The Pathway to Decarbonisation in LPMitP: Carbon Management Framework

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ABSTRACT

In the 2020 Policy Address, the Chief Executive announced that Hong Kong would strive to achieve carbon neutrality before 2050. All stakeholders of the society should take the initiative to work towards this goal. The Landslip Prevention and Mitigation Programme (LPMitP), being a rolling programme, has a role to play in reducing carbon emissions and to exemplify low-carbon practices for geotechnical works. This paper briefly introduces the key concepts of an ongoing framework study on the carbon management of LPMitP, including an introduction of relevant international guidance documents, a review of carbon reduction targets and policies in Hong Kong and some selected countries, the applicability on LPMitP of a commonly adopted carbon management framework possessing the whole life cycle approach, and the philosophy and methodology to establish a carbon baseline intensity of LPMit works. The challenges and opportunities of decarbonisation are identified. With this paper serving as the first episode of disseminating the carbon management study in LPMit works, updates on the study will follow as the journey continues.

1 INTRODUCTION

1.1 Background

Climate change refers to the long-term shifts in temperature and weather patterns (UN 2024). While such shifts can be natural; yet human activities in the past two centuries are well considered to have accelerated climate change. It is generally believed that there is an inevitable linkage between climate change and greenhouse gases (GHGs) concentrations in the Earth's atmosphere which have been significantly increased due to the burning of fossil fuels to boost industrialisation and urbanisation. According to the European Union, the global GHG emissions reached 53.8 Gt-CO2e in 2022, which is 1.4% higher than 2021 and 45.4% higher than 2000 (Crippa et al 2023). The average global temperature on Earth has increased by 1.1°C since the pre-industrial age (NASA 2024). Most of the warming has occurred since 1975 at a rate of about 0.2°C per decade. The impacts of climate change are already being felt around the world from the increase in the intensity and frequency of extreme weather events, including heatwaves, tropical cyclones, flooding and torrential rains which lead to landslides, wildfires, flooding, famines and climate migrations. These subsequently cause physical, social and economic damages. Climate change has been identified as one of the greatest challenges facing the world and will continue to affect us in the future. This drives a growing demand for actions on mitigating climate change. Many of the actions fall into the category of decarbonisation.

In the 2020 Policy Address, the Chief Executive announced that Hong Kong would strive to achieve carbon neutrality before 2050. Hong Kong's Climate Action Plan 2050, published in 2021, set a target to reduce Hong Kong's total carbon emissions by 50% against the 2005 level before 2035. All stakeholders of the society should take the initiative to work towards these targets. The Landslip Prevention and Mitigation Programme (LPMitP) is no exception. Being a rolling programme with annual output target of upgrading 150 government man-made slopes and implementing risk mitigation works for 30 natural hillside catchments across the territory, the LPMitP has clearly a role to play in reducing carbon emissions and to exemplify low-carbon practices for geotechnical works.

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1.2 Carbon management

Carbon management focuses on the identification, quantification, reduction, and removal of carbon dioxide (CO_2) and other GHG emissions from various sources. It aims to (1) achieve a net reduction in CO_2 and GHG emissions by implementing innovative technologies, adopting sustainable practices and fostering interdisciplinary collaboration, (2) promote the transition to a low-carbon economy and (3) create sustainable legacies to *meet the needs and aspirations of the present without compromising the ability of future generations to meet their own needs* (WCED 1987).

1.3 Objectives of the study

This paper briefly introduces an on-going carbon management framework study partnering between the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) of the Hong Kong Special Administrative Region (HKSAR) Government and AECOM. The main aims of the study include:

- determine the baseline carbon intensity of current LPMit works,
- recommend practical carbon emissions reduction targets for LPMitP,
- develop and implement decarbonisation measures, and
- formulate the strategy roadmap to realise the carbon emissions reduction targets, thus achieving sustainability in the LPMitP.

While the study is still at its early stage, this paper focuses on presenting an overview of the study attempting to show the geotechnical practitioners different ingredients of the study and to illustrate how a sustainable LPMitP can be achieved via a holistic appraisal of the carbon management of LPMit works.

1.4 Layout of the paper

A brief review will first be provided to highlight some international guidelines and standards which are often referred to when implementing carbon management. The policies and targets of reducing carbon emissions in Hong Kong and some selected countries will be presented to offer the vision and driving engine of the study. A carbon management framework will then be presented illustrating the best practice of the carbon management, how a carbon baseline intensity of LPMit works could be formulated and decarbonisation measures suitable for LPMit works.

2 INTERNATIONAL GUIDELINES AND STANDARDS

The carbon footprint reduction polices, standards, practices and targets related to the construction industry of some selected countries have been reviewed. There are some international policies and standards that are widely referred to or followed by the industries of countries in the endeavour of carbon management, e.g., the Paris Agreement by the United Nations Framework Convention on Climate Change (UNFCCC), ISO 14064-1 (2018), ISO 14064-2 (2019), ISO 14064-3 (2019), PAS 2060 (2014), PAS 2080 (2023), GHG Protocol (www.ghgprotocol.org), etc.

The Paris Agreement, first adopted on 12 December 2015 at the 21st meeting of the Conference of the Parties (COP21), is an agreement within the UNFCCC dealing with the mitigation, adaptation and finance of GHG emissions. The Paris Agreement aims to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. As of today, 197 countries and the European Union (EU), representing vast majority of global GHG emissions, have ratified or acceded to the Agreement (UNTC 2024). This includes China and the United States of America (USA) which are two largest GHG emissions country in the world. According to the JRC Science for Policy Report on GHG Emissions of All World Countries (Crippa et al. 2023), China contributed 29.2% while the USA contributed 11.2% of global GHG emissions in 2022. In accordance with the Basic Law of the HKSAR, the Paris Agreement also applies to the HKSAR (UNTC 2024).

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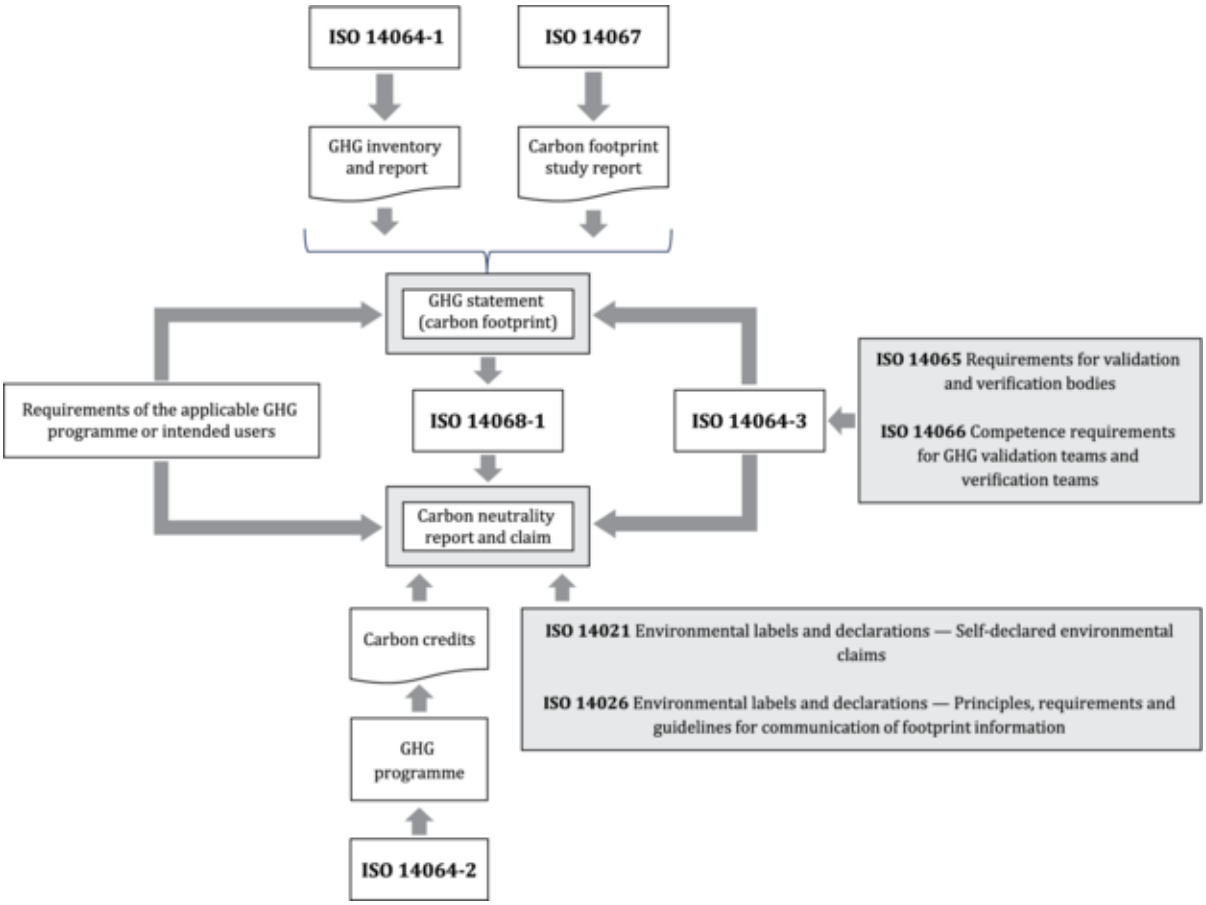

Figure 1: ISO 14068-1 in relation to other International Standards (extracted from ISO 14068-1 (2023))

There are 17 standards published by the ISO/TC207 Subcommittee 7 on greenhouse gas and climate change management and related activities. ISO 14064-1 (2018) provides detailed principles and requirements for designing, developing, managing and reporting organisation-level GHG inventories which includes the requirement for determining GHG emissions and removal boundaries, quantifying an organisation's GHG emissions and removals and identifying specific company actions or activities aiming to improve the GHG management. It also includes the requirements and guidance on inventory quality management, reporting internal auditing and the organisation's responsibilities in verification activities. ISO 14064-2 (2019) details principles and requirements for determining baselines, and monitoring, quantifying and reporting of project emissions. It focuses on GHG projects or project-based activities specifically designed to reduce GHG emissions and/or enhance GHG removals. It provides the basis for GHG projects to be verified and validated. ISO 14064-3 (2019) details requirements for verifying GHG statements related to GHG inventories, GHG projects and carbon footprints of products. It describes the process for verification or validation, including verification or validation planning, assessment procedures, and the evaluation of organisational, project and product GHG statements. ISO 14064 is a well-known GHG accounting framework.

PAS 2060 (2014) is a specification describing how to demonstrate carbon neutrality by a four-stage process: measurement, reduction, offsetting and documentation. It sets out the requirements for quantifying, reducing and offsetting GHG emissions for organisations and products. It is worthy to note that ISO 14068-1 (2023) was published in November 2023. It provides principles, requirements and guidance for achieving and demonstrating carbon neutrality. It focuses on quantifying, reducing and offsetting carbon footprints, utilizing a hierarchical approach prioritising direct and indirect GHG emission reductions and removal enhancements within the value chain over offsetting. PAS 2060 (2014), therefore, will be withdrawn from use on

20 November 2025. Figure 1 shows the relationships among ISO14068-1 (2023), ISO 14064 family and other related ISO documents.

PAS 2080 (2023) presents a framework looking at the whole value chain aiming to reduce carbon and reduce cost through more intelligent design, construction and use (Figure 2). It ensures carbon is consistently and transparently quantified at key points in infrastructure delivery which promotes sharing of data along the value chain.

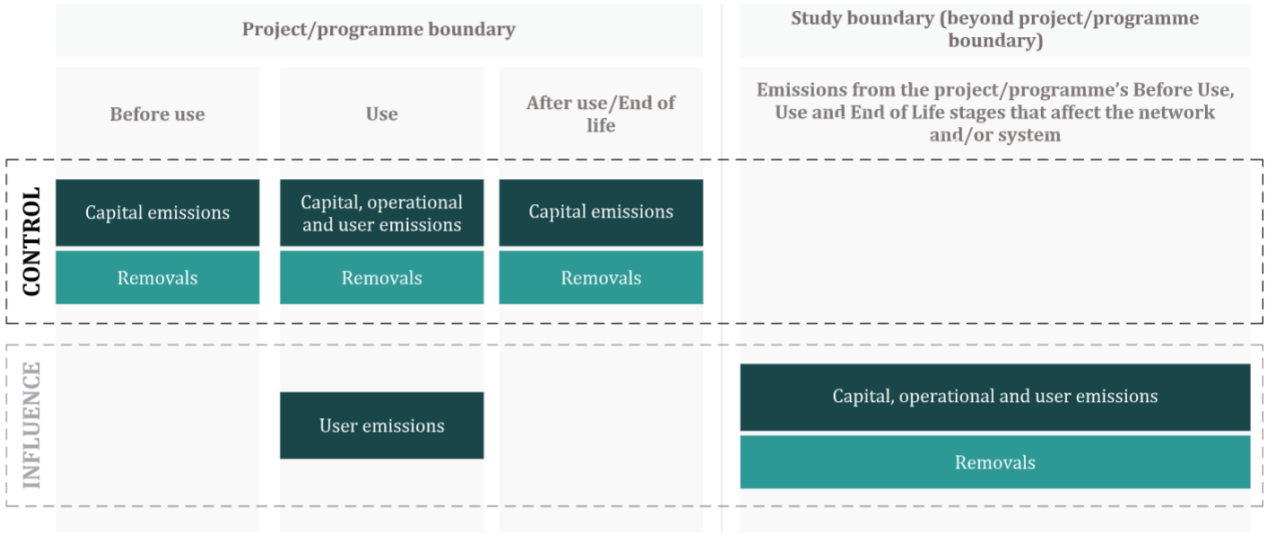

Figure 2: PAS 2080 whole life carbon framework for decision-making (extracted from PAS 2080 (2023))

GHG Protocol, with the joint efforts made by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), provides standards, guidance, tools and training for private and public sector operations to measure and manage GHG emissions (www.ghgprotocol.org). GHG Protocol is another commonly known GHG accounting framework. The GHG Protocol Corporates Standard classifies a company's GHG emissions into three scopes. Scope 1 emissions are direct emissions from owned or controlled sources, e.g., operation of company-owned equipment. Scope 2 emissions are indirect emissions from the generation of purchased energy, e.g., purchased electricity. Scope 1 and 2 are related to company operations. Scope 3 emissions are all indirect emissions, apart from Scope 2, that occur in the value chain (i.e., entire business model) of the company/organisation, including both upstream and downstream emissions, e.g., waste generated in operations, employee commuting, construction, etc.

The ISO 14064 standards and the GHG Protocol are largely overlapping. However, there are some differences which should be highlighted. First, the GHG Protocol constitutes a voluntary standard while the ISO 14064 standards can be used for certification purposes. Second, the GHG Protocol methodology is often adopted by governments, NGOs and other organisations while ISO 14064 standards are mostly used by industrial enterprises. There are also minor differences regarding the setting of organisational boundaries and calculation methods in these two methodologies.

3 TARGETS AND POLICIES

3.1 Carbon reduction target

Hong Kong, the UK, Singapore and Australia have set the long-term target of achieving carbon neutrality or net zero emissions by 2050 while Mainland China has set the same national target to be reached by 2060. Hong Kong has set the regional target to reduce its carbon emissions by 50% against the 2005 level before 2035. The UK has set a series of interim targets and milestones before 2050 that gives a clear descending curve of GHG emissions against time. Singapore targets to reduce carbon emissions to about 60 Mt-CO2e in 2030.

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The UK has also set the target of zero avoidable waste in construction sector by 2050. China has published energy efficiency targets for the cement industry and reduce-reuse-recycle targets for construction waste. However, the corresponding progress has not yet been published. Australia has published the progress of GHG emission reduction in the construction sector and in cement industry. However, no carbon reduction targets in the construction sector have been published. It is worth noting that neither carbon emissions target nor progress of the construction sector in Hong Kong or Singapore has been announced.

3.2 Action plans

To understand the regulatory drivers of carbon management, three types of policies and standards are considered as highly relevant to this study. They are:

- National action plans for carbon emission management,
- Action plans, guidelines and standards for low-carbon construction, and
- Design and construction standards for slope upgrading works.

Table 1: List of selected climate action plans

City / Country	Action Plan	Remarks	Link
Hong Kong	Hong Kong's Climate Action Plan 2050	Published in October 2021	https://www.eeb.gov.hk/sites/default/files/pdf/cap_2050_en.pdf
Mainland China	China Action Plan for Carbon Dioxide Peaking Before 2030	Published in October 2021	http://english.scio.gov.cn/topnews/2021-10/27/content_77835815.htm
The United Kingdom (UK)	The Climate Change Act 2008	Became law in November 2008	https://www.legislation.gov.uk/ukpga/2008/27/contents
	Industrial Decarbonisation Strategy	Published in March 2021	https://www.gov.uk/government/publications/industrial-decarbonisation-strategy
	Carbon Budgets	Last updated in July 2021	https://www.gov.uk/guidance/carbon-budgets#setting-of-the-fourth-carbon-budget-2023-2027
	UK Net Zero Strategy: Build Back Greener	Last updated in April 2022	https://www.gov.uk/government/publications/net-zero-strategy
	Decarbonising Transport: A better, Greener Britain	Last updated in January 2023	https://www.gov.uk/government/publications/transport-decarbonisation-plan
Singapore	Mitigation Efforts on National Climate Change Secretariat	Website	https://www.nccs.gov.sg/singapores-climate-action/mitigation-efforts/overview/
	Charting Singapore's Low-Carbon and Climate Resilient Future	Published in April 2020	https://www.nccs.gov.sg/files/docs/default-source/publications/nccsleds.pdf
Australia	Australia's Long-Term Emissions Reduction Plan, A whole-of-economy Plan to Achieve Net Zero Emissions by 2050	Last updated in October 2021	https://www.dcceew.gov.au/sites/default/files/documents/australias-long-term-emissions-reduction-plan.pdf

Table 1 summarises a list of climate action plans from Hong Kong and some selected countries. In 2021, the HKSAR Government announced the Hong Kong's Climate Action Plan 2050. The plan sets the vision of "Zero-carbon Emissions-Liveable City-Sustainable Development" and outlines four major decarbonisation strategies, namely (1) net-zero electricity generation, (2) energy saving and green buildings, (3) green transport; and (4) waste reduction, which would lead Hong Kong towards the goal of carbon neutrality before 2050. The Government plans to allocate about 240 billion Hong Kong Dollars in next 15 to 20 years to implement climate mitigation and adaptation measures.

China sets ten key tasks to advance actions on carbon dioxide peaking including actions for:

- green and low-carbon energy transition,

- energy saving, carbon emission mitigation and efficiency improvement,
- peaking carbon dioxide emissions in industry sector,
- peaking carbon dioxide emissions in urban-rural development area,
- promoting green and low-carbon transportation,
- promoting circular economy in carbon mitigation purpose,
- advancing green and low-carbon technology innovation,
- consolidating and enhancing carbon sink,
- green and low-carbon society, and
- promoting all regions to peak carbon dioxide emissions hierarchically and orderly.

In the UK, the Climate Change Act 2008 is a legal document which sets a framework for the country to reduce GHG emissions and build capacity to adapt and strengthen resilience to climate risks. The original Act committed the UK to cut its emissions by at least 80% against the 1990 level by 2050. In 2019, the target was amended. The UK now commits the target of net zero emission by 2050. Some of the devolved states have their own policies and targets. For example, Scotland is committed to achieve a net zero target by 2045. The UK is the first country to set legally binding carbon budgets. The budget places a restriction on the total amount of GHGs that the UK is allowed to emit over a 5-year period. The first six carbon budgets cover the period from 2008 to 2037. It implies that every tonne of GHGs emitted between now and 2050 will count and an emission rise in one sector would require a reduction in other sectors. The fourth carbon budget covers from 2023 to 2027 with 1,950 metric tonne CO_2 equivalent (Mt-CO2e), which corresponds to a 52% cut from the 1990 level.

Singapore has committed to achieve net zero emissions by 2050. Four key thrusts are used to accelerate the low-carbon transition for industry, economy, and society. They are:

- catalysing business transformation,
- investing in low-carbon technologies,
- pursuing effective international cooperation, and
- adopting low-carbon practices.

The thrusts are supported by a carbon tax policy, which is the first carbon pricing scheme in Southeast Asia, implemented on 1 January 2019. The carbon tax will increase from five Singapore Dollars per tonne CO_2 equivalent (i.e., S$5/t-CO2e) between 2019 and 2023, to tentatively S$50-80/t-CO2e by 2030.

Australia plans to achieve net zero emissions by 2050 based on five key principles. They are:

- technology not taxes,
- expand choices, not mandates,
- drive down the cost of a range of new energy technologies,
- keep energy prices down with affordable and reliable power, and
- be accountable for progress.

The prioritised essential low emission technologies are clean hydrogen, ultra low-cost solar, energy storage for firming, low emission steel, low emission aluminium, carbon capture and storage and soil carbon. The Australian Government is expected to invest at least 20 billion Australian Dollars to advance low emissions technologies from now to 2030.

3.3 Low-carbon construction

Hong Kong's Climate Action Plan 2050 promotes the environmental perspective in planning for new development areas and urban renewal projects to reduce embodied carbon emissions during the construction process, such as the use of Modular Integrated Construction (MiC) method and electrified machinery.

The Mainland China Government promotes the reduction in using high-carbon construction materials and increase in adopting low-carbon materials including new low-carbon cementitious materials, carbon-sequestration mineral materials and new cementitious materials made from solid wastes. The Government also

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promotes factory-based precision processing and refined management of building materials to reduce the waste rate of building materials on construction sites by 20% by 2030 against the 2020 level. Besides, the Government also encourages energy-saving construction equipment, energy consumption monitoring of key equipment, and group control management for multiple similar equipment. Furthermore, it prioritises the selection of building material products that have obtained the green building certification and supports the centralisation treatment and graded utilisation of construction wastes.

The UK Government supports the decarbonisation of intermediary industrial products such that the supply chain is gradually supplied with green materials which in turn produces greener final products. The UK Government encourages consumers to make informed choices about the environmental impact of products, so to create pressure feeding upwards to encourage greener purchases throughout the supply chain. It is expected that an annual saving from resource efficiency and material substitution in manufacturing and construction, mostly in cement manufacturing, is 9 Mt-CO2e by 2050. A Timber in Construction Road Map is under planning which promotes the safe use of timber in construction improving carbon capture. Besides, the Low Carbon Concrete Routemap has set out currently available methods of reducing carbon in concrete.

In Singapore, a Green Mark Certification Scheme was launched in 2005 as an initiative to drive Singapore's construction industry towards more environmentally friendly buildings. It is a benchmarking scheme to promote sustainability in the built environment and to raise environmental awareness among developers, designers and builders. The builders are encouraged to use recycled and sustainable materials for non-structural applications, e.g. precast drains, precast road kerbs and wheel stoppers. Solar cells and biodiesel can be used instead of diesel fuels. Besides, the builders are recommended to connect to AC power grids for power supply whenever feasible.

In Australia, Infrastructure Australia is the Australia's independent infrastructure advisor to share knowledge, promote good practice and facilitate collaboration and leadership. It undertakes research and provides advice to the government, industry and community on the infrastructure investment and reforms that will benefit Australians. The 2021 Australian Infrastructure Plan is a practical and actionable roadmap for infrastructure reform. There are 20 recommendations in the Plan, focusing on nine key areas including transport, energy, water and waste.

3.3 Design and construction of slope upgrading works

In Hong Kong, greening of engineered slopes is recommended while vegetation on man-made slopes helps erosion control and serves landscape functions. Guidance for vegetative protection measures is provided in the Geotechnical Manual for Slopes (GEO 2011a). GEO (2011b) presents guidance on good practice of landscape treatments for man-made slopes and engineering works on natural terrain in Hong Kong. On one hand, the role of vegetation on slope stabilisation via complex hydromechanical interaction might be difficult to quantify and be approved in conventional engineering design. On the other hand, the presence of vegetation as a carbon offset over the whole life of the engineered slopes appears attractive from the perspective of carbon management. However, the contribution of each of the commonly adopted slope greening plant species to carbon offset is yet to be quantified.

In Mainland China, the Code for Design of Landslide Stabilisation stipulates the applicability of plant protection engineering which can be used for landscaping. Similar to Hong Kong, engineering design on slope stability should not rely on the potential beneficial effects from vegetation.

4 CARBON MANAGEMENT FRAMEWORK

4.1 Appraisal of carbon management in LPMit works

In 2010, the GEO launched a rolling LPMitP to systematically manage landslide risk associated with both man-made slopes and natural hillsides. Under the LPMitP, the most deserving man-made slopes and natural hillside catchments are selected each year in accordance with a risk-based priority ranking system for further

study. The necessary landslip prevention and mitigation works for man-made slopes and natural hillside catchments under Government's maintenance responsibility are implemented under the LPMitP. The target annual outputs of the LPMitP are to: (1) upgrade 150 government man-made slopes, (2) conduct safety-screening studies for 100 private man-made slopes, and (3) implement risk mitigation works for 30 natural hillside catchments (CEDD 2024a). As of 1 March 2024, there are 32 active LPMit works contracts (CEDD 2024b). A brief overview of LPMit works from the perspective of carbon management would identify the major sources of carbon emissions and thus in turn would help to produce a practical decarbonisation strategy. Table 2 summarises a list of major engineering works which are commonly conducted in LPMit works. By examining the construction of each feature, the associated carbon emissions can be quantified. For instance, the construction of soil nails involves materials such as steel and cement grout, site operation such as drilling and formwork construction for soil nail heads.

Table 2: Commonly conducted engineering works in LPMit works

Man-made slopes	Natural hillside catchments
Soil nailing	Flexible barrier
Retaining wall	Rigid barrier, e.g., gabion barrier, concrete barrier
Soil replacement	Deflection structure
Soil compaction	Boulder fence
Surface and subsurface drain	Rock bolt
Surface protection	
Landscaping	

It is expected that most of the carbon emissions would have happened during the construction stage of LPMit works (i.e., embodied carbon). In Hong Kong's slope engineering practice, most of the slope upgrading/stabilisation measures possess low maintenance requirement. In other words, the operational carbon of LPMit works is low when compared to other civil engineering structures such as buildings, tunnels and highways. Furthermore, greening of slopes by vegetation offers an opportunity to offset the embodied carbon. Therefore, it would be crucial to quantify the contribution of slope greening in the carbon management of LPMit works.

4.2 Best practice of carbon management

BS EN 17472 (2022) outlines carbon assessment methodology by establishing the requirements and specific methods for the assessment of environmental, economic and social performance of a civil engineering works while taking into account the civil engineering works' functionality and technical characteristics. The assessment of environmental and economic performance of a civil engineering works is based on the Life Cycle Assessment (LCA), Life Cycle Cost (LCC), Whole-Life Cost (WLC) and other quantified environmental and economic information. The approach to the assessment covers all stages of the civil engineering works life cycle and includes all civil engineering works related construction products, processes and services, used over its life cycle. Figure 3 shows the organisation of the different information modules used for reporting the assessment of the civil engineering works.

In this modular approach, Module A0 covers all the pre-construction stages (Figure 3) including, for example, planning costs, land costs and tax incurred. In general, all costs and impacts before the tender may be included in Module A0. Modules A1 to A3 cover the cradle-to-gate processes for materials and services used in the construction, e.g., the production of steel bar for the construction of soil nails in a slope (i.e., the product stage). Module A1 includes fuel, electricity, direct emissions from extraction and production of raw materials such as cement, recycled waste, additives, etc. Module A2 includes transportation of the materials. An example would be the fuel consumption to transport materials to the manufacturing plant. Module A3 includes the carbon emissions in the manufacturing process of materials, such as mixing, packaging, curing, etc. Modules A4 and A5 cover carbon emissions associated with construction activities. Module A4 covers the transportation of materials and products from the factory gate to the works site, e.g., the transportation of concrete to the construction site. Module A5 covers the construction/installation process at site including ground works and landscaping, storage of products and transport of persons and construction equipment to and from the site.

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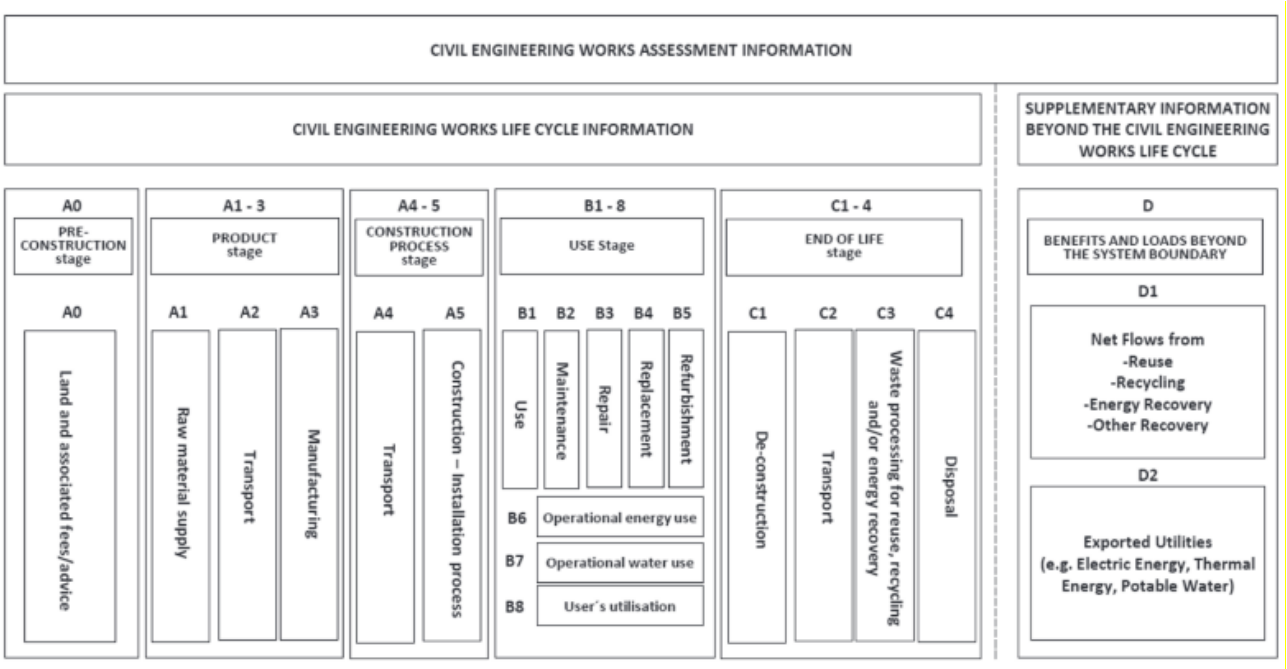

Figure 3: Modular information for different stages of civil engineering works' assessment (extracted from BS EN 17472 (2022))

Modules B1 to B8 relate to the use/operation stage, covering the protection, conservation, moderation, maintenance, control and operation of the object of assessment including works-integrated technical systems. In general, Modules B6 to B8 may be minimal for most LPMit works. For instance, soil nails are considered as maintenance free and do not require any energy to operate. These modules, therefore, can be largely considered as negligible. Yet, some works such as repainting safety access and maintenance inspection would fall into this category.

Modules C1 to C4 belong to the end-of-life stage which starts when the engineering works is decommissioned and not intended to have any further use. At this point, the works' demolition can be considered as a multi-output process that provides a source of materials, products and construction elements that are to be discarded, recovered, recycled, or reused. These modules are scoped out for the carbon management of most LPMit works, as most of the engineering works concerned should have a relatively long service life. It is also challenging to estimate the future decommissioning impacts accurately.

Module D can be divided into two parts: the potential resources for future use (i.e., D1), and the exported energy and other utilities (i.e., D2). These serve as the supplementary information beyond the LPMit works life cycle and are beyond the scope of carbon management in LPMit works.

In general, computation of carbon emissions at the Product Stage (A1-A3) and part of the Use Stage (B1-B5) would need information of material types and quantities. To evaluate carbon emissions at the Construction Process Stage (A4-A5) and part of the Use Stage (B1-B5), one would need fuel consumption of site activities and material transport information.

The current study will follow this modular approach to assess the carbon emissions of whole life cycle of LPMit works. The study will focus on the Product Stage (A1-A3), Construction Process Stage (A4-A5) and Use Stage (B1-B8).

5 COMPUTATION OF CARBON BASELINE INTENSITY

With the appraisal of LPMit works as presented in Section 3.1 and the modular approach following BS EN 17472 (2022) as shown in Section 3.2, a tailor-made data survey form has been prepared to collection site information aiming to evaluate the GHG emissions associated with the construction stage of LPMit works.

The survey form is divided into eight categories as explained in Table 3. Group A questions aim to understand the scale of the site which would be helpful to undertake normalisation, if necessary, at a later stage of the analysis. Group B questions would help further understand the types of engineering works undertaken in the site. Group C questions collect data aiming to evaluate the total amount of construction materials used in the site and help to shed light on the carbon emissions associated with major construction activities. Groups D to F questions collect energy and materials consumption associated with construction activities. Groups G and H questions devote to understand the transport of persons and construction equipment to and from the site.

Table 3: Summary of data survey form

Group	Group description	Items	Potential module following BS EN 17472 (2022)
A	Scale of LPMit site	Size of sites	N/A
B	Engineering works	Soil nail, rock dowel, buttress, rock dentition, drains, fill excavation/replacement, retaining system including rigid and flexible barrier, slope surface protection	A5
C	Material consumption	Cement, concrete, steel, fills, PVC	A1, A2, A3, A4
D	Fuel consumption	Diesel fuel, petrol fuel, biofuel, electricity	A5
E	Water consumption	Water	A5
F	Waste Disposal	Inert and non-inert C&D material	A5
G	Transportation	Electric and Non-electric car	A4
H	Labour	Number of labour	A4

This study will use data collected from active LPMit sites between July 2022 and June 2023 to evaluate the baseline intensity of LPMit works during the construction stage. A generic review of carbon emissions during the operational stage of the works will be conducted separately. Combining the results will give a holistic picture of LPMit works covering both its construction and operational phases.

Carbon emissions of items in Modules A1 to A3 can be calculated using below generic formula:

$$\textit{Amount of GHG emissions} = \textit{Unit of measurement} \times \textit{Density conversion} \times \textit{Emission factor} \quad (1)$$

Carbon emissions of items related to transport of assets and materials can be evaluated using equation (2):

$$\textit{Amount of GHG emissions} = \textit{Weight of materials} \times \textit{Distance travel} \times \textit{Emission factor} \quad (2)$$

Carbon emissions of transportation of labour can be evaluated using equation (3):

$$\textit{Amount of GHG emissions} = \textit{No. of labour} \times \textit{Average distance travel} \times \textit{Emission factor} \quad (3)$$

Carbon emissions of items in Module A5 can be evaluated using equation (4):

$$\textit{Amount of GHG emissions} = \textit{Quantity of consumption} \times \textit{Emission factor} \quad (4)$$

Table 4 shows some examples of emission factor for selected materials. The carbon emission of a one-way economic class flight between the Hong Kong International Airport and the London Heathrow Airport is 1.12 t-CO2e (Cathay Pacific 2024). This serves as an example to give a practical impression of the magnitude of carbon emissions, and thus offers a sense of understanding of the emission factors as shown in Table 4.

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Table 4: Examples of emission factor for some commonly used construction materials

Category	Description	Emission factor	Reference
Material	Cement	0.91 kg-CO2e / kg	Zhang et al. 2014
Material	Concrete (C30-C60)	265-429 kg-CO2e / m^3	Gan et al. 2017
Material	Steel (Rebar)	2.25 kg-CO2e / kg	Gan et al. 2017

6 DECARBONISATION: CHALLENGES AND OPPORTUNITIES

Establishment of carbon baseline intensity serves another purpose. It helps to identify items which contribute most to the overall GHG emissions of LPMit works and gives an insightful direction to formulate decarbonisation measures.

In general, decarbonisation measures of LPMit works can be categorised into three aspects, namely:

- Materials
- Workflow
- Energy efficiency

In the material category, consideration should be given to the use of recycled materials, materials sourced from sustainable sources, materials with lower embodied carbon and plants to purify harmful chemicals. Ground granulated blast furnace slag (GGBS) is a by-product of steel production and can be used to replace cement of up to 80% to form GGBS-based low carbon concrete. Pulverised fly ash (PFA) is a by-product of coal-burning power stations and can be used as a cement substitute to reduce the consumption of cement. Scrap steel recycling has potentials to alleviate carbon emissions.

In the workflow category, one could consider low carbon transportation and digitisation for reducing consumption of paper, MiC for reducing on-site pollution and waste of materials, smart design of LPMit agreements/contracts which groups works sites geographically for minimising travel distance of site staff among slope sites and site depot. In the energy efficiency category, one could consider the use of clean energy sources for on-site power supply, new energy sources such as hydrogen, equipment with higher energy efficiency, new generation of solar panel, etc.

One of the challenges to decarbonisation includes limited availability and elevated cost of low-carbon materials in the market. However, the situation might be improved by promoting mass production as well as establishing a stable and sustainable supply chain. Besides, with increasing R&D works in new energy such as printable solar panels, electrified and hydrogen-powered construction equipment, more choices of reduced cost green energy should be available in near future. A unique contribution of LPMit works towards carbon offset is the adoption of vegetated slope cover and wall panels for retaining structures. The whole life cycle of an engineered slope feature is significantly long which could provide an opportunity to offset the embodied carbon during the construction and maintenance stages.

7 CONCLUDING REMARKS

Hong Kong has set out the target to reduce its carbon emissions by 50% against the 2005 level before 2035, and to achieve carbon neutrality by 2050. LPMitP, being a rolling programme, has a role to contribute to the task. This paper introduces a recently commenced study of carbon management of LPMit works. It sets the scene by reviewing international standards, policies and action plans, providing a brief appraisal of LPMit works, introducing a carbon management framework, suggesting how a carbon baseline intensity can be formulated, and highlighting potential decarbonisation measures suitable for LPMit works. The paper serves as the introductory episode of the entire carbon management journey.

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