

TRANSLATING RESEARCH & INNOVATION

In the Built Environment for the Tropics



TRANSLATING RESEARCH & INNOVATION In the Built Environment for the Tropics

Building and Construction Authority

Building and Construction Authority

52 Jurong Gateway Road
#11-01
Singapore 608550

CONTACT CENTRE : 1800-3425222 (1800-DIAL BCA)
+65 6534 0219 (for Overseas Call)
FAX : +65 6334 4287
EMAIL : bca_enquiry@bca.gov.sg
WEBSITE : www.bca.gov.sg



Building and Construction Authority

TRANSLATING RESEARCH & INNOVATION

In the Built Environment for the Tropics



DISCLAIMER

This guide is published by the Building and Construction Authority.

Copyright © 2017 Building and Construction Authority.

All rights reserved. This document or any part thereof may not be reproduced for any reason whatsoever in any form or means whatsoever and howsoever without the prior written consent and approval of the Building and Construction Authority.

The information contained in this publication is for general information purposes only. While we endeavour to keep information contained in this publication up to date and correct, we make no representations or warranties of any kind, express or implied, about the completeness, accuracy, reliability, suitability or availability with respect to the information, products, services, or related graphics contained in this publication for any purpose. Any reliance you place on such information is therefore strictly at your own risk.

In no event will the Building and Construction Authority be liable for any loss or damage including without limitation direct or indirect, or consequential loss or damage, or any loss or damage whatsoever arising from loss of profits arising out of, or in connection with, the use and / or reliance of any part or all of this publication.

The publication may include information of the fund applicants who have, in one way or another, contributed to the development of this publication. The Building and Construction Authority does not endorse the research included. It is the responsibility of the users to select appropriate information and ensure the selected information meet their specific requirements.

CONTENTS

Foreword	02	CHAPTER 9.3	Smart Facade	
Preface	03		Cool Paint Incorporating Phase Change Material for Buildings in the Tropics	38
Technology Translational Level	04		Solar Control Smart Window for Tropical Buildings	39
CHAPTER 3			Heat Reflective Coating to Improve Thermal Performance of Window Frames	40
New Testbedding Platform		CHAPTER 9.4	Modelling Tool	
BCA SkyLab	06		Residential Auto-Designer	42
Centre for Lean and Virtual Construction (CLVC)	08		Development of Green Building Environment Simulation Technology (GrBEST)	43
CHAPTER 4		CHAPTER 9.5	Daylighting	
Future Office			Daylighting in Singapore	46
ZEB Plus: Enhancement of ZEB at BCA Academy	10	CHAPTER 9.6	Advanced Construction Materials	
CHAPTER 5			Design for High Strength Concrete	48
Technology Integration			Tropical Hempcrete Wall Panel	49
Net Zero Energy Building (NZEB@SDE)	14		Encased Composite Columns with High Strength Materials for High-Rise Construction	50
3for2 @ UWCSEA	16	CHAPTER 9.7	Integrated Digital Delivery (IDD)	
CHAPTER 6			Automated Code Compliance Check in Building Information Modelling (BIM)	54
Positive Energy School			Three-Dimensional Building Interactive Walkthrough (3D-BIW)	55
Positive Energy School: Creating a Conducive and Sustainable Learning Environment for the Future	18		Smart and Semi-Automated Precast Elements Logistics Management and Installation System	56
CHAPTER 7		CHAPTER 9.8	Robotic Technology	
JTC LaunchPad			Unmanned Aerial Vehicle (UAV) for Indoor Navigation	58
Block 81 of JTC LaunchPad @ One-North		CHAPTER 9.9	Design for Manufacturing and Assembly (DfMA) Solutions	
Optimising for Mass Engineered Timber (MET)	20		Prefabricated Pre-finished Volumetric Construction (PPVC)	60
CHAPTER 8		CHAPTER 10	Funding Programmes	
Eco-Green Building			Two-Stage Innovation Grant (iGrant)	62
Use of Recycled Concrete Aggregate (RCA) for Structural Concrete	24		Green Buildings Innovation Cluster (GBIC)	63
CHAPTER 9			Enhanced Partnerships for Capability Transformation to Drive Government Lead Demand (Gov-PACT)	64
Industry-Centric Innovation			Capability Development Grant (CDG)	65
CHAPTER 9.1		Glossary		66
Air-Conditioning and Mechanical Ventilation (ACMV) and Indoor Air Quality (IAQ)		Editorial Team and Acknowledgements		68
Desiccant and Nano-Woven Membrane Air Dehumidification	30			
Functionalised Aerogel for Treatment of Indoor Moisture and Air Contaminants (FATIMAC)	32			
CHAPTER 9.2				
Building Management and Information Systems (BMIS)				
Circuit-Level Electricity Metering and Analytics for Buildings	34			
Smart Building Analytics	36			

Foreword

Hugh Lim

Chief Executive Officer
Building and Construction Authority



Singapore's Built Environment sector will continue to grow, even as we work towards a sustainable future, both during construction and in operation. As such, we must transform the way we build while at the same time actively contribute to reducing emissions from the Built Environment sector. In support of this, the Building and Construction Authority (BCA) is working with other government agencies, academia and industry to promote innovation in the Built Environment sector.

We recently completed the Construction Productivity R&D roadmap which identified seven clusters with 35 recommended technologies that would help drive the industry towards Design for Manufacturing and Assembly (DfMA) that is intelligent, real-time and fully digital. BCA's Centre for Lean and Virtual Construction (CLVC) which opened in 2015 allows the industry to experience virtual design and construction first-hand, while leveraging emerging information and communication technology (ICT) in the construction industry.

On the energy efficiency front, our longer term aspiration is for all low-rise buildings in Singapore to be positive energy, all medium-rise buildings to be zero energy, and all high-rise buildings to be super-low energy. To realise this aspiration, we need breakthroughs through research and innovation to accelerate our green building agenda. BCA will thus be enhancing the Building Energy Efficiency

Roadmap to guide related technology research and innovation.

Last year, the launch of the BCA SkyLab, the world's first high-rise rotatable lab for the tropics, placed BCA at the helm of green building technology research and development (R&D) arena. The ground-breaking laboratory provides a platform to support technology testbedding under real-world building conditions to determine the technology performance. This will help minimise risks to building owners when a new technology is deployed to actual buildings.

Moving forward, BCA will be retrofitting the existing Zero Energy Building (ZEB) at BCA Academy to become a positive energy low-rise building (ZEB Plus), pushing the boundaries of building performance further. In addition, BCA will also develop a zero energy mid-rise building (ZEB 2.0) and a super low energy high-rise building, where new technologies will be tested and deployed to bring research into commercialisation.

This publication showcases some exemplary building projects and technologies in the areas of energy efficiency, construction productivity and ICT, funded under the various BCA's R&D grants. I hope that this publication will be useful in facilitating knowledge and technology transfer between academia, research institutes and the industry. Let us work together to create a better and future-ready Built Environment for all.

Preface

Er Lam Siew Wah

Managing Director
Built Environment Research and
Innovation Institute
Building and Construction Authority



Since 2007, BCA has obtained Research and Development (R&D) funding from various government funding sources. To date, there are 76 completed R&D projects, amounting to a total funding of S\$ 33 million, while 60 over projects with committed funding of S\$ 34 million are still ongoing. These projects cover a wide variety of topics for the Built Environment, mostly on green building technologies, with some on construction materials and construction productivity. About 40% of the completed R&D projects have resulted in successful deployment in the Built Environment, ranging from small scale prototypes to wider industry adoption. For example, the Passive Displacement Ventilation (PDV) system has been implemented in the Ministry of Manpower Headquarters Building and various teaching facilities and a sports hall in NTU. Another is the Samwoh Eco-Green Building which is the first-of-its-kind in the region to be constructed using structural concrete with up to 100% Recycled Concrete Aggregate (RCA). A smart LED Lighting system which was piloted at ZEB at BCA Academy, has since been implemented in several commercial buildings in Singapore.

But there is a lot more to be done. To raise the performance of the Built Environment, it is essential to push for more R&D projects to be testbedded or demonstrated in actual projects to increase the likelihood of new technologies / solutions being proliferated in the industry and translated into commercial use. BCA will continue to place emphasis on the involvement of industry partners in its grant calls for research proposals. We will deepen our engagement with other government agencies, industry firms and academia to translate more research and innovation into the Built Environment sector. New industry-centric R&D strategies will also be put in place to encourage R&D by the industry for the industry. This includes setting up joint laboratories or Centres of Excellence between industry and academia. We will also explore consortium-based¹ research projects with early key stakeholders' involvement.

With so much exciting plans and developments ahead, let us continue to work together on this journey towards transforming the Built Environment sector through research and innovation.

¹ A consortium-based approach is an association of two or more companies, organisations, academia or governments (or any combination of these entities) with the objective of participating in a common activity or pooling their resources for achieving a common R&D goal.

TECHNOLOGY TRANSLATIONAL LEVEL

In order to assess the technology readiness level of completed Research and Development (R&D) projects, the Building and Construction Authority (BCA) classifies the technologies / solutions into four categories:

PATENT



R&D projects resulted in the Patents developed by the Principal Investigators or Host Institutes.

PROTOTYPE DEVELOPMENT & LICENSING



R&D projects resulted in the following:

- Development of a working laboratory scale prototype which has yet to be tested in an actual working environment.
- Technology being licensed to companies.

DEMONSTRATION IN ACTUAL OPERATION ENVIRONMENT



R&D projects resulted in the application of technology in an actual working environment.

WIDER INDUSTRY ADOPTION AND CODE IMPLEMENTATION



R&D projects resulted in the adoption of the developed technology by industry and lead to changes / recommendations made to Building Code or Code of Practices.

CHAPTER 3

New Testbedding Platform



BCA SkyLab



BCA SkyLab is **the world's first high-rise rotatable laboratory for the tropics**. This highly calibrated facility is developed to study the performance of individual technology or inter-dependency of innovative building systems and effective controls. Taking reference from Lawrence Berkeley National Laboratory's FLEXLAB initiative, BCA SkyLab features a rotatable laboratory simulating an office environment with flexible plug 'n' play configuration to facilitate testbedding of emerging green building technologies. The objective of BCA SkyLab is to accelerate the pace of research, development and deployment of energy efficient technologies, exemplifying Singapore's ambition towards being a global leader in Green Buildings for the tropics and sub-tropics.



BCA SkyLab

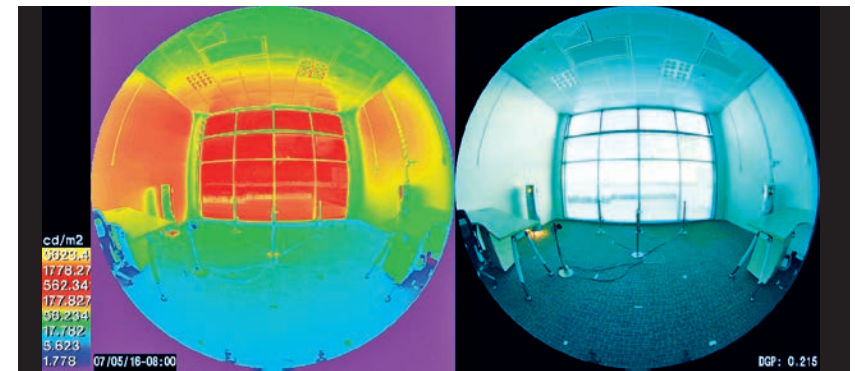
BCA SkyLab is an outdoor testbed for technology testing under real world conditions. It is capable of rotating 360 degrees to enable the energy and indoor environmental performance study at different orientations relative to the sun or building of interest where the tested technologies may be deployed. The test facility is fully equipped with more than 200 high precision laboratory grade sensors in its two identical compartments (test cell and reference cell). This allows comparative and benchmark analysis with reference to codes and standards such as the BCA Green Mark Scheme.



Test Cells



BCA SkyLab is open to researchers and the industry stakeholders to carry out testing for their research, development and deployment of innovative technologies. It is ideal for the industry, including developers, designers and technology suppliers, to gain insights and confidence before adopting new technologies so as to reduce the risk of failure which could result in economical loss and cause inconvenience to the building occupants.

Since its completion in March 2016, BCA SkyLab has embarked on a study of four emerging technologies, i.e. automated blinds, chilled beam, brushless DC motor FCU, and thermo-chromic glass. In the first testing of the integration of the auto-dimming lighting system with automated reflective blinds, it is found that this integrated system effectively eliminates the glare discomfort and is also able to achieve lighting energy saving of more than 70% in our tropical climate.



Thermal Imaging

FUTURE TESTING OF TECHNOLOGIES

-  **Low Energy Lighting Technologies**
(e.g. smart lighting system, extra low voltage lighting, dimmable ballast, addressable lighting)
-  **Air-Conditioning or Cooling Technologies**
(e.g. passive and active chilled beams, radiant ceiling / floor, displacement ventilation, UnderFloor Air-Distribution (UFAD), decoupled cooling and dehumidification)
-  **Facade, Envelope and Solar Shading**
(e.g. thermo-chromic / electro-chromic / photo-chromic glass, heat reflective coating / paint, dynamic facade, automatic solar shading device)
-  **Building Control Strategies**
(e.g. wireless sensing system, self-learning and calibration sensor, fault-detection and diagnostics, adaptive and predictive control)



For more information, please contact:

 Ms Alice Goh

 alice_goh@bca.gov.sg

 Building and Construction Authority

Centre for Lean and Virtual Construction (CLVC)



Centre for Lean and Virtual Construction (CLVC) is a new million-dollar facility that fosters communication and effective collaboration among stakeholders in a construction project to improve their work efficiency. The centre is first-of-its-kind in Singapore for the Built Environment sector and is equipped with an array of latest three-dimensional (3D) immersive technologies and Building Information Modelling (BIM) software for Virtual Design and Construction (VDC) with a special focus on Lean Construction. It aims to gear the industry towards both mind-set change and process change based on the concepts of Lean and Virtual Construction, leading to increase in productivity. With industry firms sponsoring most of the software components, it is also the first large-scale fully immersive and experiential learning facility for VDC in Southeast Asia.



Visit by Prime Minister Lee Hsien Loong

With the use of advanced technology, both industry and academia get to try out the concepts, technologies and tools, without having to expense the associated large initial outlays. The centre will continually import, showcase, and experiment with the state-of-the-art solutions and tools through partnerships and sponsorships.



Visit by Finland Delegates



For more information, please contact:

Mr Jusuf Anggono

jusuf_anggono@bca.gov.sg

Building and Construction Authority

CHAPTER 4

Future Office



ZEB Plus: Enhancement of ZEB at BCA Academy



The Zero Energy Building (ZEB) at BCA Academy was unveiled in 2009. In the last seven years, the building has maintained its status as a net zero energy building, generating more electricity than it consumes with an average of 8% surplus over the years. To ensure that the building continues to live up to its name and contribute to BCA's vision of Positive Energy Low-rise Buildings, ZEB will undergo an enhancement in 2017-2018. With the enhancement, ZEB will be renamed as ZEB Plus.



Preliminary Layout & Concept



Photovoltaic Technology at the External Facade of ZEB

ZEB PLUS

ZEB Plus will house new office spaces in Levels One and Two and a revamped ZEB Visitor Gallery in Level Three. In addition, enhancement works will be carried out on the Building Management System, and the air-conditioning system at CLVC. The solar photovoltaic panels are also slated for replacement. More efficient modules will be installed, while existing panels will be relocated to neighbouring rooftops to maximise their useful lifespans.

The office spaces are envisioned to be adaptable, smart, biophilic, and healthy. Through collaborative design with office users, the “Office of the Future” will be an exemplary model for the design of new office spaces in the public sector and beyond.

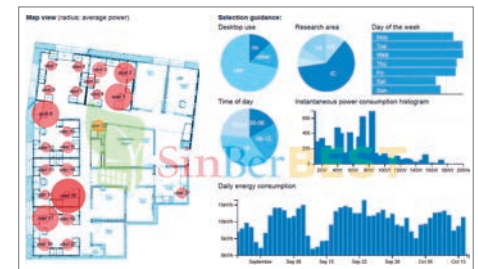


Four Key Features to be Implemented in ZEB Plus

The main research collaborator for this project is the Singapore-Berkeley Building Efficiency and Sustainability in the Tropics (SinBerBEST), a research programme funded by NRF and Sanken Setsubi Kogyo Co., Ltd (Sanken), a Japanese based M&E Contractor with strong R&D capabilities. Together with other technology providers, ZEB Plus will play host to more than 20 novel technologies and strategies to spur the translation of R&D products into the green building industry.

DEMONSTRATION PLATFORM

The technologies and strategies implemented in ZEB Plus are expected to contribute to BCA's long term aspiration to achieve “Positive Energy Low-rise, Zero Energy Mid-rise and Super Low Energy High-rise Buildings in the Tropics”.



Example Monitoring & User Setting Features

With thousands of visitors annually from industry, academia, governments and educational institutions, both international and local, ZEB Plus is an ideal platform to disseminate best practices and innovative technologies for wider adoption.

Results from the deployment at ZEB Plus will also serve as feedback to SinBerBEST and other collaborators before they commercialise their technologies and strategies for wider adoption.



Example of Technology Deployment



For more information, please contact:

Mr Majid Sapar

majid_sapar@bca.gov.sg

Building and Construction Authority

CHAPTER 5

Technology Integration



Net Zero Energy Building (NZEB@SDE)



The new Net Zero Energy Building (NZEB@SDE) at the School of Design and Environment (SDE), National University of Singapore (NUS) is the first purpose-built net zero energy building commissioned by a Singapore tertiary institution. It will make the case – through design and, eventually, operations – that stringent energy targets for Singapore buildings are not only possible, but are also necessary and can lead to an architecture of delight. The search for a high comfort, biophilic experience is not at odds with energy targets. Indeed the two are synergistic. The integration of renewable energy technologies such as solar photovoltaics, in meaningful and pleasing ways, can lead to new forms and expressions of climatic response.

ENERGY AND COMFORT

To generate power from the sun, NZEB@SDE relies on an array of solar photovoltaic (PV) panels on its roof. The project team began by maximising the number and efficiency of the solar PV. They then set about minimising energy demand, getting it to work within budget, and optimising every appliance and system within the building.

TROPICAL ARCHITECTURE

NZEB@SDE deploys a slew of climatic strategies. The large overhanging roof of NZEB@SDE, for instance, or the double facades on East and West elevations, can trim the incident solar load that might otherwise warm its interior, contributing to cooling load. The building's southern exposure offers views and draws in daylight. Envelope glazing is amply shaded with glare-reducing and light-redirecting lamellas that reflect daylight deeper into teaching spaces. Air-conditioning is used only where it is needed. Rooms can be opened to prevailing breezes, weather permitting. The spaces between these cooled rooms are naturally ventilated, acting as thermal buffers and social spaces, much like the traditional verandah.



Social Plaza



Learning Studio

INTEGRATED DESIGN PROCESS

The design process of NZEB@SDE is unusual in the way that it was structured. This had its roots in the design brief that made explicit both performance targets and project aspirations.

This brief set into motion a new kind of process in which the project team came together to define approach and align viewpoints. These meetings – design charrettes – punctuated the timeline. Seven day-long charrettes were held at which the project team, sitting with building users, facility managers and a panel of SDE experts, reviewed approaches and outcomes.

These meetings, in one respect, focused on building systems and features. But they were also about team-building. What emerged was not just a better building, but also a cohesive and collaborative team whose members had learnt to communicate with each other, and learnt to resolve conflicts.

INNOVATIVE COOLING SYSTEM

Critical to the designing of NZEB@SDE was a rethink of air-conditioning – typically the biggest consumer in Singapore buildings – which resulted in the design of an innovative hybrid cooling system. This system supplies rooms with cool air – albeit at higher temperature and humidity levels than a conventional system – and augments this with elevated air speeds from ceiling fans. The cool, moving air creates comfort mode that is significantly better than the over-cooled rooms currently experienced in SDE.



South Facade

LIVING LABORATORY

NZEB@SDE will add to an existing configuration of three building blocks at SDE. It will house teaching and research facilities – design studios, laboratories, workshops, testbedding facade, a 3D Scanning Laboratory, the NUS-JTC Industrial Infrastructure Innovation (I³) Centre, the NUS-CDL Smart Green Home – functioning as a living laboratory that promotes research collaboration with public agencies and industry partners.



For more information, please contact:

Dr Nirmal Kishnani

akintk@nus.edu.sg

National University of Singapore

3for2 @ UWCSEA



The 3for2 is a concept developed by ETH Zurich under the Future Cities Laboratory at CREATE. This applies to commercial buildings where ceiling plenum spaces can be reduced by integrating ducting works into the floor slabs, thereby reducing the floor to ceiling height for each floor, resulting in more floors to be created with the same building height. Conceptually, for every two conventional office floors, you can create three floors by adopting the 3for2 technology.



3for2 @ UWCSEA

DEMONSTRATION PLATFORM

Early benchmarking of the 3for2's Energy Use Intensity (EUI) as compared to the top performing office buildings in Singapore shows 71kWh/m²/year for the former as against 112kWh/m²/year for the latter. ETH-Zurich has plans to make further improvements to EUI with the introduction of a low-lift chiller to provide higher temperature chilled water supply, tuning of dehumidification system and refinement and optimisation of 3for2 building control in order to achieve a target of 42.6kWh/m²/year (40% improvement).

This project also showcases UWCSEA as a research platform where 1350+ data streams from sensors, actuators and BMS settings are collected in one-minute intervals, resulting in more than 700 million measurements per year. This BIG DATA is useful to the facilities management team to understand usage patterns and make adjustments for further energy savings.



For more information, please contact:

Mr Simon Thomas

simon@uwcsea.edu.sg

United World College of South East Asia

CHAPTER 6

Positive Energy School



Positive Energy School:

Creating a Conducive and Sustainable Learning Environment for the Future



The aim of this project is to enable school to tap on the use of renewable energy and energy efficient innovations to achieve positive energy status. This means a school can produce more renewable energy than it consumes on an annual basis.

Specific focus has been placed on reducing solar heat gain, improving thermal comfort, raising energy efficiency, and applying solar photovoltaic technologies. The team has also carried out studies on solar shading optimisation, air flow enhancement, heat reflection, greenery integration, and utilisation of solar energy through the SolarNova programme. These green building technologies, when implemented in schools will give opportunities for our coming generation to learn about the science and techniques of sustainable building using dedicated information sharing and interactive features.

The push towards Positive Energy School will not only make schools more energy self-sufficient but also helps to position Singapore as a regional leader in championing green buildings.

RESEARCH OUTCOMES

Researchers and engineers are carrying out further analysis and optimisation of the technologies identified through the field tests and technology review. Comprehensive energy modelling of generic schools (one primary school and one secondary school) will be established and calibrated with field measurements to ensure that progress towards the target of Positive Energy School is on track. In addition, various passive and active solutions such as sunshades, verticals fins, and energy efficient ceiling fans for better ventilation are being considered.



Industry Consultation Sessions



For more information, please contact:

Mr Selvam Valliappan selvam_valliappan@bca.gov.sg

Building and Construction Authority

CHAPTER 7

JTC LaunchPad



Block 81 of JTC LaunchPad @ One-North

Optimising for Mass Engineered Timber (MET)



For tropical Mass Engineered Timber (MET) structure, the lack of acceptable solutions make developers, industry, regulators and engineers uneasy in adopting MET. In addition, they also need to consider escalating costs and timeframe for earmarked projects. Venturer Pte Ltd uses its completed project at Block 81 of JTC LaunchPad @ one-north as an example to evaluate and reconsider efficient detailing and methodologies in order to enhance future commercialisation and implementation of Cross-Laminated Timber (CLT) and Glued-laminated timber (Glulam).

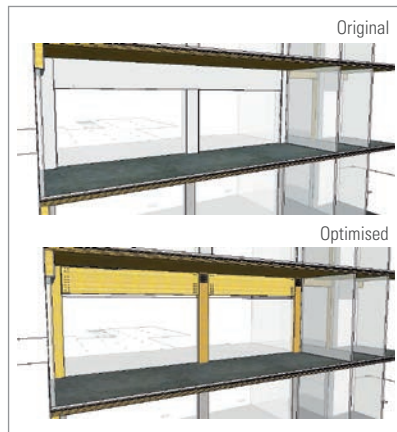


JTC LaunchPad (image courtesy of JTC)

FIRE COMPARTMENT

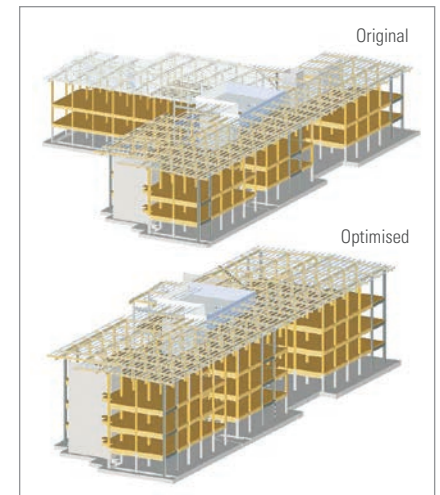
The original timber structure is designed to be covered with an accredited fireboard system. In the optimised solution, the fireboard is omitted and the timber structure, except at connections, is used as an integral part of the compartment wall. In line with published requirements, full scale system tests were executed to prove its efficacy. There are practical, economical and aesthetic advantages of exposing the beam.

Manpower saved: **10%**



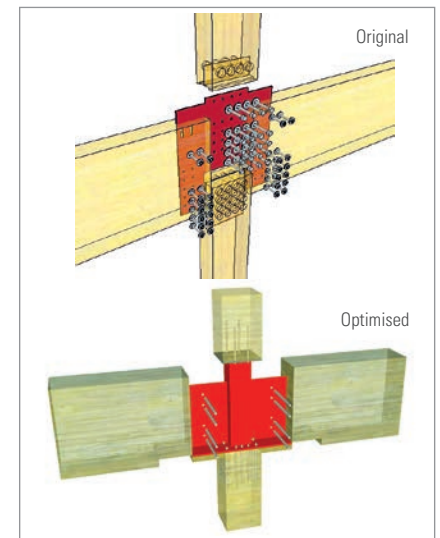
HYBRID DESIGN

The original layout consists of a three-phase construction, in which each phase has three storeys. The optimised solution consists of only two phases, uses lesser steel (roofing and connections), fewer concrete amount (slab level) and requires lesser manpower. By using MET components, the optimised solution has four storeys, with the same ground loading and Gross Floor Area (GFA). The optimised solution provides no additional ground loading, which will not affect the MRT tunnel under the building.



NEXT GENERATION CONNECTIONS

The original connection design includes steel plate and dowels. The optimised connection design consists of steel bearing plate and glued-in rods. By using embedded and concealed connections in the optimised solution, there could be savings in manpower and steel costs.



POTENTIAL APPLICATIONS

The project has helped to lower the perceived risk of adopting MET by demonstrating the benefits of design and build of MET structures.



For more information, please contact:

Mr Joseph M. Sayre

joseph@venturer.biz

Venturer Pte Ltd



Craftsmanship has inspired me into my field of expertise. I have always appreciated not only the finished product created by a craftsman, but also the process itself. Before planning large timber structures, I was a shipwright where I built and restored historic wooden boats and traditional timber-frame buildings. Today, even though I personally create lesser sawdust than I did then, I try to bring the same level of craftsmanship to my job and continue on my path toward mastery.

At Venturer, we have worked hard to create a very positive and cohesive team including not only our staff, but all of our regular partners as well. We accept each other's strengths and weaknesses, communicate openly and bring a good attitude to our work. We motivate each other to do good work and can count on each other to let us know if we need to do better.

My aspiration for the future Built Environment would be wanting to see more timber buildings, but there is a specific construction which is easy, economical, and still has not been done in Singapore: Timber and Glass Curtain wall. Of course, most curtain wall systems are specified and built with an aluminium framework. However, based on the amount of curtain wall in Singapore, the high embedded carbon in aluminium versus the carbon negative nature of timber, this single application of timber could have a larger impact on the sustainability than dozens of completely CLT buildings.

Mr Joseph M. Sayre

Technical Director, Venturer Pte Ltd

CHAPTER 8

Eco-Green Building



Use of Recycled Concrete Aggregate (RCA) for Structural Concrete



The project evaluates the use of Recycled Concrete Aggregate (RCA) in structural concrete for building construction. RCA is derived from the processing of Construction and Demolition (C&D) waste. There has been much scepticism on the use of RCA as most literatures reported that it has adverse effects on concrete properties. As such, its applications were limited to non-structural applications prior to this research project. Extensive laboratory testings were conducted to evaluate the engineering and durability properties of concrete containing RCA (RCA concrete). Using a three-pronged approach, with emphasis on processing of C&D waste, quality control of RCA and mix design method, RCA was effectively incorporated in concrete. RCA concrete was found to achieve comparable performance against conventional concrete mix containing natural aggregate.



Samwoh Eco-Building



Samwoh's Batching Plant

POTENTIAL APPLICATIONS

The three-storey Samwoh Eco-Green building, first in the region to be constructed using up to 100% RCA, has built confidence in the use of RCA concrete. This is a technology breakthrough in the construction industry and has demonstrated the feasibility of RCA concrete for structural applications. BCA has allowed the use of up to 20% RCA to replace coarse natural aggregate for the production of structural grade concrete and RCA concrete has also been accepted in the Green Mark Assessments for New Residential and Non-Residential Buildings.



Recycled Concrete Aggregate



For more information, please contact:

Mr Lim Wee Fong

weefong.lim@samwoh.com.sg

Samwoh Corporation Pte Ltd



"According to NEA's statistics, the amount of C&D waste generated every year has always been one of the highest. The disposal has posed great pressure on our limited land space. Moreover, there is a strong reliance on imported natural aggregates to fuel the construction industry and the cost has been rising over the years. We envisage that this challenge will escalate to a new magnitude if the situation continues at current pace. As such, Samwoh has started recycling C&D waste since early 2000 as we envisaged that the recycled C&D waste is able to provide an alternative source of material for the nation.

The research team comprises experienced researchers, engineers and academics specialising in civil engineering and concrete technology. A special laboratory test equipment was developed to evaluate the creep or long-term deformation properties of concrete, providing a comprehensive evaluation of the long-term performance of concrete containing RCA. Through extensive laboratory tests, a rational mix design method was developed to show that the use of RCA in concrete is able to provide comparable performance to conventional concrete containing natural aggregate. This led to the construction of Samwoh Eco-Green Building, a three-storey office building using up to 100% RCA in concrete. The building has also been awarded with many prestigious accolades which include the Top 50 Engineering Feats 2016 @ IES-SG50, ASEAN Outstanding Engineering Achievement Awards 2015, etc.

Though the Built Environment has improved tremendously over the years, we believe that the use of innovative and productive technologies can further enhance and inject a new lease of life in the future Built Environment. With these collective efforts, we are confident that the industry will embrace the idea of sustainable construction and consumers will be more receptive towards environmental sustainability. Eventually, Singapore can become a truly zero-waste nation while shaping into an active and gracious community supported by a leading green economy."

Samwoh Research Team

Samwoh Corporation Pte Ltd

CHAPTER 9

Industry-Centric Innovation



CHAPTER 9.1

Air-Conditioning and Mechanical Ventilation (ACMV) and Indoor Air Quality (IAQ)



Desiccant and Nano-Woven Membrane Air Dehumidification



Conventional air-conditioning system cools the outdoor air below the required indoor air temperature in order to sufficiently remove moisture to a comfortable level and then reheats the air to prevent over-cooling, thus consuming more energy in the process.

This project looked at developing a hybrid air-conditioning solution that comprises of a novel composite desiccant (Fig. 1) and a nano-woven membrane (Fig. 2) to effectively remove moisture from the outside air with minimal energy, before cooling the air to the required temperature without the need to reheat.

This process of separating the removal of latent load from sensible load reduces energy required for cooling the buildings by up to 40%.

POTENTIAL APPLICATIONS

The hybrid air dehumidifier can be incorporated into existing air-conditioning system to reduce its overall energy consumption significantly.

The technology is currently being licensed to Memcond Pte Ltd for further development and actual testbedding on site.

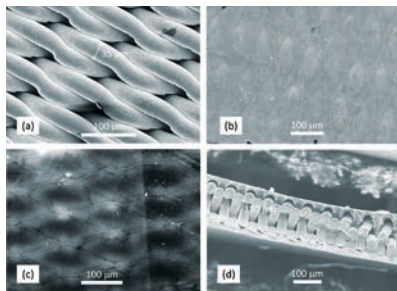


Fig. 2 Nano-woven Membrane



Fig. 1 Composite Desiccant

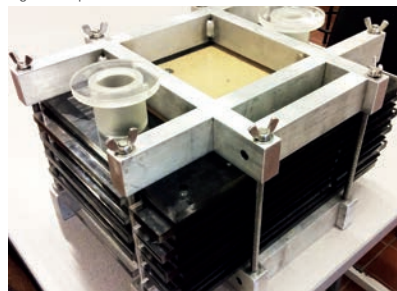


Fig.3 Desiccant and Nano-woven Membrane Air Dehumidifier Prototype



For more information, please contact:

Associate Professor Ernest Chua mpeckje@nus.edu.sg National University of Singapore



"Since young, I aspire to be researcher as I can continuously search for new innovative yet pragmatic solutions to today's problems in Built Environment. My research focuses on new technologies and improving existing technologies to reduce energy consumption in buildings while improving their performance. From air-conditioning to indoor air quality, today's buildings are more complex than they have ever been. This complexity has presented my team and I with new impetus to evolve game-changing solutions for buildings in making them healthier and smarter while consuming lesser energy.

Any research dream comes along with its challenges. The bigger the dream, the tougher the challenges. When my team and I are faced with challenges, we will spend hours brainstorming ideas to generate solutions. We then proceed to the lab to test out these new ideas and their impact in addressing these challenges. We strongly believe that the courage and persistence to keep innovating, in the face of new obstacles, is powered by our common research dream of developing game-changing solutions for modern-day buildings.

Ultimately, I believe that the future Built Environment is one that is smart, resilient, sustainable, exciting and healthy. I believe that the collective efforts of researchers will progressively but surely enable us to reach our desired future Built Environment."

Associate Professor Ernest Chua

Principal Investigator,

School of Mechanical Engineering, National University of Singapore

Functionalised Aerogel for Treatment of Indoor Moisture and Air Contaminants (FATIMAC)



The indoor air quality of air-conditioned buildings is important as we spend a substantial amount of time in the indoor environment.

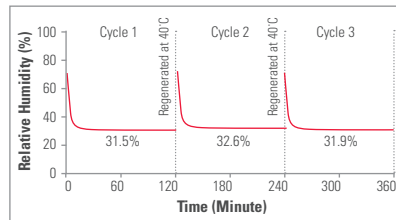
This project looked at developing low-cost and safe nano-materials that are well-suited for hybrid air dehumidification and purification to improve the indoor environmental quality and at the same time achieve a more energy efficient air-conditioning system in buildings.

The novel desiccant material with high moisture uptake and low regeneration temperature improves humidity comfort level and coupled with nanostructured CuO-TiO_2 , the material improves indoor air quality by photo-degradation of Volatile Organic Compounds (VOCs) in the air.

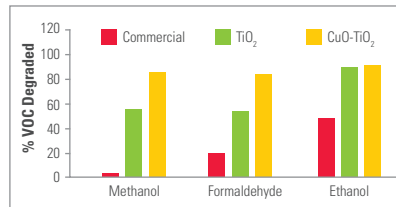
The technology is envisaged to reduce energy usage of an air-conditioning system by up to 40%.

POTENTIAL APPLICATIONS

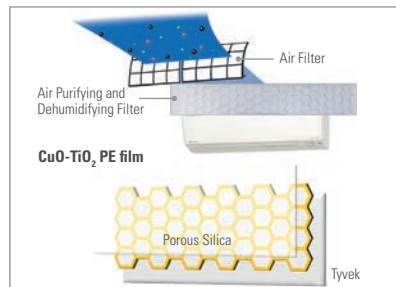
The materials can be incorporated into the existing air handling unit or fan coil unit to improve the indoor air quality.



Reduction in Indoor Relative Humidity over Time using a Desiccant Material



Effectiveness of CuO-TiO_2 in Removing VOCs as Compared to Other Commercially Available Products



Prototype of Filter Cartridge to be Inserted in Fan Coil Unit



For more information, please contact:

Dr Ho Ghim Wei

elehgw@nus.edu.sg

National University of Singapore

CHAPTER 9.2

Building Management and Information Systems (BMIS)



Circuit-Level Electricity Metering and Analytics for Buildings



Ampotech Pte Ltd is developing and piloting a non-invasive circuit-level electricity submetering technology that enables the collection of highly-granular data about electricity use for the spaces and equipment in a building. The project is a translational effort to commercialise intellectual property developed by one of Ampotech's founders in a Singapore-based research institute. The project focuses on enhancing the hardware, software, and installation process for the electricity use monitoring system, which is called AmpoSense. In 2015, Ampotech created a first-generation AmpoSense solution with hardware and cloud-based software in a pilot deployment at a Singapore-based electronics manufacturer, which identified possible mitigating measures to achieve over 10% potential energy savings. Subsequently, Ampotech developed and deployed a second-generation system with two commercial property developers in Singapore. These projects focus on identifying and quantifying energy saving opportunities in an office environment and creating APIs for third parties to display and use the data.

POTENTIAL APPLICATIONS

The project will see the development of a third-generation prototype hardware and will pilot in four building sites in Singapore, covering over 4,500 sqm.



Pilot Prototype Hardware

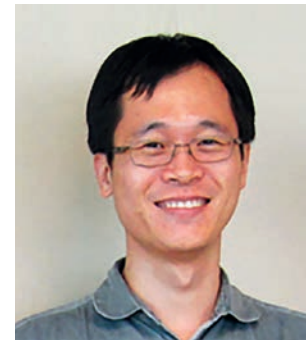


For more information, please contact:

Mr William Temple

william@ampotech.com

Ampotech Pte Ltd



"I started working on smart grids and smart building technologies from around 2011, when I saw great potential of such technologies to enable a more sustainable future. My invention of the non-invasive energy monitoring technology is directly motivated by first-hand experience in using some electricity sub-metering devices available at that time, which were difficult to install and too expensive for wide adoption. I saw that the lack of good tools made it very difficult for users to understand and manage their electricity usage.

While Ampotech is making good progress in developing innovative electricity monitoring solutions, one challenge the team faces is that many customers do not give a high priority to electricity saving, nor do they fully understand the additional value they may get from detailed observation and analysis of their electricity usage patterns. We believe this will change soon, when early adopters of smart building technologies begin to quantify their benefits and share their experiences with the community."

Dr Chen Binbin

Co-Founder, Director of Ampotech Pte Ltd
Senior Research Scientist,
Advanced Digital Sciences Centre



"I've always been interested in taking on challenging, socially-significant engineering problems. As an undergraduate mechanical engineering student, I originally planned to enter the aerospace industry, and I even spent a year as an intern with the operations team for one of NASA's satellite observatories. However, towards the end of my studies, I became interested in energy and the transition to renewables, and opted to pursue a Master's degree studying electric power grids and how wind power and electric vehicles could be integrated into the future smart grid. After moving to Singapore in 2011, I was introduced to building energy systems as an ACMV design engineer. It was this experience and a resulting appreciation for challenges faced in building services that led me to co-found Ampotech with research centre colleague Dr Chen in late 2014 after seeing the breakthrough potential of his non-invasive sensing technology."

Mr William Temple

Co-Founder, Director of Ampotech Pte Ltd

Smart Building Analytics



The project involves establishing a Smart Building analytical system to optimise building operations in areas including energy and water usage, maintenance and security. This can be achieved through a centralised integrated system comprising Equipment Analytics (EA) and Video Analytics (VA). The Proof-Of-Concept (POC) has been established by adopting EA that utilises fault detection and diagnosis to identify faults and anomalies that were previously left unnoticed by existing Building Management Systems.

Through the use of the rule-based VA, the productivity and response time of security teams improved as they were able to view real-time video footages of incidents and take immediate actions when they were alerted to incidents through SMS and email simultaneously. These contributed to an estimated annual energy savings of 8.5% from air-conditioning systems and 3.5 man hours per day saved on patrolling.



For more information, please contact:

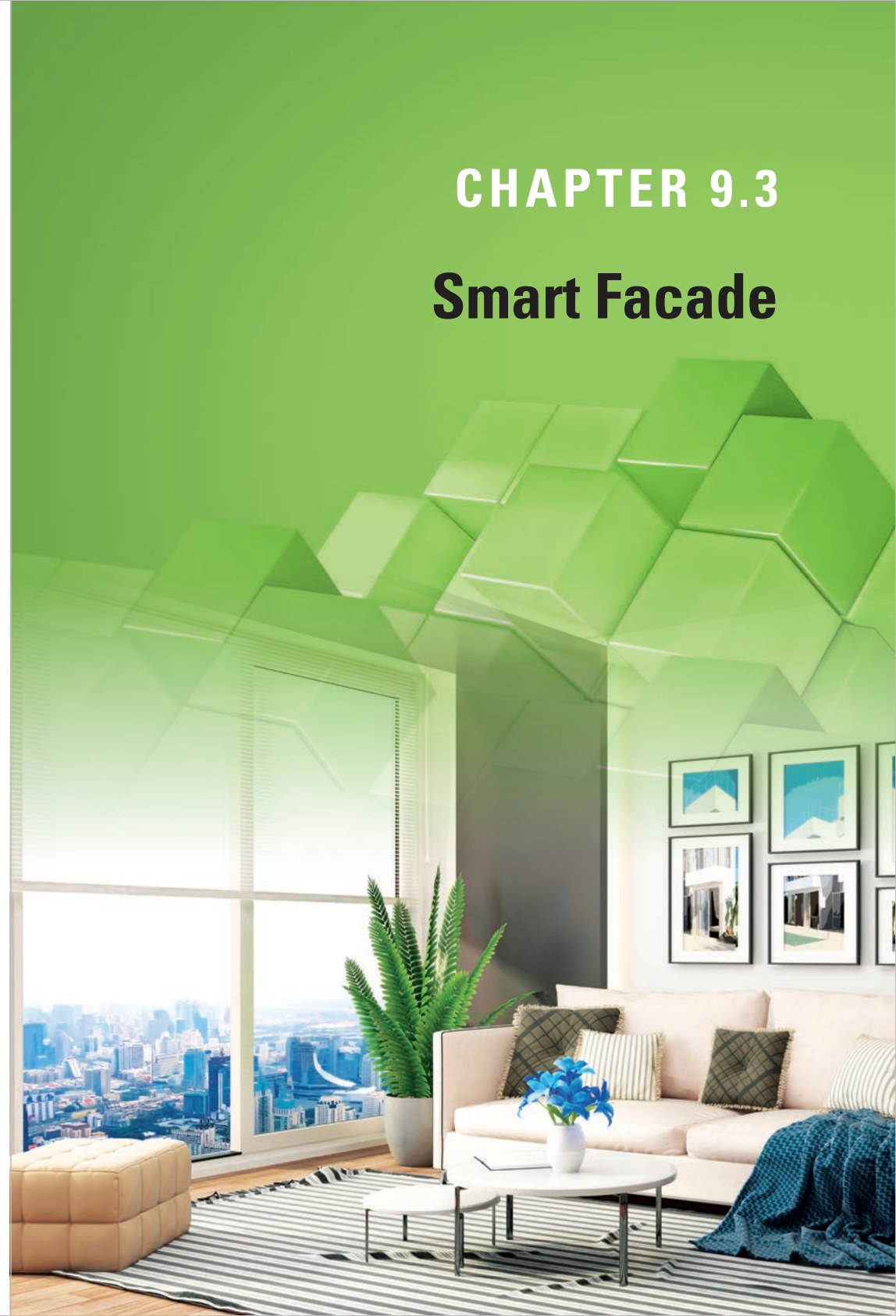
Mr Adrian Ting

adrian.ting@capitaland.com

CapitaLand Limited

CHAPTER 9.3

Smart Facade



Cool Paint Incorporating Phase Change Material for Buildings in the Tropics



In tropical climate, using passive strategies are important for reducing energy usage in the buildings.

This project looked at developing a cool coloured coating system (Fig. 1) comprising a cool coloured top coat that serves as first protection to reflect solar radiation and a thin layer of Phase Change Material (PCM) as second layer of protection to absorb the conductive heat from entering the buildings.

This technology is able to reduce building cooling energy by as much as 12%.

POTENTIAL APPLICATIONS

The cool paint can be applied to both new and existing building surfaces including horizontal surfaces (e.g. roof) and vertical surfaces (e.g. facades).

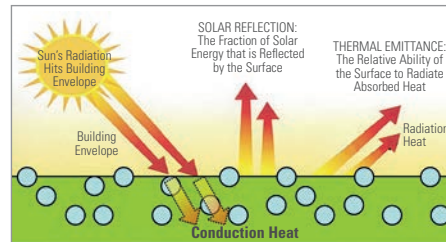


Fig. 1 Cool Coloured Coating System

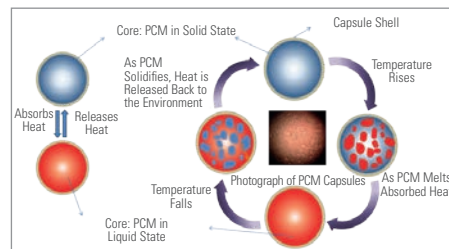


Fig. 2 How PCM Microcapsule works

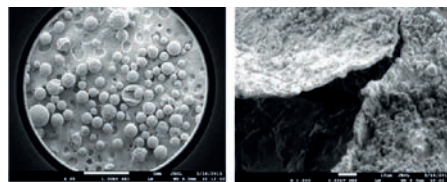


Fig. 3 PCM Microcapsules with Inorganic Shell



For more information, please contact:

Dr Yang En-Hua

ehyang@ntu.edu.sg

Nanyang Technological University

Solar Control Smart Window for Tropical Buildings



A smart window will turn translucent to reduce daylight transmittance on bright days and turn clear on cloudy days to let more light in. This feature can help to maintain a more constant indoor temperature and prevent too much heat gain into the buildings.

This project looked at enhancing smart window performance by using transparent and clear photo-chromic coating to reduce visible light transmittance and infrared coating to reduce solar heat gain into the buildings. The infrared coating can reduce up to 80% solar heat gain while maintaining more than 80% visible light transmittance.

POTENTIAL APPLICATIONS

The solar control smart window can be applied to existing windows through stick-on applications.



For more information, please contact:

Dr Linda Wu Yongling

ylwu@SIMTech.a-star.edu.sg

A*STAR Singapore Institute of Manufacturing Technology

Heat Reflective Coating to Improve Thermal Performance of Window Frames

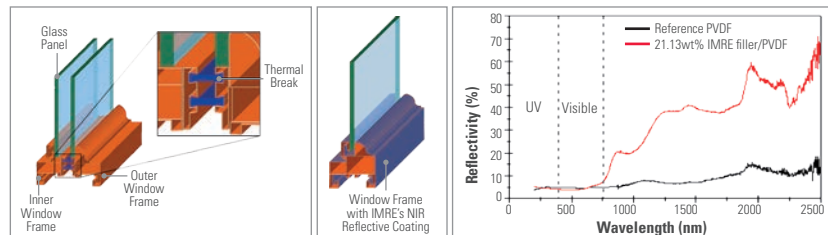


Heat reflective coatings have been used to coat on building surfaces and rooftops in order to enhance the thermal efficiency of the building. Heat reflective coatings in the market are primarily white or light-coloured and they function by reflecting Near-Infrared Radiation (NIR) from sunlight. However, white or light-coloured heat reflective coatings have also been known to reflect heat in a specular manner, which causes damage to adjacent structures and properties. Thermal breaks, which have been used in temperate countries to prevent heat loss from the building to the outside environment, would not be effective in tropical climates where heat is mainly transferred through radiation rather than just conduction.

Recognising the constraints of the thermal break system and lack of dark-coloured NIR reflective coating in the market, Positive Engineering and Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR) have developed the concept of using heat reflective coatings as a “thermal jacket” for metal structures. The project involves developing dark-coloured NIR reflective pigment that can be incorporated into epoxy, acrylic and PVDF-based paints for aluminium window frames. These coatings have been proven to reflect at least 20% NIR and some of them have achieved a good adhesion to aluminium even without priming. Further tests are ongoing to determine the durability and stability of the paints prior to being introduced to the market.

POTENTIAL APPLICATIONS

The coatings can be easily applied onto both new and existing metal structures, and in some cases without the need to strip the base paint. Apart from building facade, the paint can also potentially be used in automotive and logistics applications.



Conventional Thermal Break Approach

Positive Engineering Approach



For more information, please contact:

Mr Lin Wei Yang

wylin@positive.com.sg

Positive Engineering Pte Ltd

CHAPTER 9.4

Modelling Tools



Residential Auto-Designer

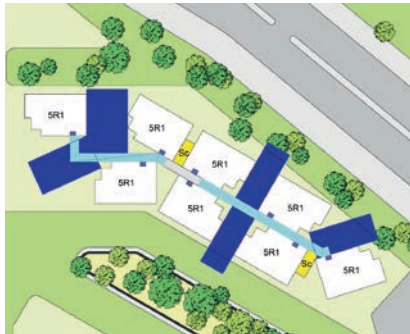


In the design of residential development, architects and engineers face multiple design requirements from the authorities, clients and fellow consultants. This challenge is exacerbated by the extreme shortness of time in which the design needs to be delivered. In response to this need, a model-based, computational approach is employed to develop a new tool to aid design productivity and precision.

POTENTIAL APPLICATIONS

The outcome is a housing auto-designer plugin that works with visual scripting software to optimise different clusters of design attributes that participate in each stage of the conceptual design.

We target a significant increase in design productivity and design precision to comply with requirements incorporated within the auto-designer. It is being beta-tested within Surbana Jurong now and we intend to monetize this project in one to two years.



Autofloor

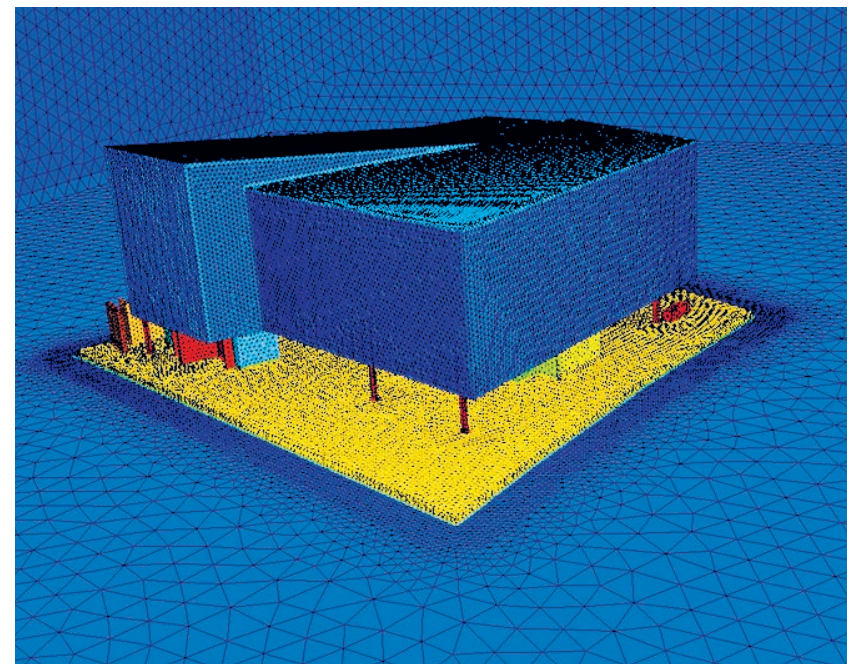


3D View

Development of Green Building Environment Simulation Technology (GrBEST)

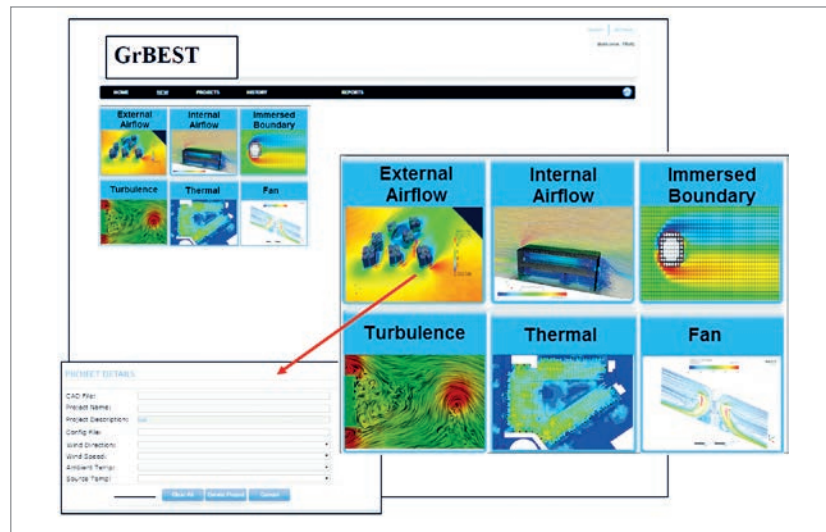
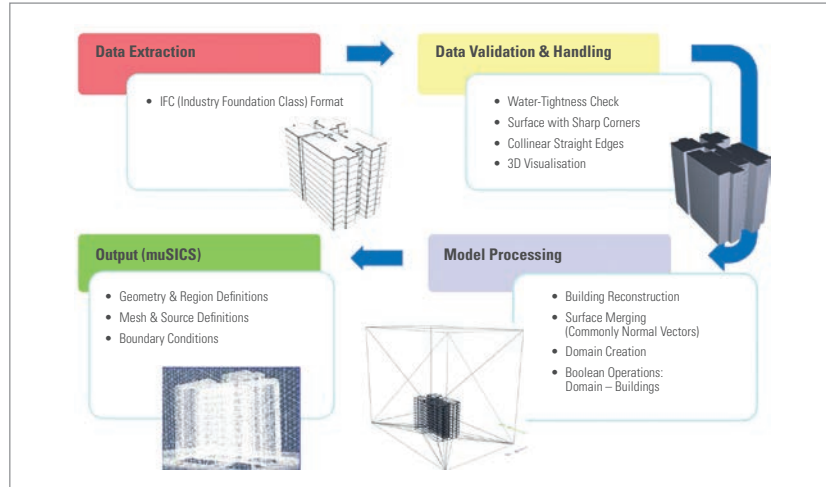


GrBEST has been developed as an easy-to-use and cost-effective natural ventilation simulation software for the building industry. As a design tool for architects, planners and engineers, it can also facilitate related Green Mark Computation Fluid Dynamic submission to BCA. The GrBEST enables green building industry practitioners, to perform air-flow simulation studies without utilising too much computation resources and time. This has shortened the time taken in optimising their design for natural ventilation in buildings.



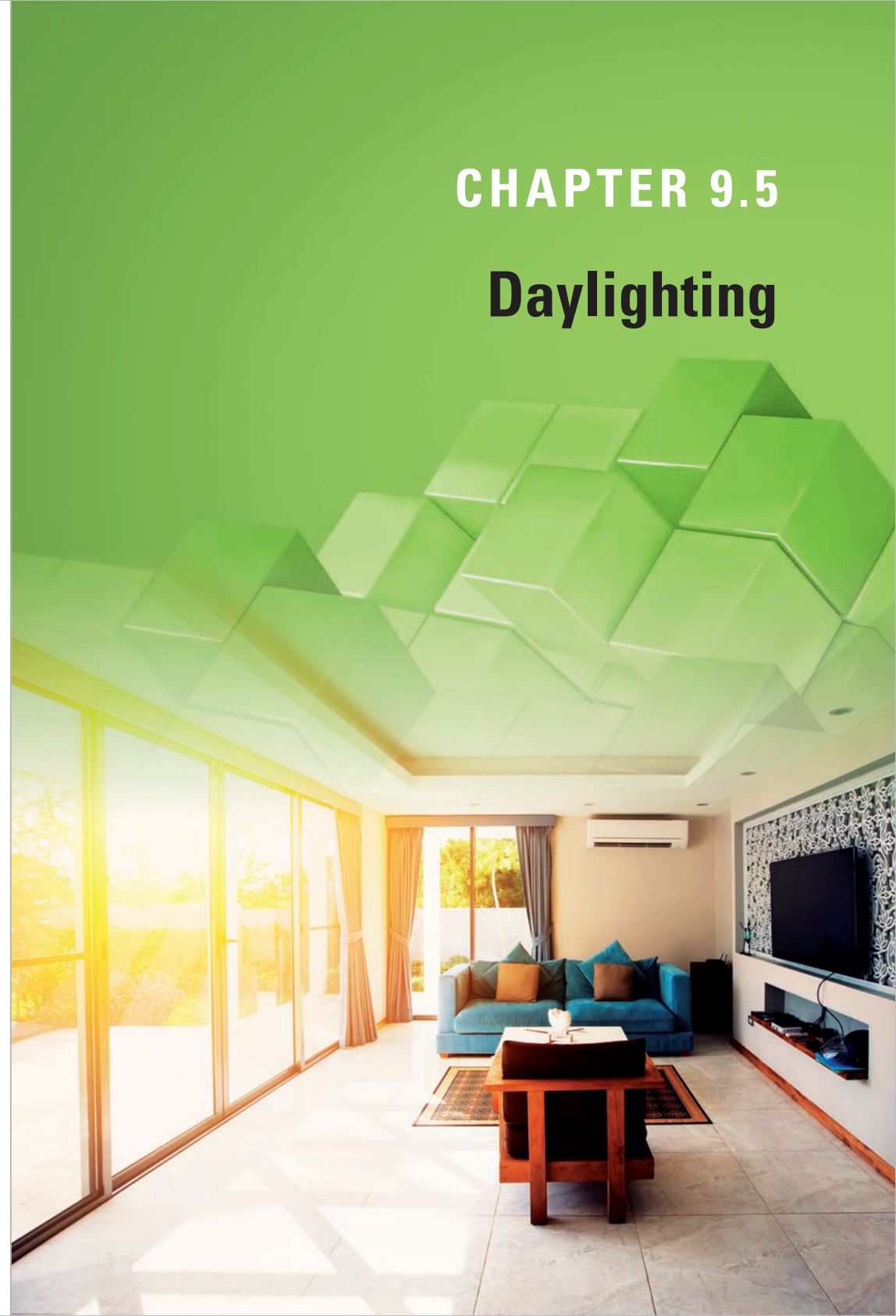
POTENTIAL APPLICATIONS

GrBEST can be deployed as a design and modelling tool for larger scale green building Research, Development and Deployment (RD&D) in Singapore.



CHAPTER 9.5

Daylighting



Daylighting in Singapore



The “Daylighting in Singapore” study aims to understand lighting preferences in Singapore to support the design of daylit buildings, reduce energy consumption, and improve connection to the outdoors. Through detailed measurements, subjective surveys, and calibrated annual lighting simulations, the project aims to identify meaningful lighting targets and visual discomfort metrics specifically for use in Singapore and tropical regions.

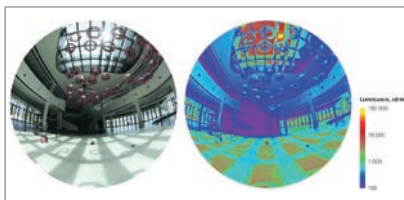
The project is broken into three phases:

- 1 Updating daylighting simulation standards for Green Mark (GM) versions 2015 and 2016
- 2 Pre-computing daylighting results for standard designs and communicating the results for GM application within 2015 and 2016 versions
- 3 Hosting collaborative three-day daylighting workshops for BCA staff and members of industry

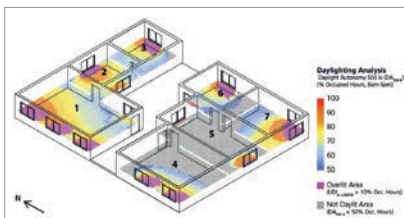
POTENTIAL APPLICATIONS

Design of better buildings through changes to the GM green building rating system.

Establishment of methodologies and evaluation criteria for use by designers and consulting engineers when predicting lighting performance of offices, buildings and residential homes in Singapore.



High Dynamic Range (HDR) Luminance Photograph of SUTD's Campus Centre



FLOOR	ROOM	Total Area (m ²)	Daylit Area (m ²)	Overlit Area (m ²)	Comfortable Daylit Area (m ²)	Overlit Area (%)	Comfortable Daylit Area (%)
1	1	72.1	72.1	11.4	60.7	15.8	84.1
1	2	26.5	26.5	2.5	24.0	9.3	90.7
1	3	24.5	23.6	3.5	20.1	14.1	82.1
1	4	60.1	27.6	6.1	21.5	10.2	35.7
1	5	55.6	8.4	1.1	7.3	2.0	13.1
1	6	29.3	20.7	3.9	16.8	13.2	57.3
1	7	33.0	30.2	4.5	25.7	13.6	77.8
TOTAL		301.1	137.0	33.0	115.4	11.0	38.3

An Example of New Climate-Based Daylight Simulation Criteria in GM 2015



For more information, please contact:

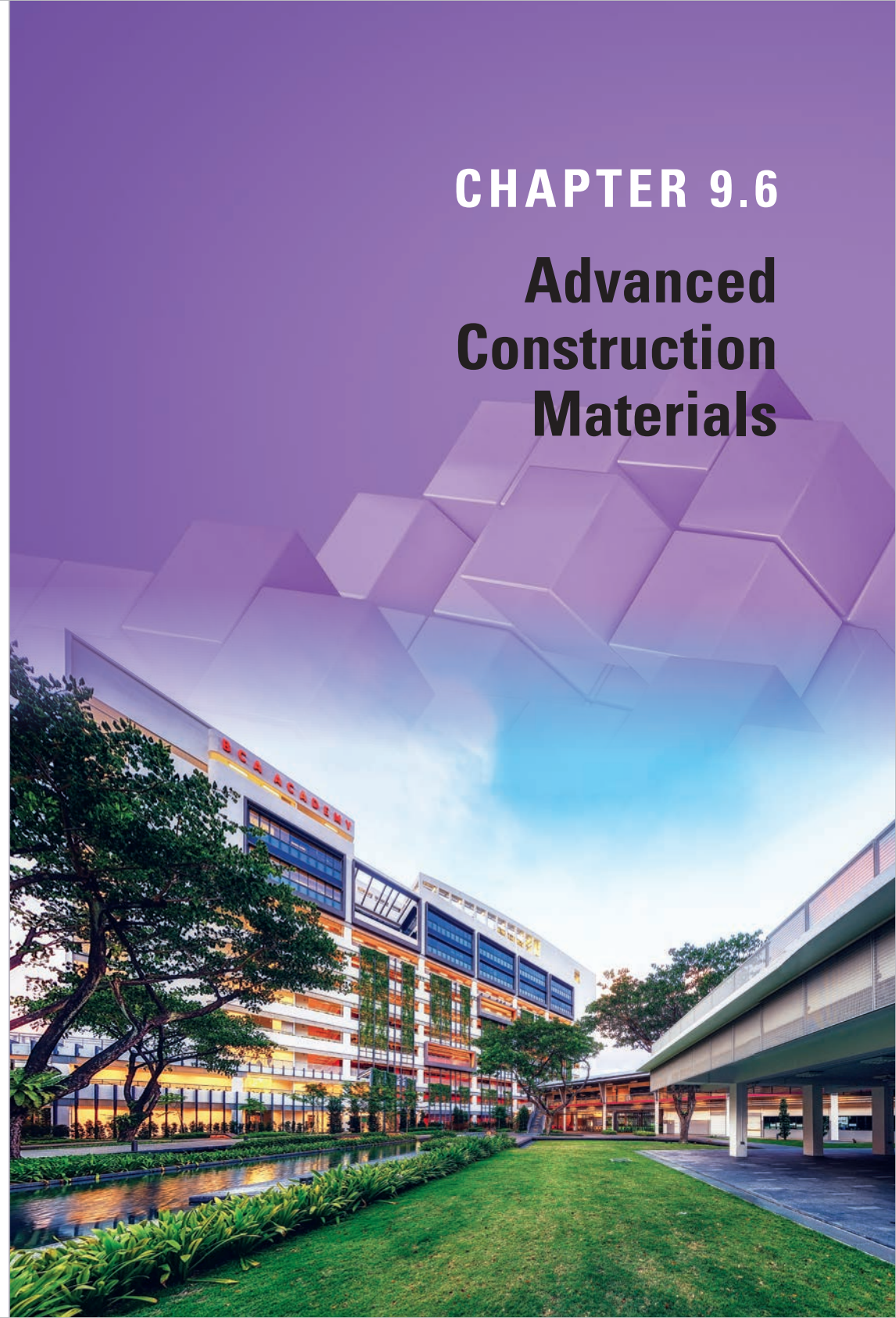
Dr J. Alstan Jakubiec

john_jakubiec@sutd.edu.sg

Singapore University of Technology and Design

CHAPTER 9.6

Advanced Construction Materials



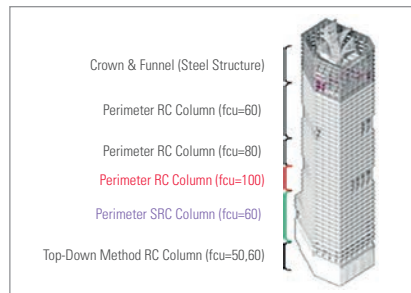
Design for High Strength Concrete



CapitaGreen is the first high-rise commercial building in Singapore to use G100 high strength for cast-in-situ columns and G100 / G80 high strength concrete for precast columns. The 40-storey Grade A office tower, located in the heart of Singapore's CBD, was designed by Pritzker Prize winner, Toyo Ito, and constructed by Takenaka Corporation. Its environmentally sustainable and inclusive design has garnered BCA's Green Mark Platinum and Universal Design Mark Platinum awards.



The CapitaGreen



Use of High Strength Concrete for the 40-Storey Building



A Piece of Architecture that is like a Plant Growing towards the Sky

Concept Design by Toyo Ito



For more information, please contact:

Mr Hidetoshi Ito

itou.hidetoshi@takenaka.co.jp

Takenaka Corporation

Tropical Hempcrete Wall Panel



The project involves turning agri-based, fast-renewable waste material into lightweight, energy saving wall panels, which are naturally pre-finished beautifully, durable and meets building code requirements. The Hempcrete Wall Panels are able to replace non-loadbearing Concrete Panels, Concrete Blocks and Drywalls productively, aesthetically, and sustainably. Hempcrete Wall Panels are a convenient 'all-in-one' bio-composite wall solution for thermal, acoustic insulation and productive construction. The panels used as external insulated wall or internal partitions are pre-finished with timber 'sandstone look', detailed with tongue and groove for ease of installation, and is potentially a carbon neutral material. The panels are tested to various performance assessment such as fire, strength and robustness, water, thermal, acoustic and non-toxicity tests, and are proven to exceed BCA's PPVC requirements on wall panels.

POTENTIAL APPLICATIONS

The novelty of the project is the nature of its raw material, Hemp, with the ability to sequester global greenhouse gases efficiently. The low energy manufacturing process of Hempcrete production makes it a carbon storage within building walls.



Hempcrete Wall Panels



For more information, please contact:

Mr Francis Lim

info@studiogreen.sg

Studio Green Pte Ltd

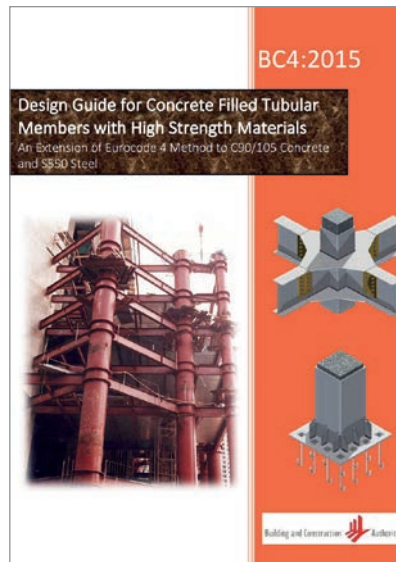
Encased Composite Columns with High Strength Materials for High-Rise Construction



High strength construction materials are gaining increasing popularity due to their structural and architectural advantages. For instance, smaller member sizes can be adopted when using high strength concrete and high strength steel, saving floor space and cost, especially for high-rise construction. However, their applications may be deterred by concerns on the material brittleness for high strength concrete and the local buckling and vulnerability to fire for high strength steel. To overcome these problems, one solution is to use composite structural members, such as Concrete Encased Steel Columns (CESSs), for load bearing columns. In this way, ductility of concrete can be enhanced while local buckling resistance and fire resistance of the steel section can be improved by the concrete cover.

POTENTIAL APPLICATIONS

The research is expected to generate fundamental knowledge on structural performance of high strength encased composite columns used in high-rise construction. At the end of this project, a design guide on the use of high strength encased composite columns for implementation in Singapore will be published.



For more information, please contact:

Professor Richard Liew Jat Yuen
 ceeljy@nus.edu.sg
 National University of Singapore



“One of the central themes of sustainable development is to overcome the constraints of the planet to sustain an ever growing world economy serving growing population. In the context of construction industry, we are facing huge challenges and opportunities in the years ahead. As more space is needed to accommodate these people, the pressure on civil engineering practitioners to build the space for them will put untold strains on the planet’s non-renewable resources and environmental pollutions.

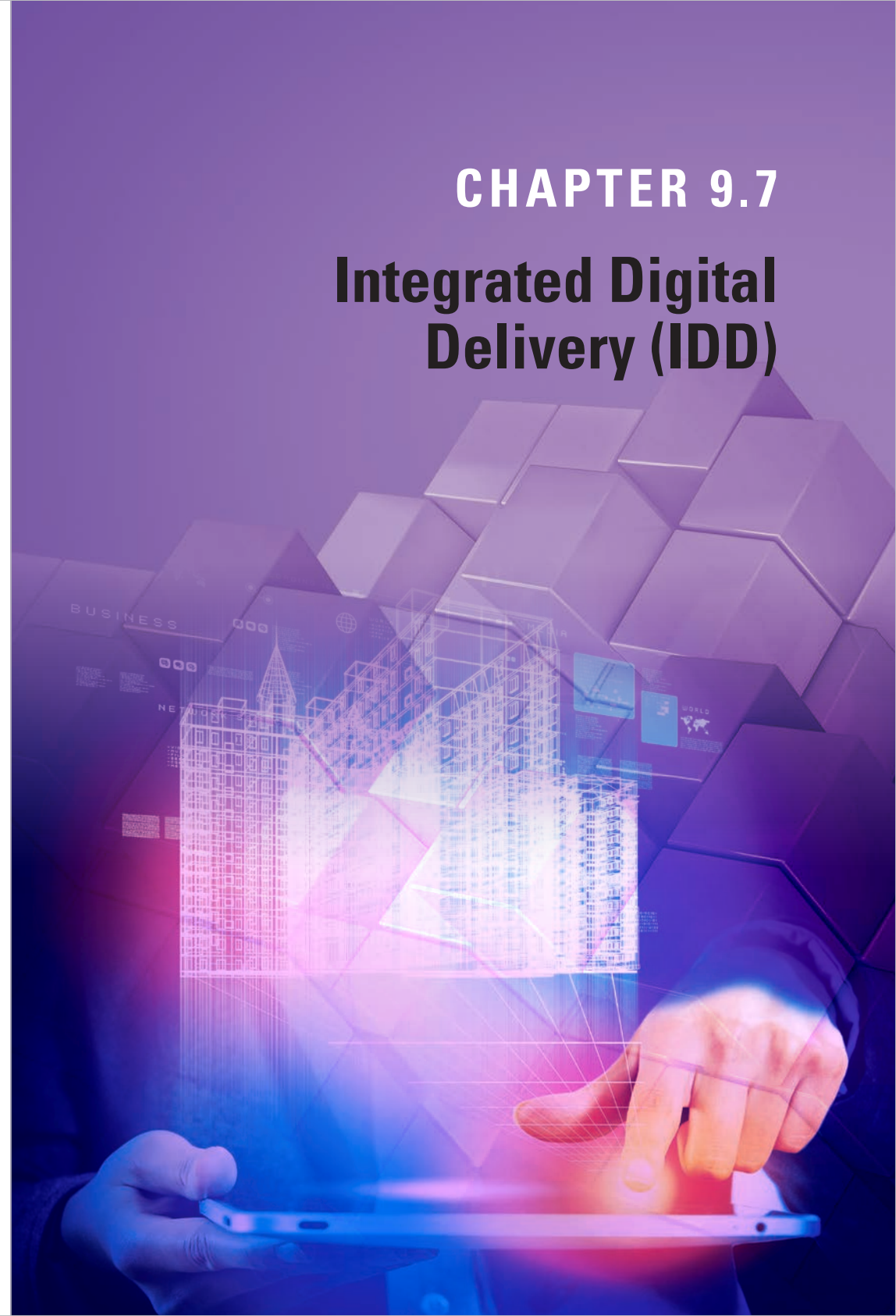
Meanwhile, there are immense opportunities to develop sustainable and efficient structural designs as well as construction methods to reduce the carbon footprint resulting from construction activities. In view of this, our research group is dedicated to invent structural systems, construction methods and materials of versatility and high quality, while requiring minimum energy inputs. Therefore, we are determined on this path and are motivated to tackle any challenges arising along the way.”

Professor Richard Liew Jat Yuen

National University of Singapore

CHAPTER 9.7

Integrated Digital Delivery (IDD)



Automated Code Compliance Check in Building Information Modelling (BIM)

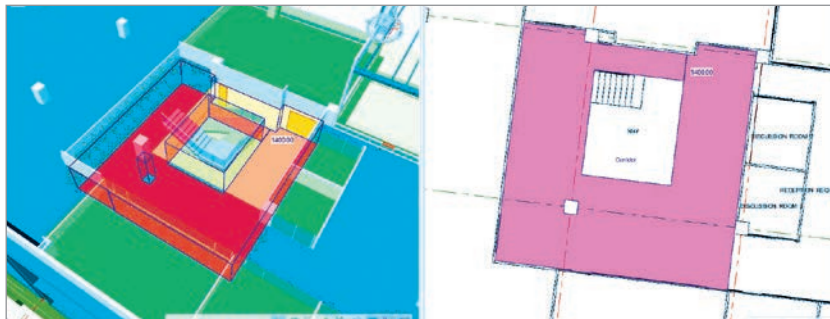
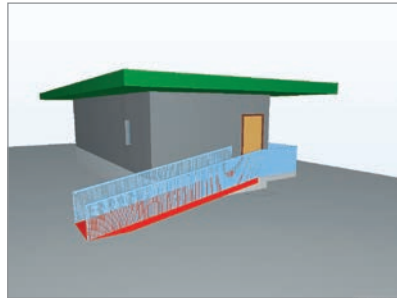


To fully harness the capability of Building Information Modelling (BIM) as well as improve the overall efficiency and productivity, BCA is currently exploring the feasibility of tapping on technologies that could aid in model validation and code compliance check for regulatory submissions.

The adoption and availability of such technology will help to transform the current conventional plan review process and improve turnaround time. More importantly, it can help to identify non-compliances upstream so as to avoid unnecessary and costly reworks that need to be carried out before the building may be commissioned.

POTENTIAL APPLICATIONS

The automated BIM model checker technology could be made available to the industry and allows industry to self-check their BIM models prior to the formal plan submission.



For more information, please contact:

Ms Ma Khine Wa ma_khine_wa@bca.gov.sg
Ms Sharon Tan sharon_hc_tan@bca.gov.sg

Building and Construction Authority

Three-Dimensional Building Interactive Walkthrough (3D-BIW)



The idea behind the Three-Dimensional Building Interactive Walkthrough (3D-BIW) is the creation of a software solution, embedding visual and interactive frameworks, that will allow end users to automatically create two-dimensional (2D) floor plans from 3D building models and use the floor plans to interactively navigate through a 3D visualisation of the building models. This high-level interaction will lead to a better cognitive process where information is easier to memorise and process in order to simplify the decision making process.

POTENTIAL APPLICATIONS

3D-BIW will develop an innovative system to support several phases of the building life cycle, such as planning and design, as well as provide a visualisation tool to showcase and discuss about building models.

3D-BIW will be based on the standard building format IFC and will be able to:

- Extrapolate the floor plan
- Visualise the 3D virtual environment
- Render it and visualise it in real-time
- Match the 2D maps with the 3D environment to provide an intuitive and unique walkthrough experience
- Extrapolate and visualise all semantic information in the rendered model of the building embedded into the IFC file such as modelling and structural analysis



Interactive Navigation through Visualisation of Building Models



For more information, please contact:

Dr Antonio Feraco antonio.feraco@fraunhofer.sg

Fraunhofer Singapore,
Interactive Digital Media Ltd

Smart and Semi-Automated Precast Elements Logistics Management and Installation System



Extensive use of prefabricated elements in the industry has resulted in a new sequence of work and increased usage of tower cranes. The project aims to improve construction productivity and site safety by enhancing capabilities of new technological adoptions such as prefabricated elements and BIM. With the adoption of Radio-Frequency Identification (RFID), information and status of each prefabricated element are uploaded instantly onto a database integrated with BIM. The information uploaded is used to generate a hoisting and installation schedule, efficient and safe path, and track and update the BIM model real-time with the use of Global Navigation Satellite System (GNSS) supported by Singapore Satellite Positioning Reference Network (SiReNT); an initiative by the Singapore Land Authority (SLA).



Adoption of RFID for Inventory Checking

POTENTIAL APPLICATIONS

The system was tested at the Signature @ Yishun Executive Condominium in 2016. Productivity improvements of 10-20% in terms of site logistics and up to 30% reduction in time used for on-site inventory checking prior to hoisting were recorded. Another key improvement is the added visibility provided by the camera mounted on the crane hook, which resulted in a reduced number of “blind lifts” the crane operator had to execute, leading to improved on-site safety.



For more information, please contact:

Mr Choo Tat Jin

tjchoo@kimly.com.sg

Kimly Construction Pte Ltd

Associate Professor
Robert Tiong

clkiong@ntu.edu.sg

Nanyang Technological University

CHAPTER 9.8 Robotic Technology



Unmanned Aerial Vehicle (UAV) for Indoor Navigation



A primary objective of this project is to increase the potential use for drones in building construction by achieving autonomous indoor navigation and drone flight - without an operator and access to GPS, Wi-Fi or beacons. While Unmanned Aerial Vehicle (UAV) - or drones - are increasingly being used in construction, primarily flying outdoors, these are remotely controlled by a drone operator and have mission planning based on GPS data.

POTENTIAL APPLICATIONS

The project will see the development of self-fly drones on building construction sites to collect photographic data. The drones will be able to fly to multiple floors autonomously and automatically generate a report containing the images with their specific locations.



Vision for Development of Self-Fly Drones on Building Construction Sites to Collect Photographic Data



For more information, please contact:

Mr Craig Rice

cr@tectusdreamlab.com

Tectus Dreamlab Pte Ltd

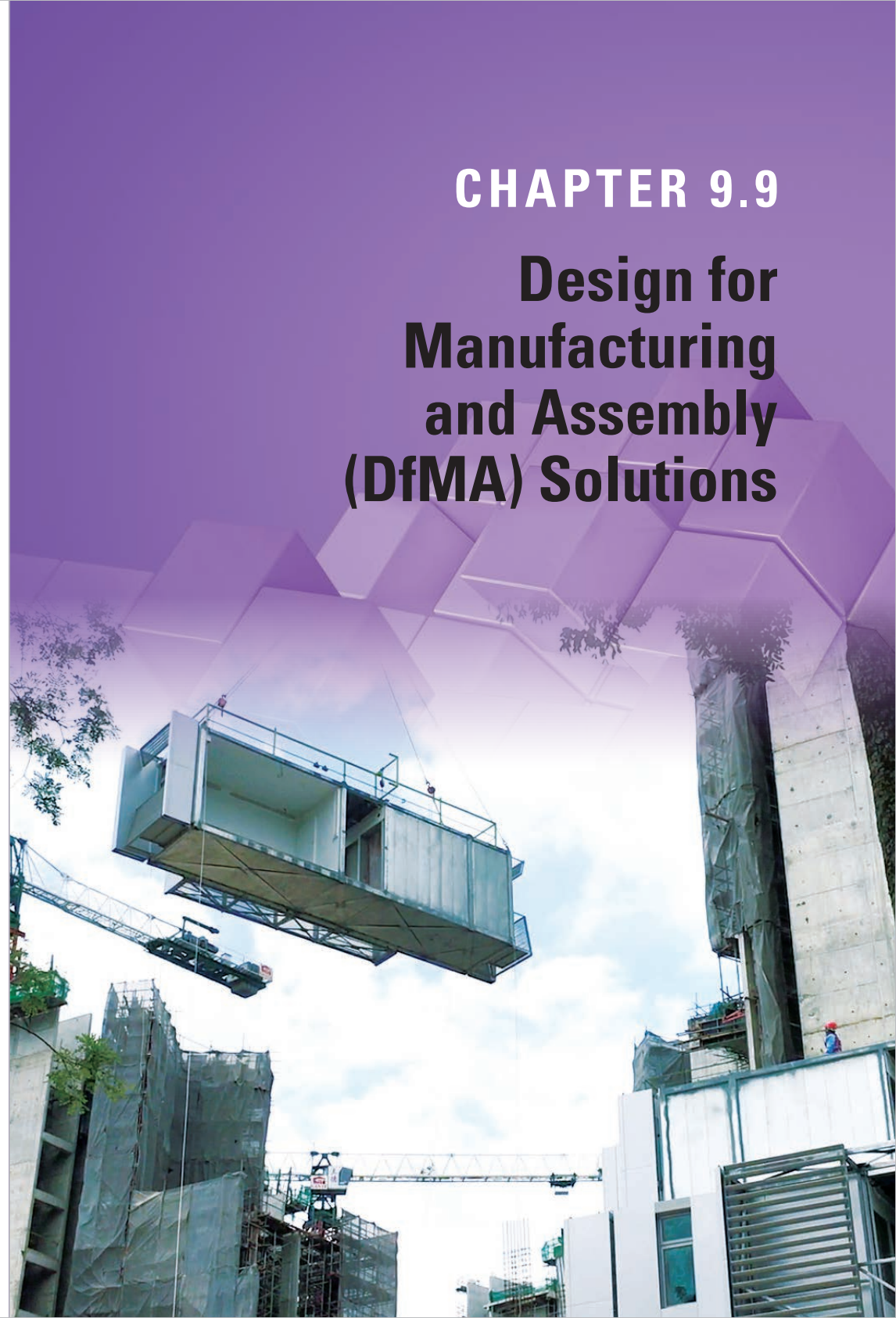
Professor David Chua

ceedavid@nus.edu.sg

National University of Singapore

CHAPTER 9.9

Design for Manufacturing and Assembly (DfMA) Solutions



Prefabricated Pre-finished Volumetric Construction (PPVC)



The project aims to develop smart corrosion protective coatings for Prefabricated Pre-finished Volumetric Construction (PPVC) structures, so as to enhance construction productivity.

The project involves evaluating commercially-available zinc coatings and their corrosion inhibiting mechanisms, leading to the development of a single-coat coloured zinc coating or a coloured top coat to be compatible with the zinc coating in a two-coat system. The processes involved include corrosion inhibitor encapsulation process and incorporation of encapsulated inhibitors into coatings for “smart” release in response to physical damage.

POTENTIAL APPLICATIONS

The main application focus is on structural steel used in PPVC and prefabricated structures.



Accelerated Exposure for Corrosion Resistance Evaluation of Coatings



Scanning Vibrature Electrode Technique (SVET) Evaluation of Coatings



For more information, please contact:

📧 Dr Sudesh L. Wijesinghe

✉️ sudeshw@SIMTech.a-star.edu.sg

🏢 A*STAR Singapore Institute of Manufacturing Technology

CHAPTER 10

Funding Programmes

Two-Stage Innovation Grant (iGrant)

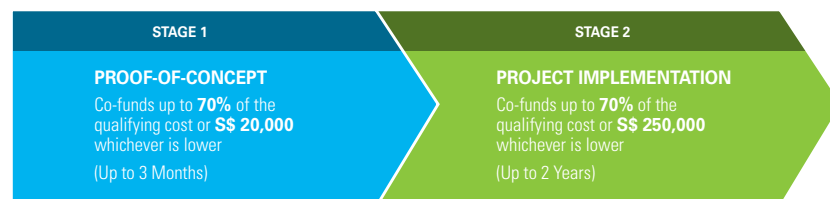
The Two-Stage Innovation Grant (iGrant) is set up to encourage and support the building and construction industry to conduct fast track, Proof-Of-Concept (POC) type of R&D projects for subsequent quick deployment in a fast moving business environment. The scheme facilitates the introduction of novel tools, methodologies and technologies that have high potential for mass scale market deployment.

EVALUATION CRITERIA

- Innovative new design tools, methods and technologies
- Competency and track record of the applicant and project team
- Degree of replicability and scalability with commercialisation potential
- Degree of impact to BCA's strategic focus areas



FUNDING SUPPORT



For more information, please contact:

- Ms Ma Khine Wa ma_khine_wa@bca.gov.sg
 Ms Grace Goh grace_goh@bca.gov.sg

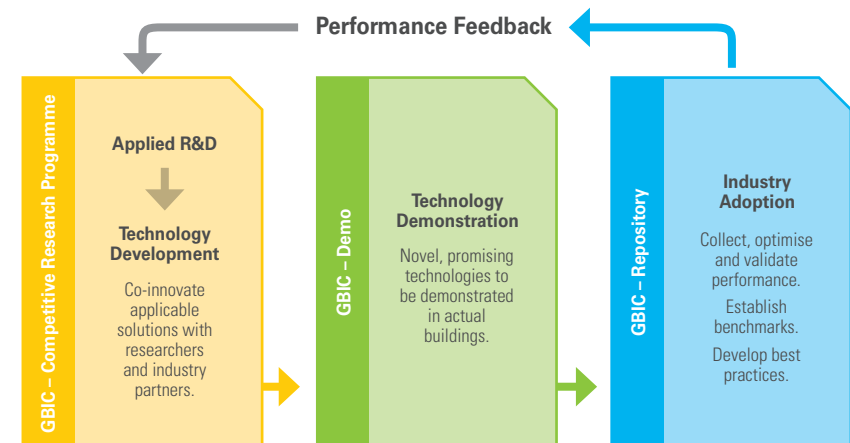
Building and Construction Authority

Green Buildings Innovation Cluster (GBIC)

The aim of Green Buildings Innovation Cluster (GBIC) is to support Singapore's long-term aspiration of "Positive Energy Low-rise, Zero Energy Mid-rise and Super Low Energy High-rise Buildings for the Tropics", to accelerate the development and pilot demonstration of adoption of promising building energy efficient technologies and solutions, and thereby bringing them closer for mass market adoption.

It is a one-stop integrated Research, Development and Demonstration (RD&D) hub to experiment, exhibit and exchange knowledge of emerging energy efficient building solutions with industry stakeholders.

KEY ACTIVITIES OF GBIC



**NATIONAL
RESEARCH
FOUNDATION**
PRIME MINISTER'S OFFICE
SINGAPORE

For more information, please contact:

- Mr Wong Ngian Chung wong_ngian_chung@bca.gov.sg Building and Construction Authority

Enhanced Partnerships for Capability Transformation to Drive Government Lead Demand (Gov-PACT)

ABOUT GOV-PACT

As part of efforts to develop industries and enterprises, SPRING Singapore (SPRING) will provide assistance to Small- and Medium-sized Enterprises (SMEs) and startups to collaborate and undertake innovative projects initiated by government agencies. Under Gov-PACT, SMEs and startups will be funded at various stages of product and solution development for these innovative projects. Under the existing PACT programme, SPRING works with Large Organisations (LO) to identify and implement collaborative projects between LO and local SMEs in the following areas (see Fig.1).

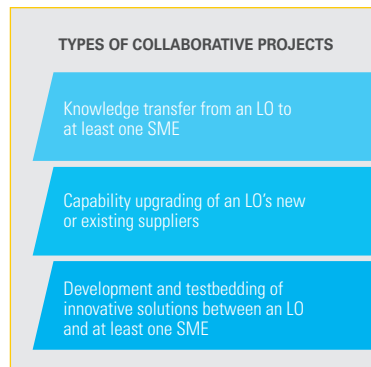


Fig. 1

HOW DOES IT WORK?

SMEs / startups, whose projects are approved, are eligible for up to 70% funding support for qualifying development costs. Under Gov-PACT, the Government will serve as the LO with which the SMEs / startups will work with to develop and testbed innovative solutions that do not yet exist in the market. Participating government agencies would generate lead demand by identifying problem statements that could be addressed by innovative solutions and seek partners through calls for proposals. Participating companies will go through different stages of product development from the ideation stage to pilot runs with the support of the lead demand agency. If procurement expectations are met, agencies will procure the final solution from the participating company. The opportunity to supply solutions to the Government will help SMEs / startups build up their innovation capabilities. More importantly, this will also help companies to build track records with the Government as their reference customer as they scale up locally or export overseas. The programme will also allow the Government to find relevant and innovative solutions that can address national needs. These include projects from emerging sectors such as urban solutions, security, healthcare, biomedical sciences and the Internet of Things.



For more information, please contact:

Ms Kathleen Tan

kathleen_tan@spring.gov.sg

SPRING Singapore

Capability Development Grant (CDG)

ABOUT CDG

The Capability Development Grant (CDG) aims to support SMEs to scale up business capabilities and ensure business sustainability. You can take on projects in areas such as product development, human capital development, business processes enhancements for productivity and business model transformation. The grant defrays up to 70% of qualifying project costs such as consultancy, training, certification and equipment costs.

CDG DEVELOPMENT AREAS



ELIGIBILITY

- Registered and operating in Singapore
- At least 30% local shareholding
- Group annual sales turnover ≤ S\$ 100 million or group employment of ≤ 200 employees



For more information, please contact:

Ms Kathleen Tan

kathleen_tan@spring.gov.sg

SPRING Singapore

Glossary

A*STAR	Agency for Science, Technology and Research
ACMV	Air-Conditioning and Mechanical Ventilation
API	Application Programming Interface
ASEAN	Association of Southeast Asian Nations
BCA	Building and Construction Authority
BIM	Building Information Modelling
BMIS	Building Management and Information Systems
C&D	Construction and Demolition
CBD	Central Business District
CDG	Capability Development Grant
CDL	City Development Limited
CESSs	Concrete Encased Steel Columns
CFD	Computational Fluid Dynamics
CLT	Cross Laminated Timber
CLVC	Centre for Lean and Virtual Construction
CuO-TiO ₂	Copper Oxide Titanium Dioxide
DC	Direct Current
DfMA	Design for Manufacturing and Assembly
EA	Equipment Analytics
EUI	Energy Use Intensity
FATIMAC	Functionalise Aerogel For Treatment of Indoor Moisture and Air Contaminants
FCU	Fan Coil Unit
GBIC	Green Building Innovation Cluster
GFA	Gross Floor Area
Glulam	Glued-laminated timber
GM	Green Mark
GNSS	Global Navigation Satellite System
Gov-PACT	Partnerships for Capability Transformation to Drive Government Lead Demand
GPS	Global Positioning System
GrBEST	Green Building Environment Simulation Technology
HDR	High Dynamic Range
I ³	Industrial Infrastructure Innovation
iGrant	Innovation Grant
IAQ	Indoor Air Quality
ICT	Information and Communication Technology
IDD	Integrated Digital Delivery
IES	Institution of Engineers Singapore
IFC	Industry Foundation Class
IMRE	Institute of Materials Research and Engineering

JTC	Jurong Town Corporation
LED	Light Emitting Diode
LO	Large Organisations
M&E	Mechanical & Electrical
MET	Mass Engineered Timber
NEA	National Environment Agency
NIR	Near-Infrared Radiation
NRF	National Research Foundation
NUS	National University of Singapore
NZEB	Net Zero Energy Building
PCM	Phase Change Material
PDV	Passive Displacement Ventilation
POC	Proof-Of-Concept
PPVC	Prefabricated Pre-finished Volumetric Construction
PV	Photovoltaic
PVDF	Polyvinylidene Fluoride
R&D	Research and Development
RB	Residential Buildings
RC	Reinforced Concrete
RCA	Recycled Concrete Aggregate
RD&D	Research, Development and Demonstration
RFID	Radio Frequency Identification
SDE	School of Design and Environment
SinBerBEST	Singapore-Berkeley Building Efficiency and Sustainability in the Tropics
SiReNT	Singapore Satellite Positioning Reference Network
SLA	Singapore Land Authority
SME	Small- and Medium-sized Enterprises
SMS	Short Message Service
SUTD	Singapore University of Technology and Design
SVET	Scanning Vibrating Electrode Technique
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
UFAD	UnderFloor Air-Distribution
UWCSEA	United World College of South East Asia
VA	Video Analytics
VDC	Virtual Design and Construction
VOCs	Volatile Organic Compounds
ZEB	Zero Energy Building
3D-BIW	Three-Dimensional Building Interactive Walkthrough

EDITORIAL TEAM

Tan Tian Chong
Stephen Mok
Matilda Kenanga
Ma Khine Wa

ACKNOWLEDGEMENTS

Building Plan and Special Projects Department, BCA
Centre for Construction IT, BCA
Corporate Communications Department, BCA
Green Building Research Department, BCA
Green Mark Department (New Development), BCA
SPRING Singapore

ISBN: 978-981-11-3668-9

Printed on Green Forest paper

Designed by Redbean De Pte Ltd



