Green buildings in Singapore: assessing the feasibility of an energy transition in the building sector under the current policy approach

by

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Abstract

Singapore is widely recognized as a global leader in affairs pertaining to sustainable urban development. Green buildings that boast visually spectacular vertical gardens and feature technology to increase resource use efficiency have become an unofficial emblem of the city-state, representing a unique opportunity to position sustainability in the forefront of the intensively urban landscape. Government initiatives directed toward the less apparent features of sustainable operations have now taken precedence over aesthetic greenery to address pervasive energy challenges. Singapore has successfully introduced higher efficiency green buildings into the construction sector through a strong policy approach. To stimulate continued integration, the government has set an overarching goal to green a minimum of 80% of buildings in Singapore by 2030. This paper addresses the pertinent question: Do the existing policy initiatives offer sufficient regulatory support and market integration stimulus to fulfill Singapore's green building objectives? Analysis involves conducting a policy scan to identify the legislative documents pertinent to green buildings and employing an original hybridized framework merging force-field and PEST analyses. The framework evaluates four macroeconomic classifications influencing green building uptake by the market: policy (separately evaluated by regulation and market stimulation proficiency), economic barriers, social barriers, and technological barriers. Singapore was found to excel in its regulatory role. The current policy approach is characterized by mandatory prescriptive policy and strong government involvement. This has largely been responsible for the successful initial introduction of green buildings. The numerous market barriers and policy implementation gaps identified by the study suggest that the current policy approach does not offer sufficient market stimulus. Economic and social barriers due to valuation issues, poor industry productivity, and low market demand were found to be significant. Technological barriers were moderate and generally associated with uptake issues. The results highlight the importance of utilizing different policy approaches at different stages of market maturity.

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1 Introduction

The building sector is a vital component of the built urban environment. However, the industry also plays a significant role in the degradation of the environment. Building operation and construction was found to be responsible for approximately 36% of global energy consumption and 39% of global energy-related carbon dioxide emissions by a study conducted in 2016 (UNEP, 2017). These numbers are expected to rise as the global population continues to increase. The negative environmental effects of the building sector have prompted the introduction of green buildings. Green buildings incorporate sustainability features and promote the efficient use of energy, water, and other resources throughout their entire life cycle to reduce the negative impacts associated with conventional buildings (Siva et al., 2017). In many major economies such as Singapore, the government promotes the adoption of green technology in the building sector through policy initiatives (Zhang et al., 2018). Green buildings are especially relevant to Singapore. As a city-state with a very high population density, buildings are the most effective option for minimizing the amount of land area used while maximizing the number of individuals being accommodated (Hwang et al., 2017). Singapore is widely acknowledged as a leader in both Asian economic development and global sustainable environmental performance (Liu & Yu, 2013). The city-state is especially recognized for its considerable advancement in the green building field.

The environmental benefits associated with green buildings produce numerous economic and social outcomes. Direct economic benefits generally relate to energy and water savings, reduced waste, and lower operations and maintenance costs (Kats, 2003). According to the United Nations Environment Program (UNEP), the use of green features in buildings can reduce energy consumption by 30-80% (BCA, 2013). This directly translates to monetary savings. From a broad perspective, green buildings represent an opportunity to address the energy security challenges faced by Singapore. As a nation with an exceedingly small land area and very few natural resources, the city-state relies heavily on imported fossil fuels from neighbouring countries (Heinzle et al., 2013). Energy prices are therefore subject to high volatility (Yu et al., 2011). The assimilation of green buildings represents an opportunity for Singapore to capture greater energy price autonomy. Indirect economic outcomes are associated with the social benefits of green buildings. Green buildings have been proven to enhance occupant health by improving indoor air quality and ventilation (Liu & Yu, 2013). Singapore has been found to sustain one of the highest qualities of life compared to other countries (Beatley, 2012). This is largely because of its commitment to offering the best possible environment for its citizens. In office buildings, these conditions improve employee comfort and productivity (Kats, 2003), translating into increased work efficiency and higher company profitability.

This paper will explore the feasibility of incorporating green buildings into the Singaporean building sector. A comprehensive review of existing green building literature, policies, and planning documents will assess the factors that have advanced and limited the sectoral energy transition of the building industry and demonstrate whether the target set out by the government to green 80% of buildings by 2030 is attainable. Green buildings were estimated to comprise 25% of the total built environment in 2014 following nine years of concerted government effort (BCA, 2014). Achievement of the ambitious goal would require tripling current green gross floor area numbers in a span of only 16 years. The research question to be addressed by this paper is: Do the existing policy initiatives offer sufficient regulatory support and market integration stimulus to fulfill Singapore's green building objectives?

This paper is profound for the future of sustainable urban planning. Green buildings are among the least invasive methods for incorporating sustainability into urban settings, where minimal lifestyle change offers the potential for very high positive impact. According to the Intergovernmental Panel on Climate Change (IPCC), green buildings have the highest and most cost-effective potential for significantly decreasing greenhouse gas emissions (Albino & Berardi, 2012). There would be no discernable difference in the function of such buildings, indicating that the current lifestyle of residents/occupiers would be largely unaffected by the assimilation of sustainable design features. However, the positive environmental benefits would be hugely impactful because of the large quantity of buildings present in urban environments. Green buildings represent the idealized future of metropolitan landscapes by contributing to environmental, social, and economic longevity.

This paper is organized as follows: Section 2 provides a literature review of green building status in Singapore. Comprehensive studies focusing on current factors influencing green building uptake in the city-state are examined. Section 3 presents a detailed explanation of the methodology used to guide this study. Section 4 details the results of the study followed by a summary. This involves the identification and analysis of current green building policy, policy implementation gaps, and market conditions. Section 5 expresses conclusions derived from the findings.

2 Literature Review

This section discusses four studies related to policy and market factors that are particularly relevant to this paper. These studies functioned as both sources of information and catalysts to further research by providing search prompts. Majority of the references utilized by this paper were found using search terms originating from one of four of these studies. It is important to note that studies are not overtly abundant. Therefore, statistical data is considered to be inconclusive and its relevance is derived from identifying trends and correlations between the findings of different experts. The existing literature is also found to be disjointed, requiring the culmination of many sources to formulate a comprehensive image of the Singaporean macroeconomic landscape pertaining to green buildings. Very few papers offer connections between different policy aspects and market factors, instead isolating disparate components dominated by financial considerations. Studies are not comprehensive and generally do not have the "bigger picture" in mind. The most comprehensive paper of those studied is by Siva et al. (2017), which offers insight on both regulatory and market-oriented considerations. It analyzes the systemic conditions of Singapore that influence green building integration. The paper follows the Sectoral Innovation Systems (SIS) framework to analyze the conditions that strengthen or weaken green building uptake. The framework is comprised of four dimensions:

1. *Agents, interactions and networks,* referring to stakeholders involved;
2. *Institutional framework*, referring to relevant policy;
3. *Technological regime*, referring to technology itself and knowledge base; and

4. *Market demand*, referring to end-user preferences.

The study features primary data collected through interviews, participation in conferences, and green building site tours, and secondary data collected through literature review. The results of the paper suggest that the current sectoral innovation system is supportive of green building uptake in Singapore, however substantial barriers remain, listed as follows: inflexible mindsets, government as a main driver, and ineffective collaboration. Siva et al. also cites potential solutions to the identified barriers, namely the use of performance-based policy as an alternative regulatory approach. This paper is useful in its provision of foundational knowledge. However, it does not assess each topic thoroughly, instead opting to succinctly introduce concepts and then move on. The greatest value derived from this paper is in its contribution of search terms such as “performance-based policy” and “energy system modelling tools,” both of which were later found to be highly relevant to Singaporean green building integration.

The paper by Liu & Yu (2013) is a useful resource for understanding the regulatory function of the government and illustrating the importance of a mandatory policy model for green building promotion. The basis of the paper is a comparative study analyzing the differences in green building performance in Singapore and Hong Kong. Singapore models mandatory development, meaning that green building implementation is led by the government. Hong Kong models voluntary development, meaning that green building implementation is driven by the free market with no government involvement. Non-government organizations are independently responsible for promoting green buildings. The findings of this paper are predominantly derived from conducting thorough policy analyses and visiting both city-states. A formal framework for analysis is not used; rather, Liu & Yu clearly establish four guiding policy considerations: policy, programs, implementation methods, and evaluation of policy success. Singapore and Hong Kong were chosen for comparison because of their similarities. The two city-states both have small, densely populated land areas with similar climates and strong economic development agendas. The regulation-oriented approach of Singapore has been found to be much more successful than that of Hong Kong. Green Mark, the presiding green building code in Singapore, came into effect in 2005, however green building growth remained low until the scheme was made mandatory in 2008, after which a significant increase in green buildings was observed. From 2005 to 2008, there were 239 projects that received certification. This is significantly lower than the 1,247 projects certified from 2008 to 2012. Liu & Yu credit this dramatic increase to the introduction of mandatory requirements associated with higher compliance levels. It is concluded that private developers under voluntary schemes are less inclined to participate because they are primarily concerned with profit, not sustainability. One weakness of this study is that additional macroeconomic influences are not considered nor controlled for. Therefore, this does not offer a completely accurate representation of the development model utilized by either one of the city-states.

The paper by Hwang, Zhu, & Ming (2017) offers an introduction to market barriers from the developer perspective. While the explicit aim of the paper is to investigate cost premiums associated with green buildings, the study goes further by examining causative reasons. The basis of this study is founded on a literature review followed by a survey of Singaporean development companies to gather data on green and conventional construction projects. The main questions posed to participants can be summarized as follows:

1. Indicate the cost premiums, size, and type of green and traditional construction projects that have been partaken in;
2. Rate the significance of various factors' effects on the cost difference between green and conventional buildings using a five-point scale; and
3. Rate the effectiveness of various solutions to reducing cost premiums and increasing cost performance of green buildings using a five-point scale.

The results of the study indicate that perceived green cost premiums range from 5-10% and that project type and size are statistically significant variables that influence green cost premiums. The results of the first rating component, ranking of reasons for differences in green and conventional building costs, are listed from most to least significant:

1. High cost of green technologies and materials;
2. Higher research and development costs for green buildings;
3. Lack of required green expertise and information;
4. Difficulty in obtaining green technologies;
5. Difficulty in obtaining green services from contractors and subcontractors;
6. Higher consultant and designer fees;
7. Lack of government incentives/subsidies for green building projects.

Some of these findings contradict those proposed by Siva et al. (2017). Namely, the reasons listed from ranks 1 to 4. According to Siva et al., green technology has become cost effective and readily available for purchase as the niche market has grown. The results of the second rating component, ranking of solutions to reduce the cost premiums of green buildings, are listed from most to least significant:

1. Tax relief for green buildings;
2. Availability of skilled and experienced project team and contractors;
3. Increase in government incentives/subsidies for green building projects;
4. Increase in government subsidies for green building professional and specialist courses;
5. Increase in government subsidies for research and development of green building products, systems, and technologies;
6. Increase in government offerings of green building educational courses;
7. Low-interest loans.

This study offers information on the economics behind green buildings, while the two ranking components offer guidance and key search terms for further research in multiple market integration barriers.

The study by Addae-Dapaah & Chieh (2011) is the end-user-centric counterpart of the study by Hwang, Zhu, & Ming (2017), offering an introduction to green building market barriers from the perspective of end-users. The paper evaluates whether the market understands Green Mark using hedonic price regression and a survey targeting the residential green building market. Use of the hedonic price model to identify the influence of green features on building price is a research method used in this study to estimate the current free market value of green buildings in Singapore. Property-specific data is collected from 34 BCA-certified buildings and 34 non-certified buildings from a government database. The accuracy of this model is dependent on the meticulous identification of property variables that can influence price, such as structural features, location, neighbourhood, and amenities. The face-to-face survey of 300 randomly selected participants featured 4 main sections for the following purposes:

1. Section A: Gauging participants' understanding of the term "green building";
2. Section B: Further interpreting attitudes and perceptions toward green buildings, awareness of different Green Mark ratings, and willingness to pay green premiums;
3. Section C: Identify factors that would significantly impact participants' decision to purchase a residential unit; and
4. Section D: Collect participants' demographic data.

The hedonic price regression finds an illogical distribution of premia across the various Green Mark rating tiers, where premium did not increase proportionally to rating. This indicates low market understanding of Green Mark. The survey also finds that the premia participants are willing to pay for green features is significantly lower than the estimated values derived from the hedonic model. This indicates that green features have a low impact on participants' purchasing decision. One weakness of the study is related to unidentified socioeconomic differences across participants. A very small percentage of wealthier Singaporeans are interested in purchasing privately developed residential buildings, while majority of the general public reside in public housing. Therefore, results derived from those living in public housing may be biased due to their inability to purchase.

3 Methodology

A case study format was chosen to investigate the details of an energy transition within the context of an existing location. Singapore was selected as the case study because it represents a hyper-urban environment that is considered a frontrunner for green building integration in the tropics and subtropics. Inefficient resource use and consumption are inevitable accompaniments of urbanization, therefore further study of sustainability initiatives within different metropolitan areas has the potential to generate valuable knowledge for improving green building integration in such settings. Data collection for the study conducted in this paper is based on a comprehensive review of existing literature. Key search terms were identified and applied to gather information.

The methodology employed by this study involves the use of a policy scan and an original framework. A policy scan of green building legislation was conducted to provide foundational knowledge on the institutional framework of Singapore. Information was collected from publicly accessible legislative databases and ministerial websites maintained by the Singaporean government or associated statutory boards. A new proposed model synthesizing two existing frameworks was used to present the research study. Initially, the force-field analysis framework was loosely followed. The framework is depicted in Figure 1. The force-field method assumes that the state of any given situation exists because of a balance between restraining forces and facilitating forces (Nicholas, 1989). Restraining forces are those that oppose change, while facilitating forces are those that support change. In order for a change to occur, facilitating forces must exceed restraining forces. The analysis aspect of this paper broadly follows this framework by evaluating supportive and inhibitory considerations. This coincides with facilitating and restraining forces, respectively. Whereas some force-field analysis models use a tiered point system, this study weighs each consideration equally for the purpose of simplicity. When applicable, mitigatory responses meant to reduce inhibitory considerations and strengthen supportive considerations are analyzed.

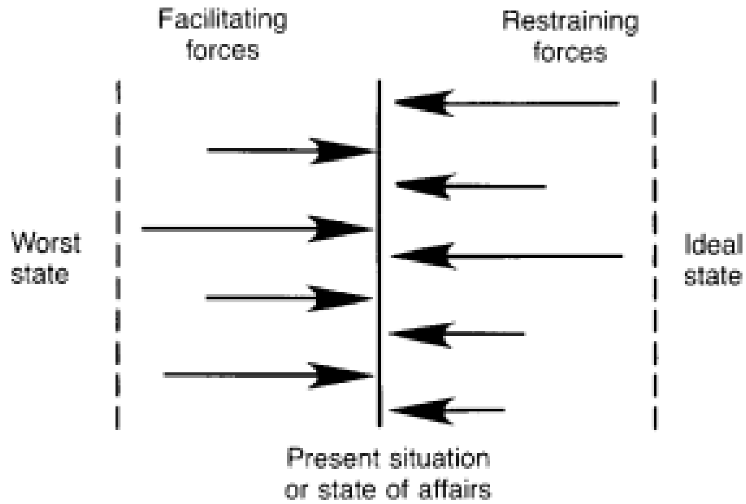

Figure 1. Graphical representation of force-field analysis. Reprinted from Nicholas (1989).

Political, Economic, Social, and Technological (PEST) analysis was incorporated at a later stage once the analysis was underway. PEST analysis involves identifying the strengths and weaknesses of each of the four macroeconomic factors listed in its name. The hybridized framework examines the contrasting supportive and inhibitory considerations of each macroeconomic factor involved in PEST analysis. The framework is depicted in Figure 2. For the purpose of this study, the modified framework is more effective than the individual comprising models because it offers an improved method for organizing the factors influencing green building integration. Four macroeconomic factors comprise the framework:

1. *Political*: This factor is divided into two parts to better examine the regulatory and market stimulatory function of policy. This modification was added upon completion of the study to further improve organization of the findings;
   - Political (Regulation): Examines regulatory policy instruments;
   - Poltical (Market): Examines market-based policy instruments;
2. *Economic:* This refers to factors influencing the financial feasibility of green buildings such as additional costs, valuation issues, and cost overruns;
3. *Social:* Social considerations focus on human capital and behaviour relating to green building uptake. This includes issues relating to industry productivity and market demand;
4. *Technological*: This section addresses the physical green technology and its uptake;

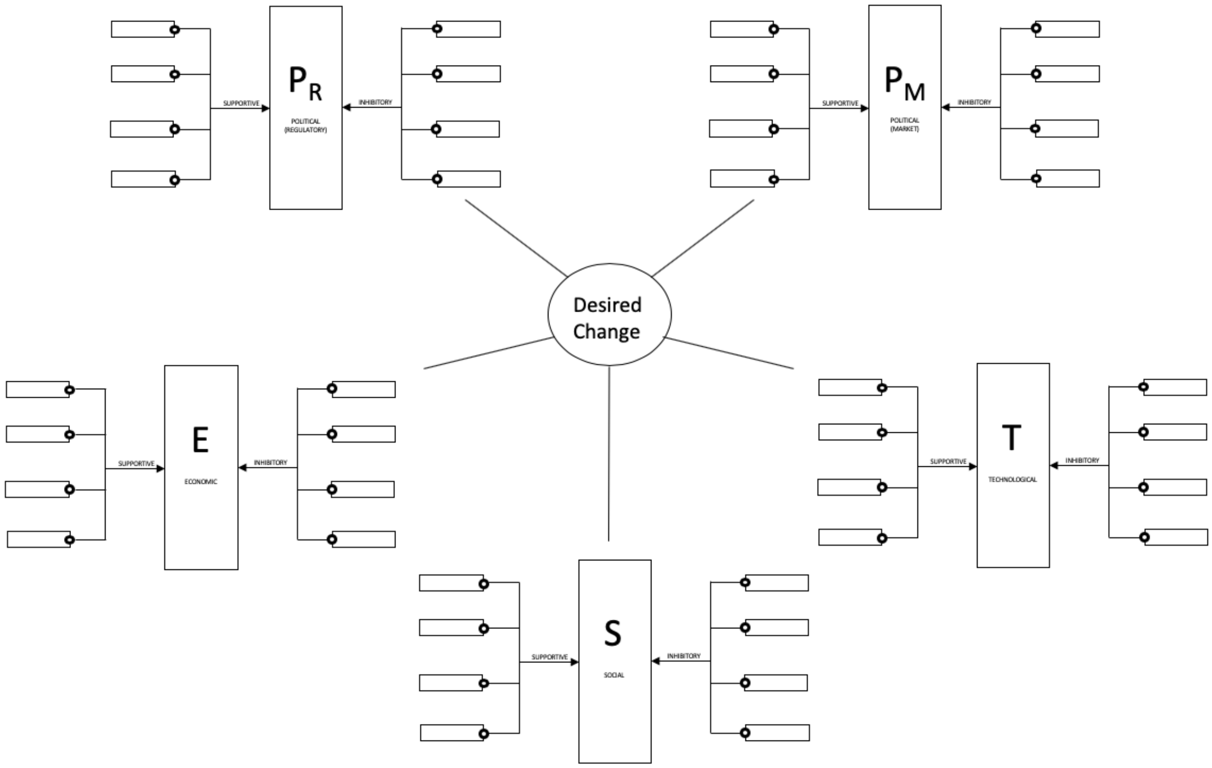

Figure 2. Graphical representation of hybrid framework.

The scope of this research study has been narrowed via three deliberate omissions. First, the study will be temporally limited by refining the policy scan to legislation implemented from 2005 until present. This is because Green Mark was implemented in 2005. Subsequent green building policy is an extension of the Green Mark scheme. Exceptions will be made only if an existing policy unrelated to green buildings has direct relevance to Green Mark. Such exceptions will be evaluated for their pertinence to the paper. Second, other macroeconomic factors that can influence the green building sector are examined only in the context of policy. The three additional factors that are analyzed in this paper are economic, social, and technological forces. Third, this paper will not consider the complete green building life cycle. The focus will remain on the operational stage of green buildings and the effect that policy will have on current or future building operation. The study will not consider the mandated sustainability practices, costs, or effects associated with other life cycle stages. This may represent a limitation of this paper because other life cycle stages such as construction and demolition produce significant energy expenditures that are important to acknowledge. To understand the full extent of Singapore's commitment to greening its building sector, it would be beneficial to examine the policy applicable to each life cycle stage of green buildings. Four additional limitations of this study were identified. First, primary data collection was not incorporated into the research design of the study. Therefore, the results of existing studies could not be corroborated for their validity and information gaps could not be filled. Second, the information in the literature was incomplete. To date, very few studies have been conducted on green buildings, making it difficult to understand the effect of policy changes. Therefore, the sample studies referenced in this paper may not be representative of actual figures. As well, precise values that may be pertinent to this study were largely unavailable. Statistical information on the number of green buildings and exact cost figures were difficult to find due to confidentiality issues (Hwang, Zhu, & Ming, 2017). Conclusions were inferred from the few studies found and the interpretations of various experts. Third, the effectiveness of policy can be difficult to quantify. Market integration barriers of green buildings pertaining to social factors such as market demand cannot be measured quantitatively and are predominantly based on interviews and/or surveys with small sample sizes. Therefore, results may not be statistically valid or representative of the entire population. Finally, the contribution of this study to the general body of knowledge on green buildings is limited because of its case study design. Results are specific to Singapore and therefore cannot be generalized. This study is useful for preliminary research and formulating hypotheses rather than theorizing a universal best practice for green building policy.

4 Results and Discussion

Results are organized loosely following the hybridized force-field/PEST framework. The findings of this study are presented in four broad subsections. The first subsection begins by stipulating the results of the policy scan. This provides an overview of the relevant green building policy in Singapore. The second subsection is comprised of an analysis of the current policy approach, which characterizes both regulatory and market-based policy instruments. The third subsection investigates policy implementation gaps and solutions. The final section assesses existing market conditions associated with economic, social, and technological considerations. As direct outcomes of policy, the conditions of the three macroeconomic factors indicates the effectiveness of the current policy approach in stimulating the market. The summary section succinctly presents the results and organizes the findings formally within the hybridized framework.

4.1 Policy Review

Singapore has a strong agenda for sustainability policy. The Building and Construction Authority (BCA) is the government agency responsible for the development and enforcement of most mandatory codes, acts, and regulations related to the operation, maintenance, and construction of buildings (APEC, 2013). Other agencies develop supporting codes that the BCA can adopt (APEC, 2013). Table 1 depicts a timeline of the relevant green policy in Singapore. It is important to note that, while plans are not explicitly considered policy documents, they are an element of this policy scan because they are released by the government to disseminate green building policy information.

Table 1. Timeline of relevant green building policy by date effective.

2005	BCA Green Mark Scheme
2006	1st Green Building Masterplan
	Public Sector Taking the Lead in Environmental Sustainability (PSTLES)
2008	Building Control (Environmental Sustainability) Regulations
	Code for Environmental Sustainability of Buildings (1st Edition)
2009	2nd Green Building Masterplan
2013	Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations

	Code for Environmental Sustainability Measures for Existing Buildings (1st Edition)
	Code on Periodic Energy Audit of Building Cooling Systems
2014	3rd Green Building Masterplan

4.1.1 Certification Scheme

The Green Mark certification scheme is the primary regulatory system governing green building standards in Singapore (APEC, 2013). Other green building policies are implemented for the purpose of modifying or supplementing Green Mark. Though it is not part of the National Building Code System, it is enforced as a code (APEC, 2013). Green Mark is a rating system developed by the BCA to evaluate the environmental sustainability performance of buildings in the tropics and sub-tropics (BCA, 2013). It is applicable to residential and non-residential buildings, both new and existing (BCA, 2013). Buildings are rated on the basis of 5 key criteria:

1. Energy efficiency;
2. Water efficiency;
3. Environmental protection;
4. Indoor environmental quality; and
5. Other innovative green features contributing to improved building performance (BCA, 2009).

Green Mark follows a prescriptive policy model, in that it stipulates the exact sustainable design elements to utilize (refer to section 4.3.1 for additional details regarding prescriptive policy). One relevant mandate involves the use of building information modelling (BIM) for design plan submission. BIM is a computer software that simulates the construction and operation of a building to provide a detailed digital representation of the facility (Teo et al., 2015). The compulsory submission of a virtual building plan using BIM is meant to ensure the logical inclusion of green features (Ali, 2019). Green Mark uses a scoring methodology that awards points for compliance with prescribed features. The scores associated with the different Green Mark ratings are as follows:

- Green Mark Certified = 50-74 points
- Green Mark Gold = 75-84 points
- Green Mark GoldPlus = 85-89 points
- Green Mark Platinum = 90+ points (APEC, 2013).

Certified buildings require re-assessment every three years to maintain Green Mark status (Siva et al., 2017). New buildings are initially awarded a rating based on design and are re-assessed upon project completion (Siva et al., 2017). Subsequent assessments occur under the existing building criteria (Siva et al., 2017). Launched in 2005, the rating system did not become mandatory until the 2008 amendment to the Building Control Act (refer to 4.1.2.1 for additional details) (BCA, 2013). The mandatory requirements differ for private and public sector developments. For the private sector, new buildings and existing buildings undergoing major energy changes via retrofits must achieve the minimum Green Mark certified level (BCA, 2013). This denotes fulfillment of the minimum required regulations. Achievement of higher-level regulations is voluntary and encouraged with incentives. For existing buildings in the private sector not undergoing retrofitting, Green Mark is voluntary (CCAP, 2012). Public sector buildings are held to more stringent green building requirements (CCAP, 2012). New buildings must achieve Green Mark Platinum and existing buildings must achieve Green Mark GoldPlus by 2020 (CCAP, 2012). The BCA updates Green Mark every two to four years. More codes become mandatory though each update (APEC, 2013), energy efficiency remaining the most significant feature (Lee & Tham, 2016). Green Mark has been updated five times since its inception (Lee & Tham, 2016), with smaller revisions occurring more frequently. The most recent version of Green Mark was released in 2015 and emphasized occupant health and wellbeing (Lee & Tham, 2016). Expanding on the 2015 focus on social impact was the release of a higher rating status in 2019, known as the Green Mark Pearl Award (BCA, 2019). The award is given to building owners of GoldPlus- or Platinum-rating base buildings with substantial numbers of occupants certified under the Green Mark occupant-centric schemes (BCA, 2019). The occupant-centric schemes were created in 2009 and 2011 to encourage green user practices and further decrease building energy consumption (BCA, 2016b). The Pearl award recognizes high total building performance and is the most prestigious Green Mark award (BCA, 2019). Commercial offices, retail malls, and business park developments are the three building types eligible for the award (BCA, 2019). Green Mark has been credited with launching the green building movement in Singapore and has led to the implementation of various supporting codes, regulations, incentives, and plans (BCA, 2014).

4.1.2 Codes and Regulations

The Building Control Act is the primary policy document governing building standards and regulations in Singapore, covering the requirements for plan submission, design, inspection, and construction (APEC, 2013). It is also responsible for approving the use of codes and standards recommended by other government agencies (APEC, 2013). The act was developed and continues to be maintained and mandated by the BCA, however any modifications must first be confirmed by the Parliament of Singapore (APEC, 2013). Two relevant amendments to the Building Control Act have been devised by the BCA in support of Green Mark. Associated codes were released concurrently with each revision to establish the specific standards and guidelines that buildings must meet under the regulations. Both the regulations and the codes are mandatory and enforced (APEC, 2013). In addition to these base codes created by the BCA, Green Mark has adopted other codes and standards related to green buildings that satisfy the required minimum certification criteria or award additional credit toward higher levels (APEC, 2013). The voluntary codes and standards become mandatory once complied with (APEC, 2013). Singapore does not follow an established revision schedule for building energy codes, instead updating codes depending on technological advancements and global trends (IPEEC, 2015).

4.1.2.1 New Building Legislation

The first relevant amendment was the addition of the Building Control (Environmental Sustainability) Regulations in 2008 (BCA, 2008). Coinciding with the amendment was the implementation of the Code for Environmental Sustainability of Buildings (1st Edition) (BCA, 2008a). The code has been updated three times since its inception to reflect updated compliance standards (BCA, 2008a). The most notable decree under this amendment is mandating Green Mark certification for all new buildings and existing buildings undergoing major energy efficiency retrofits (BCA, 2013). The transition to an involuntary certification system has been an essential step for spurring Singapore's green building agenda (BCA, 2013). The regulations require the achievement of the minimum Green Mark certified rating by the following:

- Buildings with a gross floor area of 2000m^2 or more
- Addition of 2000m^2 or more of gross floor area to an existing building
- Existing buildings with a gross floor area of 2000 m^2 or more undergoing major retrofitting (BCA, 2008)

The second relevant directive of the amendment is the introduction of mandatory higher Green Mark standards for key development areas under the Government Land Sales (GLS) Programme (BCA, 2008). In order to build wholly or partly on designated key land, developments must achieve Green Mark GoldPlus or Platinum ratings (BCA, 2008), as specified by the land sale tender conditions (IPEEC, 2015).

4.1.2.2 Existing Building Legislation

While the first amendment offers legislation for new buildings, the second amendment emphasizes existing buildings. The addition of the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations in 2012 (effective 2013) lists three legislative requirements to ensure that existing buildings operate efficiently throughout their life cycle (IPEEC, 2015). First, the regulation requires existing buildings undergoing major retrofits to meet the minimum Green Mark certified score (BCA, 1989). This generally requires the installation of a prescribed chilled water-cooling system (energy efficient air conditioning system) and energy saving lighting (Yu et al., 2011). The initial score for an existing building undergoing a major energy-use change will be based on the anticipated design, to be completed and re-assessed within three years (BCA, 1989). Second, buildings will be required to submit energy efficiency audits of building cooling systems every three years (BCA, 1989). Existing buildings will undergo their first energy audit upon completion of retrofitting, and every three years thereafter (Sung, 2014). New buildings with building cooling systems will undergo their first audit within one year of building completion, then at intervals of three years (Sung, 2014). Third, building owners will be required to submit energy consumption data and related building information annually (BCA, 2014). The data is used to formulate national energy benchmarks, to be shared publicly through the BCA Building Benchmarking Report (BCA BEBR) (BCA, 2014). The regulation applies to offices, hotels, retail malls, and mixed-use buildings including any of the aforementioned building types, with a gross floor area of 15,000 m^2 or more (BCA, 1989). Building types that are exempt from the regulations are industrial buildings, railway premises, port services and facilities, and airport services and facilities (BCA, 1989). The amendment to the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations in 2016 (effective 2017) extended the legislation to more building types. The update dictates that the regulations apply to any single- or multi-use buildings with a centralized cooling system and a gross floor area of 5000m^2 or more (BCA, 2016). Exemptions remain the same as for the previous version of the regulations, with the additional exclusions of religious buildings, data centres, utility buildings, residential buildings (other than serviced apartments), and any buildings with large shared cooling systems (BCA, 2016). Two codes were implemented in support of the amendment in 2012. The Code for Environmental Sustainability Measures for Existing Buildings (2013) offers guidance for the first of the three legislative requirements regarding existing buildings undergoing retrofits (BCA, 2019a). The code has been revised two times to revise the criteria of applicable buildings and the scoring methodology (BCA, 2019a). The remaining two legislative requirements regarding energy audits must occur in accordance with the Code on Periodic Energy Audit of Building Cooling Systems to ensure the consistent operation of building systems (IPEEC, 2015). The code has been revised twice to reflect compliance standards for the GLS Programme and to update the building exclusion list of the regulation (BCA, 2016a).

4.1.3 Incentives

Incentives exist under the Green Mark scheme to motivate the private sector to achieve beyond the minimum requirements and accelerate the adoption of green technology. They do so by making green buildings more desirable through financial and non-financial benefits. For majority of private developers, the cost of sustainability would be an externality in the absence of government support (Liu & Yu, 2013). Three general types of incentives are offered: monetary, non-monetary, and financing schemes. Exceptions to this generalization exist, one of particular importance being the Green Buildings Innovation Cluster (GBIC) released in 2014 (BCA, 2014). The GBIC is a compilation of government initiatives, including monetary incentives. The scheme features a S$52 million allocation directed toward establishing a program to encourage research and development (R&D) and research, development and demonstration (RD&D) (BCA, 2014). This is primarily concerned with facilitating knowledge exchange and creating demonstration projects of green buildings and technology to display their performance to both the industry and the public (BCA, 2014). There are 4 key initiatives comprising the GBIC:

1. *GBIC Energy Efficiency Research & Development (GBIC-R&D),* which aims to accelerate the commercialization of promising R&D solutions by offering a grant and award recognition to eight projects annually that have developed innovative green building solutions;
2. *GBIC-Prototyping,* which aims to increase adoption of research outcomes in the local Singaporean environment by offering grants for refining and customizing local or overseas research outcomes to test in actual buildings;
3. *GBIC Building Energy Efficient Demonstrations Scheme (GBIC-Demo*), a program that brings together industry professionals to established platforms where green technologies can be tested, showcased, and monitored to collect local performance data; and
4. *Super Low Energy Building (SLEB) Smart Hub,* which is a database meant to share knowledge and provide resources to facilitate the effortless inclusion of energy efficient building features (BCA, n.d.-a).

Incentive schemes cease operation either at an established point in time or once the monetary/non-monetary fund allocation has been fully committed. Monetary incentives apply to both new and existing buildings, typically offering cash to private developers that achieve Green Mark ratings above a certain designated level (BCA, 2009). For existing buildings, incentives to co-fund retrofitting costs also exist, where a higher Green Mark rating is eligible for greater co-funding (Siva et al., 2017). The capital allocation and funding caps vary by scheme (refer to 4.2.2.1 for further analysis). This affects the reach of individual incentive schemes because it can influence the number of green developments that can benefit from funding. Under non-monetary incentives, the most relevant scheme is the Green Mark Gross Floor Area (GM GFA) Scheme (refer to 4.2.2.2 for further analysis). Introduced in 2009, the incentive awards additional gross floor area to developers that attain a Green Mark rating of GoldPlus or higher, applicable to both new and existing buildings (BCA, 2009a). For the achievement of a GoldPlus rating, up to 1% additional gross floor area may be awarded (with a maximum of 2,500m^2) (BCA, 2009a). For Platinum, up to 2% (with a maximum of 5,000m^2) (BCA, 2009a). After the GM GFA scheme expired in 2014, the government extended it for another 5 years (Fan et al., 2015). Financing schemes often involve the BCA working collaboratively with financial institutions. In most instances, this is to help counter high upfront retrofitting expenses in existing buildings. Such incentives are meant to underwrite risk for private developers (Siva et al., 2017). A relevant example is the Building Retrofit Energy Efficiency Financing (BREEF) Scheme, where the BCA collaborates with participating financial institutions to co-share half of the risk of any loan default associated with retrofitting (BCA, 2013).

4.1.4 Plans

Three strategic Green Building Master Plans (GBMPs) were released by the BCA to offer direction and strategy corresponding to the fulfillment of Green Mark requirements (Siva et al., 2017). The GBMPs are meant to act as an end-user resource to disseminate information and initiatives related to green buildings. Each GBMP demonstrates current industry goals for advancing the green building agenda and introduces incentives and initiatives to achieve the targets. The first GBMP was released in 2006 and focused on guiding the construction of new buildings from the design stage through financial incentives, R&D, and capability enhancement (BCA, 2009). The plan aimed to frame green buildings as the norm for any new projects in Singapore (BCA, 2013). The second GBMP, released in 2009, featured a shift in focus from greening new to existing buildings (BCA, 2014). The plan introduces six “strategic thrusts” to encourage public sector leadership, motivate the private sector, increase R&D for green building technology, build industry capability, and impose more stringent green building regulations (CCAP, 2012). The third GBMP released in 2014 to encourage the development of human capital and behavioural changes in building end-users. The BCA has implemented training programs, conferences, and academic degrees to promote increased professional capacity and improve the green collar workforce. As well, the plan emphasizes end-user engagement in sustainable behaviour through green leases and focuses on occupant well-being, monitoring of energy consumption, and collaboration between the public, private, and people sectors (BCA, 2013). The plan corresponds with the shift toward a more holistic, social impact-driven approach to green buildings presented in the 2015 update of Green Mark.

4.2 Analysis of Current Policy Approach

Existing literature concedes that green building policy in Singapore is characterized by regulation and mandatory development. The results of the policy scan support this assertion. This section evaluates the pertinent regulatory and market-oriented characteristics of the current policy approach. The strategy has allowed for the rapid introduction of green buildings, however uncertainty surrounds its efficacy in promoting continued sectoral diffusion.

4.2.1 Regulatory Policy Instruments

Regulatory policy instruments are characteristics offering direct government intervention in affairs pertaining to green buildings. Such features often involve mandatory imposition of established standards and requirements.

4.2.1.1 Strong Government Presence

Singapore follows an authoritarian environmentalist policy-making approach characterized by strong top-down, non-participatory governance and extensive state planning and management (Han, 2016). The strong mandatory policy and prominent government involvement have largely been responsible for the success of green building uptake in Singapore. As well, the prescriptive policy approach has accelerated the introduction of green buildings by providing the exact details that must be adhered to for the achievement of each Green Mark rating. The Green Mark scheme effected a high volume of certified buildings only after it was made mandatory in 2008 (Liu & Yu, 2013). According to Siva et al., the effectiveness of government policy can be mostly attributed to the implementation and enforcement of strict regulations (2017). This is because mandatory policy and a central government role leads to higher compliance levels. Voluntary schemes have been found to be ineffective (Liu & Yu, 2013). While the prominent regulatory role of the government is considered supportive in some respects, in others it is seen as a disadvantage (refer to 4.3.1 for additional information).

4.2.1.2 Public Sector Leadership

The Singaporean government has taken on a leadership role to further encourage the private sector, namely through the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative. PSTLES was introduced in 2006 and enhanced in 2014 to focus on sustainability outcomes and improve resource use management (APEF, 2017). Outlined in the second GDMP, the government acts as a leader for green buildings by complying with higher Green Mark standards. New public sector buildings are required to achieve Green Mark Platinum while existing public sector buildings must to attain Green Mark Gold or GoldPlus ratings, depending on gross floor area specifications (APEF, 2017). The public housing system represents one of the most advanced areas in the nation's sectoral green building development. Public housing is an integral part of the residential living situation in the city-state. Approximately 82% of the residential population currently live in public housing (Heinzle et al., 2013). Due to severe overcrowding and shortages of affordable and sanitary housing that emerged after Singapore gained independence in 1965, the government developed the Housing and Development Board (HDB) to coordinate a public housing program (Heinzle et al., 2013). In accordance with the inception of Green Mark, public housing began elevating its project features to include sustainability features for new HDB projects starting in 2006 (Ng, 2012) and existing buildings in 2012 (Hwang et al., 2017). The HDB is now a leader in Singaporean green building development and has helped contribute innovative and influential solutions to encourage sustainable technology uptake. Public housing dominates the residential building market. As HDB projects comprise the majority of residential buildings in Singapore with close to 1 million flats having been developed (Ming et al., 2010), they have had a significant influence on the number of higher-tier residential buildings present throughout Singapore. This has helped establish the green building market in Singapore by setting an example and making available the necessary green facility suppliers and professionals to support private sector developers (Olanrewaju et al., 2019). Actual data collected on HDB buildings' efficient performance can also be used to dispel market doubts on the cost savings of green buildings and decrease the risks associated with higher initial investment costs (Olanrewaju et al., 2019). The HDB is also an innovator in many respects. The agency was an early adopter of BIM in Singapore and has been using the simulation software to plan new housing projects since 2009 (HDB, 2015). The HDB was also the first and only public sector organization to be recognized with an award in 2015 for their implementation of BIM (HDB, 2015). Refer to section 4.3.2 for additional information on BIM in Singapore. As well, the agency has been responsible for piloting numerous programs and patenting several innovative products/solutions through their R&D efforts to encourage the higher-level greening of buildings (Ming et al., 2010). Most distinguished was the establishment of the HDB Building Research Institute (HDB BRI) in 2009 to advance green technologies and transfer building competencies to the private sector building industry (Ming et al., 2010).

4.2.1.3 Comprehensive Building Coverage

Green building regulations in Singapore offer comprehensive coverage of many different building types. Targeting existing buildings represents a strength in Singapore's policy approach. Existing buildings comprise the vast majority of buildings in Singapore. The BCA claims that in any given year, new construction projects account for less than 5% of the entire building stock (IPEEC, 2017). Therefore, conventional existing buildings constructed prior to Green Mark being made mandatory in 2008 are responsible for a significant amount of energy use associated with the building industry due to suboptimal design (Jian et al., 2013). This indicates the importance of enforcing energy-related requirements for existing buildings undergoing renovations. The implementation of the Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations in 2012 was the first step in initiating sustainability policy specifically applicable to existing buildings. Under these regulations, the BCA has also mandated for annual energy performance submissions to ensure continuous energy efficiency and identification of poor performers. Incentives specifically targeting existing buildings have also been created to encourage private developers to engage in green renovations. The use of incentives to complement mandatory regulations has served as a strong tool for encouraging existing buildings to transition toward greater energy efficiency.

Green Mark also covers many different building types. The comprehensive coverage observed in Singapore is not commonplace for building regulations in other countries and represents an asset to the green building strategy. As an example, the building energy requirements in many European countries extend primarily to the residential sector only (Economidou, 2012). Green Mark is continuously expanding to include more and more building types. This ensures that there are no inadequacies in the various building types seen across Singapore, and that green buildings are being integrated consistently across the entire building sector. Currently, the buildings covered by the Green Mark scheme are as follows:

- Non-residential buildings (new and existing);
- Residential buildings (new and existing);
- Landed houses (residential homes); and
- Existing schools (BCA, 2013).

This list does not include the BCA Green Mark programs applicable to spaces beyond buildings and/or within buildings.

4.2.1.4 Poor Collaboration

Poor collaboration refers to inconsistent building design standards and ineffective collaboration with other agencies. The lack of integrated policy for building design has led to contradictions between sustainability and buildability standards, two mandatory regulations under the Building Control Act. Buildability is a mandatory scoring system used to denote the productivity level of buildings. In mandating Green Mark under the Building Control Act, it is evident that buildability standards were not considered to the extent that they should have been because of contradictions in the criteria of each scheme. The compartmentalization of buildability and sustainability regulations as two separate mandatory requirements is detrimental to both objectives because a decision made in one domain can influence the outcome of the other (Low, 2011). Treating interrelated policy components in isolation from one another has resulted in the overall policy outcome to be suboptimal and lacking in continuity (Rayner & Howlett, 2009). An integrated code for building design would allow for the concurrent consideration of design development to ensure that, in the case of the aforementioned standards, design for environmental sustainability would not interfere with buildability, and vice versa (Low, 2011). The lack of communication between different government agencies involved in various aspects of green building projects is another instance of poor collaboration. Each respective agency creates sustainability goals independently rather than in a collaborative manner, resulting in a number of separate goals that may not be considered in the creation of green building policy. For example, there exist discrepancies between the guidelines created by the BCA and the goals of the Public Utilities Board (PUB), the government agency responsible for sustainable water usage (Siva et al., 2017). The BCA prescribes the use of water-cooled chiller systems to improve building sustainability, however the technology increases water consumption (Siva et al., 2017). This conflicts with the PUB's goal to lower water consumption (Siva et al., 2017). A more integrated policy-making approach would involve all of the relevant government agencies to ensure more consistent policy goals and prevent the deployment of contradictory regulations (Rayner & Howlett, 2009).

4.2.2 Market-Based Policy Instruments

Market-based policy instruments have been developed by the government to encourage voluntary private sector involvement and acceptance of green buildings. This is accomplished by minimizing market barriers through an adaptive policy approach and improving sectoral capabilities.

4.2.2.1 Monetary Incentives

The primary concern of developers is profit, therefore the objective of incentives is to lower developer investment costs as much as possible (Liu & Yu, 2013). For this reason, a comprehensive set of incentives are important for spurring the private sector. Analysis and stakeholder feedback are indicative of well-developed monetary incentives. Various developers in Singapore considered the size of grants awarded to be generous (Siva et al., 2017) and reach of the incentives was found to be satisfactory. Table 2 outlines several relevant monetary incentives and depicts estimates of the number of developments that can be covered by a given scheme. This prediction was manually determined by comparing the amount of funds allocated with the upper and lower cap ranges outlined.

Table 2. Description of relevant monetary incentives and estimated reach.

Scheme	Description	Allocation	Cap	Minimum Buildings Covered
Green Mark Scheme for New Buildings (GMIS-NB) (2006)	Cash incentives for new developments that achieve Green Mark Gold or higher and have a minimum gross floor area of 2,000m^2 (Anggadjaja & Leng, 2009)	$20 million (Anggadjaja & Leng, 2009)	$400,000- $3,200,000 (lower cap is for Gold-level buildings and higher cap is for Platinum-level) (BCA, n.d.-b)	6-50
Green Mark Incentive Scheme for Design Prototype (GMIS-DP) (2010)	Cash incentives for developers/owners that invest in design stage of new or existing projects that have achieved Green Mark Platinum rating, a minimum 40% energy savings greater than current base code, and have a minimum gross floor area of 2,000m^2 (BCA, 2010)	S$5 million (APERC, 2014)	S$600,000 or 70% of qualifying costs (whichever is lower) (BCA, 2010)	8
Green Mark Incentive Scheme for Existing Buildings (GMIS-EB) (2018)	Co-funding of existing buildings undergoing major retrofits for projects that achieve Green Mark Gold or higher and have a minimum gross floor area of 2,000m^2 (BCA, 2018)	$100 million (BCA, 2009)	35% - 50% or $2,400,000 - $5,100,000 (lower cap is for Gold-level buildings and higher cap is for Platinum-level) (BCA, 2018)	19-41

It is important to note that the table depicts only minimum values to illustrate the hypothetical reach of different incentive schemes. The table is neither certain nor conclusive. Most development projects will receive grants that are lower than the cap value, therefore incentive schemes are actually expected to benefit a greater number of projects than the stipulated numbers. For example, assuming a generous grant value of $500,000 per project under GMIS-EB would benefit an estimated 200 building projects.

4.2.2.2 Non-Monetary Incentives

GM GFA is an important non-monetary incentive offered by the Singaporean government. The scheme promotes the achievement of higher Green Mark tiers in the private sector. The number of Green Mark Gold Plus and Platinum development projects was found to have increased from 82 to 125 in three years following the implementation of the GM GFA scheme in 2009 (Fan et al., 2015). GFA concessions have been and will continue to be important for Singapore's green building initiatives. This type of scheme has been found to be especially valuable for dense cities with high land prices and scarce urban land area, such as Singapore (Qian et al., 2016). Private sector building developers may be increasingly motivated by the provision of more land because it designates more saleable GFA and therefore more profit (Fan et al., 2015). Given that GFA concession schemes for green buildings are a relatively new policy technique (Fan et al., 2015), governments lack experience and the scheme may require revisions to ensure that it remains beneficial. The GFA scheme is well-executed in Singapore because of skillfully formulated concession caps. Research has shown that disadvantageous aspects of GFA concessions can arise when caps are too high. Negative impacts include increased building bulk and height (Fan et al., 2015), resulting in a reduction in daylight, views, and air ventilation effectiveness (Qian et al., 2016). Modest concession caps help prevent potential negative effects while facilitating the assimilation of higher rated green buildings. Singapore has a comparatively low concession cap of 2% compared to other densely populated cities such as Hong Kong, where the cap is set at 10% (Qian et al., 2016). The lower cap also means that more development projects are able to participate in the incentive scheme. More buildings have achieved higher Green Mark ratings because less land has been awarded to each project, and any additional bulk or overcrowding issues are mitigated. To further regulate overcrowding, GFA concessions in Singapore also consider land value when calculating the additional area to be granted to a project. If a project is located in an area with high land value, the awarded GFA amount is lower than that of a similar project in a suburban area (Qian et al., 2016). In this way, Singapore is successfully making green buildings a prerequisite for urban development.

4.2.2.3 Emphasis on R&D and RD&D

The Singaporean government has invested heavily into R&D and RD&D initiatives related to green buildings, most notably GBIC (refer to section 4.1.3 for additional information). Substantial efforts have been pursued by the government in the attempt to address two market barriers suppressing green building uptake: innovation potential (refer to section 4.4.4.3) and industry productivity (refer to section 4.4.2). The International Monetary Fund (IMF) and the BCA attribute Singapore's low innovation potential to insufficient R&D investment by the private sector (Bhaskaran, 2018). According to a study by the IMF, the proportion of total R&D investment relative to other nations differs widely between the public and private sector. Investment by the private sector is below average compared to more innovative countries such as Japan and South Korea, while investment by the public sector is on-par or above average (Bhaskaran, 2018). Accrediting low innovation potential to a lack of private sector R&D investment is implausible, however. Given the strong presence of the public sector, the significant R&D efforts should be sufficient in mitigating risk aversion and diffusing information throughout both the public and private sector. Therefore, additional investment into R&D beyond the current amounts are unlikely to produce the desired increases in innovation potential and green technology uptake that the Singaporean government seeks. Innovation potential is a market barrier that necessitates a regulatory shift rather than a market-based solution. The government should incorporate performance-based policy (refer to section 4.3.1) into Green Mark to facilitate an environment that is more supportive of risk and innovation. Performance-based policy would offer a greater degree of autonomy to developers by allowing the independent formulation of green technology solutions that satisfy overall efficiency requirements under Green Mark. This would largely replace the current prescriptive mandates, which are easier to enforce and monitor but tend to exacerbate risk aversion. The Singaporean government has also responded to low productivity growth by investing more heavily into R&D, however the results have been unsatisfactory (Bhaskaran, 2018). Instead, these funds would be more effective if redirected toward improving the use of policy modelling simulations. For BIM, the focus would be on funding training programs, of which there would be a minimum of two types: a novice-level program offered generally to professionals in the construction industry, and an advanced program to specifically train BIM experts to equip them for their role as intermediaries during construction projects (refer to section 4.3.2).

4.2.2.4 Initiatives for Professional Knowledge Base

Professional expertise is important for improving the efficiency and effectiveness of green building projects. Significant action to encourage a more skilled green collar workforce and increase engagement across all stakeholders has been put forth by the third GBMP. Singapore has taken significant steps toward progressing human capacity. Data gathered by the Global Buildings Performance Network (GBPN) and presented in a paper by Evans et al. shows five important examples of training and tools to improve human capacity and the countries that employ each method (Evans et al., 2017). Singapore was the only country listed as using all five methods (Evans et al., 2017). The training and tools are listed as follows:

- "Training programs for local governments on code requirements and compliance;
- Software and software training;
- Code compliance resource kits;
- Training and certificate programs for building inspectors; and
- Sponsored university degree programs on building energy efficiency" (Evans et al., 2017)

4.3 Policy Implementation Gaps and Solutions

This section evaluates probable policy implementation gaps responsible for the market conditions stipulated in the following section. Though each market barrier represents a disparate hinderance in itself, the potential solutions address them collectively. Five significant implementation gaps and associated solutions are assessed in this section: performance-based policy, policy modelling simulations, financing schemes, a valuation framework, and end-user knowledge base initiatives.

4.3.1 Performance-Based Policy

Prescriptive and performance-based policy each offer distinct value to green building advancement. A prescriptive methodology ensures consistency in regulatory applications by providing a standardized means for complying with design rules and offering predictability for building sustainability outcomes (May, 2004). Performance-based policy poses the risk of inconsistency and lack of predictability because interpretations and outcomes are variable. The higher degree of uniformity amassed by prescriptive policy also supports equity between companies of different sizes (May, 2004). Under a performance-based model, smaller companies would be at a competitive disadvantage compared to larger companies due to fewer resources available for the development of alternative sustainability approaches (May, 2004). However, performance-based policy offers increased effectiveness in achieving regulatory objectives because the higher degree of flexibility promotes innovation (May, 2004). In addition, a performance-based approach considers the interactions between different building systems and can optimize their combined performance (Hui, 2002). By setting requirements for overall building performance rather than prescribing the use of specific components, developers and other relevant stakeholders would be required to devise a personalized approach to fulfill regulatory requirements. This also promotes increased stakeholder collaboration and therefore supply chain continuity. The increased autonomy afforded to the private sector could create a stronger foundation for green building directives by balancing the predominantly government-led initiatives (Siva et al., 2017) with a greater contribution from the private sector. This is imperative to avoid an overly rigid system (Siva et al., 2017). The higher level of independence effected by a performance-based approach could also reduce risk perception across the supply chain. According to an Australian study by Zou & Couani, the two most important risks present throughout the green building supply chain are associated with "'lack of commitment in the supply chain to go green' and 'higher investment costs'" (Zou & Couani, 2012). Under a performance-based model, stakeholders could formulate a plan of their choosing that they feel best fulfills the mandated green building regulations while minimizing costs. The potential result is greater confidence in the plan's efficacy, improved project commitment, and a perceived cost-benefit, regardless of true savings. The actual cost effect of performance policy compared to that of prescriptive policy is uncertain (May, 2004). It is expected that performance-based regulations would be less costly to implement because of a reduced necessity for specialized understanding, albeit more costly to enforce due to more ambiguous performance standards and lower enforcer expertise (May, 2004). Performance-based codes would require higher levels of expertise by designers and enforcers due to complex evaluation processes, as well as more advanced benchmarking and monitoring technology (Hui, 2002). Increased government investment into raising institutional and human capacities in the building industry would therefore be required (Hui, 2002). This can be interpreted as both beneficial and detrimental in that it increases understanding and proficiency however requires greater funding. A summarized comparison of prescriptive and performance-based policy can be observed in Table 3.

Table 3. Comparison of prescriptive and performance-based policy approaches.

	Prescriptive	**Performance**
Consistent regulatory applications	✓	

Predictable sustainability outcomes	✓	
Equity between companies of different sizes	✓	
Potentiality for increased government costs	✓	
Increased effectiveness in achieving regulatory objectives		✓
Greater flexibility and innovation potential		✓
More stakeholder collaboration and supply chain continuity		✓
Greater responsibility given to the private sector		✓
Perceived cost-benefit and decreased risk by developers		✓
Potentiality for increased institutional and human capacity		✓
Considers building system interactions to optimize overall performance		✓

Singapore's green building policy approach is not performing as well as it could be because of an overly prescriptive approach to green building regulations (Siva et al., 2017). Under a prescriptive policy approach, each building component is standardized to ensure adherence to the prescribed regulation. Conversely, a performance-based building energy code is concerned with energy consumption of the building overall, and not with prescribing how it is to be achieved (Hui, 2002). Designers are responsible for specifying a proposed design and providing evidence of its estimated energy behaviour based on the integrated performance of various constituents (Hui, 2002). Regulations would be results-oriented and based on the performance of the entire building rather than on compliance with a prescribed technology (May, 2004).

Green Mark currently hovers between a traditional prescriptive pathway and a partial-performance pathway (system/component performance) (Hui, 2002). The code specifies the exact design and technology that must be used to achieve a certain sustainability standard (Siva et al., 2017), as well as their associated energy efficiency calculation. Green Mark does not specify any performance outcomes for overall building energy efficiency. Points are allocated for compliance with individual design components rather than for building performance overall. For the minimum Certified level, the prescribed technology is required. However, there is a degree of flexibility regarding meeting the additional criteria to achieve higher ratings. The government develops and enforces building regulations which specify standards, codes, and best practices that are mandatory, however allows for the use of equivalent alternatives that satisfy the regulatory requirements (APEC, 2013). Building developers can choose from an index of accepted design stipulations to achieve a higher rating or can opt for an equivalent alternative that satisfies energy efficiency requirements for a given component. Though the current prescriptive policy technique has accelerated the implementation of green buildings, the maturing market may necessitate an update to the current regime to achieve future green building targets.

Under a performance-oriented approach, Green Mark could maintain minimum prescriptive requirements to ensure a baseline level of sustainability is achieved. Alternatively, Singapore could follow the lead of Denmark, where building codes specify single element requirements as supplementary demands to overall energy performance requirements (Economidou, 2012). All other prescribed design features would be replaced with overall efficiency requirements. This approach would be more supportive of risk and innovation. As well, it would encourage stakeholder collaboration because creative solutions would be necessitated. The greater level of autonomy would allow designers to optimize building design with consideration of the interrelated workings of the entire building. Green Mark is well-positioned to incorporate performance-based elements because it has already incorporated the use of BIM, a useful tool for project planning. BIM becomes especially relevant for green buildings where less experience makes it difficult to conceptualize the technology within the context of a building. A transition toward performance-based building codes is a trend that has been observed globally, arising from the rapid advancements in building technology, improved design techniques, and higher expectations of building conditions (Hui, 2002). Performance-based policy allows for flexible building codes that can adapt to dynamic conditions such as technological advances (Hui, 2002). The implementation of performance-based green building policy could encourage a higher degree of stakeholder collaboration, foster innovative solutions, and incentivize individuals to go beyond the Certified level.

4.3.2 Policy Modelling Simulations

The primary reasons for the adoption of BIM in Singapore have been to mitigate the productivity issues affecting the construction industry and to enhance collaboration across the supply chain (refer to section 4.4.2) (Ali, 2019). Singapore is one of the few countries in Asia to have implemented the use of BIM (Ali, 2019). Studies suggest that the adoption of BIM by the construction industry has been successful, where a survey conducted by the BCA found that use had risen from only 20% of the industry in 2011 to 65% in 2013 (Teo et al., 2015). Use of BIM has many benefits associated with enhanced productivity. Pre-project planning allows for the early identification of potential problems (Teo et al., 2015). This eliminates many uncertainties prior to physical construction of a building (Teo et al., 2015). The opportunity to simulate and analyze potential impacts of different technology, both positive and negative, is especially important for green buildings because there is less familiarity with their construction and therefore a greater margin for error (Teo et al., 2015). In effect, this reduces the likelihood of project delays and reworks associated with cost overruns (Teo et al., 2015), another relevant market integration barrier (refer to section 4.4.1.2). Use of BIM has also been found to produce higher quality buildings with improved design (Teo et al., 2015). The software's second primary function in improving supply chain continuity occurs because project participants are able to work simultaneously and integrate their respective knowledge and contributions into a single consolidated model (Teo et al., 2015). In this way, BIM serves as a useful communication tool for participants across the entire supply chain. Advanced planning through BIM also has the additional benefit of decreasing risk aversion in developers. Despite the increased use of BIM, the Singaporean construction industry has been unable to realize the full extent of the benefits associated with the software and productivity remains low. Two main shortcomings exist in its use in Singapore. First, BIM is predominantly used only at the beginning stages of construction projects because of cost constraints related to purchasing and operating the software (Teo et al., 2015). An interview by (Teo et al., 2015) suggests that BIM utilization varies widely across the construction industry, where some companies have achieved advanced levels in its application and others use the software only for compulsory submission (Teo et al., 2015). However, it is most effective when used throughout the entire duration of the project. This includes the pre-construction design phase and continues post-construction, where BIM can be used for identifying documentation errors and monitoring productivity using actual construction site data (Teo et al., 2015). To mitigate costs and extend the use of BIM, the BCA has implemented the BIM Fund to offer monetary incentives to cover the cost of training, consultancy services, and purchase of hardware/software to help construction firms that adopt BIM (Teo et al., 2015). However, these efforts have not had the desired effect in extending the use of the software throughout the entire construction process and productivity in the industry necessitates further improvement (Teo et al., 2015). Second, the desired connectivity between participants has not been achieved because BIM submissions are not as collaborative as intended. Currently, the various participants submit separate, uncoordinated BIM submissions to the BCA for evaluation (Kaneta et al., 2016). This means that, upon approval, construction guided by BIM is unable to proceed immediately because the separate submissions must first be consolidated into a single plan by the recipient contractor (Kaneta et al., 2016). However, contractors' absence of expertise in BIM technology has been identified as one of the primary challenges to BIM adoption in Singapore (Ali, 2019). While the BCA has taken efforts to incorporate BIM training into academic programs, the number of BIM-proficient industry professionals remains low (Teo et al., 2015). The pre-existing lack of expertise paired with the complexity of the reworks that will most likely be required due to contradictory design aspects has diminished the effectiveness of BIM for productivity. The hypothetical idealized use of BIM would avoid this by coordinating the BIM plans from each participant prior to submission to ensure that on-site construction could begin immediately following regulatory approval (Kaneta et al., 2016). To bring the current model closer to that of the idealized version, a BIM manager specializing in the software is needed to consolidate each design drawing following regulatory submission approval and prior to sending the plan to the general contractor for construction (Kaneta et al., 2016).

4.3.3 Financing Schemes

Incentives and financing schemes are essential for alleviating the financial disadvantages associated with green buildings. Transactional incentive schemes involving the allocation of monetary or non-monetary rewards are well-developed in Singapore. The BCA continues to update these types of incentives and consistently offers new schemes relevant to private developers. A revision that would further improve the efficacy of such incentives would be to implement benchmarking and quotas. Smaller private development companies are underrepresented in the incentive schemes and are therefore falling behind in their efforts to engage in sustainable practices (Siva et al., 2017). Therefore, improving benchmarking methods and establishing quotas for the incentives would ensure that development companies of all sizes are benefiting.

Financing schemes have not achieved the same level of maturity as the other two types of incentives. Currently very few exist and they are not regularly updated. Further development of financing schemes will be crucial for future green building integration into the construction industry. Financing schemes have the ability to elicit a more systemic change in the market by shaping its maturation to incorporate green buildings, an important endeavour not yet accomplished by the Singaporean government. Collaboration with key financial institutions will result in green buildings becoming a more permanent fixture in the Singaporean economy. In this way, financing schemes offer benefits beyond incentivizing the voluntary engagement of the private sector. Financing schemes are more impactful than transactive incentives because the economy rather than the government rewards developers for adopting sustainability. In this way, financing schemes would also increase the market value of green buildings, which are currently underappreciated in Singapore (Siva et al., 2017). The following are the three most relevant financing schemes to Singapore:

1. Tax credits and deductions
2. Green loans
3. Contingency fund

Financing schemes related to taxes would be comprehensive. First, property tax credits could be established and made applicable to new and existing buildings. This is a reduction in the property tax to be paid for a building. For developers and/or owners facilitating the retrofitting of existing buildings, the credit would become active following the achievement of a Green Mark rating. For new purchasers, the credit would be active upon acquisition of the unit or building. In this way, the scheme appeals to both developers and end-users. Owners would qualify for the property tax credit for a temporary time period following certification and the value of the credit would depend on the rating tier. This is a technique that is already being utilized by various jurisdictions in the USA as an incentive under LEED (USGBC, n.d.). For instance, in Howard County, Maryland, five-year and three-year property tax credits have been established for new and existing buildings, respectively (USGBC, n.d.). The credit increases depending on certification level, as follows:

- LEED Silver (lowest rating) = 25% for new, 10% for existing;
- LEED Gold = 50% for new, 25% for existing;
- LEED Platinum = 75% for new, 50% for existing (USGBC, n.d.)

This could serve as a model for property tax credits in Singapore. The duration and value distribution of property tax credits would be higher for new buildings. This is because another tax benefit would be introduced for existing buildings only, which are tax deductions on rental income following retrofitting to obtain Green Mark status. This is a reduction in the amount of tax paid on rental income. Like the property tax credit, this exemption would be active for a limited period of time and the magnitude of the exemption would increase proportionally to rating tier. Financing schemes targeting existing buildings are crucial to increase engagement in green practices because they comprise the vast majority of the Singaporean building stock and are at risk of facing operational disruptions. Finally, 100% tax deductions would be granted on capital expenditures for green equipment and materials used in new and existing buildings. Currently, general capital expenditures qualify for a 33.3% tax deduction per year of assessment over a period of three years (KPMG, 2018). Therefore, this would represent significant tax savings. According to a study by Hwang et al., tax relief is the most effective solution for reducing the financial burden of green buildings because it is a flexible and feasible solution (Hwang, Zhu, & Ming, 2017).

Green loans and mortgages in collaboration with Singaporean banks could also be implemented. This would involve the provision of reduced interest rate loans and mortgages for buildings qualifying under Green Mark. This is an action that has already been taken in Germany through the state-owned KfW bank to spur green building development (Siva et al., 2017). This would benefit developers through green loans and prospective end-users through mortgages. Contingency funds are another important initiative that can be established through government collaboration with banks. This would represent a form of insurance that would cover the cost overrun of a project in the event of project delays or other unforeseen expenses. It would be available for purchase following approval of the submitted building plan and estimate of construction or retrofitting costs.

4.3.4 Valuation Framework

A formal valuation framework developed by the government would establish a connection between building sustainability and value. If executed properly, the framework would make green buildings the new market standard. The study by (Runde & Thoyre, 2010) suggests the use of the Sustainability Valuation Model because it is a standardized framework that still offers flexibility by considering all types of properties and any changes to market conditions that could occur over time. The framework emphasizes the importance of properly identifying the sustainability orientation of respective markets prior to introducing formal sustainability valuation practices (Runde & Thoyre, 2010). This is because additional value manifesting as a higher cost, known as a green premium, is contingent on whether the market recognizes the additional cost as added value (Runde & Thoyre, 2010). For instance, a sustainability-oriented market would recognize the premium as added value, whereas a conventional-oriented market would view the premium as an externality. Singapore represents an immature sustainability-oriented market. The market is generally sustainability-oriented but remains at the earlier stages and does not yet possess the characteristic strong orientation. The reasoning behind this deduction is founded on four important considerations:

1. Significant green building policy action
2. Significant green building stock
3. Moderate voluntary action by developers
4. Low end-user demand and understanding

It is important to note that the Singaporean government propels the green building movement in Singapore. In general, governance of Singapore is characterized by a strong regulatory presence. End-users are highly compliant with the government's decisions and are unlikely to question their decrees due to the high uncertainty avoidance of Singaporean culture. For majority, government statements on sustainability will carry more weight than personal perceptions. Therefore, the behaviour of developers and end-users is dependent on the actions of the government. The unique market consideration of uncertainty avoidance makes the reduced actions of these stakeholders less important in considering the sustainability orientation of the market. Figure 3 depicts the market orientation spectrum for sustainability with Singapore's position. As a point of familiar comparison, the position of Canada has also been identified and included on the spectrum.

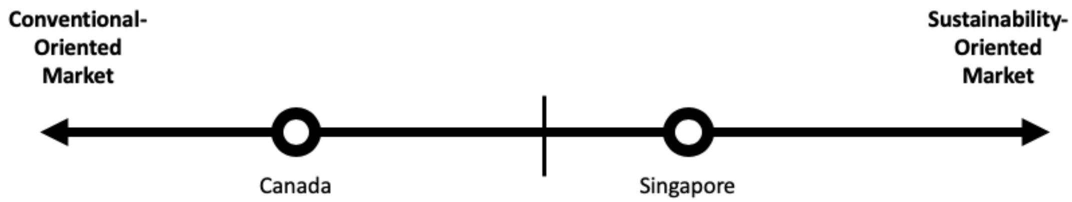

Figure 3. Sustainability market orientation of Singapore and Canada. Adapted from Runde & Thoyre (2010).

Valuation of green features can be difficult to establish because there are many non-economic impacts associated with sustainability that add value but are difficult to quantify in economic terms (Runde & Thoyre, 2010). The criteria for valuation would broadly align with the requirements of Green Mark, however Green Mark rating would not explicitly be a criterion. Both green and conventional buildings would be evaluated based on the inclusion of any prescribed features and overall performance of the building. For instance, a conventional building with a single sustainability feature such as energy-efficient lighting would be awarded some additional value despite not being classified as a "green building". Additional environmental considerations that may be included in the valuation framework are construction practices, waste disposal, and longevity of equipment. Technology that will be replaced frequently, green or conventional, is unsustainable because it produces unnecessary waste. The valuation framework would also consider the monetary savings derived from increased building efficiency by decreasing the estimated value of operating expenses (Yu et al., 2011).

The additional value of green buildings would initially be reflected in the market as a slightly higher renting and purchasing price than that of the market standard. This represents artificial inflation because the increased cost to purchase/rent green buildings is offset by significant monthly energy savings. The price of conventional buildings is the market standard. Assuming that the market-based policy instruments are successful in overcoming the barriers to green building integration, there would be an increase in both the developer supply and end-user demand for green buildings. Ultimately, the market standard will equalize with the green price, representing the establishment of a new standard and the disappearance of green premiums (Runde & Thoyre, 2010). This will only occur once the end-user demand for green buildings becomes greater than the demand for conventional buildings, and there exists significant supply of green buildings (Runde & Thoyre, 2010). Conventional building price will remain below the standard and at a cost considered to be "discounted." This represents a transition toward eventual obsolescence because conventional buildings will become the minority. Supply will gradually reduce as developers construct and retrofit new and existing buildings to be sustainable, respectively. Demand will be reduced upon increased market uptake of green buildings. Introduction of a formal valuation framework would be most effective as a final step following the other proposed market-based policy stimuli. This is because the market is expected to be more sustainability-oriented, therefore maximizing the effectiveness of the valuation framework. Valuation also has important implications for green mortgages (refer to section 4.3.3), which will require adjustment accordingly to consider the updated value of green buildings.

4.3.5 Initiatives for End-User Knowledge Base

End-user understanding concerning green buildings is very deficient and therefore demand for these types of constructions remains relatively low. This is largely because current engagement efforts have not considered the preferences of end-users when marketing green buildings. Introducing the Green Mark Pearl Award and associated green leases have been effective for engaging end-users, however this represents a solution more oriented toward improving end-user behaviour rather than market demand. This is because green leases are used to encourage sustainable behaviour in tenants through contractual agreement rather than influencing the perceived attractiveness of green properties. Green Mark is a corporate-oriented scheme (Martek et al., 2019). It is evident in the technicality of the documents that the scheme was not designed with end-user understanding in mind. Currently, the GBMPs are the primary government resource used to disseminate information regarding Green Mark to end-users. The documented poor understanding of the scheme suggests that the GBMPs have been largely unsuccessful. It would be highly beneficial for the BCA to release an end-user centric version of the Green Mark document omitting the technical jargon and focusing on metrics that are relevant to end-users. This would frame the different ratings in an understandable and appealing way to end-users. Adapted from the recommendations of (Martek et al., 2019), the BCA should consider four important metrics when appealing to end-users:

1. Economic benefits
2. Luxury
3. Quality of life
4. Altruism

The list is ranked based on importance to Singaporean end-users. To facilitate end-user understanding of the four different rating tiers, each should be distinctly defined in reference to these four influences. Economic benefits are the most important consideration because end-users are most concerned with pricing. Each tier could be defined economically using the percent savings of operating expenses and energy consumption compared to the Singaporean average for conventional buildings. Furthermore, tax credits and green mortgages for each rating tiers could also be included, assuming their implementation. The second consideration is that of luxury. The perception of “luxury” is synonymous with other desirable building features, such as location, amenities, and design. This is especially important for the private residential sector because majority of citizens seeking to purchase or rent such buildings are part of the wealthier socioeconomic category and will be actively seeking higher-end constructions. The connection between sustainability and luxury was first initiated in 2008 with the introduction of the GLS program. However, this connection has not been advertised to end-users. To encourage the idea of green buildings as being luxury, existing high-profile buildings could serve as demonstrations. For instance, Marina Bay Sands is a luxury hotel that characterizes the Singaporean skyline and is one of the most well-known urban landmarks of the city-state. Currently, it retains Green Mark Gold status (Marina Bay Sands, 2013). Establishing a strategic partnership between the hotel and the BCA to rebrand itself as a “green” hotel could help to intertwine end-users’ perceptions of green as being a luxury amenity. Third, quality of life. The BCA should aim to quantify the positive social impact of each green building tier. For instance, by measuring the average air quality improvement for each tier. It is important to note that social considerations may be difficult to quantify because they are not definitive. Finally, altruism will look to define environmental benefits, such as through inclusion of the percent reduction of energy consumption associated with green buildings.

4.4 Market Conditions

Market conditions are outcomes reflective of the current policy approach. This section identifies market barriers inhibiting the continued integration of green buildings and offers further indication of whether policies have provided adequate market stimulus. Each subsection corresponds with a relevant macroeconomic factor: financial details classify under economic factors; industry productivity and market demand classify under social factors; and technological capacity classifies under technological factors.

4.4.1 Financial Details

Financial details are generally concerned with the inability of the market to protect developer interests. Profitability is paramount for developers, indicating the importance of neutralizing the cost externalities associated with green buildings. Four interrelated elements are evaluated in this section: additional investment costs, market value, distribution of financial benefits, and cost overruns.

4.4.1.1 Additional Investment Costs

Additional investment costs associated with green buildings, deemed "green costs," represent a significant deterrent to the uptake of green buildings in Singapore. Exact green cost values are inconclusive and estimated ranges vary across the current literature; for example, Hwang et al. (2017) denotes a range of 3.5-9.2% while Liu & Yu (2013) denotes a smaller range of 3-5%. While there are no exact values to denote the additional costs incurred by sustainable construction, the connection between green buildings and higher initial capital expenditures is evident. Green costs can also vary with the type of technology used, specialty green building professionals employed, and degree of project planning. More advanced technologies produce higher costs for purchase of the technology itself and professional expertise, while passive design features such as building orientation, window design, and ventilation techniques meant to work with climate are not found to contribute significant additional costs (Liu & Yu, 2013). Planning was also an important determinant of green costs. Siva et al. and Hwang et al. both cite the importance of planning in reducing green costs.

4.4.1.2 Cost Overruns

Delays associated with poor planning lead to cost overruns, a term that refers to any unforeseen additional costs related to green building construction (Hwang et al., 2017). This represents a pertinent issue in Singapore, where green building projects generally have a cost overrun of 2.5-7% while traditional building projects tend to be underbudget (Hwang et al., 2017). Cost overruns are directly correlated with project delays and productivity loss primarily caused by a lack of expertise and poor planning (Hwang, 2018). The performance of sustainable technology is generally less understood and there is a higher risk of technological failure due to defects or omissions by inexperienced designers or contractors (Hwang et al., 2017). Stakeholders do not possess sufficient knowledge of the complex green technologies and the many requirements of Green Mark, resulting in the inefficient integration of green design features, delays, and cost overruns (Hwang, 2018). The evaluation process of green buildings, which includes planning-related tasks such as designing and budgeting, can be time-consuming because of its complexity (Khodadadzadeh, 2016). Currently, the absence of adequate planning and lack of expertise in the green construction industry are major factors contributing to cost overruns in Singaporean green building projects. As well, industry practitioners in Singapore tend to disregard some of the additional up-front capital associated with green technologies and additional consultancy/design fees when estimating the cost of green building construction projects (Hwang et al., 2017). This is in part due to the immature stage of the Singaporean green building construction industry, where industry practitioners have not yet gained enough experience to thoroughly understand the green building sector (Hwang et al., 2017). Cost overruns are also related to low industry productivity (refer to section 4.4.2).

4.4.1.3 Market Value

Green buildings have not been integrated into the Singaporean economy and remain an externality imposed by the government from the perspective of the private sector. Current literature suggests that the primary causal reason is that green buildings have not been positioned in the market to reflect their true value, which is higher than that of conventional buildings. End-users do not possess a sufficient understanding of green buildings to drive the increased value that green buildings deserve. Stakeholders involved in the design and construction of green buildings in the private sector are therefore unmotivated to act beyond the mandated level without explicit government instruction. Currently, the Singaporean government has not implemented a formal valuation framework for green buildings (refer to section 4.3.4 for additional details). Indirect policy instruments such as incentives act as the primary legislative tool to influence green building value. However, majority of the current incentives are transactive in nature. At most, this covers only the additional amount spent on green building features. This means that the cost of construction is the same or, more commonly, higher than that of conventional buildings, and there is no perceptible difference in market value. The price premiums did not increase in proportion to higher Green Mark levels, as would be expected. The calculated premiums in two different studies are not consistent with one another, however they both show the disproportional allocation of resale premiums for different rating levels. Table compares the results adapted from the two different studies.

Table 4. Comparison of green premiums by Green Mark rating tier. Adapted from Addae-Dappah & Chieh (2011) and Poe (2017).

	Green Building Market Price Premiums	
Green Mark Rating	Study by Addae-Dappah & Chieh (2011)	Study by Poe (2017)
Certified	12.97%	11.5%
Gold	9.64%	2.5%
GoldPlus	9.61%	16.5%
Platinum	27.74%	10.4%

4.4.1.4 Distribution of Financial Benefits

The unequal distribution of financial benefits represents one of the most significant impediments to widespread green building development and market integration in Singapore. This section will focus on the relationship between green building construction costs and additional value. The presale value of green buildings has been shown to increase proportionally to the incurred green costs and does not assume much additional value, while resale value is significantly higher. This discrepancy is not well-understood because the energy savings brought about by green technology would benefit initial buyers as well as resale buyers. However, this reduced value represents an important barrier to market integration for developers because they are disinclined from contributing the additional funding and effort if they anticipate minimal financial benefit. Presale cost premiums benefit developers and are meant to cover the additional expenses associated with constructing new buildings that include sustainability features. Developers are responsible for covering the additional costs themselves or finding investors to cover these costs, making them liable to greater financial risk. While green building developers and investors are expected to fund the additional costs, the financial benefits associated with energy savings are only experienced by end-users (Siva et al., 2017). Retrofitting for existing buildings may offer greater incentive when looking at greening buildings because building owners facilitate the technological changes and directly benefit from the increased value and future energy savings. According to the BCA, the presale premium of green buildings as compared to their conventional counterparts range from 0.3-1% for Certified-level buildings, 1-2% for Gold, 1-3% for GoldPlus, and 2-8% for Platinum (Baietti et al., 2013). Green Mark buildings achieve their maximum market value during resale, where the market price premium increases from 4% at the presale stage to 10% at the resale stage (Poe, 2017). In addition to the increased property value, end-users also experience the monetary savings associated with reduced energy consumption. Although developers are responsible for covering the additional costs for green features, they reap very few of the benefits associated with the premium because they arise in full only at the resale stage of the property (Poe, 2017). Presale values are minimal and appear to counteract the initial green costs with no additional value added to the price. End-users are therefore the primary beneficiaries from an economic standpoint, while developers are mostly rewarded by government incentives and improved public image. The inequality in financial benefit is where financing schemes are critical to ensuring market integration (refer to 4.3.3 for additional information).

4.4.2 Industry Productivity

Low productivity is a pervasive issue in the construction industry. One productivity index asserted a significant decline from 4% in 2010 to -2.7% in 2013 (Hwang, Zhu, & Ming, 2017). Despite the efforts of the government, productivity in the construction sector remained low at 2% in 2018 (MTI, 2018). Low productivity manifests in an especially damaging way in the green construction industry. According to Hwang, Zhu, & Ming (2017), construction productivity is a determining factor in ensuring the achievement of the BCA's goal for greening at least 80% of buildings by 2030. Low productivity is exacerbated in the green building sector by four factors: inconsistent building design standards (previously discussed in 4.2.1.4), ineffective project planning, limited professional capability, and supply chain discontinuity.

4.4.2.1 Ineffective Project Planning

Existing planning models struggle to manage the increased complexity of green building construction projects (Hwang, Zhu, & Ming, 2017). The procedures to obtain planning approval for the inclusion of green features is an additional step found to waste a considerable amount of time and cause significant delays in green construction project schedules (Hwang et al., 2017). This is because the procedures involved in obtaining approval are lengthier and more complex (Hwang et al., 2017). One study found that 33% of green building projects in Singapore experienced delays, compared to only 17% of traditional building projects (Hwang et al., 2017). While BIM is mandated to improve project planning, it has been used incorrectly and therefore produces suboptimal results. Developers, designers, and contractors continue to face difficulty in conceptualizing the green technology that they wish to incorporate into building project design.

4.4.2.2 Limited Professional Capability

Issues with professional capability arise from both a lack of specific expertise and employment constraints. According to Hwang, Zhu, & Ming (2017), limited green expertise represents a major barrier to the sectoral integration of green buildings. Green expertise refers to both knowledge on the technology itself and proficiency in modelling the technology in real-life applications (Siva et al., 2017). Experts diverge in their assessments of the green workforce aptitude in Singapore. According to Hwang et al. (2017), competent and experienced local green design professionals in Singapore are extremely deficient (Hwang et al., 2017). Siva et al. believe that there is sufficient stakeholder knowledge and expertise concerning green buildings and related technology, however availability of specific knowledge is limited to only a few stakeholders (Siva et al., 2017). The results of the two studies in conjunction with other market considerations suggest that the overall green building knowledge base is a culmination of each stakeholder possessing satisfactory expertise concerning the installation and operation of a single green building technology. While the overall pool of green building knowledge is sufficient, at the individual level it is not. The green building construction/retrofitting process in Singapore can be thought of as an assembly line. Each stakeholder possesses adequate knowledge on a specific prescribed technology and separately contributes their part to the project. Supply chain discontinuity is both a secondary effect and amplifier of this limited knowledge base. Inadequate government initiatives to improve the green workforce does not appear to be the issue. Rather, the established uncollaborative system has rendered this division in roles and limited professional capabilities. Professional capacity is very limited in any green building practices that are unrelated to prescribed technology, most commonly the modelling of non-prescribed technology in real life applications. This represents a significant disincentive to pursuing a performance-based pathway in green buildings because stakeholders are largely unaware of how to execute a personalized green technology approach. Important stakeholders that do not possess specialized knowledge are unable to efficiently utilize green technologies due to their increased complexity, contributing to a high likelihood of project reworks and difficulty complying with Green Mark standards (Hwang, Zhu, & Ming, 2017). For this reason, many private developers elect to incorporate the prescribed technological features explicitly mentioned under Green Mark guidelines (Siva et al., 2017). Refer to section 4.3.1 for additional details regarding performance-based policy. Employment constraints represent a legality issue in Singapore's institutional framework that contributes to low professional capability. Workers with green residential construction expertise are designated as “unskilled or semi-skilled workforce,” a classification that is under strict control for work permit issuance to foreigners (Hwang et al., 2017). This is meant to limit the number of foreign workers to ensure that local Singaporeans are not priced out of the job market (Hwang et al., 2017). However, this government-imposed control is counterintuitive for the green building industry because it further reduces the number of professionals with specialized expertise.

4.4.2.3 Supply Chain Discontinuity

In Singapore, the stakeholders involved in green building projects usually gather at scattered intervals along the project’s timeline, resulting in minimal collaboration, lack of coherence, and, consequently, sub-optimal green building design (Siva et al., 2017). The inconsistent temporal involvement results in the dilution of project goals, where stakeholder contribution is based on the fulfilment of personal objectives due to the absence of collective goals and dissociation from the overall project. Supply chain discontinuity and ineffective stakeholder collaboration are also related to the current prescriptive policy approach. It is suggested in the paper by Siva et al. that transitioning to a performance-based regulatory model could potentially counteract the problem of inconsistent stakeholder participation (Siva et al., 2017). A performance-based model would promote collaboration from the beginning of a project because stakeholders would need to think of a creative way to achieve the desired green building performance while optimizing building design (Siva et al., 2017). This is a departure from the current framework, where the design is carefully outlined and stakeholders do not necessarily need to engage in discussion. BIM has done little to improve discontinuity due to incorrect use.

4.4.3 Market Demand

Market demand for buildings with green technology is relatively low in Singapore. For residential buildings, the three most important factors influencing prospective buyers in Singapore were found to be price, accessibility, and location (Addae-Dappah & Chieh, 2011). Green features rank 6th out of 8 on the same list, exhibiting the general indifference of Singaporean people toward sustainable technology (Addae-Dappah & Chieh, 2011). While Green Mark certification is not a motivator in its own right, it becomes a relevant criterion for purchasing decisions when buyers are deciding between two units that are otherwise similar and satisfy the more important factors (Heinzle et al., 2013). Citizens of Singapore are therefore only willing to pay for the premium associated with green features if they are accompanied by the other features that they deem more important. For commercial and office buildings, market demand is largely derived from corporate and government lessees that may place more importance on green features to meet social corporate responsibility standards (Yu et al., 2011). Market demand has a significant influence on achieving Green Mark ratings that are beyond the minimum mandated level. Low market demand induces a chain reaction in other stakeholders across the green building supply chain. Investors are deterred from funding the additional capital costs associated with green construction because they believe there is no demand for green buildings (Heinzle et al., 2013). This lack of funding prevents developers from constructing green buildings, resulting in a lack of supply for the property buyers that do seek green buildings (Heinzle et al., 2013). We are therefore left with both a lack of supply and demand.

The low market demand is primarily a result of limited market understanding of the Green Mark rating system. A survey of 300 Singaporean citizens conducted in 2011 found that only 34% of the participants have heard of the Green Mark rating system (Addae-Dappah & Chieh, 2011). Furthermore, only 83% of this proportion are aware of the differences between the four rating tiers (Addae-Dappah & Chieh, 2011). This indicates that the market has very little knowledge of green buildings in Singapore. One reason for this is the prescriptive policy approach. Each rating is associated with different prescribed technical requirements, making it difficult to understand for end-users. Overall energy performance, as is the measurement metric of performance-based policy, would be better understood by end-users. While certification schemes/eco-labeling have been proven to help overcome information asymmetries and increase consumer confidence by validating environmental stature (Heinzle et al., 2013), they have not helped in the case of the Singaporean property market. For most, Green Mark continues to be an ambiguous designation and its value remains misunderstood. This may be due to the complexity of Green Mark documents, which do not appear to have been designed with the needs of end-users in mind. This lack of understanding is further suggested in several studies that show the illogical distribution of resale premia across the different Green Mark tiers (refer to 4.3.1.3 to view the study).

4.4.4 Technological Capacity

The term "green technology" refers to the green equipment and features that are incorporated into buildings to satisfy Green Mark requirements. Technological capacity considers the type, availability, and innovation potential.

4.4.4.1 Types of Technology Used

Green Mark stipulates the exact technologies necessary under their prescriptive guidelines. With the exception of three prerequisite features, building developers are able to choose the additional green features they wish to incorporate from a list to earn additional points toward obtaining their desired Green Mark certification tier. Refer to this link to view the elective list of prescriptive criteria (this is the list designated for non-residential buildings, however criteria for residential buildings are identical apart from the number of points awarded changes incrementally). The primary criterion for selecting the type of green technology to be used in a green building is economic feasibility (Siva et al., 2017). The cost of green technology has gradually decreased as the global market for sustainable products expands. Cost effectiveness of green technology is further accentuated by decreasing payback periods due to higher efficiency equipment. Payback periods refer to the time it takes for a technology to recover the cost of initial investment through energy savings. This represents long-term economic feasibility. As well, the complexity of the technology influences cost. Developers favour technology with shorter payback periods (Siva et al., 2017). Passive design features are also preferred for this reason because they focus on altering design features of the building and therefore require less expertise and lower costs to incorporate. Green technologies revolve around improving energy efficiency, water efficiency, air quality, and the interior environment of a building. In an interview conducted by Siva et al., interviewees stated that the most popular green technologies featured in green buildings in Singapore were energy-efficient lighting systems, chiller plant systems, and photovoltaic cells (solar panels) (Siva et al., 2017). Energy-efficient lighting system is the most economically feasible because it is both inexpensive and has a comparatively short payback period of less than three years (Siva et al., 2017). Paradoxically, both chiller plant systems and solar panels are more expensive and have long payback periods of over five years (Siva et al., 2017). Chilled plant systems are a type of centralized air conditioning system that use chilled water as the medium to cool buildings in an energy efficient manner (BCA, 2019a). This technology has gained popularity because of regulations mandating the installation of such equipment in existing buildings undergoing major retrofitting. It is suggested that the commonality of solar panels is derived from government subsidies encouraging the use of renewable energy and options for solar leasing, which refers to an agreement between building owners and solar panel companies whereby roof space is made available for solar panel installation, from which building owners are also able to derive energy at a discounted rate (Siva et al., 2017). Chiller plant and solar panel technologies have been continually advancing and their feasibility is anticipated to increase (Siva et al., 2017). Other key technological features used in green buildings in Singapore are as follows:

- Insulated glass to reduce solar heating through windows;
- Design features to improve natural light;
- Equipment to control energy efficient lighting;
- Energy efficient cooling plans and natural ventilation systems (Siva et al., 2017)

The increased incidence of green technology has also prompted rising demand for complimentary technologies, namely building management systems and high sensitivity sensors, to monitor and control the green equipment for optimal energy use (Siva et al., 2017). Singapore is also largely considered a pioneering influence for vertical gardens, one of the most visually astounding technological features that can be incorporated into the built environment. Roof and vertical greenery are elective technology options for the allocation of additional Green Mark points. Such technology offers a variety of sustainability benefits such as increased energy efficiency through heat buffering, decreased indoor temperature, rainwater reclamation, and extending the lifespan of the external building skin (Ali, 2019). Despite long payback periods reported as ranging from 13-17 years (Radic, Dodig, & Auer, 2019), greenery in the built environment has become increasingly popular in Singapore.

4.4.4.2 Availability of Technology

Hwang, Zhu, & Ming (2017) denote high costs and low availability of green technology as two major reasons for the increased construction costs associated with green buildings (refer to 2). The findings in this section contradict these claims. High green technology costs are a common misconception because of the highly marketed features, namely solar panels. This has incorrectly given green technology the reputation of being significantly higher than conventional technology. However, most technology does not require significant initial investment. Green technology also possesses the same degree of availability in the market as conventional technology. Mandatory requirements for certain technologies since 2008 saw the insurgence of green technology in the domestic market to fill this need. Green technology is readily available in Singapore predominantly through importation from overseas manufacturers (IBP, 2011). The current market for green technology is characterized by a large number of foreign manufacturers competing in a small market (IBP, 2011). It is expected that imports will continue to be the dominant supplier of green technology in Singapore due to two main reasons. First, the local market generally has a preference for imported green technologies because they are perceived to be the most proven and reliable products (IBP, 2011). The Singaporean market values competitive pricing and proven reliability most when making a purchasing decision (IBP, 2011). Second, trade policy dictates that there are no duties, taxes, or tariffs on imports to Singapore for all construction-related equipment and materials (IBP, 2011). Given the mandatory prescriptive requirements of Green Mark, many foreign products have already been able to establish strong competitive positions (IBP, 2011). Green material and equipment beyond the mandatory requirements are not as readily available and do not possess the same market presence, therefore they normally require long periods of time for delivery from overseas manufacturers (Hwang et al., 2017). Though Singapore has globally competitive manufacturing clusters (Bhaskaran, 2018), there is limited local manufacture of green technology (IBP, 2011). This is likely because of the market's preference for foreign products due to their perceived reliability. Indigenous manufacturers therefore lack the economies of scale to be competitive against foreign producers. Economies of scale refer to a state where low unit costs of production are achieved by being able to rapidly scale up in a large market, a position that Singaporean manufacturers have not been able to achieve because of the city-state's small, competitive market. Meaningful statistical information regarding quantities of imported green technology in comparison to quantities produced locally is absent in the existing literature. Changes in local manufacture of technology are unlikely to occur because Singapore is a very import-oriented economy and, assuming no drastic changes, will remain this way.

4.4.4.3 Innovation Potential

Innovation potential does not refer to the production potential of green technology because it is not relevant to Singapore. Instead, innovation potential in this study will focus on the potential for green technology uptake. Singapore has comparatively weak overall potential for innovation and ranks low in related indices such as creative productivity. According to the Asian Development Bank (ADB) and the Economist Intelligence Unit (EIU), Singapore's low ranking on the Creative Productivity Index (CPI) is a result of disbalance between inputs and outputs, the two measures comprising the index (Bhaskaran, 2018). The input side evaluates a nation's innovation capacity and how conducive the environment is to innovation while the output side considers the produced outcomes of innovation to understand the economy's proficiency in turning innovation "inputs" into tangible "outputs". Singapore ranks high in terms of inputs but significantly lower for outputs (Bhaskaran, 2018), therefore diminishing its overall CPI score and indicating its ineffectiveness as an innovator. When considering this low CPI score in direct reference to green buildings and technology, the absence of overall innovative capacity may represent a significant long-term barrier because it does not support sustained sectoral growth. This has implications for both the production of technology locally and the uptake of more advanced imported technology. The score suggests that the Singaporean green building market retains the capability and availability to use and produce advanced green technology but may elect not to. This coincides with the findings of Siva et al. that most people only implement green technology that is explicitly prescribed by the mandatory Green Mark requirements and neglect to go beyond the minimum (Siva et al., 2017). This suggests low technological innovation in the green building sector. Performance-based policy, which can paradoxically be thought of as "regulated deregulation," could play a significant role in improving this technological barrier by creating an environment more supportive of risk, among other multifactorial impacts.

4.5 Summary

Policy is the single most important driver of green building integration in Singapore because the city-state is accustomed to a strong government presence. The sectoral transition of the construction industry is therefore contingent on the government's ability to perform its role in the regulation and market stimulation of green buildings. Currently, green building policy in Singapore excels in its regulatory function but has been insufficient in stimulating the market. Strong regulation and mandatory provisions have been responsible for the initial implementation of green buildings into the Singaporean urban landscape. The initiation step is the point at which regulation is most important. However, continued implementation features greater emphasis being placed on the free market. The desired outcome associated with overcoming the market integration barriers to green buildings would be an increase in both the supply, generated by developers, and the demand, generated by the end-users. The Singaporean government has generally been ineffective at overcoming the existing market barriers to green building integration. To position green buildings as a lasting fixture of the Singaporean economy, it would be advisable for the BCA to place a greater focus on market-oriented policy measures. Significant barriers exist with respect to both economic and social considerations. Economically, green buildings remain disadvantageous to developers. Green buildings remain undesirable to stakeholders involved in green building projects, preventing the growth in supply and popularity of such constructions. Social considerations, which are concerned with human capital and behaviour, are also insufficient. Low productivity remains a pervasive issue that is especially prevalent in the green building industry because of its relative immaturity. This barrier has also contributed to reduced green building supply. Low market demand is an outcome of end-user behaviour that has not yet shifted toward a sustainability orientation. This is largely a result of a poor understanding of Green Mark. Green technological capacity is ample in Singapore, predominantly due to cost effectiveness and extensive availability. The single identified inhibitory consideration relates to the poor uptake of green technology. This is less related to actual technology and more concerned with risk aversion. Policy implementation gaps are responsible for existing market barriers. The interrelatedness of market conditions means that a single policy measure can help overcome multiple barriers. The connection between policy implementation and resulting market outcomes is depicted in figure 4.

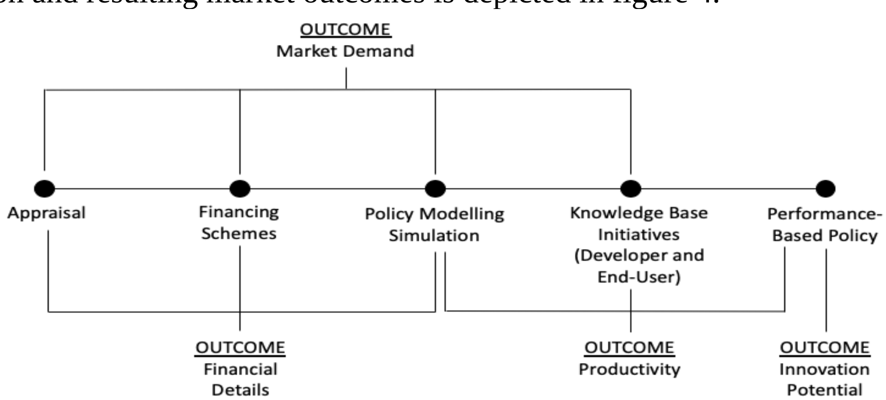

Figure 4. Graphical representation of policy solutions and market outcomes.

The results of this study have been organized to visually represent the current macroeconomic environment under which green buildings are being adopted in Singapore. The graphical representation is depicted in figure 5.

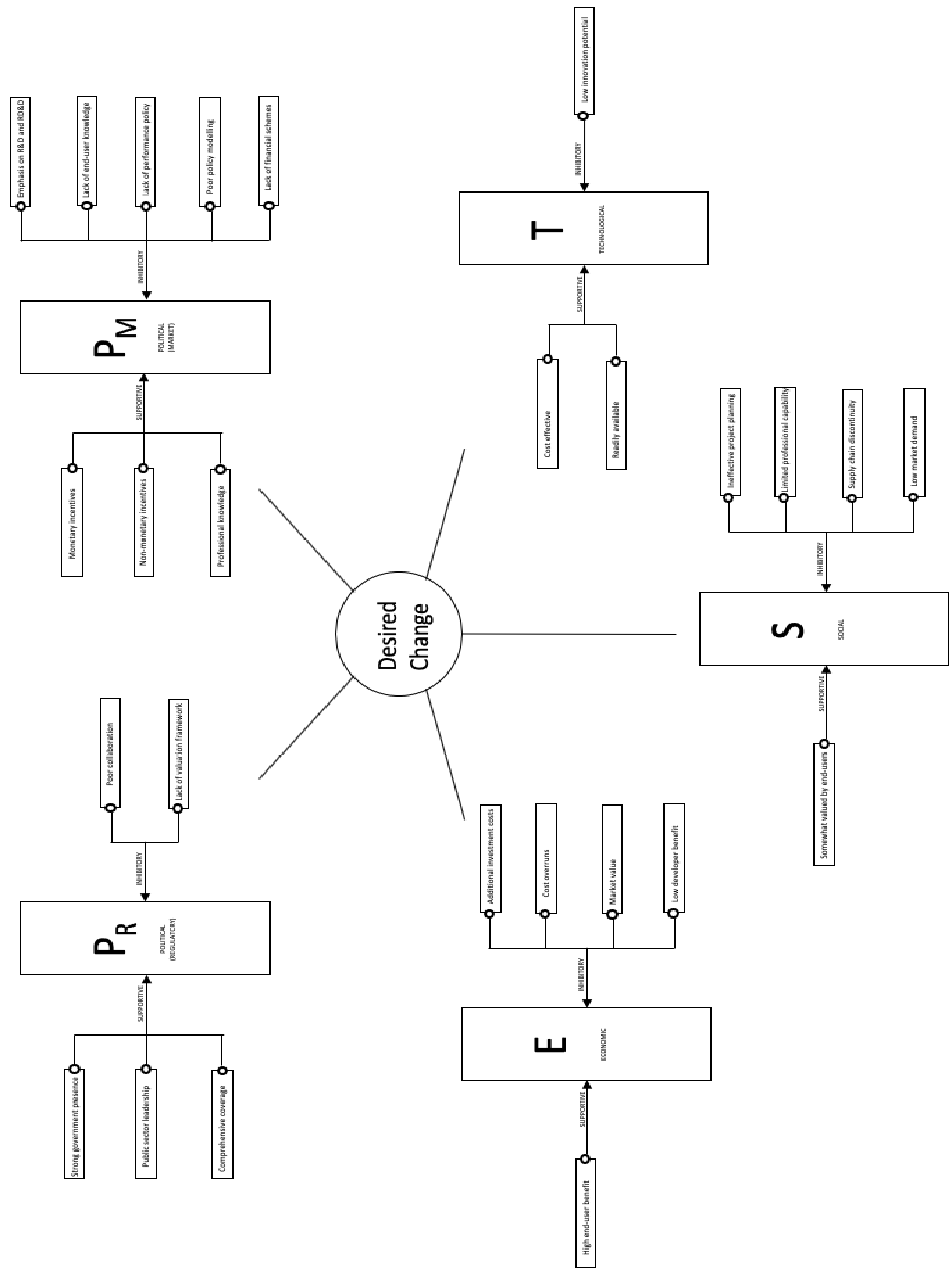

Figure 5. Graphical representation of study findings using hybridized framework.

5 Conclusions

This paper set out to answer the following research question: Do the existing policy initiatives offer sufficient regulatory support and market integration stimulus to fulfill Singapore's green building objectives? The phrase "green building objectives" alludes to the most recent goal announced by the BCA to green a minimum of 80% of buildings in Singapore by 2030.

This study evaluated whether the current policy approach was facilitative of macroeconomic conditions supporting green building integration. This involves examining the respective regulatory and market stimulation functions of policy, as well as market considerations pertaining to economic, social, and technological factors. A hybridized framework merging force field and PEST analyses models was used to organize the findings of the study and extract insightful deductions. The results of this study suggest that the current policy approach has been effective in establishing the initial position of green buildings within the economy. Designating Green Mark as a mandatory requisite for construction projects in Singapore and developing complimentary codes and regulations have generated numerous positive outcomes associated with this regulation-oriented system. Market-based policy instruments were found to be underdeveloped and many implementation gaps were identified. Therefore, has been ineffective in overcoming the prevalent market barriers to integration. Economic and social conditions were found to be unfavourable for stimulating market integration due to the significant inhibitory considerations identified. Technological conditions can be considered moderately favourable. While barriers pertaining to physical green materials and equipment in the market have largely been overcome, low innovation potential has been identified as a significant inhibitory consideration preventing the behavioural adaptation necessary for widespread green technology uptake.

Existing studies identify different macroeconomic features as the primary barrier to green building integration. For example, Hwang, Zhu, & Ming (2017) identify low industry productivity as the main barrier to green building integration, while Siva et al. (2017) concludes that the inflexible habits and mindsets of end-users are responsible. The results of these studies are inconclusive and this paper does not claim to know which is correct, however the identified commonality is insufficient policy. Nevertheless, the results indicate that Singapore represents a sustainability-oriented market. The government is principally responsible for this. Voluntary activity by developers and behavioural reform by end-users remains insignificant due to largely unfavourable macroeconomic conditions. Continued maturation of the green building market is dependent on the stimulation of the lagging stakeholders. Establishing favourable market conditions could encourage an increase in green building supply from developers and demand from end-users. This represents an opportunity for a synergistic cycle to develop within the market, where abundance would increase demand and greater demand would drive production outputs. Prospective policy modifications best suited for optimizing macroeconomic conditions within the Singaporean market were adapted from techniques used in other cities/countries that presented successful policy outcomes. Green building integration in Singapore has stagnated. This study presents the importance of modifying the green building policy approach as the market matures and evolves. The Singaporean government continues to maintain an authoritarian governance approach despite trends of increasing deregulation, liberalization, and privatization of the nation's economy (Han, 2016). Policy dominated by strong regulation was effective for green building introduction but has been unsuitable for motivating the free market and driving sustained integration. The market is expected to be more receptive to a reoriented policy focus toward market-based instruments. At present, the limitations and policy implementation gaps associated with suboptimal market engagement suggest the deterrence of goal fulfillment.

The key findings of this study are summarized as follows:

Policy overview

- Green Mark certification scheme is the primary system governing green building standards
- Two relevant regulations were implemented for the purpose of modifying Green Mark: (1) Building Control (Environmental Sustainability) Regulations in 2008 to make Green Mark certification mandatory; (2) Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations in 2012 to enforce regulations for existing buildings
- Three GBMPs released in 2006, 2009, and 2014 to describe current industry goals and initiatives
- Incentives are market-based policy instruments meant to spur the private sector by alleviating the financial externalities of green buildings
- Three types of incentives: (1) Monetary (offering cash reward); (2) Non-monetary (offering non-cash reward); (3) Financing schemes (indirect savings retained from tax exemptions, green loans, loan co-sharing, etc.)

Analysis of current policy approach

Regulatory policy instruments

- *Strong government presence*: Mandatory development model has been the driving force for green buildings and the greatest increase in green building numbers occurred after Green Mark was made mandatory
- *Public sector leadership*: Achieves higher Green Mark ratings to set an example for the private sector, for example, green public housing leads the residential building sector
- *Comprehensive building coverage*: Green Mark covers new and existing buildings of many different types (residential, non-residential, landed houses, existing schools)
- *Poor collaboration:* Has led to discrepancies between mandatory standards under the same legislature (sustainability and buildability standards) and contradictory goals between government agencies (BCA and PUB)

Market-based policy instruments

- *Monetary incentives:* Generous grants and high reach to encourage the private sector
- *Non-monetary incentives:* Gross floor area concessions are most important, offering additional gross floor area for achievement of Green Mark GoldPlus or Platinum ratings in designated development locations
- *Emphasis on R&D and RD&D:* Substantial R&D investment by government to address low innovation potential and industry productivity, an initiative that has been ineffective
- *Professional knowledge base initiatives:* For developers, training is mostly well done other than the need to improve specific professional expertise (i.e. in BIM)

Policy implementation gaps and solutions

Performance-based policy

- Green Mark is currently prescriptive but could be more effective under a performance-based pathway

Policy modelling simulations

- BIM has been implemented in Singapore to increase productivity in the construction industry and its use has risen from 20% of the industry in 2011 to 65% in 2013 (Teo et al., 2015)
- Despite successful uptake of BIM, productivity remains low due to two areas of misuse: (1) BIM is mostly used only in the beginning stages of construction projects; (2) BIM submissions are as collaborative as intended

Financing schemes

- Financing schemes are underdeveloped and need further development of tax credits/deductions, green loans, and contingency funds will be important for the future

Valuation framework

- A formal valuation framework can be established, incorporating sustainability factors to accurately display the higher value of green buildings
- Implementation of a formal framework is possible because Singapore is considered to be sustainability-oriented due to (1) significant green building policy action; (2) significant green building stock; (3) moderate voluntary action by developers; (4) low end-user demand and understanding
- This policy tool would be most effective following others that first increase developer and end-user considerations, which would improve sustainability-orientation of the market
- Ultimately, the goal of the framework is to sufficiently increase supply and demand of green buildings to drive conventional constructions into obsolescence

End-user knowledge base initiatives

- Knowledge is deficient because Green Mark documents are highly technical and should be remade using better understood metrics

Analysis of market conditions

Financial details

- Green buildings are undervalued in the market and distribution of price premiums across Green Mark tiers are illogically allocated
- Financial benefits are unequally distributed, where end-users benefit much more than developers, because the maximum market value is achieved only at resale (10% market premium); for comparison, presale value is 4% (Poe, 2017)
- Cost overruns of 2.5-7% are frequent for green buildings, while conventional building projects are often overbudget (Hwang et al., 2017)
- Cost overruns are directly correlated with project delays and low productivity caused by low expertise and poor planning
- Additional costs associated with green building construction ranged from 3.5-9.2% (Hwang et al., 2017)

Industry productivity

- Low productivity is a significant issue in Singapore but is worsened in the green construction industry by four factors: (1) inconsistent building design standards; (2) ineffective project planning; (3) limited professional capability; (4) supply chain discontinuity
- Ineffective project planning is associated with the increased complexity of green building construction projects and is a cause for significant delays in green construction project schedules
- 33% of green building projects in Singapore experienced delays compared to 17% of traditional building projects (Hwang et al., 2017)
- Limited professional expertise and employment constraints result in a diminished green workforce
- Stakeholders participate in the construction project separately and at different times therefore there is little collaboration

Market demand

- End-user market demand is low for green buildings
- Surveys indicate that end-users have little knowledge of Green Mark and green features do not have a significant effect on renting/purchasing decisions

Technological capacity

- Most popular green technology features have been reported as energy-efficient lighting systems, chiller plant systems, and photovoltaic cells (solar panels) (Siva et al., 2017)

- Green technology has become more cost-effective and is readily available in Singapore
- Green technology market is characterized by many foreign manufacturers competing in a small market, where local green products are largely absent
- Innovation potential is low, meaning that there is a degree of aversion to incorporating green technology features

Recommended future research could involve further analysis of particularly underdeveloped areas of research specific to Singapore. This predominantly refers to closer examination of the macroeconomic factors affecting market conditions and the changing dynamics of the market. This is an advisable research concentration for the purpose of understanding the impact of market forces on various stages of green building integration. The outcomes of different types of policy with consideration of market conditions specific to Singapore could also be an area of further study. Analysis of policy applicable to different life cycle stages such as construction and demolition would be complimentary to this paper. As well, future studies could emphasize the market behaviour of end-users because research regarding social considerations have previously been a neglected subject. End-user perspectives of different demographic groups, namely income level and terms of residence (leasing or ownership), could be studied to analyze green building demand and understanding of each distinct group. For example, conducting two separate comparative studies on the importance of green features when considering the purchase of a private residential building unit for end-users classified under the higher wealth category and the lower wealth category. Future work directed toward macroeconomic analyses of other cities and/or countries following a similar method as the one in this paper is also recommended to facilitate comparative evaluation and knowledge exchange. Despite the identified limitations associated with the policy approach, Singapore exemplifies rapid green building integration under a mandatory development model that may be useful for policymaking reference in other cities striving to adopt green buildings.

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