POTENTIALS AND CHALLENGES OF MYCREST: A MALAYSIAN INITIATIVE TO ASSESS CARBON EMISSIONS FROM BUILDINGS

by Fadhlin Abdullah
MIT-UTM Malaysia Sustainable Cities Program
Massachusetts Institute of Technology

Abstract

Because countries have identified buildings as a key source for carbon reduction strategies in coping with climate change and global warming, energy consumption and carbon reduction have become increasingly become important criteria for building rating tools. This study explores the potential and challenges of the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST), a rating tool adopted by the Malaysian government to evaluate and reduce carbon emissions from buildings. This was undertaken through a document analysis of the criteria in MyCREST, and a case study on the mandatory adoption of MyCREST for government buildings implemented by the Public Works Department. The extensive coverage of sustainability criteria in MyCREST across the stages of a building life cycle provides a more holistic and comprehensive basis for the design team to identify opportunities and strategies for carbon reduction. The lack of enforcement mechanisms, resource constraints, and industry-wide awareness, however, have hampered the effective implementation of the tool in enhancing carbon reduction performance in buildings. A combination of policy prescriptions—including establishing a regulatory framework, enforcing the existing energy code of practice, establishing a mandate for a single responsible organization, and setting a plan for capacity expansion—have been identified to help enhance the potential of MyCREST in contributing to overall carbon reduction in the building sector, which in turn will further help the building sector contribute to the national carbon reduction targets.

Introduction

In an effort to help mitigate climate change, countries around the world have committed to long-term goals for reducing carbon emissions (Paris Summit, 2015). This global effort extends to Malaysia, which has volunteered to reduce its carbon emission intensity by up to 45 percent by 2030. Buildings have been widely recognized as one of the key sectors that can contribute to carbon reduction strategies, as they account for more than 40 percent of total energy use and 20 to 40 percent of greenhouse gas (GHG) emissions (Ahn et al, 2010; Ibn-Mohammeda, 2013; Abd Rashid & Yusoff, 2015). This has prompted the establishment of “green” buildings, defined as environmentally sustainable buildings designed, constructed, and operated to minimize their environmental impacts. Guided by this definition, various building rating tools have been developed by countries worldwide to evaluate the environmental impacts of buildings.

In addressing buildings’ potential contribution to carbon reduction targets, it is imperative for rating tools to be able to gauge the life cycle carbon emissions intensity of buildings, so that the potential amount of reduction can be determined, and appropriate measures can be introduced to maximize carbon reduction performance. Within this context, the Malaysian government—through the Construction Industry Development Board (CIDB) and the Ministry of Works—has developed the Malaysian Carbon Reduction & Environmental Sustainability Tool, known as MyCREST. This building rating tool aims to evaluate and reduce carbon emissions from buildings across all stages of a building life cycle. The government has led the way in adopting MyCREST, by making its use mandatory for all government projects valued at RM50 million and above implemented by the Public Works Department (PWD) beginning in January 2016.

This study explores the potential of MyCREST in contributing to carbon reduction in buildings, and examines the challenges to implementing MyCREST effectively. Understanding the motivations, experiences, and challenges inherent in MyCREST provides a basis for developing policy prescriptions for enhancing potential carbon reduction performance from buildings, in both the broader industry and related contexts.

Context of the study

It is well established that greenhouse gas (GHG) emissions are the driving force behind climate change and global warming. As defined by the

Kyoto Protocol (1997), GHGs mainly consist of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. Among these GHGs, carbon dioxide is the most important GHG, accounting for nearly 80 percent of the global warming effect (IPCC, 2007). In quantifying and reporting the overall global warming impact caused by various GHGs, an aggregate measure known as “carbon dioxide equivalent” is normally used. Carbon dioxide equivalent is estimated by combining all GHG values and converting into a single carbon dioxide equivalent value that leads to the same global warming impact (Hong, T. et al, 2014). Hence, the term “carbon emissions” used throughout this paper refers to carbon dioxide equivalent emissions.

Buildings have been identified as one of the main sources for GHG emissions (Raslanas et al., 2014). The building sector’s contribution to carbon emissions can take place directly through direct emissions to the atmosphere, or indirectly, through the consumption of resources that emit carbon. Energy consumption and carbon emissions occur in all stages of a building life cycle, as indicated in Figure 1. Carbon emissions from individual buildings are divided into *operational* and *embodied* impacts.

Operational impacts are carbon emissions resulting from a building’s energy load, such as lighting, heating, ventilation, and air conditioning used during the operational stage of a building. Embodied impacts are those carbon emissions created in the resource-extraction processes, the manufacture and transportation of building materials, construction-related activities, and the eventual demolition and disposal of the building. The transitions between many of the different stages of the building life cycle shown in

Figure **1** generally involve a considerable amount of transportation. These transportation-related carbon emissions need to be considered in the estimation of building carbon footprint (Ng, S.T. et al., 2012).

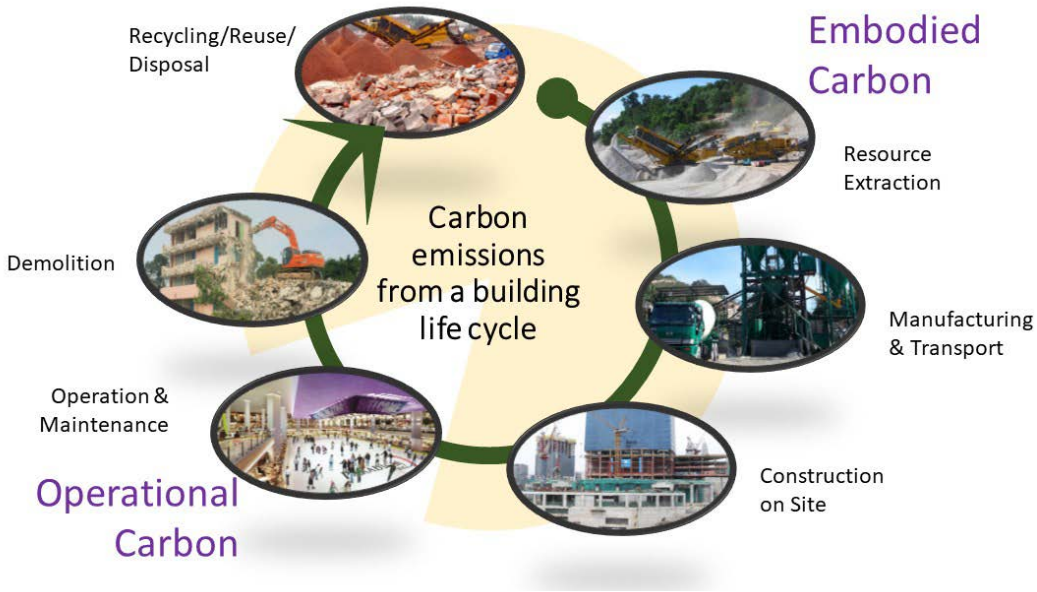

Figure 1. Embodied and operational carbon emissions from all stages of a building life cycle.

Global building sector impacts on carbon emissions

The International Energy Agency (IEA) reports that the global building sector consumed nearly 30 percent of total final energy use, as illustrated in Figure 2. Building construction, including the manufacturing of materials such as steel and cement, accounted for an additional 6 percent in estimated global final energy use (UNEP, 2017). As shown in Figure 3, buildings constituted 28 percent of global energy-related carbon emissions, while building construction represented another 11 percent of energy sector carbon emissions (UNEP, 2017). Therefore, buildings and their construction accounted for 36 percent of global energy use, and almost 40 percent of energy-related carbon emissions in 2016. IEA has also indicated that global building-related carbon emissions have continued to rise by nearly 1 percent per year since 2010, and forecasts that if more aggressive efforts are not made to address low carbon and energy efficient solutions for buildings and construction, buildings-related carbon emissions will increase by another 10 percent by 2060 (UNEP, 2017).

Acknowledging that addressing the challenges posed by the construction sector can contribute significantly to mitigating global warming, the United Nations Environment Programme (UNEP) initiated the Global Alliance for Buildings and Construction (GABC) working groups in 2016. The groups' objective is to bring together the building and construction industry, countries, and stakeholders to raise awareness and facilitate the global transition towards low emission, energy efficient buildings. GABC aims to reduce carbon emissions from the global building stock by increasing the share of eco-friendly buildings, both new and renovated (UNEP, 2016). In line with this goal, building environmental assessment tools have been developed for evaluating carbon emissions.

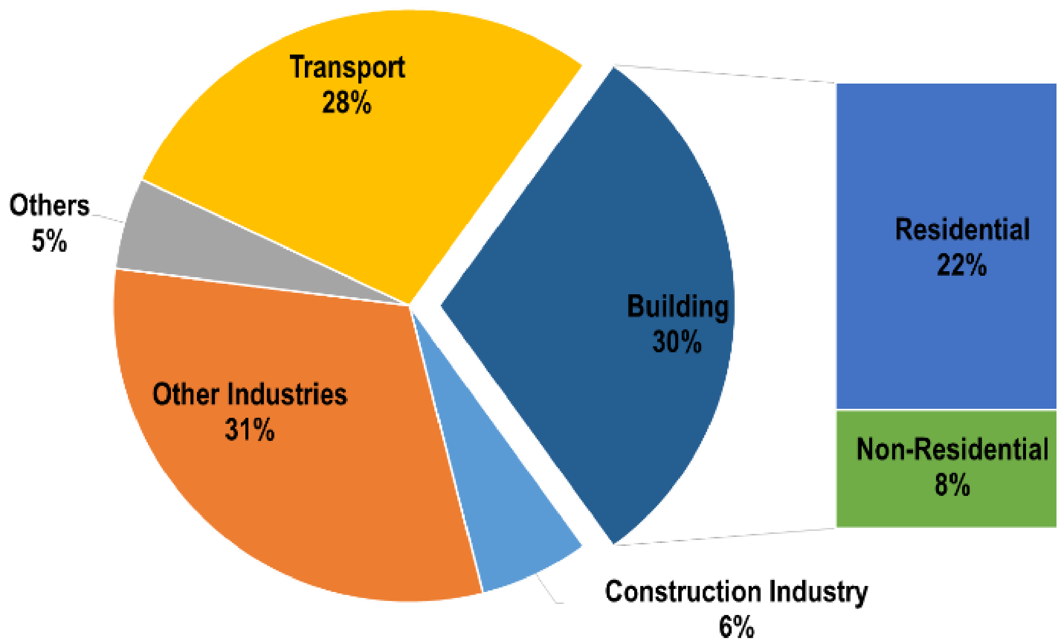

Figure 2. Share of global energy consumption by sector, 2016[1]

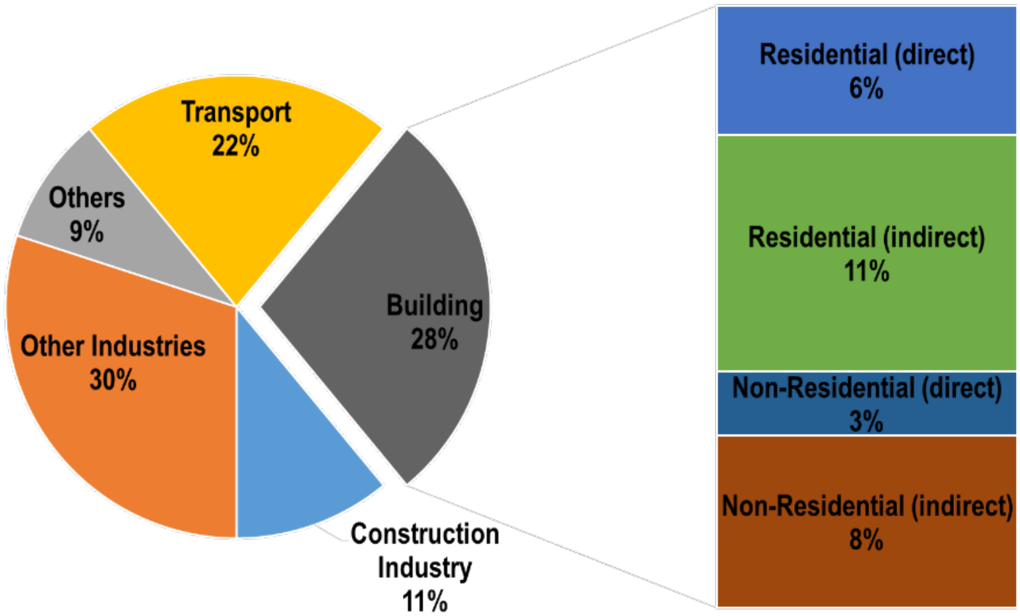

Figure 3. Share of global energy-related CO2 emissions by sector, 2016[2]

Malaysia's commitment to carbon emissions reduction and the role of the building sector

Malaysia's rapid economic transformation from an agriculturally-based economy to an industrialized economy has led to increased carbon emissions. The BP Statistical Review of World Energy (June 2017) reported that Malaysia's carbon emission was a total of 263.80 million tonnes for 2016, an increase of 340 percent from 1990 levels. Rapid economic transformation has prompted massive new construction projects, contributing to a trend of increasing annual energy consumption and carbon emissions as illustrated in Figure 4. At 16 percent of the total, the Malaysian construction industry is the third largest contributor to the country's carbon emissions, behind industry and transportation. Residential and commercial buildings together consume 15 percent of total energy, and are key contributors to the industry's carbon emissions (CIDB, 2015). The sector's extensive linkages to other industries have indirectly contributed to carbon emissions in those other industries.

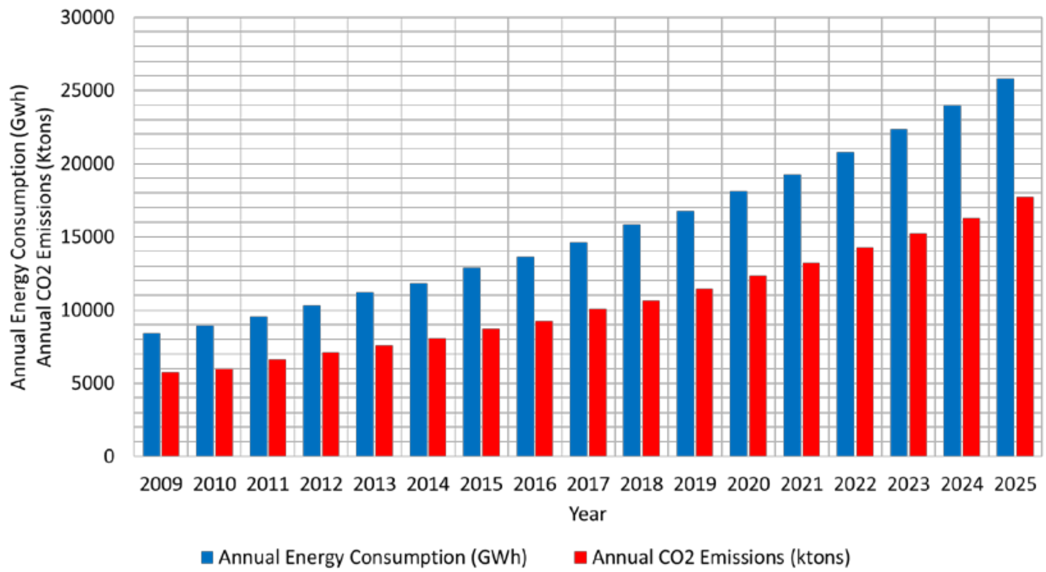

Figure 4. Forecast of annual energy consumption & CO2 emissions, Malaysian building sector[3]

In light of the above, the building sector has been identified as one of the key areas in various development plans and policies for carbon reduction strategies and low carbon growth, including the National Green Technology Policy (2009), the 10th and 11th Malaysia Plans, and the Green Technology Master Plan (2017). In fact, however, the effort goes back a half-decade earlier. Malaysia began its initiatives to reduce the impact of buildings on the environment in 2004, by promoting energy-efficient structures that have popularly come to be known as “green” (or sustainable) buildings. Demonstration building projects embarked upon by the government include the Low Energy Office (LEO) building belonging to the Ministry of Energy, Green Technology, and Water; the Green Energy Office (GEO) building of the Malaysian Green Technology Corporation; and the Diamond Building by the Energy Commission—developed in 2004, 2007, and 2010, respectively. It is now well understood that green buildings have a lower carbon emission intensity (Siva, 2017).

Green building rating tools

The need to assess the performance of green buildings has led to the development of green-building rating tools, used to define and promote the adoption of sustainable and environmentally efficient practices throughout a building’s life cycle. These tools are country-specific and are designed by a variety of different institutions, reflecting their different purposes, approaches, and fields of applicability.

A global overview of green building rating tools

Well-established green-building rating tools include the Building Research Establishment's Environmental Assessment Method (BREEAM) in the United Kingdom, the Leadership in Energy & Environmental Design (LEED) program in the United States, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, the Building Environmental Assessment Method (HK – BEAM) in Hong Kong, and the Green Star initiative in Australia. As noted, these tools use various methods to assess the "green" potential or performance of a building in relation to sustainability criteria—usually including site management, energy efficiency, indoor environment quality, water efficiency, materials and resources, and other environmental protection and green features (Bernardi et al, 2017). Studies undertaken to review established rating tools have suggested that, while different in many of their details, these tools are rather similar in terms of their coverage of sustainability criteria, implementation mode, and scoring scales (Ng S.T. & Wong, M.W., 2013; Sebake N., 2014; Bernardi E. et al, 2017).

These tools were part of voluntary systems when they were first introduced. However, policy-makers' increasing awareness of the environmental impact of buildings has gradually turned the adoption of rating tools compulsory for new buildings in several countries. BREEAM, for example, has made its assessment method mandatory, after a review of the program in 2008 (Ng,S.T. & Wong, M.W., 2013). LEED version 3 has also been made mandatory in for many proposed buildings in the United States (Stancich, 2009). Green Mark has also been made compulsory for newly constructed buildings in Singapore, and likewise, the Hong Kong government is advocating to make energy efficiency compulsory for government buildings (Ng, S.T. & Wong, M.W., 2013).

The above-cited rating tools place primary emphasis on operational carbon emissions, which account for most of the carbon emissions in a building's life cycle. In order to maximize carbon reduction, however, life cycle analysis (LCA) has been increasingly integrated into the rating tools (Collinge, 2015). This mainly relates to the embodied carbon that is associated with raw materials extraction, procurement, manufacturing, transportation, construction, and decommissioning. The latest international version of BREEAM, for example, awards points for calculating and reducing embodied carbon emissions. LEED version 4 has included Building Life Cycle Impact Reduction as a new credit. Green Star assessment tools have also recognized embodied carbon measurement and its mitigation as part of minimizing building life-cycle impacts (RICS, 2014; S.T. Ng et al, 2013). In summary, there has been evolution in the sustainability indicators of rating tools. This should not be surprising: Sustainability is an area of rapid change, and building rating tools must adapt to meet the dynamic and emerging needs of stakeholders (Poveda, 2015).

Green building rating tools in Malaysia

The development of green-building rating tools in Malaysia started in 2009 when the Green Building Index (GBI) was established by the Institution of Architects Malaysia and the Association of Civil Engineers Malaysia. Other rating tools that have evolved alongside GBI are the *Skim Penilaian Penarafan Hijau JKR,* or the JKR Green Ratings Assessment Scheme (pH JKR), developed by the Public Works Department in 2012, and Green Real Estate (GreenRE) by the Real Estate and Housing Developers' Association, in 2013. GBI and GreenRE were promulgated by the private sector, while pH JKR is government-driven. These rating tools are not related to regulatory obligations and therefore their adoption to evaluate the environmental impacts of buildings is voluntary. They are criteria-based, whereby the green performance of buildings is assessed based on a set of sustainability criteria, including site management, energy efficiency, indoor environmental quality, water efficiency, materials and resources, and other environmental protection and green features. The tools include scoring scales based on the level of criteria met, and green building ratings are based on the scores attained.

Although energy efficiency is the main focus of these rating tools, meeting this criterion is not compulsory. In fact, the absence of any compulsory criteria enables the design team to decide which criteria to include in order to meet the minimum points for green building certification. In other words, a building can be certified as green without assessing its carbon-reduction performance. And while the adoption of these guidelines at the design and construction stages can promote sustainable building design and construction practices, that is often as far as their influence extends. For example, the building's performance during the operational stage is not assessed—despite studies suggesting that the operational stage consumes the most energy, and contributes to the highest proportion of carbon emissions from buildings (X. Zhao, Pan, & Lu, 2016).

In short, these tools do not appropriately analyze a building's impact to the environment over its life cycle. A more holistic approach in evaluating and reducing carbon emissions is therefore needed, if buildings are to maximize their potentials in contributing to national carbon reduction targets.

MyCREST: The Malaysian Carbon Reduction and Environmental Sustainability Tool

The Ministry of Works recognized this need. In 2015, therefore, the Ministry released the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST)—the result of a collaboration between the Ministry and the Construction Industry Development Board. MyCREST is a building rating tool that aims to evaluate and promote the reduction of carbon emissions throughout the design, construction, operation, and maintenance stages of a building life cycle, awarding one- to five-star ratings based on sustainability criteria and carbon reduction goals that are met. To understand how the sustainability criteria in MyCREST can contribute to reducing carbon emissions from buildings, a comparative analysis of sustainability criteria between MyCREST and the different rating tools was undertaken.

Although, as noted above, the purpose of green building rating tools is to measure the environmental performance of buildings, different tools emphasize different aspects of sustainability. Table 1 summarizes a comparative analysis of sustainability criteria considered in GBI, pH JKR, Green RE, and MyCREST. The checkmarks in Table 1 indicate the sustainability criteria that are assessed by the various rating tools, and the percentages represent the percentage distribution of points for each sustainability criterion. The percentage distribution, in other words, reflects the relative importance of the respective sustainability criteria.

Energy efficiency, indoor environment quality, and water efficiency are included in all four rating tools—similarities that reflect local environmental conditions and sustainability issues. The percentage distribution of points show that all the tools place the most emphasis on energy efficiency or energy performance, indicating that energy efficiency is a major sustainability criterion in rating green buildings. Although this is in line with previous studies where energy efficiency is determined as one of the most important criteria influencing low carbon buildings (Ng et al, 2013), this indicates that assessment of green buildings by GBI, pH JKR, and Green RE mainly relate to the operational stage of buildings. The only criterion that has relevance to the other life cycle stages of a building is materials and resources, which considers incorporation of recycled and reused sustainable materials.

On the other hand, as the only rating tool designed to cover the entire building life cycle, MyCREST considers more sustainability criteria from pre-design through demolition and disposal factors (as shown in Table 1). MyCREST has also put considerable emphasis on embodied carbon emissions that include the assessment of material selection, reuse and recycling, industrialized building systems, and life-cycle analysis. MyCREST's sustainability criteria also include pre-design, social and cultural sustainability, and demolition and disposal factors.

The intensity of the sustainability criteria in MyCREST is vital to the accurate assessment of green buildings and their respective carbon reduction performance. In subsequent sections, this study considers how MyCREST contributes to reducing carbon emissions from buildings.

Sustainability Criteria	**GBI**	**pH JKR**	**Green RE**	**MyCREST**
Energy Efficiency	√ (35%)	√ (37%)	√ (60%)	√ (48.5%)
Indoor Environmental Quality	√ (21%)	√ (22%)	√ (5%)	√ (2.9%)
Sustainable Site Planning & Management	√ (16%)	√ (20%)	-	-
Materials & Resources	√ (11%)	√ (7%)	-	-
Water Efficiency	√ (10%)	√ (10%)	√ (9%)	√ (5.9%)
Innovation	√ (7%)	√ (5%)	-	√ (bonus)
Environmental Protection	-	-	√ (20%)	-
Other Green Features	-	-	√ (4%)	-
Carbon Emission of Development	-	-	√ (2%)	-
Pre-design	-	-	-	√ (4.4%)
Infrastructure & Sequestration	-	-	-	√ (20.6%)
Lowering Embodied Carbon	-	-	-	√ (11.8%)
Social & Cultural Sustainability	-	-	-	√ (3.7%)
Demolition & Disposal Factors	-	-	-	√ (2.2%)

Sustainability Criteria	GBI	pH JKR	Green RE	MyCREST
Total	100%	100%	100%	100%

Table 1. Sustainability criteria included in Malaysia's green building rating tools

Data and methods

The researcher used a qualitative approach that combined document analysis and case study. The study began with a comprehensive review of MyCREST, and a comparative analysis of different rating tools used in Malaysia in order to understand how the criteria in MyCREST can provide a basis for carbon reduction performance in buildings. To explore the challenges inherent in implementing MyCREST effectively, a case study of government projects adopting MyCREST was undertaken. While MyCREST can be adopted for different types of new and existing air-conditioned and non-air-conditioned buildings, this study focuses on new air-conditioned government office buildings that have adopted MyCREST. Within the context of this study, the buildings under the case study are termed as "business as usual" buildings, as no extra resources were allocated for the adoption of MyCREST. This type of facility not only constitutes the highest proportion of government buildings registered for the adoption of MyCREST, but currently they are the only buildings that have embraced the government's requirement for the adoption of MyCREST. Since these projects are at the design stage, this study focuses on the adoption of MyCREST at that (early) stage.

Eight semi-structured interviews were conducted with personnel from the Public Works Department (PWD), comprising members of the project team and a MyCREST-qualified professional responsible for facilitating the adoption of MyCREST. Their approach in addressing the criteria and sub-criteria in MyCREST at the design stage was documented, revealing some of. the challenges inherent in embracing MyCREST. In addition, thirteen other semi-structured interviews were conducted with relevant industry practitioners, in an effort to derive further insights on the potentials and challenges in the adoption of MyCREST. Table 2 shows the breakdown of the interviewees.

The interviews were audio-recorded and transcribed. Descriptive analysis was used to convey the findings from the document analysis of MyCREST and the interview transcripts. These were categorized into various themes where findings were derived. In accordance with the aims of the study, the findings are presented and discussed in two sections: carbon-reduction potentials of MyCREST, and the adoption challenges of MyCREST.

Interviewee Roles and Organizations	**No**
Architects – PWD	2
Engineers – PWD	2
Quantity Surveyors – PWD	2
MyCREST facilitators – PWD	2
Deputy General Director - PWD	1
Personnel from Construction Industry Development Board Malaysia	3
Personnel from Sustainable Energy Development Authority Malaysia	1
Researcher/ Academician	2
MyCREST development team	2
Green building consultant	1
Personnel from Malaysian Green Technology Corporation	1
Personnel from the Economic Planning Unit	1
Contractor	1
Total	**21**

Table 2. Interviewees by role and organization

Carbon reduction potentials of MyCREST

The findings for carbon-reduction potential comprise three themes: the coverage of sustainability criteria, the extent of current adoption, and carbon reduction performance. The key findings are summarized in Table 3.

Theme	Key Findings
Coverage of sustainability criteria	The extensive coverage of sustainability criteria in MyCREST across the different stages of a building life cycle, and the linking of these criteria to carbon emission impacts—as well as the integration of various planning requirements, code of practices and carbon calculators into the sustainability criteria—have provided a more holistic and comprehensive basis for the building design team to identify opportunities and strategies for carbon-reduction potentials.
Extent of current adoption	The criteria in MyCREST that have been mainly addressed include energy performance impacts, occupant health, infrastructure and sequestration, and water efficiency factors. This reflects that the adoption of MyCREST has mainly focused on potential operational carbon emissions.
Carbon reduction performance	For "business as usual" new government buildings, a potential to reduce 44.82 kgCO2/m^2/year—or a 27% reduction from the baseline—can be achieved by the adoption of MyCREST. This is from operational carbon impacts. Evaluation for embodied carbon, which as noted constitutes a significant part of a building's life cycle carbon emissions, still remains a relatively untouched potential within MyCREST.

Table 3. Key findings: Carbon-reduction potentials of MyCREST

Coverage of sustainability criteria

MyCREST evaluates the performance of a building from the pre-design stage through to construction, operation, maintenance, demolition, and disposal. Figure 5 illustrates the coverage of sustainability criteria in MyCREST along the different stages of the building life cycle. As explained above, this study focuses on the design stage, which is important, because decisions made at the design stage will influence emission performance throughout the construction, operation, and disposal stages of the building's life cycle.

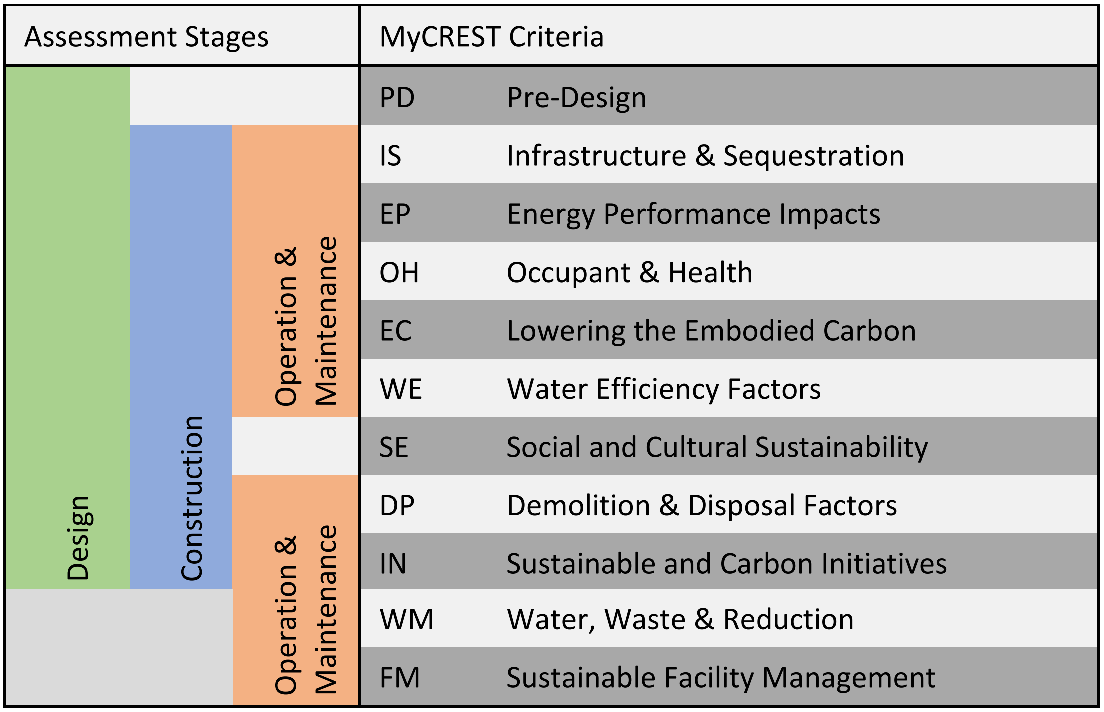

Figure 5. Distribution of MyCREST criteria across life cycle stages

As shown in Table 1, MyCREST considers nine main sustainability criteria in the design stage. With each main criterion, there are 56 sub-criteria or indicators. The sub-criteria are either compulsory prerequisites—identified as "required"—or non-compulsory sub-criteria assigned with a weighting. Each sub-criterion is also assigned to a carbon-related impact, consisting of either *carbon reduction*, *carbon impact,* or *sustainable*, indicating which sub-criteria are directly or indirectly related to carbon emission performance. *Carbon reduction*, as its name implies, directly relates to carbon reduction, and requires carbon emission calculations; *carbon impact* indirectly relates to carbon reduction and is not calculated; while *sustainable* does not relate to carbon reduction but has impact on other sustainability issues. These sustainability indicators of MyCREST are summarized in Table 4. For example, Table 4 shows that the energy performance impacts (EP) criterion has 16 sub-criteria, of which 5 are compulsory and 11 are non-compulsory. Within these sub-criteria, 13 are assigned to have carbon reduction impacts that require carbon emissions to be determined using carbon calculators that are integrated in MyCREST. The detailed tabulations for Table 4 are included in the appendix.

Carbon calculators, planning requirements, and Codes of Practices are also integrated into MyCREST, requiring carbon emissions evaluation to be conducted at the different stages of a building life cycle. A member of the MyCREST development team explains:

"*The aim of MyCREST is to calculate the type of carbon emitted in a building which comprises of 2 sub-items, referring to operational carbon and embodied carbon; we are also referring to strategies on how to* reduce *carbon in a building from the design, construction, operational, and maintenance stages.*"

Hence, the linking of sustainability criteria to carbon emissions impact criteria, the integration of the various planning and construction codes of practices, standards and guidelines, and the inclusion of carbon calculators in MyCREST help the PWD design team to identify opportunities and strategies for carbon reduction in the design stage.

Criteria	**Compulsory sub-criteria**	**Non-compulsory sub-criteria**	**Carbon related impacts**		
			Carbon reduction	**Carbon impact**	**Sustain-able**
Pre-design		PD1, PD2, PD3, PD4, PD5, PD6		PD1	
Infrastructure and sequestration	IS-Req1, IS-Req2	IS1, IS2, IS3, IS4, IS5, IS6, IS7	IS-Req1, IS-Req2, IS2, IS4, IS6	IS1, IS3, IS5	
Energy performance impacts	EP-Req1, EP-Req2, EP-Req3, EP-Req4, Ep-Req5	EP1, EP2, EP3, EP4, EP5, EP6, EP7, EP8, EP9, EP10, EP11	EP-Req1, EP-Req2, EP-Req3, EP1, EP2, EP3, EP4, EP6, EP7, EP8, EP9, EP10, EP11	Ep-Req4. EP-Req5, EP5	
Occupant & health	OC-Req1, OC-Req2	OC1, OC2, OC3		OC3	OC-Req1, OC-Req2, OC1, OC2
Lowering the embodied	EC-Req1	EC1, EC2, EC3, EC4,	EC5, EC6	EC-Req1, EC1, EC2,	

Criteria	Compulsory sub-criteria	Non-compulsory sub-criteria	Carbon related impacts		
			Carbon reduction	Carbon impact	Sustain-able
carbon		EC5, EC6		EC3, EC4	
Water efficiency factors	WE-Req1	WE1, WE2, WE3, WE4	WE-Req1, WE1	WE2, WE3, WE4	
Social & cultural sustainability		SC1, SC2, SC3, SC4			SC1, SC2, SC3, SC4
Demolition & disposal factors		DP1, DP2, DP3		DP1, DP2, DP3	
Sustainable & carbon initiatives		Bonus			
Note: The codes for the sub-criteria are elaborated upon in the appendix					

Table 4. MyCREST sustainability criteria for the design stage

Extent of current adoption

The extent of current MyCREST adoption for government buildings within the case study is reflected by the targeted percentage scores for each individual criterion, as indicated in Figure 6. It is observed from the case study that the criteria in MyCREST that have been mainly addressed include energy performance impacts, occupant and health, infrastructure and sequestration, as well as water efficiency factors. These criteria contribute to the measurement of energy consumption during the operational stage, leading to operational carbon emissions. On the other hand, life-cycle analysis—which is the main sub-criteria under the lowering-the-embodied-carbon criterion—as well as the demolition and disposal factors criterion, have not been addressed. These criteria mainly relate to embodied carbon, reflecting the relatively low consideration overall for embodied carbon impacts. The reasons for these relative emphases are revealed by a member of the PWD design team:

“The requirements for these (Energy Performance Impacts, Occupant and Health, Infrastructure and Sequestration sub criteria) are the same as the local authorities’ requirements, building standards and

guidelines that are adopted by PWD and these are our normal practices. That is why we can score points on these criteria. Although these are our normal practices, yes! MyCREST has provided a mechanism and guidelines for the project team to work in a more systematic manner in producing green building design."

As the interviewee further pointed out:

"The score for Lowering Embodied Carbon criteria is achieved through the Industrial Building System (IBS) sub-criteria. This is a mandatory requirement: for all government projects to include at least 70 percent IBS components. We don't do life cycle analysis [which is the main sub-criteria under the Lowering Embodied Carbon criterion] or Demolition and Disposal Factors. We don't have the resources and expertise, and it is not a requirement for us to do."

Hence, the case study reveals that the current implementations of MyCREST mainly focus on the operational stages of the building life cycle, event though MyCREST provides a comprehensive basis for considering both operational and embodied carbon impacts.

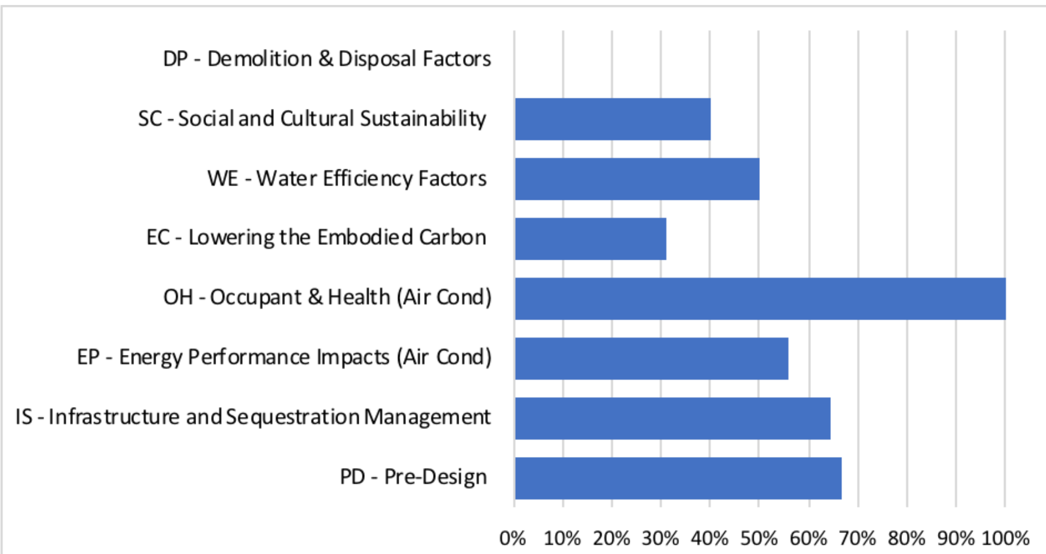

Figure 6. Targeted percentage scores for MyCREST indicators, reflecting the extent of adoption of MyCREST

Carbon reduction performance

The requirements for energy savings and carbon emissions calculations in MyCREST have provided the basis for gauging carbon-reduction potentials from buildings. Energy savings for buildings in the case study are derived from the estimated Building Energy Index (BEI), which is the total energy consumption per meter square of floor area per year (kWh/m²/year). Total energy consumption is defined as total energy of electricity consumed by the building in kWh (kilowatt hours) per annum. The PWD design team has calculated a BEI of 160 for the government office buildings in the case study, whereas the average BEI for office buildings in Malaysia is between 200 and 300kWh/m²/year. The design team adopts a BEI of 220kWh/m²/year as its baseline. Hence, there is an energy savings of 27 percent [(220 – 160)/220 x 100%] for the buildings in the case study that have adopted MyCREST.

Carbon emission intensity—the amount of carbon in terms of weight emitted per unit of energy consumed—for the buildings is calculated by multiplying the buildings' BEI by the carbon emission factor. The carbon emission factor adopted by MyCREST is 0.747kgCO2/kWh, based on the Building Common Carbon metric published by the Malaysian Green Technology Corporation. Using this multiplier, the baseline carbon emission intensity for government office buildings is 164.34kgCO2/m²/year (220 x 0.747) and for the buildings in the case study is 119.52kgCO2/m²/year (160 x 0.747). The potential carbon reduction, therefore, is 44.82 kgCO2/m²/year (164.34 – 119.52), or a 27 percent reduction from the baseline. Based on the case study, the potential carbon reduction for an office building with a floor area of 4,000m² will be 179,280kgCO2/year, or 0.179248ktCO2/year. Thus, additional measures will be required to achieve the targeted total carbon emissions reduction of 98.2ktCO2 from government buildings by 2020, as envisaged in the Malaysia Green Technology Master Plan (2017) developed by the Ministry of Energy, Green Technology and Water.

The carbon-reduction potential cited above is based solely on operational carbon emissions. If both operational and embodied carbon impacts were considered, potential carbon reduction would be even higher. A more energy efficient building with a lower BEI will also contribute to greater carbon-reduction potential. A building with a BEI of 80 will yield a potential carbon reduction of 104.58kgCO2/m²/year [164.34 - (80 x 0.747)] or 63 percent reduction from the baseline. Again, emissions from material production, transportation to site, construction, maintenance, and demolition stages have not been addressed, and therefore remain only a potential benefit of MyCREST.

Adoption challenges of MyCREST

Most interviewees agreed that MyCREST has provided a useful mechanism for the project team to work in a more systematic manner in developing a green building design within various resource constraints. However, there are limitations in the extent to which the adoption of MyCREST has helped to evaluate and reduce potential carbon emissions from buildings. These challenges can be categorized into three themes: lack of enforcement mechanisms, capacity constraints to enhance the potential of MyCREST, and lack of industry-wide awareness. The key findings on the adoption challenges of MyCREST are summarized in Table 5.

Theme	**Key Findings**
Lack of enforcement mechanism	Lack of regulatory provisions on the adoption of MyCREST for government projects. Inconsistencies in implementing the requirement to adopt MyCREST amongst the government ministries and departments. Lack of resource allocation for adopting MyCREST in government projects. Inconsistencies in addressing current carbon reduction initiatives that have been integrated into the sustainability criteria in MyCREST. Unclear roles of the various government agencies and private organizations relating to various aspects of green buildings and carbon reduction targets.

Theme	**Key Findings**
Capacity constraints to enhance the potential of MyCREST	Level of potential carbon reduction from the adoption of MyCREST is influenced by the design approach and technology adopted, availability of resources, and expertise. Budget constraints have impacted the ability to adopt active mechanical systems and advanced technology in addressing the sustainability criteria in MyCREST. Lack of openly available and transparent data, such as those pertaining to specific green material standards, green building cost data, and carbon emission baselines that could be used as a basis for decision making by the design team. Unavailability of data and expertise for deriving life cycle carbon emissions.
Lack of industry-wide awareness	Lack of common vision relating to carbon reduction initiatives and the adoption of MyCREST amongst stakeholders. Gap in the awareness and understanding of the requirement for project teams to adopt MyCREST. Insufficient knowledge-sharing and comparative information on establishing green buildings with the adoption of MyCREST.

Table 5. Key findings: Adoption challenges of MyCREST

Lack of enforcement mechanism

Study data indicate that the lack of enforcement mechanisms centers on two aspects: lack of regulations requiring the adoption of MyCREST, and inconsistencies in enforcing existing regulations. Interviewees have raised concerns that despite requirements for the adoption of MyCREST for projects implemented by PWD, there is no regulatory obligation to do so. This has given rise to inconsistency in carrying out the requirements for adopting MyCREST for government buildings. A member of one project team adopting MyCREST raised the following concern:

"*Although there is directive from the Director General of PWD for all government projects implemented by PWD to adopt MyCREST, there is* *no legal provision for this. Because of this, the ministries and government departments (who are clients to PWD) have not considered the requirements of MyCREST in their project brief and project estimates. The requirements of MyCREST are only considered when the proposed projects are handed over to PWD for implementation. Within such constraints, the project team at PWD is not able to fulfil all the requirements of MyCREST. Our approach is not to incur extra cost, as we cannot exceed the initial estimates.*"

The government plans to make it mandatory for all government projects to adopt MyCREST by 2020 through the "government to lead" policy, whereby the government aspires to increase the number of certified green government buildings. In line with this, Malaysia has set a target of 550 green buildings by 2020 and 1750 by 2030 (GTMP, 2017). As of December 2017, there were about 442 private sector buildings certified by a green building rating tool in Malaysia. Based on data published by CIDB on the total number of projects, this constitutes less than 2 percent of total buildings nationally. Previous studies have suggested that the role of government in promoting green building is undeniable and effective (Samari et al, 2013). However, without any form of regulatory push factors in place, there is a tendency for adoption of MyCREST for government projects to remain voluntary. Increasing the number of certified green government buildings through the voluntary adoption of MyCREST will not be easy.

Although the government has taken initiatives to develop low-emission, energy efficient buildings, the emphasis to date has been on major government administrative buildings that are considered exemplary. These buildings were given sufficient funding to achieve the pre-determined green building certification. The interviewees felt that other government buildings should also get access to resources and additional financial support for adopting MyCREST, in particular, and for generally incorporating sustainability criteria towards supporting carbon reduction targets. A government official involved with the development of green government buildings raised a related concern:

"*Those so-called exemplary buildings cannot be used as the basis or guidelines for other government buildings, as they were given extra budget to achieve the pre-determined green building certification from MyCREST or others; whereas other normal government projects were not allocated with such extra budget. It is better for the budget to be distributed to more buildings so that more buildings can get at least a minimum green certification for the start than just focus on one or two buildings with high certification level.*"

It seems clear that a regulatory obligation is needed to ensure the adoption of MyCREST by all government projects. In addition, proper planning needs to be established to strategize and prioritize resources pertaining to the development of green government buildings.

Energy performance impacts have been given the greatest focus in MyCREST, as energy efficiency has been the focus for low carbon building designs. The requirements of the "Malaysian Standard, MS 1525: Code of Practice on energy efficiency and use of renewable energy for non-residential buildings" are incorporated into MyCREST as a compulsory criterion. MS 1525 provides recommended measures, and prescribes energy performance standards for the different elements of buildings, such as maximum permissible rates for heat transfer through the building fabric and maximum lighting power densities; and requires the calculation for overall thermal transfer value (OTTV), roof thermal transfer value (RTTV) and energy management system. Although it is a compulsory criterion in MyCREST, it has not been fully addressed because it is not a mandatory submission requirement for securing development approval. As was noted by a senior official from PWD:

"*I don't think anyone has done the calculation yet because it is not a mandatory submission requirement; OTTV is not part of the planning approval submission. Once they make it mandatory, gazetted by all states and all Local Authorities, then for Development Order to be approved, need to submit the calculation. Now, only 3 states that agree to the principle.*"

The same inconsistency is observed for rainwater harvesting: although it is a requirement in MyCREST to reduce potable water consumption by 10 percent, only eight Malaysian states have made it mandatory for new building projects to install rainwater harvesting systems. Such inconsistencies reflect a lack in enforcement mechanisms, again limiting the potential of MyCREST.

Another challenge related to enforcement mechanisms and highlighted by the interviewees is the lack of coordination among various government agencies and private organizations with different motivations, tasks, and responsibilities for green-building development and reducing carbon emissions from buildings. This can distract from the pursuit of green-building goals and hamper potential emission reductions. A member of a project team involved in adopting MyCREST reflected on the absence of a single agency responsible for data services:

"*We need information—for example, the availability of re-cycled materials, or other sustainable materials—that we can use for our projects, or cost analysis that we can refer relating to the cost of green materials or products, also data relating to carbon reduction from buildings. As for now, we don't know who collects and manage all this information. There seem to be many bodies involved relating to green buildings, green products, energy efficiency such as CIDB, SEDA, MGTC, SIRIM, KETTHA and* *others—but when we ask them for the information we need, they cannot provide it.*"

Although MyCREST is a requirement for government projects implemented by PWD costing more than RM50 million, the lack of a reliable and accessible data source that can be used as a basis for decision making by the design team hampers its enforcement, and contributes to low motivation—particularly among the design team and contractors—in developing new energy efficient low carbon buildings. Clearly, data pertaining to green buildings and carbon-reduction potentials need to be developed, standardized, and shared.

Capacity constraints to realizing the potential of MyCREST

The study revealed that the degree of potential carbon reduction from the adoption of MyCREST is influenced by the design approach and the technology adopted, as well as the availability of resources and expertise. For "business as usual" new government buildings, the mandatory adoption of MyCREST for government office buildings has contributed to approximately a 27 percent potential carbon reduction. This was achieved by the passive design approach—where the design uses natural elements, often sunlight, to cool, heat or light the building—that was adopted by the design team, as explained by a PWD representative:

"*The Energy Performance Impacts criteria were mainly addressed by the passive design approach, as there was no extra funding for adopting advanced mechanical systems, high performance materials. or renewable energy. This allows only a targeted BEI of of 160. It's unlike the MyCREST exemplary project, which is the new head office for the Ministry of Works Malaysia, where the extra funding available has enabled the installation of photovoltaic solar panels that cover 2.5 percent of the energy required, rainwater harvesting system, filtration system for greywater recycling, triple glazed energy efficient glass for the building envelope, and other high-performance materials and systems that have contributed to a BEI of 80.*"

Thus, enhancing MyCrest's potential to improve carbon reduction performance in buildings will incur extra costs related to adoption of active mechanical systems, advanced technology, materials and expertise. A senior PWD official pointed out:

"*Whether you like it or not, when I say I want 5-star rating, [there is] extra cost involved. So the designers and the clients are more concerned on how much money they have. To get more carbon reduction it will cost more. For example, to achieve the 5-star rating for the Ministry of Works* *new headquarters building cost an additional 10 to 15 percent more than the average 3-star rating.*"

Despite efforts undertaken to develop a comprehensive tool such as MyCREST, adoption has not gone beyond helping to evaluate potential operational carbon impacts, mainly focused on the operational stage. Evaluation of building life cycle carbon emissions, mainly characterized by embodied carbon (emissions from material production, transportation to site, construction, maintenance and demolition stages) still remains a relatively large untapped area of potential for MyCREST. Most interviewees are of the opinion that a lack of relevant knowledge, expertise and information from various sources; the unavailability of an established standard method; and uncertainties over the future of the buildings have hampered the evaluation of life cycle analysis for reduction of carbon emissions.

Studies have indicated that as buildings are constructed to higher energy efficiency standards that use less energy to operate, a greater proportion of the building's life cycle carbon emissions has shifted from operational carbon emissions to embodied carbon emissions (Wheating, 2017; Zhao, X., & Pan, W., 2015). Other well-established rating tools such as BREEAM and LEED have recognised embodied carbon measurement and its mitigation as part of minimizing building life-cycle carbon impacts (Wheating, 2017). Hence, the growing awareness and importance of embodied carbon in contributing to carbon reduction targets may require life cycle analysis to be included as a requirement for assessment in the planning process. It has been successfully implemented in some municipal and local councils such as the Brighton and Hove City Council in the UK (RICS, 2014).

Lack of industry-wide awareness

The study also revealed a lack of common vision among the stakeholders—such as the ministries and government departments initiating new building projects, the Economic Planning Unit in the Prime Minister's Office, and PWD—pertaining to the adoption of MyCREST. The clients who prepare the project brief and cost estimates have not considered the requirements to adopt MyCREST. Likewise, the Economic Planning Unit responsible for approving and allocating the budget for the projects have not required the inclusion of estimates for addressing the requirements of MyCREST into the proposed budget. As an officer who handles building projects with one of the ministries points out:

"*At our level we have not specifically considered the requirement to adopt MyCREST. Is it mandatory? With the current budget constraints, we* *are more concerned about how to get the budget approved for the building. We want to fulfil the basic functional requirements of the building. Yes, we understand that it is important to reduce carbon and provide energy efficient buildings, but we do not have enough budget. If we can get extra budget then we can consider.*"

One green building consultant observed that there are designers and project team members who are not aware of carbon reduction targets. They tend to merely regard the rating tool as an examination, of sorts, and are motivated by the need to "score" points, rather than by any concern over environmental impact; further reflecting the awareness and knowledge gap. Most interviewees felt that the absence of a clear vision and direction on the requirement to adopt MyCREST and the broader context of carbon reduction targets have led to the gaps in awareness and knowledge. Key issues pertaining to the adoption of MyCREST—and the development of low carbon, energy efficient buildings in general—needs to be clearly defined, as this will help determine what measures need to be taken by all parties involved in a building project.

Policy prescriptions

This study reveals that despite providing a comprehensive basis for carbon reduction in buildings, MyCREST's potential in enhancing carbon reduction performance is negatively impacted by the lack of enforcement mechanisms, inadequate resource capacity, and lack of industry-wide awareness. Based on these key findings, several policy prescriptions (illustrated in Figure 7) are suggested here in order to enhance the potential of MyCREST for contributing to the achievement of overall carbon reduction targets.

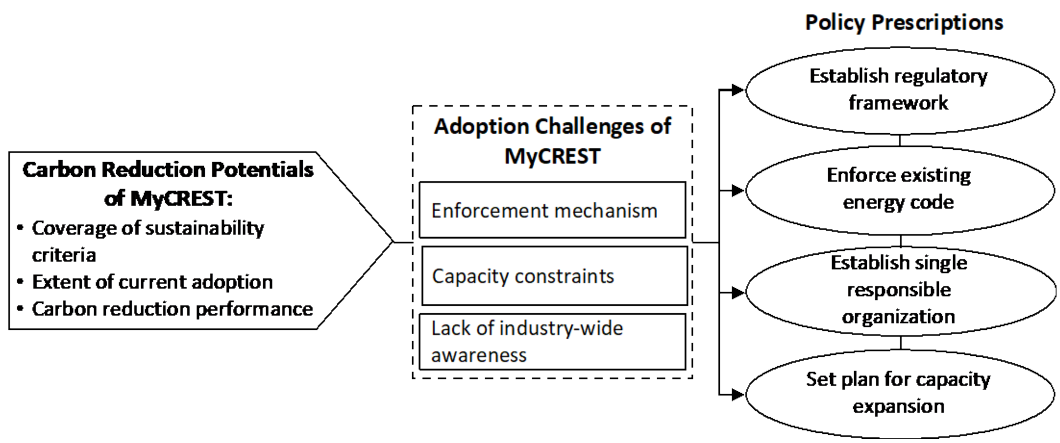

Figure 7. Policy prescriptions for enhancing potential and addressing adoption challenges of MyCREST

1) Establish regulatory framework

National green building goals:

Although the building and construction industry has been identified as a key sector to contribute to carbon reduction targets, national green building goals have not been explicitly set. There are inconsistent carbon reduction targets for the building sector published by different organizations—such as those published in the Construction Industry Transformation Plan by CIDB, which differ from the targets published in the Green Technology Master Plan by KeTTHA. Sound national green building goals and carbon reduction targets need to be put in place to engage stakeholders and governance across all levels, ensuring alignment of objectives and broad commitment to meeting targets. This is vital: stakeholders need to understand carbon reduction targets so that appropriate measures can be taken in executing projects from the pre-design stage through to completion. Clarification of the mandatory requirement to adopt MyCREST for government projects will be an important contributor to meeting green building goals and carbon reduction targets.

Regulations requiring the adoption of MyCREST:

Although the adoption of MyCREST has been made mandatory for government projects implemented by PWD, there have been inconsistencies in carrying out this requirement, as there are as yet no regulatory obligations to do so. This hampers the potential of MyCREST to help in carbon-reduction efforts. In order to help achieve the country's set target of 550 and 1750 green buildings by 2020 and 2030 respectively (as compared to 442 as of December 2017), it is recommended that a clear regulation be promulgated by PWD for the mandatory adoption of MyCREST for government projects. There are clear and compelling precedents for such an approach. Singapore's mandatory adoption of Green Mark for new buildings, for example, has contributed to an increase in green buildings from 17 in 2005 to 1,700 in 2013 (BCA, 2013). Similarly, a study undertaken to compare the impact between mandatory and voluntary adoption of building rating tools on the environmentindicated that mandatory schemes can yield greater environmental impacts than voluntary schemes with incentives, as long as there is no significant political obstruction (Ho, DCW, 2013).

Engagement of clients and stakeholders:

Currently, mandatory adoption of MyCREST is only applicable within the jurisdiction of PWD. Otherwise, MyCREST requirements have not been taken into consideration at the critical pre-design stage, where clients develop project briefs and project estimates. Including clients within the regulatory obligations for the mandatory adoption of MyCREST will help those clients understand the expectations inherent in MyCREST. Without this understanding, clients will not be motivated to meet the requirements specified by the tool. Previous studies have also pointed out that for successful carbon reduction within a project, clients need to properly understand the expectations involved (Wheating, 2017). The engagement of a broader case of clients in MyCREST ultimately will help push the public sector to adopt it.

2) Enforce existing energy code of practice

The Code of Practice on Energy Efficiency and Use of Renewable Energy for non-residential buildings (MS 1525), which sets minimum requirements for energy efficiency, has been integrated into the Energy Performance Impacts criteria of MyCREST. However, except for the three states that have made it mandatory, MS 1525 does not currently include enforcement provisions, and so its implementation is largely on a voluntary basis.

Worldwide, building energy codes play an important role in improving the energy performance of buildings. The Global Alliance for Buildings and Construction has highlighted the critical need to implement and enforce mandatory building energy codes for new construction in developing countries to help address carbon reduction targets (UNEP, 2017). It is thus critical to enforce mandatory implementation of MS 1525 across all states in Malaysia. The shift from voluntary to mandatory adoption will enable consistency across the building sector, while enhancing the potential of MyCREST. This is in line with other established rating tools—such as BREEAM, LEED, CASBEE, BEAM Plus, Green Mark and Green Star—that have implemented mandatory requirement for energy efficiency (S.T. Ng, 2013).

3) Mandate a single responsible organization

Malaysia does not have a single organization that brings together all stakeholders in the building sector to establish green building goals (GTMP, 2017). There is a lack of coordination amongst the organizations with different roles on various aspects of green buildings. Clearly, it would be more effective if one organization were responsible for coordinating the whole ecosystem involved in delivering green buildings. Currently, it is CIDB's role to manage the adoption of MyCREST, assess the application for MyCREST, award certifications, conduct MyCREST Qualified Professional trainings, and otherwise encourage and assist with adoption of MyCREST. It would be appropriate to extend CIDB's role, mandating it to bring together all relevant parties from both the public and private sectors to support national green building goals, raise awareness, and facilitate progress towards energy efficient and low carbon buildings.

As is emphasized in the next section, the single responsible organization should also be charged with coordinating and managing the data required to address sustainability criteria—not only in MyCREST, but also in other rating tools.

Data services:

All calculations for potential carbon reduction rely on data—whether carbon factor data for buildings and materials, data on lifecycle impacts to use in carbon calculators in MyCREST, or for benchmarking and comparison purposes. At present, although MyCREST has been made mandatory on a selective basis, there is a lack of accessible and reliable data that can be used as a basis for decision making by the design team. Therefore, it is critical to build an open access data source for delivering green buildings.

The data source should provide information from different lifecycle stages of projects. Hence, a tracking mechanism would be required to track quantified targets of potential carbon reduction in buildings, and capture data of actual carbon reduction performance. Based on the current difficulties in capturing such data, it is recommended that buildings to be rated by MyCREST be required to provide data on energy consumption for at least the first 5 years of their operations. These data can be used as inputs for deriving potential life cycle emissions, as well as provide a robust evidence-based database. Again, there is precedent elsewhere. For example, the LEED program in the United States compiles energy consumption data during the operational stages of buildings, thereby putting transparent data in the public domain for various purposes relating to green building ratings, including verification and monitoring (CSE, 2012). It has been increasingly recognized that without such transparent and open information, the uptake of green measures will be suboptimal (UNEP, 2016).

4) Plan for capacity expansion

The study reveals that the current extent of MyCREST adoption focuses on operational carbon emissions. Realizing the potential of MyCREST beyond operational carbon impacts will require additional resources. Within the current financial constraints for government projects, it will be a challenge to accelerate cost investment in order to expand the capacity within a short time frame. Therefore, a strategic plan is required to prioritise actions within the capacity constraints. Establishing the regulatory framework and enforcing the existing energy code of practice can be an important starting point to increase the adoption of MyCREST.

Once more information on carbon reduction performance at the different stages of the building life cycle is available, it can be used as inputs for calculating life cycle emissions. The life cycle emissions can be connected to life cycle financial analysis. This will lead to increased awareness and improved confidence in financing decisions by the respective authorities. There is increasing evidence that points to the positive links between a building's sustainability and financial performance (UNEP, 2016).

Conclusion

The selective adoption of MyCREST on certain projects has had an important impact on carbon-reduction related decisions made during the design stage for those projects. Its comprehensive sustainability criteria provide a more holistic and comprehensive basis for identifying opportunities and strategies for carbon reduction. However, lack of enforcement mechanisms, resource constraints, and a lack of industry-wide awareness hamper a broader implementation of the tool. A combination of policy prescriptions—including establishing a regulatory framework, enforcing the existing energy code of practice, establishing a mandate for a single responsible organization, and planning for capacity expansion—will help realize the potential of MyCREST. This will further improve carbon reduction performance by buildings, thereby contributing to the achievement of national carbon reduction targets.

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Appendix

Code	Criteria	Sub-criteria/Indicators	Maximum points	Carbon-related impacts		
				Carbon reduction	Carbon impact	Sustain-able
PD	**Pre-Design**					
PD1		Sustainable & carbon reduction target in Needs Statement	1		1	
PD2		Initial target of MyCREST & estimation MyCREST green budget	1			1
PD3		Green Eco Charrette	1			1
PD4		Use of integrated design process	1			1
PD5		Potential environmental impact of development	1			1
PD6		Facilities manager in design team	1			1
Total Scores Allocated for PD			6 (4.4%)		1 (0.7)	5 (3.7%)
IS	**Infrastructure and Sequestration**					
Req1		Site inventory analysis on greenery	Required	√		
Req2		Compliance with landscape requirement from local authorities	Required	√		
IS1		Low carbon city characteristics	6		6	
IS2		Carbon accounting on site	8	8		

Code	**Criteria**	**Sub-criteria/Indicators**	**Maximum points**	**Carbon-related impacts**		
				Carbon reduction	**Carbon impact**	**Sustain-able**
IS3		Environmental Management Plan	1		1	
IS4		Factors in storm water management	3	2	1	
IS5		Low carbon transport factors	5		5	
IS6		Urban heat island mitigation	4	4		
IS7		Control in external light spill & brightness	1			1
Total Scores Allocated for IS			28 (20.6%)	14 (10.3%)	13 (9.6)	1 (0.7%)
EP	**Energy performance impacts**					
Req1		Building envelope performance	Required	√		
Req2		Roof thermal performance	Required	√		
Req3		Building energy efficiency performance	Required	√		
Req4		Fundamental refrigerant management	Required		√	
EP1		Building envelope performance – thermal performance	3	3		
EP2		Decentralization of lighting systems control	2	2		
EP3		Admission of daylight zone & provision of automatic controls	3	3		

Code	**Criteria**	**Sub-criteria/Indicators**	**Maximum points**	**Carbon-related impacts**		
				Carbon reduction	**Carbon impact**	**Sustain-able**
EP4		Artificial lighting: improvement of design lighting power density & LED lighting for 24-hour area & carpark	5	5		
EP5		Individual metering	1		1	
EP6		Provide renewable energy	4	4		
EP7		Energy efficient unitary air-conditioning systems	1	1		
Req5		Main commissioning of building energy systems	Required		√	
EP8		Improved commissioning during design stage	3	3		
EP9		Air penetration	2	2		
EP10		Building energy management systems	1	1		
EP11		Building energy efficiency performance; % of energy savings improvement	40	40		
		Energy reduction from shaded trees	1	1		
Total Scores Allocated for EP			66 (48.5)	65 (47.8%)	1 (0.7%)	
OC	**Occupant & health**					
Req1		Air quality performance	Required			√
Req2		Indoor smoking	Required			√

Code	**Criteria**	**Sub-criteria/Indicators**	**Maximum points**	**Carbon-related impacts**		
				Carbon reduction	**Carbon impact**	**Sustain-able**
		restriction				
OH1		Control & strategies to reduce mould occurrence	1			1
OH2		Indoor air quality pollutants	2			2
OH3		Carbon dioxide level control	1		1	
Total Scores Allocated for OC			4 (2.9%)		1 (0.7%)	3 (2.2%)
EC	**Lowering the embodied carbon**					
Req1		Recycling facility	Required		√	
EC1		Green products; green product scoring system	2		2	
EC2		Sustainably sources materials & products	3		3	
EC3		Industrial building system	3		3	
EC4		Solid waste management: route & recycles	1		1	
EC5		Life cycle analysis: % of carbon emission reduction	6	6		
EC6		Salvaged & reused materials	1	1		
Total Scores Allocated for EC			16 (11.8%)	7 (5.2%)	9 (6.6%)	
WE	**Water efficiency factors**					
Req1		Reduce potable water – 10%	Required	√		

Code	Criteria	Sub-criteria/Indicators	Maximum points	Carbon-related impacts		
				Carbon reduction	Carbon impact	Sustain-able
WE1		Water conservation strategies	2	2		
WE2		Reduced potable water for landscape	2		2	
WE3		Water sub-metering & leak detection	2		2	
WE4		Recycled grey water	2		2	
Total Scores Allocated for WE			8 (5.9%)	2 (1.5%)	6 (4.4%)	
SC	**Social & cultural sustainability**					
SC1		Design for social responsibility	1			1
SC2		Access to views from work areas	1			1
SC3		Compatibility of urban & façade design to cultural values	2			2
SC4		Maintenance of heritage value of existing facilities	1			1
Total Scores Allocated for SC			5 (3.7%)			5 (3.7%)
DP	**Demolition & disposal factors**					
DP1		Responsible sourcing of materials	1		1	
DP2		Design for dis-assembly	1		1	
DP3		Existing structural material reused	1		1	
Total Scores Allocated for DP			3 (2.2%)		3 (2.2%)	
IN	**Sustainable & carbon initiatives**		Bonus			

Code	**Criteria**	**Sub-criteria/Indicators**	**Maximum points**	**Carbon-related impacts**		
				Carbon reduction	**Carbon impact**	**Sustain-able**
			points (max 7)			
Total scores for design stage			136 (100%)	88 (65%)	34 (25%)	14 (10%)

Scoring system for sustainability criteria and carbon-related impacts of MyCREST for building design stage

[1] UNEP, 2017
[2] UNEP, 2017
[3] Kamaruzzaman, S.N., et al., 2016