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Navigating Climate Neutrality Planning: How Mobility Management May Support Integrated University Strategy Development, the Case Study of Genoa

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Abstract

Higher education institutions face a critical methodological challenge in pursuing net-zero commitments: Within the amount ofhe emissions related to Scope 3, including indirect emissions from water consumption, waste disposal, business travel, and mobility, employees commuting represents 50–92% of campus carbon footprints, yet reliable quantification remains elusive due to fragmented data collection and governance silos. The present research investigates how purposeful integration of the Home-to-Work Commuting Plan (HtWCP)—mandatory under Italian Decree 179/2021—into the Climate Neutrality Plan (CNP) could constitute an innovative strategy to enhance emissions accounting rigor while strengthening institutional governance. Stemming from the University of Genoa case study, we show how leveraging mandatory HtWCP survey infrastructure to collect granular mobility behavioral data (transportation mode, commuting distance, and travel frequency) directly addresses the GHG Protocol-specified distance-based methodology for Scope 3 accounting. In turn, the CNP could support the HtWCP in framing mobility actions into a wider long-term perspective, as well as suggesting a compensation mechanism and paradigm for mobility actions that are currently not included. We therefore establish a replicable model that simultaneously advances three institutional dimensions, through the operationalization of the Avoid–Shift–Improve framework within an integrated workflow: (1) methodological rigor—replacing proxy methodologies with actual behavioral data to eliminate the notorious *Scope 3 data gap*; (2) governance coherence—aligning voluntary and regulatory instruments to reduce fragmentation and enhance cross-functional collaboration; and (3) adaptive management—embedding biennial feedback cycles that enable continuous validation and iterative refinement of emissions reduction strategies. This framework positions universities as institutional innovators capable of modeling integrated governance approaches with potential transferability to municipal, corporate, and public administration contexts. The findings contribute novel evidence to scholarly literature on institutional sustainability, policy integration, and climate governance, whilst establishing methodological standards relevant to international harmonization efforts in carbon accounting.

Keywords: climate neutrality; higher education; Scope 3 emissions; commuting plans; governance integration; institutional innovation; carbon accounting

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1. Introduction

Climate neutrality (CN) constitutes a defining global challenge, described as the leading environmental goal of the 21st century, substantially boosting a new industrial revolution [1], thus requiring widespread, large, and coordinated action across governments, organizations, and private sectors [2]. CN is indeed intended to achieve net-zero emissions through the limitation of global warming to 1.5 °C compared to pre-industrial levels [3], necessitating net-zero emissions by the mid-century [4]. Achieving climate neutrality means balancing anthropogenic emissions of greenhouse gases (GHGs) into the atmosphere with anthropogenic removals over a specific period. Focusing on European Union (EU) strategies in this direction, it needs to be highlighted that the EU's initiatives are centralized under the European Green Deal (EGD), which commits Europe to becoming the first climate-neutral continent by 2050 [5]. Nevertheless, the "Fit for 55" legislative package [6], which includes revising the Emissions Trading System (ETS) and the Effort Sharing Regulation [7], sets the intermediate goal of achieving a 55% reduction in net GHG emissions compared to 1990 levels by 2030 [8]. Subsequently, the European Climate Law has embedded the final goal to achieve net-zero greenhouse gases across the EU economy by 2050 [9].

Such ambitious goals present evidently several systemic challenges that have been largely discussed within academic and scientific debate. From a methodological perspective, the first barrier is represented by a general lack of standardization and robustness. There are no international standards or criteria to assess whether net-zero commitments are feasible or truly represent effective low-carbon performance [10]. Only about 20% of net-zero targets globally pass quality assurance [11]. Moreover, an inconsistent approach in defining targets, as well as data gaps, significantly hampers a proper assessment [12]. Methodological inconsistencies also transfer to planning processes and tools. Inconsistencies exist regarding [13] emission coverage, activities included, timelines, general approach, scope, timing, equity, future uncertainties, dependence on other actors, and governance [14]. Taxonomy and terminology variations (e.g., "net-zero," "carbon-neutral," and "climate-neutral") also lead to inaccurate pledges [15]. Subsequent plans' implementation proves to be critical as well. Developing credible plans, securing stakeholder agreement, and implementing complex transition policies are non-trivial tasks [10]. In this direction, according to Larrea et al. [2], action plans and offsetting represent the most suitable areas for further improvements. As far as responsibility allocation is concerned, it needs to be pinpointed how many neutrality claims come from companies with high emissions, but no realistic reduction plans [16]. The voluntary carbon markets are expected to struggle to cope with the immense demand for offsets [17]. Finally, many entities (whether public, such as cities and regions, or private companies) lack the necessary personnel, expertise, or resources to conduct emission inventories, model future scenarios, or implement complex transition policies [10]. The rationale to develop comprehensive CN plans is multifaceted and strongly dependent on the values and purposes of the subject involved. Mitigation and adaptation constitute the main goals to be targeted: an environmental imperative to slow global warming and protect the natural environment [18] is usually declined through climate action, insisting particularly on a more intensive use of renewable energy sources (RESs) and energy efficiency, which should stimulate economic growth, create jobs, and reduce dependency on imported fossil fuels [19].

Notwithstanding, it may also represent an economic opportunity. Since the transition to a low-carbon economy can provide several benefits to companies [20], the EGD is defined as a new growth strategy aimed at transforming the EU into a prosperous society with a competitive economy where economic growth is decoupled from resource use [21]. A voluntary basis of similar commitment requires companies to grasp similar opportunities in

this direction, thus assuming respective responsibilities and costs linked to their pledges [2]. In this direction, universities may support several steps in terms of climate neutrality commitment. Firstly, they could provide a significant contribution in terms of design and refining of standardized frameworks to assess and quantify climate commitment [2]. This is the case for the "Taking stock" [11] and "Targeting Net-Zero" [22] approaches, thus providing essential criteria and guidance for the assessment of net-zero pledges. Academic institutions may support the development and validation of innovative methodologies, mostly addressing quantitative and multicriteria evaluations [23]. As Bresciani et al. [24] highlight, higher education institutions may support policy-making innovation, thus providing a key contribution towards standardized and effective methodologies to assess and reduce environmental impacts. Relevant efforts have been made in this direction to create and implement decision-making tools to model, test, validate, and compare the effectiveness of climate-neutral policies. Significant case studies may be traced in this direction, employing the Local Energy Planning Assistant (LEPA) tool [23] and the PEDRERA model tool [25]. Key performance indicator (KPI) calculation is also addressed.

Similar considerations led to the present research to address whether universities' net-zero pledges may support institutional and governance innovation through virtuous synergies and integration between voluntary and compulsory planning tools. As quantitative evaluations are increasingly popular and addressed within academic debate, the proposed approach is to design an integrated workflow that may support data collection and provision for the quantification of climate-neutrality commitment, through the definition of a joint and shared dataset, including the information coming from the survey that is required to implement the Home-to-Work Commuting Plan (HtWCP). With a compulsory tool required by Italian National legislation for companies and administrations above 100 employees, a virtuous cycle may be implemented, without the need to re-collect detailed and dedicated information to support the CN planning process.

Universities' mobility management may therefore be targeted as a key field for sustainable transition and climate neutrality due to its direct impacts on one of the most environmentally relevant sectors.

In this direction, Bertolin et al. [26] underline the key role of individual behavioral changes within university environments to reach sustainable development goals, as well as their capability to complement legislation requirements with standardized and shared approaches and methodologies to collect meaningful and quality data [27]. The variety of potential users to be targeted by sustainable mobility policies makes universities ideal test-bed for similar experimental climate neutrality-led initiatives [28].

The following sections will therefore deepen the proposed methodology, thus integrating CNP and HtWCP (Section 2). Then, the University of Genoa case study and respective data collection and processing will be discussed (Section 3). Finally, potential drivers and barriers to the implementation of a similar approach will be addressed (Section 4) before concluding by presenting future fine-tuning and further steps (Section 5).

2. Background and Methodological Approach

Companies and public entities usually achieve climate neutrality through two main operational tools: i. Climate Neutrality Plan and ii. Home-to-Work Commuting Plan.

The CNP may be considered the framework to develop the HtWCP. The latter represents the sectoral application of CNP principles to the commuting mobility component. In this direction, it may be particularly interesting to delve into respective methodological approaches to point out potential synergies and integration drivers.

The first develops usually develops in the following five steps [2].

Stemming from strategy definition and commitment pledges, companies and entities are required to assess whether the neutrality claim is feasible given the deployed tools, resources, and strategy. This includes verifying intermediate deadlines and considering climate risks within the sustainability strategy. Once general strategies are set, the methodological approach needs to be described. In this direction, determining whether the company has calculated its carbon footprint, which scopes and GHG are included, and whether the footprint calculation is certified by third parties are the main focus of the second part of this plan. An implementation roadmap represents the third step, where companies and entities are called to define a budgeted carbon neutrality action plan that may be supported by a cost-effectiveness analysis, thus striking a proper balance between reduction and offsetting towards net-zero. The evaluation of the requirements that companies and entities set regarding the types of offset projects, the standards used, and the inclusion of co-benefits in project selection represents the main focus of this fourth stage. Finally, communication initiatives need to support subject transparency regarding neutrality objectives, the calculation of the carbon footprint, and offsetting practices. Operationally, the CNP usually includes three main scopes [29]:

- Scope 1: Direct GHG emissions and indirect energy emissions attributable directly to the activity of the company/entity (emissions from natural gas and diesel fuel and refrigerant gas losses due to periodic maintenance of air conditioning systems and the vehicle fleet) [30].
- Scope 2: Indirect GHG emissions from energy consumption, i.e., those from the use of electricity [30].
- Scope 3: Other indirect emissions from water consumption and disposal of waste produced, and emissions generated by business travel and mobility of employees commuting. Purchases of consumables will be included within the operational boundaries in future inventory updates [31].

It is therefore evident that a similar approach requires massive data collection [32]. Nevertheless, a significant gap is separating data collection between Scopes 1 and 2, which are directly linked to company/entity consumptions and respective emissions, and Scope 3, where data are not fully available to the subject that is designing the CNP, since mobility data related to employees' commuting needs to be collected on purpose. In this direction, from a methodological point of view, a relevant issue needs to be addressed: how can the data needed to assess the mobility-related component from Scope 3 be obtained?

The proposed approach suggests identifying potential workflow mainstreaming data from the survey that needs to be implemented to design HtWCP. In detail, according to Decree 179/2021, companies and entities counting more than 100 employees are required to implement their own HtWCP, and to do so, they need to submit a dedicated questionnaire to their staff.

A proposal for questionnaire structure is also defined, according to the same law. In this direction, modal choices, travel times, and routes of employees should be recorded, together with their willingness to shift to sustainable alternatives. Stemming from similar data, indirect emissions from commuting mobility of workers may be calculated, along with a potential reduction in the future according to the adopted supporting measures (Figure 1). The proposed approach aims at targeting potential integration of the respective approach and governance perspectives, thus highlighting potential contaminations and hybridization that could support a more effective and shared strategy development towards university and institutional green transition.

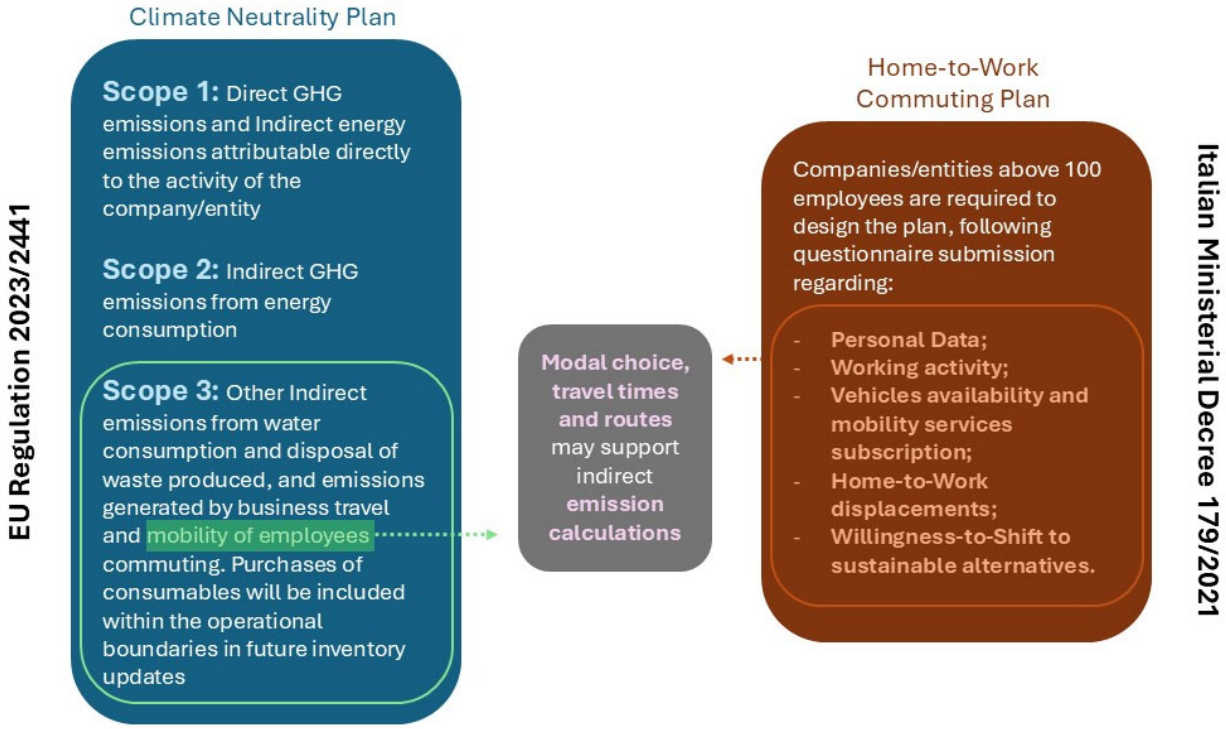

Figure 1. Proposed approach of integrating CNP and HtWCP. Source: Authors.

Similar data collection and flow should follow a rigorous path that should comply with the university's previous commitments to the Race To Zero initiative and the emission calculation standard set by UNI ISO 14064-1. Thus, GHG emission inventory and calculation should follow the standardized process (e.g., emission factors and related parameters), subsequently validated by third parties.

3. UniGe Case Study

The University of Genoa (UniGe) has made a strong commitment to combating climate change, accounting for and validating its carbon footprint since 2014 [33] through the commitment to be climate neutral by 2030, joining the United Nations global campaign Race To Zero for Universities and Colleges, and systematically managing sustainability through the ad hoc University Sustainability Commission. It should also be noted that UniGe, along with a few other Italian universities, had already obtained accreditation from the UNFCCC in 2010 to participate in the United Nations' work on climate change, including COP21 held in Paris in December 2015, which saw the signing of the historic Paris Agreement on limiting global warming. In particular, having joined "The Sustainable Development Goals Accord," an initiative coordinated by the UN Environment Youth and Education Alliance declaring a Climate Emergency, and the United Nations global campaign Race To Zero for Universities and Colleges [34], UniGe approved its climate strategy in 2022 to achieve climate neutrality by 2030. This commitment also requires that, within three years from the start of implementation, a climate action plan be developed to achieve climate neutrality (mitigation plan) and to reach the defined resilience thresholds (adaptation plan). The plan must include a target date and intermediate milestones to meet these objectives as soon as possible. UniGe's climate action plan, therefore, comprises both the mitigation plan and the climate change adaptation plan.

The mitigation plan defines the pathway and actions needed to attain climate neutrality, establishing short- and medium-term interim targets as well as long-term goals toward net-zero emissions. Based on UniGe's most recent certified greenhouse gas inventory (2024)

(Figure 2), the plan outlines strategies to reduce direct emissions from fossil fuel combustion and indirect emissions associated with electricity consumption. Specific measures are also foreseen to cut other indirect emissions, including those related to mobility, waste, water use, and procurement. Residual emissions will be offset through the purchase of certified credits registered on national or international platforms.

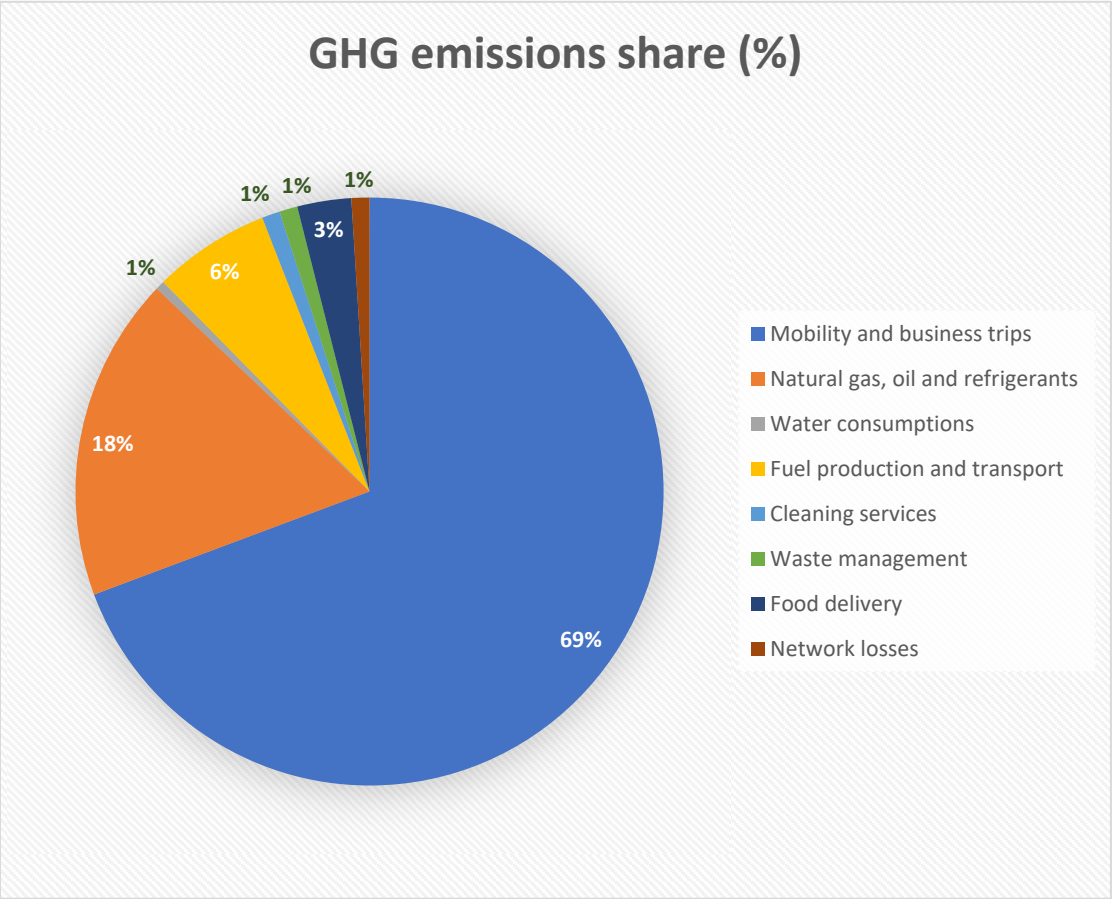

Figure 2. University of Genoa emissions clustering 2022. Source: University of Genoa CNP.

The climate change adaptation plan, in turn, aims to enhance UniGe's resilience—its capacity to adapt to ongoing climate change. It is grounded in the Liguria Region's Climate Change Adaptation Strategy (SRACC) and integrates UniGe's own procedures for responding to weather alerts and guidelines to mitigate risks linked to extreme temperatures. According to the CNP document and the related scopes, UniGe's most significant contribution to its overall emissions—around 80%—is derived from Scope 3, i.e., other indirect emissions from goods and services procured by the university. For Scope 1, the main source of emissions is heat generation from natural gas boilers. Thanks to the purchase of electricity with a Guarantee of Origin, Scope 2 now accounts for only about 0.6% of total emissions, compared to around 30% in 2015–2016, 70% in 2013–2015 (when Scope 3 was not yet included), and approximately 3.3% in 2019. The figure below shows emissions by category expressed as percentage shares.

In accordance with the ISO 14068 approach, UniGe has defined an emissions management hierarchy based on reducing emissions within its organizational boundaries and offsetting residual emissions. Improving greenhouse gas removal within the organization's boundaries is not considered an option that can bring significant results for the anthropogenic context in which the organization operates. This is applied through the following actions:

- Avoiding or reducing greenhouse gas emissions through efficiency and savings;
- Reducing emissions by switching to renewable energy sources;
- Offsetting any residual emissions.

As a general guideline, the emissions management plan follows a continuous improvement approach to reduce the use of offsets over time. Residual greenhouse gas emissions are greenhouse gas emissions along the organization's carbon footprint that remain after the implementation of all technologically and economically feasible measures.

Going into greater detail on Scope 3, particularly sustainable mobility, as the field of investigation of this paper, it should be specified that, in the methodology adopted for UCNPs, climate neutrality must be achieved by including the reduction, elimination, or offsetting of GHG emissions associated with fleet vehicles; commuting by students, teachers, and staff; and business and mission travel.

This is precisely where the connection with the Home-to-Work Commuting Plan comes in (Table 1). The UCNP requires the inclusion of a roadmap setting progressive reduction targets, in line with what is realistically achievable within the assigned timeframe, segmented into transitional targets until 2050. Therefore, the only reliable source officially approved by university governance regarding sustainability actions in relation to transport policies is precisely the HtWCP. Regarding the nature and purposes of this plan, they have already been explained in Section 2. In this part, we will focus on how the roadmap was drawn up and the challenges involved in defining intermediate objectives in such a long-term strategy (2050, with actions spanning a 25-year period), starting officially with the updated editions of the HtWCP, which are drawn up every two years (2022–2024).

Table 1. Summarizes the objectives, scope, and methodologies of the two plans, providing initial guidance for discussion.

	Objectives	Methodology	Time Frame
University Climate Neutrality Plan	Baseline calculation for current GHG emissions' production by scope and reduction target setting	GHG emissions' data direct and indirect collection related to Scopes 1, 2, and 3	25 years
University Home-to-Work Commuting Plan	Commuting mobility management and sustainable modal shift	Actions shaped around structural conditions and commuting mobility data collected through voluntary surveys	2 years

3.1. UniGe Climate Neutrality Plan

UniGe has been quantifying and externally certifying its carbon footprint since 2014, using it as a foundational element for strategic planning. The university has established governance structures dedicated to environmental sustainability, such as the Sustainability Office and dedicated working groups, and participates in national and international sustainability networks. All campuses and university buildings are included in regular GHG inventories (latest certified: 2019), which measure both direct and indirect emissions (Scope 1, 2, and 3). The majority of emissions (around 70%) are related to indirect sources such as mobility, commuting, and purchased goods/services, with direct energy use and heating comprising a smaller fraction. UniGe aims for climate neutrality (net-zero GHG emissions) by 2030 for Scopes 1 and 2, and by 2050 for Scope 3, in alignment with the United Nations Race To Zero campaign. Additional intermediate milestones are established for monitoring progress, and all efforts are regularly evaluated and updated according to international guidelines and best practices.

In this direction, once GHG emissions' baseline has been assessed, some distinctive lines of action may be identified:

- Energy efficiency and retrofit: University runs extensive building energy retrofits (e.g., improved insulation, high-efficiency heating systems, and LED lighting), and contracts integrate energy service providers for optimal management and technical upgrades.
- Renewable energy: Expansion of on-campus solar capacity and the purchase of certified renewable electricity are central to the decarbonization strategy.
- Sustainable mobility: Measures include incentives for public transport and bike sharing, improved cycling infrastructure, discounted fares for students, and collaboration within European university networks for low-carbon mobility.
- Purchasing policy and waste reduction: UniGe promotes green procurement standards and aims for minimal waste generation through the application of "5R" principles (reduce, reuse, recycle, collect, recover). The university organizes information campaigns, provides reusable water bottles, and manages separate waste collection throughout its facilities.
- Offsetting and compensation: Unavoidable residual emissions will be neutralized using certified carbon credits or local sequestration initiatives, following strict social justice and biodiversity protection criteria.
- Education, community engagement, and equity: The strategy integrates climate neutrality, resilience, and sustainability into the curriculum and research activities, supporting a wide inclusion of internal and external stakeholders in climate action planning.

3.2. UniGe Home-to-Work Commuting Plans

The first UniGe Mobility Manager was appointed in 2021, and in 2022, the first HtWCP was approved. Behavior investigation showed relevant results. Most UniGe community members own a car, but motorbike and bicycle ownership is also relevant, and a non-negligible proportion of students lack personal mobility assets, sometimes intentionally choosing soft mobility or shared modes. Parking needs for cars, motorcycles, and bicycles emerge as an issue, with a significant use of both university-managed and free street parking around campuses. Many respondents regularly travel between multiple university locations each week, including internal (Genova) and regional campuses. A majority use public transport and multimodal solutions, often with subsidized fares, though constraints such as long travel times, irregular service, high costs, and parking difficulties lead many to choose alternative or multimodal options. There is a strong willingness to change mobility habits, primarily if alternative options become more efficient, regular, and integrated. Awareness of innovative solutions like Mobility as a Service (MaaS) is still limited, but interest exists especially for app-based integration of coordinated multimodal transport.

The HtWCP aims to encourage a modal shift toward public and active transport modes, reduce single-occupancy car use, and improve accessibility and inclusion for all campus users. The conceptual framework includes incentive-based measures, infrastructural improvements, and awareness-building to support a more sustainable, efficient, and equitable travel environment for students and staff. Similarly to UCNP, selected actions are then shaped around this knowledge background:

- Sustainable modes of infrastructure and services: Installation of e-bike charging stations, increased bike-sharing and velostation agreements, creation of new cycling paths and racks, improved monitored parking, and ongoing mapping of campus accessibility.
- Public transport incentives: Renewal and expansion of discount and free fare arrangements for students and staff, including new providers and more flexible payment solutions.

- Smart working: Institutionalization of remote work for staff, supported by municipal coordination, especially during major urban construction phases.
- Mobility management and MaaS: Pilot university-led testing of MaaS platforms to integrate diverse transport options and payment into seamless digital experiences for users.
- Awareness and education: Targeted campaigns, events tied to European Mobility Week, and specialized mobility management coursework for students and staff.

The implementation program, monitoring protocols, and benefit analyses are aimed at reducing UniGe's carbon footprint and traffic congestion, increasing safety, and ensuring satisfaction and inclusion for the university population. The effectiveness will be evaluated via periodic surveys and updates to the plan.

As shown in Table 1, from a general perspective and the UniGe case study, it is self-evident how similar planning tools align in terms of general goals and the operational strategies to achieve them. The Avoid–Shift–Improve (ASI) approach supported by UniGe's HtWCP, where transport sector decarbonization and mitigation are pursued through the limitation of unnecessary displacements, the promotion of sustainable alternatives, and the enhancement of adopted technologies, may actually be seen as a significant way to achieve climate neutrality targets [35].

In this direction, selected actions included in UniGe's HtWCP may not only support the achievement of a more sustainable mobility targeted by UniGe's Climate Neutrality Strategy, and reduce emissions and waste production, but also support community engagement through the promotion of dedicated campaigns and communication events.

Moreover, as far as sustainable mobility targets are concerned, potential synergies with UniGe's HtWCP may be traced in terms of GHG emissions assessment for Scope 3, relating them to users' modal choices and traveled distances. In this direction, the match between the UCNP and HtWCP could overcome the impossibility of deriving similar data directly from company structural and organizational assets, thus requiring employees' commitment and contribution.

UniGe represents, in this direction, an interesting case study supporting the implementation of a simplified approach that considers the following (Figure 3):

- Modal share;
- Traveled distances;
- Emissions per kilometer according to national official data.

A subsequent upscaling of the collected sample to the wider UniGe community could therefore support the current evaluation of the GHG emissions footprint and reduction targets to be pursued in the future.

The implementation of a similar integrated approach indeed showed some relevant challenges at the university level:

- Low response rate, translating into difficult and ineffective data collection, and non-representativeness of the obtained results;
- Non-uniform responsiveness of different community member segments, resulting in the selected sample potentially being statistically irrelevant;
- The need to rely on standardized methodology to assess and calculate Scope 3-related emissions from data on modal choices.

In this direction, subsampling of the respondents to meet the representativeness of the targeted population was implemented. Moreover, emission factors were derived from official data provided by European institutions.

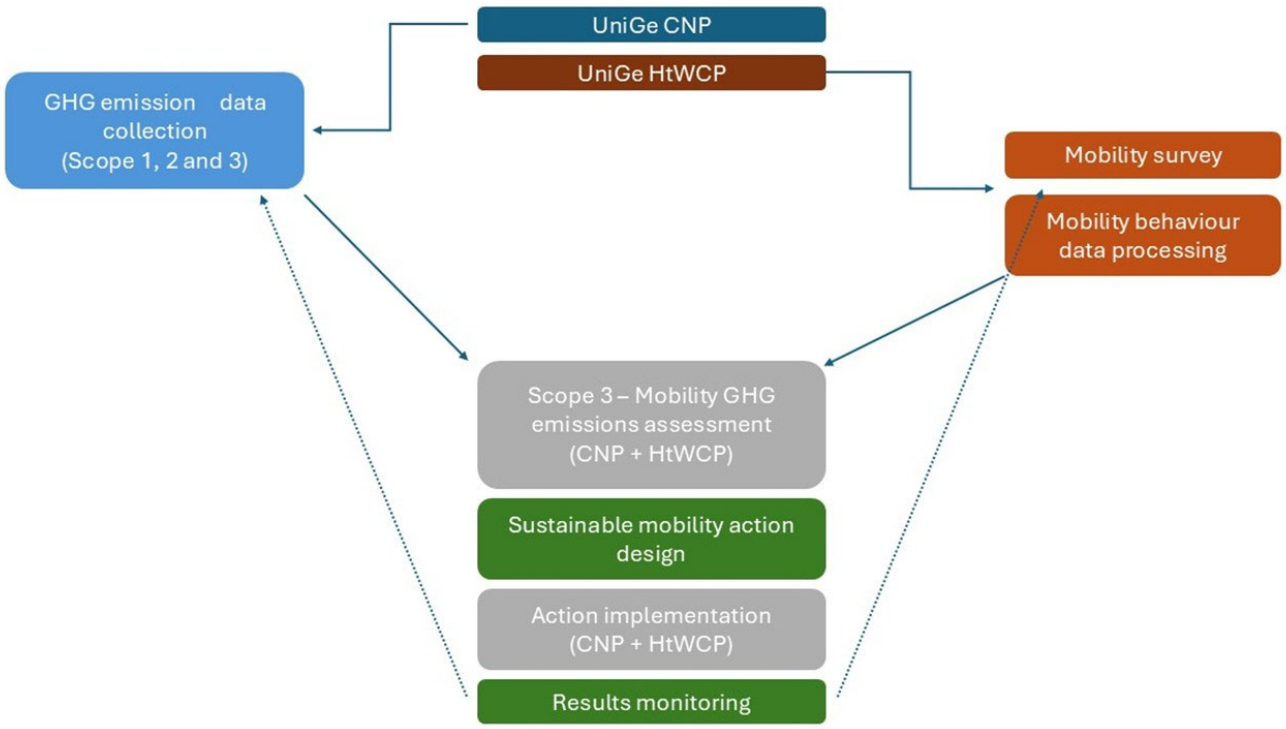

Figure 3. Integrated planning workflow. Source: Authors.

4. Discussion

4.1. Institutional Perspective

Similar points of contact show the potential relevance of purposeful integration of the HtWCP into the CNP, thus constituting an innovative governance and data-management strategy for universities seeking to achieve net-zero emissions commitments while simultaneously satisfying regulatory obligations. The present study addresses a critical gap in the scientific debate: while substantial scholarship exists on climate accounting methodologies and on sustainable mobility policies independently, relatively little work has examined how these two complementary frameworks can be operationalized as mutually reinforcing instruments within institutional practice [36,37]. The University of Genoa case study exemplifies how institutions can transcend siloed planning approaches to generate synergistic benefits. The urgency of this integration proposition stems from a well-documented structural challenge in higher education decarbonization efforts. Scope 3 emissions—particularly those arising from employee and student commuting—consistently represent the largest share of university carbon footprints, often accounting for 50–92% of total emissions depending on institutional context [38,39]. Yet collecting reliable, granular data on commuting behaviors has historically proven one of the most resource-intensive and methodologically fraught aspects of GHG accounting [40]. The GHG Protocol's distance-based methodology requires detailed information about transport modes, commuting distances, and frequency of travel (GHG Protocol Initiative, 2015), data that organizations typically lack within their operational boundaries [38]. Traditional approaches have employed spend-based proxies or averaged national datasets, sacrificing organizational specificity and limiting the utility of emissions inventories for setting meaningful reduction targets [39,41]. The Italian regulatory context presents a unique opportunity to overcome this impasse: the mandatory HtWCP surveys required under Decree 179/2021 collect precisely the granular mobility data needed for reliable Scope 3 accounting. By leveraging this compulsory data stream, institutions can address the dual imperatives of compliance and credibility without multiplying institutional burden. Nevertheless, in this direction, stronger emphasis should

be put on the rigorous design and spread of HtWCP surveys. Subsequently, since currently companies and public entities are coordinated and the municipal level by the Area MM structure, thus usually collectively benefitting from incentives and shared efforts, some response rate thresholds could be set in order to push local entities to pursue quality data and relevant results.

4.2. University Look

The extant literature in institutional sustainability and governance recognizes that climate integration in higher education succeeds primarily through cross-functional collaboration and the purposeful alignment of multiple planning streams [39]. Strategic planners and sustainability professionals increasingly acknowledge that sustainability governance cannot be merely technical—it must embed climate considerations into institutional decision-making architectures, resource allocation, and strategic planning cycles.

The challenge is that universities typically manage the CNP and HtWCP as distinct initiatives, governed by separate legislative mandates and institutional departments. The CNP falls under voluntary climate commitments (e.g., Race To Zero for Universities), whilst the HtWCP responds to mandatory national labor and environmental regulations. This separation creates inefficiencies: parallel data collection efforts, fragmented accountability structures, and limited institutional learning across planning domains. The operational model proposed herein reframes this fragmentation. Rather than viewing CNPs and HtWCPs as competing demands on organizational resources, the integration approach treats the HtWCP survey infrastructure as a shared evidence foundation that simultaneously strengthens the methodological rigor of climate accounting and deepens the impact orientation of mobility interventions. This reorientation aligns with emerging best practices in transport decarbonization.

To this aim, the growing relevance of sustainability divisions and offices in universities may coordinate and support similar integration through an holistic approach, and building multi-dimensional datasets could lead to more data-driven and effective sustainability policies.

The Avoid–Shift–Improve (ASI) framework—a hierarchical approach increasingly adopted in urban transport policy—prescribes a sequence whereby avoiding unnecessary trips and shifting to low-carbon modes are prioritized over technological improvements [42]. Evidence demonstrates that Avoid and Shift strategies together can achieve substantial emission reductions [43] and, critically, can achieve near-term emissions reductions cost-effectively compared to Improve-only strategies [42]. The University of Genoa HtWCP operationalizes this hierarchy precisely through its emphasis on structural accessibility, multimodal integration, and voluntary behavioral change rather than vehicle-fleet electrification alone. When these mobility actions are systematically linked to Scope 3 emissions accounting, as the proposed integration model enables, universities can simultaneously advance climate targets and mobility sustainability while generating robust evidence for future policy refinement.

A pervasive concern within the academic and practitioner literature concerns the heterogeneity and limited comparability of university carbon accounting methodologies globally. Whilst the GHG Protocol provides internationally recognized standards, implementation varies significantly across institutions [38,41]. Universities face particular challenges in defining Scope 3's boundaries—what to include, what to exclude, and how to handle student versus staff commuting—leading to figures that are often institution-specific artifacts rather than comparable baselines [38,40]. Recent systematic literature reviews of carbon accounting in higher education reveal widespread reliance on proxy data, questionable assumptions, and acknowledged data gaps, particularly regarding commuting

emissions methodologies [37,38]. The University of Genoa's approach mitigates these vulnerabilities by grounding commuting emissions estimates in actual behavioral data collected through a comprehensive, mandatory survey instrument. By aligning the HtWCP questionnaire structure with GHG Protocol distance-based methodology requirements, the institution captures travel distance, transportation mode, and commuting frequency in sufficient granularity to apply officially recognized national emissions conversion factors, thereby achieving what scholars identify as superior methodological rigor [40,41].

Moreover, this data integration supports continuous methodological improvement. Rather than conducting emissions surveys once per climate planning cycle (typically 5–10 years), the biennial HtWCP updates provide a regular temporal cadence for monitoring commuting behavior evolution and validating emission projections [44]. This cyclical feedback mechanism embeds adaptive management into institutional practice—a feature notably absent from conventional CNP design. The emerging literature on corporate and institutional climate governance emphasizes the importance of iterative, learning-oriented approaches to emissions management [41]; the integrated model operationalizes this principle concretely. The framework for campus carbon emission accounting developed by Yang et al. [41] provides additional validation, demonstrating through the case of Sichuan University that ongoing attention to uncertainty analysis and data quality substantially improves the credibility and policy utility of carbon accounting systems.

4.3. Stakeholders' Involvement

A third dimension of scholarly debate centers on how climate commitment translates into institutional culture change and stakeholder mobilization. Substantial research demonstrates that climate initiatives succeed only when grounded in genuine stakeholder participation and embedded within institutional identity and values [45,46]. Universities face a particular imperative: as educational institutions, they must model the behavioral and organizational changes they espouse academically. The integration of HtWCP into CNP planning reshapes this dynamic by repositioning mobility as a central institutional practice rather than a peripheral compliance item. The recent literature on community-based participatory climate action emphasizes that deepened participation requires real opportunities to set priorities, make decisions, and participate in implementation and monitoring stages—not merely consultation [46]. The University of Genoa case illustrates how integrated planning can generate multiple engagement vectors: the HtWCP survey itself becomes a dialogue platform for understanding community mobility preferences and constraints; the translation of survey data into Scope 3 baseline emissions renders abstract climate targets concrete and locally meaningful; and the Avoid–Shift–Improve interventions derived from mobility data simultaneously respond to stated commuter preferences and measurable climate objectives.

Furthermore, this integration supports what recent sustainability governance studies have termed institutional reflexivity—the capacity of organizations to learn from their own practices and adapt strategies accordingly. By operationalizing a closed feedback loop linking data collection, emissions accounting, intervention design, and periodic review, universities create conditions for what scholars identify as transformative sustainability governance [45,46]. The HtWCP represents not merely an employment or transportation policy but an institutional mirror reflecting collective mobility choices and their climate consequences. This reflective capacity fosters broader stakeholder buy-in and commitment than technical compliance-driven approaches typically achieve. Importantly, the gendered dimensions of commuting behavior—documented extensively in recent transport research—underscore why participatory approaches to mobility planning are particularly valuable. Research has demonstrated that women exhibit distinctive travel patterns, including shorter

commute distances, multiple trip chaining, and greater reliance on public transit [47,48], patterns often overlooked in traditional transport planning. By incorporating mobility data through systematic HtWCP surveys, universities capture these gendered dimensions and can design more inclusive and equitable mobility interventions.

Beyond immediate emissions accounting benefits, the integration framework contributes to a broader scholarly conversation about institutional innovation in universities and collaborative climate governance. Recent scholarship emphasizes that universities can serve as living laboratories for sustainability transformation, testing and refining approaches that may subsequently scale to municipal, regional, or national levels [45]. The University of Genoa's experience with HtWCP-CNP integration exemplifies this potential. By demonstrating that voluntary climate commitments can be methodologically strengthened and stakeholder engagement deepened through purposeful alignment with regulatory instruments, the university contributes evidence to the growing literature on policy integration and collaborative governance [45,46].

4.4. Up-Scaling Potential

Moreover, the integration approach resonates with international policy discussions around the coordination and effectiveness of multiple governance instruments. The EU Cities Mission, Sustainable Urban Mobility Planning (SUMP) frameworks, and emerging standards for university sustainability commitments all emphasize the need for coherence across legal, financial, and institutional tools. Universities that model integrative practice internally position themselves as institutional partners capable of contributing expertise and evidence to broader urban and regional decarbonization initiatives. The replication of such models across multiple institutions could contribute to establishing de facto best practices and eventually inform the development of standardized protocols for integrating mobility and climate planning in higher education, filling what Valls-Val and Bovea [38] identified as critical research gaps in higher education sustainability.

5. Conclusions

5.1. Research Outcomes

This research presents a paradigmatic shift in how universities approach the integration of voluntary climate commitments and mandatory mobility management regulations, demonstrating that the purposeful articulation of the CNP and HtWCP constitutes a novel methodological contribution that resolves a long-standing data quality challenge in higher education decarbonization. By developing and validating an integrated operational workflow, the University of Genoa case study fills a critical gap in the scientific literature: while substantial scholarship documents climate accounting methodologies and sustainable mobility policies in isolation, this research provides the first systematic examination of how these complementary instruments can be operationalized as synergistic governance tools within institutional practice. This integration addresses not merely an operational inefficiency but a fundamental methodological vulnerability that has plagued university carbon accounting globally—the absence of reliable, granular data for Scope 3 commuting emissions, which consistently represent the largest and most difficult-to-quantify component of campus carbon footprints.

In this direction, the CNP approach could provide a new perspective towards implementing the HtWCP's mobility actions, thus suggesting a compensation mechanism that currently is not taken into account but could support the effectiveness of strategies and plan development for most relevant companies and administrations. Joint and shared actions developed through coordinated planning could therefore benefit from this new paradigm.

The added value of this research extends across several analytically distinct dimensions. First, on the methodological front, the proposed framework overcomes the notorious "Scope 3 data gap" documented extensively in the recent literature. Rather than employing proxy methodologies, spend-based estimates, or averaged national datasets—all of which sacrifice organizational specificity and undermine emissions inventory credibility—the integration model leverages mandatory HtWCP survey infrastructure to collect precisely the behavioral data required by GHG Protocol distance-based methodology: transportation mode, commuting distance, and travel frequency. This methodological innovation transforms a compliance burden into an evidence asset, eliminating the need for parallel data collection efforts and substantially improving the rigor of climate accounting.

Second, on the governance and policy integration front, this research contributes to an emerging body of scholarship emphasizing that climate action succeeds only through coherent alignment of multiple institutional tools and legislative instruments. Recent work in institutional sustainability has highlighted that governance fragmentation—wherein climate commitments and regulatory obligations are managed in silos—leads to inefficiencies, duplicative efforts, and suboptimal policy outcomes. The University of Genoa demonstrates concretely how integrative governance models can be operationalized, providing evidence valuable to the broader policy integration literature and resonating with recent strategic partnerships such as the ISO-GHG Protocol harmonization initiative, which similarly aims to reduce fragmentation and simplify carbon accounting globally. Universities that adopt similar integrative approaches position themselves as institutional innovators capable of modeling governance practices that may eventually inform municipal, corporate, and national policy frameworks. Similar cross-fertilization may indeed contribute to the widening of the temporal frame of mobility management and the HtWCP, thus suggesting the introduction of a strategic long-term decisional framework, integrating the tactical one, often hampered by the operational nature linked to a two-year planning perspective.

Third, on the innovation and replicability dimension, this work contributes to scholarship on institutional innovation and the transferability of sustainability solutions. The methodology developed at the University of Genoa, while anchored in the Italian regulatory context, embodies design principles—systematic data integration, feedback mechanisms, and cross-functional collaboration—that are generalizable across diverse institutional and geographical contexts. The emerging literature on the applicability of novel sustainability methodologies reveals that successful transfer requires both methodological flexibility and sensitivity to local regulatory and organizational contexts. The present framework provides this balance: core principles of data integration and synergy remain robust, whilst specific implementation protocols can be adapted to accommodate varied legal frameworks, institutional sizes, and geographic conditions. This positions the model for replication and scale-up across the European higher education sector and beyond.

This research, whilst contributing novel insights, operates within several important limitations that merit explicit acknowledgment. First, regulatory and legal context: The developed model is deeply embedded within the Italian legal and administrative framework, specifically Decree 179/2021, which establishes mandatory HtWCP requirements for organizations exceeding 100 employees. Whilst numerous European nations have adopted comparable mobility management regulations, implementation details, survey methodologies, and governance structures vary significantly. International generalization requires careful institutional adaptation and empirical validation in diverse regulatory environments. Second, institutional specificity: The University of Genoa case reflects particular organizational characteristics—institutional size, geographic location (coastal city with moderate public transit), campus structure, local labor market, and climate history—that may not obtain uniformly across higher education. Smaller universities, those in geograph-

ically remote or rural locations, and those in regions with underdeveloped public transport infrastructure may face distinct constraints in implementing this integrative model. Research on sustainability education integration worldwide reveals that effectiveness depends substantially on institutional context and capacity.

Third, temporal and behavioral dynamics: The research captures a single institutional moment (2022–2024 HtWCP surveys). However, university commuting patterns are dynamic, particularly in the post-pandemic era characterized by increased remote work adoption, flexible learning arrangements, and evolving mobility preferences. Sensitivity to these temporal dynamics requires multi-year data comparison and validation—a recommendation implemented implicitly in the proposed framework's biennial cycle but warranting explicit methodological emphasis. Fourth, self-reported data limitations: HtWCP surveys rely on voluntary respondent participation, introducing well-documented risks including response bias, social desirability effects, and seasonal variation. Whilst the present framework includes mitigation strategies (large sample sizes, multiple survey rounds, and cross-validation with available transport data), residual measurement uncertainty remains. Fifth, partial scope coverage: By emphasizing Scope 3 commuting emissions, this research addresses a critical but partial component of university decarbonization. Scope 1 (direct emissions), Scope 2 (purchased energy), and other Scope 3 categories (procurement, waste, and business travel) require distinct analytical approaches and remain beyond the present integration framework.

Building on the findings and limitations documented, several research trajectories warrant prioritization. Comparative institutional studies across multiple universities operating in different regulatory contexts—not only within Italy but across Europe and internationally—would validate the generalizability of the proposed integrative model, identify context-specific adaptations, and generate standardized protocols for best practice dissemination. Digital infrastructure and monitoring innovations, including smart campus sensors, digital twins, and real-time mobility data platforms, represent emerging opportunities to enhance the temporal granularity and coverage of commuting data collection whilst reducing respondent burden. Standardization efforts aligned with recent international initiatives, such as the ISO-GHG Protocol partnership, could embed mobility–climate integration principles into emerging harmonized global standards, facilitating cross-institutional comparison and policy uptake.

Gendered and equity dimensions of commuting and climate planning merit deeper investigation. Research demonstrates that women exhibit distinctive commuting patterns, including shorter distances, multi-stop trip chains, and greater reliance on public transit—patterns often rendered invisible in aggregate data. Future research should explicitly examine how integrated CNP-HtWCP frameworks can capture and respond to these gendered mobility dimensions, enhancing both climate equity and social inclusion. Integration with broader urban decarbonization strategies deserves attention: universities do not operate in isolation but are embedded within municipal, regional, and metropolitan contexts. Future work should clarify how campus-level mobility–climate integration interfaces with municipal Sustainable Urban Mobility Plans (SUMPs), regional climate strategies, and emerging EU Cities Mission initiatives, positioning universities as institutional partners in broader urban transitions.

Ultimately, this research demonstrates that universities pursuing net-zero commitments can substantially enhance both the methodological rigor and governance effectiveness of their climate strategies by purposefully integrating mandatory regulatory instruments (such as commuting plans) with voluntary climate commitments. The University of Genoa exemplifies how institutions can transcend siloed planning approaches to generate

synergistic benefits: improved data quality, streamlined compliance, deeper stakeholder engagement, and iterative learning embedded in institutional practice.

5.2. Policy Inspiration

The proposed synergy and integration between the climate neutrality realm and the one targeting sustainable mobility management at the university level requires looking at the bigger picture of territorial MM and potential policy implications.

As previously stated, Italian legislation has introduced a two-level MM mechanism. Companies and entities should collect data that is subsequently shared and aggregated at the territorial level, thus supporting data-driven and bottom-up sustainable mobility and incentivizing municipal policies.

To this aim, universities may represent an effective booster to integrate this mechanism. Aggregated data at the municipal level could indeed be processed in a standardized way to calculate Scope 3 emissions, both at the territorial and company level. Nonetheless, to obtain significant data, two main criticalities should be addressed.

- Collected data should be quantitatively representative of the current state of the art. In this direction, acting on territorial MM leverages, incentives for sustainable MM could be limited only to companies reaching a relevant response rate (e.g., above 60%).
- Multi-dimensional datasets should be implemented both at the company and territorial levels. Integrated and holistic data sources are necessarily required to implement data-driven planning and actions.

5.3. Research Limitations and Perspectives

Some limitations of the study need to be pointed out as well. Because planning tools are derived from regulatory prescriptions, they rely strongly on national legal frameworks; thus, the transferability of the proposed methodology should be discussed according to different countries' regulations. Further validation of a similar approach should therefore be implemented, considering variable frameworks.

Moreover, the uniqueness of the considered case study should be considered as well. The University of Genoa comprises more than 30,000 community members, so a low response rate to questionnaires does not undermine data quantitative representativeness. Non-university entities, whether public institutions or private companies, may face more relevant issues in terms of data unavailability, thus relying on voluntary participation only.

Nevertheless, the significance of this finding extends beyond the specific institutional context. Universities increasingly operate as "living laboratories" for sustainability transformation, testing and refining approaches that may subsequently scale to municipal and corporate contexts.

In this direction, universities may play a pivotal role in supporting a compensation mechanism where entities and companies that prove to be quantitatively more relevant may benefit from a shared and coordinated commitment. Higher education institutions may deploy their double role of territorial stakeholder and governance active entity to reduce the distance between the regulatory layer and the operational one.

Future research may indeed target universities more systematically. HtWCP surveys may be used to obtain statistically relevant samples, thus leading to more representative results.

Moreover, comparative studies involving multiple Italian institutions and other EU academic entities may lead to the identification of more solid and transferable frameworks for emission calculation factors, data collection, and respondent sampling.

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Abbreviations

The following abbreviations are used in this manuscript:

ASI	Avoid-Shift-Improve
CN	Climate Neutrality
CNP	Climate Neutrality Plan
EGD	European Green Deal
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse Gases
HtWCP	Home-to-Work Commuting Plan
MaaS	Mobility-as-a-Service
SUMP	Sustainable Urban Mobility Plan
SRACC	Climate Change Adaptation Strategy

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