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Research Article

Carbon-neutral Existing Buildings Strategies

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Abstract

Background: The world screams for carbon-neutral pledge every day. Existing buildings (EBs) are a good starting edge. EBs account for more than one-third of greenhouse gas (GHG) emissions and use of more than half of the world's energy as reported in the 2020 Global Status Report for Buildings and Construction. Without evolving effective strategies to transform the EBs into carbon-neutral structures, there is no chance of confronting this huge adverse impact on the climate. A carbon neutral building does not waste energy, uses less water, and produces as much energy as it consumes or uses renewables as their energy resource.

Objective: This study aims to build up a new, easy, and practical carbon-neutral audit (CNA) rating tool to put forward carbon-neutral existing buildings (CNEB) strategies to reduce the GHG effect.

Methods: This study responds to this pledge call to lay down the strategies to retrofit existing structures into carbon-neutral buildings. Carbon-neutral potentials of an existing building are the guidance for the setup of CNEB strategies. Assessing the carbon-neutral potentials in an EB is rarely touched in the past literature. With the help of a CNA scheme, an easy scanning rating tool, a list of carbon-neutral potentials can be built up for the instigation of the CNEB strategies.

Results: The findings established that using the above CNEB strategies, a total of energy savings in a range of 45-65% can be achieved.

Conclusion: This high energy savings will attribute a carbon intensity reduction in the range of 25-35%, thus triggering a gateway to decarbonisation of the EBs.

Keywords: carbon-neutral existing buildings strategies, carbon-neutral potentials, carbon-neutral audit

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1 INTRODUCTION

Pursuant to the 2020 Global Status Report for Buildings and Construction released on 16 December 2020[1], the greenhouse gas (GHG) emissions from the operations of the existing buildings (EBs) hit their highest level in 2019. Recent survey also envisages that the average global temperature may upsurge as high as 8°C by the year of 2100[2]. This dissuades the EBs' huge carbon neutral contributions to the goals of the Paris Agreement, effective on 4 November 2016[3] to limit the temperature rise to 2 degrees Celsius. To get on track to carbon-neutral existing buildings (CNEB) stock by 2050, the International Energy Agency estimates that the EBs' GHG emissions need, by 2030, to fall by 50 per cent. The rising emissions escalate an urgent and immediate need for triple CNEB strategies to aggressively lessen the energy demand in the built environment and implement materials strategies that reduce lifecycle GHG emissions. Transforming the EBs into a carbon-neutral (CN) pathway will slow climate change and deliver a healthy living environment to all tenants; all governments should prioritize this CNEB strategy.

What is the situation in Hong Kong? EBs in Hong Kong account for 90% of electricity consumption essentially from air conditioning, lighting systems and water pump systems. That means EBs in Hong Kong contribute to about 60% of GHG emission[4]. Therefore, turning the EBs CN has a significant role to play in GHG emission reduction in Hong Kong.

Hong Kong is congested with 7.5 million residents within a 1,100km² land crammed with high-rise buildings everywhere. In the past, society was anxious with the quantity of buildings without due regard to the carbon neutrality concern. Increasingly, the continued lack of eco-performance of buildings prior 1990 poses a vital challenge to the city's progress in decarbonisation. There are currently no energy use (EU) intensity targets in kWh/m²/year for EBs in neither Hong Kong's legislation nor any significant strategies to elevate EBs' eco performance.

To this end, a new carbon-neutral audit (CNA) is initiated to activate the CNEB strategies identifying the CN potentials of the EBs. In response to the challenges and ambitions set for this study, the following 4 "A" ideologies are advocated and initiated:

1.1 Aspiration

The CNEB will be a breaking ground to embrace the latest eco-building design technologies. Over 50 different eco-features and technologies are showcased in a number of the actual buildings established in Hong Kong. Most of the technologies are innovative and aspiring. Some of them are used in Hong Kong for the first time such as using bamboo furniture for the public area and running the HVAC system based on the biofuel reprocessed from the kitchen waste. While not all are crucial to achieve the CN target of CNEB strategies, they all serve the purpose of demonstrating how the CN technologies work in practice.

1.2 Advancing

The CNEB is upgradable with the evolving future CN technologies. Flexibility should be embedded as far as possible for the installation of renewable energy system such as the solar photovoltaic (PV) panels as there are widespread development of PV technologies in supporting the deployment of electricity produced directly from sunlight. The key PV technologies comprise but not limited to crystalline silicon PV, cadmium telluride solar cells, copper indium gallium diselenide solar cells, etc. Other examples include the adoption of a mezzanine floor for the interactive displays and housing all the utility conduits and cables for an easily upgradable eco-office.

1.3 Appraisal

Collecting of various information of the CN technologies is crucial for cost appraisal in terms of capital costs, operation costs energy saving and carbon emission. To this end, a number of sensors are installed throughout the existing building for record and evaluating the eco-performance parameters such as CO_2, humidity, energy consumption and generation, energy draw-in and out from the city electricity grid. The information will be fed into the Building Management System for analysis if any eco-performance optimization can be initiated.

1.4 Arousing

Interactive displays and guide tours should be provided to the public end-users each day to explain the merits of the CN devices. Without the support of public end-users, the institution of CNEB strategies, like wastes classification and disposal, cannot be effectively implemented.

The CNEB strategies adopted will be aimed to the large reduction of the operational energy uses inducing from HVAC, lighting, electrical equipment / appliances which account 90% of the total building energy used[5]. In this way, both the energy and the carbon intensity can be essentially reduced transforming the EBs CN and more habitable[6-8].

Each existing building is unique and will be individually probed to identify its CN potentials to set forth the CNEB strategies. What gets measured gets done. To see the positive outcome of the strategy adopted, unless it is well measured to see what is improving and what is not. A new scanning rating tool named as CNA is established for this purpose. The implementation of CNA is essential as there is no such rating measure in Hong Kong. As it is well aware, the current Building Environmental Assessment Method (BEAM) Plus in Hong Kong for greening existing buildings (GEB) is BEAM Plus EB v2 (2016) which is

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Table 1. The Prerequisites in BEAM Plus Eb v2 (2016) Prior the Certification

Items	BEAM Plus EB v2 (2016)	Proposed CNA
1	Defines the best practice criteria and performance standards for design, constructed and operated	Assess the carbon-neutral potentials at the outset of EB in its status quo
2	Applicant must demonstrate that all the pre-requisites are achieved otherwise no formal assessment to be performed. For instance: (1) Management (MAN) Green Purchasing Plan (p.39) (2) Materials and Waste Aspects: Waste Recycling Facilities & Materials Purchasing Plan (P.83) (3) Energy Use (EU): Minimum Energy Performance (p.103) (4) Water Use (WU): Water Conservation Plan, Water Efficient Devices, Water Quality Survey (p.123) (5) Indoor Environmental Quality (IEQ): Minimum Ventilation Performance (p.151)	No pre-requisites are required
3	Timeline: 3 years	2-3 months (inclusive of provision of improvement plan)
4	Management system to be provided (p.23) (1) Environmental Management System certified to ISO 14001 (2) Sustainability Policy and targets to the public (3) Management: two Building Environmental Assessment Method Professionals (BEAM Pro) with EB credentials (4) Planned maintenance programme	No such requirements as they do not reflect the green performance of the EB
5	Data to be provided: e.g. Energy Use (EU) (p.30) (1) Data collection record -energy consumption data record of more than 3 years for major electrical loads (2) Data Analysis (3) Energy Audit Record (4) Carbon Audit Report	No such requirements as they do not reflect the green performance of the EB
Overall comments	Tedious, focus on the design and green management performance and implementation prior the assessment	Quick, easy and cost effective to be implemented without pre-stated burden for the applicants

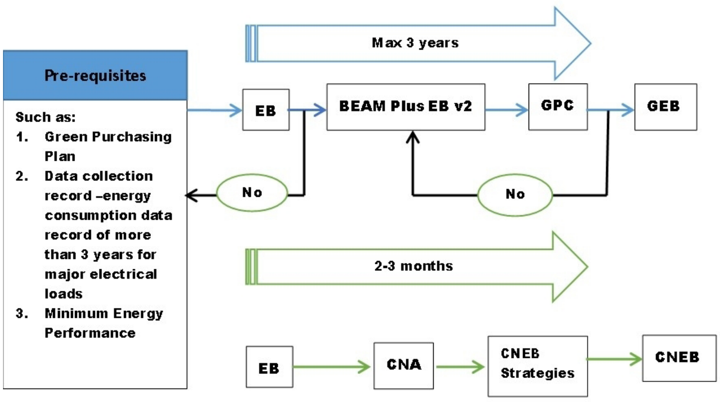

Figure 1. Assessment and Certification process for BEAM Plus EB v2 (2016) the proposed CNA.

the green performance certification (GPC) scheme to be followed prior the provocation of the green retro-fit adoption for the EBs. A cross comparison can be easily demonstrated in the following Table 1.

The process for the assessment and certification between BEAM Plus EB v2 (2016) and the proposed CNA can be further illustrated in the following Figure 1.

The objective of this study can therefore be summed up as in Figure 2.

A unique CNA rating tool is developed under this study to help evaluating the carbon neutral potentials of the EB coupled with carbon neutral improvement implementation. The same CNA is also used to assess the carbon neutral improvement results.

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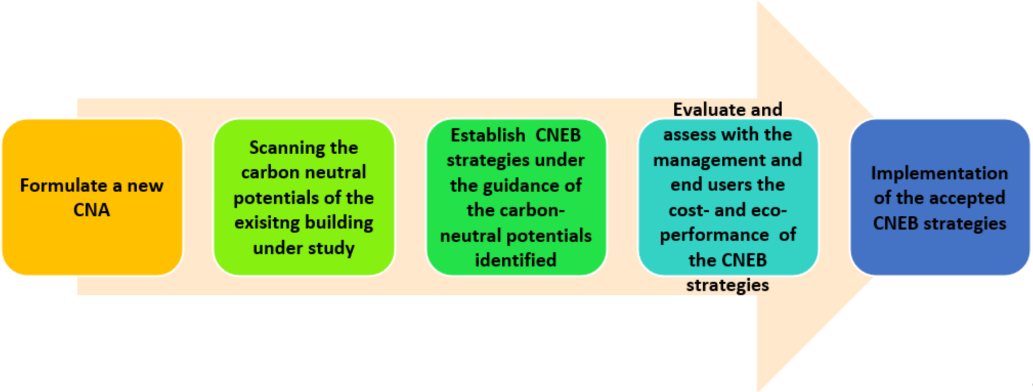

Figure 2. The objective of the CNEB strategies formulation.

Table 2. Admission Statistics of BEAM Plus EB for the Past 12 Years

Year	Existing Buildings Applicants
2011	-
2012	2
2013	3
2014	2
2015	2
2016	32
2017	30
2018	15
2019	104
2020	69
2021	107
2022	131
Total	497

In this way, the city / countries will progressively turn carbon neutral ultimately. On the basis of Leadership in Energy and Environmental Design (LEED) protocol and the scoring scheme from the Hong Kong BEAM Plus rating system, a new CNA rating system is developed. In this way, the new CNA rating system will be more identifiable and easily adapted in Hong Kong's situation. The problems defined in this study thus include: (1) Global concern to CNEB? Is it appropriate to Hong Kong's situation with heavily populated and restricted land resources? (2) Any cost-effective scanning tool to identify the carbon neural potentials of the EBs? (3) Following the above scanning mechanism, any operative strategies can be established in the CNEB in Hong Kong? (4) Why a new CNA is implemented to evaluate the carbon neutral performance of the EB whilst there exists BEAM Plus for EB in Hong Kong?

Motivations of this study can be derived from the following incentives: (1) Buildings (residential and commercial) consume around 35% of the total energy consumption and emit 40% GHG in developing countries[1]; (2) Hong Kong Special Administrative Region (HKSAR) Environmental Control Target in 2035 (2005 as base) is aiming to achieve a reduction of energy intensity by 40% and carbon intensity by 50-60%.

This inspired to implementation CNEB strategy to save the environment. However, before the adoption of CNEB strategy, it needs to set up an easily applicable scanning tool (CNA) which is rare to find from previous literature review, to quickly identify any CN potentials of the EB. CN improvement plan can then be established under what have been assessed (by CNA). The EB after the improvement can be reassessed again using the CNA to verify if the CNEB strategy is effective. This study's contribution is to build up a new, easy, and practical CNA rating tool to put forward CNEB strategies to reduce the GHG effect. Thus, the purpose of this study is to: (1) Apply existing GPC measures in Hong Kong to establish the CNA principles; (2) Investigate if there is any unique CNA rating tool to cost-effectively effectuate and develop CNEB strategies; (3) A pilot test using a case study of residential EB to validate this new CNA rating tool; (4) Find out how this CNA rating tool can be accepted and adopted in Hong Kong to achieve the target of Hong Kong Government to reduce the energy power by 40% and carbon emissions of 55-65% by 2035 treating 2005 as the base year; (5) Establish the logics behind why a new CNA is to be adopted to assess the eco- performance of the EB while BEAM Plus for EB is used in Hong Kong?

2 MATERIALS AND METHODS

2.1 Drawbacks of the BEAM Plus EB

Facts speak the truth. Table 2 below shows the admission statistics of BEAM Plus EB for the last 12 years.

In Hong Kong, the most prevalent green performance rating tool is BEAM Plus, a green rating scheme run by the Hong Kong Green Building Council (HKGBC) in alliance with BEAM Society Ltd. However, when it comes to EBs, there encounters a high resistance as there is no incentive like the new buildings with building gross floor area concessions. Besides, the pre-requisites are onerous to be achieved prior the certification as illustrated in Table 1 above. No doubt there attracts only a single-digit number of enrolments every year from 2012 to 2015 as revealed in the above Table 2.

The findings from the published paper in 2021 "Transaction Cost and Agency Perspectives on Eco-certification of EBs: A Study of Hong Kong" analysed jointly by the Hong Kong Polytechnic University and Delft University of Technology in the Netherlands revealed that: (1) Only large and well-organised developers can make it through the demanding assessment under BEAM Plus EB; (2) Building age is not the major barrier to the attainment of BEAM Plus EB certification. It is the multi-ownership of most EBs that posed the concern, as the threshold is high for the enrolment of BEAM Plus EB and the consensus is difficult to reach for most of the owners.

To make the change, an Owners' Corporation Committee (OCC) under section 3.3A of the Building Management Ordinance (Cap 344) of Hong Kong Government should be formed to take the lead to trigger the CNEB strategies under this study. It is also imperative to simplify the process of the green performance rating tool using CNA.

2.2 CNEB

A CNEB has its mission of carbon neutrality. That is, the existing building does not contribute to the GHG emission with net zero energy consumption during its operations on an annual basis. To achieve this CN strategy, the existing building uses smart technologies (ST) and on-site energy distribution to optimize the demand flexibility for energy cost, city electricity grid integration services, occupant needs and preferences in a continuous and integrated way.

A CNEB uses renewables as their energy source, does not waste energy, consumes as little water as possible, and produces as much energy as it consumes. A carbon neutral building is one where the design, construction, and operations do not contribute to emissions of GHG that cause climate change.

Most of the studies on CNEB focus on the environmental aspect of de-carbonization. Other dimensions in social and economic aspects are often neglected. The following sections will give a full report regarding CNEB in all aspects of studies.

2.2.1 Environmental Aspects

The focus area on environmental aspects of the CNEB includes energy, water and materials efficiency and GHG emission reduction[9]. To illustrate, fly ashes could be used for structural elements of CNEB retrofit design which help to save the energy as well as to reduce the landfill waste[10]. In the same remark, the execution of precast technologies helps to diminish the construction waste to a great extent[11]. In fact, precast reinforced concrete panel and prefabricated steel are most commonly accepted CNEB techniques in building in Hong Kong to avoid climate crisis[11].

2.2.2 Social Aspects

The social aspects of CNEB cover occupant comfort, health and safety, corporate social responsibilities[12]. This social CN performance indicator should be taken into account of social impacts and contemplation of local community[13]. The Chartered Institute of Building adopts the corporate social responsibility achievement as one of the criteria when awarding contracts. This has inspired the building industry to place vital focus on social aspects in retrofit activities. Some guru argued that CN training should form part of social aspect dimension of CNA rating tool over the building's whole life cycle[14]. Others have also suggested covering wellbeing and comfort of occupants, accessibility to public facilities and level of awareness of green building issues[15].

2.2.3 Economic and Cultural Aspects

The impact of economic and cultural aspects of CNEB attends to the economic value, impacts to local economy, cultural perception and inspiration[16]. The merits of energy retrofit are reflected not only the cost savings ensued from the improved energy efficiency but also the value added to the property with improved rental value and market value[17]. This will help to curtail / reduce the payback period of investment for energy efficiency execution to the CNEB.

2.3 The CN ST

2.3.1 The ST

The World Green Building Council has been calling on all organizations to participate in the Advancing CN agenda to reach CN operating emissions by 2030, and for all EBs to be CN in operations by 2050. This will be crucial to limiting global temperature rise to 1.5 degrees Celsius by mid-century. To accomplish this target, 3 percent to 5 percent of all EBs would need to be retrofitted each year until 2050.

The above urgent carbon-neural pledge escalates the need to have a significant reduction in carbon emissions. As recalled, retrofit EBs is a good place to start as they consume nearly more than half of the world's electricity used for HVAC and lighting. In other words, the EBs account for more than one-third of energy-related GHG emissions. Transforming an existing building into that of CN may seem like an ambitious and challenging undertaking. However, the challenges did rely on the achieving the use of the following ST developed so far. EBs in Hong Kong will be used to illustrate how these ST work.

ST1- Natural Ventilation: Natural ventilation is activated by the pressure differences between internal and external area of the building, drawing fresh air in the building by the natural power of wind, by means of cross ventilation and stacking effect. For EBs, ceiling fans can be utilized to increase the air movement, making spaces more comfortable by promoting the evaporation of moisture. Installation of louvre in the corridor can also improve the cross ventilation to each flat. Natural ventilation allows a substitution for air-conditioning plants, saving 10%–30% of entire energy used. While existing building may not be able to retrofit to allow the natural ventilation but the concept can be a valuable guide to put forward the CNEB strategies particular at times of renovation.

ST2- Reflective Envelope: The external building façade is the key element to control heat entry through sunlight. To maximize daylight while keep away undesired heat transfer, glass coated with low-E was used to keep the heat away outside. Reflective paint, tiles or hollow walls design on external wall help to reduce cooling load in air-conditioned area while improving interior comfort in those area that have no air-conditioning. The lowering of exterior surface temperature is crucial to eradicate the heat island effects, thus removing the pollution level and heat-related illness that developed by heat retaining in those urban area.

ST3- Energy Efficient Lighting Systems: Replacing the traditional incandescent bulbs with that of light-emitting diode (LED) can reduce the building's lighting energy being used. As compared with incandescent light bulbs, LED bulbs have a longer shelf-life, use less power, produce more light and do not release heat thus keeping the rooms much cooler. Coupled with the use of occupancy sensors, the lighting control can further reduce the energy consumes.

ST4- Water Saving Devices: Installation of low-flows faucets in sinks and dual flush toilets can reduce the water used without affecting functionality. Much water can be further saved for using reclaimed water from rainwater, cooling towers, and process water like humidifiers, dishwashers, clothes washers and pools for landscaping. As water requires energy to be treated and distributed to occupants, water savings are energy savings as well.

ST5- Renewal Energy: Various sources of renewal energy can be used, these include, but not limited to the following measures: (1) Solar PV components to draw the energy from sun. These may be in the form of thin film solar PV stone / pebbles tiles; (2) Solar ventilation preheating collector operation, trapping the heat in a solar wall and distributed to all rounds of the building; (3) Wind and water turbine transforming the natural wind and water running energy into electrical energy; (4) Heat pump to extract heat energy from the earth inner core; (5) Organic waste to produce fuels for transportation and generate electricity.

ST6- Reusable Materials: In lieu of opting for low-carbon materials for the retrofit, existing materials can be used. The energy embodied in the construction comprises the energy to extract, manufacture, and transportation. This energy represents the total carbon emissions of a building. The reused materials, like steel decking can be sourced from other site as far as the material used is sound and tested reusable.

ST-7 Use of Native Plants: Native plants for landscaping are beneficial to environmental health, ecological and economic as they normally do not require fertilizers or trimming and need fewer insecticides than grasslands. They necessitate less water and help avoid erosion while providing cover and nourishment for wildlife.

2.3.2 Illustrations of ST

The following Tables 3 and 4 illustrate the ST used so far.

2.4 Key Findings from Previous CNEB Studies

EBs which have adopted CN ST for their retrofit are explored to find out if such implementations are effective. All types of EBs are included as far as possible. They are the commercial office buildings, residential buildings and other type of building like a University building. Data were summed up below to evaluate what and how the current CNEB technologies can improve their energy efficiency and eco- performance.

2.4.1 Commercial Office Buildings

Five office buildings types in Europe[18]: Five office buildings types in South Mediterranean, Continental, Mid-Coastal and North Coastal in Europe are examined. The result revealed that the uses of energy efficient lighting systems to the office buildings will have an energy savings of 40% ~ 60% in the north climatic zones. The general energy savings are drawn up in Table 5.

2.4.2 Residential Buildings

Five Belgian residential buildings[19]: Grounded on a statistical analysis, five EBs were chosen to represent the average residential types in Belgium. The choice of good insulation to roof, glazing and heating system has accounted an energy savings extending from 36% to 60%. The energy savings are drawn up in Table 6.

2.4.3 Other Types of Buildings

The campus of Melbourne University, Australia[20]: The lighting fixtures at Melbourne University of Australia

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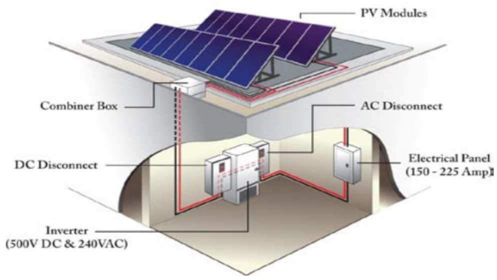
Table 3. Illustrations of CN ST Development in Renewable Energy

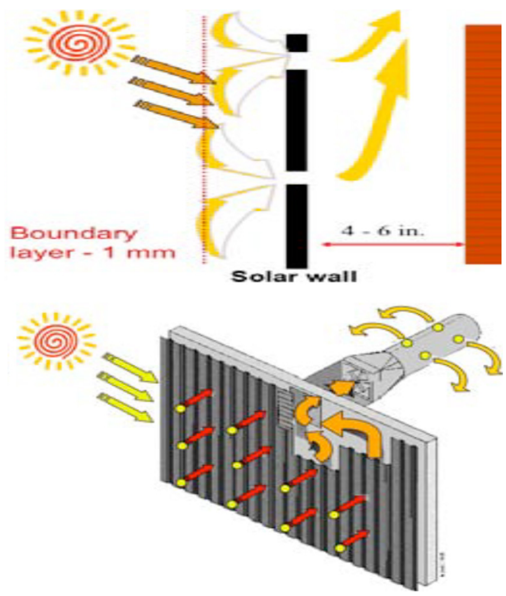
Solar photovoltaic (PV) components



Thin-film solar PV stone / pebbles tiles

PV panels in Hong Kong

Solar ventilation preheating collector operation

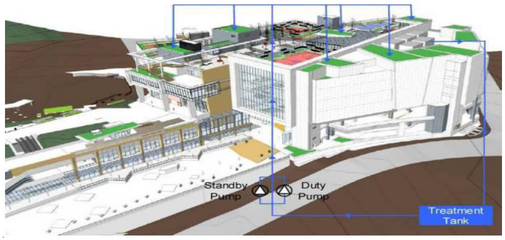


External solar ventilation preheating system installed on the USA Department of Energy's National Renewable Energy Laboratory Research Support Facility

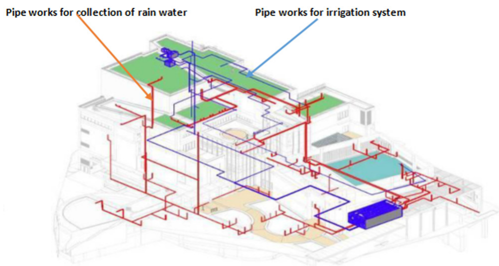
Wind Turbine, USA owns a Northern Power Systems Northwind 100 wind turbine sited at McGlynn Elementary and Middle School

Table 4. Illustrations of CN ST

Treated reclaimed water from cooling towers, process water like humidifiers, dishwashers, clothes washers and pools for irrigation of soft landscape area



Both rain water and condensate from the shopping centre's Air Conditioning system is harvested for irrigation. 65% annual reduction in water consumption for irrigation



Provision of green roof to the top roof of the shopping centre and vertical greening to the refuse / pump room

Sound Barrier balcony with sloped glass panes to bar the sound absorption

Acoustic window which can achieve noise attenuation up to 8 dB(A)

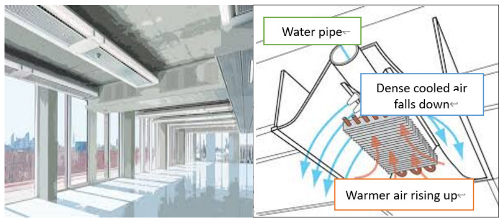
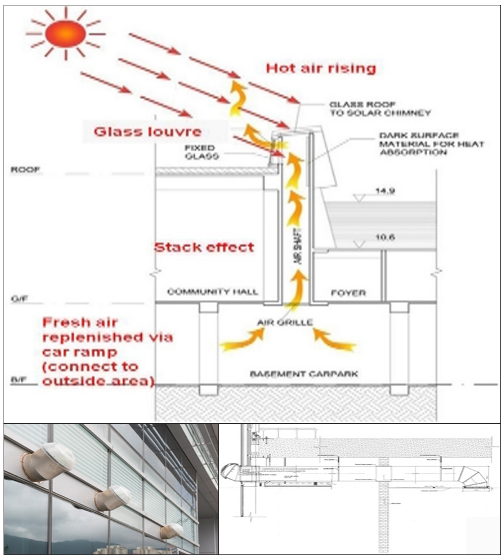
Natural Ventilation Hysan Place in Causeway Bay of Hong Kong provision of natural ventilation design	
Chilled Beam - Pipes of water are passed through a "beam" (a heat exchanger) to chill the air and becomes denser & falls down. Warmer air moving up causing convection effect, cooling the room	
Solar chimney Stacking ventilation system	

Table 5. The Overall Savings in Energy for the Five Office Buildings

Key CN measures used	Improve the building enclosure with insulated CN materials; Replace the lightings to LEDs and use daylight as far as possible; Upgrade the heating and air conditioning systems with energy saving motors
Means for the energy savings record	Use Simulated model
Key findings	Total average energy savings were recorded from 30%-55% in the Northern area

Table 6. The Savings in Energy for the Five Belgian Residential Buildings

Key CN measures used	Improve insulations to roof and floor; Replace glazing to low-E glass units; Install photovoltaic cells at roof level to generate energy
Means for the energy savings record	Use Net Present Value method and Simulation model
Key results	Total average energy savings were recorded from 35-65%

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Table 7. The Savings in Energy for Using the Four Type of Lighting Ballasts in the Australian University

Key CN measures used	Substitute the 1,200mm fluorescent lighting with T5/T8 electronic and magnetic ballasts
Means for the energy savings record	Computation
Key results	The substitution of four ballasts has resulted the following average energy savings:
	15% for using electronic ballasts;
	20% for T8 magnetic ballasts;
	25% for T8 electronic ballasts; and
	65% for T5 electronic ballasts

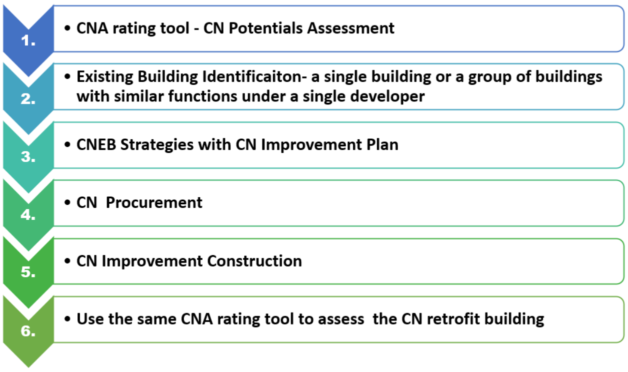

Figure 3. CNEB Procedure.

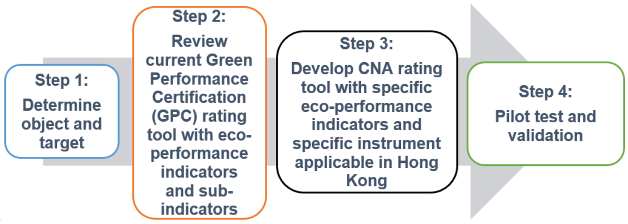

Figure 4. Four Steps to develop the CNA.

Object	Target
• Exisiting Buildings • Single / Group of buildings with similar functions	• Carbon Neutral Existing Building (CNEB)

Figure 5. Step 1 of the CNA development.

attributed almost 30% of the electricity being used. The existing fluorescent fixtures were altered to four different energy efficient lighting fixtures. It was found that the electricity bill has significantly reduced. The four dissimilar lighting fixtures have caused the following energy savings: (1) 13.9% for using electronic ballasts; (2) 20.5% for T8 magnetic ballasts; (3) 24.4% for T8 electronic ballasts; and (4) 64.9% for T5 electronic ballasts. The energy savings are drawn up below in Table 7.

2.5 The Identification of the Top Five GEB Technologies

The above CNEB studies indicated a significant improvement of energy savings if the CN ST are carefully identified and initiated suitably. Based on the above different types of CNEB case studies, the top five most acceptable CNEB ST with satisfactory cost benefits and eco-performance can be recognized as follows[21]: (1) Energy savings equipment adoption; (2) Low / energy savings lamps (T5 fluorescent); (3) Time control trigger; (4) Motion control; and (5) LED as a source for lighting.

This correlates with the study by Ng et al.[22] identified by a questionnaire survey carried out in most of different districts in Hong Kong from June to July 2013. However, more CNEB studies are required to convince the stakeholders and end-users to adopt CN ST to improve their EBs' eco- performance.

3 ASSESSING THE CN POTENTIALS OF THE EXISTING BUILDING

3.1 The Development of CNA

To recall, a simple CNA rating tool has to be used to quick scan the CN potentials of the existing building or a group of EBs with similar functions under a single developer. The procedure of CNEB is elaborated again under the following Figure 3.

Based on the literature review, four steps as listed below are used to develop the new CNA rating tool as required: (1) Determine; (2) Review; (3) Develop and (4) Pilot Test and Validation[23-26]. These four steps can be further elaborated in Figure 4 below.

3.1.1 Step 1: Determine Object and Target

This step requires determining the object and target of the CNA. The target is the EBs whether they are single building block or large building blocks with similar functions under a single developer such as an estate or a university campus. Figure 5 below illustrates the subjects of CNA under Step 1.

This CNA is fully different from traditional eco-performance certification i.e. GPC for EBs, like BEAM Plus EB v2 (2016) as elaborated under Figure 6 below.

While both rating tools of CNA and GPC (EB) aim to assess green attributes in an EB, the vital difference of CNA from GPC (EB) is that GPC (EB) assessments are

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CNA	GPC (EB)
• Assessed **BEFORE** the retrofit is done without any pre-requisites and time limit set up; •To assess how 'carbon-neutral' an EB could be; •Find out the CN potentials of the EB with CN improvement plan; •Applicable to a single /a group of EBs with similar function under a single developer; •Rank the selection of buildings for CN priority using a simple tally system.	•Assessed **AFTER** the EB has complied with certain prerequisites such as obtaining energy consumption data for the major electrical loads for at least three years before the EB is qualified for GPC (EB) rating assessment; •To assess how 'green' an EB is ; •Find out the actual rated scores; •Applicable to individual building, often designed to be green; •Assess the actual performance under the indicators of GPC with green certification award.

Figure 6. CNA vs GPC (EB).

done after the existing building has complied with those prerequisites under GPC (EB) rating tool criteria. The criteria as laid down in BEAM Plus EB v2 (2016) comprise setting up the Environment Management System certified to ISO 14001, and in pursuing the planned maintenance programme, etc. In comparison, CNA is an assessment that is done prior to the retrofit of an EB. CN potentials are established and CN improvement plan will be set up to convert the EB into a CN building. The GPC (EB) advises the assessor on the 'greenness' of an EB whilst CNA determines how far along is an EB from being a CN building to be transformed.

3.1.2 Step 2: Review Current GPC Rating Tool with Eco- Performance Indicator and Sub-Indicator

Step 2 dedicated on the appraisal of the current GPC rating tool worldwide including those now applicable in Hong Kong. Review of the literature had refined nearly twenty GPC rating tools in total, but only seven were taken into account generally practised today. They are Building Research Establishment Environmental Assessment Methodology (BREEAM) in UK, LEED in USA, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, Green Globes in Canada, Green Star in Australia, Green Mark in Singapore, and BEAM Plus EB in Hong Kong. The Green Performance Indicators listed in these GPC rating tools worldwide are summarized in Table 8.

The difference between Hong Kong and its neighbour Singapore with similar building environment should be noteworthy. The table indicates the most commonly adopted eco-performance indicators as: energy efficiency, material and resources, indoor environment quality, site planning, water efficiency and design and innovation. They are thus adopted to be used for the CNA.

3.1.3 Step 3: Develop CNA Rating Tool with Specific Eco- Performance Indicators and Specific Instrument Applicable in Hong Kong

This study adopted a new CNA to improve social factors like human impacts and regional priority by initiating an end-users' cognizance survey. Many GPCs integrate users' cognizance under the Indoor Environmental Quality (IEQ) indicator to rate green features in buildings. Thus, the proposed CNA uses the same users' cognizance of IEQ as one of its eco- performance indicators.

As it is aware, EBs are often designed without due considerations for CN features. CNA is intended to be a simple scanning rating tool for building managers to rate each EB or a group of EBs with similar functions under a single developer to prioritize those eco- potentials for retrofit. Thus, it is not appropriate to use an extensive green category of indicators as this approach will defeat the original objective of the CNA rating tool as a simple scanning measure. It is vital, therefore, to examine each eco-performance indicator for adoption in CNA so that the data collection retained is practicable and measurable. This study has carefully chosen those indicators from GPCs that can be measurable quantitatively. For instance, one measurable indicator has been adopted as an assessment method using energy consumption only[27]. This will ensure the CN assessment being a quantitative tool rather than qualitative which are rather subjective to be evaluated. For the purpose of this study, the following indicators are used as laid down in Table 9. All the proposed sub-indicators as listed are now quantifiably measureable using specific instrument like power logger, water logger and occupant survey.

The proposed instruments to be used for the CN potential assessment for the EB are power, water and energy loggers and occupant surveys. These methods have been widely adopted in numerous studies as the generally accepted instrument to measure the eco- performance indicators[28-31]. The proposed instrument adopted for each indicator is listed below:

(1) Power and Energy data logger (for indicators of Energy and Economic value): The power and energy data logger will give the real-time electricity consumed against time. This annual energy consumption (kwh/year) obtained

Table 8. Summary of Green Performance Indicator Listed in GPC Rating Tools Worldwide

	BREEAM	LEED	CASBEE	Green Globes	Green Star	Green Mark	BEAM Plus EB	Total
Country of origin	UK	USA	Japan	Canada	Australia	Singapore	Hong Kong	
Energy Efficiency	✓	✓	✓	✓	✓	✓	✓	7
Materials & Resources	✓	✓	✓	✓	✓	✓	✓	7
Indoor Environmental Quality (IEQ)	✓	✓	✓	✓	✓	✓	✓	7
Site Planning	✓	✓	✓		✓	✓	✓	6
Water Efficiency	✓	✓		✓	✓	✓	✓	6
Design & Innovation	✓	✓			✓	✓	✓	5
Emissions and Effluents	✓			✓	✓			3
Management	✓			✓			✓	3
Transport	✓				✓			2
Awareness & Education		✓						1

Table 9. Proposed CNA with Its Eco- Performance Indicators and Sub-Indicators

Indicator	Sub-Indicator	Score			Specific Equipment
		L	M	H	
		0	1	2	
Location and Transportation	Alternative transportation	0	1	2	Occupant Survey
Sustainable Site	Preserve existing native plants landscaping	0	1	2	Site survey and Investigation
	Rainwater Control	0	1	2	
	Natural ventilation	0	1	2	
Water Efficiency	Water Saving Devices	0	1	2	Water logger
	Water use record appliances	0	1	2	
Energy	Renewal Energy	0	1	2	Power logger
	Energy Efficient Lighting	0	1	2	
Material and Resources	Carbon-neutral Material	0	1	2	Site survey and Investigation
	Reusable Material	0	1	2	
Indoor Environmental Quality (IEQ)	IEQ control scheme	0	1	2	Occupant Survey
	Improved IEQ measures	0	1	2	
	Comfort Inquiry	0	1	2	
Added Value	Economic benefits acquired	0	1	2	Power / Water Logger
Human Impact	Impacts on local comforts	0	1	2	Occupant Survey
	Value to aged/inferior groups	0	1	2	
Innovation	New measures	0	1	2	Observation
	CN-Pro qualified assessor	0	1	2	
Regional Priority	Local peculiarity	0	1	2	Site survey and Investigation
Total		0	19	38	

Notes: L for low score with 0 point; M for medium with 1 point; H for high score with 2 points.

from the logger divided by the building net floor area will determine the building's energy performance for cross comparison with other EB[32,33]. Evaluating this energy consumption over building size is able to ascertain if the building over-consumes or under-consumes energy. This energy data together with that from the water used when converted into money terms will give the data for the economic value under this CNA rating tool.

(2) Water logger (for indicator of Water efficiency): Water consumption can be measured using a data logging equipment attached to the water meter. For data analysis, it should be pointed out that water consumption may differ substantially depending on the function of the EB. For

instance, the use of water in a student hostel will be much higher than the main academic building in a university campus.

(3) Occupants' survey (for indicators of Location and Transportation, IEQ and Human Impact): Though there may be a number of equipment available to measure these set of indicators (i.e. devices for checking temperature, lighting, humidity, car packing capacity, etc.)[34,35], a study by Baird and Penwell, 2012 revealed that seeking the occupants'/users' perception of the above indicators will be more meaningful and will help to produce a better building for the users. The survey of users using public transport and private cars will give a good indication of number of occupants using alternate transport other than using private cars. The occupants' involvement in the domestic waste separation / reduction campaign / programme, promotion to use less lighting and local garden campaign, etc., will augment the participation of each occupant to take part in the reduction of energy / water consumption and recycle of waste. This constitutes the major part of CNEB strategies.

(4) Site Survey and Investigation (for indicators of Sustainable Site, Material Resources and Regional Priority): A site survey should be devised at the EB for the following investigations.

If the existing state of the EB has been planned to preserve the existing natural state like using the existing landscaping;

If there is any rain water harvesting systems to be used ;

If the orientation of the building has been designed to alleviate the heat island effect;

If there are any public glaring / pollution effect to be incurred;

If there are any waste recovery activities to be arranged;

If there is any scheme for the disposal of all environmental hazardous materials like mercury containing lamps;

If the timber is used from sustainable source certified by Forest Stewardship Council (FSC);

If the disposal of construction waste / debris are being monitored;

If there are any refuse storage and material recovery room to be provided;

If the provision of Barrier-free access (BFA) is adequate and well covered over the building block;

If there is any exercise equipment to be provided for the aged people who are dominated in the EB.

(5) Observation / Design Evaluation (for indicator of Innovation): This is the final indicator that is not measured quantitatively. Design of the EB should be evaluated before any innovation features have been identified. This part of assessment requires subjective evaluation. However, all the identifiable design features can be listed as exemplified in Table 10 below to help the appraisal to this effect.

It is obvious that those sub-indicators with zero score are those CN potentials that effort should be placed for CN improvements. This CNA rating system is applicable to both a single individual building as well as a group of buildings with similar function under a single developer. When comparing a group of buildings, the CNA assessor should make sure that the buildings are of similar functions[33].

The functions of the building will govern its water and electricity consumptions. For instance, the consumptions of electricity and water for a workshop building will be significant than the academic building in a university campus. Comparing the same annual energy consumption per net floor area will be misleading. The type of building function is therefore crucial in this CNA assessment.

Once the type of similar functions of buildings is determined, a simple tally system as laid down latter in this study will illustrate how to rank the buildings in their CN potentials priority. For the building with the highest ranking will be chosen to retrofit into a CN building than another building with less CN potentials as it will take a lot of work and effort to transform the building into a CN building. For the CNA rating tool, score band may be labelled as "High Potential", "Low Potential", and "No Potential".

3.1.4 Step 4: Pilot Test and Validation with a Case Study

Hong Kong public housing estate of 11 blocks, Wan Tsui Estate (WTE) in Chai Wan, Hong Kong, was elected to illustrate the application of the CNEB strategies and the CNA assessment plan adopted above. Table 11 below indicates the key features of the Estate under study.

The six houses over 40 years are assessed using the CNA and the scorings are summarised in Table 12 below.

All the zero and 1-point scoring will indicate the CN potentials for further improvement. Proposals for the improvement are listed in the following Table 13.

4 RESULTS

4.1 The CNEB Strategies

With the help of the newly built-up CNA to scan the CN potentials of the EBs, the CNEB strategies can then be activated. The procedure can be elaborated below in Figure 7 and is further delineated as a flowchart in Figure 8.

To achieve a great success of prompting the above CNEB strategies, the following key considerations should be satisfied: (1) The existing building facilities fail to provide adequate eco-comfort and retrofit is inevitably to be instituted, like water seepage, fading out of plastering works, etc; (2) The building is recommended to form an

Table 10. Example of Listing All the Identifiable Design Features to Assess the Innovation Indicator

Name of the Building	ABC Building Located at 123 Stanley Street, Central, Hong Kong
Building Facade	Curtain walling with aluminium cladding
Building Type	28 storeys commercial building with oblong shape
Building Orientation	Facing South- East
Roof Properties	Flat roof
Glazing Properties	Use insulation glass unit
External Wall Properties	Aluminium cladding
Internal Wall Properties	Gypsum plaster with chilled beam
Ventilation Type	Centralized MVAC system
Internal Space	Open plan design office
Lobby	Centre of the building with ceiling extended to 2nd floor level
Walkway / Corridor	Enclosed
Staircase	Along external wall
Toilet	Along external wall
Lift	Three number of lifts are provided
Observations and Comments	Chilled beam ceiling are provided with energy saving design
	Considered an innovated design as compared with the same type of building among the other similar buildings

Table 11. Key indicators of WTE

District	Wan Tsui Estate
Completion Year	1979-2001 (only six houses / EBs reach 40 years old and are under this pilot test)
Estate Area	55,000m^2
Domestic Flats	3,600
Population	10,600
	Elderly: 3,200 (30%)
	60% of Households have elderly members aged 60 or above
	60 Flats are occupied with members with physical disabilities
Ancillary Facilities	Shopping mall & Market (1)
	Single storey Car Parks (2)
	Community Hall (1)
	Primary Schools (2) & Kindergarten (1)
Type of Domestic Blocks	4 Old Slab Blocks, 2 Single H blocks, 4 Double H blocks and 1 Small Household block (17 to 18 storeys)

Table 12. The Scorings Under CNA for the Six Houses

Indicator	Sub-Indicator	Score			Remarks
		L	M	H	
		0	1	2	
Location and Transportation	Alternative transportation			2	Adjacent to Mass Transit Railway
Sustainable Site	Preserve existing native plants landscaping			2	Existing landscaping is preserved with good rainwater control. Open space design with natural ventilation
	Rainwater Control			2	
	Natural ventilation			2	
Water Efficiency	Water Saving Devices	0			No water saving devices and water use recorders are installed
	Water use record appliances	0			

Energy	Renewal Energy	0			No renewal energy and energy efficient lighting scheme is implemented
	Energy Efficient Lighting	0			
Material and Resources	Carbon-neutral Material	0			No CN or reusable materials are used
	Reusable Material	0			
Indoor Environmental Quality (IEQ)	IEQ control scheme	0			No IFQ control or measures are implemented but the internal open space design allows the minimal human comfort for the occupants
	Improved IEQ measures	0			
	Comfort Inquiry		1		
Added Value	Economic benefits acquired	0			No economic value is recorded as there is no energy or any water saving devices being executed
Human Impact	Impacts on local comforts	0			Not enough covered walkways or vertical lift access to public area
	Value to aged / inferior groups	0			
Innovation	New measures	0			No innovative devices like sound barrier balcony or Twin Tank System to provide uninterrupted water supply to tenants, even during the cleansing of the water tank
	CN-Pro qualified assessor	0			
Regional Priority	Local peculiarity	0			Not enough covered Barrier-free access (BFA) for aged and inferior group
Total		0	1	8	

Table 13. The Improvement Plan for CNEB Strategies

Indicator	Sub-Indicator	Score			Improvement Plan Proposed
		L	M	H	
		0	1	2	
Water Efficiency	Water Saving Devices	0			Install water saving devices to all sinks and use dual flush toilets in all public area
	Water use record appliances	0			
Energy	Renewal Energy	0			Replace the existing incandescent lighting to LED Lighting with sensor control to all public area and staircase. Connect the city Grid with the PV panel system located at the rooftop
	Energy Efficient Lighting	0			
Material and Resources	Carbon neutral Material	0			Use waste separation and collection container for waste reuse, like paper waste and use timber from Forest Stewardship Council (FSC) certified for retrofit with all the public doors. Use eco-blocks for the replacement of the damaged pedestrian walkway
	Reusable Material	0			
IEQ	IEQ control scheme	0			Install De-odorizes at the Covered Refuse Collection Points. Install air ventilation technology and conduct periodically on-site measurements to verify its effectiveness and generate data for benchmarking improvement opportunities. Adhere to the nontoxic cleaning agent
	Improved IEQ measures	0			
	Comfort Inquiry		1		
Added Value	Economic benefits acquired	0			Install a LCD panel at the G/F lift lobby of all the blocks of WTE to arouse the tenants' awareness of energy conservation and showing the regular consumption of water, electricity and gas. Use energy-saving lighting installation / motion sensors that can save 10% energy consumption
Human Impact	Impacts on local comforts	0			Increase the rate of domestic refuse recovery and reduce refuse for disposal. Add lift tower to shopping centres for those disadvantaged groups
	Value to aged / inferior groups	0			
Innovation	New measures	0			Use Twin Tank System to provide uninterrupted water supply to tenants, even during the cleansing of the water tank. Incorporate Sound Barrier Balcony to those flats that close to the main roads at the lower 3 levels using sloped glass panes as a sound barrier and sound absorption materials at the two sides and top level. These innovative slope glass panes can bar up the noise level within 8 decibels
	CN-Pro qualified assessor	0			

Regional Priority	Local peculiarity	0	As 30% of the population belongs to the aged group, wherein 60% households have elderly members aged 60 or above and 60 flats are occupied with members of physically disabilities, more provisions like disable toilets, travelling ramps, tower lifts, and leisure / recreation area for elderly persons with fitness equipment for senior adults should be provided. Provide Barrier-free access (BFA) and connectivity to adjacent shopping area. Set up a waste reduction campaign to engender the waste reduction concept and habits in the Estate

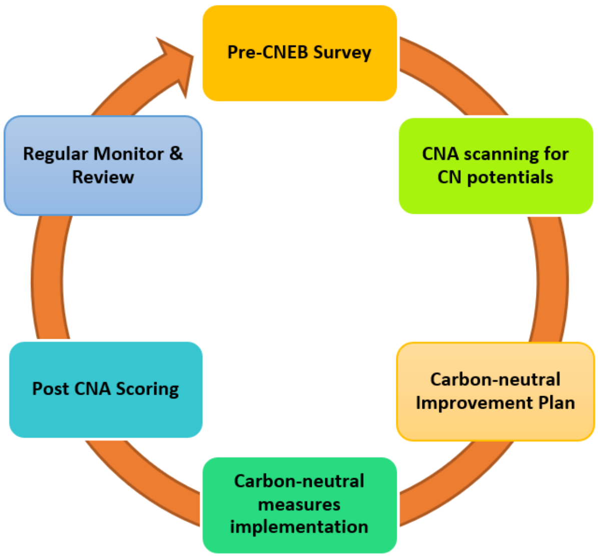

Figure 7. The Procedure for the execution of CNEB. Strategies.

OCC under section 3.3A of the Building Management Ordinance (Cap 344) of HK Government. It would facilitate the decision making much easier and quicker as the power and obligations of this OCC are accredited by the Hong Kong Government; (3) Maintenance and CN improvement should be carried out in one go as HK Government has subsidies and credits provided for maintenance under the Building and Maintenance Scheme (BMMS) first launched in January 2005.

The CNEB Strategies as elaborated in the above flow-chart in Figure 8 stipulates the following strategic stages:

(1) **Pre CNEB Survey:** Once it is ascertained that the building necessitates a major renovation / maintenance, the OCC should carry out an appraisal to: a. Establish the scope and area of the maintenance and CN to be carried out; and b. Identify if the Government subsidies and loans are available or eligible for this type of maintenance / CN area. Upon approval by the OCC, a qualified CN assessor can be appointed to assess and categorize the CN potentials of the building. The qualified CN assessor should be accredited by the HKGBC. To distinguish from the Building Environmental Assessment Method Professionals (BEAM Pro), this qualified CN assessor using CNA as the assessment tool is proposed to be retitled as the CN Pro under this study. If all goes affirmative, the CN Pro can be recruited to carry out the CN Performance Assessment.

(2) **CNA grading:** The CN performance evaluation can be carried out under the above proposed CNA. Once it is assessed with a number of CN potentials, a CN improvement plan can then be documented.

(3) **CN Improvement Plan:** The CN potentials laid out under the CNA can be grouped under each eco-performance category and a CN improvement plan can be set out to carry out the CN improvement and the maintenance works simultaneously.

(4) **CN measures execution:** Once the CN improvement plan is decided to carry out, the OCC should go through the cost benefit and risk checkup taking due considerations of the amount of the Government grant / loan to be granted together with the available CN ST to be embraced. Reference can be made to the most cost effective and efficient CN ST that have been established under this study.

(5) **Post CNA grading:** A post CN performance assessment should be evaluated if the CN standard can be achieved. Further CN improvement works should be done until the mission of CN is verified.

(6) **Regular monitor and review:** It is imperative that a frequent monitoring of the building energy savings performance data should be analyzed to ascertain both the energy savings and the occupants' health and comfort are incessantly sustained. Incorporation of a maintenance policy documenting all the CN measures and data is conducive for future CN sustainability for the building.

5 DISCUSSIONS AND CONCLUSION

5.1 Conclusive Remarks

The Earth has suffered an average rise in temperature of 0.6°C over the past century due to over-use of energy accrued essentially from heating, ventilation and air-conditioning and lighting. Whilst new building works add a small % annually[36], the remaining large % of existing building blocks accounts for 30% - 40% of the total EU in modern countries. The CNEB strategies under the newly formulated CNA in this study integrate two strategic elements, CN retrofit and eco-performance. However, prior to the implementation of the CN improvement plan, the CN assessor should consult with the end-users of the building that the following objectives have been clarified[37]: (1) Is the CNA aims to reduce the cost of the energy management? If yes, more options can be put forward for the CN improvement; (2) What are the budget for the CN improvement plan and the time for the investment return? This will limit the scope and size of the CN improvement plan; (3) Will the maintenance of the buildings and the CN improvement plan be taken concurrently? If so,

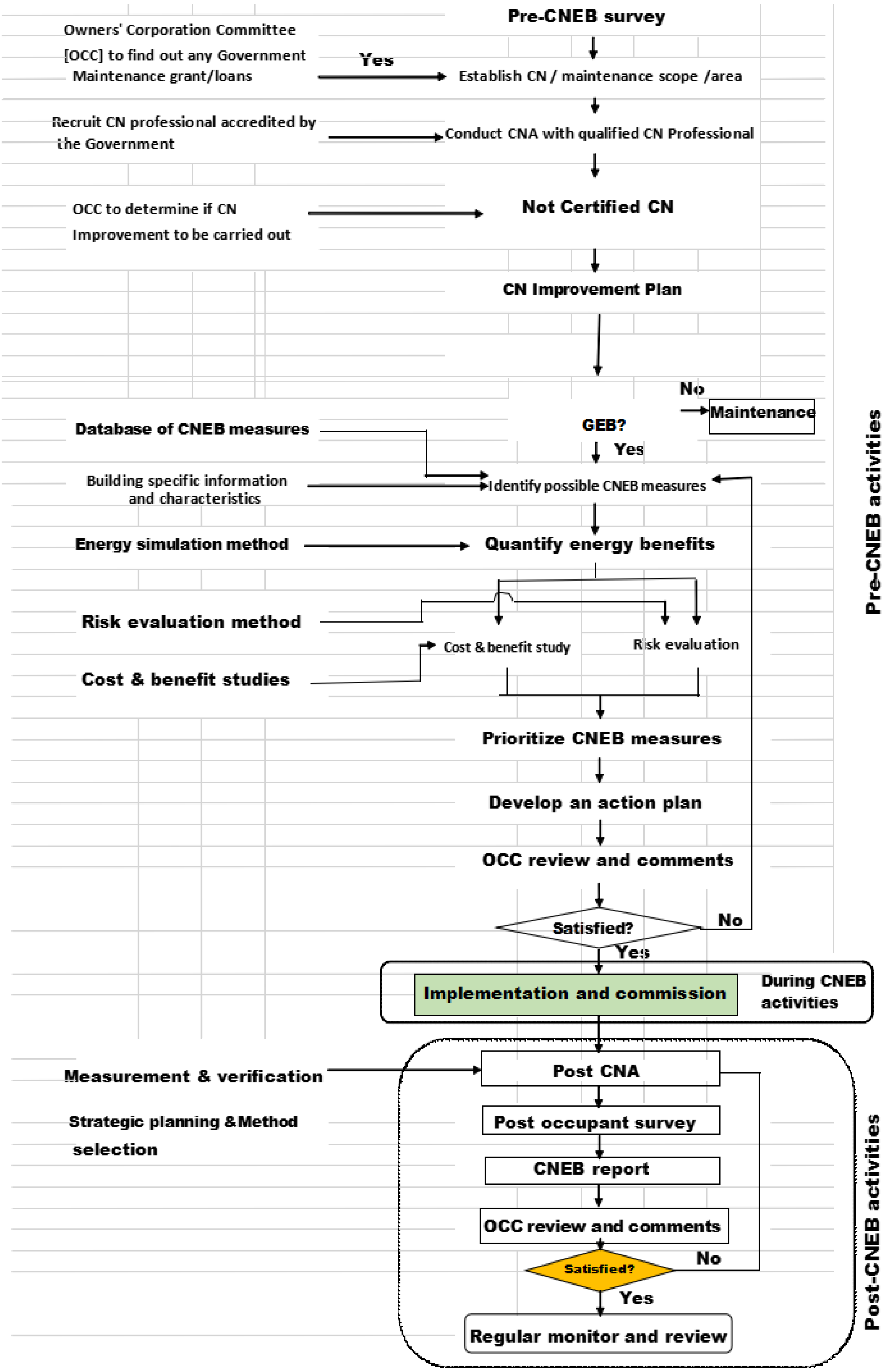

Figure 8. Flow Chart for the CNEB strategies to CN the existing building.

Government grants / loans can be pursued under the Building Maintenance Scheme currently run in HKSAR.

Once the building has promoted its CN performance, it is important to initiate a maintenance policy to continue sustaining such services. All the CN measures identified and instigated are crucial elements of the maintenance policy for future sustainability. Reference can be made to the standard ISO 50001 "Energy management systems—Requirements with guidance for use" (ISO 50001-Energy Management Systems Standard) to standardize the maintenance policy systematically.

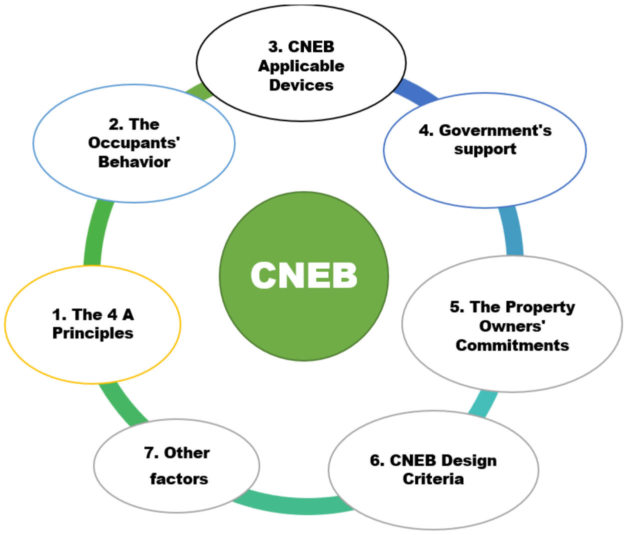

Figure 9. Key Elements governing the success of CNEB.

Renovating a building to CNEB in this way may seem like an ambitious undertaking, but the impact of this CN pledge is huge. Experts concede that without altering how buildings are retrofitted and operated, there is no chance of confronting the adverse climate crisis.

5.2 Key Elements Governing CNEB Success

The success of advocating the CNEB relies on many factors. Figure 9 indicates the key elements that govern the success of CNEB.

5.2.1 The 4A Principles

In responding the 4A principles in terms of Aspiration, Advancing, Appraisal and Arousing as mentioned in this study, the CNEB strategies should be cross evaluated if the 4 A principles have been adopted:

(1) Aspiration: If the latest and efficient CN ST have been selected? Not all ST are achievable the CN target of CNEB strategies, careful scrutiny and evaluations should be made to find the one adaptable to one's own purpose.

(2) Advancing: Can the CNEB is upgradable with the evolving future CN technologies? There are various kinds of renewal energy system using different ST. The CNEB strategies should take this flexibility into account to upgrade the system as it evolved to achieve economic replacement as far as possible.

(3) Appraisal: Has the elected ST been undergone any cost-benefits analysis prior the operation? Assembling various data of the applicability of the CN ST is essential for cost and benefits appraisal. The eco-performance parameters should be evaluated in terms of the carbon emission, capital investment, payback period, amount of energy draw-in and out from the city electricity grid.

(4) Arousing: If the occupiers have been motivated to take part in the CN campaign? Local gardens can be set up to promote occupiers' involvement in the CN undertakings. The local gardens should be most welcome for the estate with a high % of the aged group. Planting day and CN functions can also be organized. Waste reduction campaign can be set up to engender the waste reduction concept and habits in the building. The support of the end-users is critical to bring success in the CNEB.

The Occupants' Behaviour: The occupants' behaviour towards thermal, visual, and acoustic comfort and their anticipations on the requirements of indoor air quality will essentially outline the wellbeing zone state of the energy input. Various studies like that use by Yohanis[38] and Santin et al.[39] indicate that the occupants' topographies can direct the EU of around 4-5%.

CNEB Applicable Devices: The methods of GEB applications may involve external insulation cover like using insulated glass unit and efficient energy savings appliances / lamps and HVAC system...etc. Electrical and mechanical systems of the highest efficiency (also referred to as active systems) should be designated. Main examples are the floor cooling system combined with radiant cooling from the ceiling, high volume low speed ventilation fans, separate cooling and humidity removal systems, active skylights and light tubes. The adoption of those active systems may lead to an additional 25% energy saving. A survey can be initialized to discover the utmost cost-effective and satisfactory CNEB applicable devices. The choice of each carbon –neutral devices relies very much on the exploration and actual involvement of the participants.

Government's Support: The Government's financial incentives and support to the building owners can help to promote the achievement of energy renovations to the EBs. The Hong Kong Building Management and Maintenance Scheme launched in January 2005 sets up a good convincing move. They have offered a financial assistance with funding of HK$1 billion in its first launch to support those aged owners.

The Property Owners' Commitments: Payback period is the vital decisive factor for the investment of the stakeholders to adopt the kind of CNEB strategies[40]. Thus the most cost-effective CNEB smart techniques will be highly preferred by the stakeholders. However, a study by Alajmi[28] revealed a significant capital investment of applying CNEB ST could save energy consumption of almost 50% annually. A precise payback period with the choice of CNEB strategies should be cautiously assessed case by case for each existing building to conform to the stakeholder's commitments.

CNEB Design Criteria: The building design data like the building orientation, energy-saving devices / HVAC scheme, the external casing of the building structures, the life cycle of the insulation materials …etc. will dominate the choice of CNEB strategies and their energy- saving effectiveness.

The retrofit design should dictate to the use of natural elements to heat, cool, or light a building like natural ventilation, natural lighting, solar shading and thermal insulation.

To enhance cross ventilation, a pervious built form can be considered to provide a large void deck at the reception hall to effectively ventilate the space. This will also benefit the local air ventilation to avoid any urban island effect in the area. Ceiling mounted fans can also be instigated as mechanically cooling to help delaying the air conditioning usage by more than 20°C in summer climate condition.

Direct solar gain through windows can be much mitigated by the use of external solar shading and high performance low-E glazing. Window to wall ratios for respective facades should be optimized for daylighting and view without excessive ingress of heat. Relatively higher glazing ratio for transparency is used for the north facing façade. Deep overhang of the southeast façade provides shading while allowing good views towards the landscape area. The high performance low-E glazing with fritted pattern controls the opaqueness of the facades to avoid heat gain.

The building envelope should be air-tight. This is predominantly significant for reducing energy demand in Hong Kong's climate condition as the dehumidification of high humidity infiltration has a disproportionally large impact on the capacity of mechanical cooling plant and its EU. Good air tightness also eliminates the risk of condensation.

The shading fins are another device that should not be overlooked. The shading fins can be computer controlled with sunlight sensors and their shading angles are constantly adjusted to cut out direct sunlight as the sun passes over the sky.

Other Factors: Each building is unique and considerations of other aspects should be visualized to ensure that no possible best energy savings substitutes are left behind. However, the landscaping should not be understated. The landscape design improves the cooling effect and is estimated to be able to lower the air temperature by up to 1°C, leading to a positive impact on the local microclimate. The variety of native trees and native shrubs offer food and shelter to appeal native wildlife into the area, generating a high quality environment surrounded in the area. This kind of landscaping scheme is highly recommended for an Estate in Hong Kong. A key feature of the landscape area is the planted urban native woodland, which contains some 200 trees of over 30 different native species. The planting pattern is random to emulate the natural woodland, with small trees intermingled amongst the medium and large trees aiming at the formation of a dense tree canopy in due course. Some trees with ornamental characters have been selected to improve visual comfort. It offers pleasant natural fragrance and fresh oxygen and helps remove gaseous and particulate air pollutants to improve air quality.

5.3 Promotions

5.3.1 Support from the Government

To make the target of HKSAR to reduce the energy power of 40% and carbon concentration to 50-60% by 2030 using 2005 as the base year, the above CNEB strategies can make the above the target achievable. The findings from the CNEB studies for office, residential and other types of buildings[18-20], indicated that the CNEB strategies can achieve a total of energy savings in a range of 40%-60%, with carbon intensity reduced to 20-30%. The BMMS launched in January 2005 offering a financial funding of HK$1 Billion in its first launch to implement the grant scheme for aged owners. Since 1 April 2011, the "Integrated Building Maintenance Assistance Scheme" is another building renovations service that will augment the CNEB strategies. To prioritize the Government granting norm, a simple scoring system is proposed with pointers to select each of the EBs with similar functions for the subsidy. In addition to the data merited under the CNA plan, three indicators will be measured: (1) Energy Efficiency (2) IEQ and (3) Water Efficiency. The measuring instruments are: (1) Power use data report for the Energy Efficiency; (2) Occupant survey for the IEQ and (3) Water Meter result for the Water Efficiency. The above tools have been widely recognized in various cases to prioritize the building for the subsidy[28-31].

The tactics used are elaborated as follows:

Energy Efficiency: The EU over size of the existing building is termed as building energy pointer (BEP)[41-43]. The total building energy consumed in a year (kWh/year) over its total floor area (m^2) is its BEP.

IEQ: IFQ is derived by the building occupants' survey to conform the users' satisfaction to the thermal / visual / acoustic comfort. Despite pointer of humidity / glaring / heat, etc., with equipment in the studies[34,35], seeking users' perception are more indicative of the actual comfort feeling in reality.

Water Efficiency: The number logger attached to the measured appliance allows monitoring of actual WU over the time (say in month) measured as m^3 per month. Table 14 illustrates the scoring method.

Existing building A scores 8 ranks better than that of B of 10. A is chosen for the CN improvement in priority. B may need a bit more of investment in the retrofits than A. Any number of buildings can be used under this scoring tactic.

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Table 14. Illustration of Tallying the Score for a Group of Two EBs of Similar Design and Facilities

Indicator	Measurements	Unit	Bench mark	Existing Building A	Rank A	Existing Building B	Rank B
Energy Efficiency	Computation of BEP	Annual kWh per floor area	Smaller is better	60	1	75	2
Indoor Environmental Quality (IEQ)	Thermal comfort	Score per 100 occupants survey	Higher is better	60	2	65	1
	Visual comfort			85	1	83	2
	Acoustic comfort			65	2	75	1
	In-house air quality			70	1	65	2
Water Efficiency	Water use	m^3/month	Smaller is better	1,100	1	1,280	2
Total					8		10

Notes: The numbers put in are for illustration only.

5.3.2 CN Pro

Like the BEAM Pro accredited by the HKGBC for the complete building life cycle, particularly in the building planning and design stage, a CN Pro can also be acknowledged by HKGBC in the same manner for the CNA assessor for CNEB. The engaged CN Pro will assure the CNEB can be accomplished in a professional manner to achieve CN in the EBs.

5.3.3 Proposals of Legal Enforcement

Upgrading the current legal and administrative measures may offer a better tactics to tackle those owners who are unwilling to decarbonise their EBs. Amendments to the current land grant clauses, the deed of mutual covenant and / or the Building Management Ordinances may conducive to define the owners' responsibilities for regular eco-upkeep of their buildings. A Renovation / Retrofit Reserve Funds should be set aside for the future eco-upgrading works. For instance, when a newly innovated refrigerant is available, the EBs owners should be obliged to upgrade their air-conditioning equipment for their decarbonisation liability.

5.4 Strengths and Weakness

5.4.1 Strengths

The formulated CNA has embraced specific CN performance indicators measurable with specific instruments except the Design and Innovation indicator that is not measured quantitatively. However, a list of identifiable design features has systematically defined the performance value. The CNA is supported by a field study indicating that the CNA is applicable both to a single EB and a group of EBs with similar functions under a single developer. Thus, a large number of EBs can be assessed and transformed into CNEB simultaneously in a more economic manner.

The findings in this study have concluded that using the proposed CNEB strategies can achieve a total of energy savings in a range of 40%-60%. This high energy savings will contribute to the carbon intensity reduction in the range of 20%-30%.

5.4.2 Weakness

The study may suffer the following weakness: (1) Applicability of CNA rating tool to the EB in Hong Kong: The CNA rating tool is the new concept to rate the EB for CN potentials. In-depth literature reviews should be pursued if the inclusion of the proposed CN performance indicators and sub-indicators can be applicable in a densely populated area in Hong Kong. Whilst the indicators should be measured quantitatively to avoid any subjective bias, the choice of the indicators should cover all aspects of the CN building features and characteristics. There may be other indicators that may be left behind and may not be recognized by the HKGBC. Without the support and accredited by the HKGBC, the CNA rating tool may not be adoptable by the building professionals. (2) The investigation of CN performance indicators may be restricted which may bias the findings: The CN performance indicators may not cover the other CN features of CNEB. Each indicator allocated may be subject to query and elucidation, though every efforts have been made to cover all aspects of CNEB like environmental (the energy and water efficiency indicators), social (human impacts), economic (economic value) and cultural (regional peculiarities) features. Other CN performance indicators that may be valid in Hong Kong like heat island effect and wind screening wall effect may also be beneficial to build up the CNA rating tool. (3) Deficiency of case studies: One case study may not be capable of generalizing the findings. More variety of EBs should be investigated in different countries may be required.

5.5 Theoretical and Practical Contribution

5.5.1 Theoretical Contribution

The development of CNA rating tool is a new concept distinguished against the traditional GPC rating tool in EB. CNA scans the EB direct before its retrofit without bothering the prerequisites as laid down in GPC. A group of buildings with similar functions under a single developer can also be evaluated. Ranking of the buildings for the priority of CNEB scheme can be easily identified under a very simple tally system.

On the other hand, GPC rating tool is used to assess after the completion of the retrofits of the EB pursuant to the prerequisites laid down under the GPC rating tool guidance. GPC is used as a green certification award only for individual building often designed to be green. Assessment of the CN potentials in EB is rarely discussed in past literature unlike other types of assessments, such as a building's current performance and qualities. The study will give a new CNA rating tool to directly identify the CN potentials of the EB for CNEB.

Additionally, the CNA rating tool will formulate a CNEB strategy with improvement plan. The study will stimulate a CN market and encourage the use of CN products and ST to improve the eco- performance of the EBs.

5.5.2 Practical Contribution

The new CNA rating tool will motivate the top management to set up good CNEB strategies to instil CN culture in the company. CN vision and mission statement can be set up by the top executives to increase economic value of the EB. CNEB strategies can be instigated as a long term CN implementation goal for the EB.

The incorporation of the CNA rating tool with CNEB strategies as CN management practices will add value to the project owners, shareholders, consumers and the community alike. The EB re-certification status will give a brand prestige to the company as well as generating an appealing appraisal to the community, thus retaining more loyal customers[44]. An association of corporate social responsibility image with brand quality icon will exacerbate the sales and stock prices ultimately. They may initiate a "CNEB strategies" campaign effects which is appreciated to the marketing manager[45].

After all, for the success to put forward the CNA rating tool and CNEB strategies, full commitments of top executives are considered essential. Without the top management's commitments, the CN management team will not be sustained with adequate and in-time facilities and financial back-up to realize the CNEB outcomes desired. Apart from filling the knowledge gap of perceiving the CN potentials of the EB, the stakeholders concerned will strategize their economic efforts to decarbonisation the large existing building blocks as proposed by CNA.

5.6 Limitations

The indicators used by CNA may be subject to challenges for their theoretical and practical achievability. Expert opinions and insights should be pursued for enhancement and validating of the proposed indicators. More tests should be conducted to evaluate the workability of the CNA rating tool to evaluate the CN potentials of the EB.

The as-built project studies cannot accommodate the exploration of the CNA and CNEB strategies in other building lifecycle stages and it may offer another worthwhile study. Additionally, the perspectives of the project building stakeholders are also vital for the CNA and CNEB strategies. Multi perspectives can shed light on the study relating the conflicts that may be encountered in this aspect. Critical analysis of the success factors on CNA and CNEB strategies may give a further insight for pragmatic application to step up the CNEB's policy to combat the global warming.

Advanced construction information technology (e.g. building information modelling), employing 2D and 3D modelling platforms may help the scrutinizing process of the CN potentials of the EB in more details. Other establishment of information platform for CN market and suppliers with performance details to develop the CNEB strategies is also worth scrutinizing to lower down the CN costs and encourage the CNEB strategies to be set off in a more efficient and cost effectively way.

5.7 Future Agenda

Research in CNEB measures can be found in various publications but CN improvement in EB committed at a very slow progress. The retrofit rate for commercial buildings is only at a very slow rate e.g. 2.2% per annum in 2010[46]. Many researches have established that the CN performance of EB can be achieved considerably through adequate CNEB strategies. The support by the Government and the local CN bodies' support such as US/HK Green Building Council are crucial to endorse this CNA as discussed in this study.

To achieve building pliability and adaptability due to the variance of weather changes, more studies on low energy CNEB measures in a more pragmatic way is required. In adopting the most cost effective CNEB strategies, appropriate selection criteria and weighting factors should be considered in optimizing this multi-objective assignments, like the owner's impact / human factors should be evaluated carefully as it will directly affect the building eco-performance effect. The CNA rating tool should be further improved by validating the proposed CN performance indicators, the sub-indicators and the credit scoring system through expert opinions and insights. More comprehensive research in this area is needed.

The last but not the least, risk assessment of CNEB strategies should be elaborated as investment of CNEB strategies has a high risk factor. Building scientists and professionals have a long way to go in order to make EB more CN proficient and environmentally viable.

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Conflicts of Interest

The author declared no conflict of interest.

Author Contribution

Leung BCM designed the experiment, supervised the work, performed the data analysis, drafted the manuscript and writing the article, read and approved its submission.

Abbreviation List

BEAM Pro, Building Environmental Assessment Method Professionals
BEAM, Building Environmental Assessment Method
BEP, Building energy pointer
BFA, Barrier-free access
BMMS, Building and Maintenance Scheme
BREEAM, Building Research Establishment Environmental Assessment Methodology
CASBEE, Comprehensive Assessment System for Built Environment Efficiency
CN, Carbon-neutral
CNA, Carbon-neutral audit
CNEB, Carbon-neutral existing buildings
EBs, Existing buildings
EU, Energy use
FSC, Forest Stewardship Council
GEB, Greening existing buildings
GHG, Greenhouse gas
GPC, Green performance certification
HKGBC, Hong Kong Green Building Council
HKSAR, Hong Kong Special Administrative Region
IEQ, Indoor Environmental Quality
LED, Light-emitting diode
LEED, Leadership in energy and environmental design
OCC, Owners' Corporation Committee
PV, Photovoltaic
ST, Smart technologies
WTE, Wan Tsui Estate
WU, Water use

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