Carbon-Neutral Campuses
An Integrated Assessment Framework for Sustainable Universities in Hong Kong

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Abstract

As global warming and sustainable urban design have become increasingly important topics, universities around the world are adopting net-zero carbon goals. Hong Kong's government has announced that it would strive to achieve carbon neutrality by 2050, however sustainability practices at its higher educational institutions are still at an early stage. Recent literature reveals that Hong Kong is missing policies related to carbon-neutral campuses, and there are no uniform guidelines to evaluate a campus' environmental performance qualifications. Therefore, there is an urgent need for an integrated assessment framework for carbon-neutral campuses, to support Hong Kong universities to be carbon-neutral on time. This study has analysed the current environmental practices of three leading overseas universities and used their achievements and processes of change to form a comprehensive assessment framework. The Chinese University of Hong Kong was used as a case study site to test the feasibility of this framework and identify challenges and opportunities as part of a roadmap for further improvement. The research shows how building a carbon-neutral campus is a multi-faceted and multi-year process, encompassing policies and management, infrastructure and facilities, and the joint efforts of everyone. The comprehensive framework for carbon-neutral campuses can provide awareness and strategies for administrators and planners in universities, or other large organisations aiming to achieve sustainable operations.

Keywords

Sustainability, Carbon Neutrality, University Campus Planning, Urban Processes

1. Introduction

As the amounts of greenhouse gas emissions continue to increase and lead to global warming, sustainability has become an increasingly urgent topic (Stocker et al., 2013). Rising temperatures will change weather patterns and disturb the balance of nature, bringing multiple risks to humans and other species such as rising sea levels, extreme storms, droughts, food shortages and disease outbreaks (The World Bank, 2013). In order to address these threats, various international initiatives have been created. In 1992, the United Nations adopted the United Nations Framework Convention on Climate Change (UNFCCC), which ultimate goal is reducing greenhouse gas (GHG) emissions. In 1997, the "Kyoto Protocol" stipulated that GHG control or emission reduction is a legal obligation of developed countries (Breidenich et al., 1998). In 2015, 193 countries pledged their support for the 17 Sustainable Development Goals (SDGs), of which climate action is the 13th (UN, 2016). In the same year, the Paris Agreement called for pursuing efforts to limit the temperature increase to 1.5°C (UNFCCC, 2015) and achieving net zero carbon dioxide emissions by 2050 (UN, 2020). Many countries and regions have set carbon-neutral targets, policies, and measures. The US government has enacted a series of policies on transportation, construction, and clean energy (Williams et al., 2021). The British government has formulated measures in five major areas: building, transportation, clean energy, waste management, energy saving, and low-carbon services (Wei et al., 2022). Many countries have announced plans to phase out internal combustion engine vehicles in favour of electric vehicles (Nian et al., 2019).

As one of the first Asian cities to act against climate change, Hong Kong has been gradually replacing coal with natural gas and zero-carbon sources for power generation since 1997 (Chan & Yeung, 2005) and has seen reduced carbon emissions since their peak in 2014 (Chan et al., 2016). The current government plans are aimed at achieving carbon neutrality by 2050 (Environment and Ecology Bureau, 2021). In 2021, the Hong Kong government published the Hong Kong's Climate Action Plan 2050, which outlines how the most significant sources of carbon emission in Hong Kong are electricity generation (66%), transport (18%), and waste (7%). For this, the Hong Kong government proposed four strategies, including Net-zero Electricity Generation, Energy Saving and Green Buildings, Green Transport, and Waste Reduction (Environment and Ecology Bureau, 2021). The Council for Sustainable Development in Hong Kong has conducted a comprehensive public engagement exercise with a "bottom-up" approach, which encourages businesses, schools, and NGOs to set carbon neutrality goals and timetables, and promote and encourage citizens to practice low-carbon lifestyles. One of them is getting universities involved to contribute to the region's goal of net-zero carbon.

In response to the UN's and government's call, eight Hong Kong public universities co-established the Hong Kong Sustainable Campus Consortium (HKSCC) in 2010, forming a platform

for the Higher Educational Institutions (HEIs) in Hong Kong to share information and practices on sustainability-related issues (Xiong & Mok, 2020). However according to scholars, the HKSCC has concentrated mostly on the internal operations and the reporting of annual reports, while more could have been done towards community engagement and sustainability education (An et al., 2019). The HKSCC hasn't provided exemplary sustainability practices for its member organisations and hasn't yet formulated standardised evaluation tools and systems to promote transformations to carbon neutrality across universities in Hong Kong (Xiong & Mok, 2020).

Compared to HEIs initiatives in Australia, Europe, and the US, sustainability practices in Hong Kong are still at an early stage (Xiong & Mok, 2020). The literature review has revealed that Hong Kong is missing policies related to carbon-neutral campuses, and there are no uniform standards to evaluate a campus' environmental performance qualifications. Therefore, there is an urgent need for an integrated assessment framework for carbon-neutral campuses, to support Hong Kong universities to be carbon-neutral on time. The study presented in this article explores how to develop such a framework, by reviewing current carbon-neutral practices of leading universities and extracting guidelines for policies and strategies aimed at achieving carbon-neutral campuses in Hong Kong. It has reviewed Hong Kong's specific measures for achieving carbon-neutrality, as well as its policies relevant to universities. The new assessment framework has been tested in a case study application at The Chinese University of Hong Kong, to identify the critical strategies already implemented and outline its current and future challenges in implementing sustainable campus systems.

2. Precedent Analysis: International Examples of Carbon-neutral University Campus Initiatives

Different countries have varying internal processes towards carbon neutrality, resulting in different conditions in which environmental university policies emerge. This study selected three leading universities in different political contexts, to gather detailed insights into their corresponding strategies. The first precedent is Arizona State University (ASU) in the United States, where the university decided internally to pursue carbon-neutral goals and measures. The second is Plymouth University in the United Kingdom, which follows targets and policies set by the national government. The third is the University of Tasmania (UTAS) in Australia, in which the university followed governmental guidelines and voluntarily implemented a range of measures.

To evaluate different universities' carbon reduction strategies, we first refer to the generalised protocols for categorising different types of carbon emissions (Ayça & Gülden, 2014; Semeraro et al., 2020). The 'Green House Gases Protocol' (World Economic Forum, 2022) is the most common standard, which classifies GHG emissions into three domains:

1. Direct GHG emissions that occur from sourc-

es that are owned or controlled by the institution, such as vehicles, heating plants, etc.

2. Indirect GHG emissions, primarily those generated by purchased electricity.

3. Indirect GHG emissions from the activities in the organisation, but which occur from sources not owned or controlled by it, such as commuting, waste generated in certain operations, or the transportation of purchased goods.

The measures found in international precedents address all three of these different domains. After reviewing literature relating to the three selected universities, we classified them into five categories: energy and green buildings, transportation, waste reduction, campus greening and carbon offsets, and community engagement. These measures have emerged under the influence of national policies, university policies, and in cooperation with other organisations (Figure 1).

Figure 1. Content for achieving a carbon-neutral campus

2.1 Internal drivers for a carbon-neutral campus: Arizona State University

In August 2022, the US government adopted plans to invest 370bn dollars towards sustainable transportation, construction, and clean energy. The packages of measures is estimated to be able to reduce US greenhouse gas emissions by 40% by 2030 (Jenkins et al., 2022). Until this recent milestone, The United States did not have any nation-wide legislation on carbon neutrality, nor does it have any specific policies relating to universities. However, many universities in the US have signed the American College & University Presidents' Climate Commitment (ACUPCC), committing to achieving a carbon-neutral campus. Many US universities have announced that they have achieved carbon neutrality, and Arizona State University (ASU) is one of them.

ASU ranked No. 1 in the United States in the Climate Action category of the 2022 Times Higher Education Impact Rankings (THE, 2022). The university announced in 2006 that it would be carbon-neutral by 2025, and it achieved the goal six years ahead of schedule through energy efficiency, green construction, carbon offsetting, and renewable energy acquisition (Tricoles, 2020). In 2007, ASU identified the causes of carbon emissions, and developed a baseline GHG inventory. The primary sources of carbon

in ASU are purchased electricity (42.4%), student commuting (23.2%), directly financed air travel (8.0%), and heating (6.2%) (ASU, 2020). The university implemented the following measures:

Energy and Green Buildings

ASU began to pay attention to energy in the early 2000s and installed improved lighting, air conditioning, heating systems in its buildings to reduce energy consumption. It also has had a comprehensive solar system since 2004, which has reduced approximately 42,642 metric tons of carbon dioxide (ASU, 2020). Besides, ASU has installed meters in its building to monitor the energy usage of each room. Since 2007, students and staff have been able to see their electricity consumption through real-time data, urging them to reduce energy use. The Leadership in Energy and Environmental Design (LEED) program is a green building certification system that determines if a building is sustainable. So far, ASU has 65 LEED-certified buildings, which equates to 26.5 per cent of ASU's total building volume (ASU, 2021).

Transportation

The university encourages pedestrian transportation. It has also expanded bike parking spaces and installed 66 electric vehicle charging ports on the campus. These measures promote students and staff to be more active, and use bicycles and electric bikes (ASU, n.d.). The university also offers free intercampus shuttles to reduce private car use.

Waste Reduction

ASU's 'Zero Waste' program includes basic waste sorting and recycling, as well as rewards. For example, staff and students can receive a discount on beverage purchases if they bring a reusable cup to any Starbucks and market on campus. Also, there are almost 1,000 free water stations across all ASU campus locations for filling reusable water bottles (ASU, n.d.).

Campus Greening and Carbon Offsets

ASU has taken many measures to maintain and improve the ecological diversity of the campus, including planting various native tree species to reduce the urban heat island effect. In 2018, ASU started collaborating with external organisations to achieve carbon offsets (ASU, 2020). 'Carbon offsetting' refers to the use of specialised companies or institutions to compensate for carbon emissions into the atmosphere through tree planting or other environmental protection projects (Bumpus & Liverman, 2008).

Community Engagement

The arboretum in ASU mitigates university's carbon emissions while providing a learning laboratory for ASU faculty and students (ASU, n.d.). This promotes students' engagement with environmental protection and enriches accredited courses. In 2019, 16.6% of ASU students took courses related to sustainable development, and 22% have participated in a sustainability-related volunteer activity (ASU, 2019). ASU also implemented 'Campus Metabolism', a website which displays historical and real-time energy

use and generation on campus (ASU, 2020).

2.2 External drivers for a carbon-neutral campus: University of Plymouth

The United Kingdom was one of the first country to enshrine its mid-and-long term emission reduction targets in law. Therefore, universities in the UK are driven by governmental policies and objectives (Ayça & Gülden, 2014). The Higher Education Funding Council for England (HEFCE) has created a carbon-neutral roadmap, which encourages universities to set objectives in line with the national carbon strategy (Ozawa-Meida et al., 2013). In 2008, the UK government formulated carbon-reduction measures in five major areas: buildings, transportation, clean energy, waste management, energy saving, and low-carbon services (Lockwood, 2013). In 2010, the British Standards Institution released the PAS 2060 Standard for Carbon Neutrality, the world's first carbon-neutral specification. The standard defines a set of measures and requirements for organisations how to demonstrate carbon neutrality. Each organisation must create a Carbon Management Plan which contains a target time, specific targets, measures for achieving reductions, and how to offset residual emissions (The British Standards Institution, 2011).

Although the University of Plymouth (UOP) has not achieved carbon neutrality, it ranked No. 2 in the UK in the Climate Action of 2022 UNSDGs (THE, 2022), becoming a model for other universities. In 2008, UOP issued the first Sustainability Strategy and Carbon Management Plan (Selby, 2009). Moreover, in 2019, the university published its first Carbon Strategy to align with the new goals of net zero for scope 1 & 2 emissions by 2025 and net zero across all emissions by 2030 (University of Plymouth (UOP), 2019). Based on the primary sources of carbon in UOP, which are procurement related (39.2%), student and staff commuting (21.8%), electricity (14.1%), and air travel (9.5%) (UOP, 2019), the initiatives implemented at this university as following:

Energy and Green Buildings

In 1994, the UOP installed the first automated building management system to control the energy use 95% of the buildings on the campus (Ayça & Gülden, 2014). Since 1990, the British government has published the Building Research Establishment Environmental Assessment Method (BREEAM), a certification system for sustainable buildings. Until now, seven UOP buildings have achieved the standard (UOP, n.d.). In 2014, the university upgraded its light fittings with LEDs, which used five times less energy than traditional lighting. In 2019, UOP operates a lower-carbon Energy Infrastructure to reduce the use of natural gas (UOP, n.d.).

Transportation

To improve access in the city, the Plymouth government will implement a more sustainable travel scheme, including electric vehicle charging points, a car club share scheme, and e-bikes (Plymouth City Council, n.d.). UOP adopted the first Green Travel Plan in 2003 and has installed 318 bicycle parking locations across campus to support cycling. Moreover, the University has

hosted a pilot project with e-bikes on campus (UOP, n.d.).

Waste Reduction

The UOP has developed a Waste Strategy in 2005. It has taken a different approach from other universities by introducing system in which all recyclable materials can be mixed in the same recycling bin. This method reduces the effort needed to recycle materials and has increased the amounts of recyclables (UOP, n.d.).

Campus Greening and Carbon Offsets

The UOP has participated in the UK Emissions Trading Scheme (UKETS) since 2002. This scheme enables the university to sell allowances or save them for future years if it reduces emissions below its target. If it has any excess, it could buy allowances from other organisations to cover it.

Community Engagement

The UOP has integrated sustainability and carbon neutrality in its curriculums so more students can understand and contribute to sustainable development (Selby, 2009). Students and staff can participate in the Physic Garden on campus as volunteers, which helps increase awareness of sustainability (UOP, n.d.). It regularly organises events on campus to promote bicycle use, including team riding, cycle maintenance courses, the sale of second-hand bikes, and cycle workshops (UOP, n.d.).

2.3 Voluntary drivers for a carbon-neutral campus: University of Tasmania

Australia relies on consumers and businesses instead of passing legislation to achieve carbon neutrality goals. The government issued guidelines and standards to achieve carbon neutrality. In 2010, the Australian government launched a voluntary standard, Climate Active, to provide a credible framework and recommendations for achieving carbon neutrality in organisations (Australian Government, 2019). Although there are no specific environmental guidelines for Australian universities, they need to join the Climate Active scheme to obtain their climate-neutral certifications (Sen et al., 2021).

According to this scheme, the University of Tasmania (UTAS) achieved carbon neutrality in 2016, becoming the second university to be certified in Australia (University of Tasmania, 2016). It was the top ranked university for climate action for three years (THE, 2022). In 2005, UTAS adopted Governance Principle GLP9 on Environmental Sustainability which stated that the key priorities in the university's operation are environmental protection and sustainability. In 2008, UTAS issued the first Sustainable Environment Designs Policy, followed by the development of design requirements in 2009 (University of Tasmania, 2021). The primary sources of carbon in UTAS are electricity (28.3%), transport (15.8%), waste (13.1%), fuel energy (11.7%), and construction (10.5%) (UTAS, 2022), and the initiatives implemented at this university as following:

Energy and Green Buildings

Since 2012, UTAS has taken energy performance contracts (EPC) to monitor and verify

efficiency of buildings' operation. Other initiatives include replacing diesel fuel with natural gas, installing a photovoltaic and solar hot water system, and upgrading to LED lighting systems (UTAS, 2021). Besides, UTAS aims to completely divest from fossil fuel-exposed investment funds, and it aims to phase out fossil fuels itself (UTAS, 2021). In 2003, the Australian government founded Green Star, a rating system for sustainable buildings and places (Australian Government, 2022). In 2012, a UTAS building was certified as a 5-star Green Star certification, becoming the first educational building in Tasmania to achieve a Green Star rating for environmental design (UTAS, 2021). Since then, two more buildings of UTAS have been certified.

Transportation

In 2012, UTAS created the Sustainable Transport Strategy. The University identifies carpooling, car sharing, public transportation, electric vehicles, cycling, and walking as sustainable transportation methods and encourages students and staff to implement them (UTAS, 2021).

Waste Reduction

In 2019, the university established a trial recycling wall for difficult-to-recycle objects. It started the Waste Minimisation Action Plan in 2021, which aims to recycle wherever possible by sorting waste generated from university operations and activities (UTAS, 2021).

Campus Greening and Carbon Offsets

Since 2009, UTAS' Natural Environment Strategy has delivered improved flora and fauna for its communities and installed an extensive green roof on a new building, using plants with local provenance (UTAS, 2021).

3. The Creation of a Comprehensive Framework for Carbon-neutral Campuses

Learning from these precedents, we can see how in order to achieve carbon-neutrality across Hong Kong's university campuses within the United Nations' timeline, they need to adopt comprehensive planning, development and management strategies in relation to the various dimensions of sustainability measures. The universities need to consider government policies and management, cooperate with other organisations, and implement strategic improvements across the internal policies and measures of the university and the behaviour and habits of students and staff.

From the precedent analysis we can conclude that whether it is an internally driven, externally driven, or voluntary-driven set of university policies, the improvements need to impact policies, measures, and behavioural habits. From the examples presented above, we can summarise a more detailed series of initiatives that support these processes of change and help maintain a university's current or future sustainable operations. The initiatives can be generalised and incorporated in an integrated assessment framework for carbon-neutral campuses, forming a checklist that can identify which aspects are in place and which issues remain to be addressed

Level	Category	Policies, measures and systems
National or Regional Government	Legislation, guidelines and standards	Standards and certification to measure carbon neutrality
		Legal guidelines for carbon neutral goals and operations
		The objectives, policies and measures of the university are aligned with the country/region's carbon neutral goals and policies
		A mechanism, body or institution for coordination and sharing of university policies and strategies
	University Consortium	Provides uniform policies and measures
		Applies standardized evaluation tools and systems
University	Energy and Green Buildings	Install large-scale and up-to-date solar systems
		Achieve environmental performance certified buildings
		Implement Automated building management systems
		Install meters to monitor and publish energy use
		Install LED lighting across the campus
		Phase out of fossil fuels
	Transportation	Create supportive walking routes
		Create comprehensive cycling networks
		Provide bicycle parking spaces
		Introduce bike-sharing systems
		Provide electric vehicle charging ports
		Use clean energy buses
		Discourage private cars
		Promote public transport for commuting
	Waste Reduction	Facilitate recycling
		Use reward mechanisms for sustainable practices
		Create mixed recycling collection points
		Provide recycling points for difficult-to-recycle objects
		Implement a Waste Minimization Action Plan
		Reduce the use of plastics
	Greening and Carbon Offsets	Plant varied native tree species
		Create interactive community gardens
		Install roof greening
		Employ carbon offsetting responsibly and sparingly
Community	Community Engagement	Set up volunteering and internship programmes in environmental practices on campus
		Use websites and dashboards to displays energy use and energy generation on campus
		Integrate environmental sustainability practices into curriculums
		Organise regular cycling campaigns and events
		Provide training and information on waste sorting, energy conservation

Table 1. An integrated assessment framework for carbon-neutral campuses

as part of a roadmap for the complete transition to carbon neutrality.

To implement the framework presented above towards the analysis of a university's campus planning, management and operations, the following steps can be conducted as a means to evaluate the achievements towards carbon-neutrality:

1. Analyse the university's operations through literature review, interviews and site observations;

2. Referencing the framework, apply scores to each category by consulting relevant professionals or stakeholders;

3. Based on this scoring, identify structural problem or secondary opportunities for improvement;

4. Develop a roadmap for completing the university's energy transition.

4. Case Study Testing: The Chinese University of Hong Kong

For this project, a case study application at The Chinese University of Hong Kong (CUHK) was conducted to demonstrate the implementation of the assessment framework and explore its feasibility. CUHK was the first university in Hong Kong to announce a carbon neutral target and has declared a plan to be fully carbon neutral by 2038 (SRSDO, 2021), ranking no. 1 in Hong Kong for Climate Action of 2022 UN-SDGs (THE, 2022). Following the assessment steps outlined above, the following sections document our findings gathered through literature, internal reports, interviews with stakeholders and site observations. The information is organised in the categories provided in the framework.

4.1 Policies and measures towards carbon neutrality in the Chinese University of Hong Kong (CUHK)

CUHK published its carbon reduction targets in the Campus Master Plan in 2010 and introduced its Sustainability Policy in 2012. From internal reports, it can be seen that over 90% of GHG emissions in CUHK are from electricity consumption, and 90% of this electricity consumption comes from buildings. Transportation, paper consumption, and waste are also carbon sources (SRSDO, 2021). The measures implemented at CUHK are described below.

Energy and Green Buildings

Since 2004, CUHK has installed around 1,000 photovoltaic panels. The energy generated by the panels is sold to a power company and reduces energy bills (SRSDO, 2021). In addition, CUHK has installed energy efficient installations across the campus, including LED lighting. It uses uses energy-efficient freshwater evaporative cooling towers with environmentally-friendly refrigerants in all new buildings (SRSDO, 2021). In student dormitories, a Hostel Smart Metering System allows residents to access their energy usage data and patterns. CUHK has fourteen BEAM (Building Environmental Assessment Method) and BEAM Plus Certified Projects, which could save around 20% of elec-

tricity (SRSDO CUHK, 2019). An interview with a building facilities manager showed that while the university is implementing sustainability measures, students and staff often do not turn off the lights when they leave their classrooms, so more training is needed to reduce energy use.

Transportation

For its internal bus transportation system, CUHK has adopted cleaner fuels such as biodiesel. Interviews with a transportation manager showed that electric buses were trialled, but the power of the electric vehicles was not sufficient for the steep roads of the campus' mountainous site. Also, the charging equipment was too slow to maintain efficient operations. The biodiesel solution is currently more expensive to run than electric buses, so further improvements might be implemented in the future. To improve walkability, several link bridges and lifts have been incorporated at strategic locations in the campus, to connect walking routes across different height levels and encourage students and staff to walk instead of taking the buses (SRSDO, 2021). Some cycling paths have been constructed, however through observation it can be seen that these are rarely used because of the hilly terrain.

Waste Reduction

CUHK has implemented a Waste Management Policy, assigning a high priority to waste reduction at source and encouraging cyclical use of resources (SRSDO, 2021). At the same time, at management level the university promotes procurement of products and services with sustainable production, transportation, use, and disposal with the lowest negative impact on the environment (SRSDO, n.d.). To ascertain the levels of training and awareness, thirteen students from different colleges and majors were interviewed. Eleven said they did not yet receive training on waste utilisation and sorting in CUHK. Two students mentioned that a professor brought them to the Jockey Club Museum of Climate Change in CUHK, but they didn't learn how to sort waste from this visit. Three students mentioned taking a course that referred to sustainability issues, helping them to learn about the urgency of global warming related changes, but not providing detailed information about potential solutions. Since 2018, the university has advocated for a plastic-free campus, encouraging CUHK students, staff, and caterers to discontinue plastic disposables (SRSDO, 2021). However, according to our observations, plastic cutlery is still provided in each canteen, and 27% used a straw during a lunchtime snapshot observation.

Campus Greening and Carbon Offsets

More than 60% of the CUHK campus is covered in vegetation, including natural woodlands, landscaped slopes, lawns, and roof gardens. Canteen waste and food sludge is composted on campus and used to improve the soil on the campus grounds (SRSDO, 2021). Interviews with the CUHK Social Responsibility and Sustainable Development Office (SRSDO) revealed that the university currently uses carbon offsetting in the form of paper waste recycling and tree planting at present and buying carbon

credits may be considered in future.

Community Engagement

CUHK has integrated climate action into the curriculums, with 11 related courses offered. In 2012, CUHK launched the Green Office Program ('GO!'), which cultivates sustainability knowledge and drives behavioural changes in all offices (SRSDO, 2021). From the facilities manager interview, we found that office procurement follows sustainable development principles, yet many staff do not know much about this program, so more internal publicity and training are needed. In 2013, CUHK established the Jockey Club Museum of Climate Change, which is the world's first museum dedicated to this topic (MOCC, 2022). The museum contains interactive multimedia exhibitions that introduce climate change concepts, and organises workshops, activities and tours of ecological sites and facilities on the CUHK campus. Interviews with museum staff showed that engagement from students was not widespread, and limited to some courses that included a visit to the museum in their syllabus.

4.2 Evaluating CUHK's achievements towards carbon-neutrality

Although CUHK's sustainable and carbon-neutral policy is remarkably complete and covers a wide range of issues, our investigation and interviews have shown that there are still gaps between the strategies and desired process in practice. For the reviewing process, a scoring system was applied according to the following standards: (0) the policies or measures are not in place; (1) the policies or measures are being implemented, but the processes in practice do not yet achieve the policy goals; (2) policies or measures have been implemented and practices meet policy goals; (3) policies, measures and practices have been implemented to their maximum potential.

After this scoring process, which is intended as a 'proof of concept' to demonstrate the assessment framework rather than a highly accurate and comprehensive scientific evaluation, some key issues can be identified in each category. As Hong Kong lacks guidelines for universities to achieve carbon-neutral campuses, individual universities can do more to propose and promote unified standards. In relation to energy use, CUHK's automated building management systems are not yet widely implemented, and not all students and staff have access to data regarding their energy usage. In relation to transportation, CUHK was not yet able to implement an effective electric vehicle strategy. The university has built bicycle lanes, but these do not yet form a comprehensive network that efficiently connects origin and destination points. It also encourages walking, but many routes are difficult to navigate and contain many slopes or stairs, resulting in a low walking rate. Recycling stations are well implemented, and a specialist recycling point is under construction (Campus Planning and Sustainability Office, 2022), but more publicity and training are needed to inform users. Thanks to the cooperation of the canteen staff, the use of plastic has decreased significantly, however many students still unconsciously use disposable plastic tableware

Category	Policies, measures and systems	Score
Legislation, guidelines and standards	Standards and certification to measure carbon neutrality	○○○
	Legal guidelines for carbon neutral goals and operations	○○○
	The objectives, policies and measures of the university are aligned with the country/region's carbon neutral goals and policies	●●●
	A mechanism, body or institution for coordination and sharing of university policies and strategies	●●●
University Consortium	Provides uniform policies and measures	○○○
	Applies standardized evaluation tools and systems	○○○
Energy and Green Buildings	Install large-scale and up-to-date solar systems	●●○
	Achieve environmental performance certified buildings	●●○
	Implement Automated building management systems	●○○
	Install meters to monitor and publish energy use	●○○
	Install LED lighting across the campus	●●●
	Phase out of fossil fuels	●●●
Transportation	Create supportive walking routes	●●○
	Create comprehensive cycling networks	●○○
	Provide bicycle parking spaces	●○○
	Introduce bike-sharing systems	○○○
	Provide electric vehicle charging ports	○○○
	Use electric vehicles	○○○
	Discourage private cars	●○○
	Promote public transport for commuting	●●○
Waste Reduction	Facilitate recycling	●●○
	Use reward mechanisms for sustainable practices	○○○
	Create mixed recycling collection points	○○○
	Provide recycling points for difficult-to-recycle objects	○○○
	Implement a Waste Minimization Action Plan	●○○
	Reduce the use of plastics	●●○
Greening and Carbon Offsets	Plant varied native tree species	●●●
	Create interactive community gardens	●●●
	Install roof greening	●●○
	Employ carbon offsetting responsibly and sparingly	●○○
Community Engagement	Set up volunteering and internship programmes in environmental practices on campus	○○○
	Use websites and dashboards to displays energy use and energy generation on campus	●○○
	Integrate environmental sustainability practices into curriculums	●○○
	Organise regular cycling campaigns and events	○○○
	Provide training and information on waste sorting, energy conservation	●○○

Table 2. The applied assessment framework and scoring for the CUHK campus

and straws. Finally, more can be done to offer relevant course content to support knowledge on climate change and sustainability and stimulate the CUHK community to apply more effective practices in everyday life.

4.3 Roadmap for further improvements

The assessment framework and precedent analysis can help identify solutions and pathways towards further improvement of CUHK's sustainable campus operations. In relation to the governmental policies and guidelines in Hong Kong, creating a voluntary framework for the university may be the most suitable approach since Hong Kong's carbon neutrality process does not yet have proper legal support. The HKSCC can also work with the government to develop standards and assessment tools and focus on proposing policies and measures suitable for carbon-neutral campuses. The improvement of CUHK's facilities can be gradual and in phases but will require comprehensive university policy guidance and sufficient support across management and user levels. Automated building management systems can be expanded in parallel with expanding photovoltaic systems which directly drive local electricity consumption. Electric buses suitable for CUHK's terrain can save money and energy compared to biodiesel buses and should be introduced in parallel with trials for new mobility systems such as electric bicycles or e-scooters. Since these are not yet legally allowed on public roads in Hong Kong, this pilot scheme can be limited to campus use. To promote walking, a comprehensive walking route scheme could be implemented that add widened, covered and inviting pedestrian walkways across campus, supported by high quality public spaces, facilities, elevators and escalators at strategic building hub locations. To reduce waste, a reward mechanism could increase participation, for instance offering discounts when bringing a personal cup to get coffee, etc. Systematic training and promotion campaigns for students and staff can help to change habits. The university can further increase the number of roof greening to improve environmental performance and use trees to create shaded walking routes. Finally, community engagement should be part of all the above measures, involving all end-users in constructing a carbon-neutral campus.

5. Discussion and Conclusions

From the analysis of the case study university and its potential further steps, it is clear that achieving carbon neutrality is not something that can be achieved overnight, but rather consists of a multi-faceted, multi-year process of careful planning and collaboration. By combining top-down and bottom-up approaches, policy and management strategic can translate to improved infrastructure, energy and material flows, and user processes.

The precedent analysis in this study has shown how leading universities have implemented various measures which cover many aspects to reduce carbon emissions, together forming a comprehensive plan for large scale processes of change. These processes should incorporate a degree of flexibility to take advantages of con-

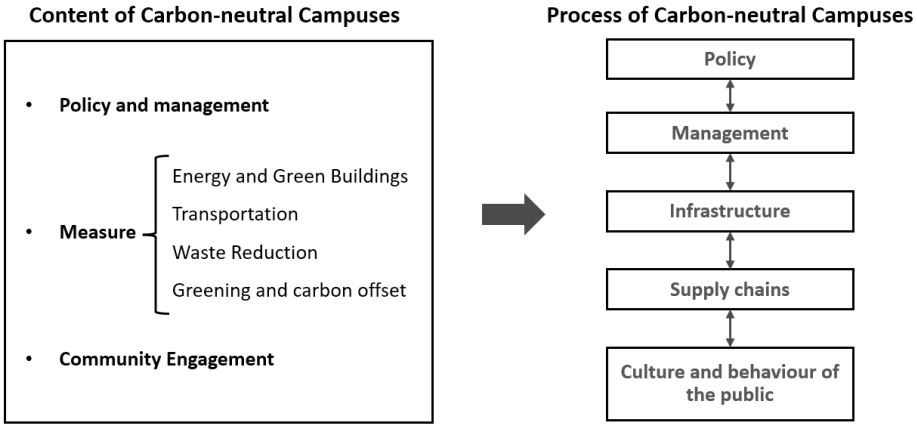

Figure 2. Interplay between the assessment framework (left) and the practices of carbon-neutral campuses

tinued advances in technology, research and development. As a fundamental part of the successful implementation of these transformations is the adoption by everyone in the organisation, a critical planning aspect is communication, education and engagement by the community. Our comprehensive framework, created through extracting policies and measures from the three universities, provides a reference and comparison for the realisation other universities' carbon neutrality, demonstrated by its application to The Chinese University of Hong Kong. In reality, however, there will be no ideal framework for achieving carbon-neutral campuses, and universities should adjust their strategies and planning according to existing internal policy structures and the limitations of their wider regulatory and cultural contexts. Nevertheless, while the process of achieving carbon neutrality may seem arduous, our comprehensive framework may provide a rationale and approach for administrators and planners working in universities, or also in other large scale and complex organisations.

As the training grounds for future leaders, universities are where the awareness and education of sustainability, climate change, and carbon neutrality are most needed. This paper has analysed the process of achieving carbon neutrality under different national policies, requiring targeted goals and strong driving forces. It has described these achievements as processes through time, dependent on various forms of support from major stakeholders. There is increasing awareness, however, that carbon-neutrality is being demanded by the public and is also becoming a cost-effective business proposition. The recent impacts of climate change in vulnerable territories around the world place extra urgency on developed countries, regions and institutions to lead by example, and invest in systems that help create a safer future for all. Although universities have an educational role in leading carbon-neutral action, tackling climate change will require organisations and countries to work together.