Geography HL

Extended Essay

May 2021

Topic	**Core theme (Unit 2, Subtopic 3):** Responding to Climate Change **OT (G.3):** Urban microclimate modification and management **OT (G.4):** Building Sustainable Urban Systems for the future
Title	Investigating Sustainable buildings as a viable solution to urban micro climatic problems.
Research Question	**Are sustainable buildings a viable solution to urban microclimatic problems as seen through *Tampines Concourse*, an Industrial Region in Singapore?**

Word Count: 3830

Geographic Context

Context (what makes this research relevant and meaningful)	Forward looking research that evaluates the effective use of sustainable building practices as a solution to urban microclimatic problems a- Adoption of sustainable building practices, through use of recycled materials and improved energy performance b- Integrating government plans and policies through the implementation of the BCA Green Mark Scheme c- Evaluation into the success of sustainable building strategies in *Tampines Concourse* as by measuring the temperature and humidity of this area, and comparing it to an urban counterpart (*Tampines Concourse Bus Interchange*)
Concepts	a- Urban Heat Island Effect b- Urban environmental stress c- Building sustainable urban systems for the future d- Resource stewardship strategies

ACKNOWLEDGMENTS

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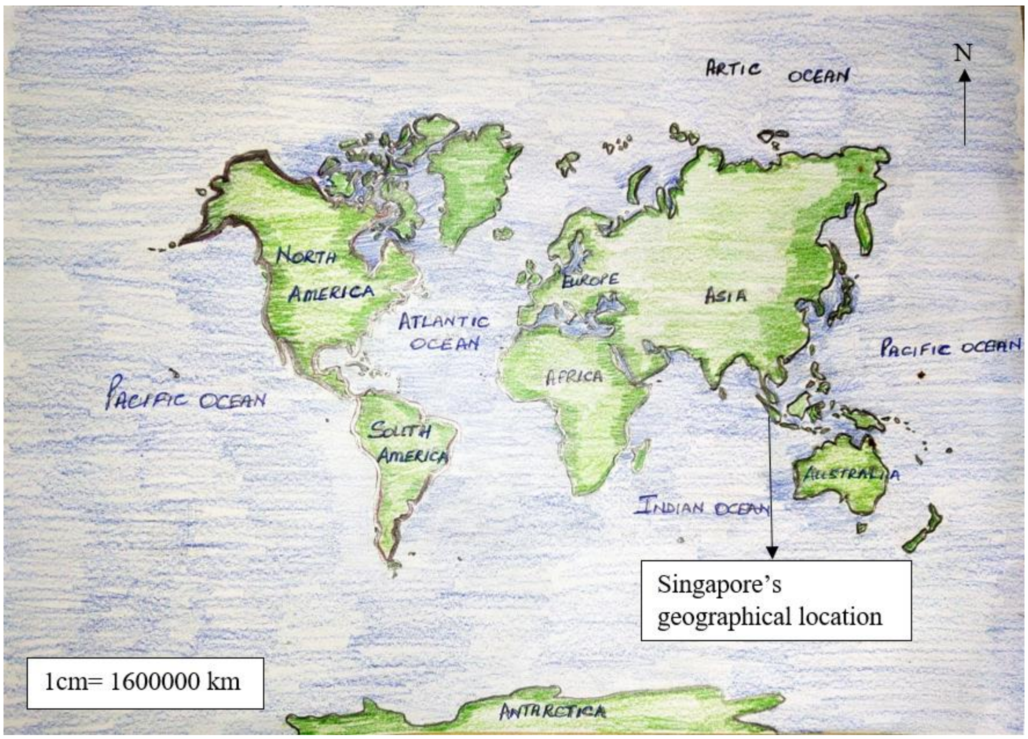
Research Question

Are **sustainable buildings** a viable solution to **urban microclimatic problems** as seen through *Tampines Concourse*, an Industrial Region in Singapore?

INTRODUCTION

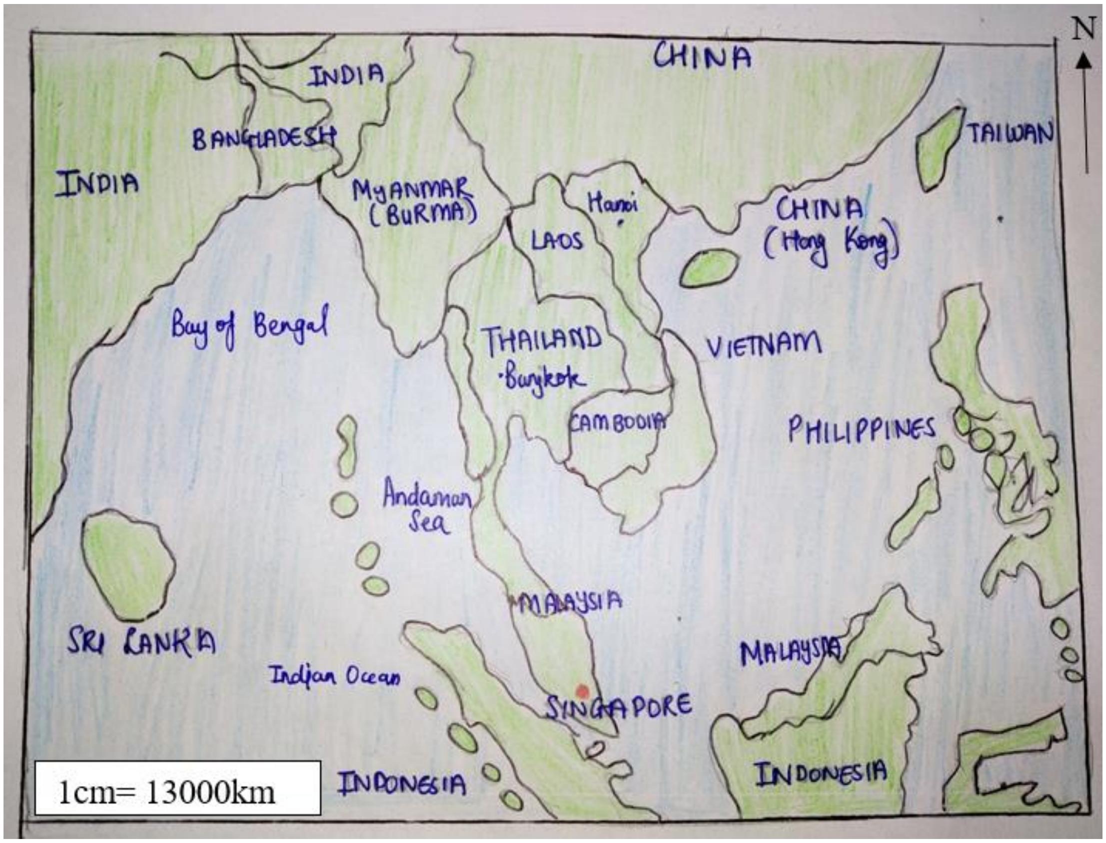
Introduction to the topic

Singapore is located in South-East Asia, as indicated in the World Map [Map 1, Pg7] and is part of the ASEAN countries. Being a country situated in South-East Asia [Map 2, Pg8], it has a population of around 5.685 million people, and a land area of 728 sq. km[1].



Map 1: Singapore's geographical location on The World Map

[1] Department of Statistics Singapore. (n.d.). *Population and Population Structure*. Singstat. Retrieved March 5, 2020, from https://www.singstat.gov.sg/find-data/search-by-theme/population/population-and-population-structure/latest-data



Map 2: Singapore located within South East Asia

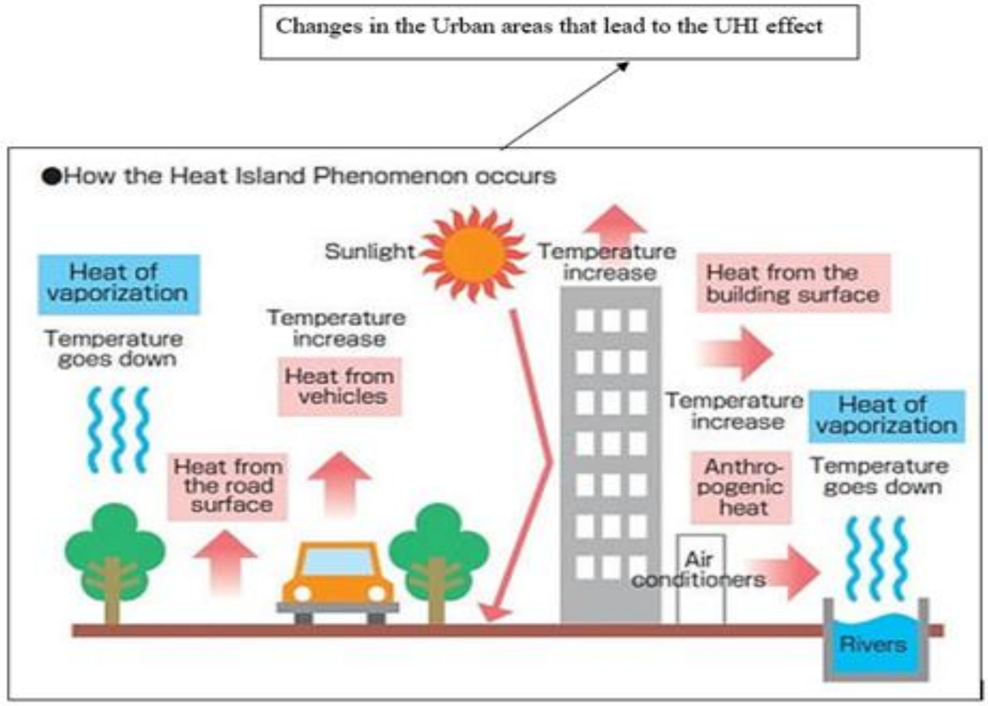
In Singapore, 100% of the population lives in the urban areas[2]. One of the fundamental aspects of development in Singapore is, sustainable construction. It is, however, a challenge due to lack of natural resources. Through the set-up of the SSB[3] masterplan[4] in conjunction with the BCA, aims are set out to ***alleviate*** the UHI effect[5] [Model 1, Pg9]

[2] *Urban Population (% of total population)- Singapore*. (n.d.). The World Bank. Retrieved March 3, 2020, from https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=SG

[3] Sustainable Singapore Blueprint

[4] *Sustainable Singapore Blueprint 2015*. (2015). Nccs.Gov.Sg. Retrieved February 24, 2020, from https://www.nccs.gov.sg/docs/default-source/default-document-library/sustainable-singapore-blueprint-2015.pdf

[5] Urban Heat Island effect



Model 1: Phenomenon of the 'Urban Heat Island' effect

Focus of the essay

By striving balance between economic growth and environmental sustainability, the 3 pillars of sustainability are integrated [Model 2, Pg10]. This EE would specifically focus on the **sustainable building strategies** and **its effectiveness** in reducing the microclimatic problems as seen through changes in **temperature and humidity**.

Model 2: Sustainable Construction Development Plan

<u>Scope of research: study area context, theoretical context, subject context</u>

Tampines Concourse [Figure 1A, Pg11], being a 3-storey building, is one of the first in Asia Pacific to incorporate sustainable development practices.[6]

[6] *TAMPINES CONCOURSE*. (n.d.). BCA. Retrieved October 19, 2020, from https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/tampines_concourse.pdf

Figure 1A: Study area, Tampines Concourse

Image 1: *11 Tampines Concourse*, Study area

After studying Option G: "Urban Environments", I was intrigued to learn about the **changes in the urban microclimate processes** and explore how **sustainable development** can affect the microclimate of Tampines *Concourse* [Image 1, Pg11].

Relevance to a global issue, worthy of investigation

Globally, there has been a developing interest, in microclimate issues as they address significant factors in improved *sustainability performance* and *mitigation of climate change effects*. Urban areas, similar to Singapore are developing towards megacities with **higher density urban planning** and skyscraper metropolitan designs. Such cities tend to exhibit the **UHI effect**.[7] The construction industry is held accountable for the intensive use of energy in both, the creation of buildings and the operational phase[8], which leads to increased CO_2 emissions that significantly contribute to Climate Change.

Methods of data collection

The main course of data was primary in nature. Although, significant amounts of data were taken from **research papers[9], news articles[10], and books[11]** to learn more about SSB, the masterplan and BCA. Data for this investigation was collected from 5th-30th September, 10th-11th October and 27th- 28th December 2020. Firstly, to survey recycled materials, an

[7] *Holistic Method on Performing Microclimate Analyses of an Urban Area in The Tropics*. (2015). Meteo. Retrieved July 10, 2020, from http://www.meteo.fr/icuc9/presentations/UDC/UDC3-6.pdf

[8] Chew, K. C. (2010, July 20). *Singapore's strategies towards sustainable construction*. Tandfonline. Retrieved August 29, 2020, from https://www.tandfonline.com/doi/full/10.1080/19373260.2010.491641#:~:text=Two%20key%20focus%20areas%20of,as%20shown%20in%20Table%201.

[9] Appendix A1- Research papers with regards to Sustainable Construction, Pg43

[10] Appendix A2- News Articles based on Sustainable Construction, Pg45

[11] Appendix B1- Books that address Sustainable Construction in Singapore, Pg47

interview with the BCA[12] was conducted, based on concrete usage. From that, the CUI[13] was calculated using this formula and compared to standards by BCA.

$$\text{CUI}= \frac{Total\ Volume\ of\ Concrete\ Used}{Area\ covered\ by\ Concrete}$$

Using **government websites**[14], statistics were collected on the 'Average Operating Margin'. The **temperature of this area was then measured**[15], using a mercury thermometer [Image 2, Pg13] and the temperature was compared to *Tampines Concourse Interchange* [Image 3, Pg14] in order to test the effectiveness of these 2 variables.

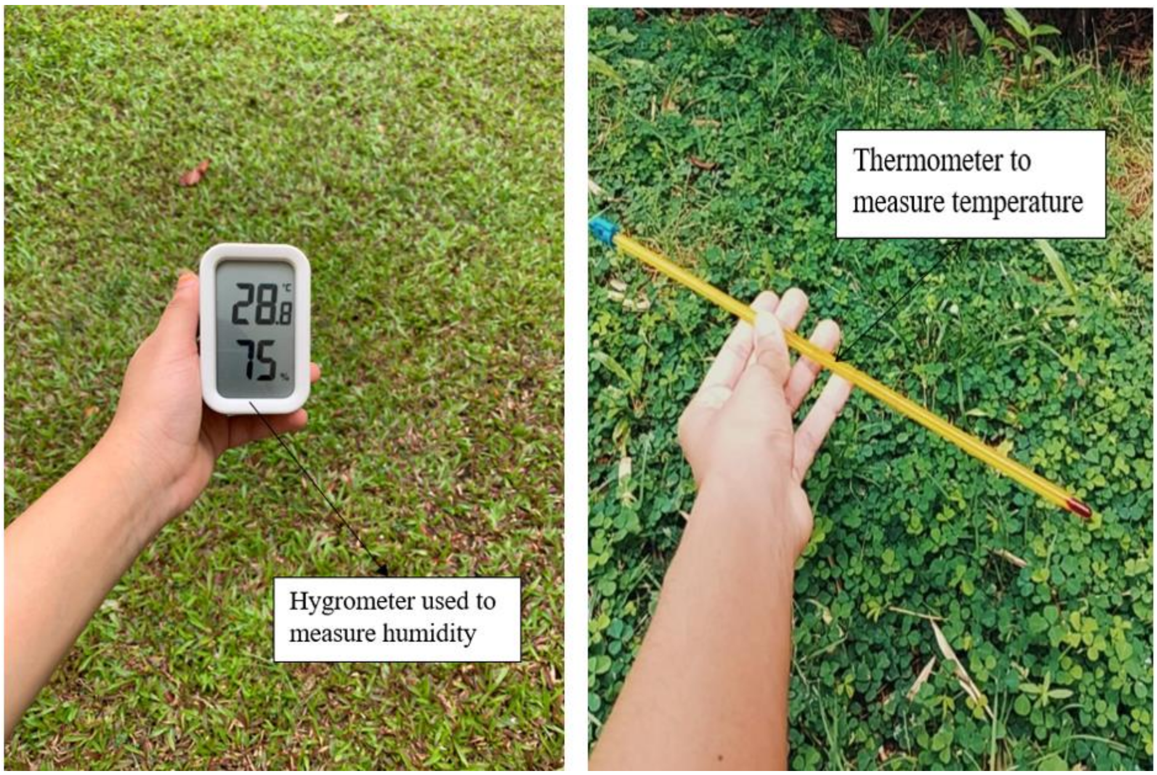


Image 2: Hygrometer (Left) for Humidity and Thermometer (Right) for Temperature

[12] Appendix D1- Interview Questions with BCA, Pg54
[13] Concrete Usage Index
[14] Appendix B2- Secondary data for Electricity Grid Emission factors, Pg49
[15] Appendix C1- Temperature readings at *Tampines Concourse* and *Tampines Concourse Interchange*, Pg50

Image 3: *Tampines Concourse Bus Interchange*, as an Urban Counter-part

To investigate the BCA Green mark scheme policies, data for the **water consumption and waste generated**[16]. The **targets predicted and performance** for the year 2009 was outlined and analysed. *Vertical greening*, relied heavily on **personal observations**. The effectiveness of this was tested through the changes in the **humidity levels**[17] using a hygrometer [Image 2, Pg13], and it was then compared to *Tampines Concourse Interchange*.

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[16] *BCA AWARDS 2016 – CDL EXTENDS LEAD IN TENANT ENGAGEMENT AS THE MOST-AWARDED DEVELOPER IN GREEN MARK PEARL CATEGORY*. (2016). City Developments Limited. Retrieved September 26, 2020, from https://ir.cdl.com.sg/static-files/cb0db75c-f3ab-4b43-b62f-55bd4ba02578

[17] Appendix C2- Humidity readings at *Tampines Concourse* and *Tampines Concourse Interchange*, Pg52

Hypotheses

A- Applying **sustainable building practices** such as, using **recycled materials**[18] and **improving the energy performance**, have significantly brought down the **temperature** of this region.

B- Government led plans and policies such as **the implementation of the BCA Green Mark scheme**[19], as seen through the **green features, vertical greening, waste and water management practices** have succeeded in minimizing the UHI effect, making this area cooler than its urban counterparts through the lower **humidity** levels

The hypotheses are relevant, significant and authentic to the research question. It directly connects the explanations of testing **sustainable building practices**, and **government strategies** as a solution through its **effects on the temperature and humidity**.

ANALYSIS OF DATA COLLECTED

Sustainable Building Practices adopted through the Concrete Usage

When looking at Singapore in context, **Sustainable Construction** has an important role to play, as its ulterior goal is on the utilization of materials and items in the buildings that devour fewer natural resources and accordingly that builds the reusability of such materials

[18] Copper slag, Ground Granulated Blast Furnace Slag (GGBS) & RCA

[19] Building and Construction Authority. (n.d.). *Green Mark Certification Scheme*. BCA. Retrieved October 7, 2020, from https://www1.bca.gov.sg/buildsg/sustainability/green-mark-certification-scheme

for comparable purposes. As for sustainable construction, in Singapore, there are two focus areas which are important. They are, the reusing and utilization of *sustainable materials* and the utilization of *effective design* such that the **use of natural resources has been optimized[20]**. Keeping this in mind, Singapore developed a Sustainable Construction Masterplan[21] [Figure 1B, Pg16] to highlight these aims.

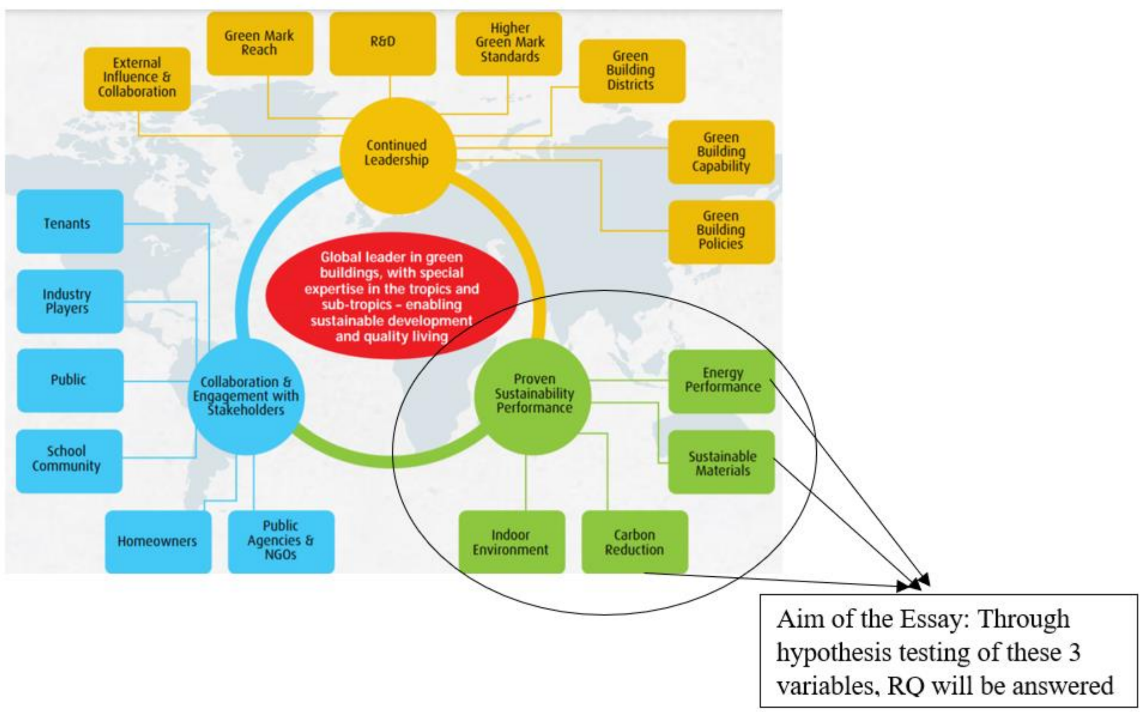

Figure 1B: Sustainable Construction Masterplan

[20] Chew, K. C. (2010, July 20). *Singapore's strategies towards sustainable construction*. Tandfonline. Retrieved August 29, 2020, from https://www.tandfonline.com/doi/full/10.1080/19373260.2010.491641#:~:text=Two%20key%20focus%20areas%20of,as%20shown%20in%20Table%201.

[21] Building and Construction Authority. (2005). *3rd Green Building Masterplan*. BCA. Retrieved August 30, 2020, from https://www.bca.gov.sg/greenmark/others/3rd_green_building_masterplan.pdf

Government support is essential in stimulating the implementation of this masterplan. Therefore, BCA along with the administrative and government organizations just as well as the industry affiliations, framed the Sustainable Construction Steering Group (SCSG)[22].

Tampines Concourse, has acquired distinction in being the very first carbon-neutral building in Asia-Pacific. Reused materials like copper slag, ground granulated blast furnace slag (GGBS) and recycled concrete aggregate (RCA) have been utilized significantly in the development of this structure. Because of the utilization of this, in excess of 1000 tons of natural sand and granite have been saved and 6750 tons of CO_2 have been balanced[23].

Type of Cement Used (%)									
Normal Concrete	**Semi- Green Concrete**			**Green Concrete**			**Eco- Concrete**		
	Copper Slag	**GGBS**	**RCA**	**Copper Slag**	**GGBS**	**RCA**	**Copper Slag**	**GGBS**	**RCA**
Not Surveyed	10	20	0	10	20	20	30	20	20
	30% of the Total			**50% of the total**			**70% of the total**		

Table 1: Survey of Cement used for Construction[24]

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[22] Singapore: Ministry of Manpower and Ministry of National Development. (1999). *Construction 21*. Eresources.NLB. Retrieved October 10, 2020, from https://eresources.nlb.gov.sg/printheritage/detail/cda47e8d-4565-4c54-bf05-0c98905d01f0.aspx

[23] *Our Concrete Responsibility: Sustainability*. (n.d.). PanUnited. Retrieved December 1, 2020, from https://www.panunited.com.sg/page/sustainability/

[24] Appendix D1- Interview Questions with BCA, Pg54

Here, [Table 1, Pg17], we can see that there are different types of concrete used, such as normal concrete, semi- green concrete, green concrete and eco-concrete. Normal cement is comprised of a combination of sand, rock, gravel and other aggregates that are solidified by a paste of concrete and water. It was observed that, it releases around 2.8 billion tons of CO_2 which is between 4-8% of the world's greenhouse gas emissions. Due to its contribution to the greenhouse gas production and increasing the **UHI effect**, normal concrete is used in ***relatively lower amounts*** for the construction of this industrial area. ***Sustainable concrete***, on the other hand, makes use of Copper Slag, RCA, and, GBBS[25]. Copper slag is a non-plastic material, which has preferable compaction qualities over sand. It is a result acquired through first, purifying and afterward refining the copper. GGBS has its only raw material which is a different type of slag that is a by-product from the blast furnaces that make iron. It replaces something that is created by a profoundly energy intensive process[26]. Lastly, RCA is the coarse aggregate used from the first solid that is made after the mortar is isolated from the rock that is reused. By collecting the used concrete and breaking it up, recycled concrete aggregate (RCA) is created[27]. Moreover, as for the semi- green concrete, which uses 30% of the total concrete, comprises 10% of Copper Slag, which makes use of the by-product obtained from refining copper, hence making **efficient use of the energy**, thereby ***lowering the CO_2 emissions***. As CO_2 emissions have decreased, it would be hypothesised that there would be a **decrease in the**

[25] Appendix D1- Interview questions with BCA, Pg54

[26] csma. (n.d.). *Sustainability*. Cementious Slag Makers Association. Retrieved December 2, 2020, from https://ukcsma.co.uk/sustainability/

[27] *Recycled Concrete Aggregates: A Review*. (2013, March 29). Springer Link. Retrieved December 1, 2020, from https://link.springer.com/article/10.1007/s40069-013-0032-5

temperature. When tested in *Tampines Concourse*, the results of the temperature readings, reveal how the use of such sustainable concrete has brought down the temperature of the region by an average of 4 ℃, in comparison to the urban counter-part (*Tampines Concourse Interchange*) [Table 6, Pg26]. Semi- green concrete was the type of concrete that was mainly used for primary structures which include all columns, walls [Image 4, Pg19], precast beams, including those with a down hang.

Image 4: Pictures of Sustainable Concrete used for the columns in the building

Green concrete also uses the same components but however, the percentage used varies. For example, green concrete uses 50% of the total concrete. The only difference between the semi-green concrete and the green concrete is the percentage of RCA used (20% difference). Through recycling 20% of the recycled concrete aggregates, ***energy wastage is minimized***, thereby producing a more sustainable version of the buildings and helps integrate the ideas of *sustainable construction practices*, which shows that it is effective as seen through the *decrease in temperature readings* at the site [Table 6, Pg26]. Eco-concrete on the other hand, makes use of 70% of the total concrete. This is used majorly in comparison to the other type of concretes. Due to this, there is a much lower dependence on the natural resources, which reduces the *amount of energy required for production*, and that can help *reduce the* CO_2 *emissions*, which have ultimately been effective in *lowering the temperature* [Table 6, Pg26].

<u>Concrete Usage Index and Buildability Score in Tampines Concourse</u>

There are benchmarks established [Table 2, Pg21] to quantify the degree to which sustainable development is being adopted on an undertaking premise and the industry as a whole. On an undertaking premise, the BCA has set up the *concrete usage index* (CUI), which has been determined dependent on the all-out *volume of concrete utilized* against the *total floor areas of the structure* and comparatively, that is utilized to gauge the efficiency of the concrete. Using the CUI limit conditions set by the BCA[28] [Table 2, Pg21], and using *Tampines Concourse* as a reference, let's see where does this industrial region stand.

Based on the conditions that have been mentioned, the CUI is then calculated and through that, points have been assigned to buildings[29]. The building with the higher points is naturally considered to be the more sustainable one. As, the building which is planned all the more effectively, without settling on development security and efficiency, normally acquires a lower CUI Value. Hence, the lower CUI value, obtains the highest points.

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[28] Building and Construction Authority. (n.d.-b). *Sustainable Construction: A guide on Concrete Usage Index*. BCA. Retrieved November 4, 2020, from https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/sc_cui_final.pdf

[29] Building and Construction Authority. (2020, August 31). *Revised BCA Green Mark Criteria for New Buildings (Version 4.0)*. Corenet. Retrieved November 17, 2020, from https://www.corenet.gov.sg/einfo/Uploads/Circulars/CBCA100902.pdf

Project CUI (m^3/m^2)	Points
≤ 0.70	1
≤ 0.60	2
≤ 0.50	3
≤ 0.40	4
≤ 0.35	5

Table 2: Points based on CUI[30]

The following data [Table 3, Pg22], highlights case specific data for Tampines Concourse. In order to deem this building as sustainable, the *CUI index, the buildability score* and the *green mark award* was recorded. As for *Tampines Concourse*, the CUI was measured to be 0.31, which according to the scoring system displayed in the above table, is given to be 5 points [Figure 2A, Pg22], indicating the degree of sustainability through usage of sustainable materials, like green concrete in the construction process. This information verifies my analysis of the *adoption of recycled materials* through a scoring system.

[30] Appendix D1- Interview Questions with BCA, Pg54

Project CUI (m3/m2)	Points
≤ 0.70	1
≤ 0.60	2
≤ 0.50	3
≤ 0.40	4
≤ 0.35	5

Tampines Concourse falls here with a CUI of 0.31 and has 5 points (highest based on standards)

Figure 2A: Where *Tampines Concourse* stands with regard to CUI and points

With respect to the buildability score, which depicts the degree to which the plan of a building encourages simplicity of development just as the degree to which the ***adoption of construction techniques and processes affects the productivity level of building works***. According to the BCA, the minimum buildable score for an industrial building is 62. But however, *Tampines Concourse* has a buildability score of 81. Moreover, because of all this, the region has earned a Gold Plus Green Mark Award. Through this, it has been established how *Tampines Concourse* makes use of sustainable building practices through the concrete usage.

CUI Index	0.31
Buildability Score	81
Green Mark Award	Gold Plus

Table 3: Case Specific Data for Tampines Concourse[31]

[31] Building and Construction Authority. (2020, August 31). *Revised BCA Green Mark Criteria for New Buildings (Version 4.0)*. Corenet. Retrieved November 17, 2020, from https://www.corenet.gov.sg/einfo/Uploads/Circulars/CBCA100902.pdf

Through the sustainable concrete usage, we can see that sustainable building practices have been adopted. Therefore, through this, it can be deduced, that, the temperature has gone down significantly in this area [Table 6, Pg26], proving the effectiveness of the use of recycled materials in construction.

<u>Sustainable Buildings Practices Adopted- Electricity Grid Emission factors</u>

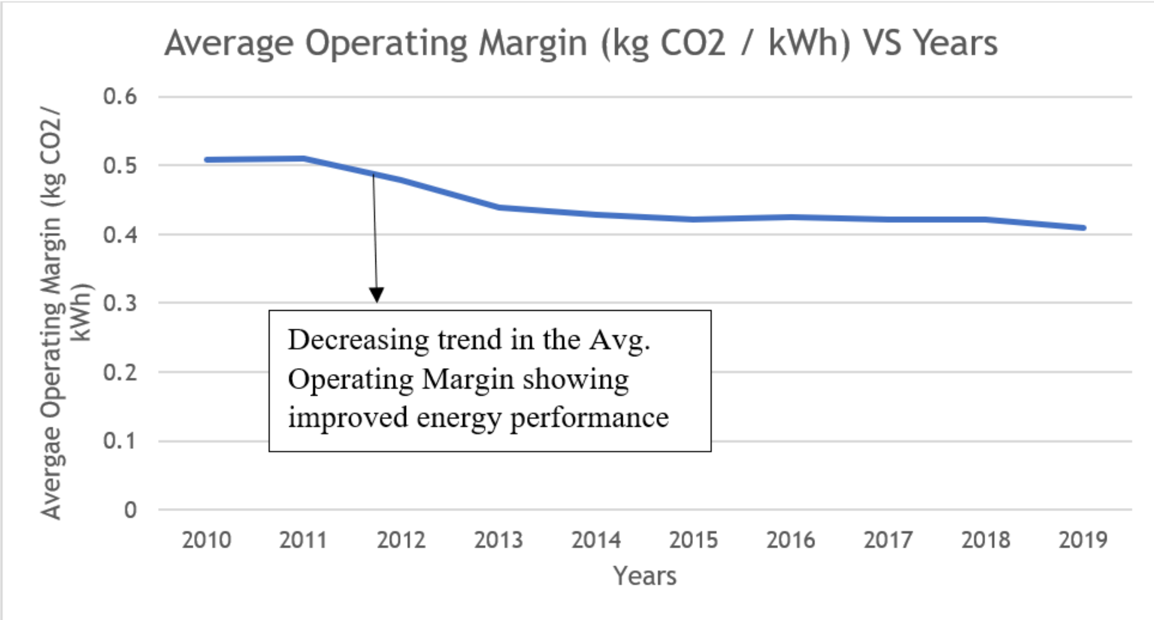
In conjunction with Concrete Usage, another effective indicator of sustainable building practice is the ***energy performance***. Electricity grid emission factors[32], particularly, average operating margin were measured over time [Table 4, Pg23] [Graph 1, Pg24]

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Average Operating Margin (kg CO_2 / kWh)	0.508	0.509	0.478	0.439	0.428	0.422	0.424	0.421	0.421	0.409
Build Margin (kg CO_2 / kWh)	0.432	0.458	0.416	0.414	0.409	0.394	0.398	0.402	0.403	0.401

Table 4: Electricity Grid Emission factors over time[33]

[32] Singapore Government. (n.d.). *Energy Market Authority*. Electricity Grid Emissions Factors and Upstream Fugitive Methane Emission Factor. Retrieved September 4, 2020, from https://www.ema.gov.sg/statistic.aspx?sta_sid=20140729MPY03nTHx2a1

[33] Appendix B2- Secondary data for electricity grid emission factors, Pg49



Graph 1: Average Operating Margin over time

From the trend [Table 4, Pg23] [Graph 1, Pg24], it is visible that the average operating margin, which acts as a measure of *energy performance* has decreased immensely over the past few years. From 2010, the Average Operating Margin was 0.508 kg CO_2/ kWh. But however, as per 2019, it is 0.409 kg CO_2/ kWh. There has been a 19.4% decrease. In order to test the **strength of the relationship**, we can use the **Spearman Rank Correlation**[34] as a statistical test [Table 5, Pg25]

Data Set A	Rank A	Data Set B	Rank B	d	d^2
2010	10	0.432	2	8	64
2011	9	0.458	1	8	64
2012	8	0.416	1	7	49
2013	7	0.414	1	6	36
2014	6	0.409	1	5	25
2015	5	0.394	5	0	0

[34] *Spearman's Rank-Order Correlation*. (n.d.). Laerd Statistics. Retrieved January 2, 2021, from https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php

2016	4	0.398	4	0	0
2017	3	0.402	2	1	1
2018	2	0.403	1	1	1
2019	1	0.401	1	0	0

Table 5: Spearman Rank Corelation Analysis

$$d = Difference\ between\ the\ ranks$$

$$d^2 = 64 + 64 + 49 + 36 + 25 + 0 + 0 + 1 + 1 + 0 = 240$$

$$Spearman\ Coorelation\ Coefficient = 1 - \frac{6\sum d^2}{n(\ n^2 - 1)}$$

$$Spearman\ Coorelation\ Coefficient = 1 - \frac{6 \times 240}{10(\ 10^2 - 1)}$$

$$Value\ for\ Spearman\ Coorelation\ Coefficient = \ -0.4545$$

The Spearman corelation was found to be -0.45 indicating a ***weak negative corelation*** between the years and the average operating margin, proving that there is a ***decreasing relationship*** between the two variables.

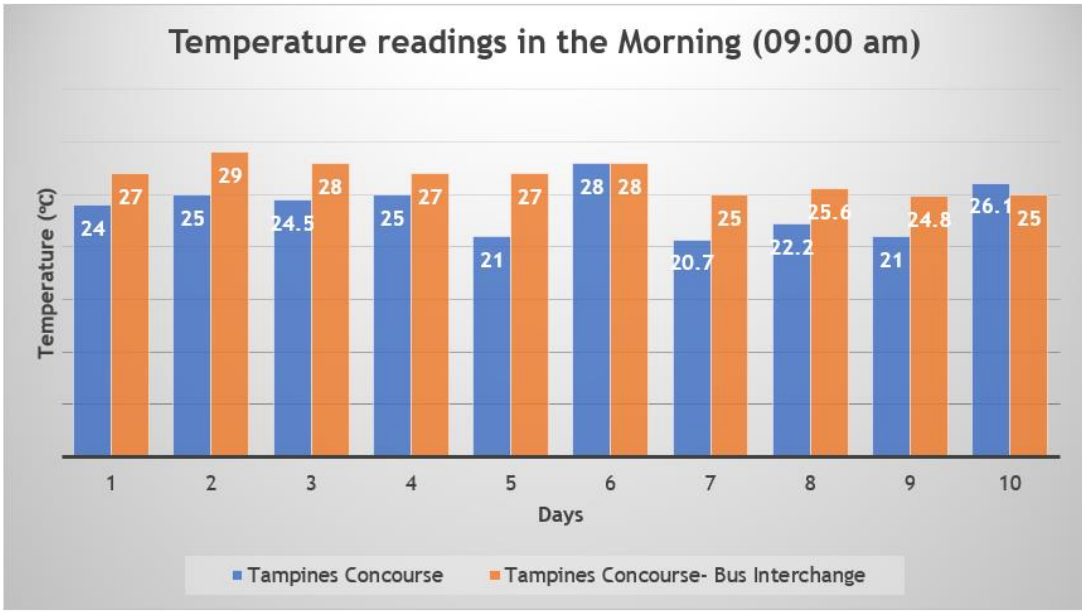
Due to the decreasing energy utilization, we can infer the building has adopted sustainable building practices, through the impressive **energy performance**. The effectiveness of this strategy, of ‘Concrete Usage’ and ‘Energy Performance’ was tested through measuring the temperature and seeing how that directly proves to be a solution to manage the urban microclimatic problems. As observed [Table 6, Pg26], there has been relatively lower temperatures in *Tampines Concourse* than in *Tampines Concourse Interchange,* hence showing that decrease in the average operating margin as a measure of the CO_2 offset. Therefore, proving hypothesis A, as it is well supported with these results relating adoption of sustainable materials and minimised electricity utilization as a solution to urban microclimatic problems, through lowering the temperature [Table 6, Pg26].

Effectiveness of the Sustainable Building practices strategy through temperature measurements.

The table below shows the temperature recordings at the site [Table 6, Pg26].

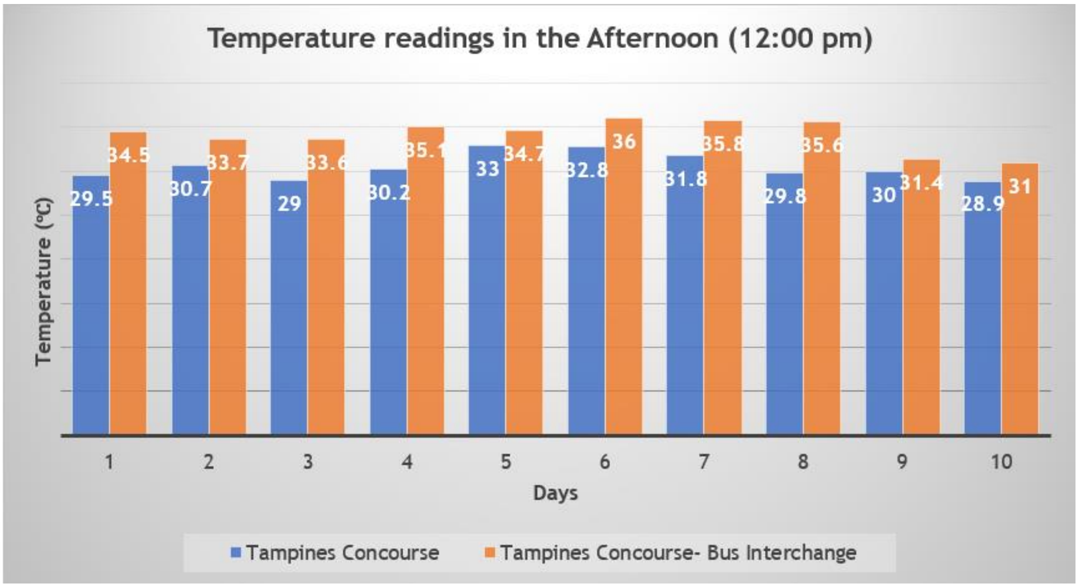
Temperature Readings (°C)						
Day	Morning (09:00am)		Afternoon (12:00 pm)		Evening (06:00 pm)	
	Tampines Concourse	Tampines Concourse-Bus Interchange	Tampines Concourse	Tampines Concourse-Bus Interchange	Tampines Concourse	Tampines Concourse-Bus Interchange
1	24	27	29.5	34.5	27.5	29.6
2	25	29	30.7	33.7	26.3	28.4
3	24.5	28	29	33.6	26	28
4	25	27	30.2	35.1	25.3	26.5
5	21	27	33	34.7	28.6	28.5
6	28	28	32.8	36	27.2	29.5
7	20.7	25	31.8	35.8	25.4	31.3
8	22.2	25.6	29.8	35.6	28.7	30.2
9	21	24.8	30	31.4	30.1	30.1
10	26.1	25	28.9	31	28.6	28.9

Table 6: Temperature Readings at *Tampines Concourse* &*Tampines Concourse Interchange*



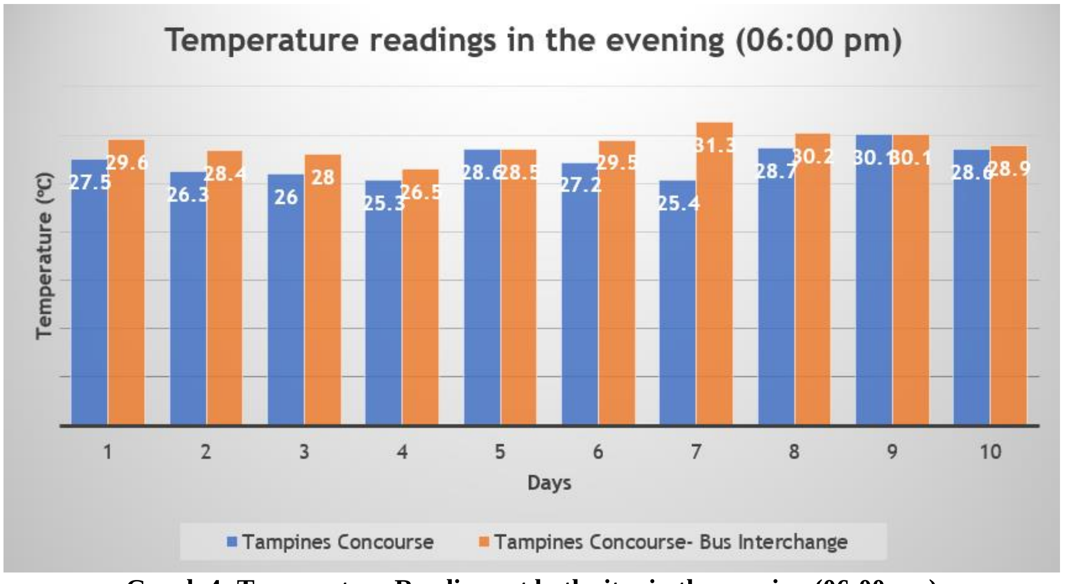
Graph 2: Temperature readings at both sites in the morning (09:00 am)

In the morning [Table 6, Pg26] [Graph 2, Pg27], the temperatures, recorded at *Tampines Concourse*, was **significantly lower** in comparison to the *Tampines Concourse Bus Interchange*. The significant difference recorded is 4.3℃ recorded on Day 7, with *Tampines Concourse* being at 20.7℃ and *Tampines Concourse Bus Interchange* at 25℃.



Graph 3: Temperature Readings at both sites in the afternoon (12:00pm)

Temperatures were higher at noon [Table 6, Pg26] [Graph 3, Pg27], as the sun was positioned directly above the earth's surface at 90°. But it still followed the conventional trend of the *Tampines Concourse Bus Interchange* being at a higher temperature than the *Tampines Concourse* area.



Graph 4: Temperature Readings at both sites in the evening (06:00 pm)

In the evening (06:00 pm) [Table 6, Pg26] [Graph 4, Pg28], similar patterns were noticed with regard to **lower temperatures** in *Tampines Concourse.* This is due to the use of *sustainable building materials* used and the *improved energy performance*, which lowered the temperature at this site. A reduction in temperature, helps manage microclimatic problems, as the *type of concrete* used is **high albedo**. This decreases the measure of approaching solar radiation retained through building envelops and metropolitan constructions, thus, keeping the surfaces cooler. Thereby, **mitigating the UHI effect** in this area, showing that the data found perfectly aligns with my hypothesis.

Implementation of the BCA Green Mark Scheme

BCA continually makes an increased effort to engage the industry, on the benefits of sustainable construction. Through highlighting the plans and policies for the future, there is a platform created for knowledge sharing. In order to raise the profile of this movement in Singapore, publicity of high-profile events in Singapore such as the ISWA/WMARS World Congress jointly organized by the International Solid Waste Association and Waste Management & Recycling Association of Singapore in November 2008 and the inaugural International Green Building Conference in October 2009 have been participated in, along with the BCA.

11 *Tampines Concourse* bears the Green Mark Pearl Award. It was designed and built keeping the concepts of environmental sustainability in mind. This area is well equipped with *green features such as an innovative, indoor non-compressor fresh air-cooling system, natural day-lighting systems, photocell sensors, water efficient fittings, use of low VOC paints for internal painting*. [35]

Ways through which the BCA Green Mark Strategy has been implemented

Few observations [Table 7, Pg30] made at the site and their potential benefits were recorded. Each variable was then analysed, in terms of a sustainable advantage, and how it

[35] Chew, K. C. (2010, July 20). *Singapore's strategies towards sustainable construction*. Tandfonline. Retrieved August 29, 2020, from https://www.tandfonline.com/doi/full/10.1080/19373260.2010.491641#:~:text=Two%20key%20focus%20areas%20of,as%20shown%20in%20Table%201.

brings down the humidity of the area, comparatively to the other urban areas in Tampines, which is, *Tampines Concourse Interchange* [Table 9, Pg36] [Graph 9, Pg37].

Green Features	Benefits
Presence of an indoor fresh air-cooling system	Savings of 620,000 kWh per year
Vertical greening area= 2,504 m^2 Green roof system= 1,921 m^2	Reduces the urban heat island effect and solar heat gain
Natural daylighting system in common areas	Maximizes natural daylighting
Water-efficient fittings in washrooms	Reduces potable water usage and water savings of 280m^3 per year
All walls and ceilings use low VOC paints	Improves urban comfort levels

Table 7: Key Observations and their potential advantages at the site

All of these green features, whether it is non-compressor *fresh air-cooling system*, *vertical greenery*, *natural daylight schemes*, *water- efficient fittings*, and *use of minimal chemicals* ensure **sustainable operation**, through **preservation of natural resources**, thereby, improving **occupational health and comfort of building users** [Image 6, Pg32]. Energy and waste management is effective in reducing the UHI effect through a **reduction in humidity levels** in comparison to the urban counterparts [Table 9, Pg36] [Graph 9, Pg37].

Vertical greening has been adopted by this industrial region [Image 5, Pg31], and it is been done through adopting a simple Green Façade System[36] [Figure 2B, Pg31].

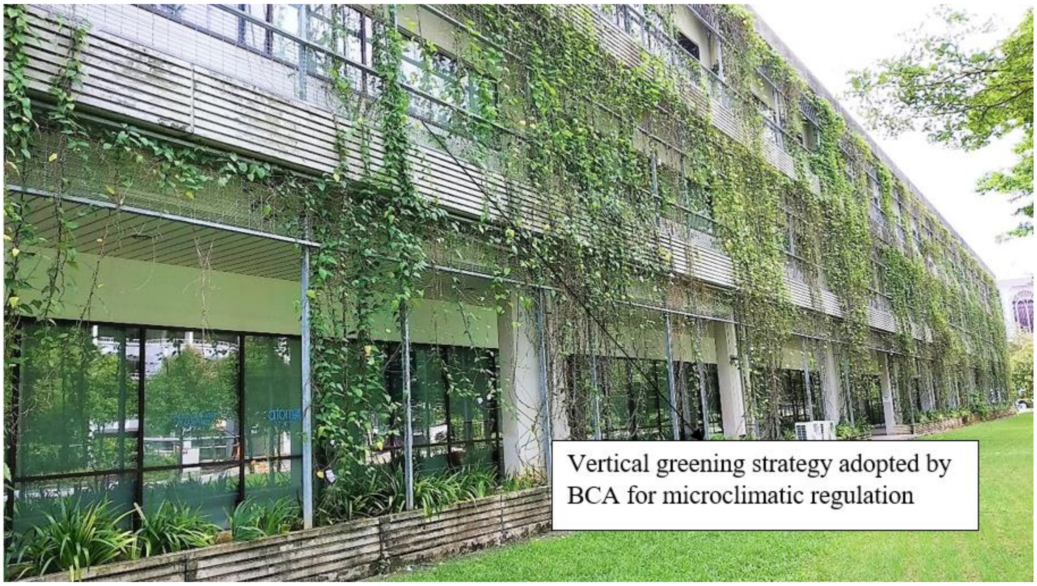


Image 5: Vertical Greening implemented by BCA at the site

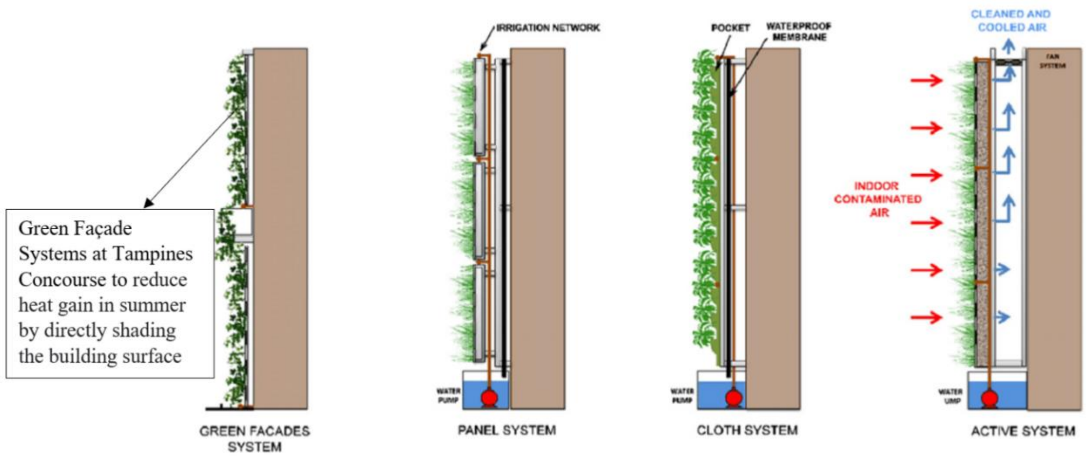


Figure 2B: Type of Vertical Greening system implemented at *Tampines Concourse*

[36] *Green Facades*. (n.d.). Architek. Retrieved January 2, 2021, from https://architek.com/products/green-facades/#:~:text=A%20green%20facade%20uses%20a,to%20purchase%2C%20install%20and%20maintain.

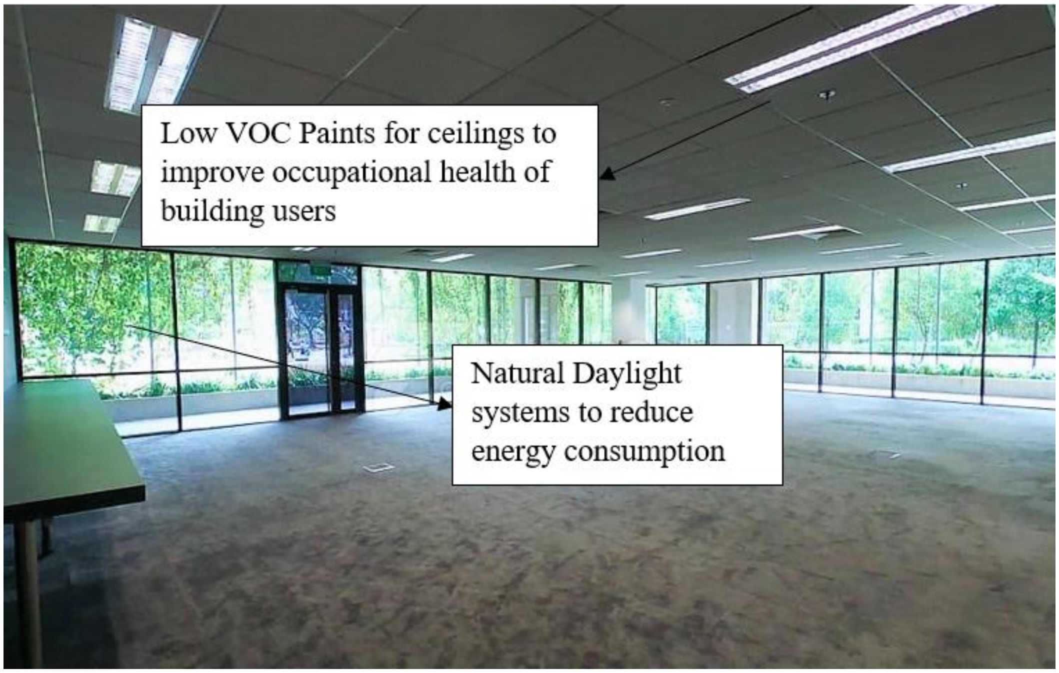
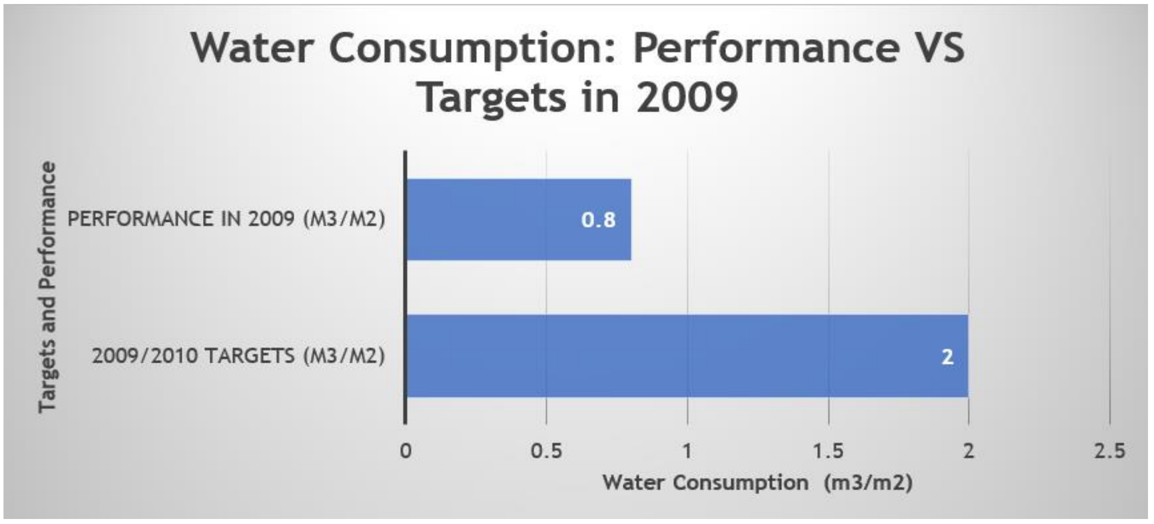


Image 6: Natural Daylight Systems and low VOC paints in *Tampines Concourse*

The government has also set out targets for *waste generation and water consumption* when the BCA Green Mark Scheme was introduced. [Table 7, Pg30] shows the data for the targets they planned to achieve in 2009-2010, and therefore, this will be compared with their performance in the same year [Table 8, Pg33]

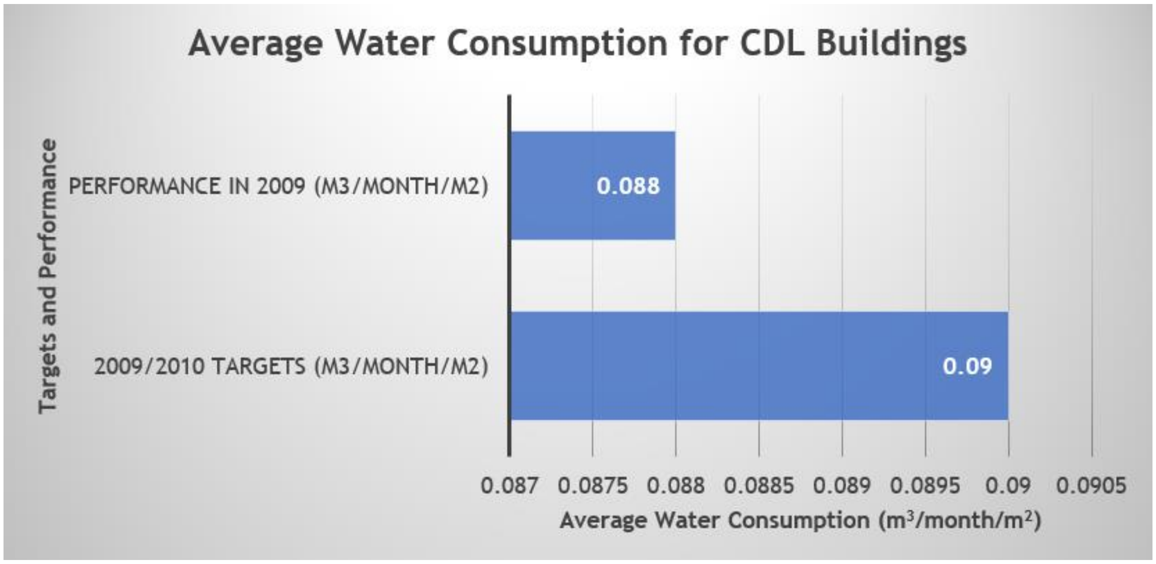
Projects Division	2009/2010 Targets	Performance in 2009
Water Consumption	$2m^3/m^2$	$0.8m^3/m^2$
Avg. water consumption of the CDL Buildings	$0.09\ m^3/month/m^2$	Achieved $0.088\ m^3/month/m^2$
Waste Generation	$75\ kg/m^2$	$61.7\ kg/m^2$
Avg. electricity consumption of the CDL Buildings	$9.9\ kWh/month/m^2$	Achieved $9.745\ kWh/month/m^2$

Table 8: Targets VS Performance of water, waste and electricity consumption[37]



Graph 5: Water Consumption Performance and Targets in 2009/10

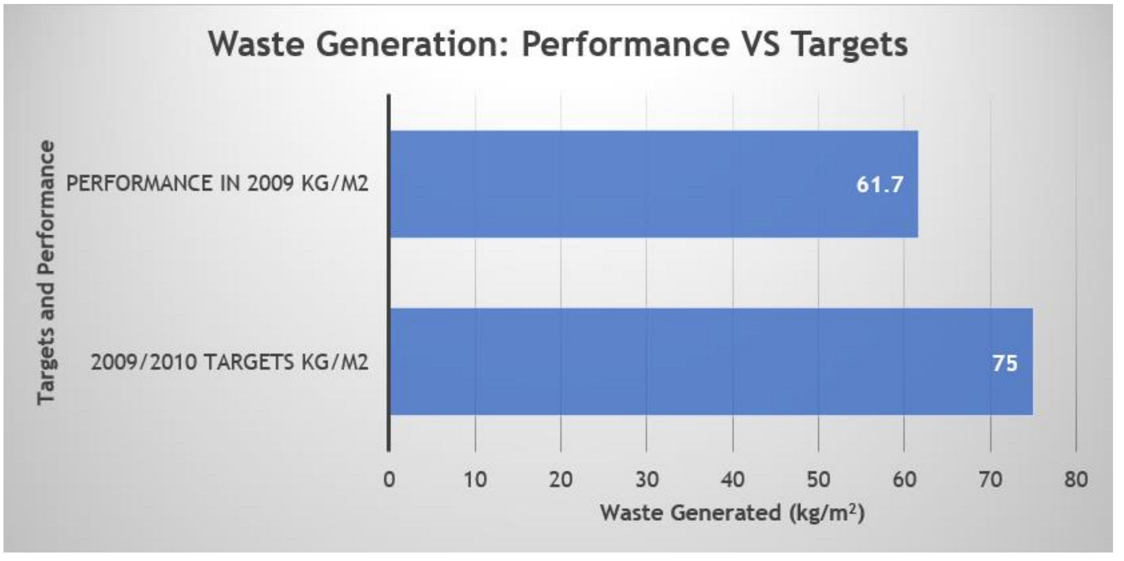
[37] *BCA AWARDS 2016 – CDL EXTENDS LEAD IN TENANT ENGAGEMENT AS THE MOST-AWARDED DEVELOPER IN GREEN MARK PEARL CATEGORY*. (2016). City Developments Limited. Retrieved October 28, 2021, https://ir.cdl.com.sg/static-files/cb0db75c-f3ab-4b43-b62f-55bd4ba02578



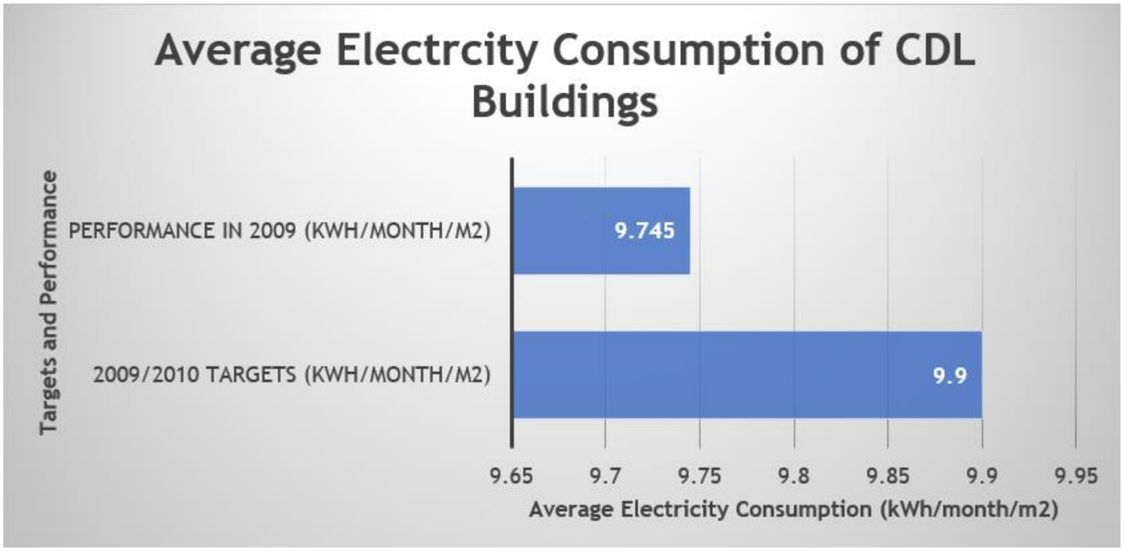
Graph 6: Average Water Consumption for CDL Buildings Targets VS Performance

[Table 8, Pg33] which highlights the targets and the performance in 2009, we are given insights into *the effectiveness of the government policies*, analysis of the *water, waste and electricity targets VS performance*, and the effectiveness of that in minimizing the UHI effect through the reduced humidity levels, in *Tampines Concourse* as compared to the urban counter-part [Table 9, Pg36] [Graph 9, Pg37]. The performance and targets for the 'Water consumption' [Graph 5, Pg33] and the 'Average Water Consumption of the CDL Buildings' are highlighted [Graph 6, Pg34]. Therefore, it can be deduced that the target for 'Water Consumption' and the 'Average Water Consumption of CDL Buildings' is $2m^3/m^2$ and 0.09 $m^3/month/m^2$ respectively. However, in terms of their performance, or rather, how much of it has been achieved, is $0.8m^3/m^2$ as for the Water consumption and 0.088 $m^3/month/m^2$ for the 'Average Water Consumption of CDL Buildings'. There is relatively a greater difference between the target and the performance for the water consumption, only $1.2m^3/m^2$, but it could be identified as a **potential anomaly**. However, as for the

'Average Water Consumption', there is a very insignificant difference, of only 0.002m^3/month/m^2. This difference in data shows that the targets for the average water consumption aspect have nearly been achieved, and hence that would have led to a **decrease in the humidity** [Table 9, Pg36] [Graph 9, Pg37].



Graph 7: Waste Generation Performance and Targets in 2009/10



Graph 8: Average Electricity Consumptions of CDL Buildings targets VS performance

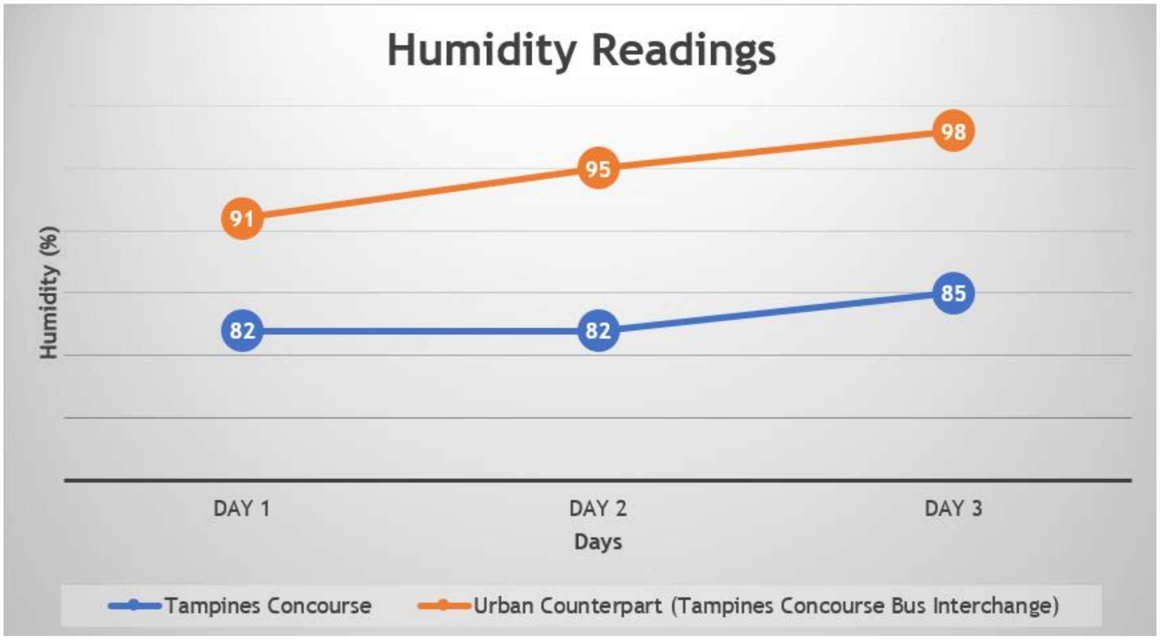
From the data [Table 8, Pg33] [Graph 7, Pg35] [Graph 8, Pg35], we can see that there is only a slight difference between the target and the performance. With regards to the waste generation [Graph 7, Pg35], the target was 75 kg/m^2 and the performance by the site was 61.7 kg/m^2. There is a difference of only 13.3 kg/m^2. Through this, it can be deduced that there is very little waste generated and it is sustainable as we also know this to be a region which has saved 21 tons of CO_2 emissions annually. On the other hand, it is observable that the target for the 'Avg. electricity consumption of the CDL Buildings' [Graph 8, Pg35], is 9.9 kWh/month/m^2 whereas the performance in the year 2009, is 9.745 kWh/month/m^2. This also indicates the closeness of the performance to the target. There is a difference of only 0.155 kWh/month/m^2, which highlights the insignificant difference and that *Tampines Concourse* was able to meet its sustainable targets which proved beneficial in reducing the **humidity levels** in this area in comparison to its urban counterpart [Table 9, Pg36] [Graph 9, Pg37].

Effectiveness of the BCA Green Mark Scheme through measuring the humidity levels

Days	Humidity Readings at 9:00 am (%)	
	Tampines Concourse	**Urban Counterpart (Tampines Concourse Bus Interchange)**
Day 1	82	91
Day 2	82	95
Day 3	86	98

Table 9: Humidity Readings at the Site[38]

[38] Appendix C2- Humidity Readings at *Tampines Concourse* and *Tampines Concourse Interchange*, Pg52



Graph 9: Comparison of Humidity readings at the site and the urban counterpart

Looking at the collected data [Table 9, Pg36] [Graph 9, Pg37], it is seen that the humidity of the area in *Tampines concourse*, is relatively less, than the humidity in the Urban counterpart, *Tampines Concourse Bus Interchange*, on all the days. For example, the greatest difference is observed to be on Day 2. In *Tampines Concourse*, the humidity was 82%, but in the *Tampines Concourse Bus Interchange*, it was 95%. There is a difference of 13%. Through this, we can see the success of the BCA Green Mark Scheme as being such that can **reduce the humidity** of the *Tampines Concourse* region. As, because of these green features, and the water, waste and electricity targets, the data for humidity readings were much lower than the urban counterparts.

CONCLUSION

This research revealed that sustainable buildings lowered the temperatures and humidity of the site through integration of sustainable building practices, such that the microclimatic problems are managed. Thereby, **answering the research question**, *"Are sustainable buildings a viable solution to urban microclimatic problems as seen through Tampines Concourse, an Industrial Region in Singapore?"* to be true.

Hypothesis A was **significantly proven** as through the sustainable concrete usage and the trend observed with a decline in the energy consumption. On an average, there was an overall lower temperature, in the *Tampines Concourse* region in comparison to the *Tampines Concourse Bus Interchange* as sustainable materials use less energy for production, hence reducing the CO_2 emissions.

Moreover, **Hypothesis B**, which explored the aims of the BCA Green Mark Scheme, was relatively successful in implementation, hence **proving the hypothesis to be true.** Having outlined the targets and performance for waste and water management practices, it was suggested that the targets have nearly been met. But however, the $1.2m^3/m^2$ for the Water Consumption target, was higher in comparison to the other targets, thereby making it an **anomaly**, which challenged the hypothesis. It was further confirmed by measuring the humidity levels in the *Tampines Concourse* area and *Tampines Concourse Interchange*, proved to be significantly lower and hence leading to management of the microclimate processes.

Evaluation

My extended essay journey, was both, fulfilling and enriching. Through the entire process, I was able to conduct online interviews as a geographer for the first time and although it was challenging at times, I was able to broaden my perspectives, further develop my communication, and geographical skills. Moreover, I am confident in my data, as they prove to be relevant to the study, and backed up by secondary sources. Through the process, I developed strong analytical writing skills, and it enabled me to think critically.

This research was done amidst a pandemic. Hence, in person interviews were difficult with regard to the government regulations. When I conducted my interview through e-mail, the BCA took time to respond, which delayed my process of data collection. Moreover, after waiting for a while, they gave me valuable information which has been used throughout my extended essay. Although, there were few responses which were very generic, thereby, making the data unreliable. While taking temperature measurements, I held the thermometer at different height levels every day as I based it on approximation, hence leading to data which might be insignificant.

Generally speaking, the essential information I gathered was **supportive**, and **pertinent** in noting my hypothesis, and RQ. However, in the event that I were allowed to do this EE once more, I would expand my sample size, to make my readings more accurate. The theories I was trying to explore were sustainable building strategies and its effect on the temperature and humidity, which were proven and I personally rate this essay to be of significance. However, an unresolved question, remains whether the concrete used throughout the building is actually sustainable as they claim it to be, as a researcher, I was limited in testing the type of concrete used.

BIBLIOGRPAHY

BCA AWARDS 2016 – CDL EXTENDS LEAD IN TENANT ENGAGEMENT AS THE MOST-AWARDED DEVELOPER IN GREEN MARK PEARL CATEGORY. (2016). City Developments Limited. Retrieved September 26, 2020, from https://ir.cdl.com.sg/static-files/cb0db75c-f3ab-4b43-b62f-55bd4ba02578

Building and Construction Authority. (n.d.-a). *Green Mark Certification Scheme*. BCA. Retrieved October 7, 2020, from https://www1.bca.gov.sg/buildsg/sustainability/green-mark-certification-scheme

Building and Construction Authority. (n.d.-b). *Sustainable Construction: A guide on Concrete Usage Index*. BCA. Retrieved November 4, 2020, from https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/sc_cui_final.pdf

Building and Construction Authority. (2005). *3rd Green Building Masterplan*. BCA. Retrieved August 30, 2020, from https://www.bca.gov.sg/greenmark/others/3rd_green_building_masterplan.pdf

Building and Construction Authority. (2020, August 31). *Revised BCA Green Mark Criteria for New Buildings (Version 4.0)*. Corenet. Retrieved November 17, 2020, from https://www.corenet.gov.sg/einfo/Uploads/Circulars/CBCA100902.pdf

Chew, K. C. (2010, July 20). *Singapore's strategies towards sustainable construction*. Tandfonline. Retrieved August 29, 2020, from https://www.tandfonline.com/doi/full/10.1080/19373260.2010.491641#:~:text=Two%20key%20focus%20areas%20of,as%20shown%20in%20Table%201.

csma. (n.d.). *Sustainability*. Cementious Slag Makers Association. Retrieved December 2, 2020, from https://ukcsma.co.uk/sustainability/

Department of Statistics Singapore. (n.d.). *Population and Population Structure*. Singstat. Retrieved March 5, 2020, from https://www.singstat.gov.sg/find-data/search-by-theme/population/population-and-population-structure/latest-data

Developer. (n.d.). Good Wood Residences. Retrieved November 28, 2020, from https://goodwoodresidence.org/developer/

Green Facades. (n.d.). Architek. Retrieved January 2, 2021, from https://architek.com/products/green-facades/#:~:text=A%20green%20facade%20uses%20a,to%20purchase%2C%20install%20and%20maintain.

Holistic Method on Performing Microclimate Analyses of an Urban Area in The Tropics. (2015). Meteo. Retrieved July 10, 2020, from http://www.meteo.fr/icuc9/presentations/UDC/UDC3-6.pdf

Our Concrete Responsibility: Sustainability. (n.d.). PanUnited. Retrieved December 1, 2020, from https://www.panunited.com.sg/page/sustainability/

Recycled Concrete Aggregates: A Review. (2013, March 29). Springer Link. Retrieved December 1, 2020, from https://link.springer.com/article/10.1007/s40069-013-0032-5

Singapore Government. (n.d.). *Energy Market Authority*. Electricity Grid Emissions Factors and Upstream Fugitive Methane Emission Factor. Retrieved September 4, 2020, from https://www.ema.gov.sg/statistic.aspx?sta_sid=20140729MPY03nTHx2a1

Singapore : Ministry of Manpower and Ministry of National Development. (1999). *Construction 21*. Eresources.NLB. Retrieved October 10, 2020, from https://eresources.nlb.gov.sg/printheritage/detail/cda47e8d-4565-4c54-bf05-0c98905d01f0.aspx

Spearman's Rank-Order Correlation. (n.d.). Laerd Statistics. Retrieved January 2, 2021, from https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php

Sustainable Singapore Blueprint 2015. (2015). Nccs.Gov.Sg. Retrieved February 24, 2020, from https://www.nccs.gov.sg/docs/default-source/default-document-library/sustainable-singapore-blueprint-2015.pdf

TAMPINES CONCOURSE. (n.d.). BCA. Retrieved October 19, 2020, from https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/tampines_concourse.pdf

Urban Population (% of total population)- Singapore. (n.d.). The World Bank. Retrieved March 3, 2020, from https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=SG

Use of waste copper slag, a sustainable material. (2014, May 3). Springer Link. Retrieved December 1, 2020, from https://link.springer.com/article/10.1007/s10163-014-0254-x

Textbook- Geography – Course Companion Oxford – Garrett Nagle and Briony Cooke – Second Edition-Oxford 2017

External Sources: Class notes in Geography lessons

APPENDICES

Appendix A1- Research Papers with regards to Sustainable Construction

International Journal of
Low-Carbon Technologies

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Volume 10, Issue 1
March 2015

Article Contents

Experimental study of the urban microclimate mitigation potential of green roofs and green walls in street canyons

Rabah Djedjig, Emmanuel Bozonnet ✉, Rafik Belarbi

International Journal of Low-Carbon Technologies, Volume 10, Issue 1, March 2015, Pages 34–44, https://doi.org/10.1093/ijlct/ctt019
Published: 14 April 2013 **Article history** ▾

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Abstract

This paper presents the design and the results of a reduced-scale experimental bench to study the effect of green roofs and green

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Sustainability of Concrete Construction

Tarun R. Naik, F.ASCE[1]

Abstract: Sustainability is important to the well-being of our planet, continued growth of a society, and human development. Concrete is one of the most widely used construction materials in the world. However, the production of portland cement, an essential constituent of concrete, leads to the release of significant amounts of CO_2, a greenhouse gas (GHG); production of one ton of portland cement produces about one ton of CO_2 and other GHGs. The environmental issues associated with GHGs, in addition to natural resources issues, will play a leading role in the sustainable development of the cement and concrete industry during this century. For example, as the supply of good-quality limestone to produce cement decreases, producing adequate amounts of portland cement for construction will become more difficult. There is a possibility that when there is no more good-quality limestone in, say, a geographical region, and thus no portland cement, all the employment associated with the concrete industry, as well as new construction projects, will be terminated. Because of limited natural resources, concern over GHGs, or, both, cement production is being curtailed, or at least cannot be increased to keep up with the population increase, in some regions of the world. It is therefore necessary to look for sustainable solutions for future concrete construction. A sustainable concrete structure is constructed to ensure that the total environmental impact during its life cycle, including its use, will be minimal. Sustainable concrete should have a very low inherent energy requirement, be produced with little waste, be made from some of the most plentiful resources on earth, produce durable structures, have a very high thermal mass, and be made with recycled materials. Sustainable constructions have a small impact on the environment. They use “green” materials, which have low energy costs, high durability, low maintenance requirements, and contain a large proportion of recycled or recyclable materials. Green materials also use less energy and resources and can lead to high-performance cements and concrete. Concrete must keep evolving to satisfy the increasing demands of all its users. Designing for sustainability means accounting for the short-term and long-term environmental consequences in the design.

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Agriculture and Agricultural Science Procedia 8 (2016) 576 – 582

Agriculture and Agricultural Science
Procedia

Florence "Sustainability of Well-Being International Forum". 2015: Food for Sustainability and not just food, FlorenceSWIF2015

Green control of microclimate in buildings

Evelia Schettini[a]*, Ileana Blanco[a], Carlo Alberto Campiotti[b], Carlo Bibbiani[c], Fabio Fantozzi[d], Giuliano Vox[a]

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[b]ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development - Technical Unit Energy Efficiency - Agriculture Unit, Via Anguillarese 301, 00123 Rome, Italy
[c]Department of Veterinary Science, University of Pisa, Viale delle Piagge 2, 56124 Pisa, Italy
[d]Department of Energy, Systems, Territory and Costruction Engineering DESTEC, University of Pisa, Largo Lucio Lazzarino, 56122 Pisa (Italy)

sustainability

MDPI

Article

Green Buildings in Singapore; Analyzing a Frontrunner's Sectoral Innovation System

Vidushini Siva [1], Thomas Hoppe [2,*] and Mansi Jain [1]

1 Department of Technology and Governance for Sustainability (CSTM), Institute for Innovation and Governance Studies (IGS), Faculty of Behavioral, Management and Social Studies (BMS), University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands; vidushini.siva@gmail.com (V.S.); m.jain-1@utwente.nl (M.J.)
2 Policy, Organisation, Law and Gaming (POLG), Department of Multi-Actor Systems (MAS), Faculty of Technology, Policy and Management (TPM), Delft University of Technology, Jaffalaan 5, 2628 BX Delft, The Netherlands
* Correspondence: T.Hoppe@tudelft.nl; Tel.: +31-15-278-2783

Academic Editor: Umberto Berardi
Received: 29 March 2017; Accepted: 23 May 2017; Published: 31 May 2017

Appendix A2- News Articles based on Sustainable Construction

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Essays

Singapore's strategies towards sustainable construction

K. C. Chew

Pages 196-202 | Received 30 Apr 2010, Accepted 06 May 2010, Published online: 20 Jul 2010

Download citation https://doi.org/10.1080/19373260.2010.491641

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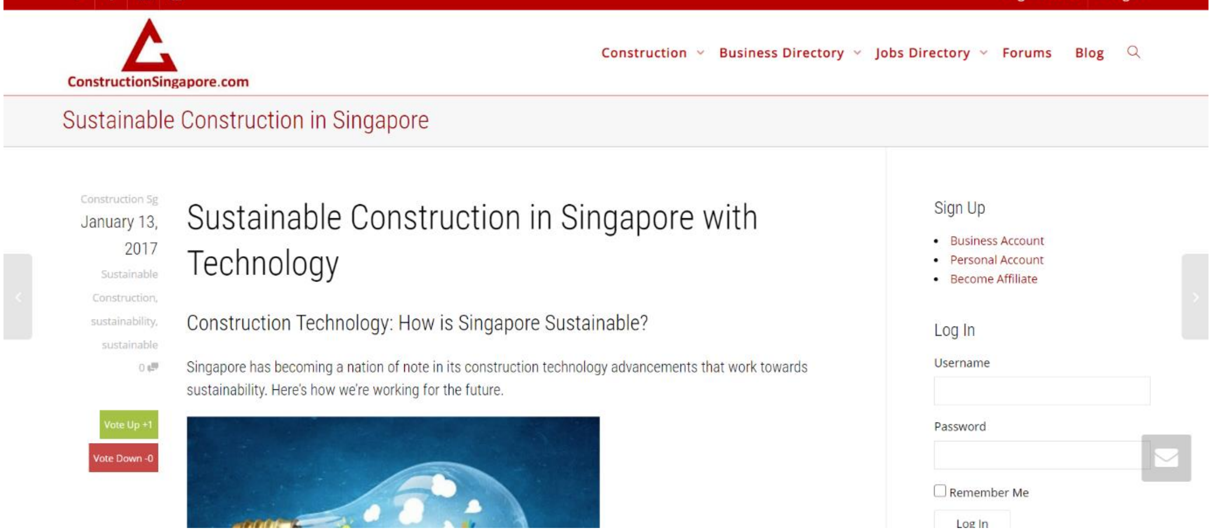

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Sustainable Construction in Singapore

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The missing piece in Singapore's green building puzzle

Singapore aims to green 80 per cent of its building stock by 2030, but experts say it is behind schedule. What's holding the city-state's green building sector back, and how can it overcome these obstacles?

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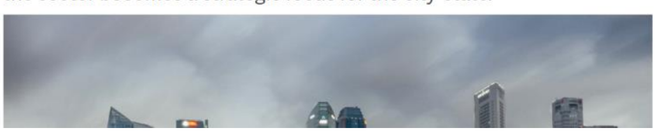
10 years in, industry takes the lead in advancing green buildings in Singapore

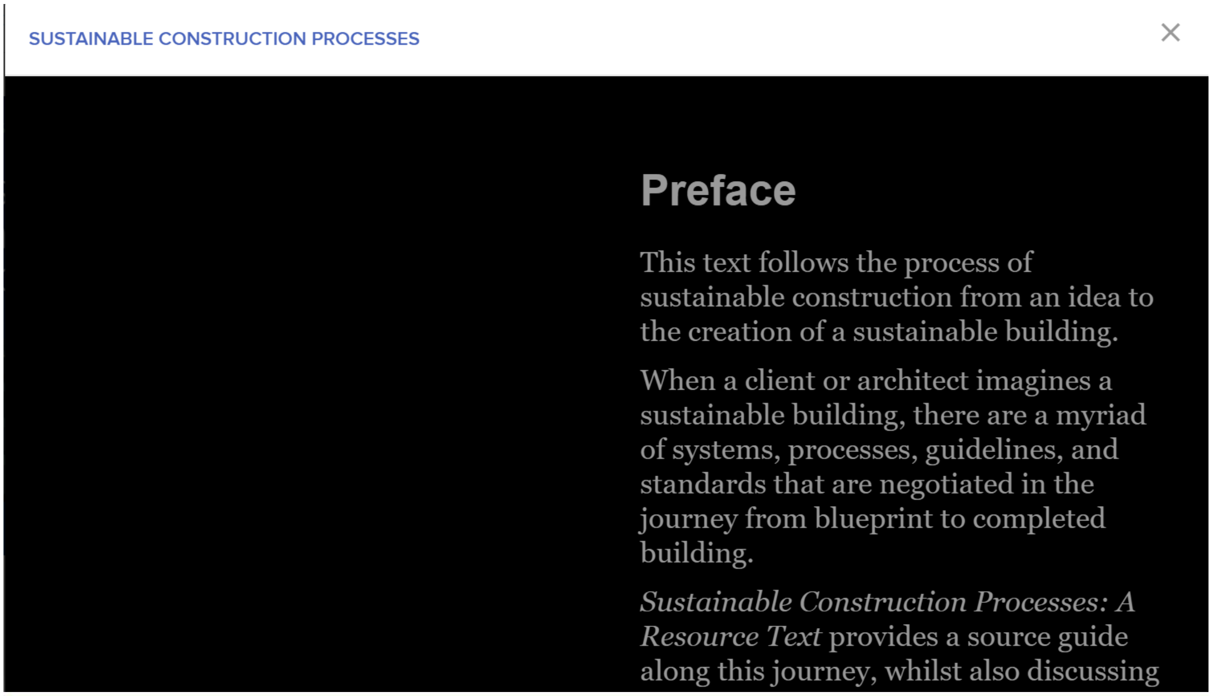
Beginning this year, the Singapore Green Building Council takes over a key green building certification scheme for professionals and an enhanced role in assessing buildings on their sustainability impact as the sector becomes a strategic focus for the city-state.

Sponsored by: 10 YEARS SINGAPORE GREEN BUILDING COUNCIL

By Mint Kang



Appendix B1- Books that address Sustainable Construction in Singapore

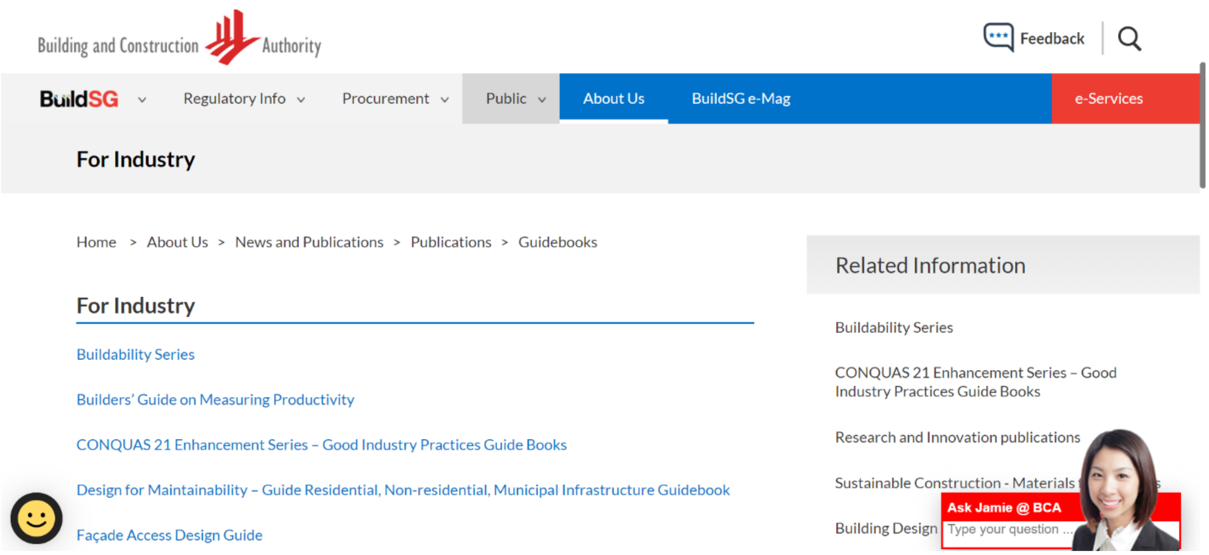

SUSTAINABLE CONSTRUCTION PROCESSES

Preface

This text follows the process of sustainable construction from an idea to the creation of a sustainable building.

When a client or architect imagines a sustainable building, there are a myriad of systems, processes, guidelines, and standards that are negotiated in the journey from blueprint to completed building.

Sustainable Construction Processes: A Resource Text provides a source guide along this journey, whilst also discussing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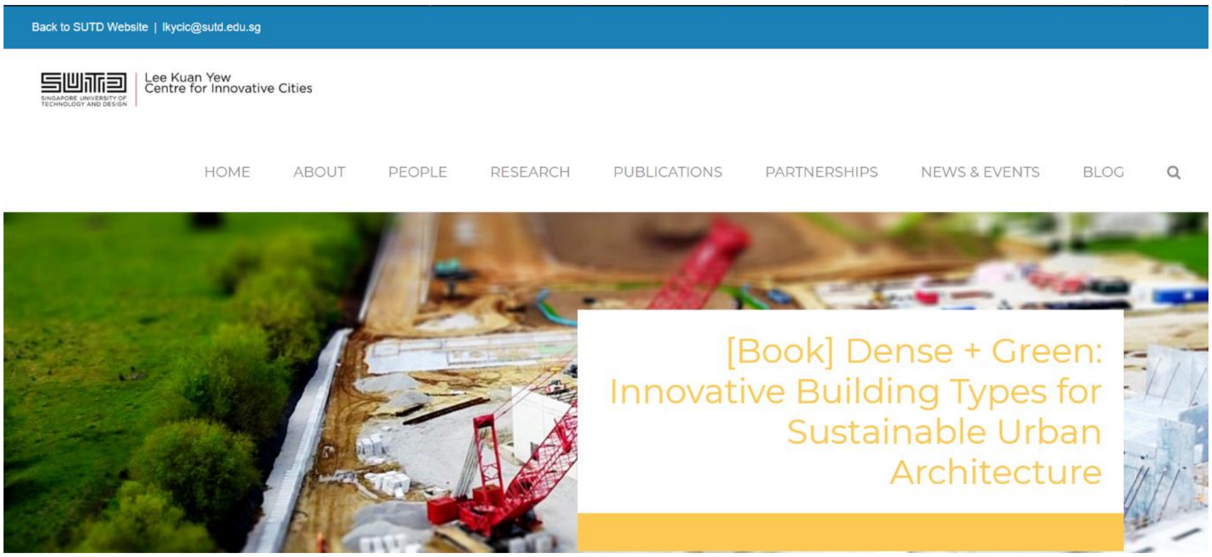
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[Book] Dense + Green: Innovative Building Types for Sustainable Urban Architecture

Appendix B2- Secondary data for Electricity Grid Emission factors

Years	Average Operating Margin (OM) (kg CO^2 / kWh)	Build Margin (BM) (kg CO_2 / kWh)	Upstream Fugitive Methane Emission Factor (kg CH_4 / kWh)
2005	0.5255	0.4205	0.00216
2006	0.5300	0.4225	0.00218
2007	0.5046	0.4352	0.00225
2008	0.4965	0.4264	0.00221
2009	0.4973	0.4208	0.00222
2010	0.5083	0.4319	0.00222
2011	0.5085	0.4578	0.00228
2012	0.4778	0.4164	0.00218
2013	0.4388	0.4137	0.00218
2014	0.4277	0.4086	0.0022
2015	0.4224	0.3941	0.00217
2016	0.4237	0.3977	0.00216
2017	0.4210	0.4018	0.00198
2018	0.4206	0.4031	0.00213
2019	0.4085	0.4013	0.00212

Appendix C1- Temperature Readings at *Tampines Concourse* and *Tampines Concourse Interchange*

Temperature Readings (°C)						
	Morning (09:00am)		Afternoon (12:00 pm)		Evening (06:00 pm)	
Day	Tampines Concourse	Tampines Concourse-Bus Interchange	Tampines Concourse	Tampines Concourse-Bus Interchange	Tampines Concourse	Tampines Concourse-Bus Interchange
1	24	27	29.5	34.5	27.5	29.6
2	25	29	30.7	33.7	26.3	28.4
3	24.5	28	29	33.6	26	28
4	25	27	30.2	35.1	25.3	26.5
5	21	27	33	34.7	28.6	28.5
6	28	28	32.8	36	27.2	29.5
7	20.7	25	31.8	35.8	25.4	31.3
8	22.2	25.6	29.8	35.6	28.7	30.2
9	21	24.8	30	31.4	30.1	30.1
10	26.1	25	28.9	31	28.6	28.9
11	25	27	30.7	32.7	25.3	28
12	24.5	27	29	36.4	28.6	26.5
13	25	28	30.2	31.4	27.2	28.5
14	21	25	33	31	25.4	29.5
15	25	27	29	35.1	28.7	31.3
16	21	27	30.2	34.7	30.1	30.2
17	28	28	33	36	27.5	31.3
18	20.7	25	32.8	35.8	26.3	30.2
19	22.2	25.6	31.8	35.6	26	30.1
20	21	24.8	29.8	31.4	25.3	28.9
21	26.1	25	30	31	28.6	28
22	25	27	29.8	34.5	27.2	26.5
23	24.5	27	30	33.7	25.4	28.5
24	25	27	28.9	33.6	28.7	28
25	21	27	30.7	35.1	28.6	26.5
26	25	28	29	34.7	27.2	28.5
27	21	25	30.2	36	25.4	29.5
28	25	27	33	35.8	28.7	31.3
29	21	27	33	35.6	30.1	30.2

30	28	28	29	31.4	27.5	31.3
31	20.7	25	30.2	31	26.3	30.2
32	24	29	33	35.1	26	30.1
33	25	28	32.8	34.7	25.3	28.9
34	24.5	27	31.8	36	28.6	29.6
35	25	27	29.8	35.8	27.2	28.4
36	21	28	30	35.6	25.4	28
37	24	25	29.8	31.4	27.2	26.5
38	25	25.6	30	31	25.4	28.5
39	24.5	24.8	29.5	34.5	28.7	29.5
40	25	25	30.7	32.7	28.6	31.3
41	21	27	29	36.4	27.2	30.2
42	28	27	30.2	31.4	25.4	30.2
43	20.7	28	33	31	28.7	30.1
44	22.2	27	32.8	35.1	30.1	28.9
45	21	27	31.8	34.7	27.5	29.6
46	25	28	29.8	36	26.3	28.4
47	24.5	25	30	35.8	26	28
48	25	27	28.9	35.6	28.6	26.5
49	21	27	30.7	31.4	27.2	30.2
50	24	28	29.8	31	25.4	31.3

Appendix C2- Humidity Readings at *Tampines Concourse* and *Tampines Concourse Interchange*

Days	Tampines Concourse (%)	Tampines Concourse Interchange (%)
1	82	91
2	82	95
3	86	98
4	81	85
5	84	90
6	82	97
7	82	94
8	81	96
9	86	98
10	81	85
11	84	90
12	82	91
13	82	95
14	86	98
15	81	85
16	80	92
17	89	90
18	88	88
19	82	94
20	81	96
21	86	98
22	81	85
23	86	98
24	81	85
25	84	90
26	82	97
27	82	94
28	81	96
29	86	98
30	81	85
31	84	90
32	82	91
33	81	85
34	80	92

35	89	90
36	88	88
37	82	94
38	81	96
39	86	98
40	81	85
41	82	95
42	86	98
43	81	85
44	84	90
45	82	97
46	82	94
47	81	96
48	86	98
49	81	96
50	86	98

Appendix D1- Interview Questions with BCA

Q.1) How exactly has Tampines Concourse been able to prove itself as "carbon-neutral building"

Q.2) What type of concrete is used in the construction process and how is it different from normal concrete

Q.3) Can you please give me substantiated data as to what the composition of the concrete is

Q.4) What conditions have been set in order to gain awards?

Q.5) Can you please help me outline the water and waste management targets by Tampines concourse, and how effectively they have performed?