storage	Stores heat by raising the temperature of materials (e.g., water, rocks)	District heating, hot water tanks, buildings
Latent Heat Storage	Uses phase change materials (PCMs) to store heat during phase transitions	Compact systems, solar thermal energy
Thermochemical Storage	Stores energy through reversible chemical reactions, offering high energy density	Long-term heat storage, concentrated solar power

Table 33: Different types of battery energy storage systems (BESS), Edina[25]

Type	Key Features	Applications
Lithium-Ion	High energy density, long lifespan, fast charging; common in renewables and grids	Solar, wind, electric vehicles, energy storage & balancing
Lead-Acid	Low cost, widely available, low energy density, slow charge	Backup power, UPS
Sodium-Sulphur	High energy density, long lifespan, high-temperature operation	Large-scale grid storage
Flow Batteries	Long-duration storage, uses liquid electrolytes, scalable	Grid-scale storage, renewable integration
Solid-State	Higher safety, higher energy density, experimental	Future energy storage, EVs
Nickel-Cadmium	Durable, reliable, environmental concerns due to cadmium toxicity	Aviation, industrial

Blanchardstown Campus – Thermal vs. Electricity Storage

Hot water storage tanks are the most common form of TES used in heating systems. The tanks can range in size from small units for individual buildings to large-scale systems that serve entire districts or neighborhoods. The most used BESS is lithium-ion batteries, which are favored for their high energy density, fast response times, and widespread use in applications ranging from electric vehicles to electricity storage. For the purposes of this analysis, tank thermal energy stores vs. lithium-ion batteries will be considered and compared. The most economic and environmental use of these systems is to store excess on-site renewable energy during periods of low demand. One example of this is electricity generated using rooftop PV.

[24] Thermal Energy Storage Types
[25] BESS Types

As detailed in section 4 above, the highest potential for rooftop PV is the Blanchardstown campus based its location outside of solar safeguarding zones, and the suitability of its buildings. Using open solar, two PV scenarios were generated for the campus. Scenario 1 maximised PV array sizing on the basis that excess electricity could either be shared between buildings, stored, or fed back into the electricity grid. The following section looks specifically at the scenario where the excess electricity generated by PV is stored, and what form of storage is the most cost-effective method of doing so. The nPro energy model was used to compare excess PV generated electricity used to heat tank thermal stores vs. lithium-ion batteries.

The results from the model, as shown in Table 34, show that both hot water tanks and lithium-ion batteries increase the amount of PV electricity that is used on site, increasing the self-sufficiency (ability to operate without using electricity imports) by 14% vs. a PV array only. This is due to the PV array being fully utilised, particularly during the summer months as shown in Figure 61. In this instance, all excess electricity is stored instead of being fed back into the national electricity grid.

Technology	Optimization range	Pre-design	Full load hours/ Charging cycles
Photovoltaics	≤ 1,086 kW_p / ≤ 5,171 m^2	**1,086 kW_p / 5,171 m^2**	593 h/a
Battery	*unlimited*	**1,324 kWh**	637 Cycles

Figure 60: Blanchardstown PV Array & Battery Sizing, nPro

Table 34: BESS vs. TES self-sufficiency comparison

Energy import		PV Trial (Scenario 1)	PV Trial (+BESS)	PV Trial (+TES)
Electricity import from grid	MWh	849	702	702
PV electricity generation	MWh	437	657	657
Self-sufficiency	%	34%	48%	48i%

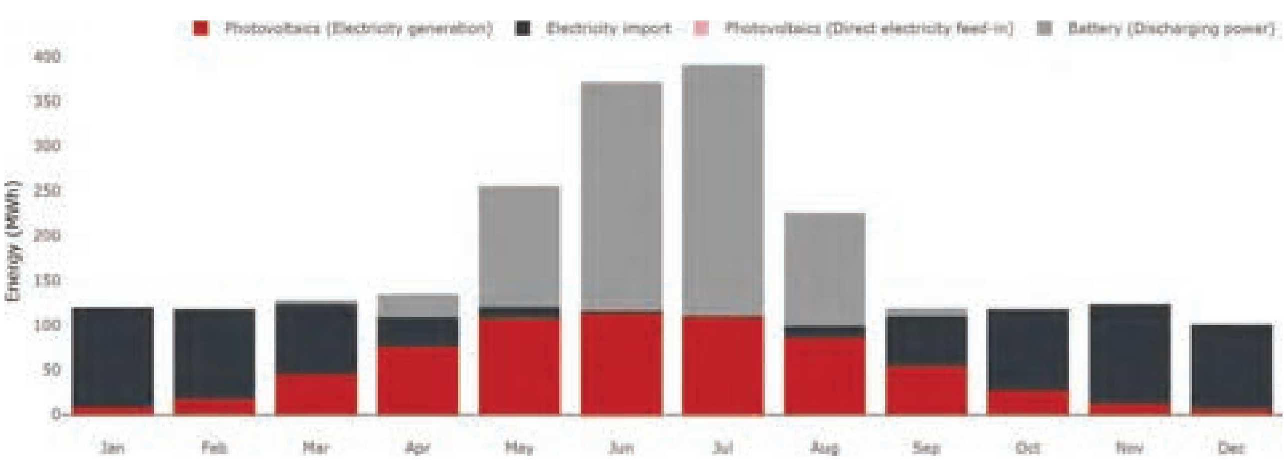

Figure 61: Blanchardstown electricity demand profile, PV + BESS

From a financial perspective, there is a notable difference between the storage options. The higher upfront capital cost (~€2.7m), and shorter lifespan (~15 years) of BESS + PV result in a negative cashflow for the system and offers no return on investment (payback) as shown in Figure 62 below. This is also evident in Table 35 and Table 36 which compare the capital investment (€) and cashflow (€/a) for each of the storage options.

Interestingly, the most financially viable option is the one with no storage (PV only).. The benefits of increased self-sufficiency and onsite increased renewable energy generation associated with storage may outweigh the increased payback time

Table 35: Capital Investment Comparison (PV + Storage), Blanchardstown

Investment		PV Trial (Scenario 1)	PV Trial + Thermal Storage	PV Trial + Batteries
Energy hub	€	944,800	1,196,016	2,004,020
Contingency (+35%)	€	330,700	418,600	701,400
Sum	**€**	**1,275,500**	**1,614,600**	**2,705,400**

Table 36: Cashflow Comparison (PV + Storage), Blanchardstown

Summary		PV Trial (Scenario 1)	PV Trial + Thermal Storage	PV Trial + Batteries
Investment (annuity)	€/a	-53,998	-67,062	-149,521
Maintenance costs	€/a	-9,448	-11,960	-20,040
Lump sum costs (annuity)	€/a	-21,168	-26,796	-44,898
Savings	€/a	170,153	170,153	185,362
Cash flow	**€/a**	**85,539**	**64,335**	**-29,098**
Payback		**10 years**	**14 years**	**No payback**

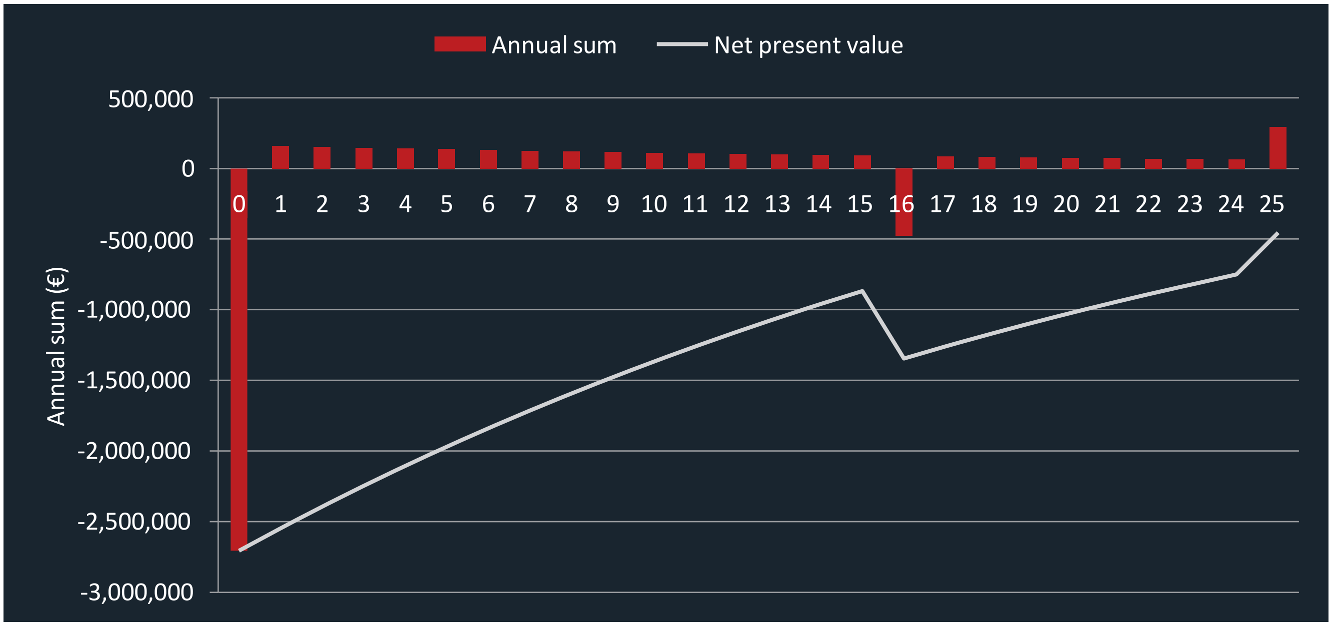

Figure 62: NPV Chart, PV + Batteries (Blanchardstown)

Another key consideration when comparing storage options is the space (footprint) required. A recent study undertaken by Codema was the Poolbeg Sector Integration Study, which "explores how district heat with thermal storage, and a separate hydrogen electrolyser, along with curtailed renewable electricity and hydrogen end-use applications, can provide an efficient, holistic and integrated energy system solution". One of the results of the study showed that for storage solutions with a capacity of 200 MWh, TTES required less than 10% of the space in comparison to BESS as shown in Figure 63.

Figure 63: Land Use & Price Comparison (TTES vs. PTES[26], vs. BESS), Poolbeg Sector Integration Study[27]

The results of the analysis above show that there is a benefit to installing storage solutions as part of the TU Dublin energy systems which serve each campus. Both TES and BESS can offer increased self-sufficiency and consumption of onsite renewable energy generation. TES, however, is a more cost-effective method of doing so and promotes the sector coupling of heat and electricity. It also requires less space than BESS alternatives.

The exact makeup of the thermal storage tanks is dependent on the infrastructure on the campus. If a district network is present (Tallaght and Grangegorman), then the TES could be in the form of large tanks that are located adjacent to an energy centre. The tanks could be also be incorporated on a building level to absorb excess PV generated electricity (using PVT[28] Collectors). A full technical detail design would need to be carried out to establish the most viable option.

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[26] Pit Thermal Energy Storage
[27] Poolbeg Sector Integration Study
[28] Photovoltaic Thermal Collectors

Broombridge BESS

While TES is more cost effective than BESS solutions for TU Dublin's consumption profile, it does mean that BESS solutions cannot be incorporated in other use cases. The proposed Broombridge facility will consist of a north wing and the central/connection building with a total floor area of 6,430 m^2 to deliver a new Design + Construct Sustainable Building Centre, an innovative, interdisciplinary teaching and learning centre for Ireland's Architecture, Engineering and Construction (AEC) and aligned sectors.

There are currently no plans to install a DH system at the new centre, and it is also located over 3km away from the Grangegorman campus. For this reason, the new development may be suitable for a BESS installation. Using the outcome from the open solar analysis combined with the nPro energy model for the proposed Broombridge facility, an analysis of BESS storage was conducted, and the results are shown in the tables and figures below.

Technology	Optimization range	Pre-design	Full load hours/ Charging cycles
Photovoltaics	≤ 938 kW_p / ≤ 4,467 m^2	**938 kW_p / 4,467 m^2**	823 h/a
Battery	*unlimited*	**645 kWh**	145 Cycles

Figure 64: Broombridge PV Array & Battery Sizing, nPro

Table 37: PV+BESS self-sufficiency comparison, Broombridge

Energy import		PV Trial	PV Trial (+BESS)
Electricity import from grid	MWh	137	72
PV electricity generation	MWh	171	467
Self-sufficiency	%	55.5%	86.6%

The total energy generated by the PV array is 744 MWh per annum. Without batteries, 171 MWh is consumed by the facility while the remainder (573 MWh) is fed back into the electricity grid. Given that the compensation is lower for direct feed in compared to self-consumption, it makes financial sense to consume as much PV generation as possible on site. This is shown in Table 38 below. Adding the BESS increases self-consumption to 467 MWh per annum and reduces the amount that is fed back to the grid to 72 MWh. Increasing self-consumption also reduces reliance on imports from the grid, where the self-sufficiency rate for PV + BESS is 86.6% compared to 55.5% for PV only.

Table 38: Savings for direct feed in vs. self-consumption, PV + BESS

Revenues	Compensation	Quantity	Revenues (€/a)
Photovoltaics (direct feed-in)	0.21	277	58,170
Photovoltaics (self-use)	0.28	467	130,667
		Sum	**188,837**

The tables and figures below show the financial comparison of PV + BESS, vs. PV only for the Broombridge centre. The most financially viable is PV only, which offers a payback of 9 years and an IRR of 9.7% for a capital investment of ~ €1.1m.

Table 39: Capital Investment Comparison (PV + BESS), Broombridge

Investment		PV Trial	PV Trial + BESS
Energy hub	€	816,060	1,332,060
Contingency (+35%)	€	285,621	466,221
Sum	**€**	**1,101,681**	**1,798,281**

Table 40: Cashflow Comparison (PV + BESS), Broombridge

Summary		Solar PV Evaluation	Solar PV + BESS
Investment (annuity)	€/a	-46,639	-93,174
Maintenance costs	€/a	-8,161	-13,321
Lump sum costs (annuity)	€/a	-18,283	-29,844
Revenues	€/a	168,176	188,837
Cash flow	**€/a**	**95,093**	**52,498**
Payback		**9 years**	**14 years**

Installing a BESS is also a financially viable option and offers a payback of 14 years and an IRR of 3.7% for a capital investment of ~ €1.8m. The benefits of increased self-sufficiency and onsite increased renewable energy generation may outweigh the increased payback time. Another benefit is the ability of the BESS to provide demand flexibility as discussed earlier in this section. Batteries are suitable for providing short duration flexibility which will be of particular importance for the electricity grid with increased penetration of wind and solar.

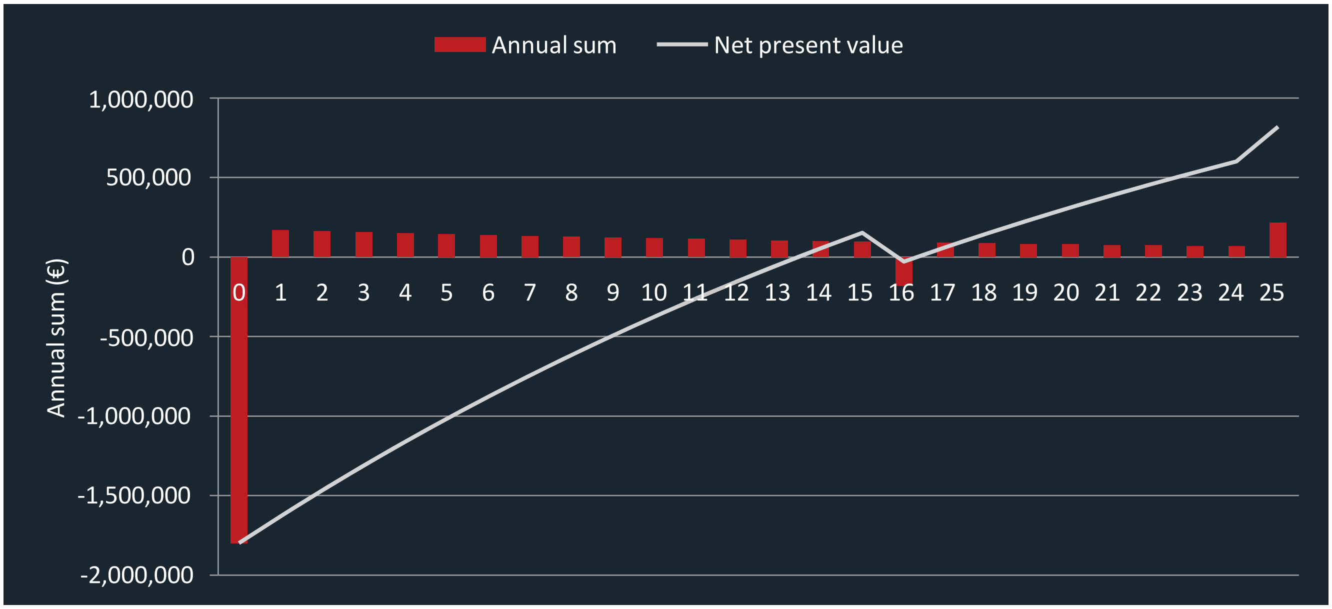

Figure 65: NPV Chart, PV + BESS (Broombridge)

6.3. Microgrid Development

The definition of a microgrid is a “small, self-contained energy system that can operate independently or in connection with the main power grid. It typically includes local energy generation (e.g., solar panels), storage (such as TES or BESS), and distribution infrastructure to supply electricity or heat to a specific area, like a campus or neighborhood.

TU Dublin’s current energy system at the Blanchardstown campus is depicted in Figure 66. This system is entirely reliant on the national gas network or the electricity grid to provide heat and electricity to the campus respectively.

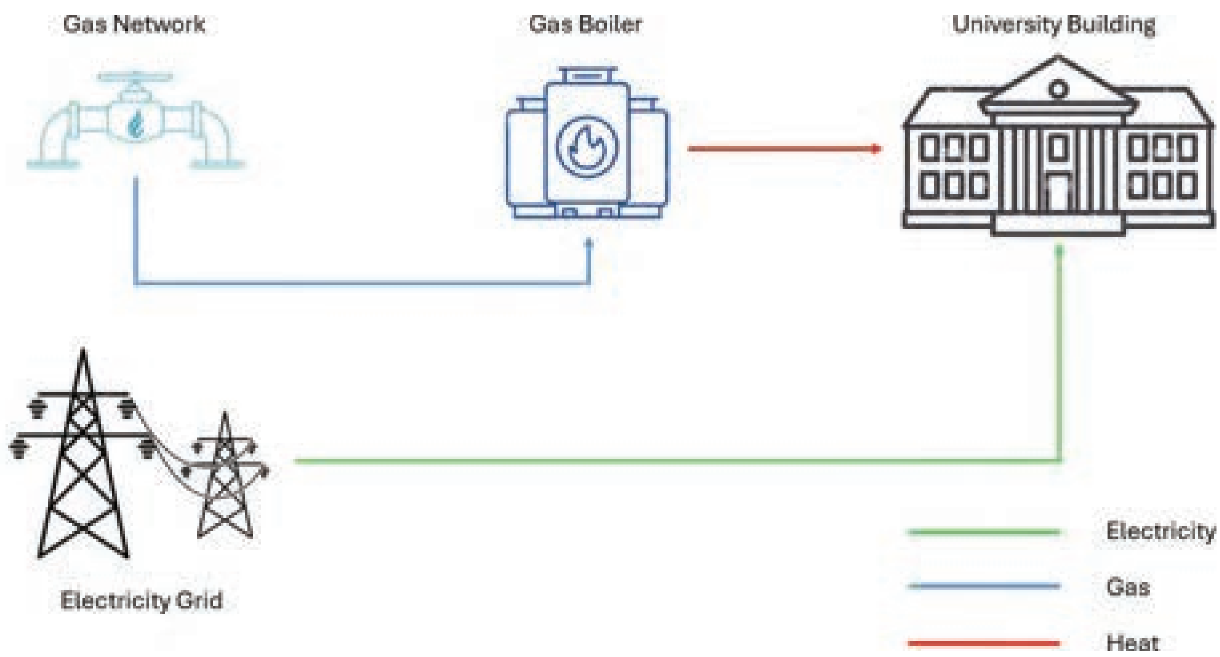

Figure 66: TU Dublin Energy System Schematic (Blanchardstown)

Figure 67 depicts a smart energy system that the Blanchardstown campus could install that would incorporate microgrid capabilities. The system is composed of several key elements:

- **Geothermal Energy**: A geothermal array or boreholes could be drilled to provide heat to a district heating network, this would remove reliance on using gas to provide heating and improve self-sufficiency.
- **Photovoltaic Energy**: PV panels could be installed on all suitable buildings to provide onsite renewable energy to the campus. Excess electricity that is generated during periods of low demand could be used to heat the thermal store via the electric boiler. Alternatively, PVT collectors could be installed to provide heat directly to the thermal store.

- **Electric Boiler**: The primary function of the electric boiler is to provide backup to the geothermal energy source and ensure continuous heat supply for the DH network. The boiler could also be used to reduce curtailment on the national electricity grid and heat the thermal store when there is excess wind generation or offer demand flexibility when the grid is constrained.
- **Thermal Store**: The thermal store can be charged during nighttime hours by either the geothermal energy source, the electric boiler, or by excess electricity generated by PV. This heat can then be dissipated during periods of peak demand to load shift demand and reduce energy costs.

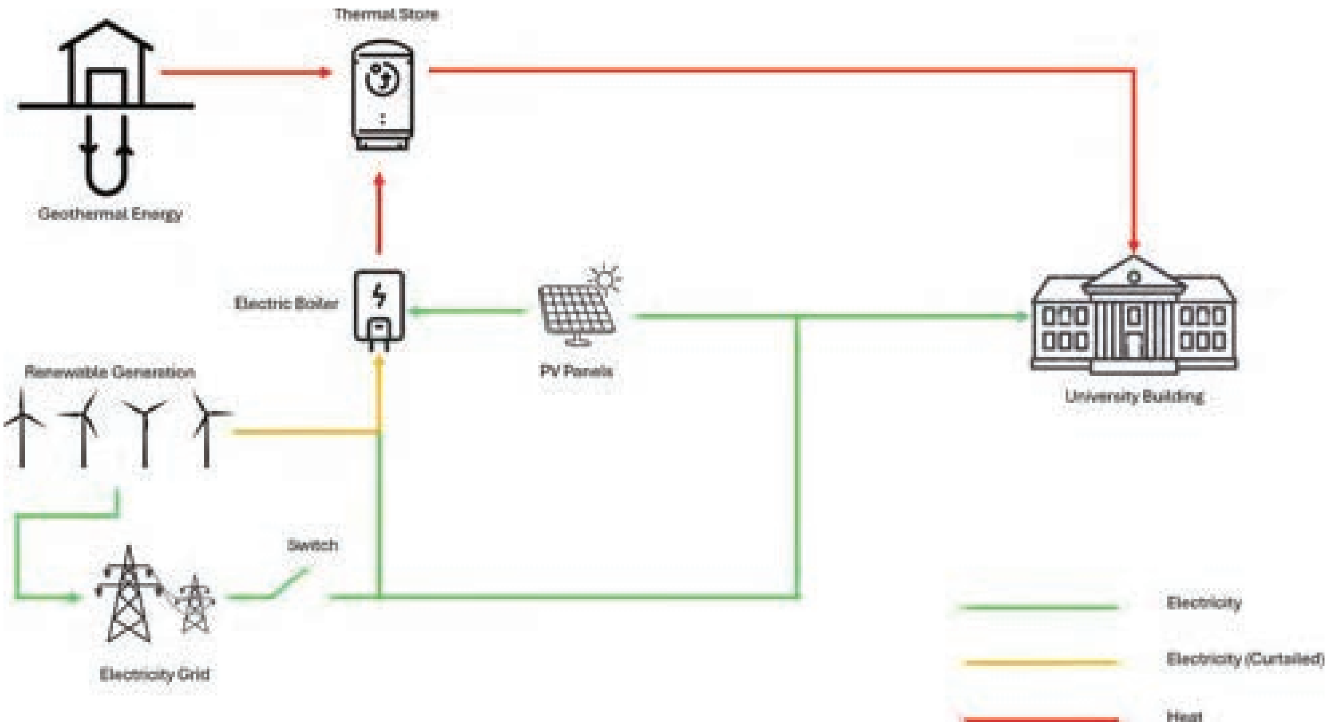

Figure 67: TU Dublin Smart Energy System Schematic (Blanchardstown)

This arrangement is an example of how a more holistic approach to energy system design on TU Dublin campuses can promote the sectoral integration of heat and electricity and improve energy efficiency. A similar approach could be taken on the other TU Dublin campuses however, it should be noted that each system arrangement will be slightly different depending on the planned energy infrastructure.

It is also feasible that, given enough onsite renewable energy generation (through either solar or geothermal energy), this system arrangement would allow the Blanchardstown campus to operate independently of the national electricity grid for a period of time (microgrid). This system will also eventually be zero carbon in line with expected national grid decarbonisation which is in line with TU Dublin’s goal to become net zero by 2050.

Tallaght Microgrid

A microgrid project is currently underway at the TU Dublin Tallaght Campus where a microgrid has been developed as part of the teaching programmes in Electric and Electronic Engineering at the campus. This microgrid includes a 34 kWp solar PV array and a 6.5 kW wind turbine. Electric car charging and battery storage are also planned to be added to the microgrid. This microgrid currently operates as an academic/ teaching project. The microgrid may however be connected to the Tallaght Main Building in the future. This project offers valuable learning opportunities for developing microgrid across the TU Dublin campuses on a larger scale.

7. DEMAND REDUCTION ANALYSIS

7.1. Introduction

The aim of this document is to investigate the electrical and gas profiles for TU Dublin's three main campus locations—Grangegorman, Tallaght, and Blanchardstown—and identify areas to reduce energy demand. The three largest campus locations were selected to provide an overview of energy profiles across the organization. Additionally, this document aims to identify opportunities for improvement through potential behavioural changes and campaigns.

Quarter-hourly electrical data was available for all locations up to June 2024. Granular thermal data was only available for the main gas skid at Blanchardstown. For this analysis, it is assumed that the thermal profile of Blanchardstown is reflective of all campuses. There have been issues with metered gas data for Blanchardstown from the end of 2019 onwards. The last complete year of gas data available was for 2019. Data from 2019 was compared to the available data for 2023 and 2024, and similar trends were observed. Therefore, the 2019 data was used for this analysis, and the trends in consumption should be investigated in relation to the actual consumption.

Electrical profiles have been created for the three main campuses, and a gas profile has been created for Blanchardstown. These profiles are indicative of energy demand across the three main campuses. Examination of these profiles can be used to assess how efficiently energy is being used across the campuses. By combining this analysis of the energy profiles with specific site knowledge gained through discussions with professional staff and site visits, opportunities for reducing energy demand have been identified.

7.2. Grangegorman Campus

Quarter-hourly electricity metering data was available for the main meter point at Grangegorman, provided by the Meter Registration System Operator (MRSO). Figure 68 below shows the hourly load profile from January 2022 to June 2024. This period was selected to assess changes in the load profile over the past few years. There is significant seasonal variation due to environmental conditions and lower occupancy during warmer periods. Both peak and baseloads are higher during the winter months and lower during the summer.

From January to mid-February 2022, peak loads increased from approximately 820 kW to 1,540 kW. The peak load then began to decrease, reaching its lowest levels in July and August at approximately 1,050 kW, and remained constant until early September. By mid-September, peak loads increased rapidly, reaching the highest load observed over the 30-month period in December 2022 at 1,670 kW, before rapidly decreasing to 640 kW due to the winter break. This trend was also observed in 2023 and the first six months of 2024; however, higher peak loads were observed from January to March in 2023 and 2024. The peak loads observed during the summer period were approximately 120 kW lower than in 2022.

The most notable observation when examining this load profile is how high the baseload remains throughout the year. The baseload rarely decreases below 600 kW. There needs to be further investigation into the causes of this high baseload. Server loads and external lighting loads during out-of-office hours should be examined to help understand what might be contributing to this.

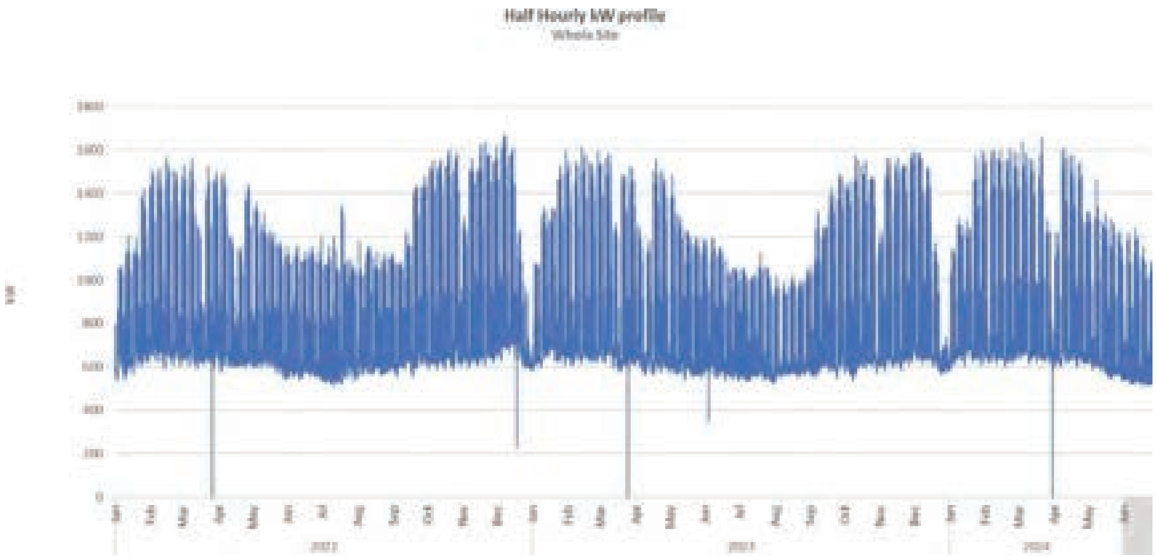

Figure 68: Grangegorman Half Hourly kW Profile (Jan 2022 - Jun 2024)

Figure 69 below shows the 2023 Heat Map[29] for the Grangegorman campus. The map displays the electricity consumptionfor each 24-hour period from January to December. Red areas in the map correspond to periods of high electricity usage, while green areas indicate periods of low usage. The average temperature column shows a temperature scale ranging from hotter days in red to colder days in blue.

From January to mid-June, activity begins at 6:15 a.m and increases, reaching its maximum at midday. Activity then begins to decrease, returning to the baseload at 10:30 p.m. During the period from mid-June to early September, the start of activity is delayed by an hour, beginning at approximately 7:15 a.m. Activity during this period reaches its maximum at midday before decreasing to baseload levels by 8:00 p.m. By mid-September, activity has returned to a similar schedule observed from January to mid-June.

It is worth noting that average out-of-office loads during mid-June to early September are approximately 45 kW lower than the rest of the year. The reason for the variation in baseloads throughout the year is not clear and may be related to external lighting or equipment being left on. This could also be due to exacerbation of behavioural issues during periods of increased activity.

[29] A Heat Map is method of data visualization that uses colour concentration and variation to represent intensity. Although the name may imply the graphic relates to heat data this is just the name of this method for visualizing data. In this context the Heat Map is referring to electricity consumption.

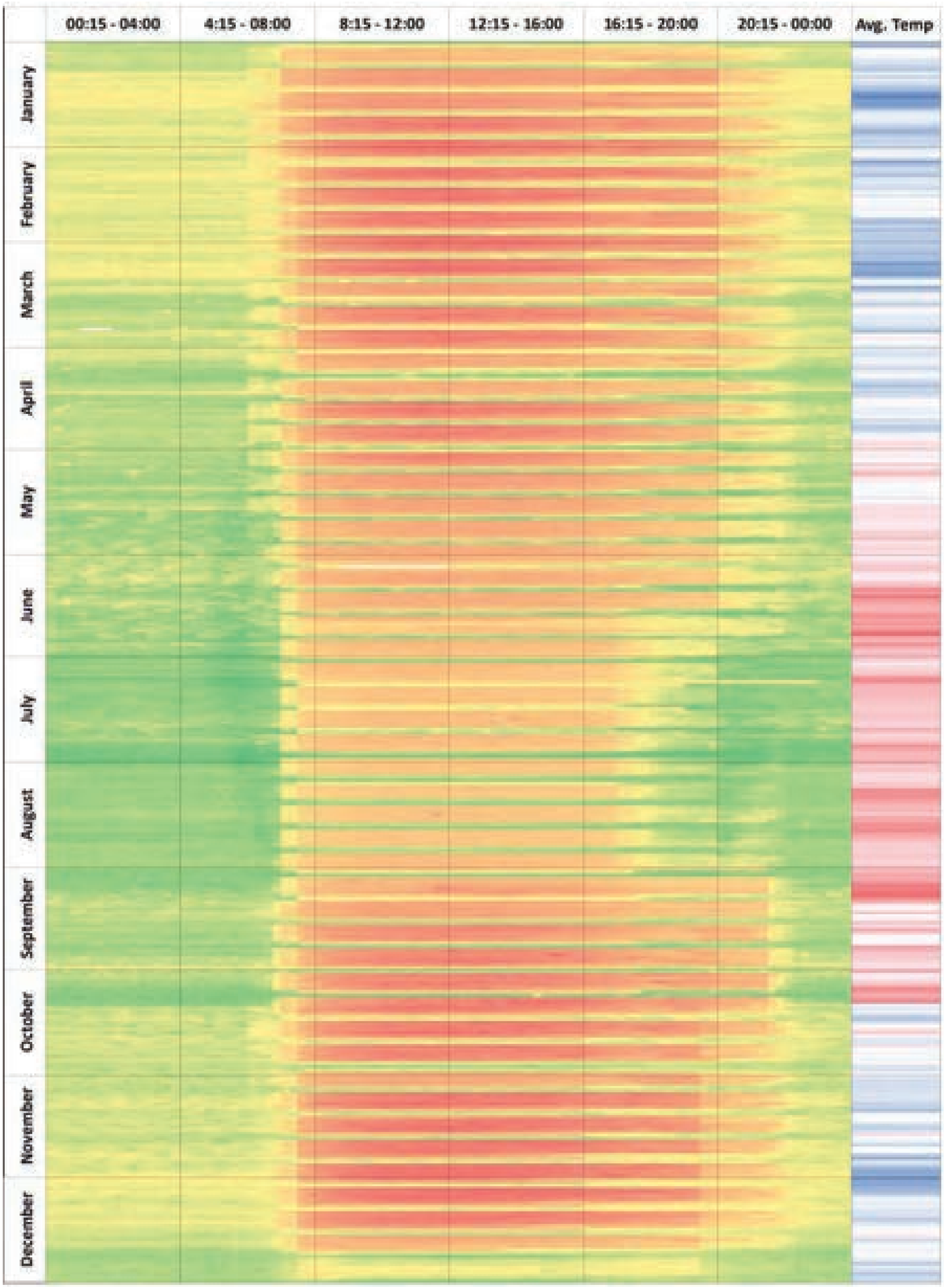

Figure 69: Grangegorman 2023 Heat Map

Figure 70 below compares the average weekly half-hourly loads between the summer period and the in-class period for 2023. For this comparison, the summer period consists of June to August 2023, while the in-class period consists of January to May and September to December 2023. During both the in-class and summer periods, peak loads are higher on Wednesdays and Thursdays compared to the rest of the week. On Saturdays, loads decrease significantly due to lower activity levels, while Sunday loads remain near baseload levels.

When comparing the baseloads between the in-class and summer periods, a decrease of approximately 40 kW is observed in the summer period. On average, midday loads from Monday to Friday are approximately 270 kW lower during the summer period. The decrease in summer loads could be achieved by optimizing space utilization and shutting down several buildings on campus during periods of lower activity.

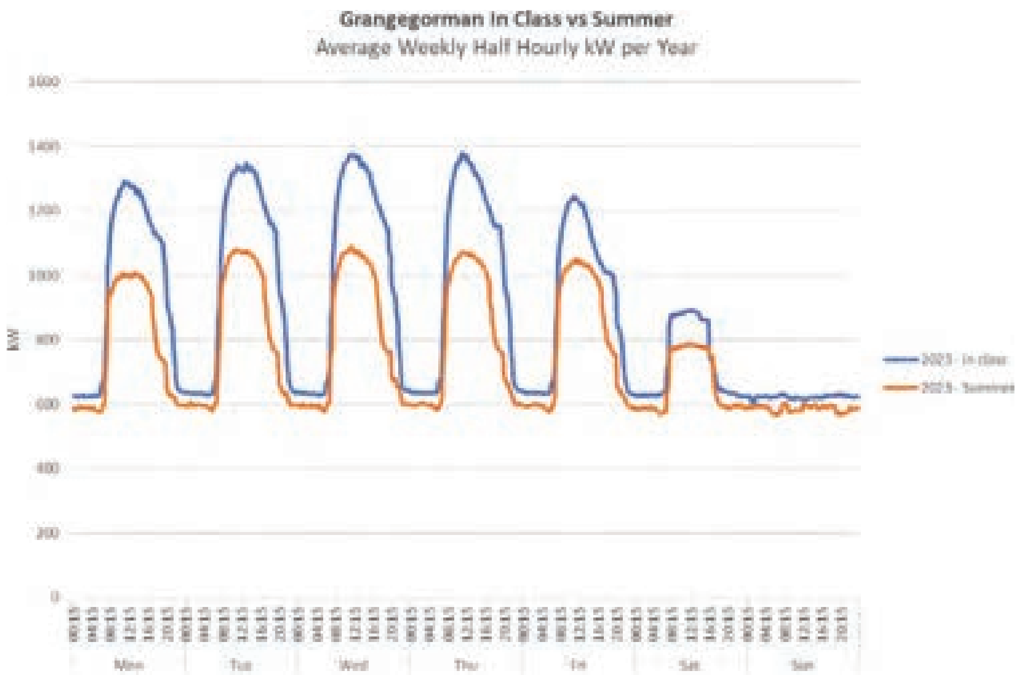

Figure 70: Grangegorman In Class vs Summer Average Weekly Half Hourly Loads kW

7.3. Tallaght Campus

Similarly to Grangegorman, quarter-hourly electricity metering data was available for the main meter point at Tallaght, provided by the Meter Registration System Operator (MRSO). Figure 71 below shows the hourly load profile from January 2022 to June 2024. This period was chosen to assess changes in the load profile over the past three years.

Like the observations made at Grangegorman, there is significant seasonal variation due to environmental conditions and lower occupancy during warmer periods. Both peak and baseloads are higher during the winter months and lower during the summer. These variations in peak and baseloads appear more sporadic than those observed at Grangegorman.

In January 2022, peak loads began to increase, reaching the highest load in the 30-month period in mid-March at 530 kW. The peak loads then decreased to 250 kW in July before rising to approximately 490 kW in December. A rapid decrease in peak loads was observed in late December 2022 to early January 2023 due to the winter break. This trend continued in 2023 and the first half of 2024; however, peak loads in 2023 were lower than those observed in 2022. The highest load observed between January and April 2023 was approximately 30 kW lower than in 2022. Additionally, peak loads in June and August 2023 experienced slight decreases when compared to 2022.

The baseloads followed a similar trend, with higher baseloads observed during the winter months and lower baseloads during the warmer periods. In 2023, baseloads decreased by approximately 20 kW compared to 2022. Between January and April 2024, baseloads increased to levels observed in 2022; however, in May and June, baseloads nearly returned to those observed in 2023. Control of out-of-hours loads should be examined to determine the cause of the sporadic variation in both peak and baseloads.

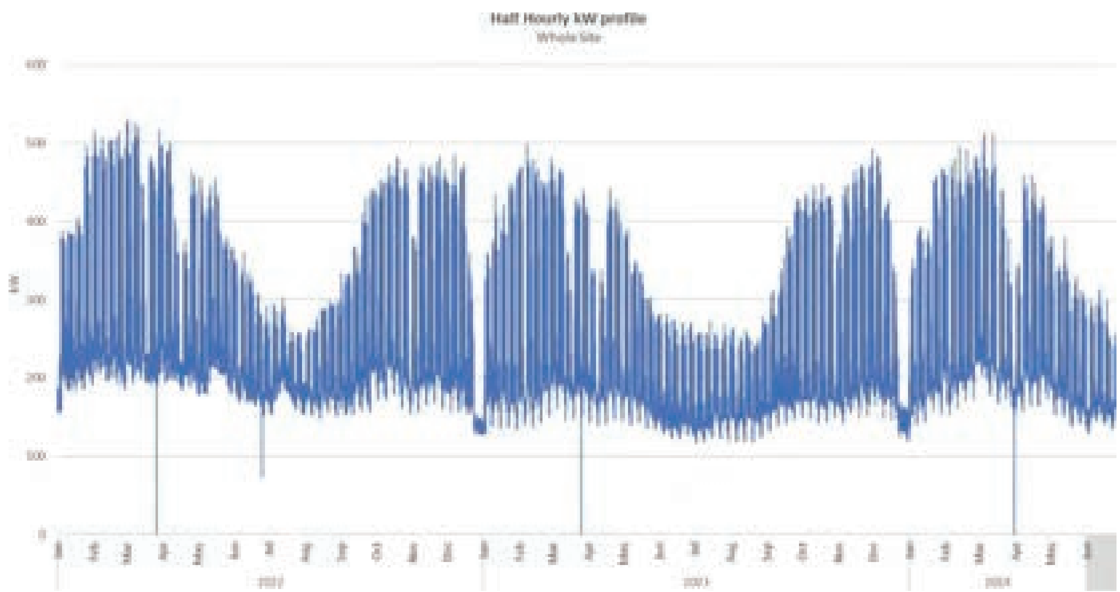

Figure 71: Tallaght Half Hourly kW Profile (2022-2024)

Figure 72 below shows the 2023 Electricity Heat Map for the Tallaght campus. Activity at this site begins at approximately 5:15 a.m. and increases, reaching its highest levels between 12:00 p.m. and 1:00 p.m. Activity then decreases, returning to baseload levels at approximately 11:00 p.m. It is important to note that from January to May and from September to December, out-of-office loads occasionally remain 10 kW to 15 kW above baseload levels and should be investigated to determine the cause. Additionally, during these periods, peak loads and baseloads are approximately 100 kW and 25 kW higher, respectively, when compared to the June to August period. Throughout the year, there is a 50 kW increase in load at 5:15 a.m. The equipment scheduled to turn on at this time should be identified and assessed to determine if it is necessary to operate at that specific time. It may also be advantageous to evaluate if all the buildings need to remain operational until 11:00 p.m., as baseload levels are not being reached until this time.

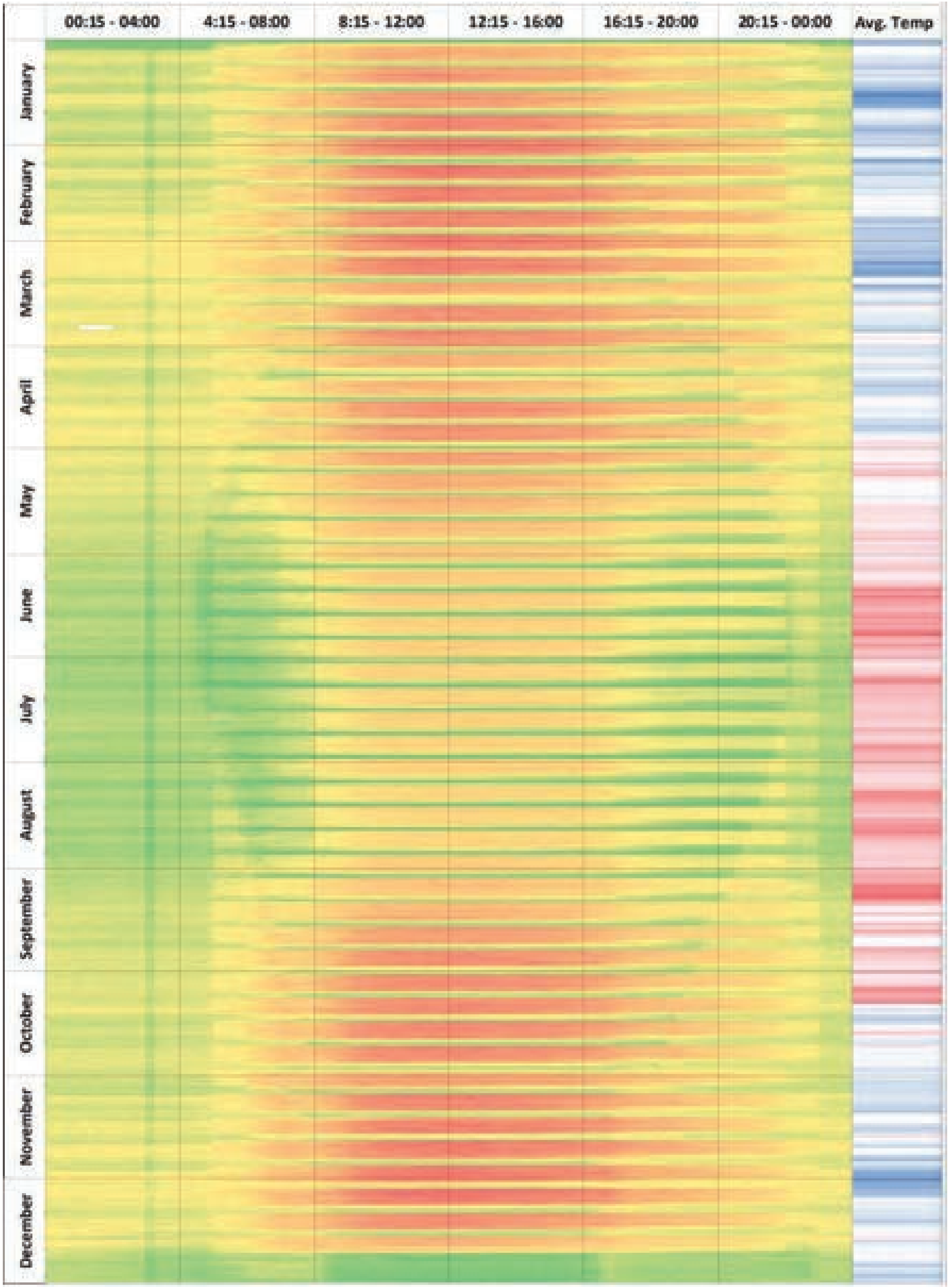

Figure 72: Tallaght Heat Map 2023

Figure 73 below compares the average weekly half hourly loads between the summer and in-class period for 2023.The highest in-class periods Monday load is approximately 360 kW at mid-day and increased reaching the highest weekly load on Wednesday mid -day reaching 390 kW before decreasing to 355 kW by Friday mid-day. A peak load of 212 kW is observed on Saturday, during Sunday mid-day the lowest load is observed at 145 kW. This trend is followed by the summer period with Wednesday's peak load of 134 kW lower than the in-class period and baseloads approximately 25 kW lower during the summer period. The lower loads observed during Sundays should be investigated to determine which equipment is turned off to replicate this during out of hours periods during the rest of the week.

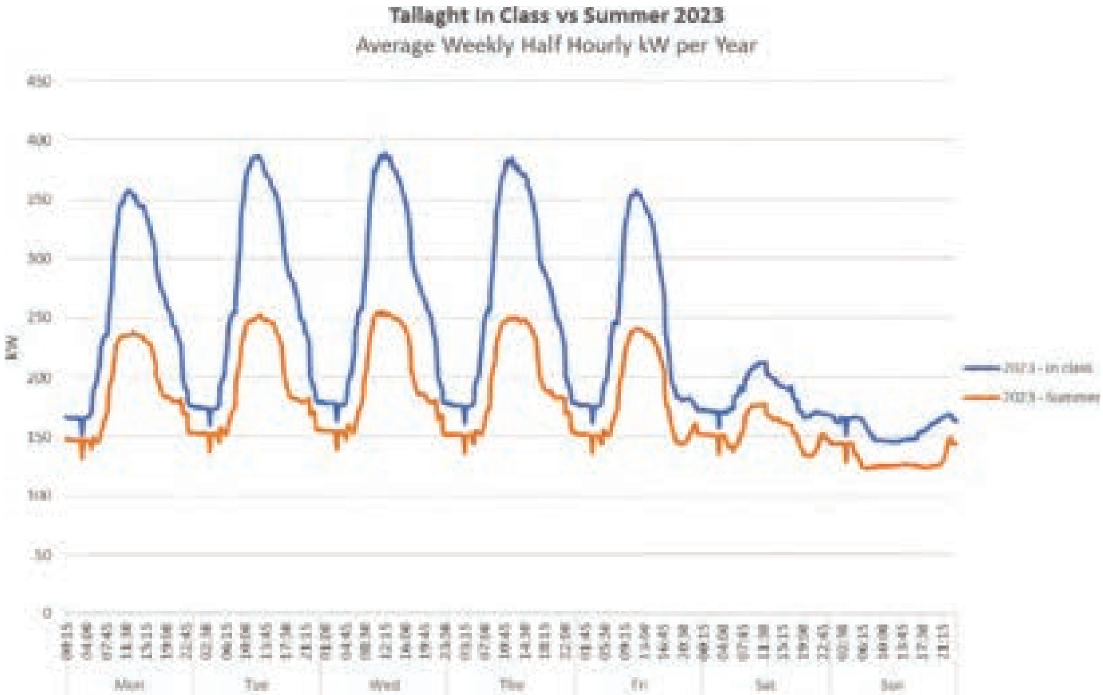

Figure 73: Tallaght in Class vs Summer Average Weekly Half Hourly kW per Year

7.4. Blanchardstown Campus

As with the other two campuses, quarter-hourly electricity metering data was available for the main meter point at Blanchardstown, provided by the Meter Registration System Operator (MRSO). Figure 74 below shows the hourly load profile from January 2022 to June 2024. This period was chosen to assess changes in the load profile over the past three years.

Similarly to Grangegorman and Tallaght, seasonal variation is observed in the peak loads, with higher loads during the winter period and lower loads during the summer. In January 2022, peak loads began to increase, reaching 440 kW in early February. The peak loads then decreased to 190 kW in mid-June, and by mid-August, loads began to increase rapidly, reaching 436 kW in November. In December 2022 and early January 2023, a significant decrease was observed due to the winter break.

This trend continued into 2023 and 2024; however, the highest load from January to May 2023 was approximately 40 kW lower than in 2022. An increase of 40 kW was observed in the 2023 summer peak loads compared to 2022. Additionally, peak loads from September to December 2023 were significantly higher than those in 2022.

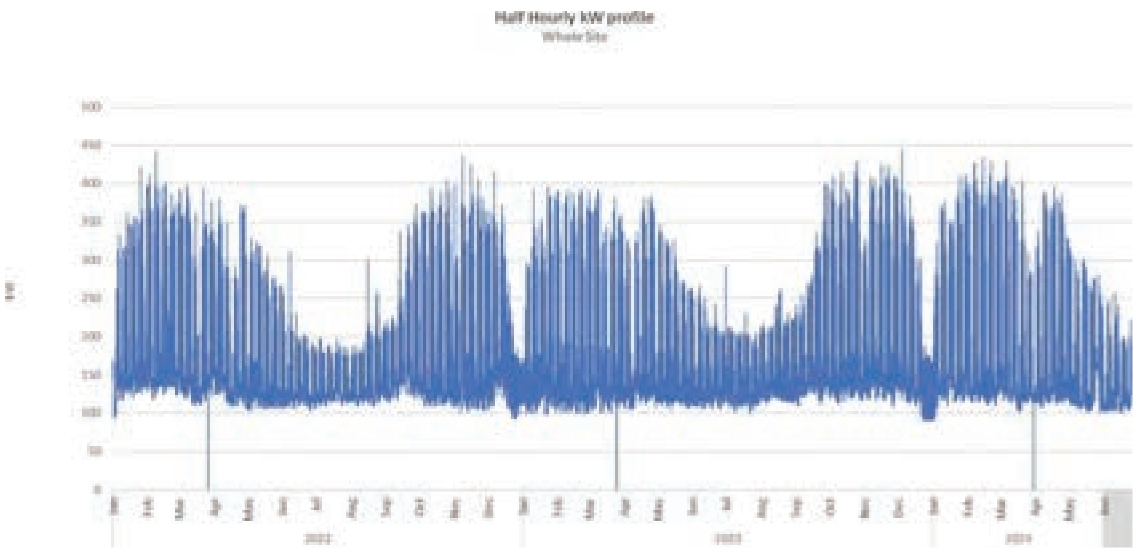

Figure 74: Blanchardstown Half Hourly kW Profile (2022-2024)

Figure 75 below shows the 2023 Electricity Heat Map for the Blanchardstown campus. From January to mid-May, activity across the site begins at 4:30 a.m. and increases, reaching its maximum of approximately 365 kW at 10:00 a.m. Activity remains at this level until approximately 2:00 p.m. before beginning to decrease and returning to baseload levels at 10:00 p.m. Additionally, a small increase in activity is observed at 8:00 p.m.. Between mid-May and August, the start of activity is delayed to 6:30 a.m., reaching its maximum of 210 kW at 9:30 a.m. By 2:00 p.m., activity begins to decrease, returning to baseload levels at 7:00 p.m. In September, operations returned to pre-summer activity levels. The winter break in December is clearly visible as baseload and peak loads significantly decrease during the last week of December. It is worth noting that equipment was operating between 8:00 a.m. and 10:00 a.m. during this period. The operating schedule should be reviewed to determine if this is necessary. Comparing baseload levels from January to mid-May and September to December, average baseloads experienced an increase of approximately 8 kW. Average baseloads observed from mid-May to August were like the January to mid-May period, at approximately 117 kW.

A high load, potentially attributed to external lighting, can be observed throughout the year. From January to February, this load begins at approximately 6:00 p.m. and is reduced at 10:00 p.m. Between March and May, the start of this load is gradually delayed, with the start time in May occurring at 9:00 p.m. In June, this load significantly decreased, and by mid-July, the load began to increase again, reaching its earliest start time in November and December at approximately 5:00 p.m.

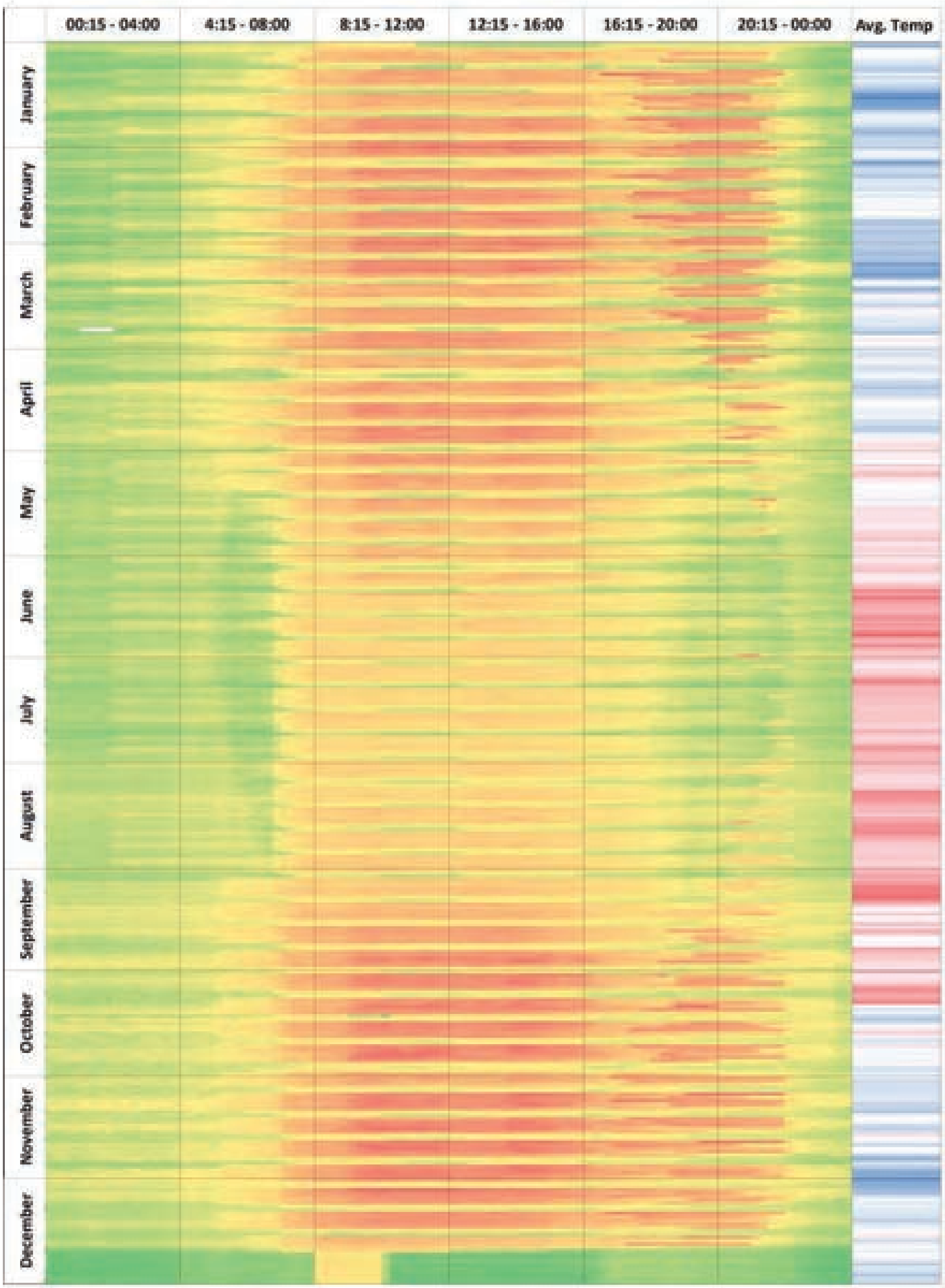

Figure 75: Blanchardstown Heat Map, 2023

Figure 76 below compares the average weekly half-hourly loads between the summer period and the in-class period for 2023. For this comparison, the summer period consists of June to August 2023, while the in-class period includes January to May and September to December 2023.

During the in-class period, the highest loads are observed on Wednesdays between 10:00 a.m. and 2:00 p.m., reaching 330 kW. In the figure below, a second peak is clearly visible between 7:00 p.m. and 9:00 p.m., which is approximately 80% of the peak loads observed between 10:00 a.m. and 2:00 p.m., potentially due to external lighting. During the summer period, loads begin increasing slightly later, with the highest average load observed on Thursdays at 1:00 p.m. at 212 kW. When comparing baseloads and weekend loads between the two periods, Saturdays during the in-class periods experience slightly higher loads, while baseloads are similar between the two periods.

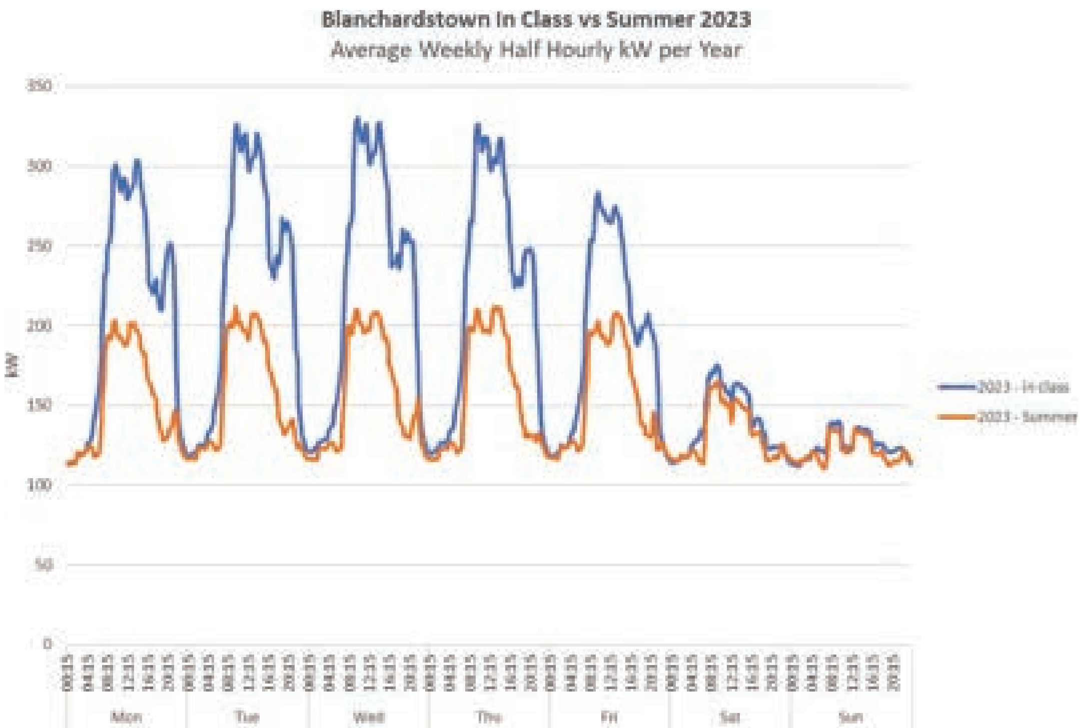

Figure 76: Blanchardstown in Class vs Summer Average Weekly Half Hourly kW per Year

7.5. Gas Consumption

Quarter-hourly gas metering data was available for the main skid meter point at Blanchardstown, as this group of buildings has a Quarter-Hourly (QH) meter on site. This data is collected by the Office of Public Works (OPW). Figure 77 below shows the hourly load profile from January 2019 to December 2019. This period was selected as it was the only year available with complete data.

In January, the peak gas load began to increase, reaching a maximum of 2,150 kW in March, which was the highest observed load in 2019. Gas consumption then steadily decreased, reaching a load of 65 kW in late July. In August, the peak load experienced a significant increase to 450 kW before steadily rising to 1,565 kW in mid-December. The winter break is visible during this period, with peak loads decreasing to 75 kW. On December 31st, a large spike was observed as the peak load increased to 1,670 kW.

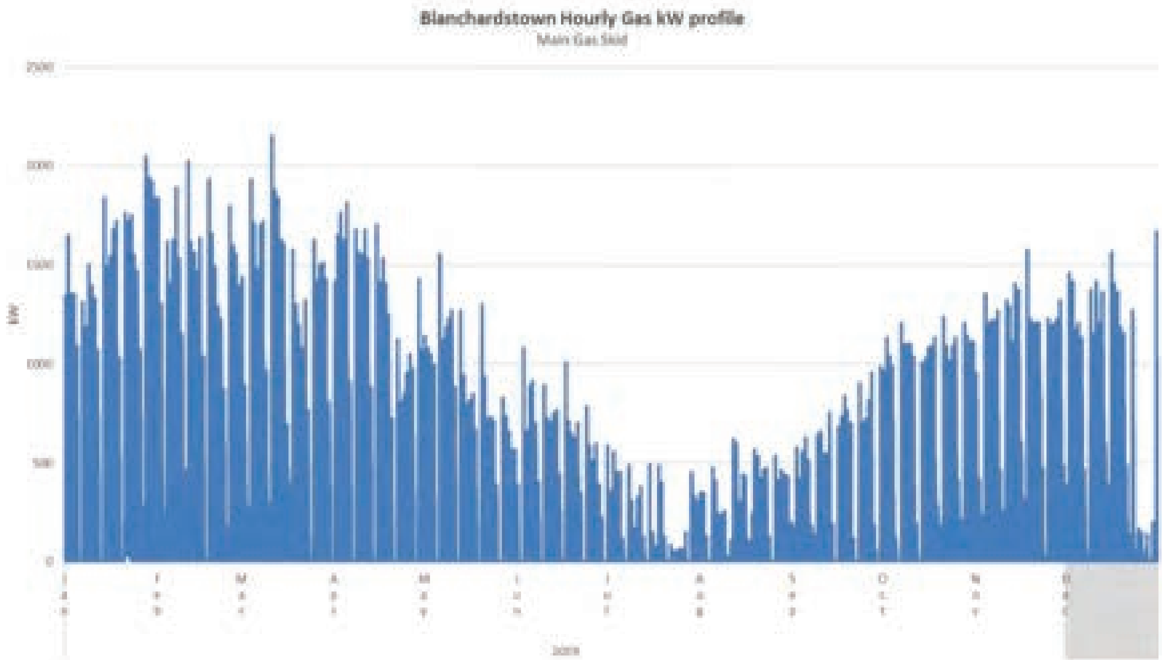

Figure 77: Blanchardstown Hourly Gas kW Profile 2019

Figure 78 below shows the 2019 heat map for the Blanchardstown campus. In general, the site is well controlled. From January to June, activity begins at 6:00 a.m., reaching its peak at 7:00 a.m., and then gradually decreases to zero by 10:00 p.m. During July and August, activity is delayed by an hour, starting at its peak load at 7:00 a.m. and gradually decreasing to zero between 8:00 p.m. and 10:00 p.m. In September, operations return to the January to June schedule. During the winter break, a large load was observed on December 31st and should be investigated. Additionally, during six days in January and February, the load did not return to zero between 10:00 p.m. and 6:00 a.m. On these days, the out-of-office load remained at approximately 30 kW.

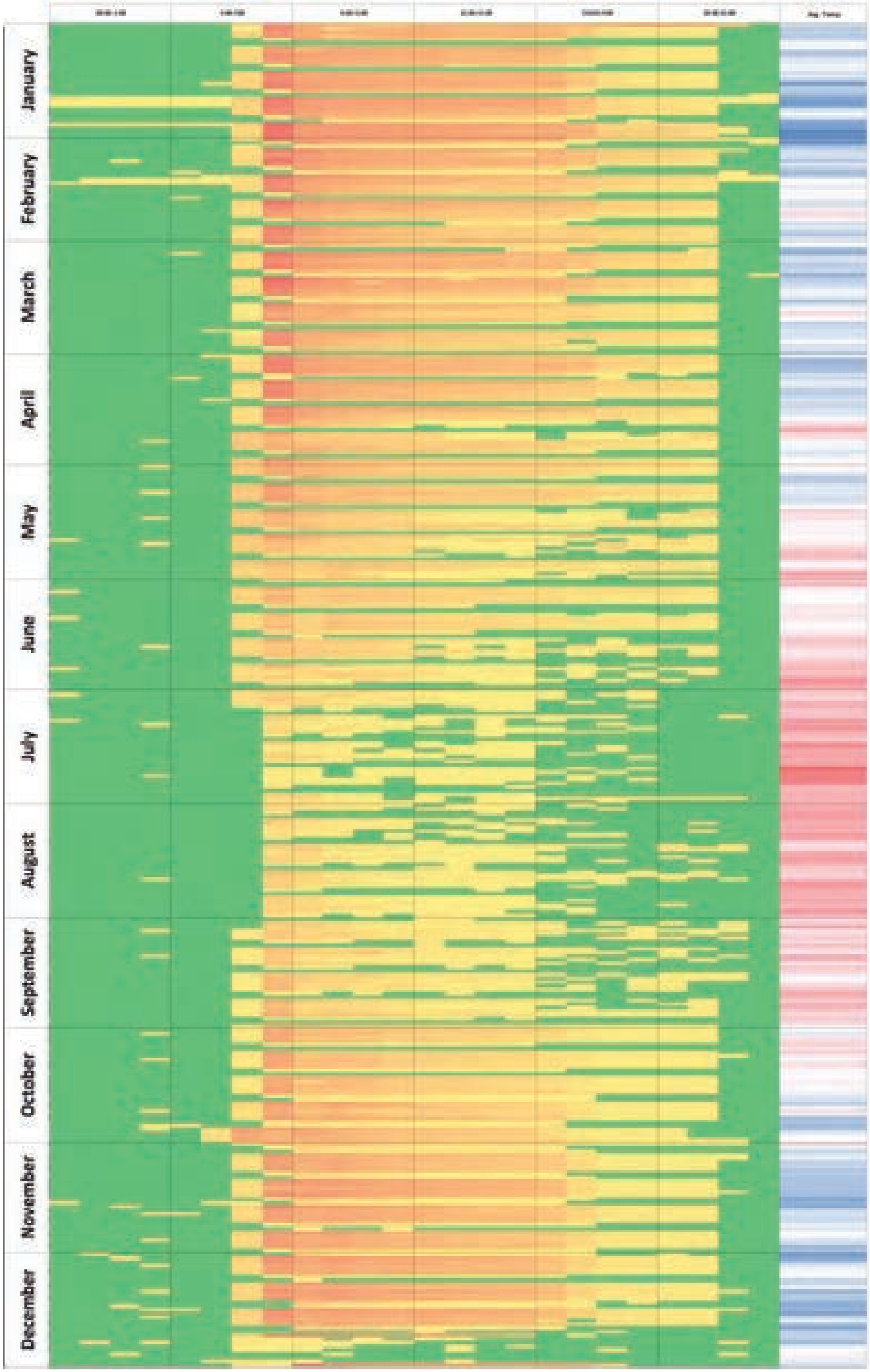

Figure 78: Blanchardstown 2019 Gas Heat Map

Figure 79 below compares the average weekly hourly gas loads between the summer period and the in-class period for 2019. For this comparison, the summer period consists of June to August 2019, while the in-class period includes January to May and September to December 2019.

During the in-class period, the highest average load is observed on Mondays at 7:00 a.m., with peak loads from Tuesday to Friday reaching 1,200 kW at 7:00 a.m. Weekend loads experience a significant decrease, with Saturdays peaking at 640 kW at 9:00 a.m. and Sundays reaching 65 kW at 9:00 a.m.

The loads during the summer period are lower than those observed during the in-class period but follow a similar trend. The highest load of 620 kW is observed on Mondays at 7:00 a.m., with Tuesday to Friday loads reaching up to 465 kW. Although the loads have significantly decreased during the summer period, they are still approximately 40% of the in-class period loads. The level of heating required during the summer period should be investigated to ensure that heat is not being wasted.

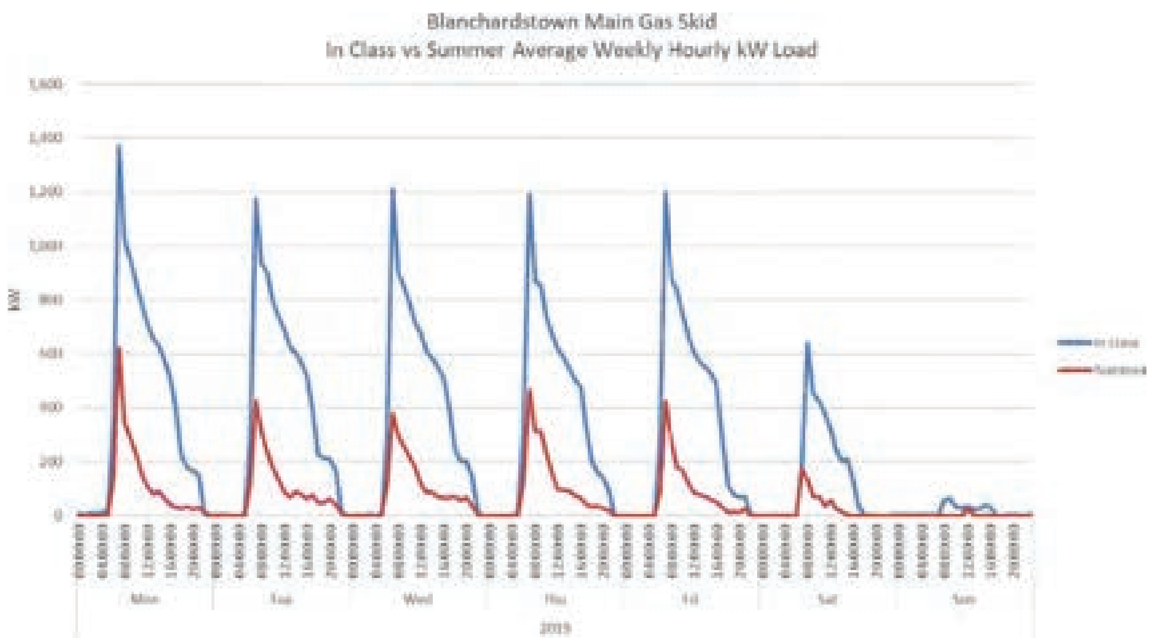

Figure 79: Blanchardstown in Class vs Summer Average Weekly Hourly kW Loads

7.6. Demand Reduction Opportunities

The following section will cover opportunities for improvement. The opportunities have been gathered through discussion with professional staff, the above electricity and gas profile analysis and campus walk throughs. The following are suggestions that require additional feasibility assessments to assess full viability and are solely based on the available information.

BMS and Metering

Building management and metering systems across the three campuses would benefit from improvements in functionality and data collection, particularly at the Blanchardstown campus. Enhanced collection and storage of this data will enable a more in-depth review of energy consumption at the building level. This, in turn, will facilitate the identification of underperforming buildings or specific equipment within a building. Additionally, it will allow for comparisons between buildings and help identify further areas for improvement.

A metering plan will provide data to investigate opportunities for optimisation and monitor changes in performance at a building level. Additional metering should be considered for equipment with high energy consumption. Utilizing the Building Management System (BMS) along with additional energy meters will enable real-time monitoring to identify issues as they occur. Improved management of the BMS will also lead to better equipment scheduling and more effective control strategies.

External Lighting Upgrades

Based on the above load analysis, external lighting has a significant impact on energy demand, particularly in the Blanchardstown load profile. An inventory of all external lighting assets should be documented across all three campuses. An external LED lighting retrofit plan should be developed to replace older and less efficient lighting types. The LED retrofit plan could include additional control measures, such as dimming external lighting between midnight and 6:00 a.m. Based on the load profiles of the sites, it is assumed that significant savings could be achieved by reducing external lighting loads.

Internal Lighting Upgrades

During the site walkthrough, it was observed that many light fittings within the campus buildings still contained T8 fluorescent lamps, particularly in the Tallaght main building. Substantial savings can be achieved by replacing these with LED alternatives. A 50% reduction in lighting loads can be achieved by replacing T8s with LEDs. It was also noted that many of the rooms contained an excessive number of light fixtures and were over-lit. A full lighting redesign should be considered, especially in the Tallaght main building.

Out of Hours Loads

In the load profile analysis, it was observed that there is a substantial baseload, indicating that some equipment may be left on overnight. This is most noticeable in Grangegorman, which has a substantial baseload of 600 kW during out-of-hours periods. Installing metering on essential out-of-hours equipment will help identify the scale of the issue. By metering necessary nighttime loads, such as server and lighting loads, unnecessary loads can be quantified. This will help determine the required effort needed to identify and reduce these unnecessary loads.

Scheduling

In Tallaght, loads begin to increase at approximately 5:00 a.m. The timing of equipment operations should be investigated to determine if it is necessary for schedules to begin at that time. Additionally, some campuses were operating until 11:00 p.m., which may not be required. Equipment scheduling should be reviewed to assess if adjustments can be made to reduce operating hours.

Space Optimisation

During the site walkthroughs, which took place during the summer period, it was observed that some buildings had very low occupancy. Low-occupancy buildings should be closed during the summer, with staff relocated to buildings with higher occupancy, thereby reducing the number of buildings in operation. Floor space in buildings should be evaluated to identify areas or floors that can be shut down during the summer period.

Occupancy Sensors

During the site walkthrough of the Tallaght main building, it was observed that lighting and mechanical ventilation was left running in some of the lecture rooms whilst unoccupied. Occupancy sensors placed in hallways and lecture halls will reduce energy consumption and ensure automatic shutoff of internal lighting and mechanical ventilation when not in use. Additionally, occupancy sensors may be coupled with daylight sensors, but will which can adjust lighting levels based on the availability of natural light, improving energy efficiency and improving internal conditions for students and staff.

Communication & Behaviour Campaigns

TU Dublin has implemented two major behavioural campaigns to reduce energy consumption across all campuses: Reduce Your Use (RYU) and the Switching Off campaign, both of which have seen some success. RYU is a joint initiative between SEAI and the Office of Public Works that supports public bodies in running winter energy awareness campaigns and taking actions to reduce heating, lighting, and operating hours. This campaign focuses on energy use from October to March, comparing usage to the same period 12 months prior. Through RYU, opportunities are identified, baselines and goals/targets are set, and staff engagement materials are provided, which can be found on SEAI's website. Actions required to achieve the goals/targets are identified and implemented during this period. Once the recommended actions have been implemented, progress should be monitored, and results communicated to staff. After the RYU period, an overall report should be conducted and shared with management and staff.

TU Dublin's Switching Off campaign targeted students and staff, encouraging them to switch off non-essential equipment and appliances during extended periods of absence, such as bank holidays, summer holidays, and Christmas. Actions in this campaign included switching off computers, monitors, printers, cold storage appliances, and laboratory equipment. Moving forward, this campaign could explore the potential of shutting down entire buildings during longer periods of reduced activity. During the summer break, where possible, staff could be temporarily grouped into fewer buildings, allowing emptied buildings to be shut down for the summer.

This strategy would reduce the number of buildings that need to be monitored and may significantly impact summer energy loads across the organisation.

The main issue with both campaigns when they were previously undertaken was the lack of a reliable way to quantify and disseminate the impact of the campaigns across various buildings due to inadequate metering. Improving metering across the campuses and utilizing displays in each building to show relevant energy and emissions content will significantly increase the impact of these campaigns. Combining and implementing the campaigns into a single set of targets may also simplify the goals for staff and students. Additionally, creating custom graphics to display relevant information will be necessary when combining multiple campaigns.

Creating a communication pathway between academic staff/students and professional staff for collaboration and feedback could significantly reduce energy consumption. Effective communication will enhance engagement and awareness of ongoing campaigns and best practices. Clear communication pathways will also enable collaboration on energy-saving projects by incorporating campus building data into coursework, providing students and academic staff the opportunity to contribute insights and new ideas.

Regular feedback through reports or digital noticeboards will enable students and academic staff to observe the effectiveness of their energy-saving activities and campaigns. Additionally, providing a method for receiving feedback from students and academic staff—such as a suggestion box or an online portal—will assist in identifying opportunities for improvement and potential issues.

8. APPENDICES

8.1. Appendix A – Heat Energy Analysis

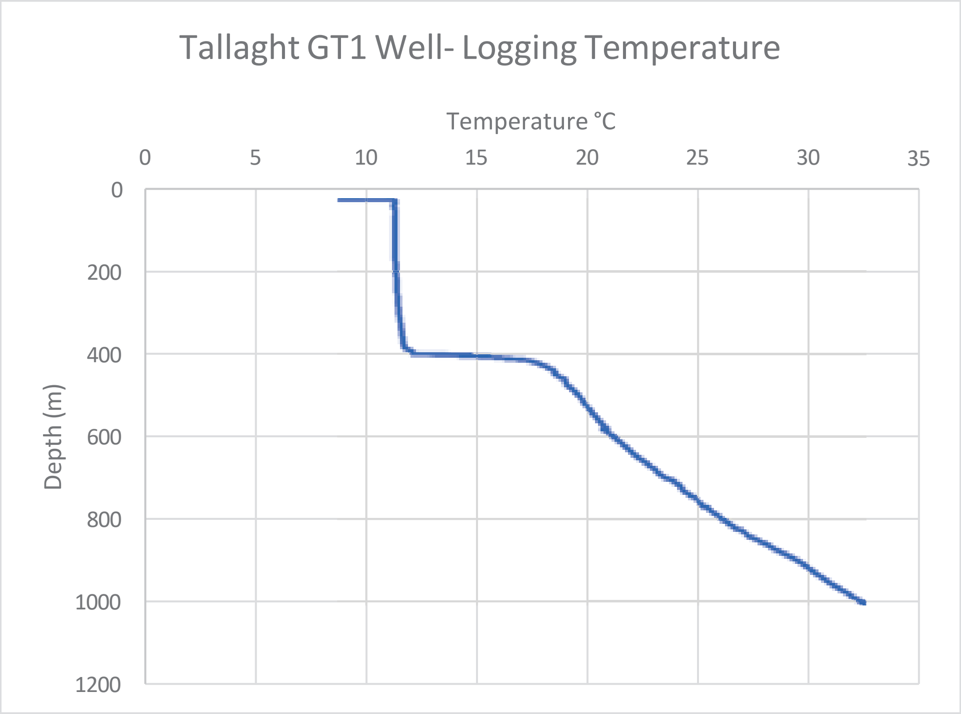

Figure 80: Tallaght Geothermal Borehole Results

Civils	⌀ mm	Length m	Cost ¤	Cost ¤/m	Losses Wh/yr	Capacity W
Hard (default)	40	52.08	37.18 k	714	9.11 M	118 k
Hard (default)	50	7.21	5.43 k	754	1.45 M	232 k
Hard (default)	65	77.44	62.81 k	811	17.37 M	496 k
Hard (default)	80	165.15	148.47 k	899	39.59 M	833 k
Hard (default)	100	62.73	81.24 k	1.3 k	16.72 M	1.44 M
Hard (default)	125	85.9	98.78 k	1.15 k	24.44 M	2.22 M
Hard (default)	150	65.9	85.01 k	1.29 k	19.73 M	2.7 M
Soft	40	126.49	71.46 k	565	22.17 M	118 k
Soft	50	125.32	75.57 k	603	24.14 M	187.92 k
Soft	65	216.96	140.81 k	649	45.9 M	299.25 k
Soft	150	84.8	74.87 k	883	25.39 M	2.7 M
All		**1.07 k**	**881.65 k**	**823.99**	**246.02 M**	**2.7 M**

Figure 81: Blanchardstown DH Network, THERMOS Costs

Figure 82: Grangegorman Boiler & District Heating Connections

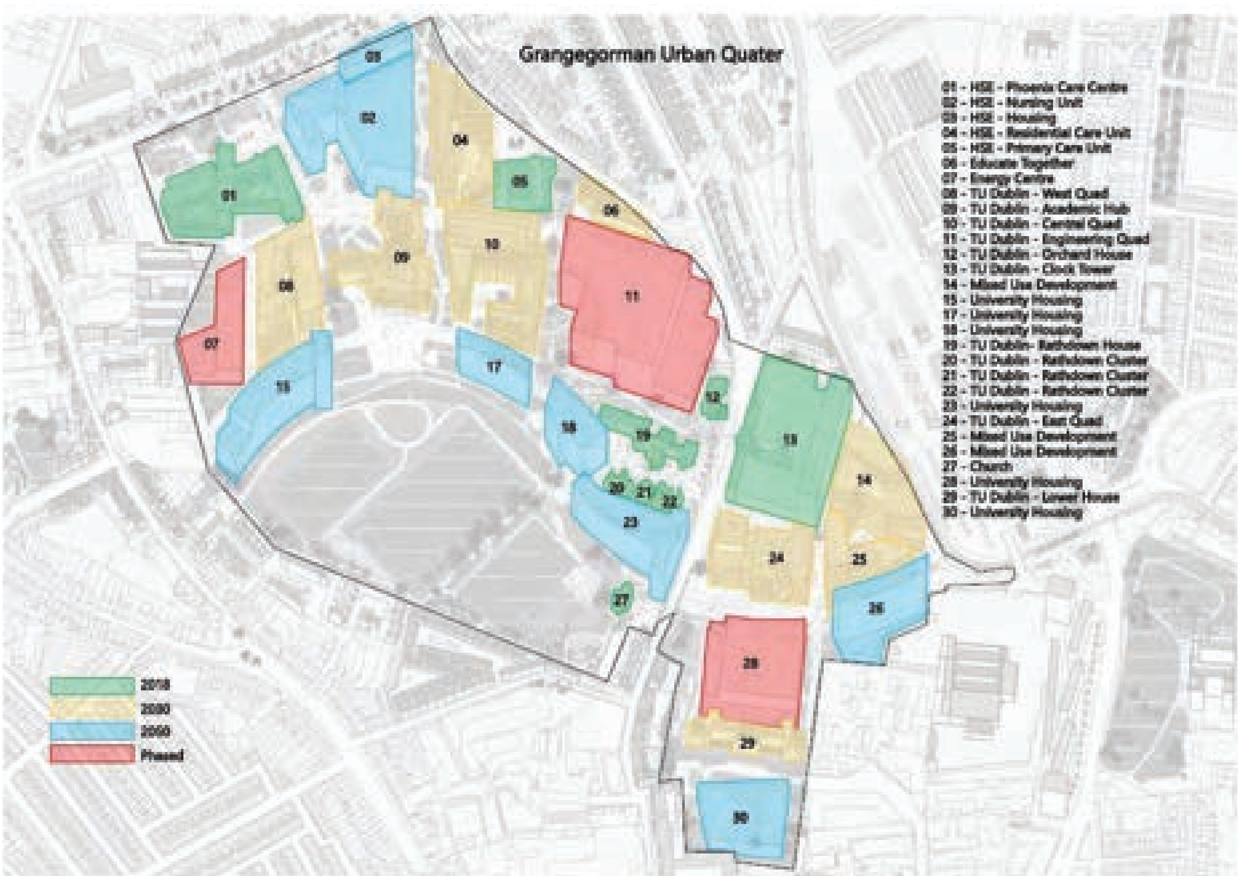

Figure 83: Grangegorman Urban Quarter, Phased Building Schedule

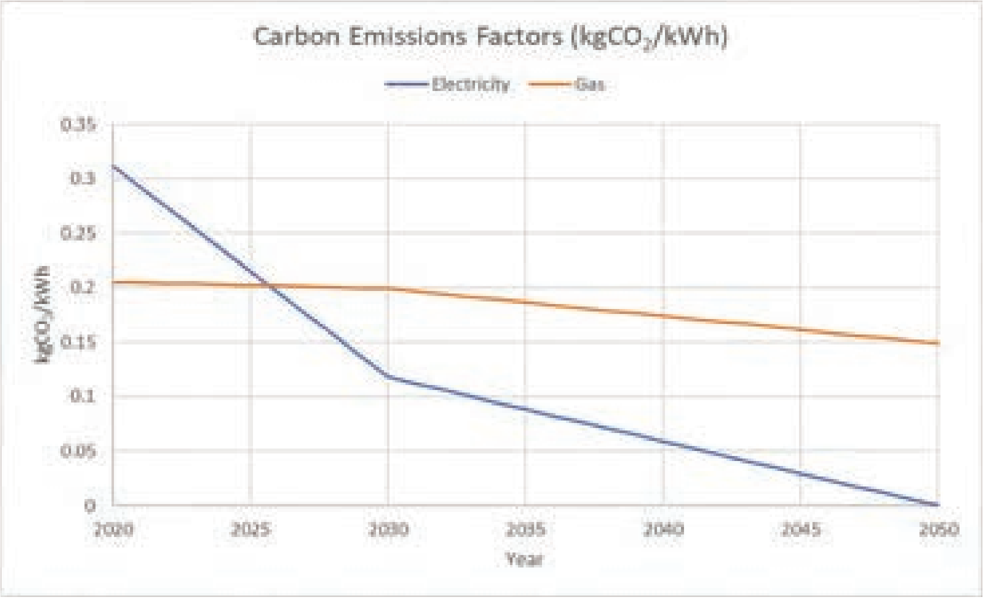

Figure 84: Projected Electricity Grid and Gas Carbon Emission Factors, DREM.

8.2. Appendix B – nPro Financial Inputs

The energy models created for each campus have been used to estimate the capital costs, operational costs, and potential savings for each opportunity identified. A detailed explanation of the financial analysis methodology is available on the nPro website[30]. Each financial appraisal assumes that:

- NPV and IRR calculated for 25 years. Discount rate of 4% and Inflation rate of 0%.
- There are no costs of capital, i.e., no loan interest repayments necessary.
- The systems are operated on a cost recoverable basis, and any annual profit is used to pay back investments or re-invested in system improvements.

The capital & operational costs for each system (€/MW) are derived from the technology catalogues which are produced and updated regularly by the Danish Energy Agency (DEA)[31]. The costs have been inflated in some cases to 2023 figures. This catalogue also provides information on technical lifetime (years), construction time (years), and space requirement (1000m2/MW) which are all considerations for techno-economic comparison. These have been cross-referenced against other sources of costs from the UK and limited cost sources from Irish projects (including the Tallaght DH Scheme which was constructed in 2022) to ensure they are in-line with other project cost estimates. These costs have been applied to each of the scenarios outlined in the technical section above to determine cost optimal systems.

The Net Present Value (NPV) is calculated over a 25-year lifetime. In some cases, the energy plant lifetime is less than this period, so a sinking fund is included in the analysis for full replacement of plant in this instance. The lifetime of some infrastructure is much longer (40-50 years) and so this element of the investment has a longer window for recouping costs and does not require a sinking fund within the investment lifespan.

Unfortunately, the technology catalogue is not an exhaustive list of technical and cost parameters, so in some scenarios cost information is derived from additional sources. The thermal store costs and information are derived from the Poolbeg Sector Integration study[32] released earlier this year. The battery costs are taken from the nPro economic parameters[33]. The capital cost of the individual heat pump option was calculated using a figure of €1,200/kW thermal output taken. This figure assumes air source heat pumps (air to water) are fully installed including fittings, buffer tank, new cylinder (existing cylinders are not deemed compatible with efficient heat pump operation due to the relatively small surface area of their coils) and controls but excluding the heat distribution system. Fabric upgrade costs, which are often significant, have also been excluded from the counterfactual capital costs. Excluding the distribution system and any fabric upgrades required in domestic settings may mean the cost estimate for an efficiently operating ASHP system may be slightly underestimated in some cases.

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[30] nPro Economic Calculation
[31] DEA technology catalogue
[32] Poolbeg Sector Integration
[33] nPro economic parameters

Table 41: Financial and Technical Modelling Parameters

Energy Plant	Nominal Investment (€m/MW)	O&M (% Investment)	Technical Lifetime (years)	Space (1000m2/MW)
Deep Geothermal	3.64	3%	50	5
Shallow Geothermal	1.891	3%	50	7m^2 per borehole
WSHP (Heat Recovery)	1.083	2.50%	25	0.5
Individual ASHP	1.2	2.50%	15	1
Gas Boiler	0.07	3%	20	Not available
Electric Boiler	0.19	3%	25	Not available
Thermal Store	700 (€/m^3)	1%	50	2-7 (m^2/MWh)
Battery Store	800 (€/kWh)	1%	10	Not available
PV Installation	0.87	1%	35	Not available

For all capital costs inputted into the model, lump sum costs are added as a percentage of the investment and are summarised as follows:

- Planning costs: 10 %
- Delivery, installation, commissioning: 10 %
- Measurement and control technology: 15 %

Fuel costs are based on unit costs for electricity and gas. The fuel cost is based on the SEAI's latest (July 2024)[34] commercial fuel costs and is applied to the annual MWh of day/night rate electricity consumed by the energy plant during normal operation.

[34] SEAI Fuel Cost Comparison

8.3. Software Programmes

nPro

nPro is a design software that optimises system configurations for a variety of energy systems, including district heating networks. nPro allows for the simulation of different scenarios at a building or network level and allows a user to conduct comparative analysis on the efficiency, operation, and profitability of different scenarios. nPro has been used to develop the campus level building models for the Grangegorman, Tallaght, and Blanchardstown campuses.

THERMOS

Thermos is an energy-planning software that was developed as part of the EU THERMOS H2020 project that seeks to accelerate the development of low carbon heating and cooling networks across Europe and to improve existing systems. The THERMOS tool allows a user to identify optimal routes and connections for creation or expansion of a district heating network.

Open Solar

Open Solar is a solar design software that allows a user to analyse the optimal size of a solar array on a building by inputting electricity consumption data of the building and then modelling a solar PV array on the rooftop of the building. Open Solar is programmed to calculate the projected irradiance of the proposed array based on the location and orientation of the building and the system being modelled. Comparison of the daily/monthly solar electricity generation and the electricity consumption for the same period can then be carried out to determine the optimal array size, location and orientation to maximise self-consumption of electricity.