Overview of 2016 Data

National Building Energy Benchmarks for Commercial Buildings

Energy Performance of Green Mark Buildings

Study on Retrofitted Buildings
Acknowledgement

We would like to acknowledge and express our gratitude to the Technical Consultative Panel for their valuable insights and feedback on this report:

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BCA Building Energy Benchmarking Report 2017  
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Climate change is a global challenge. The Paris Agreement, in force since November 2016, demonstrates the resolve of global leaders to work together to address this. Singapore will also do its part by reducing our emissions intensity by 36 per cent from 2005 levels by 2030.

The buildings sector is a crucial part of our climate strategy because it is the second largest energy consumer in Singapore. To meet our targets, we need to “green” our buildings and make them more environmentally sustainable. We are making progress. Our three Green Building Masterplans and initiatives such as the BCA Green Mark scheme have allowed us to green one-third of our buildings.

While everyone has a role to play, the Public Sector will continue to set the pace. As part of the Public Sector Sustainability Plan 2017, government agencies will reduce electricity consumption by at least 15% from FY2013 by 2020. In this regard, all new large public sector buildings will attain BCA Green Mark Platinum standards. In addition, Government agencies will only host their events in “green” venues which are more energy efficient.

At the same time, we should leverage the opportunities that arise from the need to tackle climate change. Our green building expertise puts our firms and professionals in a good position to meet growing demand for environmentally sound buildings. Companies offering green solutions and services can leverage these trends to expand their reach. This is one area of focus of our construction industry transformation map (ITM).

Through the combined efforts of public and private sector stakeholders, we can build a greener and more climate-friendly country for all Singaporeans.
In this 4th edition of the Building Energy Benchmarking Report (BEBR), we observed that the building sector is performing better in terms of its Energy Use Intensity (EUI). Particularly, the commercial buildings have shown consistent improvement in their EUI from 5% to 9% since we started this yearly report in 2013. These results are encouraging and I urge all key stakeholders such as the building owners, environmental sustainability designers (ESDs), energy services companies (ESCOs) and the facilities managers to maintain their good performance and continue to improve.

In the next phase of green building development, BCA will continue to partner the industry to develop an eco-system to enhance the environmental sustainability of the built environment. We have in place financing schemes such as Green Mark Incentive Scheme for Existing Building and Premises (GMIS-EBP), and Building Retrofit Energy Efficiency Financing (BREEF) Scheme to subsidise part of the upfront costs of green retrofits and energy efficient improvements.

This year, BCA has expanded the scope of mandatory submission to cover five more building types, including civic and community institutions, and sports and recreation centres. This will help stakeholders understand the energy usage of their buildings, set targets and make cost effective improvements.

Moving ahead, BCA will unlock more market opportunities by encouraging greater information transparency. This year, following the release of anonymised building energy performance data in 2016, BCA will publicly disclose the data of 76% of commercial buildings volunteered by building owners to name the buildings and indicate their energy performance. BCA will continue to do so for other building types and make disclosure mandatory in the near future.

Together, we can build a more sustainable built environment.
BCA publishes the Building Energy Benchmarking Report (BEBR) annually since 2014, to monitor the building energy performance of Singapore’s building stock. This publication is an initiative under the BCA 3rd Green Building Masterplan, which aims to:

- Inform building owners and facilities managers on how well their buildings have performed; and
- Spur them to initiate and implement improvements in building energy efficiency.

Under the Building Control Act, building owners have been required to submit building related information and energy consumption data to BCA on an annual basis since 2013. The information thus collected was analysed to establish the national building energy benchmarks for Singapore’s built environment.

In this year’s Annual Mandatory Submission exercise, BCA has covered the following types of buildings:

- **Stage 1 (2013)** – Commercial buildings comprising office buildings, hotels, retail buildings and mixed developments;
- **Stage 2 (2015)** – Healthcare facilities and educational institutions; and
- **Stage 3 (2017)** – Large buildings of civic and community institution, place of worship, sports and recreation centre, transport facility and light industrial building.
Submission Compliance and Building Stock

In 2016, commercial buildings, healthcare facilities, and educational institutions were targeted for the annual mandatory submission.

In total, 1,323 buildings, with a combined Gross Floor Area (GFA) of 28.0 million m² and total annual electricity consumption at 8,063 GWh, had completed the submission in time for this benchmarking exercise. There was full compliance as outstanding submissions eventually came in within grace period but too late for this exercise.

Commercial buildings achieved a compliance of 99%. Healthcare facilities and educational institutions achieved full compliance of 100%.
**Total Electricity Consumption Trend**

As electricity is the main source of energy used in Singapore’s buildings, other energy sources were excluded in the computation of energy use intensity (EUI). EUI is measured by the total electricity used within a building in a year, expressed as kilowatt hour (kWh) per gross floor area (m²). The total number of submitted buildings trended each year are updated to reflect newly added buildings and existing buildings that have completed major renovation or redevelopment.

Over the eight-year period from 2008 to 2016, the annual electricity consumption of these submitted buildings has increased at a lower rate of 28%, compared with the growth of the GFA at 40%. **EUI has therefore improved by 9% over this period, with more significant improvement over the last five years since 2012.**

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**Chart 4: Total GFA & Annual Electricity Consumption Trend of Submitted Buildings**

**Chart 5: EUI Trend of Submitted Buildings**

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**OVERVIEW OF 2016 DATA**
Total Electricity Consumption Trend of Commercial Buildings

Over the eight-year period from 2008 to 2016, the annual electricity consumption of 1,085 commercial buildings has increased at a lower rate of 25%, compared to the growth of the corresponding GFA at 37%.

The EUI has improved by 9% since 2008. This could be attributed to energy efficiency improvements in the commercial building stock, as:

- About 25% are Green Mark buildings; and
- An additional 11% are non-Green Mark buildings that have undergone upgrading and retrofitting of their air-conditioning systems (chillers; split-units; AHUs and FCUs).
Profile of Central Chilled Water Air-conditioning Systems

In total, 532 commercial buildings are using central chilled water air-conditioning systems, with majority less than 10 years old.

To go deeper, we looked at the system efficiency of the central chilled water air-conditioning systems. A total of 294 commercial buildings furnished the data from energy audits.

Chart 9 shows the relationship between the centralised air-conditioning system efficiency and the chiller age. To better analyse the 294 buildings, four quadrants have been defined, based on chiller system efficiency and chiller age.

Most of the commercial buildings (61%) are in Quadrant A where the systems are performing well as expected, given that they have newer chillers. There are a handful of buildings in Quadrant D with aging chillers, which are still performing well. This is probably due to regular maintenance and system optimisation. There is much room for improvement for buildings in Quadrants B and C. The owners and their facilities managers should look into replacing the aging chillers or system optimisation. In addition, building owners can tap onto guaranteed energy performance contracting (GESP) so as to ensure that the chiller plants stay energy efficient through proper operation and maintenance across the system’s life cycle.

Table 1: Chiller System Efficiency and Chiller Age

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Chiller System Efficiency (kW/RT)</th>
<th>Age of Chiller</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤0.75</td>
<td>≤10</td>
<td>57% (138 buildings)</td>
<td>61% (179 buildings)</td>
</tr>
<tr>
<td>B</td>
<td>&gt;0.75</td>
<td>≤10</td>
<td>20% (48 buildings)</td>
<td>22% (65 buildings)</td>
</tr>
<tr>
<td>C</td>
<td>&gt;0.75</td>
<td>&gt;10</td>
<td>18% (44 buildings)</td>
<td>14% (40 buildings)</td>
</tr>
<tr>
<td>D</td>
<td>≤0.75</td>
<td>&gt;10</td>
<td>5% (12 buildings)</td>
<td>3% (10 buildings)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>100% (242 buildings)</td>
<td>100% (294 buildings)</td>
</tr>
</tbody>
</table>
Building Owners’ and Tenants’ Electricity Consumption Relationship

For the fourth year, the breakdown of building owners’ and tenants’ electricity consumption showed an almost equal share of the total buildings’ electricity consumption.

It was observed that the proportion of the retail tenants’ electricity consumption has increased as compared to that of 2015. There is scope for building owners to work closer with tenants in reducing their energy footprint. They can consider:

I. Occupant-centric Green Mark schemes for tenants within the buildings.
II. Green Mark Portfolio Programme which simplifies the BCA Green Mark certification process for multiple tenanted spaces of a similar type, resulting in shorter time and lower costs for tenants to go green.
III. Green Mark Incentive Scheme for Existing Buildings and Premises (GMIS-EBP) which provides cash incentives to help small and medium enterprise building owners and tenants in the adoption of energy efficiency measures within their premises.
IV. Green Mark Pearl Prestige/Pearl Award which recognises the strong commitment of building owners and tenants who are willing to work in tandem to achieve greater environmental sustainability for their building.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Electricity Consumption by User Type</th>
<th>BCA BEBR 2016</th>
<th>BCA BEBR 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Buildings</td>
<td>Building Owner</td>
<td>51%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>Tenant</td>
<td>49%</td>
<td>49%</td>
</tr>
<tr>
<td>Retail Buildings</td>
<td>Building Owner</td>
<td>49%</td>
<td>47%</td>
</tr>
<tr>
<td></td>
<td>Tenant</td>
<td>51%</td>
<td>53%</td>
</tr>
</tbody>
</table>

Table 2: Electricity Consumption by User Type

DATA ANALYSIS FOR COMMERCIAL BUILDINGS
National Building Energy Benchmarks [EUI (kWh/m².yr)]

In 2016, a total of 947 commercial buildings were included for benchmarking. We omitted newly constructed or retrofitted buildings, buildings on district cooling systems (DCS), and aggregated mixed developments with electricity consumption or shared centralised air-conditioning systems that could not be segregated due to the lack of sub-metering. To facilitate the benchmarking exercise, we have categorised these buildings by type and size.

For the purpose of benchmarking, EUI can be used as an index for building owners and facilities managers to compare their building’s annual energy performance against similar building types. EUI is the combined result of energy efficiency and consumption behaviour/pattern of the building.

Table 3: 2016 National Building Energy Benchmarks

<table>
<thead>
<tr>
<th>Building Type (Size*)</th>
<th>No. of Buildings</th>
<th>Average EUI</th>
<th>EUI Ranges (kWh/m².yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Top Quartile (1% - 25%)</td>
</tr>
<tr>
<td>Office Buildings</td>
<td>180</td>
<td>247</td>
<td>≤160</td>
</tr>
<tr>
<td>(Large)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office Buildings</td>
<td>267</td>
<td>261</td>
<td>≤135</td>
</tr>
<tr>
<td>(Small)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotels (Large)</td>
<td>78</td>
<td>288</td>
<td>≤244</td>
</tr>
<tr>
<td>Hotels (Small)</td>
<td>207</td>
<td>283</td>
<td>≤189</td>
</tr>
<tr>
<td>Retail Buildings</td>
<td>74</td>
<td>369</td>
<td>≤264</td>
</tr>
<tr>
<td>(Large)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail Buildings</td>
<td>86</td>
<td>391</td>
<td>≤245</td>
</tr>
<tr>
<td>(Small)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed Developments</td>
<td>55</td>
<td>304</td>
<td>≤211</td>
</tr>
</tbody>
</table>

*Large: Office, Retail, Mixed Developments of GFA ≥15,000 m²; Hotels of GFA ≥7,000 m²
*Small: Office, Retail, Mixed Developments of GFA <15,000 m²; Hotels of GFA <7,000 m²
Chart 10: EUI of 180 Large Office Buildings

Average EUI: 247 kWh/m²·yr

Characteristics of Large Office Buildings with Higher EUI (10th Percentile)
- 5 with Aged Chillers (between 15 - 18 yrs)
- 7 with Substantial Data Centre Area (>1,000 m²)

Chart 11: EUI of 267 Small Office Buildings

Average EUI: 261 kWh/m²·yr

Characteristics of Small Office Buildings with Higher EUI (10th percentile)
- 7 with Aged Chillers (between 13 - 17 yrs)
- 4 with Substantial Data Centre Area (>1,000 m²)
Chart 12: EUI of 78 Large Hotels

Characteristics of Large Hotels with Higher EUI (10th Percentile)
8 Buildings
- 4 with Split Units / Unitary AC Systems (between 3 - 5 yrs)

Average EUI: 288 kWh/m²·yr

<table>
<thead>
<tr>
<th>Buildings (Percentile)</th>
<th>EUI (kWh/m²·yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9th (90th)</td>
<td>194</td>
</tr>
<tr>
<td>20th (75th)</td>
<td>244</td>
</tr>
<tr>
<td>40th (50th)</td>
<td>276</td>
</tr>
<tr>
<td>59th (25th)</td>
<td>329</td>
</tr>
<tr>
<td>70th (10th)</td>
<td>409</td>
</tr>
<tr>
<td>78th (1st)</td>
<td>587</td>
</tr>
</tbody>
</table>

Chart 13: EUI of 207 Small Hotels

Characteristics of Small Hotels with Higher EUI (10th Percentile)
21 Buildings
- 1 with Aged Air-cooled Chiller Plant (around 17 yrs)
- 6 with Split Units / Unitary AC Systems (between 10 - 20 yrs)

Average EUI: 283 kWh/m²·yr

<table>
<thead>
<tr>
<th>Buildings (Percentile)</th>
<th>EUI (kWh/m²·yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22nd (90th)</td>
<td>124</td>
</tr>
<tr>
<td>53rd (75th)</td>
<td>189</td>
</tr>
<tr>
<td>104th (50th)</td>
<td>258</td>
</tr>
<tr>
<td>156th (25th)</td>
<td>349</td>
</tr>
<tr>
<td>186th (10th)</td>
<td>421</td>
</tr>
<tr>
<td>207th (1st)</td>
<td>742</td>
</tr>
</tbody>
</table>

Each Column is the EUI of One Building.
Chart 14: EUI of 74 Large Retail Buildings

Characteristics of Large Retail Buildings with Higher EUI (10th Percentile)
- 7 Buildings
  - 5 with Close Proximity to Public Transport Network (MRT/LRT within 1 km)
  - 5 with Large Proportion of High Energy Consuming Tenants

Average EUI: 369 kWh/m².yr

Chart 15: EUI of 86 Small Retail Buildings

Characteristics of Small Retail Buildings with Higher EUI (10th Percentile)
- 8 Buildings
  - 3 with Aged Chiller (between 10 - 35 yrs)
  - 4 with Close Proximity to Public Transport Network (MRT/LRT within 1 km)

Average EUI: 391 kWh/m².yr
Chart 16: EUI of 55 Mixed Developments

EUI (kWh/m²·yr)

Average EUI: 304 kWh/m²·yr

Each Column is the EUI of One Building

NATIONAL BUILDING ENERGY BENCHMARKS FOR COMMERCIAL BUILDINGS
Data Comparison (2013 to 2016)
With four years of data, the energy performance of commercial buildings can be trended over 2013-2016. For this study, we used the 783 benchmarked buildings in 2013 as the baseline for trending.

Table 4: Number of Commercial Buildings across Four Years of Submission

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Targeted</td>
<td>964</td>
<td>1,065</td>
<td>1,050</td>
<td>1,086</td>
</tr>
<tr>
<td>Total Submissions</td>
<td>954</td>
<td>1,018</td>
<td>1,032</td>
<td>1,085</td>
</tr>
<tr>
<td>Total Benchmarked</td>
<td>783</td>
<td>913</td>
<td>922</td>
<td>948</td>
</tr>
<tr>
<td>Total No. for Comparison</td>
<td>783</td>
<td>783</td>
<td>783</td>
<td>783</td>
</tr>
</tbody>
</table>

Median EUI Trend for Commercial Buildings

Table 5: Median EUI Comparison Study

<table>
<thead>
<tr>
<th>Building Type</th>
<th>No. of Buildings</th>
<th>2013 Median EUI</th>
<th>2014 Median EUI</th>
<th>2015 Median EUI</th>
<th>2016 Median EUI</th>
<th>Percentage Improvement in Median EUI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Buildings</td>
<td>351</td>
<td>218</td>
<td>209</td>
<td>202</td>
<td>204</td>
<td>6.6%</td>
</tr>
<tr>
<td>Hotels</td>
<td>230</td>
<td>292</td>
<td>286</td>
<td>272</td>
<td>263</td>
<td>10.0%</td>
</tr>
<tr>
<td>Retail Buildings</td>
<td>145</td>
<td>405</td>
<td>386</td>
<td>374</td>
<td>386</td>
<td>4.6%</td>
</tr>
<tr>
<td>Mixed Developments</td>
<td>57</td>
<td>264</td>
<td>268</td>
<td>264</td>
<td>271</td>
<td>-2.8%</td>
</tr>
<tr>
<td>Total Number</td>
<td>783</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The percentage improvement of Median EUI was with reference to the base year of 2013.

Chart 17: Median EUI for 2013 to 2016

From the trending results, it was observed that:
- **Hotels had the most significant improvement in energy performance**. This could be due to hotel operators understanding the business case for green buildings as the building operates 24/7.
- **Office buildings had maintained fairly good performance** from 2013 to 2016. More could be done to engage tenants.
- In recent years, **retail buildings have been increasing the share of F&B spaces**, resulting in higher energy footprint.
Green Mark Commercial Buildings’ Performance

To ensure accurate comparison of the energy performance between Green Mark and non-Green Mark buildings, the following characteristics were taken into consideration when identifying the buildings:

- **Office Buildings**: Size, annual occupancy rate, and type of air-conditioning system
- **Hotels**: Size, annual occupancy rate, availability of function halls/meeting rooms, and type of air-conditioning system
- **Retail Buildings**: Size, annual occupancy rate, type of air-conditioning system, tenant mix, and proximity to public transport facility (MRT/LRT station)

### Table 6: Number of Buildings for Comparison Study

<table>
<thead>
<tr>
<th>Building Type</th>
<th>No. of Non-Green Mark Buildings</th>
<th>No. of Green Mark Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Buildings</td>
<td>71</td>
<td>78</td>
</tr>
<tr>
<td>Hotels</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Retail Buildings</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>105</strong></td>
<td><strong>121</strong></td>
</tr>
</tbody>
</table>

Performance of Green Mark Buildings

Green Mark commercial buildings continued to sustain their energy performance in 2016. On average, Green Mark buildings had lower EUI than non-Green Mark commercial buildings of similar characteristics.

## Chart 18: Average EUI of Green Mark & Non-Green Mark Commercial Buildings

![Chart 18](image-url)
**EUI Trend of Green Mark Commercial Buildings**

In addition, the average EUI has improved substantially over the period 2008 to 2016, by up to 21% for the hotel category. For hotels, it was observed that both the Green Mark and non-Green Mark hotels were performing almost equally well. This could be due to the long operating hours of the business where the operators will want the building to be run efficiently. Beyond energy savings, other aspects of environmental sustainability are also taken care of within a Green Mark hotel.

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**Number of Green Mark Commercial Buildings Trended**

- **78** Office Buildings
- **20** Hotels
- **23** Retail Buildings

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**Chart 19: EUI Trend for Green Mark Buildings**

- **Retail Buildings**
  - EUI (kWh/m².yr) improved 14.8%
- **Hotels**
  - EUI (kWh/m².yr) improved 20.9%
- **Office Buildings**
  - EUI (kWh/m².yr) improved 16.6%
Solar Photovoltaic (PV) Adoption
BCA Green Mark scheme drives solar PV adoption.

Chart 20: Percentage No. of Buildings with Solar PV Installed (1,323 Buildings)

- Office Buildings with Solar PV: 92.3%
- Hotels with Solar PV: 4.1%
- Retail Buildings with Solar PV: 0%
- Mixed Developments with Solar PV: 1.0%
- Healthcare Facilities with Solar PV: 0.4%
- Educational Institutions with Solar PV: 1.9%
- Buildings without Solar PV: 0.2%

Chart 21: Percentage No. of Buildings with Solar PV Installed by Green Mark Status (1,323 Buildings)

- Platinum: 85%
- Gold Plus: 93%
- Gold: 97%
- Certified/Met Min. Environmental Sustainability Standards: 97%
- Not Certified: 99.8%

- Percentage of Buildings with Solar PV
- Percentage of Buildings without Solar PV
Solar PV Roof of Zero Energy Building (ZEB) @BCA Academy
Total Electricity Consumption Trend of Healthcare Facilities

Over the eight-year period from 2008 to 2016, the annual electricity consumption of 58 healthcare facilities has increased at a faster rate of 55%, compared to the growth of the corresponding GFA at 42%.

It was observed that the EUI has increased by 10% over the period 2008 - 2016. In general, healthcare facilities had an overall increasing EUI trend since 2008. With the growing demand for sophisticated healthcare services, there will be a need for hospitals, specialist centres and polyclinics to place greater emphasis on energy efficiency.

Chart 22: Total GFA and Annual Electricity Consumption Trend of Healthcare Facilities

Chart 23: EUI Trend of Healthcare Facilities
EUI Trend of Healthcare Facilities
Other than private medical centres and traditional Chinese medicine (TCM) clinics, overall the other healthcare facilities have shown an increasing trend.

<table>
<thead>
<tr>
<th>Healthcare Facility Type</th>
<th>Average EUI (kWh/m².yr)</th>
<th>Average Electricity Consumption per Bed Space (kWh/Bed Space)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Hospitals (Public)</td>
<td>352</td>
<td>54,606</td>
</tr>
<tr>
<td>Private Hospitals (Private)</td>
<td>367</td>
<td>64,746</td>
</tr>
<tr>
<td>Community Hospitals and Nursing Homes</td>
<td>126</td>
<td>6,805</td>
</tr>
</tbody>
</table>

Table 7: Energy Benchmarks of Healthcare Facilities with Bed Spaces
Data Analysis of Educational Institutions

Total Electricity Consumption Trend of Educational Institutions
Over the eight-year period from 2008 to 2016, the annual electricity consumption of 49 educational institutions had increased at a lower rate of 36%, compared to the growth of the corresponding GFA at 57%.

It was observed that the EUI has improved by 14% over the period 2008 - 2016.
For deeper analysis, the educational institutions have been categorised into three broad categories, namely (i) Universities; (ii) Polytechnics/ITEs; and (iii) Private Colleges/Schools.

**Overall, the EUI has been improving for the educational institutions.** One reason could be for public schools, which are covered under Government’s Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative, new and existing public buildings are required to attain higher Green Mark ratings. For private colleges and schools, it was observed that 70% of the GFA has been greened. In addition, some tertiary institutions have further initiatives such as campus wide stakeholder engagement programmes that aim to reduce the overall energy use.
Last year’s study of 101 retrofitted existing buildings has been expanded to cover 124 existing buildings that had completed Green Mark assessment by 2016.

The latest data revealed the following:

- The average total annual electricity savings for retrofitted existing buildings remained consistent at about 16% since the start of this study in 2014.
- Chiller plant retrofits continued to improve the plants’ operating efficiency by an average of 42%, from 1.1 kW/RT to 0.63 kW/RT.
- The addition of 23 buildings to the study contributed an additional 35 GWh of total electricity savings per annum, increasing the combined total electricity savings of retrofitted existing buildings to 238 GWh per annum. This amounted to about S$59.5 million in savings each year.

This year, we added 11 educational institutions into the study, thereby improving the mix of building types being analysed.

- Similar to mixed developments, office buildings and retail buildings, educational institutions were shown to also achieve an average of 14% to 16% reduction in their annual total building electricity consumption after retrofitting.
- For hotels, the electricity savings were even higher at 23% on the average, as hotels typically operate 24 hours daily.
Table 8: EUI Tracking of Retrofitted Existing Buildings

<table>
<thead>
<tr>
<th>Building Type</th>
<th>No. of Buildings</th>
<th>EUI Before Retrofit (kWh/m².yr)</th>
<th>EUI After Retrofit (kWh/m².yr)</th>
<th>Average Percentage Improvement</th>
<th>Average Payback* (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Buildings</td>
<td>47</td>
<td>249</td>
<td>210</td>
<td>16%</td>
<td>6.1 – 7.6</td>
</tr>
<tr>
<td>Hotels</td>
<td>23</td>
<td>349</td>
<td>268</td>
<td>23%</td>
<td>4.6 – 5.8</td>
</tr>
<tr>
<td>Retail Buildings</td>
<td>26</td>
<td>464</td>
<td>399</td>
<td>14%</td>
<td>5.6 – 7.0</td>
</tr>
<tr>
<td>Mixed Developments</td>
<td>17</td>
<td>300</td>
<td>257</td>
<td>14%</td>
<td>6.2 – 7.8</td>
</tr>
<tr>
<td>Educational Institutions</td>
<td>11</td>
<td>216</td>
<td>184</td>
<td>15%</td>
<td>4.9 – 6.1</td>
</tr>
</tbody>
</table>

* Based on $0.20 - 0.25/kWh

Chiller Plant System Efficiency Improvement

In Singapore’s tropical climate, air-conditioning is an essential building service to meet the high cooling demand in buildings. Thus, there is a strong business case to retrofit the centralised air-conditioning system if it is no longer energy efficient. A large portion of electricity savings is a result of replacement or upgrading to a more efficient centralised air-conditioning system.

Before retrofitting, the average chiller plant system efficiency of the existing buildings stood at an average of 1.1 kW/RT, which was very inefficient. **After the retrofit, the chiller plant system efficiency improved significantly, by an average of 42%**. The new chiller plant efficiency for the 124 buildings was in the range of 0.5 – 0.7 kW/RT. Such a performance standard was comparable to a new building with a BCA Green Mark Platinum or GoldPLUS rating.

Chart 31: Chiller Plant System Efficiency of Retrofitted Buildings

40–50% Energy savings could achieved by adopting a system based approach in retrofitting existing chiller plants.
Key Observations

Since the implementation of annual mandatory submission for commercial buildings in 2013, the commercial building stock’s energy performance has been monitored over four years.

- **In general, commercial buildings have sustained their improvement in energy performance since 2013, with hotels showing the most significant improvement.** It was observed that more commercial buildings are operating on newer and more efficient building cooling systems. However, retail buildings’ tenants are showing an increasing electricity consumption trend when compared to that of their building owners. This could have led to an overall flat trend for the EUI at 290 range over the last two years.

- Green Mark commercial buildings continued to perform better than non-Green Mark commercial buildings.

From 2015, the energy performance of healthcare facilities and educational institutions have been monitored over two years.

- **Generally, healthcare facilities have an overall increasing EUI trend since 2008.** This could be due to an aging population and, healthcare services becoming more sophisticated and energy intensive.

- **Educational institutions have shown good improvement in EUI over the years.** This could be attributed to BCA Green Mark scheme as well as initiatives such as PSTLES. In addition, some tertiary institutions have gone the extra mile with campus wide stakeholder engagement programmes to reduce the overall energy use of the campus.
**Next Steps**

**Continuous Outreach.** With better understanding of building energy performance, a more targeted approach could be deployed to engage owners and building users so as to raise awareness about their building energy performance and encourage energy improvement actions. BCA will continue in this direction, with an added focus on driving behavioural change.

**Building Energy Performance Analysis on New Building Types.** In 2017, BCA expanded the coverage of targeted buildings for the annual mandatory submission to owners of large buildings under these categories: i) Civic and Community Institution, ii) Sports and Recreation Centre, iii) Place of Worship, iv) Transport Facility, and v) Light Industrial Building. BCA will continue to share the findings with various stakeholders through the BEBR.

**Disclosure of Building Energy Performance Data.** In 2017, the first set of energy performance data for commercial buildings was released, on a voluntary basis, through BESS and Singapore’s Open Data Portal, data.gov.sg. In addition, BCA will work towards implementing voluntary disclosure for healthcare facilities and educational institutions from 2018. Progressively, BCA is planning for the pipelined mandatory disclosure to allow more data to be shared on public domain in the coming years.
<table>
<thead>
<tr>
<th>Glossary Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Energy Use Intensity (EUI)</strong></td>
<td>Weighted average of the energy use intensities of buildings is calculated based on electricity consumed using gross floor area as the weightage factor.</td>
</tr>
<tr>
<td><strong>Building Owner (BO)</strong></td>
<td>Individuals or companies who legally own the building or development.</td>
</tr>
<tr>
<td><strong>Building Submission Representative (BSR)/Building Submission Officer (BSO)</strong></td>
<td>Authorised personnel assigned by a building owner to complete the annual mandatory submission. These personnel may include the building owners’ employees or managing agents engaged to manage the buildings’ facilities.</td>
</tr>
<tr>
<td><strong>Certificate of Statutory Completion (CSC)/Temporary Occupation Permit (TOP)</strong></td>
<td>Certificate of Statutory Completion (CSC)/Temporary Occupation Permit (TOP) is granted by the Commissioner of Building Control upon building completion. The building can only be occupied when a CSC or TOP is granted.</td>
</tr>
<tr>
<td><strong>Centralised Air-conditioning System</strong></td>
<td>A major air-conditioning system which distributes chilled water to heat exchangers for cooling and dehumidifying of air in multiple zones of a building.</td>
</tr>
<tr>
<td><strong>Energy Use Intensity (EUI)</strong></td>
<td>Measures the total energy consumed in a building in a year, expressed as kilowatt hour (kWh) per gross floor area (m²).</td>
</tr>
<tr>
<td><strong>Gross Floor Area (GFA)</strong></td>
<td>All covered floor areas of a building, except otherwise exempted, and uncovered areas for commercial uses, are deemed the gross floor area of the building. Generally, car parks are excluded from gross floor area computation.</td>
</tr>
<tr>
<td><strong>Management Corporation Strata Title (MCST)</strong></td>
<td>A management group formed by all the subsidiary proprietors of the estate. The MCST has powers, duties and functions conferred or imposed by law to control, manage and administer the common property for the benefit of the subsidiary proprietors.</td>
</tr>
<tr>
<td><strong>Managing Agent (MA)</strong></td>
<td>A managing agent is a person or company appointed by the building owner(s) to manage their properties.</td>
</tr>
</tbody>
</table>
# Description of Building Types

## Building Types

<table>
<thead>
<tr>
<th>Building Types</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Office building</strong></td>
<td>is a development with premises used as a place of business and for conducting administrative work.</td>
</tr>
<tr>
<td><strong>Hotel</strong></td>
<td>is a development used for accommodation purposes on a commercial basis. The predominant use of this development shall be hotel rooms.</td>
</tr>
<tr>
<td><strong>Retail building</strong></td>
<td>is a development with premises primarily used for any trade or business where its primary purpose is the sale of goods or foodstuff by retail or provision of services.</td>
</tr>
<tr>
<td><strong>Mixed development</strong></td>
<td>is a combination of any of the above three commercial building types.</td>
</tr>
<tr>
<td><strong>Healthcare facility</strong></td>
<td>is a development used mainly for medical services, such as hospitals, medical centres, community health centres, nursing homes, clinics (including dental clinics), and clinical laboratories (including x-ray laboratories).</td>
</tr>
<tr>
<td><strong>Educational institution</strong></td>
<td>comprises tertiary and private institutions. Tertiary institution is a facility space used for post-secondary education, such as Institute of Technical Education (ITE), Polytechnic and University. Private institution is a privately owned and funded facility/space used for education.</td>
</tr>
</tbody>
</table>

## Building Sizes

<table>
<thead>
<tr>
<th>Building Sizes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large buildings</strong>, excluding hotels, refer to buildings with a GFA of more than or equal to 15,000 m². Large hotels refer to buildings with a GFA of more than or equal to 7,000 m².</td>
<td></td>
</tr>
<tr>
<td><strong>Small buildings</strong>, excluding hotels, refer to buildings with a GFA of less than 15,000 m². Small hotels refer to buildings with a GFA of less than 7,000 m².</td>
<td></td>
</tr>
</tbody>
</table>
Save the Date!
5 – 7 September 2018