DRIVING INNOVATIONS TO DEVELOP PUNGGOL TOWN AS THE ECO-TOWN OF THE TROPICS

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ABSTRACT

The Housing & Development Board (HDB) has positioned Punggol Town, planned at the onset towards achieving sustainability, as Singapore's first Eco-town of the tropics. This follows its first eco-friendly public housing development, Treelodge@Punggol, through passive design strategies and active technology adoption in the areas of greenery enhancement, energy efficiency, and water and waste management. The results obtained quantitatively demonstrated the benefits of the various eco-features introduced towards achieving environmentally sustainable public housing. This allows HDB to replicate the tested initiatives on a larger scale in its bid to drive innovations to develop Punggol as the Eco-town for the Tropics. The possibilities for future development of new sustainable technologies are endless and HDB's Punggol Eco-town is just the beginning.

INTRODUCTION

Overview

The Housing and Development Board (HDB) is the largest developer in Singapore, seeking to create well-designed, sustainable and community-centric towns towards achieving better HDB living for over 80% of Singapore's population. Specifically, HDB plays a major role in promoting environmental sustainability with the industry, through practical R&D involving the identification, testing and implementation of practical and cost-effective green building technologies, sensible urban design strategies and innovations in its public housing developments.

Punggol Eco-Town

Planned to promote sustainable living from the onset, Punggol has a wide range of quality housing with supporting facilities and a well-integrated public transport network that serves the needs of the town. Located in northeastern Singapore and as the youngest HDB town, Punggol presents a good opportunity to demonstrate sustainable urban planning and design, green technology adoption and active community partnership. As such, HDB is developing Punggol Town into Singapore's first Eco-Town - 'The Sustainable Waterfront Town in the Tropics'.

An eco-town with its own character, Punggol sets itself apart from other eco-cities, seeking to develop urban solutions that address high rise high density cities particularly in the tropics and sub-tropics that are reasonably simple and affordable. In this way, the solutions would be more replicable and scalable to many Asian cities.

Treelodge@Punggol: HDB's First Eco-Precinct

Treelodge@Punggol, as HDB's first eco-friendly public housing project and having been accorded the Green Mark Platinum Award, sets a new benchmark for future public housing to encourage the community to lead an eco-lifestyle. Comprising seven public housing blocks with 712 residential units, a podium carpark and generous provision of green spaces throughout the 2.9-hectare development, it serves as a 'Live-in Laboratory' where HDB has brought together sustainable urban design with green building technologies in a single demonstration project. The guiding design principle seeks to harness the elements of nature, such as wind, daylight, rainfall and greenery in order to promote sustainable green living, whilst actively adopting green building technologies. The integrated laboratory allows HDB to measure the collective effects of the design and technologies towards achieving environmental sustainability, before scaling and replicating these successful urban solutions to the rest of Punggol Town.

This paper will focus on several key research areas in Treelodge@Punggol and the results obtained from studies in these areas, before explaining the efforts made to replicate the innovations on a larger scale.

RESEARCH AREAS

The features incorporated in the precinct fall within the following key research areas:

a) Enhanced greenery
b) Energy Efficiency
c) Water & waste management

Enhanced Greenery

The provision of greenery in urbanized settings is recognized for the generation of numerous environmental, ecological and socio-economical benefits, such as relieving the Urban Heat Island Effect. Greenery also enhances the aesthetics within precincts, thus creating a conducive living environment, especially in densely built-up areas.

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The greenery provision of Treelodge@Punggol was greatly enhanced. A Green Plot Ratio[1] of 4.14 was achieved, compared to typical new HDB developments, which achieve Green Plot Ratios of 3 to 3.5. The generous provision was introduced to

a) reduce the Urban Heat Island Effect,
b) reduce ambient temperature in the precinct,
c) reduce reflected glare from lower levels,
d) reduce noise levels in estates and
e) enhance overall aesthetics of the development

The high provision was the result of several concepts and innovations.

Firstly, Treelodge@Punggol adopted the landscape eco-deck concept where the blocks sit on a podium level car-park, maximizing the opportunity for green and social spaces at the landscaped eco-deck.

Secondly, the adoption of a hybrid green roof system makes extensive greening on the eco-deck possible. This system reduced the depth of the soil bases required for planting and the size of the deck structure. Large trees were grown at the carpark level and were allowed to emerge through air-wells to complement the hybrid green roof system.

Thirdly, green roofs were introduced on the roof decks of the seven residential blocks. This was done to further enhance the thermal comfort of residents living in the topmost storey. HDB's patented Prefabricated Extensive Green (PEG) Roof system was used to achieve this at a low maintenance cost.

Microclimatic Study

In order to validate the hypothesized environmental improvements of enhanced greenery, a microclimatic study was conducted. This took place in two phases before and after greening of the Eco-deck.

During the study, the ambient air temperatures at multiple locations on the Eco-deck of Treelodge@Punggol were measured using temperature dataloggers in order to investigate the effectiveness of greenery in reducing ambient air temperatures.

The temperature results were compared for the time range of 12pm-2pm, when the typical daily maximum temperature occurs in Singapore. The temperature range was observed to fall from 32.8-34.6°C to 31.8-33.9°C following the addition of greenery. These figures are reflected in Figure 1. The significant reduction of ambient air temperatures by an average of 0.9ºC was a validation of the hypothesis that greenery provision would lead to ambient temperature reduction.

The reduced ambient temperature will help to make community spaces more conducive for residents' enjoyment, while reducing residents' need to use mechanical means like air-conditioning to achieve thermal comfort.

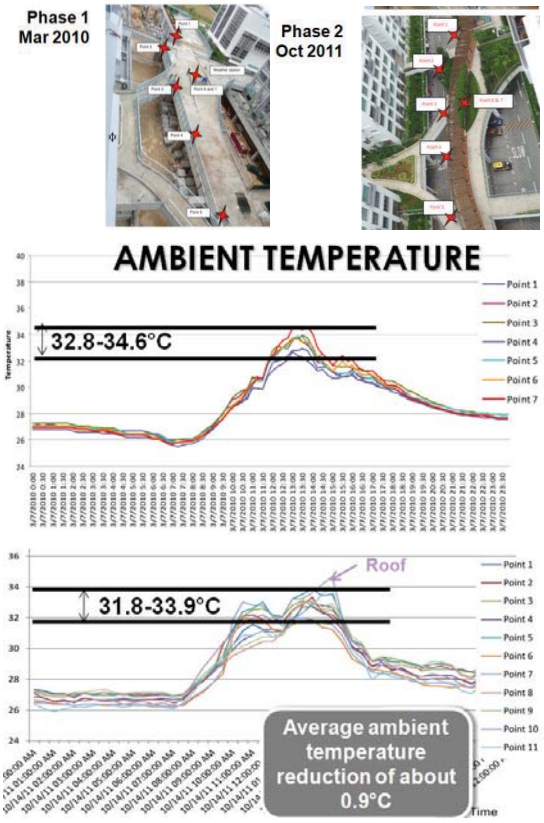


Figure 1: Microclimatic Study Ambient Temperature Results

Energy Efficiency

Household energy consumption forms about 9% of the total energy usage in Singapore. Planning and designing energy-efficient buildings will help reduce global and local environmental impact, through reduced utilization of non-renewable resources and related environmental impacts, such as air pollution.

Energy efficiency was emphasized in Treelodge@Punggol through optimizing passive design strategies and adopting active design strategies.

Passive Design Strategies

During the planning phase, the prevailing north-east wind for the precinct was taken into consideration. All residential blocks were strategically placed with façade windows that face the prevailing wind to maximize natural lighting and ventilation. This also

[1] Green Plot Ratio quantifies the amount of plant volume in a development site (measured in terms of total leaf area).

helps to minimize solar radiation from the sun into the units and reduces the energy consumption caused by the use of air-conditioning.

Validation Study on Wind Flow Analysis

Based on the predominant wind direction in Punggol town (North and North-east direction), a detailed wind flow analysis was carried out through Computational Fluid Dynamics (CFD) modeling at precinct, block and unit level during the design stage of Treelodge@Punggol. Through analysis of the wind profile, the design was fine-tuned to prevent 'stagnant' areas with low air flow, thus enhancing the natural cross-ventilation across the precinct. For example, triple volume voids were created in some of the residential blocks to allow better cross ventilation into the eco-deck.

Real time data was collected using monitoring devices during and after the construction stage. The CFD analysis was then validated using the actual wind profile observed at the site after its completion.

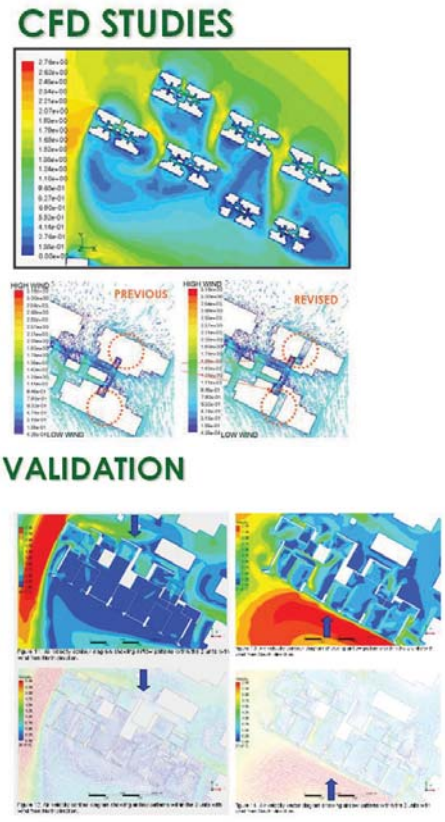


Figure 2: Validation of the wind flow analysis

In the comparative study (see Figure 2), an average wind velocity of 0.4-0.6m/s was recorded on site. This was similar to the result generated from the CFD studies. This demonstrates that advancements in computational modelling had made it possible to simulate microclimatic conditions accurately. This would enable HDB to determine the cross-ventilation performance across Punggol and the effects of urban design at both macro and micro levels.

Active Design Strategies

Energy is required to power lighting in the precinct at night, the lifts to provide vertical transportation and the pumps to supply water to the water tanks. Apart from using passive design to reduce energy consumption, active design strategies help to optimise the energy usage and reduce maintenance costs.

Energy-saving light fittings such as LED light fittings were installed in common corridors and in the podium carpark as they have a longer lifespan and greatly reduce energy demand. In addition, motion sensors were placed strategically at staircase half-landings and in the carpark to provide on-demand lighting, further reducing energy consumption. The lifts in Treelodge@Punggol include an energy regenerative system to recover kinetic and braking energy that would otherwise be lost as heat.

Solar photovoltaic (PV) panels with a total capacity of 280kWp were installed at the rooftops to harness solar energy to power the aforementioned common services such as common area lightings, lifts and pumps.

Energy saving study

After the completion of Treelodge@Punggol, a Building Monitoring System (BMS) was installed to monitor the solar energy generation and common area energy consumption.

The Solar PV system generated an average of 3700 kWh of solar power per block per month (see Fig 3), which is sufficient to meet approximately 90% of the of the total common services energy requirement.

With the implementation of energy-efficient lighting and energy-efficient lifts, the average energy usage for the common services was 38.4 kWh / dwelling unit / month, about 32% lower compared to other new HDB developments in Punggol (see Fig 4).

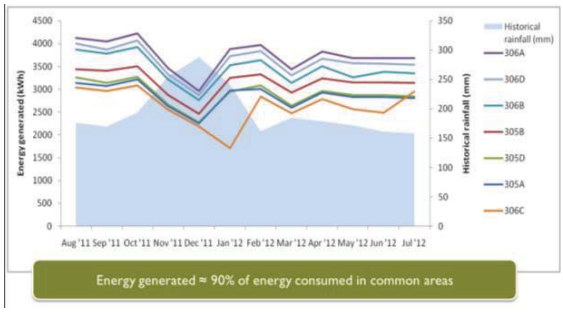
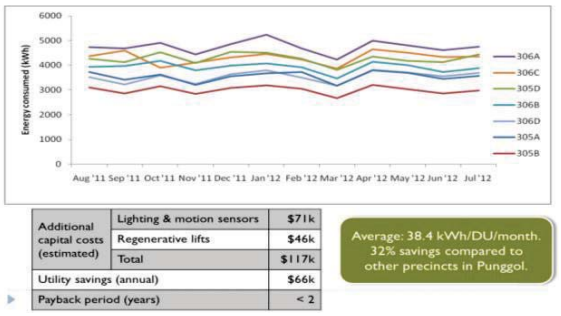


Figure 3: Solar Energy Generation



Additional capital costs (estimated)	Lighting & motion sensors	$71k
	Regenerative lifts	$46k
	Total	$117k
Utility savings (annual)		$66k
Payback period (years)		< 2

Average: 38.4 kWh/DU/month. 32% savings compared to other precincts in Punggol.

Figure 4: Common Area Energy Consumption

Waste and Water Management

Water Conservation

Efficient water management was an important factor in designing Treelodge@Punggol. The precinct incorporated a rainwater harvesting system with storage tanks at the top-most storey of each residential block. The harvested rainwater was treated with a chemical-free treatment system to remove up to 80% of bacteria, allowing the water to be used for non-potable purposes, such as common area washing and irrigation. This lowered the usage of potable water in common areas. The use of gravity to distribute the treated rainwater to lower floors reduced the energy required for water distribution further. Detailed studies are currently being conducted to determine the effectiveness of the rainwater harvesting.

To help residents conserve water within the residential units, water-efficient fittings which meet the PUB Water Efficient Labeling Scheme devices (2-ticks) were provided. All bathrooms were also fitted with an innovative integrated wash basin-toilet eco-pedestal system that allowed residents to save about 10% of the water used for flushing the toilets. The eco-pedestal enabled water used for hand-washing to be re-directed to the pedestal cistern for the next toilet flush. Further water conservation was achieved through the inclusion of a dual flush feature, allowing the user to vary the amount of water used for flushing.

Surveys were conducted with the residents to seek feedback on the eco-pedestal. It was found that residents generally supported the initiative as they found it useful to help them conserve water. Residents' feedback on the design of the eco-pedestal also helped in refining the eco-pedestal for wide-scale implementation, including improving the flow rate for hand washing, enlarging the basin and providing more space for a soap dish (see Fig 5).

Figure 5: Eco-pedestal improvements

Waste recycling

To promote waste recycling, a Centralised Chute for Recyclables system was introduced to all the blocks, in addition to the original centralised refuse chute. Dedicated for recyclable waste, the system provided added convenience for residents to recycle, whilst improving the waste collection efficiency.

Study on Recyclables Collected

Recyclable waste collection was monitored over a one-year period. With the introduction of the Centralised Chute for Recyclables system, there was a significant increase in recyclables collected. The recyclable waste tonnage was observed to be more than four times the amount collected compared to a typical HDB block with a recycling bin at the ground floor (See Fig 6). The study also provided quantitative results that would be useful in waste logistics planning. It was observed that over the festive season in December and February, there was a marked increase in the amount of recyclables collected.

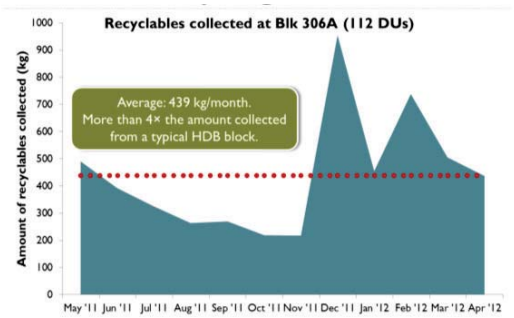


Figure 6: Amount of Recyclables collected

Community Effort

Beyond sustainable design and green building technologies, active resident participation is important in creating a green living lifestyle. A series of programmes and initiatives was developed to educate, engage and enable the community to embrace an eco-friendly lifestyle. The provision of cost-effective and space-efficient dual bicycle parking facilities and the introduction of a car-sharing scheme helped encourage adoption of green commute

modes, whilst a community garden at the centre of the eco-precinct enables greater community participation and interaction through green activities.

Post completion Survey on Eco-Friendly Practices
A survey was conducted in 2011 to determine the receptiveness towards a green living lifestyle amongst Treelodge residents. The surveys were conducted via face-to-face interviews amongst a total of 256 randomly selected residents from Treelodge@Punggol. Over 90% of respondents expressed their support for the various eco-features that were introduced both within their homes and in the precinct (see Figs 7 and 8).

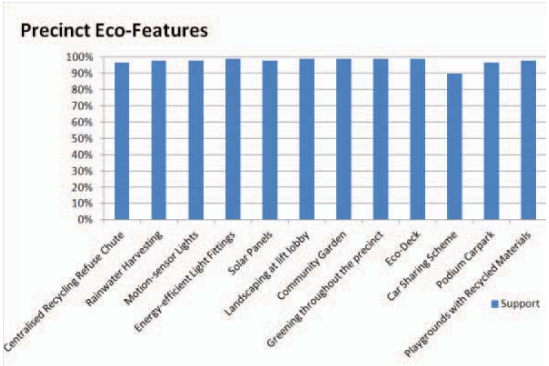


Figure 7: Survey Findings for Precinct Eco-Features

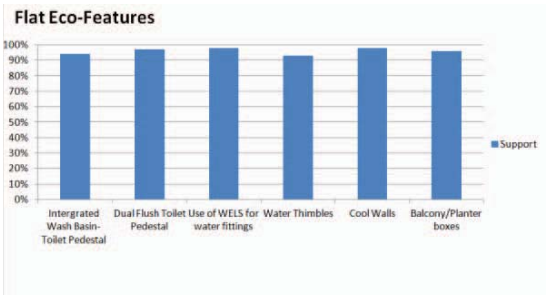


Figure 8: Survey Findings for Flat Eco-Features

Replicability & Scalability in Punggol Eco-Town
With promising results derived from the study on Treelodge@Punggol validating the measures introduced, workable eco-features were implemented to new public housing developments under construction or launched after Sep 2011. Some of these eco-features include lush greenery to reduce the urban heat build up, centralised refuse chutes for recyclables to promote recycling, rainwater harvesting systems to encourage water conservation, energy re-generative lifts, LED fittings with motion sensors, fuel cells to enhance energy efficiency, and computational fluid dynamics analysis to capitalize on wind to cool the environment.

For existing developments, HDB is working with Pasir Ris-Punggol Town Council to introduce energy urban solutions to 180 existing blocks in Punggol by 2015. The solutions include LED lighting and re-generative lifts to help improve energy efficiency in existing estates. HDB has also developed a new business model to tap on private enterprises in the wide-scale implementation of green technologies. Singapore's first solar leasing project comprising 2 mega-watt-peak (MWp) systems was completed in 2012 with solar energy generated to power the common services (common area lighting, water pumps and lift services) for 40 residential blocks. Another tender to install 3MWp for 80 blocks is currently underway and is expected to be completed in end 2013.

A holistic and comprehensive framework that covers social, economic and environmental considerations was developed to steer the development of Punggol Eco-Town. The framework sets out 10 key desired sustainability outcomes with broad strategies and initiatives to achieve them. The environmental strategies focus on reducing carbon emissions, encouraging greener forms of transport, enhancing greenery and biodiversity, achieving effective water and waste management and providing a clean, healthy and comfortable living environment. To ensure social sustainability whilst meeting the evolving and diverse social needs of a wide spectrum of residents, the social strategies seek to encourage more social activities and instil a greater sense of ownership and identity. The strategies for economic sustainability focus on creating economic and social vibrancy within Punggol Town Centre.

HDB has also expanded the CFD analysis beyond precincts, with town-level environmental modelling to simulate microclimatic conditions (wind flow, temperature, and solar irradiance). This allows HDB to study the impacts on Punggol's urban design at both macro and micro levels. The results are used to optimise the building designs to reinforce HDB's passive design strategies. At the precinct-level, air flow between residential blocks can be examined using CFD analysis, and building design and spacings can be refined to prevent air stagnation. At the town-level, air flow across precincts can be examined to ensure that precinct designs do not impede air flow between neighbouring precincts, thus achieving effective cross ventilation across the entire town. HDB has also worked with NUS academia on a Township Climatic Mapping study for the entire town to examine the macro scale effects of ambient temperature, wind, solar irradiance and shadow effects, etc to aid in the town planning and development for Punggol Eco-Town.

HDB is also developing an Urban Systems Model, which can be used to guide planning and design decisions. The model comprises 6 inter-connected environmental sectors and provides an analysis of the energy and carbon emissions generated by the town, depending on the trade-offs between urban form,

infrastructure and technology alternatives. The model allows refinements to land-use and urban design plans for the town to be made based on model predictions on the performance of the various initiatives set out for Punggol.

Beyond technology, community efforts to embrace an eco-friendly lifestyle have also been embarked on in Punggol. There are ongoing plans to develop an extensive cycling network for Punggol Eco Town to promote green commutes. These include the implementation of cycling paths in new and existing developments that take the safety of the cyclists into consideration to encourage non-motorised transport.

CONCLUSION

Punggol Eco-Town presents an opportunity for HDB to redefine our urban landscape to make the town more sustainable and liveable. Following the successful validation of the eco-features introduced in Treelodge@Punggol, many of the proven green building technologies have been incorporated into new developments within Punggol Eco-Town, whilst existing developments have also been retrofitted with selected solutions to make them sustainable in the long run.

With a holistic framework to guide the development, HDB has taken steps towards fulfilling the various desired outcomes, which has gained pace with new urban design plans and new developments brought about by HDB's ramped-up building programme. In addition, Punggol Eco-Town serves as an excellent platform to test out new ideas, innovations and technologies with various stakeholders and to identify workable ones that can be replicated in other towns. The scale of implementation also allows HDB to achieve cost efficiency with economies of scale.

Notwithstanding the importance of cost-effectiveness, Punggol Eco-Town can be the platform for HDB to pursue qualitative benefits in relation to national issues and challenges, such as improvements in quality of life, liveability and productivity. Moving forward, HDB will identify more new eco-ideas to introduce in Punggol and develop these ideas into future eco-solutions for Punggol and future towns. The possibilities for future development of new sustainable technologies are endless and HDB's Punggol Eco-town is just the beginning.