Assessing how far a ‘Net Zero’ strategy moves an organisation towards ‘Nature Positive’ contributions

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Abstract

‘Net Zero’ and ‘Nature Positive’ frameworks can guide organisations to contribute towards climate and biodiversity goals, but are often implemented separately. It remains unclear whether achieving Net Zero strategies can aid progress towards Nature Positive goals. We apply footprinting methods to a case study (Wadham College, Oxford) to quantitatively assess whether an organisational Net Zero strategy – focusing on GHG emission reductions – could deliver biodiversity co-benefits. We find the college’s 2035 Net Zero strategy alone could reduce its biodiversity impacts from utilities, built environment, and direct land use by approximately 67%. However, we find (i) Net Zero initiatives have variable embodied biodiversity impacts, (ii) achieving both Net Zero and Nature Positive goals requires extensive compensation of residual impacts, and iii) the scope of Net Zero strategies often omits activities relevant for biodiversity. Our study implies pathways exist for achieving carbon and biodiversity objectives together, provided careful and quantitative coordination between strategies.

Key words: Net Zero; Nature Positive; footprinting; biodiversity strategy

Introduction

Climate change and biodiversity loss threaten the resilience of global economies, and undermine human societies (Pörtner, 2021)(IPCC, 2023). According to international policy such as the Paris Agreement and the Global Biodiversity Framework, considerable transformation - decoupling economic development from environmentally damaging activities - is now required to reduce greenhouse gas (GHG) emissions in line with acceptable warming scenarios and to 'halt and reverse' biodiversity loss (Díaz et al., 2019; Leclère et al., 2020; Mace et al., 2018; Pörtner, 2021). In turn, transformative actions require explicit, precise, and measurable climate and biodiversity goals, supported by clearly aligned targets (Maron et al., 2021)(SBTI, 2024; SBTN, 2020) For organisations, this has led to the adoption of 'Net Zero' type targets (for GHG emissions) and, increasingly, targets aligned with a 'Nature Positive' objective within sustainability strategies (Addison et al., 2019; Hale et al., 2022; zu Ermgassen et al., 2022).

'Net Zero' is well-defined and widely applied, denoting the goal for a given actor at any scale to achieve balance between GHG production and removal (Net Zero Climate, 2024), resulting in "net zero" addition of atmospheric GHGs. Analogously, the concept of Nature Positive has recently emerged around efforts to address biodiversity loss. The Nature Positive goal can be defined as a societal goal of 'halting and reversing' nature loss against a chosen baseline year (usually 2020), although a variety of linked definitions of Nature Positive exist . This is analogous to the mission of the Global Biodiversity Framework, around taking 'urgent action to halt and reverse biodiversity loss', putting nature 'on a path to recovery' (zu Ermgassen et al., 2022).

Nature Positive aligned strategies – often framed in relation to biodiversity trends – therefore require organisations to make efforts to prevent or reduce negative impacts across their full value chain compared to a baseline year, and compensate any remaining unavoidable negative impacts (in line with the well-established mitigation hierarchy), whilst also driving transformative positive change for nature (The Biodiversity Consultancy, 2024).

It is common for organisations to have quantitative targets on GHGs, but not currently as common for biodiversity. However, when organisations do have both, their strategies for climate and biodiversity have so far largely been applied separately, despite the known physical interlinkages between the topics. Climate change (driven by GHG emissions) is an increasingly material cause of biodiversity loss, so action to reduce GHG emissions can benefit biodiversity (The Biodiversity Consultancy, 2024). Similarly, action to conserve and restore biodiversity levels can lead to large climate benefits e.g. in the form of carbon sequestration (aka nature-based solutions to climate change). However, despite the link between the two, it has not previously been shown to what extent success under an organisational Net Zero strategy implemented in isolation can be assumed to also have biodiversity benefits that can contribute to Nature Positive goals. Separation of climate and biodiversity strategies risks incompletely identifying and managing the connections between ecological and climate change drivers. In worst-case scenarios, the result could be sustainability strategies working against each other, inadvertently hindering progress in solving one, the other, or both issues (Pörtner, 2021). Conversely, there are obvious benefits to identifying synergistic climate and biodiversity strategies, increasing the feasibility of the transformative pathways needed (White et al., 2024, 2023).

This leads to our core research question: to what extent will an organisation following an existing Net Zero strategy consequently end up delivering desirable biodiversity outcomes? We investigated the biodiversity outcomes of an organisation's Net Zero strategy by applying established footprinting methods for carbon and biodiversity (Bull et al., 2022; Taylor et al., 2023) to an illustrative case study organisation: Wadham College (hereafter referred to as 'the college'). The college is a useful example as (a) extensive operational activity data are available, and (b) the organisation has both a detailed and practical Net Zero strategy and an ambitious quantitative Nature Positive-type objective ('biodiversity net positive'). Wadham is a constituent college of the University of Oxford, providing educational, housing, catering, office and recreational spaces for staff, students and fellows, alongside owning substantial offsite land holdings and investments. The college's twin carbon and biodiversity strategies are well-resourced, and representative of the scale and ambition that may be needed to meet such sustainability goals at other organisations (University of Oxford, 2021; Wadham College, 2024).

Our case study organisation – being one with considerable buildings, infrastructure and land portfolios, alongside an ambitious sustainability strategy – is representative of numerous other contexts, including the UK housing stock, retail and hotel chains, and historic organisations such as the National Trust. Like the college, these sectors consume large quantities of energy, driven by inefficient buildings and user needs. The college's extant Net Zero strategy likely reflects priorities for these other sectors, for whom reaching Net Zero goals will require retrofitting of existing building stock, coupled with decarbonisation of the electricity grid (zu Ermgassen et al., 2022a). Here, we seek to answer our core research question above by providing the first quantitative estimate of the biodiversity impacts associated with an organisation's existing Net Zero strategy. Our approach provides a novel insight into the opportunities and challenges of integrating Net Zero and Nature Positive aligned approaches – a topic of huge interest to those developing sustainability nature strategies and respond to international environmental agreements.

Methods

Our study methodology consisted of three stages (Figure 1): (1) calculating the college's baseline GHG emissions and biodiversity impacts, based on available data on their built environment, utilities, and onsite-land use activities; (2) modelling GHG emissions and biodiversity impact trajectories following the college's Net Zero strategy; and (3) identifying the financial and embodied environmental costs driven by the Net Zero strategy.

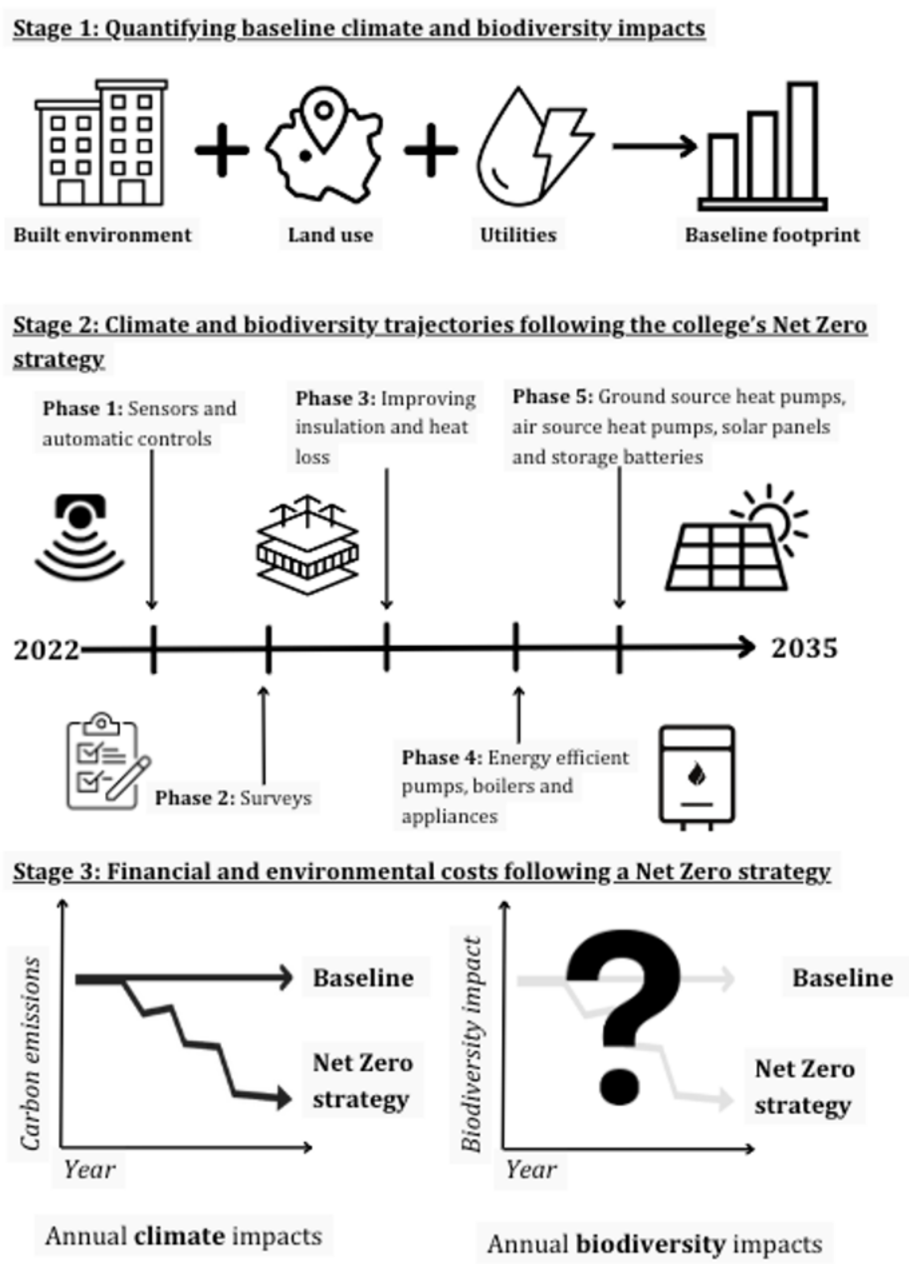

Figure 1: A graphical summary of the three stages of the analysis approach.

Scope of the study

To quantify the college's baseline GHG emissions and biodiversity impacts, we analysed data for utilities (water, electricity, and fuel use; water and general waste), the built environment (size and type of built environment), and onsite land holdings. These are referred to as 'within-scope' activities, and were calculated for the academic years 2016-2022 using data provided by the college's Estates Team.

The scope of the analysis was determined partly by the scope of Net Zero strategies and partly data availability: data was limited or unavailable for college commuting, procurement, or investments, and so was not included within our scope. Travel estimates are also not included in baseline climate and biodiversity footprints, as the data was of insufficient quality for the main purposes of our study, but are reported separately for comparison. Similarly, data for offsite land holdings was collated by the college Financial Bursar to contextualise our findings but have not been considered within our baseline impact calculations. We chose to leave out offsite land holdings as the college's land is leased in long-term tenancy agreements, making it financially and legally impractical for inclusion within the sustainability strategy. Our 'out-of-scope' activities may contribute substantially to organisational biodiversity impacts, but are often excluded from Net Zero strategies. Nonetheless, it is common for organisational biodiversity impact analyses to be forced to work with data limitations. We comment on the implications of our scope in the discussion, and note that such activities (food consumption and procurement, for example) have been explored elsewhere in the university context (Bull et al., 2022)(Taylor et al., 2023).

Life Cyle Impact Assessment

We converted the college's activity data into climate and biodiversity impacts by applying two life cycle impact assessment (LCIA) frameworks, ReCiPe and LC-IMPACT (Huijbregts et al., 2017)(Verones et al., 2020). LCIA tools build upon the classic life cycle assessment (LCA) methodology, combining LCA outputs for the major drivers of biodiversity loss (square meters of land occupation, for example) with characterisation factors (biodiversity impact per unit of environmental driver). The resulting biodiversity impacts are aggregated across freshwater, marine, and terrestrial ecosystems, reflecting the impact of human activity throughout the biosphere (Figure 2). LCIA approaches are widely used to estimate biodiversity loss across complex value chains, enabling a comparison of environmentally impactful activities in a widely accepted, standardised method. LCIA methods are highlighted as potential tools in key frameworks (the recommendations from the Taskforce for Nature-related Financial Disclosures, and European Sustainability Reporting Standards, for instance)(TFND, 2023). However, LCIA methods are known to be subject to substantial limitations and uncertainties, which we summarise in the Discussion (Bromwich et al., 2024). Our results should therefore be taken as estimates of relative, rather than absolute, impacts.

We use two key metrics of biodiversity loss in our analysis: local species loss aggregated over time (species.year; ReCiPe), and potentially disappeared fraction of species over time (PDF.year; LC-IMPACT). The PDF.year metric can be understood as the fraction of global species that are at risk of global extinction if continuously impacted by a specific driver of biodiversity loss (Verones et al., 2020). Conversely, ReCiPe measures biodiversity impact using the species.year metric, calculated as local relative species loss in terrestrial, freshwater, and marine ecosystems; species loss values are then integrated over space and time, and aggregated into a single unit (Huijbregts et al., 2017). Here we only present the ReCiPe results; LC-IMPACT results are provided in the SI to evidence the robustness of our findings across LCIA frameworks.

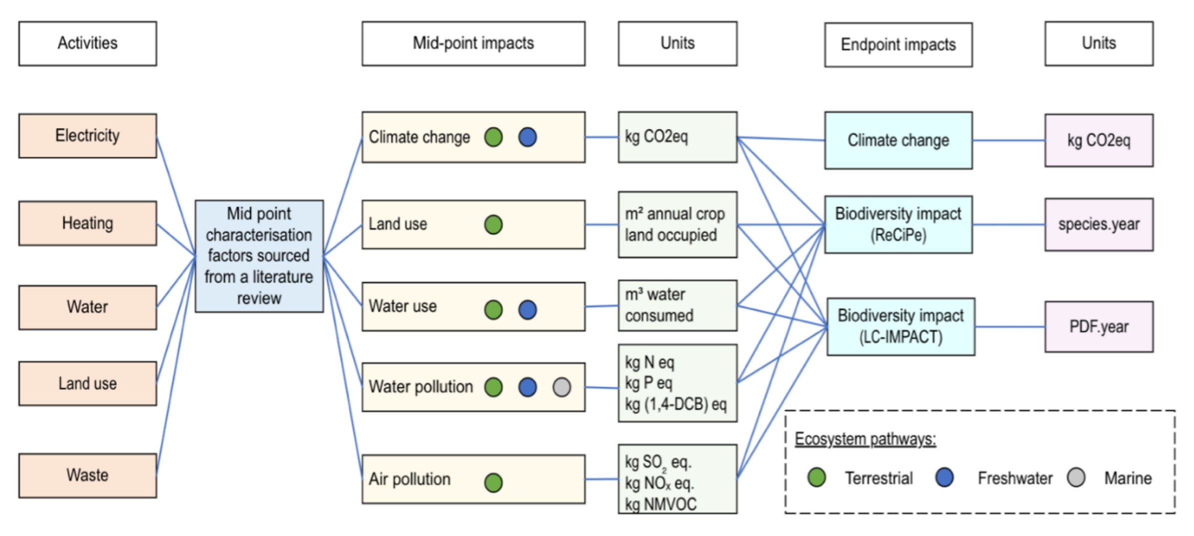

Figure 2: Assessment framework for the college's baseline climate and biodiversity impacts, adapted from (Bull et al., 2022)*. Dots represent quantified environmental pathways, across terrestrial, freshwater, and marine ecosystems.*

Quantifying baseline climate and biodiversity impacts

To quantify baseline climate and biodiversity impacts, we applied our chosen LCIA frameworks (ReCiPe and LC-IMPACT) to 'within-scope' activity data from the academic years 2016-2022. We used average activity data to reflect the variation in the college's consumption and waste patterns each year. We first converted activity data into environmental impacts using characterisation factors, such as kg CO_2eq emitted per kWh of electricity (Al Kez et al., 2022; DEFRA, 2023; United Nations Economic Commission for Europe, 2021). Characterisation factors were identified through a non-systematic literature review (for a list of sources, see SI). The full range of environmental midpoint impacts can be found in (Figure 2): LC-IMPACT and ReCiPe LCIA frameworks quantify the impact of broadly similar environmental drivers, but use different units and end-point calculations (Sanyé-Mengual et al., 2023). Notably, for electricity, we chose characterisation factors that reflected the full range of impacts from supply, construction, and operation (Ristic et al., 2019). We calculated the impacts of the college's electricity consumption using the UK's average electricity mix in 2022 (ESO, 2023). We also determined what the college's potential current electricity impacts would be under renewable energy sources only by scaling renewable sources to make up 100% of the grid.

To determine the college's environmental impacts from land use, we categorised land-based activities into a limited number of land use types, followed by conversion into a single 'annual crop equivalent' value. Environmental impacts were converted into end-point biodiversity impacts by applying ReCiPe and LC-IMPACT characterisation factors. Both ReCiPe and LC-IMPACT provide a range of characterisation factors based on the user's chosen perspectives ('value choices'). For ReCiPe, we used hierarchist characterisation factors, and for LC-IMPACT, core, and average/linear factors. For LC-IMPACT, we also applied country-specific characterisation factors where appropriate. Conversely, ReCiPe provides only global characterisation factors with the exception of water consumption. Our initial footprinting task resulted in quantified CO_2eq emissions, and two metrics of biodiversity impacts, as calculated by the chosen LCIA methods. Biodiversity impacts are therefore reported as both species.year impacts (ReCiPe) and PDF.year impacts (LC-IMPACT). All baseline impacts were reported as annual averages for the years 2016-2022.

Before determining the college's biodiversity and climate impact trajectories under a Net Zero strategy, we modelled the college's impacts following a business-as-usual (BAU) scenario. To achieve this, we extrapolated the college's baseline impacts from 2022 to 2035. We assumed that during this time the UK's electricity grid would gradually change from the 2022 average grid (ESO, 2023) to a 100% renewable grid by 2035. We modelled this transition to renewable energy to reflect the UK Government's renewable energy goals (HM Government, 2021). Importantly, we assumed that the rest of the college's impactful activities (water consumption, for instance) would remain constant from 2022-2035.

Modelling the carbon and biodiversity trajectories of the Net Zero strategy

After establishing the college's BAU scenario, we modelled the reduction in energy consumption if the college were to follow their existing Net Zero strategy (Figure 1). Energy savings were determined through a non-systematic literature review, drawing from scientific and grey literature sources including UK Government energy efficiency reports (DBEIS, 2021; IEA, 2021). Percentage ranges were chosen to reflect the difference between expected and realised savings from Net Zero activities. Such differences are a major source of variation in the college's future climate and biodiversity impacts and are driven by factors such as heating system efficiency and occupant behaviour (Berretta et al., 2021; DBEIS, 2021; Mashhadi Rajabi, 2022). For example, we used the UK Government's 'Demonstration of Energy Efficiency Potential' report, which estimates that loft insulation results in a reduction of household fuel consumption from 3.9-17% (DBEIS, 2021). Further detail on individual strategy activities and predicted energy savings are reported in the SI.

Finally, we modelled how following the college's Net Zero strategy would change the college's carbon and biodiversity impacts from 2022-2035. To achieve this, we established a timeline for implementing Net Zero activities according to the college's existing Net Zero strategy (Figure 1). This timeline was combined with the calculated potential energy savings (per Net Zero activity), and the college's baseline biodiversity and climate impacts. We assumed that under the college's existing Net Zero plans, activities would be rolled out across the entire site unless explicitly mentioned otherwise. To prevent double counting, we assumed the energy savings realised from one activity would reduce the college's baseline impacts for the following activity. For instance, loft insulation was estimated to reduce fuel consumption by 3.9% -17%, reducing the college's fuel-based impacts to 96.1-83% of their original baseline values. Subsequent Net Zero activities which reduce fuel consumption would therefore act on reducing these new post-loft insulation values.

Estimating embodied impacts and financial costs

Potential carbon and biodiversity savings of following the college's Net Zero strategy were compared with the embodied impacts and financial costs of implementation. Embodied carbon and biodiversity impacts were established through the re-application of footprinting methodologies. We sourced environmental impacts for each Net Zero activity via a literature review of LCA and environmental product declaration (EPD) databases. Where possible, exact product matches were used as sources for environmental impacts; elsewhere, we identified closely related products for analysis. EPD databases provided a particularly useful source of environmental impacts: companies producing materials for the Net Zero transition often publish their EPD data online as proof of a product's sustainability and credibility.

Collated environmental impacts were subsequently converted into estimates of total carbon and biodiversity footprints per published functional unit. For this step, we used ReCiPe characterisation factors, using the same value choices as in the baseline biodiversity assessment (Huijbregts et al., 2017). When the estimated environmental impacts did not match the required units to be compatible with RECIPE's characterisation factors (for example, freshwater ecotoxicity was reported both in terms of CTUe and kg 1,4-DCBeq), we undertook additional conversions based on previous footprinting literature (Arendt et al., 2020). We did not use LC-IMPACT to quantify embodied biodiversity impacts as the EPD data was not well-matched to LC-IMPACT characterisation factors. The embodied biodiversity impacts of the college's Net Zero strategy are therefore reported in terms of species.year (ReCiPe) values only.

Carbon and biodiversity impacts were scaled to whole site level and paired with the financial data for each Net Zero activity. We applied conversion factors (provided by the Estates Manager) to scale up carbon and biodiversity impacts from published functional units to site-level impacts. For example, the Estates Manager estimated that the college would require 4900m^2 of mineral wool insulation to fully insulate the lofts across the entire site. Consequently, we scaled our impact values for mineral wool (initially reported per m2) by 4900 to determine the total carbon and biodiversity impacts caused by insulating all the college's lofts. This scaling approach was repeated for all Net Zero activities. We did not contest any data provided by the college and assume the uncertainties on provided estimates of quantities were much smaller than those arising from LCIA methodologies. Embodied carbon and biodiversity impact values were then paired with estimated financial costs provided by the Estates Manager. The output of this stage, therefore, was total embodied carbon and biodiversity impacts, as well as financial costs, per Net Zero activity and per year from 2022 to 2035.

Evaluating the college's Net Zero strategy

Using predicted energy savings and financial costs, we identified the most cost-effective strategies for reducing both carbon and biodiversity impacts. Where appropriate, the costs and impacts of energy-saving and preparatory activities (ground source heat pumps and underfloor heating, for example) were combined. In doing so, we produced a measure of cost-effectiveness that reflected the major infrastructure changes associated with many Net

Zero activities. For each activity, cost-effectiveness was calculated by dividing carbon or biodiversity savings (minus embodied impacts) by financial costs. Embodied impacts were assumed to occur over a 20-year time horizon, reflecting the average lifespan of the products used in the college's Net Zero strategy. We reported net carbon and biodiversity savings per pound of financial spend, acknowledging the important role of embodied impacts in driving climate change and biodiversity loss. We then re-ordered the grouped Net Zero strategy activities in order of cost-effectiveness to determine the efficiency gains accrued by undertaking the most cost-effective actions first. Actions that must take place before undertaking retrofits (surveying building fabric, for instance) remained at the start of the college's cost-effective Net Zero strategy. We were therefore able to evaluate how considering costs will result in more efficient reductions in the college's climate and biodiversity impacts over time.

Results

Quantifying baseline climate and biodiversity impacts

For the academic years 2016-2022, the college's within-scope activities released an average of 1.2×10^6 kg CO_2eq annually, and drove biodiversity impacts of 5.3×10^{-3} species.year. We found the activities driving climate and biodiversity impacts overlapped: combined, fuel and electricity consumption drove 97% of within-scope annual CO_2eq emissions, and 93% of within-scope annual biodiversity impacts (using ReCiPe LCIA approach) (Figure 3). GHG emissions emerged as the largest driver of biodiversity impacts, accounting for 63% of the total annual within-scope biodiversity footprint (Figure 3a). Land use emerged as the second largest environmental impact, contributing to 12% of the biodiversity footprint. Our results were consistent across LCIA approaches, highlighting fuel and electricity consumption as key drivers of the college's GHG emissions and biodiversity impacts from utilities, built environment and direct land holdings.

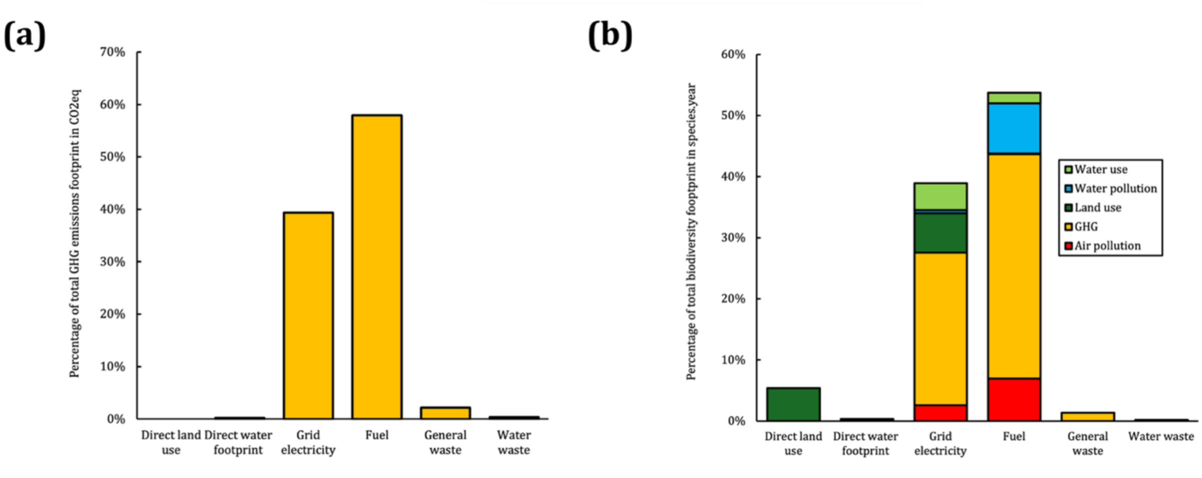

Figure 3: (a) The percentage of the college's total GHG emission footprint in CO2eq distributed across the different activities, reported as average annual impacts assessed for the baseline years 2016-2022; (b) The percentage of the college's total biodiversity footprint in species.year reported as average annual impacts for the baseline years 2016-2022, calculated using ReCiPe and distributed across the different assessed activities and environmental pressures (see key).

Climate and biodiversity trajectories following a Net Zero strategy

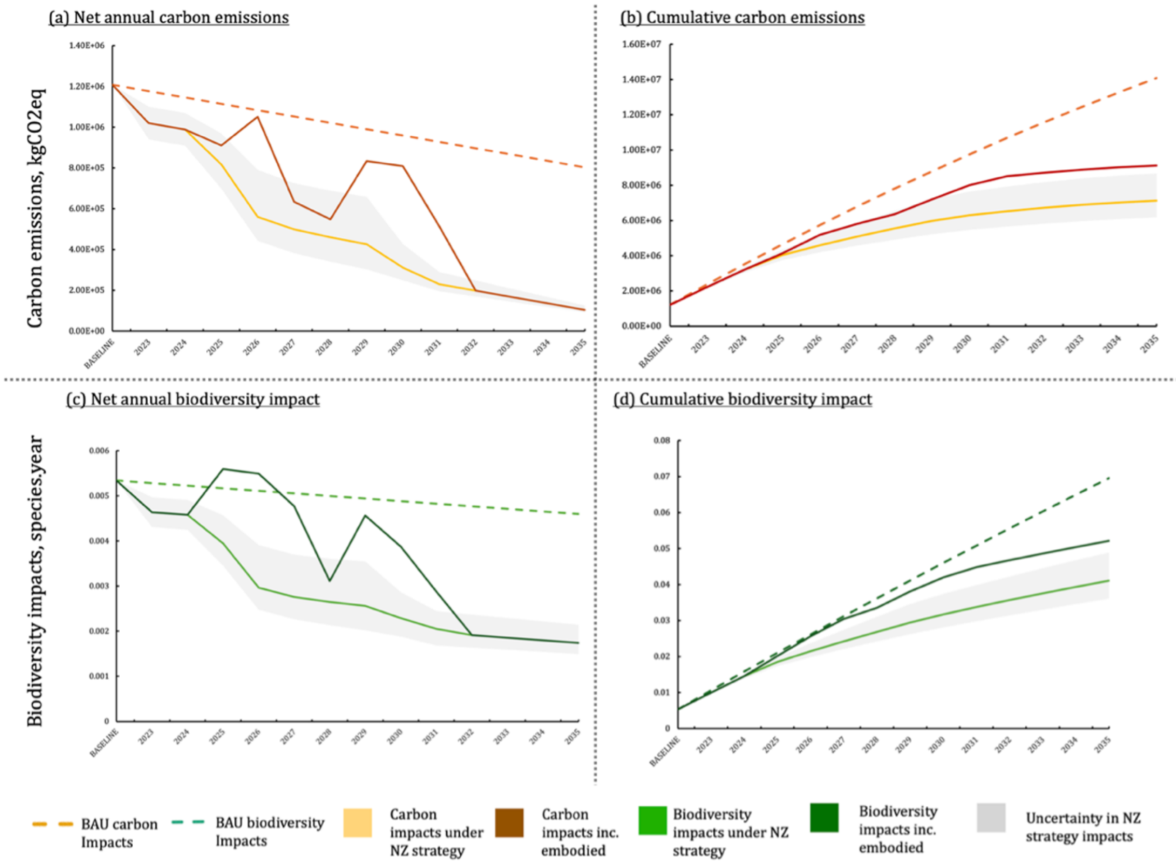

Figure 4: The college's carbon (a,b) and biodiversity (c,d) impact trajectories from the annual average baseline (2016-2022) to 2035. Trajectories are calculated for net annual impacts (a,c) and cumulative impacts (b,d). Trajectories under a baseline scenario (dashed lines) are compared against a Net Zero (NZ) strategy scenario that undertakes different activities each year to reduce impacts (light colour, solid lines), and a NZ strategy that also accounts for the potential negative embodied impacts of the specific net zero activities (dark colour, solid lines). The estimated uncertainty in possible outcomes from Net Zero activities is represented by the shaded grey bands, reflecting minimum and maximum variation in savings.

We modelled the college's potential future climate and biodiversity impacts from utilities, built environment and direct land holdings based on their existing Net Zero strategy. Impacts were first modelled following a business-as-usual (BAU) scenario, extrapolating baseline impacts from the 2016-2022 annual average baseline to 2035. We assumed the UK's electricity grid would gradually change from the average grid in 2022 to a 100% renewable grid by 2035 (reflecting UK government ambitions) and that the remaining operational impacts (water consumption, for instance) remained constant over time (HM Government, 2021). Under the BAU scenario, we calculated that the college's within-scope climate and biodiversity impacts would decrease by an estimated 33% (kg CO_2eq) and 14% (species.year) respectively by 2035 relative to the 2016-2022 annual average baseline Figure 4 a, c). We saw a smaller reduction in biodiversity impacts (relative to GHG emissions) due to an increase in non-GHG emission-associated impacts driving biodiversity loss. Such impacts are caused by the high infrastructure requirements of renewable energy technologies compared to fossil fuels, which would need to be mitigated for these project to help deliver nature positive biodiversity outcomes (Bennun, 2021). The estimated reduction in biodiversity impacts derived from a renewable electricity transition were more pronounced using LC-IMPACT than ReCiPe (27% decrease versus 12%, from the annual average baseline) due to the weighting of characterisation factors in the different LCIA models.

We then modelled the expected reduction in the college's within-scope carbon and biodiversity impacts between 2022-2035 following the existing Net Zero strategy (Wadham College, 2024). Our models showed that the college's Net Zero strategy is likely to reduce some key sources of within-scope biodiversity impacts alongside reducing GHG emissions relative to our baseline analysis. By following the Net Zero strategy, the college could reduce within-scope annual GHG (kg CO_2eq) and biodiversity (species.year, ReCiPe) impacts by an estimated 91% and 67% respectively from 2022 to 2035 (Figure 4 a,c) relative to the college's baseline impacts. Impact reduction occurs in a stepwise manner, as the Net Zero strategy is rolled out in phases. Relative to the BAU scenario, the college's Net Zero strategy will reduce within-scope cumulative climate and biodiversity impacts in 2035 by 49% (kg CO_2eq) and 41% (species.year) respectively (Figure 4 b, d). The college would – as is typical under Net Zero strategies – require some carbon offsetting in addition to GHG emissions reductions to reach Net Zero. However, even if these offsets delivered biodiversity co-benefits, it seems likely that delivery of the Net Zero ambition only goes part of the way towards concurrently achieving the biodiversity strategy objectives to contribute to NP goals; excluding the large-scale impacts of outside of scope activities.

The outcomes of the college's Net Zero strategy actions are, however, subject to uncertainty. The effectiveness of Net Zero strategy actions may vary according to factors such as occupancy behaviour and location, presenting a large source of uncertainty in predicting the college's future carbon and biodiversity impacts. To address these uncertainties, we have utilised a range of possible energy savings for each Net Zero activity, providing an indication of minimum variation in our predicted results. Energy savings from loft insulation, for instance, are estimated to equal between 3.9% and 17.0% of total fuel consumption (DBEIS, 2021). The estimated minimum and maximum reduction in carbon and biodiversity impacts are visualised in Figure 4 (grey bands). Using these ranges, we estimated that annual within-scope GHG emissions (CO_2eq) by 2035 will be between 90% and 92% lower following the Net Zero strategy (relative to the annual average baseline from 2016-2022). In the same scenario, within-scope biodiversity impacts (species.year, ReCiPe) are reduced by between 60% and 72%. Importantly, there are additional uncertainties and limitations which are not captured in the uncertainty estimates shown in Figure 4. Of particular note is impacts driven by outside of scope activities- procurements and investments, for example - which may be an order of magnitude larger than our within-scope results (for the implications of our scope, see the Discussion) (Bull et al., 2022).

Crucially we show where there are at least some trade-offs to be made to meet organisational climate and biodiversity targets concurrently; not least due to the embodied biodiversity impacts of Net Zero activities (for example, the materials and land use required for solar panels), and financial costs involved (Iacona et al., 2018; Squires and Garcia, 2018; White et al., 2022, 2024). These are discussed in the following section.

Embodied carbon and biodiversity impacts associated with mitigation

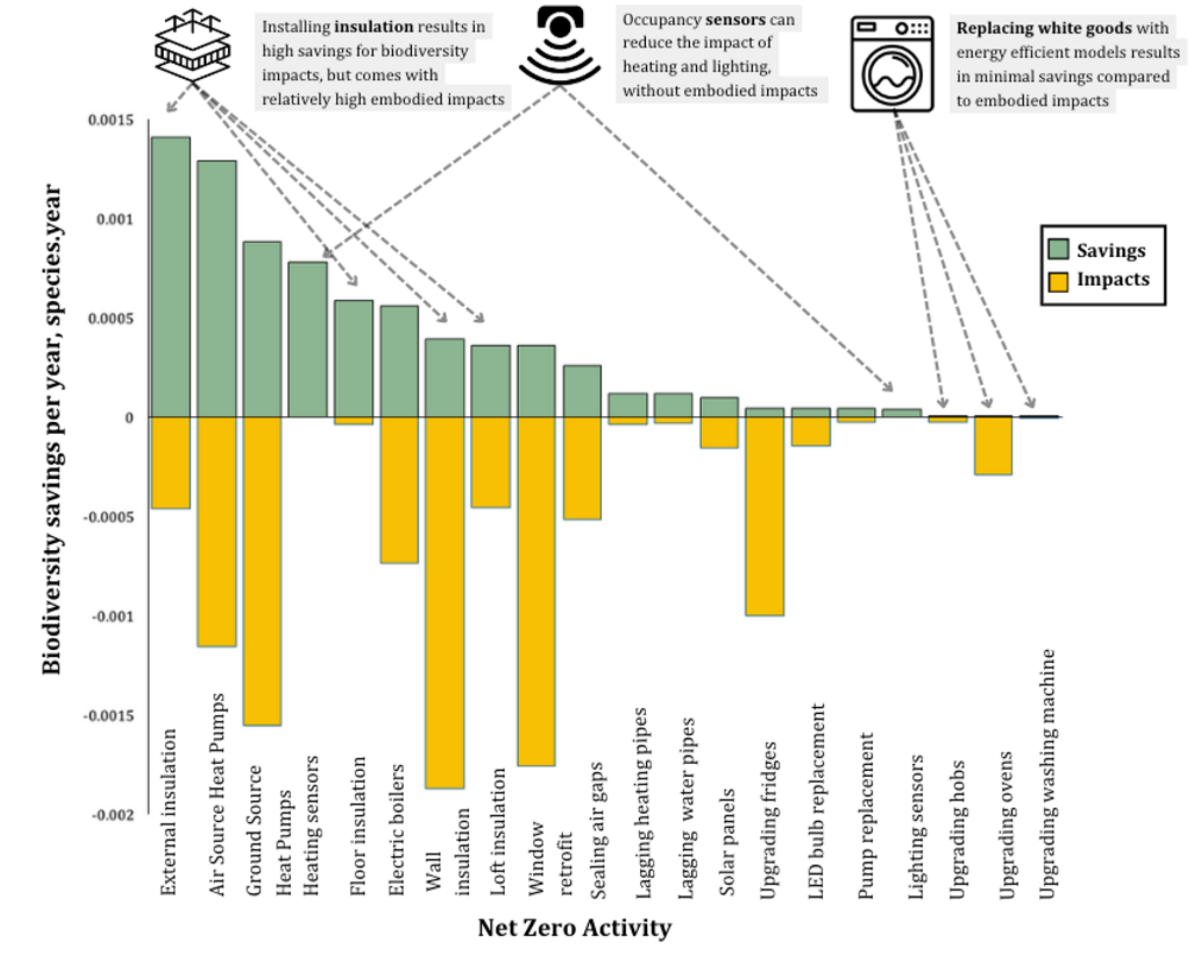

Figure 5: Embodied impacts and potential biodiversity savings of each Net Zero activity. Both the one-time embodied negative biodiversity impacts (yellow bars, negative values) and potential biodiversity impact savings (green bars, positive values) are reported in terms of annual values, i.e. occurring every year over the course of the college's Net Zero strategy for potential savings, and occurring once in the year of implementation for negative embodied impacts.

We found that implementing the college's Net Zero strategy would result in estimated embodied impacts of 2.0×10^{6} kg CO2eq emissions and 1.1×10^{-2} species.year biodiversity impacts by 2035. The climate and biodiversity outcomes of Net Zero activities therefore vary depending on whether the embodied impacts of activities outweighs their potential benefits. Occupancy sensors, for example, reduce both climate and biodiversity impacts, saving 1.9×10^{5} kg CO2eq and 7.8×10^{-4} species.year respectively per year, with negligible embodied impacts (Figure 5). In comparison, tensions emerge between embodied costs and future climate and biodiversity savings from replacing white goods. Upgrading fridges, for example, confers one-time embodied climate and biodiversity impacts of 1.1×10^{5} kg CO2eq and 1.0×10^{-3} species.year respectively, compared to annual climate and biodiversity savings of 1.3×10^4 kg CO2eq and 4.7×10^{-5} species.year (Figure 5). As such, it would take the college 21 years to 'pay back' the embodied biodiversity impacts of upgrading fridges, if relying on the impact reductions they alone provide.

Financial costs of mitigation

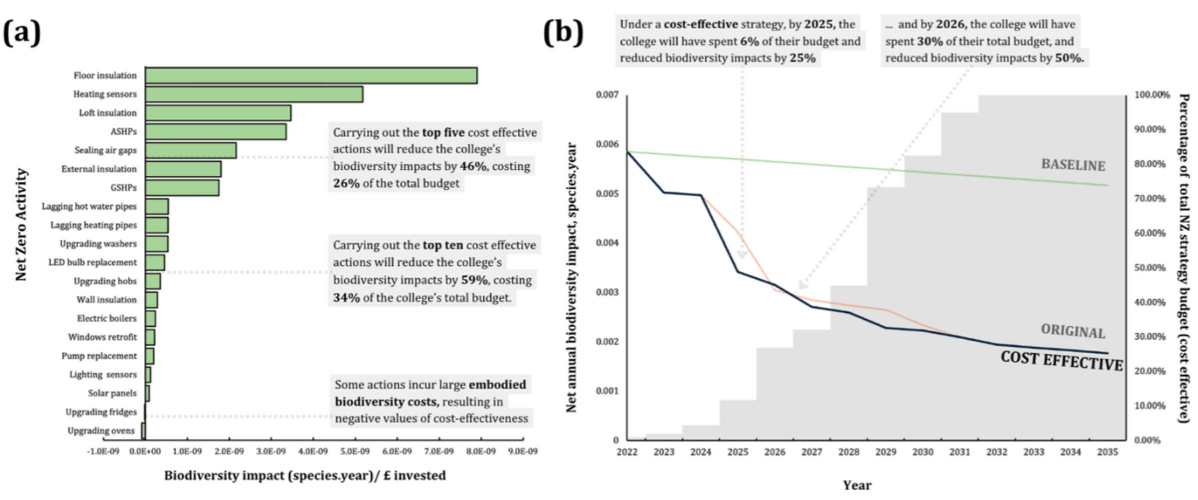

Figure 6(a) Cost-effectiveness of the college's Net Zero activities, reported in kg CO2eq emissions prevented annually, per £1 of financial spend. Figure 6 (b): Reduction in biodiversity impact from implementing the most cost-effective actions first (black line, 'cost effective') versus a business-as-usual scenario (green line, 'baseline') and the original Net Zero strategy (orange line, 'original'). Grey bars indicate the percentage of the college's total Net Zero strategy budget spent per year for the cost-effective strategy.

The financial costs and feasibility of actions must be considered in designing coordinated Net Zero and Nature Positive aligned strategies – both to ensure strategies are practical, and to help realise gains most efficiently and quickly (White et al., 2022). We assessed the cost-effectiveness of the college's existing Net Zero strategy activities by pairing the potential climate and biodiversity impact savings of each action with estimated financial cost. There was a high variation across different actions (Figure 6a) (kg CO2eq saved per £1 of financial spend). We included embodied impacts incurred by the college in our assessment of cost-effectiveness, distributed equally over a 20-year time horizon (based on average lifespan of materials used in the Net Zero strategy). Including embodied impacts revealed that some Net Zero activities (upgrading fridges, for instance; Figure 4) are cost ineffective over a 20-year timeframe and should potentially be excluded from the strategy.

We calculated potential efficiency gains realised through undertaking the most cost-effective activities first. Under the current strategy, a 25% reduction in the college's estimated within-scope biodiversity impacts (relative to the 2016-2022 annual average baseline) would cost 22% of the total Net Zero budget in 3 years, with a further 50% reduction costing 40% of the total budget in 5 years. If we shifted the order of the college's current Net Zero strategy to implement the most cost-effective actions first, in similar timescales to the original proposal (Figure 6b), we would see more efficient reductions in biodiversity impacts: a 25% reduction costing 6% of the total budget in 3 years and a 50% reduction costing 30% of the total budget in 5 years.

A consideration of costs, alongside carbon and biodiversity impacts of different actions, leads to efficiency gains for Net Zero and Nature Positive aligned biodiversity targets. Furthermore, communicating the financial and environmental benefits of the Net Zero strategy may influence the college's occupancy behaviour (reducing personal energy consumption, for example). However, our analysis does not address the potential costs of inaction, or the costs of offsets or compensation payments. Such costs could be substantial if mitigation action is not undertaken (Kotz et al., 2024). We also do not consider the cost-effectiveness of activities outside the scope of the existing Net Zero strategy, which may have large climate and biodiversity benefits. Altered agricultural management practices of offsite land holdings, for example, could be a cost-effective mechanism for delivering environmental gains.

Discussion

Net Zero strategies alone cannot be assumed to deliver Nature Positive outcomes

The college's existing Net Zero strategy will likely considerably reduce annual GHG emissions across buildings, utility, and onsite land use activities. But by following the Net Zero strategy, the college will likely also concurrently reduce their within-scope biodiversity impacts, a finding replicated across both of the two LCIA biodiversity footprinting approaches we employ here (relying upon ReCiPe and LC-IMPACT). Similar predicted carbon and biodiversity trajectories partially reflect the synergies between environmental drivers, as the college's within-scope biodiversity impacts are in a large part driven by GHG emissions from fuel and electricity consumption.

There remain, however, the likely very large biodiversity impacts of activities not included in the scope of our assessment, as they fall outside of the college's Net Zero commitment. Our analysis focused on impacts driven by GHG Scope 1 and 2 activities and associated supply chains; many organisations similarly set Net Zero targets around these GHG emissions categories, with less ambition on Scope 3 emissions (i.e. for them to plateau and reduce over time). To gauge the size of the impacts of the college's current within-scope activities relative to out-of-scope activities, we estimated the biodiversity impacts of the college's offsite land holdings using the LCIA frameworks ReCiPe and LC-IMPACT. Using ReCiPe, offsite land holdings (predominantly used for arable cropping) had an estimated 12.5 times larger biodiversity footprint than the total footprint of reported within-scope activities; although it should be noted that, due to the nature of Oxford colleges, this organisation likely has relatively large land holdings. Similarly, the estimated carbon footprint of the college's Scope 3 student and staff travel (provided by the college) was 7.5×10^5kg CO_2eq per year - equal to 62% of the college's within-scope baseline. When offsite land use is included within the college's scope, the Net Zero strategy will reduce biodiversity impacts by only 5% - 6% relative to baseline levels. These calculations raise an important issue: that the scope of Net Zero strategies is built around GHG emissions, and so cannot address the wider scope that might be necessary to consider for biodiversity impacts. It is likely that biodiversity footprints, and consequently Nature Positive aligned strategies, must consider issues of scope (such as assets, or financial investments) in a way that Net Zero strategies do not currently.

Nature Positive contributions demand greater levels of ambition

Again, like many other organisations, the college's Net Zero strategy does not address all drivers of GHG emissions or of biodiversity impacts; further, it does not consider the embodied environmental impacts of implementing said strategy. The college's activities outside of the current scope – offsite land holdings or investments, for instance – will continue to drive large biodiversity impacts. If were to extend our analysis to assess activities such as food consumption or procurement, we would expect to be able to rely even less on Net Zero strategy to deliver the necessary biodiversity outcomes (Bull et al., 2022). Understanding the full extent of the college's impacts therefore requires an extension of our scope, including impacts from offsite land use, and upstream and downstream activities that impact biodiversity indirectly. To address the major biodiversity impacts that lie outside of the current scope of the Net Zero strategy, the college could seek to improve biodiversity on- and off-site, further mitigate biodiversity impacts in supply chains, and/or invest into projects focussed on restoring offsite or externally owned land. Reaching ambitions to align with Nature Positive goals, furthermore, would require additional gains in biodiversity past the original baseline (Nature Positive Initiative, 2024).

LCIA approaches alone are insufficient for informing strategies which jointly achieve Net Zero and contribute to Nature Positive goals. Our methods have applied current good practices to produce a set of relative carbon and biodiversity trajectories that help assess the biodiversity implications of an organisation's Net Zero strategy. However, LCIA footprinting results come with major uncertainties, including those associated with model and process parameters; data variability; and methodological choices (for a list of our LCIA-based assumptions and uncertainties, see Methods). The dominance of GHG-driven biodiversity impacts relative to other drivers of biodiversity loss, for example, is likely a result of LCIA methods and assumptions, as well as the scope of our assessment.

Uncertainties remain uncharacterised in much of LCIA biodiversity literature despite being a key factor influencing the reliability of their results (Barahmand and Eikeland, 2022). As it stands, we risk organisations exploiting LCIA uncertainties to pursue climate and biodiversity goals which do not fully address the extent of their impacts. LCIA approaches are further unable to capture all aspects of biodiversity loss, including site-specific values of biodiversity, or potential biodiversity gains driven from an organisation's activities. LCIA approaches should be used alongside other tools to prioritise action, for example those which assess site-level biodiversity impacts (Bromwich et al., 2024). Despite this, since addressing the climate and biodiversity crises is time sensitive, strong arguments exist for working with best available methods while taking an adaptive approach.

Towards joint carbon and biodiversity strategies

The burgeoning threat of the climate and ecological crises demand that we recognise the connections between climate, biodiversity, and human development (IPBES-IPCC, 2021; Pörtner, 2021). Our case study's ambitious Net Zero strategy likely reflects the approaches of leading organisations in this field, at a time where many are grappling on how to implement ambitious climate and nature goals concurrently. Here, we show that it is possible to estimate the biodiversity impacts of an existing carbon strategy; identify actions that jointly target an organisation's climate and biodiversity impacts with limited trade-offs; and, determine next steps for impact reduction where additional actions are needed for biodiversity and/or climate.

To address Net Zero and Nature Positive aligned goals together, however, further research is required: identifying synergies between GHG emissions and biodiversity impact drivers across a greater range of sectors; quantifying the climate outcomes of biodiversity strategies; and evaluating broader sustainability strategies (those focused on food system change, for instance) for their climate, biodiversity, and financial outcomes. It is hoped that this proof of concept can be extended to other contexts, including organisations with large property and land portfolios. More broadly, we highlight some of the opportunities and challenges of addressing ambitious sustainability goals in tandem, seeking to facilitate efforts to tackle the climate and nature crises at the same time.

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