A GUIDE TO LOW CARBON PRACTICES IN THE MALAYSIAN CONSTRUCTION SECTOR

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Background

In 2018, the UN Intergovernmental Panel on Climate Change (IPCC) noted global average temperature rise is likely to surpass 1.5 degrees Celsius unless carbon emissions fall by 45% by 2030 and become negligible by 2050. Failing to reduce carbon emissions will amplify the effects of climate change; resulting in sea level rise, unpredictable rainfall, extreme weather conditions and reduced biodiversity. For example, in Malaysia, it is estimated sea level rise will displace 2500 people and inundate 450 km^2 of land, every year.

Under the 11th Malaysia Plan, the country has pledged to reduce the country's carbon emissions per GDP by 40% by 2020, relative to 2005. To reach this goal, Malaysia has included a strategic strive towards environmental sustainability in its Construction Industry Transformation Programme (CITP), which aims to ensure 100% of large infrastructure projects exceed sustainability requirements and reduce annual emissions by 4Mt CO2-equivalent by 2020.

With this report, we hope to provide the Construction Industry Development Board (CIDB) information and guidance to bring Malaysia's construction industry closer towards environmental sustainability. This report introduces low-carbon construction materials, with detailed explanations on the usage, limitations, carbon reduction and examples. This report also provides guidance on waste management and amendments to existing regulations and policy to encourage the transition towards a low carbon construction industry.

With a common goal of achieving environmental sustainability, we sincerely believe that this guide will prove useful to stakeholders in the Malaysian construction industry. We wish Malaysia all the best in its endeavours and development towards a leader in low emission construction.

1. Introduction

1.1. Definition of a low carbon industry

A "low carbon (C) industry" is an industry with minimal emissions of carbon-based greenhouse gases, such as carbon dioxide (CO2) and methane (CH4). This report specifically focuses upon the reduction of carbon dioxide from the construction industry.

1.2. Current state of affairs: carbon emissions in the Malaysian construction industry

The first step to solving the problem is to understand it. This section will give a brief insight into explaining what is the construction industry, its position in Malaysia, and how it is contributing to the nation's carbon footprint.

1.3. Malaysian construction Sector

The "construction sector" is defined as the sector of national economy engaged in preparation of land and construction, alteration, and repair of buildings, structures and other real properties. The construction sector is an important component of the Malaysian economy, contributing consistently to the nation's GDP. In 2017, it contributed 5.9% to the GDP and it has maintained that rate for the first half of 2018, with a total worth of RM35.6 billion in 2Q2018. As seen in Figure 1, the sector is dominated by civil engineering projects, due to its huge growth rate of 23.6% in 2Q2018, while the market of non-residential and residential building projects declined.

Construction Sub-sector	Civil Engineering	Non-residential buildings	Residential Buildings	Special Activities
Percentage makeup	41.7%	28.2%	25%	5.1%

Figure 1: Distribution of GDP within the construction sector in 2Q2018

Thus, it is important that there is continued investments and research in the construction sector, to ensure its sustainable growth and contribution towards the nation's development. With the advent of climate change, every industry must move towards decarbonisation to secure its place in an increasingly environmentally conscious world economy. The construction sector is no exception.

1.4. Malaysia's carbon emissions

In 2016, Malaysia released 218 Mt CO2 due to burning of fossil fuel, ranking it at #26 in the world. Based on data from 2010, it also has a relatively low GDP: CO2 ratio at $1,500 per CO2 ton. This compares with $3,000 in Turkey and $3,700 in Singapore.

Furthermore, Malaysia's CO2 emission growth is higher than that of most emerging countries, at a rate of 5% in Malaysia compared to 4.6% in Indonesia and 1% in the Philippines.

In Malaysia, 40% of these emissions come from the construction industry, therefore reducing emissions in this sector will make a significant contribution to the countries overall emission reduction targets.

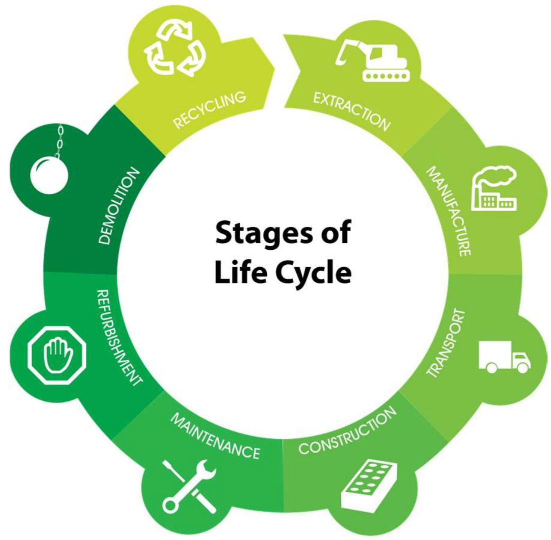

Figure 2: Stages of Construction Life Cycle

Source: Irish Green Building Council

1.5. Carbon emissions in the construction industry

Sub-Sector	MtCO²	% of total
Design	1.3	0.5%
Manufacture	45.2	15%
Distribution	2.8	1%
Operations on-site	2.6	1%
In Use	246.4	83%
Refurb/Demolition	1.3	0.4%
Total	298.4	100%

Figure 3: Amount of CO2 emissions which the construction industry has the ability to influence 2008

Source: Department for Business Innovation & Skills

The life cycle of a building encompasses a range of stages, such as: design, manufacture of materials, transport/distribution, construction, operation, demolishing and recycling. The continued operation and maintenance of a building is responsible for the largest fraction of carbon emissions over the building lifecycle, followed by manufacture and design.

Manufacture refers to the production of materials needed for construction projects. The production of conventional building materials such as concrete and cement are both energy intensive and responsible for considerable carbon emissions.

Cement production produces carbon dioxide via two mechanisms. Firstly, thermal decomposition of calcium carbonate directly releases CO2 and secondly from the production of energy to fuel the extreme heating of raw materials. Consequently, the construction industry is the second largest industrial emitter of carbon emissions, following the production of fossil fuels; with cement production alone contributing 7% of global carbon emissions (IPCC AR5).

Thus, to reduce carbon emitted during the manufacturing stage of construction, this report encourages a transition to low-carbon, sustainable materials and the re-use of construction waste.

1.6. Co-benefits of low carbon construction

When considerately managed, low-carbon economies create a myriad of benefits socially, economically, politically and environmentally. A reduction in carbon emissions reduces air-pollution and improves public health, whilst low-carbon economies present new employment and trade opportunities. Low-carbon practices are often associated with improved resource efficiency, with an emphasis on recycled and local materials; thereby, reducing the reliance on external imports and improving the resilience and competitiveness of economies. In addition to the direct benefit of decarbonising on the reduction of greenhouse gas emissions and global temperature rise, low carbon practices have a cascade of ecosystem benefits; such as reduced habitat destruction, improved biodiversity, resilience to climate extremes and the protection of ecosystem services (The Royal Society and Royal Academy of Engineering, 2018).

In many ways, low carbon practices can be considered “future-proof”. Sustainability is inherent to the development of low-carbon solutions, securing the ability of future generations to continue to meet the demands of industry. Furthermore, the progression of international agreements towards a decarbonised economy, conscious of rising global temperatures suggests international trade agreements are likely to place greater value on low carbon goods and resources. By transitioning towards a low carbon industry now, Malaysian construction will fortify its ability to perform under a changing political and economic environment.

1.7. Existing Malaysian guidelines addressing sustainable construction

Tools and policies already in place to address sustainability in the construction industry.

1.7.1. Green Building Index

The Green Building Index (GBI) is a recognised green rating tool for buildings. It was developed by PAM - the Malaysian Institute for Architects - in 2009 and has since been used to assess a building’s sustainability performance based on 6 main criteria: Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning & Management, Materials and Resources, Water Efficiency and Innovation. Assessment will be given using a point system and attaining certain amounts of points will result one of four ratings: Certified, Silver, Gold and Platinum. To maintain the certification, the building must be reassessed every 3 years.

1.7.2. MyCREST Tool

The MyCREST tool (Malaysian Carbon Reduction and Environmental Sustainability Tool) is also a green rating tool for construction tools. It was developed by CIDB and it has a stronger focus on carbon reduction in 3 stages of a building’s life cycle: design, construction and operations. A score system is used to grade each stage separately and the amount of points will determine the “star” rating of each stage (out of 5 stars). An overall star rating will also be given for the entire construction project.

1.7.3. CITP Strategic Thrust 2: Environmental Sustainability

In 2015, the CIDB released the Construction Industry Transformation Programme 2020 (CITP), outlining its goals for the construction industry to be achieved by 2020, in response to the Eleventh Malaysia Plan (RMK11). The RMK11 is a 5-year development plan for the nation from 2016-2020. The CITP has highlighted 4 main strategic thrusts, one of them being Environmental Sustainability. Under this umbrella, the CITP brought up 3 cases for change: first, the lack of sustainability-rated buildings, secondly, high carbon emissions and energy use in buildings, and lastly, high volume of construction and demolition waste dumping. Solutions have been listed for each of these issues.

2. Aims & Scope

Aims

This report seeks to contribute to the CITP Strategic Thrust 2, by providing guidelines for the Malaysian government on how to reduce the quantity of carbon emissions released from the construction industry. Our research is focused on were two main areas: new technologies and best practices. New technologies refer to new techniques or materials used in sustainable construction. General examples include fitting solar panels or integrating plants onto buildings, energy saving designs, etc. Best practices refer to government policies and enforcement which encourage the adoption of new techniques and technologies. A notable example would be the LEEDs rating system in the US, which awards building projects certification based on their environmental performance.

Provided in this report is advice on specific components of the construction industry life cycle. Due to the scoping nature of this report, this report does not aim to address every component of the construction life cycle. Explicitly out of scope is the usage of buildings and infrastructure, as the goal is to concentrate on the construction process. To ensure the reports efficacy, advice shall be tailored towards the components of the construction life cycle from which most benefits would be gained from adhering to low carbon practices. These were identified as

- Sourcing of materials
- Material types and the usage thereof
- Management of construction waste

For each of these areas, the report provides detailed, specific examples of low carbon practices which cohere to the existing guidelines. The report also provides suggestions on how low carbon practices could be implemented.

Scope of Advice

The recommendations provided within this report shall be specific and focused on a few selected high impact solutions, each to be explored in depth.

The advice provided within this report shall endeavour to follow these principles:

- Simplicity
- Non-complex technology
- High ease of application and use
- Low requirement for a skilled workforce
- Sustainability
- Durable
- Low maintenance
- Long-term
- Consistent with the demands of future generations

- Economic viability

Where possible, this report shall quantify the carbon savings associated with advice. Considerations will be given to the positive and negative impact of the low carbon practices suggested within this report on social, economic and environmental factors. Where possible, examples shall be provided of when the low carbon practices suggested within this report have been introduced successfully elsewhere. The advice provided within this report shall be mindful of existing guidelines. Hence, it's intended to complement the aims of MyCREST for the following reasons:

(i) This report shall consider the life-cycle of the built environment

(ii) This report shall provide a guide to low carbon strategies

(iii) This report shall consider and quantify Carbon emissions of suggested strategies

(iv) This report shall consider socioeconomic factors in the built environment

(v) This report shall consider and quantify the sustainability of design

(vi) This report shall consider the robustness, durability and ease of use

3. Guidelines

3.1. Sourcing of Construction Material

3.1.1. Introduction to construction materials

There are a number of factors to be considered in selecting the most suitable material for a construction project. Considerations include, but are not limited to:

- Material properties: Strength in tension & compression, temperature and expansion coefficients.
- Costs: purchase price, transport, disposal costs.
- Toxicity
- Durability
- Carbon Dioxide emissions
- Ability to be recycled

Where construction projects are implemented, the cost is often higher than anticipated, and this represents a financial constraint on the successful implementation of development plans (Shafii & Othman). This means that predictability of material cost is also of high importance, which may dissuade small construction firms from exploring new materials and construction techniques. Remedial action on this issue is discussed in Section 2.

The most commonly used materials used in Malaysia are

- Concrete
- Steel (rebar)
- Composites
- Wood
- Masonry
- Plastics

Other non-essential construction materials include paint, plaster and glass (OER CO2).

3.1.2. Introduction to construction materials

A number of inefficiencies have been identified within the Malaysian construction industry. These include

- Poor planning
- Unfinished projects
- Poor management of resources

The latter of these is the largest contributor to excess greenhouse gas (GHG) emissions during construction.

3.1.3. Reducing greenhouse emissions of steel and concrete

Steel and concrete represent more than 50% of greenhouse gas emissions within construction projects (L. Hiu), due to their low cost, high strength, and similar expansion coefficients, allowing high strength reinforced concrete structures. Improving logistical planning means that concrete and steel can be locally sourced, decreasing greenhouse gas emissions from transport. Increasing investment in prefabricated structures speeds up construction and reduces wastage. Using higher quality materials means that less needs to be used. For example, using plasticiser in concrete decreases water content, and therefore increases its compression strength. This may be more costly, and therefore government intervention may be beneficial in this area to incentivise this.

Western construction companies are more cost effective, have lower wastage, and have lower greenhouse gas emission than Malaysia's firms. As will be discussed, government incentives for domestic construction firms to mirror these international companies will have a positive impact on greenhouse gas emissions. Closer cooperation between these two industries would have the same impact.

3.1. New opportunities

3.1.1. Components of the construction life-cycle addressed

The construction life-cycle is a holistic process which incorporates a range of components, including: design, manufacture, distribution, construction, operation, refurbishment and demolition. This report focuses on the components of the construction life-cycle assessed to present the most simple and effective first steps of the transition towards a low-carbon construction industry: the design and manufacture of construction materials.

As discussed in Section 1, conventional construction relies heavily on the use of concrete and cement. Not only does the production of these materials directly release carbon dioxide through chemical reactions, but the reaction also consumes considerable amounts of heat and electricity; often sourced from carbon emitting fossil fuels (Oss and Padovani, 2003). Consequently, the construction industry is the second largest emitter of greenhouse gases (IPCC AR5). By transitioning away from the use of concrete and cement, towards the use of low-carbon materials a large proportion of these emissions could be mitigated. Furthermore, sourcing locally reduces emissions associated with transport and distribution, whilst increasing the use of recycled and durable materials reduces the net demand for new resources and their associated emissions.

3.1.2. An introduction to building with biomass

Building with biomass i.e. plant-based materials is one of the key methods The Royal Society and Royal Academy of Engineering (2018) suggested to remove carbon dioxide from the atmosphere and prevent global average temperatures rising above 2°C. The growth of biomass naturally sequesters CO2 via photosynthesis. Usually, this CO2 is released back into the environment upon burning or decomposition; however, utilising plant material for construction prevents the release of sequestered carbon into the environment. Furthermore, harvesting fast growing plants provides new space for plant growth, and therefore ensures carbon is continuously sequestered. Not only can plant-based materials be used for a variety of construction purposes, but the development of chemical and thermal treatments enhance the durability of fast growing, soft wood and fortify its resistance to fire and fungal decay (Ramage et *al.*, 2017). New construction materials suggested within this report conform to the principles of building with biomass and therefore this report encourages the use of plant-derived materials within a low-carbon construction industry.

Malaysia is one of the most biodiverse land areas globally, retaining 10% of the world's plant species and 7% worlds animals species; the majority of which reside within tropical rainforests. However, between 1990-2005, 6.6% of forest cover was lost to industries such as logging, and agriculture (FAO, 2010). Increasing the use of plant-derived materials may appear to conflict with conservation practices which aim to prevent deforestation and protect biodiversity, however this report strongly advises against deforestation as a means of acquiring new plant-based construction materials. Alternatively, it is advisable to reforest those areas already affected by deforestation, such as previous logging sites and abandoned agricultural land. Not only would this compliment the Malaysian government's reforestation efforts and provide forest cover over an area vulnerable to erosion, but it would also utilise an unused resource, reduce dependence on external imports and enhance the Malaysian economy.

To identify land areas to be used for the growth of plants for the construction industry, we advise a "traffic light system" to be implemented. This would involve an assessment of Malaysian land use, quantifying the degree of biodiversity and ecosystem services provided by different areas. Those areas which retain the highest levels of biodiversity should be marked red, indicating its unsuitability for planting, such as primary forests. Whereas those areas with low biodiversity which provide few ecosystem services would be marked as green indicating it' suitability for the growth of plants for the construction industry. Such areas include former logging sites and cleared land deemed unsuitable for agriculture. Furthermore, recycling used construction materials into new materials would not only reduce the need for growth sites but it would also prevent carbon release during the disposal of plant matter.

3.1.3. Greenhouse gas removal potential

The global adoption of plant-based building materials in place of conventional construction practices has the potential to remove 0.5-1.0 billion tons of carbon dioxide from the atmosphere each year, which could save 14-31% of global CO2 emissions (The Royal Society and Royal Academy of Engineering 2018). However, the degree of carbon reduction depends on how the biomass is treated after demolition. If the biomass is burnt or left to decompose, the carbon retained within its plant tissue will be released into the atmosphere. To ensure maximum carbon sequestration, plant-based building materials should either be recycled after use or burnt using carbon capture and storage processes (Ramage et *al.*, 2017)

3.1.4. Plant-based structural materials

Bamboo and timber make ideal plant-based materials for the structural framework of a building due to their inherent strength and resistance to decay and fire, once treated. Furthermore, the use of fast growing trees and bamboo maximises carbon uptake during growth. For example, the carbon density of a bamboo forest is four-fold greater than a spruce forest, due to fewer years needed to reach bamboo maturity (Wei et *al* 2013). This report not only advises the use of fast growing trees for timber, but specifically those species native to Malaysia. This will improve the adherence of these species to the specific soil types and climate found in Malaysia.

The use of wood in construction is a well established practice, practiced for over 10,000 years, however has fallen out of favour over recent decades with public concerns over deforestation and preference given to the structural integrity of concrete. By adopting the traffic light system suggested in section 2.2.2 along with a well managed programme, the public perception of building with timber is likely to improve. Furthermore, the structural integrity of timber has been recently reasserted by the construction of an array of multi-storey wooden buildings and bridges (Gosselin et al 2016)

3.1.5. Plant-based insulation materials

Plant-based materials offer a variety of substitutes for low density construction materials such as insulation. This report focuses on the benefits of cellulose, hemp and durisol, however alternatives are becoming increasingly available with further research and development.

Cellulose is an organic compound which provides plants with structural rigidity. It is abundant within plant matter and can occupy 40-90% of biomass, depending on the species; alternatively cellulose can be extracted from recycled paper. When mixed with water, cellulose can produce a material with a range of densities that can be moulded or sprayed; making it ideal for application within the construction industry. Furthermore, chemically treating the cellulose produces fire and insect resistant properties. When compared to fiberglass insulation, research suggests cellulose-based insulation has a higher R value, fewer health risks and consumes 800% less energy during production. (CU Denver, 1990).

Hemp is a fast-growing plant with a cellulose rich, woody core. When mixed with a lime-based binder, hemp forms a porous material with ideal thermal and acoustic insulation properties that can be cut into a variety of shapes. Hemp insulation is resistant to insects, decay and fires and is capable of absorbing and releasing moisture, buffering changes in humidity.

Alternatively, Durisol presents a unique solution to both plant-based and recycled building materials. Durisol is formed from chipped, recycled wood waste that has been bonded with cement. It is therefore capable of being moulded into a variety of shapes; creating a porous, lightweight, durable material, resistant to decay, insects and fungus with a range of uses. The production of prefabricated durisol blocks off-site allows rapid and easy construction on-site, reducing construction time and costs. Furthermore, the recycled nature of Durisol makes it an ideal disposal method for used timber frames.

3.1.6. Limitations

Transitioning towards building with biomass may encounter financial, technical, health, environmental and cultural limitations which could hinder the ease and speed of implementation. Of the aforementioned plant based building materials, cellulose insulation is estimated to cost more than fibreglass insulation which may deter construction companies from incorporating cellulose insulation within new-builds. Furthermore, there are expected to be additional costs associated with the harvesting, treating, processing and transportation for all plant based building materials. That said, this will provide new employment opportunities and the transition to plant based building materials is estimated to incur negligible costs (The Royal Society and Royal Academy of Engineering, 2018).

Before plant based building materials are incorporated into construction, well organised management and installation practices will need to be developed to ensure material performance and mitigate against health risks associated with dust. For example, without the installation of a vapour barrier, cellulose insulation will absorb moisture which may cause it to lose its integrity and decay.

As mentioned previously, plant based building materials release the carbon sequestered during plant growth if they are burnt or allowed to decay. To ensure construction practices have a minimal impact on carbon emissions, plant based materials will need to be recycled into new products or burnt alongside carbon capture and storage practices. Furthermore, to prevent additional environmental problems resulting from the implementation of building with biomass, thorough forest management practices will be required to ensure plant based materials are acquired sustainably, without resulting in loss of forest cover or biodiversity.

The public perception of building with biomass will also have to be carefully managed to ensure public opinion is in favour and prevent concerns over deforestation, fire hazards, susceptibility to decay and poor structural integrity.

3.1.7. Government support

As described in the Greenhouse Gas Removal Report (2018), policy and regulatory support could help ease the transition and success of building with biomass (The Royal Society and Royal Academy of Engineering, 2018). Incentive schemes could encourage both the incorporation of biomass within construction and sustainable forest practices. Construction guidelines will also need to be amended to include and possibly encourage building with biomass and to ensure quality control. The Green Building Index is one such document which could actively encourage the use of biomass over conventional materials, whilst discouraging the use of concrete and cement. Finally, it would be advantageous to the progression of this transition if government and business were to collaborate.

3.2. Handling waste construction material

3.2.1. An introduction to construction waste

Construction projects generate a large amount of unused waste materials. Some estimates claim that up to 30% of landfill contents come from the construction industry (Fishbein 1998). There are three reasons to reduce excess waste in construction. First, better material management reduces the amount of materials bought and increases the profit margins of those materials. Second, excess waste in landfills has direct negative effects on the environment surrounding those landfills—especially if they are unregulated or illegally ran. Third, more efficient materials and waste management reduced the amount of manufacture needed for each construction project, therefore decreasing the associated carbon emissions.

Of these three reasons, the first may be the most compelling. More efficient waste management allows construction companies to gain revenue from waste that would otherwise be disposed of. In this case, sustainability and business efficiency go hand-in-hand.

3.2.2. Waste management in Malaysia

Studies of the construction industry in Malaysia have revealed that many construction companies and contractors do not practice good waste management. Few contractors sort their construction waste, and a majority don't practice reuse, recycling, or landfill disposal (Ikau, et al). Many dispose of waste in illegal dumps that are near the construction site, instead of regulated landfills. Poor on-site practices generate a large amount of this waste. The biggest contributors to construction waste in Malaysia are wrong usage, poor storage, mishandling, and negligence, which together cause almost half of all construction waste (Othuman Mydin, M, et al.).

3.2.3. Benefits of better waste management

Improved waste management practices could increase profits by around 2.5% for many contractors in Malaysia (Begum RA et al). Waste management will also save communities from the negative health effects caused by improper disposal of construction materials, and therefore benefit public perception of contractors (Othuman Mydin, M, et al).

3.2.4. The ideal waste management hierarchy

The Environmental Protection Agency (EPA) in the United States has defined a Waste Management Hierarchy which orders the ways to deal with construction waste from best to worst:

- Reduce
- Reuse
- Recycle
- Compost
- Incinerate
- Landfill

This list can help prioritize ways of dealing with construction waste. The first goal for all waste should be to reduce the amount generated. Waste should only be directed to landfills when there is no other method for dealing with it — as in the case of some hazardous waste, for example.

The first three directives on the Waste Management Hierarchy are Reduce, Reuse, and Recycle. These methods minimize the environmental impact of construction debris and also make the most efficient use of construction materials.

3.2.5. Reducing construction waste

Reduce the amount of debris from construction projects through more careful management of resources.

First, quantify the amount of waste from each project and try to reduce it in each subsequent project.

- Predict the amount of material needed before the project begins.

- Throughout the project, monitor the amount of waste generated of each material. Quantify the waste and compare it to the original predictions at the end of the project. The difference between predicted material usage and actual usage can help to refine predictions for future projects.

Quantifying waste usually requires separating it by type and measuring it on-site. For instance, excess steel or timber should be separated and measured by volume (for example, by truckload), and the total amount of waste of each type of material recorded.

Better material management on-site also goes a long way to reducing the amount of materials wasted.

- Store materials in safe, secure, and weatherproof areas. Timber should be kept away from wet areas, for example.
- Order materials to arrive at the time they are needed, instead of letting them sit unused on-site.

Waste reduction also saves labour costs needed for transporting, storing, and disposing of the waste.

3.2.6. Reusing construction waste

Reusing waste materials is an efficient method of reducing raw materials and therefore cost. In some cases, on-site reuse may be possible. In other cases, waste from one project might be usable on a different project, or sellable to other companies on waste exchanges. For example, construction companies may have usable waste products that they will sell for a reduced price, and this can be a good way to purchase cheaper materials while cutting down on costs. Specific ways to reuse construction waste are listed below:

- Organize waste on-site by type. This advice applies to recycling waste as well. Good practice is to set up different storage containers for different types of waste—for example, one container for steel, one for timber, and one for aggregates.
- A large amount of waste derives from packaging; however, some suppliers may be able to reuse packaging.
- Crush and reuse aggregates.
- Trade waste materials on a waste exchange. One such exchange platform operating near Malaysia is www.wasteisnotwaste.com.
- Ensure reusable waste is stored properly on-site, or transported to an off-site holding area.
- Lime mortars are useful for bricklaying, as bricks laid with lime mortars can be reused after demolition.
- Contractors should try to find suppliers who will buy back unused materials.

3.2.7. Recycling construction waste

Waste that cannot be reused should be sent to a recycling plant whenever possible. The specifics (such as which plant to send materials to) will depend on the location and type of project. Most importantly, avoid illegal landfill dumping.

3.2.8. Summary and Conclusion

Waste management provides benefits for the contractor and the community in the form of increased profits, decreased environmental harms, decreased risks associated with construction projects, greater efficiency, and better public perception.

Current waste management practices in Malaysia are flagging and there are clear paths to improvement. Contractors should focus first on reducing waste by planning materials purchases more carefully and storing materials safely. Where possible, materials such as timber should be reused, which requires responsible on-site storage (e.g. protection from water damage and organized storage sites) to keep such materials usable. Absent opportunities for reuse, contractors should try to find avenues for recycling waste materials. By focusing on these three practices, Malaysian contractors can potentially increase their efficiency and profits significantly.

3.3. Policies

In this section, we will consider possible changes to existing construction policies to encourage low carbon practices. Our focus will be on the Construction Industry Standard (CIS) published by the CIDB.

3.3.1. CIIS 18: 2010 Manual for IBS Content Scoring System (IBS Score)

The CIS 18 currently places an emphasis on "prefabricated and precast concrete components". We recommend this emphasis should be removed due to the heavy carbon footprint of concrete. While we agree that offsite large scale production would be cheaper and greener than in-situ production, we think that the emphasis on "off-site production of components" has captured that. This makes the emphasis on "prefabricated and precast concrete" obsolete.

Next, it is currently possible to obtain a full score of 100 points using just prefabricated concrete. We hope to update the scoring system to complement the goal of environmental sustainability. Concrete and steel should be discouraged, while timber and bamboo are to be encouraged.

Thus, these are the recommended changes we propose:

- Remove emphasis of IBS Score on "the use of prefabricated and precast concrete components"
- For Table 1. IBS Score for Structural Systems, the recommended changes can be found in Appendix 1. Generally, the scores for using concrete and steel has been reduced, while the scores for using timber has been increased.
- Bamboo structural systems can be added and put together with timber structures.
- New combinations of plant-based structural systems can be added, with high scores attributed to them.
- For Table 1A. IBS Factor for Roof Structural System, "Prefab metal roof truss" should have its score cut to 0.8. "Prefab bamboo roof truss" can be added with a score of 1
- For Table 2. IBS Factor for wall systems, all concrete systems with a score of 1.0 should be cut to 0.8

3.3.2. CIS 7:2014 Quality Assessment System For Building Construction Work (QLASSIC)

To comply with the above Construction Industry Standard, the introduction of new building materials will require new quality controls and monitoring procedures, particularly regarding the fire safety of timber building materials

3.3.3. Regulations

Regulations should provide support to encourage the transition from conventional construction practices to low C practices by incentivising the use of low C building materials and discourage the use of conventional intensive building materials. This could be achieved by providing payment not to partake in conventional construction practices, whilst subsidising the cost of low C practices.
Regulations should incentivise the planting of fast growing trees, such as those species suggested in Section 2

Regulations should incentivise sustainable forest management and prohibit further destruction of existing forest. This could be achieved by categorising land areas relative to their biodiversity and provision of ecosystem services. Land areas scoring low on this scale, such as those areas previously deforested, should be encouraged for the growth of building materials. Whereas the growth of building materials on land areas which score highly on this scale, such as primary forests, should be discouraged.

Regulations should incentivise adherence to the Waste Management Plan and encourage the re-use and recycling of waste materials.

Regulations could encourage a C budget to be established at the beginning of the design stage of construction. This could form part of the tendering process. Regulations could encourage the adherence to the C budget specified for each new construction project by introducing financial repercussions should the C budget be exceeded.

Further efforts should be made to understand how C release can be reduced during components of the construction life-cycle other than those addressed in this report.

Regulations should enforce green building certification as a strict requirement for construction projects. The MyCrest tool can be utilised by requiring all construction projects to be certified with at least one star. It should also be made compulsory for all projects to be assessed by the Green Building Index.

3.3.4. Cooperation between government and construction leaders

Cooperation between government and construction firms is required to address how low C strategies can be implemented practically and successfully. This will prevent risk aversion within the construction industry hampering the transition to new practices.

4. Recommendations

This report provides guidelines for the Malaysian government on how to reduce the quantity of carbon emissions released from the construction industry. Discussed throughout the report are low carbon construction materials, guidance on how to improve waste management and advice on how to implement a transition towards a low carbon construction industry. A summary of these recommendations is provided below.

1. Low carbon construction materials

1.1. Reduce the use of conventional construction materials responsible for the emission of large quantities of carbon, such as steel and concrete

1.2. Increase the use of low carbon construction materials by encouraging "building with biomass". This involves the use of plant derived building materials for both structural and insulation components of construction. These materials sequester carbon during their growth and retain it throughout their use as construction materials. Such materials include, bamboo, hemp and cellulose.

1.3. Use fast growing plants to increase carbon sequestration and provide ample building materials

1.4. Chemically treat plant derived building materials to ensure their resistance to fire and fungal decay

1.5. Ensure the use of plant derived building materials does not encourage deforestation by reforesting those areas already affected by deforestation

1.6. Adopt a "traffic light system" to identify those areas most suitable for the growth of plants for construction materials. This should be achieved by quantifying the biodiversity and ecosystem services provided by different land areas. Those areas which retain the highest levels of biodiversity should be marked red, indicating its unsuitability for planting, such as primary forests. Whereas those areas with low biodiversity which provide few ecosystem services should be marked green, indicating its suitability for the growth of plants for the construction industry, such as previous logging sites or abandoned agricultural land.

1.7. The decay of plant-based construction materials that are no longer in use should be prevented as this will release the carbon sequestered during growth. Instead, plant-based construction materials could be recycled, re-used, re-treated or burned with carbon capture and storage.

2. Waste management

2.1. Reduce waste where possible to (i) increase profit margins (ii) reduce landfill (iii) reduce emissions associated with material manufacture

2.2. Use prefabricated materials to prevent waste and reduce construction time

2.3. Use high quality materials to reduce waste

2.4. Reduce waste by accurately predicting the quantity of materials needed for construction

2.5. Reuse waste where possible either on-site, on external projects, or via waste exchanges

2.6. Recycle waste when re-use is not possible

3. Implementation

3.1. Ensure construction materials are sourced locally, where possible, to reduce transport and associated carbon emissions

3.2. Build strategically placed storage depots, central to hubs of construction activity to reduce transport and associated carbon emissions

3.3. Develop well organised management and installation practices to ensure material performance and mitigate against health risks

3.4. Manage public perception to prevent concerns over deforestation, fire hazards, susceptibility to decay and structural integrity

3.5. Develop incentive schemes to encourage the use of low carbon construction materials and sustainable forest management and discourage the use of conventional high carbon construction materials

3.6. Develop incentive schemes to adhere to advised waste management practices

3.7. Develop quality controls and monitoring processes for new construction materials

3.8. Develop regulations to encourage the establishment of a carbon budget during the design stage of construction which should be considering during the tendering process. Failure to adhere to an agreed carbon budget should result in financial repercussions

3.9. Develop regulations to utilise the MyCrest tool by requiring all construction projects are certified with at least one star and be assessed by the Green Building Index

3.10. Endeavour to understand how to reduce carbon emissions from those components of the construction life-cycle not addressed in this report

5. Next Steps

Transforming conventions and habits in the construction industry will not be easy. It'll take time and the collective effort from multiple key players. This feat is especially challenging because it can be difficult to see the benefits of adopting green practices immediately and sometimes, it might even incur greater initial costs, which will be a huge deterrent to begin this transition.

However, as scientists and researchers warn of climate change and its effects start to show, people in countries all over the world are beginning to realise the urgency of the climate issue. Environmental sustainability in industries is no longer a luxury, but rather a necessity. The building and construction industry is a large emitter of greenhouse gases, but this means that it also has large potential for reducing its carbon footprint.

To help Malaysia work towards a greener construction industry, this report contains solutions which tackle the problem from various angles. Construction companies can begin looking into sourcing for alternative materials for state-of-the-art construction projects. Construction site managers can improve upon their materials management: to reuse and recycle as much material as possible and reduce materials going to waste. Last, but not least, policymakers will play the essential role of updating policies and enforcing guidelines so that transition to environmentally friendly practices can be quicker and more seamless.

In order to achieve an impactful outcome, it is essential that the different players work together towards a unified goal, with (probably) CIDB taking charge of this transformation. We sincerely hope that our report has been useful to CIDB in providing actionable methods to transform Malaysia's construction industry to become a world leader in environmental sustainability. Ultimately, the goal is to become carbon-negative; a goal which will require careful planning and innovative action.

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7. Appendices

Appendix 1: Proposed changes for IBS Scoring system for Structural system

System	Column and beams / Floor	Precast concrete slab	In-situ concrete on permanent metal formwork	In-situ concrete using reusable system formwork	In-situ concrete using timber formwork	Steel flooring system	Timber frame flooring system	No Floor
Concrete	Precast column and beam	0.9	0.8	0.6	0.5	0.9	1.0	0.9
	Precast column and in-situ beams using reusable system formwork	0.9	0.8	0.6	0.5	0.9	1.0	0.8
	Precast column and in-situ beams using timber formwork	0.7	0.7	0.5	0.4	0.8	0.9	0.7
	Precast beams and in-situ columns using reusable system formwork	0.8	0.8	0.6	0.5	0.9	1.0	0.8
	Precast beams and in-situ columns using timber formwork	0.7	0.7	0.5	0.4	0.8	0.9	0.7
	In-situ columns and beams using reusable system formwork	0.6	0.6	0.5	0.3	0.7	0.8	0.6
	In-situ columns and beams using timber formwork	0.5	0.5	0.5	0.1	0.6	0.7	0.0
Load Bearing Blockwork	Vertical and horizontal member systems / structure	0.7	0.7	0.6	0.5	0.8	0.9	0.7
Steel	Steel columns and beams	0.9	0.9	0.7	0.6	1.0	1.0	1.0