Murdoch University

The Murdoch University Decarbonisation Roadmap

Our Pathway to Achieving Net Zero Operational (Scope 1 & 2) Emissions by 2030, Carbon Positivity (Scope 1 & 2) by 2035 and Net Zero Scope 3 Emissions by 2050.

Contents

1 Introducing the Decarbonisation Roadmap

This Decarbonisation Roadmap is a comprehensive plan for the university's carbon reduction efforts. Building on the insights from the 2022/2023 Scope 1 and 2 Emissions Inventory, a comprehensive analysis of key initiatives was undertaken, evaluating their feasibility, potential impact, and integration into the university's infrastructure. The development of the roadmap was based on robust stakeholder engagement, which involved senior leadership members, the Properties and Campus Development teams, technology working groups from the university's academic departments, and potential industry partners.

The roadmap outlines a realistic and implementable strategy that aligns with the university's sustainability goals, ensuring a clear and actionable pathway to campus decarbonisation. The focus of this roadmap is Murdoch University's South St. Campus, which contributes approximately 87% to the university's total Scope 1 and 2 emissions, making it the most appropriate target for decarbonisation efforts at this stage.

This document introduces a series of projects that collectively form the Decarbonisation Program of Works, which provides a strategic framework for organising, prioritising, and executing multiple projects that contribute to the university's decarbonisation objectives. Each project focuses on a specific aspect of reducing carbon emissions or improving sustainability, such as developing a campus-wide energy management system, installing solar panels, upgrading and electrifying heating, ventilation and air conditioning (HVAC) systems, and exploring carbon sequestration opportunities.

The Decarbonisation Roadmap will enable us to meet our decarbonisation commitments outlined in the university's *Moorditj Boodja – Strong Country* Sustainability Sub-Strategy (*Moorditj Boodja* Sustainability Strategy) and accompanying Implementation Plan.

2 Decarbonisation Vision and Targets

As outlined in the *Moorditj Boodja* Sustainability Strategy, we are committed to achieving Net Zero emissions across Scope 1 and 2 by 2030, guided by the principles of the Science Based Targets initiative (SBTi), an internationally recognised Net Zero framework. Our approach prioritises reducing Scope 1 and 2 greenhouse gas (GhG) emissions by at least 90% by 2030 through innovative technologies, energy efficiency measures, and organisation-wide environmental stewardship. After achieving this substantial reduction, we will address any residual emissions either through carbon removal solutions (for Scope 1 emissions) or green power purchase agreements (for Scope 2 emissions) with a view also to reach carbon positivity for Scope 1 and 2 by 2035.

To drive this ambition forward, we will leverage our university's strengths by establishing Living Laboratory initiatives, transforming our campus into a dynamic testing ground for emerging environmental technologies. This collaborative approach not only elevates our commitment to sustainability but also contributes to the broader body of knowledge, fostering a culture of continuous improvement.

Recognising the broader impact of our supply chain and indirect emissions (Scope 3), our dedication extends to a comprehensive decarbonisation strategy to achieve Net Zero Scope 3 emissions by 2050 in alignment with the recommendations of the Paris Agreement. Through analysis and mitigation across our value chain, we aim to address the full lifecycle of our business, fostering innovation in the pursuit of a sustainable and resilient future.

3 Existing Campus Infrastructure

The Murdoch University South St Campus relies on a mix of centralised and distributed systems for its heating, and cooling needs. The campus is connected to the South-West Interconnected System (SWIS) for electricity, supplied through Alinta Energy. Two Western Power meters on the eastern side of the campus at Murdoch Drive serve as the main connection points. The university has also installed over 200 sub-meters across the campus, primarily for monitoring specific assets or asset groups, though their capability for granular monitoring within buildings is currently limited. The campus' heating and cooling requirements are met by a combination of centralised and distributed HVAC systems. The significant HVAC asset types, locations and fuel types are listed in Table 1 and summarised below.

The centralised chiller system, in the form of two 4200 kW electric absorption chillers and three cooling towers, provides a substantial proportion of the campus cooling demand via a chilled water distribution network across the campus. There is an additional absorption chiller located at B265, which has reportedly been used as a backup in some maintenance situations. Capacity and long-term plans for this unit are unknown. The remaining cooling demand is met by over 600 distributed reverse cycle/split systems. Heating demand is met by a combination of the reverse cycle units and 4 gas-fired space heating units. Hot water demand is met by over 160 instant or storage water heaters. There is a mix of electric and gas units, and around 10 solar powered units.

TYPE	LOCATION	FUEL	QUANTITY	TOTAL CAPACITY (kW)
Chilled Water Cooling	Centralised	Electric	2 (+1 reserve)	8200 (+2500 reserve)
Reverse Cycle/Split Systems	Distributed	Electric	660+	Unknown
Domestic Hot Water	Distributed	Electric	70+	Unknown
		Gas	90+	~3700
Space Heating	Distributed	Gas	4	1950

Table 1: South St Campus main infrastructure assets

Renewable energy systems on the South Street campus include two main Solar Photovoltaic (PV) installations and various test and research facilities, as listed in Table 2 below. The rooftop PV currently operating on Building 350 will be decommissioned in 2025 due to age, however, the university's overall capacity will be increased by the largest array, a 450 kW system on Building 360, which will become operational in 2025 following an upgrade of the high voltage network. Once these works are complete, the total capacity will increase from the current 62.7 kW to 456.7 kW.

TYPE	LOCATION	CAPACITY (kW)	STATUS
Solar PV	Building 360, rooftop	450	Installed, not yet commissioned Pending HV Upgrades
Solar PV Building	350, rooftop	56	To be decommissioned in 2025
Solar PV	Building 220, rooftop	6.7	3 PV systems installed and operational 1 system non-operational
Various Trial/Test Technologies	Building 190, rooftop & Outdoor Test Area	0	Not currently operational, re-work underway

Table 2: South St Campus Renewable Energy Systems

The campus's centralised space cooling system is managed through a Building Management System (BMS) that operates on time-scheduled controls. Opportunities have been identified to incorporate occupancy-based control systems, which could enable more responsive and intelligent building operations. Additionally, the implementation of a comprehensive strategy for monitoring and tracking energy use and emissions presents an opportunity to enhance data-driven decision-making in our energy management approach.

4 Scope 1 and 2 Emissions Baseline

Murdoch University has established a comprehensive Scope 1 and 2 emissions inventory for the 2022-2023 financial year, serving as the GHG Baseline against which future emission reductions will be measured and reported. This baseline has undergone review and received Limited Assurance from RSM Australia Pty Ltd, ensuring its credibility, robustness and accuracy.

The emissions inventory was developed using the internationally recognised GHG Protocol, which provides a standardised framework for quantifying and managing GhG emissions. This methodology categorises emissions into Scope 1 (direct emissions), Scope 2 (indirect emissions from purchased energy), and Scope 3 (indirect emissions from the value chain). The inventory covers all facilities and activities under Murdoch's operational control, encompassing 12 facilities across Western Australia, Singapore, and Dubai. While our decarbonisation efforts are focused on reducing emissions across Scopes 1 and 2, *Moorditj Boodja* Sustainability Strategy also outlines plans to address key contributors to Scope 3 emissions.

The total of Scope 1 and 2 emissions across all Murdoch facilities for the 2022-2023 financial year amounted to 12,502 tCO2-e. As illustrated in Figure 1, the main South St campus is the dominant contributor, accounting for 87% of total emissions. This significant proportion underscores the importance of focusing decarbonisation efforts on the South St campus, while not neglecting other facilities in the overall strategy. We will continue to monitor and report on emissions emanating from all Murdoch facilities and seek to eliminate, reduce or offset these emissions.

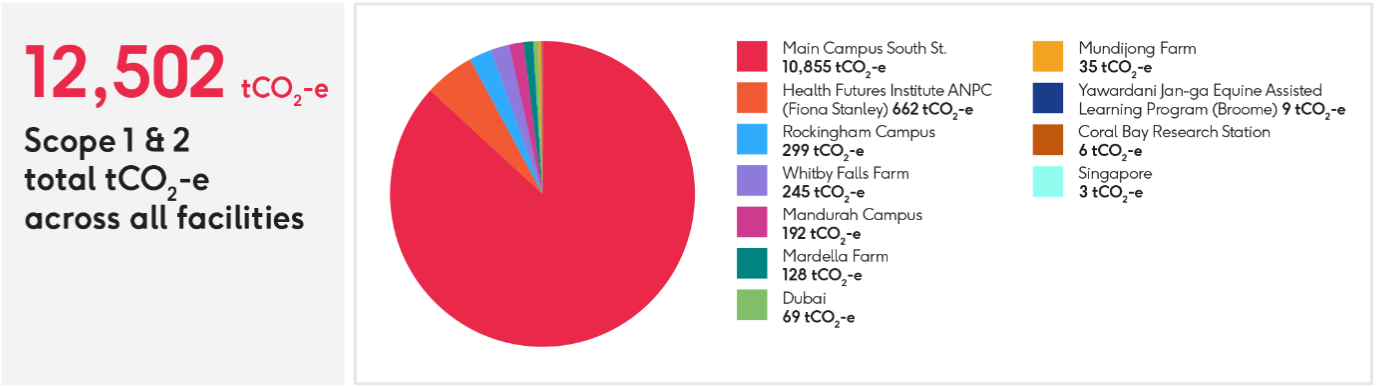


Figure 1: Murdoch University total GHG emissions by facility FY 2022-2023

As illustrated in Figure 2, the university's South St campus operational emissions of 10,855 tCO2-e are categorised into Scope 1 and Scope 2 emissions. Scope 1 emissions, which are direct emissions from sources owned or controlled by the university, total 1,806 tCO2-e. These primarily come from stationary combustion (e.g. natural gas for heating and hot water), with smaller contributions from mobile combustion (e.g. gasoline and diesel), agriculture (e.g. animals) and fugitive emissions (e.g. refrigerants).

Scope 2 emissions, which are indirect emissions associated with purchased electricity, significantly outweigh Scope 1, amounting to 9,049 tCO2-e. This clearly indicates that purchased electricity is the dominant source of GhG emissions for the South St campus, accounting for 83% of the total South St campus emissions and 72% of emissions across the estate.

By providing this detailed breakdown, the baseline allows Murdoch University to identify key areas for emission reduction efforts. The significant proportion of emissions from purchased electricity at the South St campus suggests that strategies focused on renewable energy adoption and energy efficiency improvements could yield substantial results in the university's decarbonisation journey. This baseline serves as a crucial starting point, enabling the university to set targeted goals, measure progress, and ultimately chart an effective path towards Net Zero.

1,806 tCO_2-e

South St Campus Scope 1 emissions

9,049 tCO_2-e

South St Campus Scope 2 emissions

NB: individual figures have been subject to rounding.

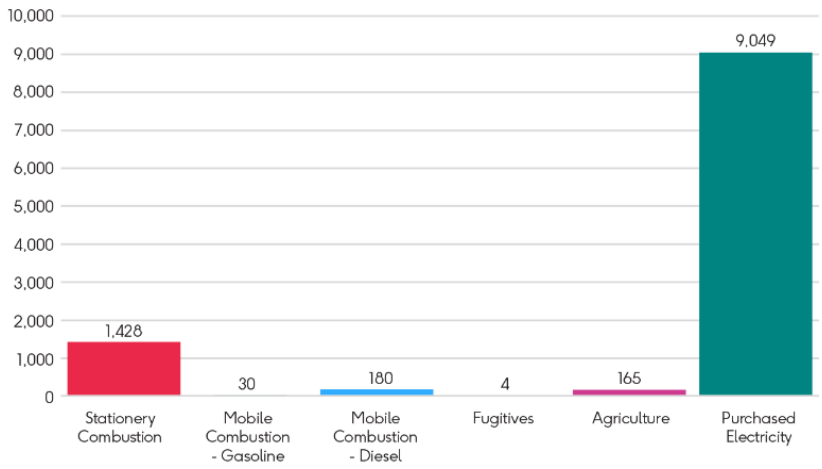


Figure 2: South St. campus emissions profile by source FY 2022-2023

5 Carbon Intensity

Carbon intensity factors are pivotal in comprehending and assessing the environmental impact of diverse activities and processes. These factors offer a standardised metric for measuring the volume of carbon dioxide (CO2-e) emissions linked to energy consumption or specific tasks. By assigning numerical values to emissions per unit of energy or activity, carbon intensity factors can facilitate comparisons across different energy and practices. Presented below are three key indicators tailored to the Main Campus: CO2-e emissions by gross floor area (GFA), by usable floor area (UFA), and by equivalent full-time student load (EFTSL). These indicators provide valuable insights into carbon intensity and opportunities for quantifying future emissions reductions.

FACILITIES	TOTAL SCOPE 1 & 2 GHG (Kg-$C0_2e$)	GFA (m^2)	UFA (m^2)	EFTSL	$KgC0_2$-e/ m^2 GFA	$KgC0_2$-e/ m^2 UFA	$KgC0_2$-e/ EFTSL
Main Campus South Street (Perth)	10,855,000	153,909	109,742	8,395	70.53	198.91	1,293.03

Table 3: Murdoch University South St Campus carbon intensity indicators ($KgCO_2$-e) FY 2022-2023

6 Decarbonisation Roadmap

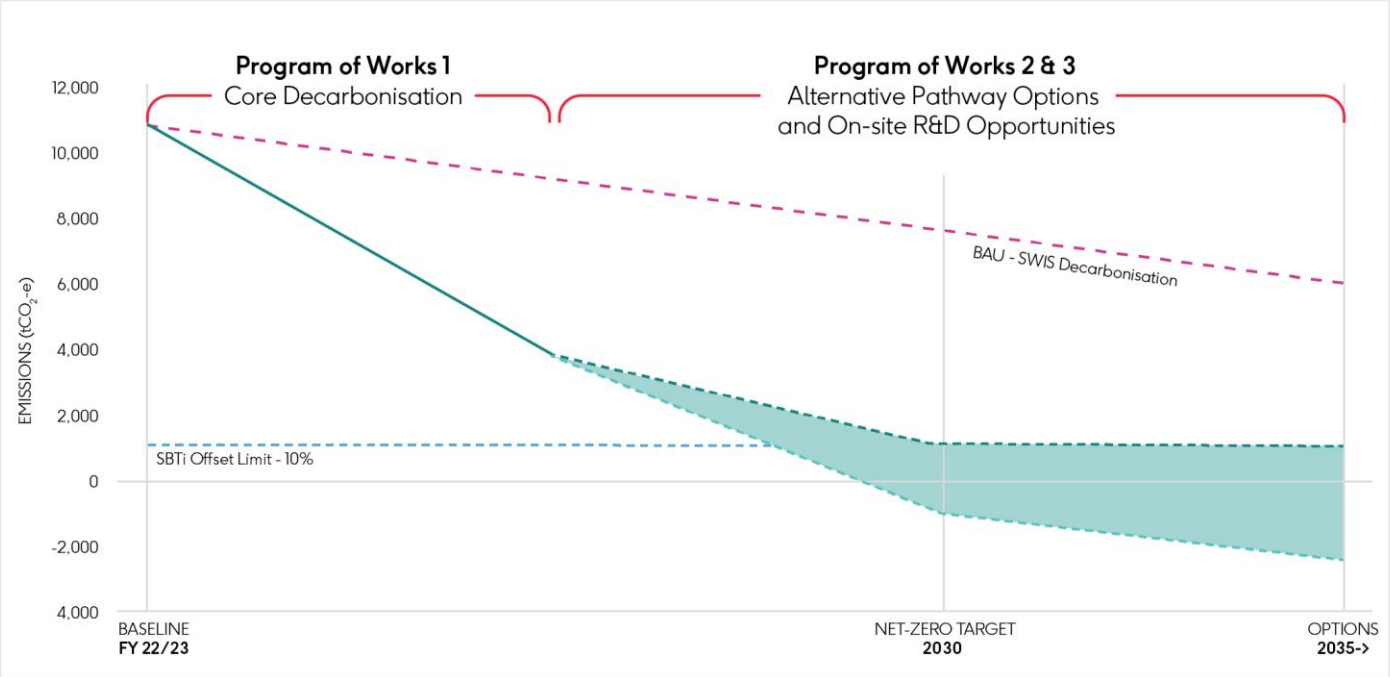
Murdoch University's decarbonisation approach is built on a foundation of core projects that form the essential backbone of any emissions reduction roadmap. These core initiatives represent the fundamental steps that the university will undertake regardless of future technological developments or policy changes.

Building upon this core strategy, the multiple potential pathways have been identified to further reduce emissions and ultimately achieve operational Net Zero carbon status. These pathways represent different combinations of technologies, strategies, and timelines that can be pursued based on factors such as technological maturity, cost-effectiveness, and alignment with the university's broader objectives.

This multi-faceted approach offers several advantages, including:

- Ensuring immediate progress through the implementation of proven, essential measures;
- Allowing for adaptability in response to emerging technologies and changing circumstances; providing decision-makers with options to tailor the decarbonisation journey to the university's evolving needs and resources;
- Facilitating a phased implementation, allowing for learning and optimisation at each stage; and
- Addressing all emissions, including those that are difficult to eliminate directly, providing a complete pathway to Net Zero.

The Decarbonisation Roadmap visualised in Figure 3, clearly delineates between the foundational efforts (Program of Works 1) and the flexible pathways for deeper decarbonisation and the strategies for addressing the most challenging emissions sources (Program of Works 2 & 3) to navigate potential challenges in the dynamic landscape of climate action and sustainability.



6.1 Program of Works 1 – Core Decarbonisation Projects

Core Decarbonisation refers to the essential projects, including enabling works, that form the backbone of the emissions reduction roadmap. These projects are fundamental to any decarbonisation pathway and will be implemented regardless of which additional strategies are chosen. They offer the potential to reduce GHG emissions by 38% from the baseline and provide the foundation for further emissions reduction efforts.

Importantly, the emissions reduction potential of these core projects is complemented by external factors including Western Power's commitment to increasing renewable energy in the South West Interconnected System (SWIS - electricity grid in South West Australia), which will further enhance the university's decarbonisation efforts. Core decarbonisation projects and their impact on emissions reductions from each source are outlined below and visualised in Figure 4.

6.1.1 Changes to Renewable Energy Mix in the SWIS

Western Power is pursuing a target of 60% renewable energy in the SWIS by 2030. This expected increase in renewable energy in the grid will result in an approximate 25.7% reduction in our own emissions.

6.1.2 Fleet Electrification

This project involves the upgrade of the University vehicle fleet from petrol and diesel vehicles to electric vehicles (EVs), and the installation of associated charging stations. This relies on adoption of a 100% EV fleet to eliminate the associated emissions and provide a complete transition away from their fossil fuel sources (in the short-term this will exclude off-road and farm verhicles as well as watercraft).

Key aspects of this project include:

- Fleet Electrification: A 100% rollout of EVs in the University vehicle fleet, implemented strategically as existing vehicles reach their end-of-life or lease renewal points. This phased approach ensures a smooth transition and optimal resource allocation.
- EV Charging Stations: The installation of charging infrastructure is crucial to support the EV fleet and promote wider adoption of electric vehicles.Suitable locations, equipment types (e.g., fast charging vs. slower 7.4/22 kW options), and quantities will be determined through analysis of vehicle use patterns and stakeholder needs. Additional charging stations will benefit university staff, students, and visitors, contributing to the reduction of Scope 3 emissions.

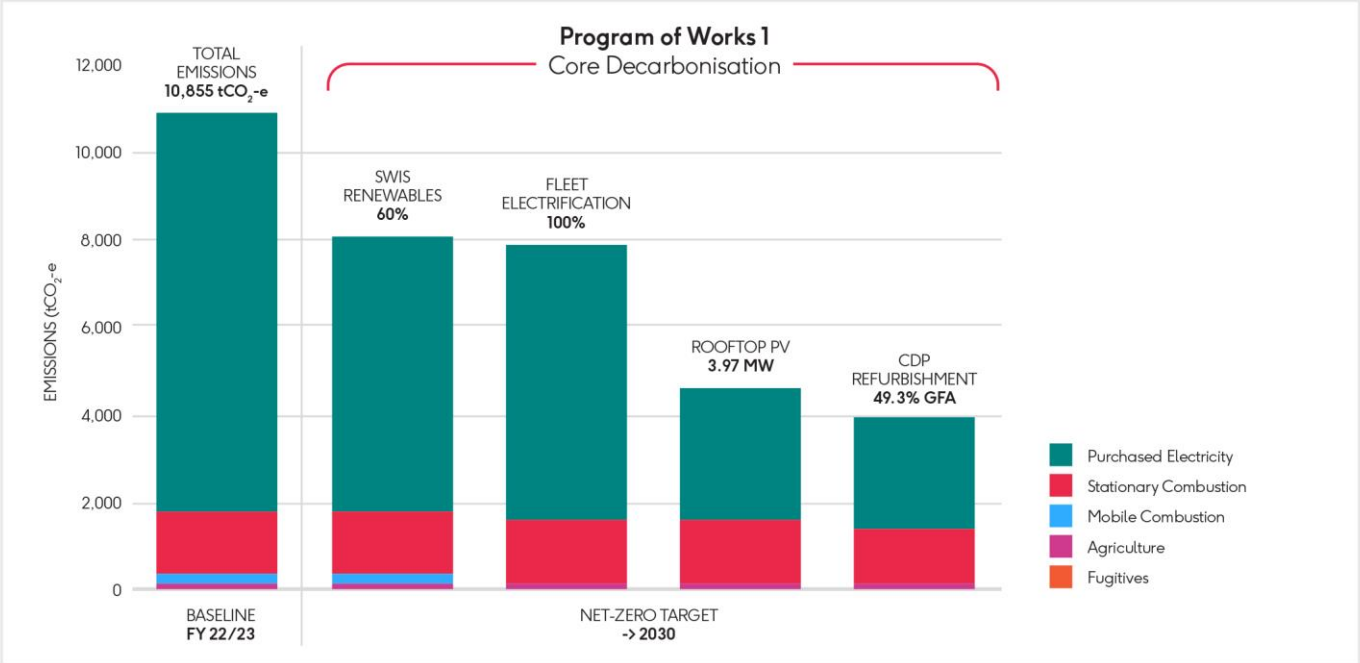


Figure 4: Core Decarbonisation Projects and Impacts on Emissions Sources

6.1.3 Rooftop Solar PV

This project involves the development of a large-scale solar PV system, which maximises the readily available rooftop availability, including construction of up to 3.52 MW of new rooftop solar PV capacity on a range of identified buildings at the South St Campus. Rooftop PV is reliant on structural assessment and can be affected by building limitations but is considered the lowest-cost option. This system is therefore intended to be a guideline of the largest readily achieved

and economic system, and considers PV placed on favourable rooftops with high likelihood of meeting the projected capacity.

Key aspects of this project include:

- 3.52 MW New Rooftop PV: Review and analysis identified a range of priority buildings on which new rooftop PV systems may be most economic, and can contribute up to 3.52 MW of new capacity on approximately 27,700m^2 of rooftops, including:
    - 1.36 MW PV on buildings with an existing structural assessment, including buildings 122, 245, 250, 260, 340, 354, 390, 440, 450, 460 and 490.
    - 1.66 MW PV on previously recommended but not yet assessed building rooftops, including building groups 551-557 and 730.
    - 0.5 MW of PV potential from buildings within the CDP Building Refurbishment Program which have not yet had structural roof assessment, including buildings 125, 127, 128, 235, 240, 330, 335, 341, 351, 430, 461, and 512.

A PV system at this scale could reduce the campus grid electricity consumption by up to 28%, delivering substantial emissions reductions.

Further detailed structural assessments, electrical system requirements, and other assessments will be required as part of the Campus Development Plan to validate the feasibility and upgrade strategy for using the buildings as suggested.

6.1.4 Campus Development Plan (CDP) Refurbishment

This initiative integrates energy efficiency measures and building electrification into the Campus Development Plan (CDP) refurbishment program. It ensures that as buildings are renovated, they are upgraded with energy-efficient systems and transitioned away from natural gas, a fossil fuel-based energy source.

Key aspects of this project include:

- Identification of 22 buildings for refurbishment by 2030, including B260, B250, B235, B240, B245, B340, B341, B335, B390, B490, B330, B430, B440, B351, B460, B461, B125, B127, B128, and B512. These buildings represent approximately 49.3% of the total gross floor area (GFA) on the South St campus.
- Energy audits conducted as part of this project will help pinpoint where efficiencies are more likely to be achieved, allowing for a more targeted and cost-effective approach to renovations. Key improvements to be considered include:
    - Installation of LED lighting;
    - Implementation of occupancy sensors;
    - Enhancements to insulation levels;
    - Replacement of leaky windows; and
    - Electrification of domestic hot water units and space heating equipment.

By systematically implementing these measures across the identified buildings, Murdoch University will significantly reduce its energy consumption, associated costs and GhG emissions. The Green Building Council of Australia (GBCA) notes that an average reduction of 30% in GhG emissions is expected from basic refurbishment of old building stock. This project not only contributes to the university's decarbonisation goals but also improves the overall comfort and functionality of campus buildings, potentially leading to increased productivity and well-being for students and staff. Reducing energy consumption also reduces renewable energy generation requirements.

Related to the CDP refurbishment program are upgrades to key energy infrastructure as an enabler for key decarbonisation projects. Key aspects of this project include:

- High Voltage (HV) Upgrades: These upgrades enable the large-scale adoption of solar PV systems across the campus, ensuring that systems meet relevant standards and barriers to system commissioning are minimised. HV upgrades can be aligned with CDP building refurbishments or other electrical works to maximise program efficiency.
- Submetering: Planning and installation of core equipment at building and specific asset-level, providing the foundation for system tracking and monitoring, as outlined below.
- Energy Tracking & Monitoring: Murdoch can enable more granular tracking of energy use and facilitate improved energy management through the implementation of energy monitoring systems linked with the submeter rollout and additional sensors and devices, as required, across the campus.

By planning and implementing the strategic rollout of these works, Murdoch can provide the framework for improved energy data visibility and efficient implementation of on-site solar PV, while also providing opportunities for energy management initiatives, predictive maintenance systems and potential cost savings.

These measures are also envisaged at regional campuses. An assessment of Rockingham will be a particular focus due to underutilisation and potential energy waste. An assessment of the Rockingham campus will include:

- Usage Assessment: Identify areas essential for current activities.
- Activity Consolidation: Relocate necessary functions to a concentrated area of the building.
- Zone Isolation: Close and seal doors to unused areas
  - Install temporary partitions if necessary
- Systems Adjustment:
  - HVAC: Modify or shut down in unoccupied zones
  - Lighting: Deactivate or install motion sensors
  - Plumbing: Disable hot water heaters in unused areas
  - Electronics: Unplug non-essential equipment in closed-off spaces
- BMS Reprogramming: Update to reflect new occupancy patterns and ensure efficient operation of active systems.
- Regular Monitoring: Implement periodic checks of closed-off areas to prevent issues like mould growth or pest infestations.

6.2 The need for further decarbonisation efforts

While the Core Decarbonisation projects (Program of Works 1) provide substantial emissions abatement, they leave a projected remainder of approximately 3,743 tCO2-e to be addressed. In this regard, the Programs of Works 2 and 3, as outlined below, could potentially tackle this remaining emissions gap both economically and with added research and reputational benefits.

6.3 Program of Works 2 - Alternative Pathway Options

Program of Works 2 - Alternative Pathway Options encompasses the various potential routes to further reduce emissions beyond the core strategy, including residual emissions management. It entails longer-term efforts requiring extensive research, collaboration with external partners, and the exploration of innovative technologies to achieve Net Zero operational emissions by 2030. The program's flexibility allows for adaptation to new technologies, changing circumstances, and emerging best practices in sustainable campus management.

The program entails:

- Energy research node
- Additional on-site solar PV
- Further electrification of space and water heating
- Residual emission management

6.3.1 Energy Research Node

This project involves design, planning and construction of a state-of-the-art interconnected energy node and microgrid system, which provides opportunity for energy research and collaborative development. The scope, size and scale of such a system is to be determined, in line with development of other strategies, but the proposed system will likely include:

- A microgrid system for both physical and virtual connection of various renewable energy modules and trial systems;
- Large capacity to accommodate a wide range of generation technologies and load types, and scope for multiple simultaneous research projects;
- Installation of electricity and energy storage systems to address intermittency of on-site solar PV systems; and
- Ease of access to data for visualisation and research purposes, and development of digital twins of the system.

Implementation of this flagship system will help promote Murdoch University to a leading position in energy studies and renewable energy technology developments. It can provide a basis for developing future technology systems that could contribute to Murdoch's emissions targets, as well as providing ample opportunity for industry collaboration, research advancements, educational opportunities, technology transfer and community engagement.

A full feasibility study will be undertaken to identify suitable size and scale of such a system and determine a suitable location.

6.3.2 Additional On-Site Solar PV

This project involves the expansion of the University solar PV system. While the Core Decarbonisation projects target the maximum PV for readily accessible and lowest-cost rooftop systems, this project revolves around implementation of additional PV in the form of either rooftop or ground-mounted systems, as required. Initial scoping work identified the potential of 1.33 MW of additional solar PV. Further analysis and development of preceding PV projects will inform the size and scale requirements for any system expansion.

Key aspects of this project include:

- 1.33 MW New PV: Review of the University's larger buildings that are not yet included in assessment or refurbishment plans provides a preliminary guideline of potential rooftops, including up to 20,933m^2 on buildings 121, 122, 161, 262, 350, 354, 415, 450, 541, 542, 543, 731, 735, 741, 892.
- There is also opportunity to implement an equivalent ground-mounted system, or a combination of both.

The addition of a PV system at this scale could reduce the South St campus grid electricity consumption by a further 6.3% up to a total of 34.3% when combined with the PV installation of the 3.97 MW system under the Core Decarbonisation projects (5.3 MW total). This can deliver further emissions reductions but also provide some excess PV generation, offering capacity for additional electrical demand or battery storage. Through implementation of a PV system at this scale, Murdoch can achieve further reductions of Scope 2 emissions from grid electricity consumption.

Larger systems may be practicable in the future as further assessment and monitoring are completed, and energy consumption patterns and impacts from other projects are understood. Further detailed structural assessments, electrical system requirements, and other assessments will be required to validate the feasibility and upgrade strategy for using the buildings as suggested.

6.3.3 Further Electrification of Space and Water Heating

This initiative aims to expand asset electrification, targeting the University's natural gas consumption via gas-operated heating assets and systems. While some gas-operated assets may be addressed under the CDP Building

Refurbishment Program, this project focuses on remaining systems, employing a range of approaches and technology options.

Key aspects of this project include:

- Domestic Hot Water (DHW) Systems:
    - Electrification through electric heat pump technologies
    - Estimated minimum reduction of 25% of total gas consumption
- Steam Boilers:
    - Electrification through electric steam systems
    - Replacement strategy dependent on individual system capacity requirements
- Gas Space Heating Systems:
    - Full electrification of gas space heating systems dependent on boiler size and current technology availability;
    - Focus on energy efficiency projects as an immediate strategy to reduce heating demand;
        - Prioritisation of building envelope improvements and smart controls to minimise overall heating requirements;
    - Use of electric heat pump alternatives for smaller systems; and
    - Ongoing reviews of technology developments for potential future replacements as assets reach end-of-life.

The potential impact of this electrification initiative is substantial, offering a significant reduction in fossil fuel gas consumption and consequently, a major decrease in emissions. Upgrades of the domestic hot water systems could yield emissions reduction between 160 and 230 tCO2-e, while the electrification on boilers could reduce emissions between 10 and 50 tCO2-e. Beyond the environmental benefits, the reduction in on-site fuel combustion will lead to improved air quality, enhancing the health and wellbeing of students and staff. While immediate full electrification may not be feasible for all systems, particularly larger space heating units, this multi-faceted approach lays a solid foundation for ongoing improvements. The focus on domestic hot water systems and steam boilers provides tangible, near-term reductions in gas consumption, while the strategy for space heating balances current technological limitations with future possibilities. As technology evolves, this project positions the University to adapt and further reduce its carbon footprint, demonstrating a comprehensive commitment to sustainable campus operations.

6.3.4 Residual Emissions Management

As noted above (see 6.2), the university is likely to face a projected remainder of approximately 3,743 tCO2-e in residual emissions after implementation of the core decarbonisation measures outlined previously. Murdoch University is committed to managing any residual emissions and will continue to investigate and consider the optimal way to deliver on this commitment to achieve our target of Net Zero Operational Emissions by 2030. There are a variety of possible approaches and emerging technologies that would enable the effective management of residual emissions.

Residual emissions management for Scope 2 emissions may involve the procurement of green power through Green Power Purchase Agreements (PPAs). PPAs are a widely used third-party decarbonisation option, which is a contractual agreement between renewable electricity producers and buyers to facilitate the purchase of a proportion of electricity from specific sources with high renewable contributions. The agreement and supply of this low-emissions power can immediately reduce the total emissions from purchased electricity and can be implemented relatively quickly. Other options, as outlined below, may include carbon sequestration technologies, which would assist with the generation of high-quality carbon offsets for hard-to-reduce Scope 1 emissions (e.g. farm animals, fugitives, etc.)

6.4 Program of Works 3 - On-site Research and Development Opportunities

The On-site Research and Development Opportunities category focuses on the co-delivery of carbon capture projects at the South St. Campus or possible off-site locations, involving collaboration with local councils, industry partners, and other key stakeholders to implement ready-to-deploy carbon capture strategies. This approach can also be coupled with Research and Development (R&D) opportunities involving emerging technologies and innovative approaches that are currently at low Technology Readiness Levels (TRL) and/or presently too expensive to consider.

This program focuses on forging partnerships to amplify the university's decarbonisation efforts and extend its impact beyond the campus boundaries. By leveraging shared resources, expertise, and technologies, this program aims to tackle complex sustainability challenges that require collective action. These partnerships not only enhance the university's capacity to implement large-scale carbon reduction projects but also create opportunities for knowledge exchange, research collaboration, and real-world learning experiences for students.

Key aspects of this program may include:

- Refining food waste collection and separation
    - Engaging with hospitality venues and improve source-separation of food organics and retain on-site for utilisation as feedstock.
- Utilising organic farm waste
    - Creating a process to improve collection of organic farm waste for utilisation for feedstock.
    - In addition, on-site technologies are being considered that align with the university’s key research strengths including, delivery of a carbonisation/ biochar facility and delivery of a small-scale Anaerobic Digester.

6.4.1 Carbonisation Plant

Initial research has identified the potential for an on-site carbonisation/biochar production facility at our campus. Further studies will be conducted to determine optimal facility size and establish a partnership model with local government and industry stakeholders. This facility would provide a sustainable solution for waste management while producing carbon-sequestering biochar that offers multiple benefits. These include soil enhancement in agriculture and horticulture, water retention improvement, carbon storage properties, and potential applications as a feedstock for various industrial processes such as concrete production and water filtration.

Key aspects of this project include:

- Feedstock: Initial feedstock source opportunities have been identified from a combination of the South St campus and local/regional supplies from parties who have expressed an interest and who can offer supply or collaborative partnership opportunities at the direction of Murdoch.
- Potential Impacts: The plant could provide significant emissions reductions through production of carbon sequestering biochar, a major contribution to our Net Zero and carbon-positive targets.
- Synergies: Strategic alignment with Murdoch's strategic plan, supporting circular economy systems. Moreover, research and partnership opportunities into biochar applications in a range of industries that align with Murdoch's academic and industry positioning as a leader in research on biochar applications. Existing and developing uses include advanced carbon materials and nanotubes, soil amendments, filtration and air/water treatment, environmental remediation, livestock additive, horticulture, advanced construction materials, battery electrodes, biofuels and hydrogen, chemical feedstock, pharmaceuticals and cosmetics, food additives, and biopolymers.
- Project development: Potential interested suppliers and operators have been identified through market review and an initial financial model has been completed. Initial discussions over carbon credit methodology have been completed to mitigate project risk.

6.4.2 Anaerobic Digestion and Algae

This project involves constructing and operating a small-scale Anaerobic Digester (AD). An AD unit would process wet organic wastes primarily sourced from the South St campus in the form of farm animal waste and will convert this waste material into AD effluent/digestate as a valuable source for algae production. The aim is to provide a sustainable solution for waste management while producing higher value feedstocks for other uses.

The facility aims to reduce emissions from existing on-site animal waste decomposition and provide the opportunity for producing algae biomass to contribute to further carbon removal. The facility can generate lactic acid which can be a feedstock for pharmaceutical, food and textile industries as well as biodegradable plastics.

Key aspects of this project include:

- Feedstock: Initial feedstock source opportunities have been identified, including animal waste and a proportion of food organics directly from the South St campus.
- Potential Impacts: The proposed plant can provide emissions reductions through eliminating emissions from animal waste decomposition and provide an opportunity for carbon removal through algal production.
- Synergies: Strategic alignment with Murdoch's sustainability and waste strategies, supporting circular economy systems as well as research and partnership opportunities into in AD byproducts and algae biomass applications in a range of industries that align with Murdoch's academic and industry positioning.

7 Conclusion

The Murdoch University Decarbonisation Roadmap outlines a comprehensive and strategic approach to achieving significant carbon reductions and advancing sustainability goals. By focusing on core decarbonisation projects, alternative pathways, and on-site research and development opportunities, the roadmap provides a clear and actionable pathway to Net Zero operational emissions by 2030.

The roadmap emphasises the importance of collaboration across various departments and stakeholders, leveraging the university's strengths and fostering a culture of continuous improvement. Key initiatives such as the development of a campus-wide energy management system, installation of solar panels, electrification of the vehicle fleet, and exploration of onsite carbon sequestration opportunities are central to this effort.

By implementing these projects and strategies, Murdoch University is not only addressing its own carbon footprint but also contributing to the broader body of knowledge and setting an example for other institutions. The commitment to sustainability, innovation, and environmental stewardship is evident throughout the roadmap, positioning the university as a responsible and credible participant in the global fight against escalating climate change.

As we move forward, we will remain adaptable and responsive to emerging technologies and changing circumstances. The roadmap's multi-faceted approach ensures that Murdoch University can navigate potential challenges and continue to make meaningful progress towards its decarbonisation goals. Together, we can create a sustainable and resilient future for our campus and beyond.

8 Glossary

Anaerobic Digestion	Anaerobic digestion is a process that breaks down organic materials in the absence of oxygen. The process produces biogas, a renewable energy source, and digestate, a solid or liquid material that can be reused.
Biochar	Biochar is a stable, porous, carbon-rich material made from organic waste that's been heated in an oxygen-deprived environment. It's used as a soil amendment to improve soil fertility and water retention, and to sequester carbon.
Boundaries (Decarbonisation Roadmap Boundary)	Scope 1 and 2 operational emissions South Street Campus, comprising close to 90% of the university's total Scope 1 and 2 emissions.
Boundaries (Emissions Inventory Boundary)	For scopes 1 and 2 the following facilities are included: Owned facilities: Main Campus South Street (Perth) Rockingham Mardella Farm Leased Facilities: Mandurah Mundijong Farm Health Futures Institute ANPC (Fiona Stanley) Yawardani Jan-ga Equine Assisted Learning Program (Broome) Singapore Dubai Unmetered Facilities: Coral Bay Research Station Food Futures Institute (Peel) For scope 3 emissions the following emissions categories are included: Upstream scope 3 emissions Category 1: Purchased goods and services Category 3: Fuel and energy related activities Category 5: Waste generated in operations Category 6: Business travel Category 7: Employee commuting Downstream scope 3 emissions Category 13: Downstream leased assets
Carbonisation	The process of breaking down organic materials into carbon and chemical compounds through heating. It's a type of pyrolysis, which is a chemical process that breaks down complex substances into simpler ones.

Carbon neutral	Carbon neutrality is achieved when an entity that produces carbon emissions removes the same volume of carbon emissions from the Earth's atmosphere.
Carbon offset	Carbon offsets compensate for emissions of carbon dioxide or other greenhouse gases by way of reducing, avoiding or removing emissions elsewhere.
Carbon positive	Carbon positivity goes beyond reaching net-zero emissions for it is about extracting more carbon from the atmosphere than is released.
Greenhouse Gas (GhG)	Heat-trapping greenhouse gases such as carbon dioxide (CO2), methane or sulphur dioxide, which drive global warming.
CO2-e	CO2-e is the abbreviation for 'carbon dioxide equivalent', which beyond carbon dioxide accounts for other greenhouses gases including methane, nitrous oxide, ozone and water vapor.
Net zero carbon emissions	The term 'net zero carbon emissions' refers to the amount of GHGs that are removed from the atmosphere being equal to those emitted by human activity. In contrast to carbon neutrality, net zero places greater emphasis on mitigating emissions, only allowing offsetting unavoidable, residual CO2 as a last resort.
Science Based Targets initiative	The Science Based Targets initiative (SBTi) is a corporate climate action organisation that enables companies and financial institutions worldwide to play their part in combating the climate crisis. Targets are considered 'science-based' if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement – limiting global warming to 1.5°C above pre-industrial levels.
Scope 1 emissions	Direct greenhouse gas (GHG) emissions that occur from sources that are controlled or owned by the organisation.
Scope 2 emissions	Indirect GHG emissions associated with the purchase of electricity.
Scope 3 emissions	Emissions from value chain activities (incl. purchased goods and services, business travel and employee commuting)
Sustainability	Many definitions for sustainability exist, yet most lack specificity or a sound ecological logic. Farley and Smith (2020) provide scientifically robust definition, describing sustainability as "the ability of an activity to sustain a system by improving its quality and operating within its limits". In operational terms at Murdoch University, this means that we are seeking to maintain and enhance ecological values on our campuses while seeking continuously to reduce our overall environmental impact.