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ENERGY AUDIT OF SELECTED HDB RESIDENTIAL BLOCKS IN SINGAPORE

By

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EXECUTIVE SUMMARY

PREMAS Energy Centre carried out an Energy Audit of a sample of 40 HDB blocks in Singapore. The blocks were selected so that the results obtained could be extrapolated for other blocks. The selected blocks consisted of mixed 3/4/5 room blocks which have and have not undergone upgrading, executive blocks and blocks with commercial units.

The audit was carried out from March 2004 to June 2004. The main objective of the audit was to profile energy consumption of the different users for the blocks so that energy saving opportunities could be identified.

During the audit, data on the electrical consumption of the different systems including lighting, transfer pumps, booster pumps and lifts was collected using highly accurate instruments and data logging systems.

The study methodology and summary of data collected are presented in Chapters 2 and 3. The main findings of the study are described in Chapter 4 while the identified energy saving measures and recommendations are provided in Chapter 5.

The total energy savings identified account for between 14% and 18% of the total annual electricity consumption of blocks. The energy saving measure identified for common area lighting is able to achieve 14% reduction in the total consumption and has an associated simple payback period of only 2.4 years. Therefore it is recommended to implement this energy saving measure for all blocks. However, some of the other measures may need to be considered only for new projects as the savings do not justify the cost that need to be incurred to achieve the savings.

Based on the total energy savings potential of 14% to 19%, the total savings achievable is about 70,000 to 95,000 MWh/year for all HDB blocks in Singapore.

PREMAS looks forward to partnering with NEA and the Town Councils to implement the identified recommendations.

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1. INTRODUCTION

1.1 BACKGROUND

The electricity consumption of systems such as common area lighting, lifts and water pumps of a typical HDB residential block is about 75,000 kWh a year. This translates to a total electricity consumption of about 500 GWh a year for all HDB residential blocks in Singapore. This is about 1.5% of the total electricity consumption in Singapore.

Preliminary energy studies of sample blocks have shown that there is potential for reducing the energy consumption by more than 5%. If such savings can be achieved, it will lead to a significant reduction in annual electricity consumption of Singapore. This will help Singapore in its drive to improve the environmental sustainability by reducing the use of fossil fuels and the emission of carbon dioxide gas.

However, before embarking on such an energy savings exercise, it is necessary to first carryout a detailed Energy Audit to study the energy usage characteristics of blocks so that actual energy saving measures can be identified.

PREMAS therefore partnered with the National Environment Agency and Aljunied Town Council to undertake such an innovative project to carryout an energy audit program which would help to improve the environmental sustainability efforts in Singapore.

1.2 SELECTION OF BLOCKS

To make the project financially viable, a detailed energy audit was carried out only for a sample set of typical blocks so that the results can be extrapolated for all other blocks in Singapore. For the study to be meaningful and the results accurate enough to extrapolate for other blocks, a total of 40 blocks were audited.

The types of HDB blocks can be generally categorized into; 3 / 4 / 5 room blocks, Executive blocks, 3 / 4 /5 room blocks upgraded under MUP, 3 / 4 / 5 room blocks upgraded under IUP, walk-up blocks and blocks with commercial units.

Based on the above, the blocks were categorized into 5 general types of blocks and are listed in Table 1.1 with the 40 blocks covered in the audit.

Type of block	Block no.
3 / 4 / 5 RM (not upgraded)	Blk 168 to 173 Hougang Ave 1 Blk 623, 624, 626, 627Hougang Ave 8 Blk 629 to 632 Hougang Ave 8
3 / 4 / 5 RM upgraded under MUP	Blk 15 to 23 Hougang Ave 3
3 / 4 / 5 RM upgraded under IUP	Blk 625 to 629 Bedok Reservoir Rd
Executive	Blk 698C & 698D Hougang Ave 1 Blk 615 & 628 Hougang Ave 8 Blk 522 & 533 Hougang Ave 6
Blocks with commercial units / walk-up apartments	Blk 209 to 212 Hougang St 21 Blk 622 & 625 Hougang Ave 8

Table 1.1 Breakdown of the type of block and block number

The audit included a comprehensive study of the various energy consuming equipment and systems installed within the blocks which are metered under “common area” electricity consumption. During the study, data on the electricity consumption of the various systems was collected and analysed enabling solutions and recommendations for improvement to be identified.

PREMAS Energy Centre has completed the energy audit and has compiled this report which describes in detail the findings and recommendations with estimated savings and costs for the identified energy saving measures.

1.3 ACKNOWLEDGEMENTS

PREMAS Energy Centre would like to thank Aljunied Town Council for their assistance and the National Environment Agency (NEA) for providing support and financial assistance to make this project a success.

2. STUDY METHODOLOGY

2.1 BACKGROUND

The energy audit of the selected 40 sample HDB residential blocks was carried out from March to June 2004. The audit included a comprehensive study of the various energy consuming equipment and systems installed within the blocks which are metered under "common area" electricity consumption. During the study, data on the electricity consumption of the various systems was collected and analysed enabling comprehensive solutions and recommendations for improvement measures to be identified.

The audit of the 40 blocks was carried out in 10 phases of 4 blocks each. The blocks for each phase were selected based on location rather than the type of block. The types of blocks and block numbers are given in Table 2.1.

Type of block	Block no.
3 / 4 / 5 room (not upgraded)	Blk 168 to 173 Hougang Ave 1 Blk 623, 624, 626, 627Hougang Ave 8 Blk 629 to 632 Hougang Ave 8
3 / 4 / 5 room upgraded under MUP	Blk 15 to 23 Hougang Ave 3
3 / 4 / 5 room upgraded under IUP	Blk 625 to 629 Bedok Reservoir Rd
Executive	Blk 698C & 698D Hougang Ave 1 Blk 615 & 628 Hougang Ave 8 Blk 522 & 533 Hougang Ave 6
Blocks with commercial units / walk-up apartments	Blk 209 to 212 Hougang St 21 Blk 622 & 625 Hougang Ave 8

Table 2.1 Type and block number of blocks audited

Data collection for each block was done for a period of 1-week. Based on this, the duration for each phase of the audit with installation of the data logging systems, collection of data and dismantling of the data logging systems was approximately 1.5 weeks.

The Energy Audit covered the following :

a. Data collection and logging including monitoring of electricity distribution (main incoming and the different users)

b. Determining the percentage usage by various end users

c. Analysis of collected data

d. Identifying energy saving measures

e. Estimating savings and cost for implementing solutions

f. Benchmarking Performance of systems

2.2. INSTRUMENTS USED

The following instruments were used for data collection and logging during the study :

Energy Survey Meter

Model: K20

Brand: Enernet

Type: Recorder

Accuracy: ±0.5%

Country of Origin: USA

Power Transducer

Model: MOC1

Brand: Elkor

Type: Transducer

Accuracy: Power: ±0.8% FS

Current: ±0.5% FS

Country of Origin: USA

Data Logger

Model: XR440 / XR5-8A

Brand: Pace Scientific

Type: Pocket Logger

Accuracy: 12 bit

Country of Origin: USA

Ultrasonic Flowmeter

Model: AT868 AquaTrans

Brand: Panametrics

Type: Clamp On, 2 Channel

Accuracy: ±0.5 to 1%

Country of Origin: USA

Ultrasonic Flowmeter

Model: ADM 6725

Brand: EESIFLO

Type: Portable, Clamp On, 2 Channel

Accuracy: ±1%

Country of Origin: UK

Power Quality Analyzer

Model: SkyLab 9032

Brand: HT

Type: Portable

Accuracy: Voltage: ±(0.5%+2dgt)

Current: ±(0.5%+2dgt)

Power: ±(1%+2dgt)

Country of Origin: Italy

Power Quality Analyzer

Model: 43B

Brand: Fluke

Type: Handheld

Accuracy: ±1%

Country of Origin: USA

Current Clamp Meter

Model: HT72

Brand: HT

Type: Handheld

Accuracy: AC Voltage: ±(1.5%+5dgt)

DC Voltage: ±(0.5%+3dgt)

AC Current: ±(2%+5dgt)

Resistance: ±(1%+3dgt)

Country of Origin: Italy

Watt Transducer

Model: M100-WA5

Brand: Multitek

Type: Transducer

Accuracy: ±0.2 %

Country of Origin: UK

Power Transducer

Model: H8035

Brand: Hawkeye

Type: Transducer

Accuracy: ±1 %

Country of Origin: USA

Pressure Transmitter

Model: 691

Brand: Huba

Type: Transmitter

Accuracy: ±0.3% FS

Country of Origin: Switzerland

Lux Meter

Model: 545

Brand: Testo

Type: Handheld

Accuracy: ±1 digit

Country of Origin: Germany

2.3. DATA COLLECTED

The following data was collected for each block during the study :

General

Type of block

Number of flats

Number of floors

Average monthly electricity consumption (from utility bills)

Average daily kWh consumption for each incoming

Lighting

Number of fixtures

Type of fixture

Lamp Wattage

Lighting level (lux)

Average daily kWh consumption

Daily operating hours

Lifts

Number of lifts

Brand of lifts

Average daily kWh consumption for each lift

Water Pumps

Design flow, head and efficiency for pumps

Rated kW for motors

Average daily kWh consumption

Average number of times the pumps are used per day

Average duration of each pump operation

Average water consumption per day

Capacity of rooftop storage tank

Others

Average daily kWh consumption by other users

(this category includes lighting in switch rooms, power sockets, CATV, refuse chamber, link-way lighting and fans for market blocks)

Outdoor Lighting

Number of fixtures, type and wattage of lamps

Average daily kWh consumption

The next chapter (Chapter 3) includes a summary of all information and data collected for the blocks during the audit.

3. Summary Of Measured Data

The Energy Audit of 40 HDB residential blocks was carried out from March 2004 to June 2004. The audit was done in 10 phases of 4 blocks each. For each block, the electrical consumption was profiled for a period of one week. The parameters monitored included the main incoming and the different end-users such as the common area lighting, water pumps, and lift systems.

The summary of data collected is presented in the following sections of this chapter while the actual data collected is included in Appendix A in the form of data plots.

3.1 General Information

The general information on the blocks audited is given in Tables 3.1A and 3.1B with the actual electricity consumption data from the monthly bills.

Block No.	Type of block	Age of block	No. of flats	No. of floors	Average annual kWh consumption	Average annual electricity cost ($)
15	4 RM	29	180	16	102,930	17,045
16	5 RM	29	78	20	58,400	9,671
17	3/4 RM	27	132	12	75,920	12,572
18	4 RM	27	132	12	100,740	16,683
19	3/4 RM	27	132	12	57,305	9,490
20	3/4 RM	27	132	12	69,715	11,545
21	3/4 RM	27	128	12	77,015	12,754
22	3/4 RM	27	132	12	79,205	13,116
23	3/4 RM	27	196	12	100,375	16,622
168	4/5 RM	8	98	15	87,235	14,446
169	4/5 RM	8	123	14	92,710	15,353
170	4/5 RM	8	91	14	62,050	10,275
171	4/5 RM	8	91	14	70,080	11,605
172	4/5 RM	8	114	13	100,010	16,562
173	4/5 RM	8	91	14	93,805	15,534
209	Shops	20	-	1	185,055	30,645
210	Shops	20	55	4	26,280	4,352
211	Shops	20	34	4	28,105	4,654
212	Shops	20	-	4	17,885	2,962
522	EXEC	18	120	12	71,905	11,907
533	EXEC	17	120	12	66,065	10,940
615	EXEC	19	72	13	50,005	8,281
622	EXEC	19	24	4	5,110	846
623	3 RM	19	132	12	43,800	7,253
624	4/5 RM	19	96	13	39,055	6,468
625	3/4 RM	19	32	4	2,920	484
626	3/4 RM	18	136	12	54,020	8,946

Table 3.1 A General information

Block No.	Type of block	Age of block	No. of flats	No. of floors	Average annual kWh consumption	Average annual electricity cost ($)
627	4/5 RM	18	148	13	67,160	11,122
628	EXEC	18	76	8	47,815	7,918
629	3/4 RM	18	132	12	48,180	7,979
630	4/5 RM	18	120	13	48,545	8,039
631	3/5 RM	19	113	13	41,975	6,951
632	3/4 RM	18	112	9	37,595	6,226
625 BR*	4/5 RM	24	20	4	6,935	1,148
626 BR*	4 RM	24	110	12	58,765	9,731
627 BR*	4 RM	24	110	12	60,955	10,094
628 BR*	3/4 RM	22	110	12	64,605	10,699
629 BR*	5/EXEC	21	110	11	75,920	12,572
698C	EXEC	6	73	18	60,590	10,034
698D	EXEC	6	64	18	51,100	8,462

Table 3.1 B General information

* Please note that "BR" is used after the block number to refer to blocks in Bedok Reservoir Road to distinguish them from blocks in Hougang Ave 8 which have the same block numbers.

3.2 TOTAL ELECTRICITY CONSUMPTION

Each block has one or more switch rooms (usually two switch rooms) each with one incoming supply. The switch rooms then supply electricity to the different users such as the common area lighting, lifts, water pumps, outdoor lighting and general use.

The average daily electricity consumption for each block was monitored and is summarised in Tables 3.2 A and 3.2 B.

Block No.	Switch room 1 (kWh/day)	Switch room 2 (kWh/day)	Switch room 3 (kWh/day)	Total for block (kWh/day)
15	278	NA	NA	278
16	161	NA	NA	161
17	156	NA	NA	156
18	262	NA	NA	262
19	161	NA	NA	161
20	201	NA	NA	201
21	173	NA	NA	173
22	155	NA	NA	155
23	285	NA	NA	285
168	263	NA	NA	263
169	280	NA	NA	280
170	178	NA	NA	178
171	203	NA	NA	203
172	278	NA	NA	278

Table 3.2 A Average daily electricity consumption

Block No.	Switch room 1 (kWh/day)	Switch room 2 (kWh/day)	Switch room 3 (kWh/day)	Total for block (kWh/day)
173	276	NA	NA	276
209	470	NA	NA	470
210	49	14	28	91
211	35	70	NA	105
212	19	10	26	55
522	134	71	NA	205
533	72	146	NA	218
615	82	58	NA	140
622	14	NA	NA	14
623	52	69	NA	121
624	77	51	NA	128
625	10	NA	NA	10
626	60	93	NA	153
627	102	102	NA	204
628	40	94	NA	134
629	73	60	NA	133
630	71	74	NA	145
631	79	33	NA	112
632	29	75	NA	104
625 BR	17	NA	NA	17
626 BR	81	81	NA	162
627 BR	95	74	NA	169
628 BR	83	52	NA	135
629 BR	64	66	66	196
698C	170	NA	NA	170
698D	141	NA	NA	141

Table 3.2 B Average daily electricity consumption

3.3 LIGHTING

Lighting is used to illuminate the common areas such as corridors, stairways, void decks and lift landings.

All lighting for the corridors and void decks use 36W, 18W and 28W (2D) fluorescent lamps with magnetic ballast. The lights are operated based on a pre-set schedule. The lighting is switched on from 6.40 pm in the evening till 7.00 am the following morning.

The number of fixtures, type of fixtures and wattage for each block are tabulated in following Tables 3.3 A to E.

Block No.	Location	Type of Fixture	No of Fixtures	Measured Lux Level	Average daily kWh consumption
15	Void deck	Fluorescent lamps	28W (2D) x 23 13W (PL) x 12	20 – 180	117
	Staircase	Fluorescent lamps	28W (2D) x 184	40 – 180	
	Corridors	Fluorescent lamps	28W (2D) x 30	40 – 160	
16	Void deck	Fluorescent lamps	28W (2D) x 14 13W (PL) x 4	20 – 150	54
	Staircase	Fluorescent lamps	28W (2D) x 19	30 – 120	
	Corridors	Fluorescent lamps	28W (2D) x 57	40 – 130	
17	Void deck	Fluorescent lamps	36W (4ft) x 4 28W (2D) x 16	20 – 90	82
	Staircase	Fluorescent lamps	28W (2D) x 44	30 – 170	
	Corridors	Fluorescent lamps	28W (2D) x 66	40 – 150	
18	Void deck	Fluorescent lamps	28W (2D) x 26 13W (PL) x 6	20 – 120	95
	Staircase	Fluorescent lamps	28W (2D) x 132	30 – 110	
	Corridors	Fluorescent lamps	28W (2D) x 20	40 – 90	
19	Void deck	Fluorescent lamps	36W (4ft) x 2 28W (2D) x 22 13W (PL) x 6	40 – 130	81
	Staircase	Fluorescent lamps	28W (2D) x 44	30 – 120	
	Corridors	Fluorescent lamps	28W (2D) x 66	50 – 140	
20	Void deck	Fluorescent lamps	36W (4ft) x 2 28W (2D) x 16 13W (PL) x 6	30 – 100	73
	Staircase	Fluorescent lamps	28W (2D) x 44	30 – 140	
	Corridors	Fluorescent lamps	28W (2D) x 66	50 – 130	
21	Void deck	Fluorescent lamps	28W (2D) x 23 13W (PL) x 6	20 – 110	89
	Staircase	Fluorescent lamps	28W (2D) x 44	30 – 140	
	Corridors	Fluorescent lamps	28W (2D) x 67	40 – 150	
22	Void deck	Fluorescent lamps	28W (2D) x 23	20 – 60	71
	Staircase	Fluorescent lamps	28W (2D) x 44	20 – 120	
	Corridors	Fluorescent lamps	28W (2D) x 66	40 – 120	
23	Void deck	Fluorescent lamps	36W (4ft) x 38 28W (2D) x 26	20 – 80	99
	Staircase	Fluorescent lamps	28W (2D) x 66	20 – 150	
	Corridors	Fluorescent lamps	28W (2D) x 99	40 – 140	

Table 3.3 A Details of lighting

Block No.	Location	Type of Fixture	No of Fixtures	Measured Lux Level	Average daily kWh consumption
168	Void deck	Fluorescent lamps	36W (4ft) x 17 13W (PL) x 16	40 – 240	126
	Staircase	Fluorescent lamps	18W (2ft) x 45	50 – 300	
	Corridors	Fluorescent lamps	18W (2ft) x 168	40 – 190	
169	Void deck	Fluorescent lamps	36W (4ft) x 20 13W (PL) x 13	40 – 300	122
	Staircase	Fluorescent lamps	18W (2ft) x 79	50 – 200	
	Corridors	Fluorescent lamps	18W (2ft) x 195	40 – 220	
170	Void deck	Fluorescent lamps	36W (4ft) x 14 13W (PL) x 33	30 – 300	69
	Staircase	Fluorescent lamps	18W (2ft) x 52	60 – 220	
	Corridors	Fluorescent lamps	18W (2ft) x 91	20 – 210	
171	Void deck	Fluorescent lamps	36W (4ft) x 15 13W (PL) x 33	30 – 310	84
	Staircase	Fluorescent lamps	18W (2ft) x 52	50 – 320	
	Corridors	Fluorescent lamps	18W (2ft) x 78	30 – 240	
172	Void deck	Fluorescent lamps	36W (4ft) x 24 13W (PL) x 13	30 – 230	107
	Staircase	Fluorescent lamps	18W (2ft) x 48	40 – 200	
	Corridors	Fluorescent lamps	18W (2ft) x 157	30 – 220	
173	Void deck	Fluorescent lamps	36W (4ft) x 27 13W (PL) x 16	20 – 240	112
	Staircase	Fluorescent lamps	18W (2ft) x 65	30 – 310	
	Corridors	Fluorescent lamps	18W (2ft) x 169	20 – 220	
209	Void deck	Fluorescent lamps	-	-	81
	Staircase	Fluorescent lamps	-	-	
	Corridors	Fluorescent lamps	36W (4ft) x 345	130 – 320	
210	Void deck	Fluorescent lamps	-	-	52
	Staircase	Fluorescent lamps	18W (2ft) x 30 36W (4ft) x 5	60 – 150	
	Corridors	Fluorescent lamps	18W (2ft) x 28	50 – 80	
211	Void deck	Fluorescent lamps	-	-	48
	Staircase	Fluorescent lamps	18W (2ft) x 27 36W (4ft) x 1	80 – 150	
	Corridors	Fluorescent lamps	18W (2ft) x 16	40 – 110	

Table 3.3 B Details of lighting

Block No.	Location	Type of Fixture	No of Fixtures	Measured Lux Level	Average daily kWh consumption
212	Void deck	Fluorescent lamps	-	-	41
	Staircase	Fluorescent lamps	18W (2ft) x 21	40 – 140	
	Corridors	Fluorescent lamps	18W (2ft) x 23	70 – 90	
522	Void deck	Fluorescent lamps	36W (4ft) x 24	20 – 130	84
	Staircase	Fluorescent lamps	18W (2ft) x 76	30 – 100	
	Corridors	Fluorescent lamps	18W (2ft) x 72 36W (4ft) x 6	70 – 90	
533	Void deck	Fluorescent lamps	36W (4ft) x 22	20 – 130	69
	Staircase	Fluorescent lamps	18W (2ft) x 77	20 – 70	
	Corridors	Fluorescent lamps	18W (2ft) x 72 36W (4ft) x 6	50 – 80	
615	Void deck	Fluorescent lamps	36W (4ft) x 17	30 – 120	50
	Staircase	Fluorescent lamps	18W (2ft) x 61	60 – 701	
	Corridors	Fluorescent lamps	18W (2ft) x 71	50 – 80	
622	Void deck	Fluorescent lamps	-	-	12
	Staircase	Fluorescent lamps	18W (2ft) x 12	30 – 120	
	Corridors	Fluorescent lamps	18W (2ft) x 16	30 – 70	
623	Void deck	Fluorescent lamps	36W (4ft) x 13 18W (2ft) x 7	50 – 100	47
	Staircase	Fluorescent lamps	18W (2ft) x 75	20 – 120	
	Corridors	Fluorescent lamps	18W (2ft) x 66	60 – 80	
624	Void deck	Fluorescent lamps	36W (4ft) x 10	50 – 100	40
	Staircase	Fluorescent lamps	18W (2ft) x 48	20 – 110	
	Corridors	Fluorescent lamps	18W (2ft) x 60	80 – 100	
625	Void deck	Fluorescent lamps	-	-	10
	Staircase	Fluorescent lamps	18W (2ft) x 8	30 – 70	
	Corridors	Fluorescent lamps	18W (2ft) x 16	50 – 80	
626	Void deck	Fluorescent lamps	36W (4ft) x 12 18W (2ft) x 6	20 – 100	57
	Staircase	Fluorescent lamps	18W (2ft) x 69	30 – 90	
	Corridors	Fluorescent lamps	18W (2ft) x 87	90 – 100	

Table 3.3 C Details of lighting

Block No.	Location	Type of Fixture	No of Fixtures	Measured Lux Level	Average daily kWh consumption
627	Void deck	Fluorescent lamps	36W (4ft) x 11 18W (2ft) x 3	50 - 90	64
	Staircase	Fluorescent lamps	18W (2ft) x 72	20 – 90	
	C o r r i d o r s	Fluorescent lamps	18W (2ft) x 120	60 – 90	
628	Void deck	Fluorescent lamps	36W (4ft) x 15	30 – 120	40
	Staircase	Fluorescent lamps	18W (2ft) x 61	20 – 80	
	Corridors	Fluorescent lamps	18W (2ft) x 44	40 – 110	
629	Void deck	Fluorescent lamps	36W (4ft) x 11	40 – 80	50
	Staircase	Fluorescent lamps	18W (2ft) x 61	20 – 90	
	C o r r i d o r s	Fluorescent lamps	18W (2ft) x 77	80 – 110	
630	Void deck	Fluorescent lamps	36W (4ft) x 17 18W (2ft) x 1	50 – 90	59
	Staircase	Fluorescent lamps	18W (2ft) x 50	20 – 80	
	Corridors	Fluorescent lamps	18W (2ft) x 93	80 – 100	
631	Void deck	Fluorescent lamps	36W (4ft) x 1	-	36
	Staircase	Fluorescent lamps	18W (2ft) x 51	20 – 110	
	C o r r i d o r s	Fluorescent lamps	18W (2ft) x 60	50 – 60	
632	Void deck	Fluorescent lamps	36W (4ft) x 12 18W (2ft) x 3	50 – 90	44
	Staircase	Fluorescent lamps	18W (2ft) x 35	30 – 90	
	Corridors	Fluorescent lamps	18W (2ft) x 76	70 – 80	
625 BR	Void deck	Fluorescent lamps	-	-	15
	Staircase	Fluorescent lamps	36W (4ft) x 1 18W (2ft) x 6	30 – 260	
	C o r r i d o r s	Fluorescent lamps	18W (2ft) x 13	120 – 150	
626 BR	Void deck	Fluorescent lamps	36W (4ft) x 13 18W (2ft) x 1	20 – 180	64
	Staircase	Fluorescent lamps	18W (2ft) x 110	20 – 160	
	Corridors	Fluorescent lamps	36W (4ft) x 2 18W (2ft) x 16	100 – 120	
627 BR	Void deck	Fluorescent lamps	36W (4ft) x 16 18W (2ft) x 1	40 – 190	72
	Staircase	Fluorescent lamps	18W (2ft) x 110	20 – 140	
	Corridors	Fluorescent lamps	36W (4ft) x 2 18W (2ft) x 16	90 – 100	

Table 3.3 D Details of lighting

Block No.	Location	Type of Fixture	No of Fixtures	Measured Lux Level	Average daily kWh consumption
628 BR	Void deck	Fluorescent lamps	36W (4ft) x 14	150 – 190	67
	Staircase	Fluorescent lamps	36W (4ft) x 2 18W (2ft) x 110	40 – 180	
	Corridors	Fluorescent lamps	18W (2ft) x 18	110 – 160	
629 BR	Void deck	Fluorescent lamps	36W (4ft) x 20 18W (2ft) x 8	20 – 150	67
	Staircase	Fluorescent lamps	18W (2ft) x 30	130 – 160	
	Corridors	Fluorescent lamps	18W (2ft) x 90	90 – 160	
698 C	Void deck	Fluorescent lamps	28W (2D) x 21 13W (PL) x 19	20 – 150	71
	Staircase	Fluorescent lamps	28W (2D) x 75	30 – 70	
	Corridors	Fluorescent lamps	28W (2D) x 124	40 – 60	
698 D	Void deck	Fluorescent lamps	28W (2D) x 17 13W (PL) x 19	20 - 150	65
	Staircase	Fluorescent lamps	28W (2D) x 35	30 – 50	
	Corridors	Fluorescent lamps	28W (2D) x 100	30 – 60	

Table 3.3 E Details of lighting

Based on the Singapore Standard CP 38:1999 – Code of practice for artificial lighting in buildings, the recommended illuminance range for corridors and stairways should be between 50- 100 Lux. Therefore based on the measured data, the lighting levels generally meet the recommended values with the exception of some of the lowest values where lamps are far apart or in isolated areas. The higher lux level measurements were recorded just below lamps and where 36W lamps are used.

3.4 PUMPS

Generally, all blocks (except low rise blocks) have two transfer water pumps located in the respective pump rooms at level 1. One pump acts as a duty pump while the other pump acts as a standby pump. The pumps are used to transfer water from the transfer water tank to the water storage tank on the rooftop of each block. These pumps are operated automatically based on the water level in the storage tank. In addition, there are booster pumps at the roof level to feed water to the higher level flats of each block. Typically there are two booster pumps which operate alternately and are triggered by water flow. A schematic drawing of the piping arrangement of the booster water pumps is attached in Appendix C.

Pump Specifications

The details of the transfer pumps and booster pumps are tabulated in Tables 3.4A and 3.4B.

Block No.	Transfer Pump No.	Design flow (l/s)	Design head (m)	Pump efficiency	Motor rated kW
15	1 & 2	9	47.85	58%	11
16	1 & 2	3.9	58.69	59%	11
17	1 & 2	6.6	37.01	59%	5.5
18	1 & 2	6.6	37.01	59%	5.5
19	1 & 2	6.6	37.01	59%	5.5
20	1 & 2	6.6	37.01	59%	5.5
21	1 & 2	6.4	37.01	59%	5.5
22	1 & 2	6.6	37.01	59%	5.5
23	1 & 2	9.8	37.01	57%	7.5
168	1 & 2	4.9	45.14	62.5%	7.5
169	1 & 2	6.15	42.43	62.5%	11
170	1 & 2	4.55	42.43	62%	7.5
171	1 & 2	4.55	42.43	62%	7.5
172	1 & 2	5.7	39.72	62%	7.5
173	1 & 2	4.55	42.43	62%	7.5
209	-	-	-	-	-
210	-	-	-	-	-
211	-	-	-	-	-
212	-	-	-	-	-
522	1 & 2	6	53.27	60%	7.5
533	1 & 2	6	53.27	60%	7.5
615	1 & 2	3.6	39.72	56%	7.5
622					
623	1 & 2	6.6	37.01	60%	7.5
624	1 & 2	4.8	39.72	62.5%	7.5
625	-	-	-	-	-
626	1 & 2	6.8	37.01	60%	7.5
627	1 & 2	7.4	39.72	60%	7.5
628	1 & 2	3.8	26.17	54%	4
629	1 & 2	6.6	37.01	55.2%	7.5
630	1 & 2	6	39.72	60%	7.5
631	1 & 2	5.65	39.72	60%	7.5
632	1 & 2	5.6	28.88	62.5%	5.5
625 BR	-	-	-	-	-
626 BR	1 & 2	5.5	37.01	60%	7.5
627 BR	1 & 2	5.5	37.01	60%	7.5
628 BR	1 & 2	5.5	37.01	60%	7.5
629 BR	1 & 2	5.5	34.3	64.5%	5.5
698C	1 & 2	3.65	37.01	56%	11
698D	1 & 2	3.2	37.01	56%	11

Table 3.4 A Transfer Pump Specifications

Block No.	Booster Pump No.	Design flow (l/s)	Design head (m)	Pump efficiency	Motor rated kW
15	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
16	1 & 2	1.17/ 4.17	4.4/ 11.3	46%	0.4
17	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
18	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
19	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
20	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
21	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
22	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
23	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
168	1 & 2	3	13	76%	0.75
169	1 & 2	3	13	76%	0.75
170	1 & 2	3	13	76%	0.75
171	1 & 2	3	13	76%	0.75
172	1 & 2	3	13	76%	0.75
173	1 & 2	3	13	76%	0.75
209	-	-	-	-	-
210	-	-	-	-	-
211	-	-	-	-	-
212	-	-	-	-	-
522	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
533	1 & 2	3	13	76%	0.75
615	1 & 2	0/ 5	10/ 14	76%	1
622	-	-	-	-	-
623	1 & 2	0/ 5	10/ 14	76%	1
624	1 & 2	0/ 3	12/ 13.5	76%	0.55
625	-	-	-	-	-
626	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
627	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
628	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
629	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
630	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
631	1 & 2	0/ 5	10/ 14	76%	1
632	1 & 2	2 / 6.67	5 / 13.8	49%	0.75
625 BR	-	-	-	-	-
626 BR	1 & 2	3	13	76%	0.75
627 BR	1 & 2	3	13	76%	0.75
628 BR	1 & 2	3	13	76%	0.75
629 BR	1 & 2	2 / 6.67	5 / 13.8	76%	0.75
698C	1 & 2	0/ 3	12/ 13.5	76%	0.55
698D	1 & 2	0/ 3	12/ 13.5	76%	0.55

Table 3.4 B Booster Pump Specifications

Pump Operating Data

The actual operating data for the transfer water pumps and booster pumps is summarised in Tables 3.5 A and 3.5 B.

Block No.	Measured motor kW	Average daily kWh consumption	Average daily water consumption (m^3)	Average no. of times the pumps are used daily	Average duration of each pump operation (min)	Storage water tank capacity (m^3)
15	8.3	26	72	3.14	56.8	58.2
16	8.1	12	32	4.17	22.18	41.4
17	4.9	9	38	2.75	38	55.2
18	5.2	11	57	5	26.68	55.2
19	5	11	47	6.2	20.7	41.6
20	4.9	11	47	2.83	45	55.2
21	4.8	10	46	5.5	23.51	41.6
22	4.7	11	48	5.5	25.86	41.6
23	6.2	32	75	4.43	72	71
168	5.9	22	65	3.3	69	71.9
169	6.8	23	74	5	40.6	83.9
170	5.7	18	60	3.2	57.6	71.9
171	5.9	16	57	3.2	54.8	71.9
172	5.8	21	72	3.5	61.8	83.9
173	5.9	17	53	3	56.5	71.9
209	-	-	-	-	-	-
210	-	-	-	-	-	-
211	-	-	-	-	-	-
212	-	-	-	-	-	-
522	6.1	18	52	5.2	34.8	52.1
533	5.8	21	54	27.2	8.1	52.1
615	4.6	18	37	7.29	72	33.0
622	-	-	-	-	-	-
623	4.8	18	60	2.14	103.8	89.5
624	6.4	21	54	7.3	26.8	53.2
625	-	-	-	-	-	-
626	6	20	61	5	40.8	73.3
627	6.2	27	69	41.8	6.2	80.0
628	3.1	22	40	5	84.6	39.7
629	6.2	19	57	5.3	32.2	73.3
630	6.5	21	47	6.5	29.5	66.6
631	5.3	25	87	10.3	29.2	59.9
632	4.1	13	42	5.3	36.4	59.9
625 BR	-	-	-	-	-	-
626 BR	5.3	24	71	3.4	76.5	62.8
627 BR	4.9	25	85	4.6	63.3	62.8
628 BR	5.1	14	54	6.14	26.8	43.7
629 BR	5.3	20	88	4	59.2	62.8
698C	6.6	14	30	3.3	39	28.6
698D	6.9	12	29	3.8	39	28.6

Table 3.5 A Transfer Pump Operating Data

Block No.	Rated pump efficiency	Measured motor kW	Average daily kWh consumption
15	49%	0.72	17
16	-	0.33	5
17	49%	0.64	14
18	49%	0.69	16
19	49%	0.59	14
20	49%	0.75	17
21	49%	0.68	14
22	49%	0.63	13
23	49%	0.72	17
168	76%	0.58	14
169	76%	0.55	13
170	76%	0.57	14
171	76%	0.56	12
172	76%	0.59	14
173	76%	0.53	13
209	-	-	-
210	-	-	-
211	-	-	-
212	-	-	-
522	49%	0.94	22
533	76%	0.56	14
615	-	0.54	13
622	-	-	-
623	-	0.46	11
624	-	0.32	8
625	-	-	-
626	49%	0.69	16
627	49%	0.68	16
628	49%	0.63	15
629	49%	0.6	14
630	49%	0.58	14
631	-	0.44	10
632	49%	0.59	14
625 BR	-	-	-
626 BR	76%	0.67	16
627 BR	76%	0.61	14
628 BR	76%	0.57	15
629 BR	76%	0.54	11
698C	76%	0.46	2
698D	76%	0.47	11

Table 3.5 B Booster Pump Operating Data

3.5 LIFTS

There are two or more lifts serving each block (other than the walk-up apartments). All the lifts act as duty lifts. Summary of data collected for the lifts is tabulated in Table 3.6.

Block No.	Number of lifts	Brand of lifts	Type of Drive	Average daily consumption per lift (kwh/day)	Average daily consumption by lifts for block (kwh/day)
15	3	OTIS	ACVF	21.7	65
16	2	OTIS	ACVF	19.5	39
17	2	OTIS	ACVF	18.5	37
18	3	OTIS	ACVF	19.7	59
19	2	OTIS	ACVF	20	40
20	2	OTIS	ACVF	19.5	39
21	2	OTIS	ACVF	20	40
22	2	OTIS	ACVF	18	36
23	3	OTIS	ACVF	20.7	62
168	2	DONG YANG	ACVF	30	60
169	2	DONG YANG	ACVF	32.5	65
170	2	DONG YANG	ACVF	27.5	55
171	2	DONG YANG	ACVF	29.5	59
172	2	DONG YANG	ACVF	41	82
173	2	DONG YANG	ACVF	29	58
209	-	-	-	-	-
210	-	-	-	-	-
211	-	-	-	-	-
212	-	-	-	-	-
522	3	FUJITEC	ACVV	23.7	71
533	3	FUJITEC	ACVV	28.3	85
615	2	FUJITEC	ACVV	23	46
622	-	-	-	-	-
623	2	FUJITEC	ACVV	14.5	29
624	2	FUJITEC	ACVV	17	34
625	-	-	-	-	-
626	2	FUJITEC	ACVV	18	36
627	3	FUJITEC	ACVV	16.3	49
628	2	FUJITEC	ACVV	18.5	37
629	2	FUJITEC	ACVV	17.5	35
630	2	FUJITEC	ACVV	18.5	37
631	2	FUJITEC	ACVV	16	32
632	2	FUJITEC	ACVV	12.5	25
625 BR	-	-	-	-	-
626 BR	2	FUJITEC	AC2	22.5	45
627 BR	2	FUJITEC	AC2	23	46
628 BR	2	FUJITEC	AC2	13.5	27
629 BR	4	FUJITEC	ACVV	19	76
698C	2	FUJITEC	VVVF	18	36
698D	2	FUJITEC	VVVF	17	34

Table 3.6 Lift Operating Data

The lifts generally have a shut down feature which shut off fans when homing to reduce energy consumption. Most lifts also have variable voltage (VV) or variable frequency (VF) drives.

Based on the monitored data, it was noted that the lifts operate in 2 modes. Normal mode (representative by positive kW readings of the lift motor) when the lifts draw power to overcome the counter weights to move the lift carriage to the respective floors. The re-generative mode (represented by negative kW readings of the lift motor) occurs when the counter weights are heavy enough to move the carriage to the correct floor without the help of the lift motor.

3.6 OTHERS

The electricity consumption by miscellaneous users like lighting in the rooms (lift motor rooms, pump rooms and switch rooms), power sockets (used for block washing etc.), CATV, link-way lighting, fans for markets and refuse chamber is categorised under "other users" and the measured consumption data is given in Tables 3.7 A and 3.7 B.

Block No.	Average daily consumption by "other users" (kwh/day)
15	53
16	31
17	14
18	28
19	10
20	60
21	16
22	17
23	16
168	28
169	25
170	9
171	6
172	20
173	32
209	160
210	2
211	3
212	0
522	10
533	29
615	13
622	2
623	16
624	14
625	0
626	24
627	40

Table 3.7 A Electricity consumption by other users

Block No.	Average daily consumption by "other users" (kwh/day)
628	20
629	10
630	14
631	9
632	8
625 BR	2
626 BR	13
627 BR	12
628 BR	12
629 BR	22
698C	28
698D	19

Table 3.7 B Electricity consumption by other users

3.7 OUTDOOR LIGHTING

Outdoor lighting is provided mainly through lamp post lighting. In addition, garden lighting is also provided. Electricity for the outdoor lighting is drawn from adjacent blocks.

Details of outdoor lighting is provided in Tables 3.8 A and B.

Block No.	Type and quantity of outdoor lighting	Average daily consumption (kwh/day)
15	-	-
16	80W (HPL) x 20 250W (HPL) x 7	44
17	250W (HPL) x 13	41
18	25W (FL) x 8 40W (FL) x 4 80W (HPL) x 4 125W (HPL) x 31 250W (HPL) x 20 400W (MHL) x 4	73
19	25W (FL) x 12	5
20	25W (FL) x 4	1
21	25W (FL) x 4 125W (HPL) x 2 250W (HPL) x 7	22
22	25W (FL) x 4 125W (HPL) x 3 250W (HPL) x 18	48
23	25W (FL) x 18 125W (HPL) x 25 400W (MHL) x 2	59
168	125W (HPL) x 8	13

Table 3.8 A Outdoor lighting

Block No.	Type and quantity of outdoor lighting	Average daily consumption (kwh/day)
169	125W (HPL) x 19	32
170	125W (HPL) x 7	12
171	125W (HPL) x 15	26
172	125W (HPL) x 20	34
173	125W (HPL) x 13 400W (MHL) x 4	44
209	36W	229*
210	36W &40W (FL) x 14 250W (HPL) x 20	37 48
211	125W (HPL) x 55	77
212	250W (HPL) x 10	31
522	125W (HPL) x 8	12
533	125W (HPL) x 7	9
615	-	-
622	-	-
623	125W (HPL) x 7	9
624	80W (HPL) x 11	11
625	-	-
626	-	-
627	80W (HPL) x 21	21
628	-	-
629	80W (HPL) x 8 250W (MHL) x 6	13
630	80W (HPL) x 5	6
631	80W (HPL) x 5	5
632	-	-
625 BR	125W (HPL) x 2	2
626 BR	125W (HPL) x 13	16
627 BR	-	-
628 BR	-	-
629 BR	-	-
698C	80W (HPL) x 9	19
698D	-	-

Table 3.8 B Outdoor lighting

* Block 209 is market lighting

3.8 SUMMARY OF DATA

The average daily kWh consumed by the different users is summarised for all the blocks in Table 3.9.

Block no.	Lighting (common area)	Lifts	Pumps	Outdoor (garden & walkway)	Others	Outdoor (lamp post)	Total
15	117	65	43	-	53	-	278
16	54	39	17	20	31	24	161 + 24
17	82	37	23	-	14	41	156 + 41
18	95	59	27	53	28	20	262 + 20
19	81	40	25	5	10	-	161
20	73	39	28	1	60	-	201
21	89	40	24	4	16	18	173 + 18
22	71	36	24	7	17	41	155 + 41
23	99	62	49	59	16	-	285
168	126	60	36	13	28	-	263
169	122	65	36	32	25	-	280
170	69	55	32	13	9	-	178
171	84	59	28	26	6	-	203
172	107	82	35	34	20	-	278
173	112	58	30	44	32	-	276
209	81	-	-	229	160	-	470
210	52	-	-	37	2	48	91 + 48
211	48	-	-	54	3	23	105 + 23
212	41	-	-	14	0	17	55 + 17
522	84	71	40	-	10	12	205 + 12
533	69	85	35	-	29	9	218 + 9
615	50	46	31	-	13	-	140
622	12	-	-	-	2	-	14
623	47	29	29	-	16	9	121 + 9
624	40	34	29	11	14	-	128
625	10	-	-	-	0	-	10
626	57	36	36	-	24	-	153
627	64	49	43	8	40	13	204 + 13
628	40	37	37	-	20	-	134
629	50	35	33	5	10	8	133 + 8
630	59	37	35	-	14	6	145 + 6
631	36	32	35	-	9	5	112 + 5
632	44	25	27	-	8	-	104
625 BR	15	-	-	-	2	2	17 + 2
626 BR	64	45	40	-	13	16	162 + 16
627 BR	72	46	39	-	12	-	169
628 BR	67	27	29	-	12	-	135
629 BR	67	76	31	-	22	-	196
698C	71	36	16	19	28	-	170
698D	65	34	23	-	19	-	141

Table 3.9 Average daily consumption (kWh / day)

4. MAIN FINDINGS

Analysis of data collected during the audit is presented in this chapter in the form of tables, pie-charts and benchmarking indices. A summary of the main findings is also included at the end of the chapter.

4.1 END-USER PROFILE

The percentage electricity consumption of each main user is given in Tables 4.1 A and 4.1 B.

Block no.	Lighting (staircase, void deck & corridor) (%)	Lifts (%)	Transfer pumps (%)	Booster pumps (%)	Outdoor lighting (%)	Others (%)
15	42.1	23.4	9.4	6.1	0.0	19.1
16	33.5	24.2	7.5	3.1	12.4	19.3
17	52.6	23.7	5.8	9.0	0.0	9.0
18	36.3	22.5	4.2	6.1	20.2	10.7
19	50.3	24.8	6.8	8.7	3.1	6.2
20	36.3	19.4	5.5	8.5	0.5	29.9
21	51.4	23.1	5.8	8.1	2.3	9.2
22	45.8	23.2	7.1	8.4	4.5	11.0
23	34.7	21.8	11.2	6.0	20.7	5.6
168	47.9	22.8	8.4	5.3	4.9	10.6
169	43.6	23.2	8.2	4.6	11.4	8.9
170	38.8	30.9	10.1	7.9	7.3	5.1
171	41.4	29.1	7.9	5.9	12.8	3.0
172	38.5	29.5	7.6	5.0	12.2	7.2
173	40.6	21.0	6.2	4.7	15.9	11.6
209	17.2	0.0	0.0	0.0	48.7	34.0
210	57.1	0.0	0.0	0.0	40.7	2.2
211	45.7	0.0	0.0	0.0	51.4	2.9
212	74.5	0.0	0.0	0.0	25.5	0.0
522	41.0	34.6	8.8	10.7	0.0	4.9
533	31.7	39.0	9.6	6.4	0.0	13.3
615	35.7	32.9	22.1	0.0	0.0	9.3
622	85.7	0.0	0.0	0.0	0.0	14.3
623	38.8	24.0	14.9	9.1	0.0	13.2
624	31.3	26.6	16.4	6.3	8.6	10.9
625	100.0	0.0	0.0	0.0	0.0	0.0
626	37.3	23.5	13.1	10.5	0.0	15.7
627	31.4	24.0	13.2	7.8	3.9	19.6
628	29.9	27.6	16.4	11.2	0.0	14.9
629	37.6	26.3	14.3	10.5	3.8	7.5
630	40.7	25.5	14.5	9.7	0.0	9.7
631	32.1	28.6	22.3	8.9	0.0	8.0
632	42.3	24.0	12.5	13.5	0.0	7.7

Table 4.1 A Percentage consumption for blocks

Block no.	Lighting (staircase, void deck & corridor)	Lifts	Transfer pumps	Booster pumps	Outdoor lighting	Others
625 BR	88.2	0.0	0.0	0.0	0.0	11.8
626 BR	39.5	27.8	14.8	9.9	0.0	8.0
627 BR	42.6	27.2	14.8	8.3	0.0	7.1
628 BR	49.6	20.0	10.4	11.1	0.0	8.9
629 BR	34.2	38.8	10.2	5.6	0.0	11.2
698C	41.8	21.2	8.2	1.2	11.2	16.5
698D	46.1	24.1	8.5	7.8	0.0	13.5

Table 4.1 B Percentage consumption for blocks

Based on the summarised data in Tables 4.1 A and B, pie-charts (Figures 4.1 to 4.6) were plotted to show the percentage electricity consumption of the different end users as a whole for all 40 blocks and based on the 5 different categories of blocks.

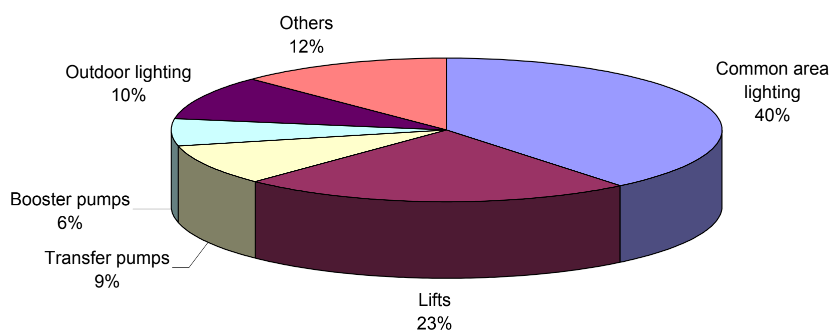

Figure 4.1 Energy consumption breakdown for all blocks

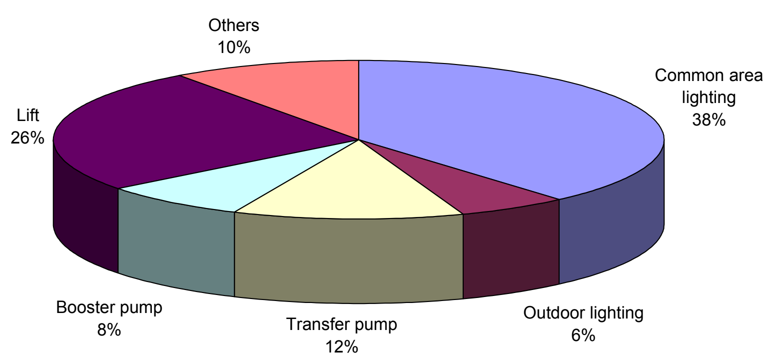

Figure 4.2 Energy consumption breakdown for 3 / 4/ 5 RM blocks (not upgraded)

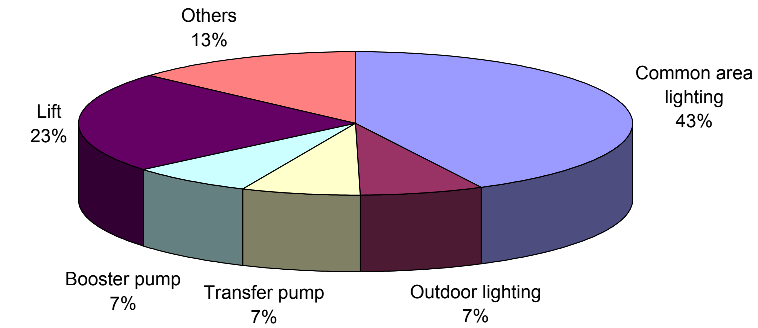

Figure 4.3 Energy consumption breakdown for 3 / 4/ 5 RM blocks undergone MUP

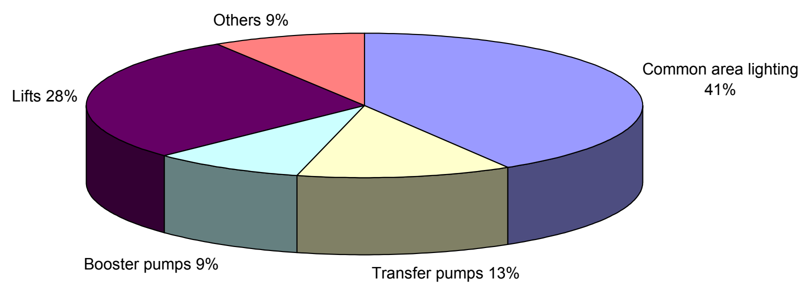

Figure 4.4 Energy consumption breakdown for 3 / 4/ 5 RM blocks undergone IUP

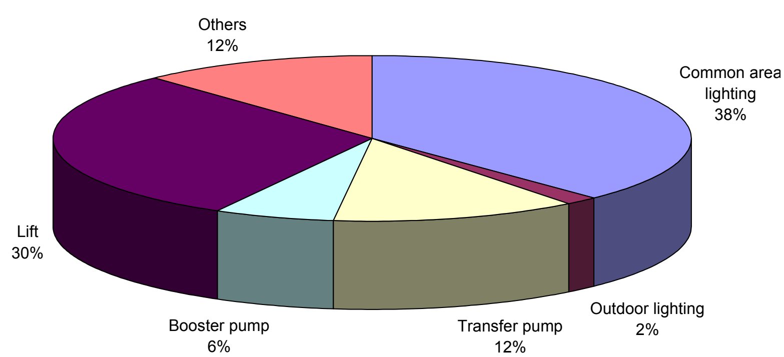

Figure 4.5 Energy consumption breakdown for Executive blocks

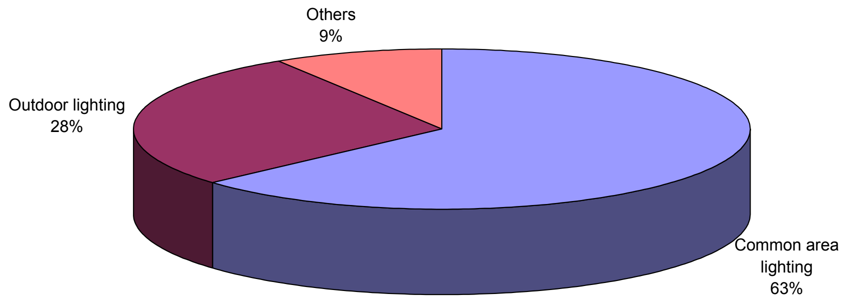

Figure 4.6 Energy consumption breakdown for blocks with commercial units and walk-up blocks

Figure 4.1 shows that in general, common area lighting and outdoor lighting accounts for 40% and 10% of the total electricity consumption of blocks, respectively. This is supported by Figures 4.2 to 4.4 (breakdown of usage for individual categories) which show that common area lighting accounts for about 38% to 43% of the total electricity consumption. The percentage value of lighting consumption for Executive blocks (Figure 4.5) is lower due to the higher percentage consumption by the lifts. Similarly, the lighting percentage for blocks with commercial units and walk-up blocks (Figure 4.6) is also higher due to the absence of lifts and water pumps in these blocks.

Figure 4.1 also shows that water pumps (transfer and booster pumps) account for about 15% of the total electricity consumption for all the blocks. This value is consistent with the combined percentage values for pumps of 14% to 22% shown in Figures 4.2 to 4.5 for the different categories of blocks. The data also show that the booster pumps account for between 1/3 and 1/2 of the total pumping electricity consumption.

The electricity consumption by lifts range from about 23% to 28% except for Executive blocks for which lift consumption is much higher at 30% due to the use of 3 lifts for some blocks (compared to average of 2 lifts per block).

Electricity consumption by “other users” which include user such as lighting in switch rooms, power sockets, CATV, link-way lighting and fans for market blocks in general account for about 10%.

Table 4.2 summarises the average daily kWh consumption of common utilities (lighting, pumps & lifts) divided by the number of flats.

The table shows that the average daily electricity consumption for common utilities for most blocks ranges from 1.4 to about 1.7 kWh/flat. However, the value is higher for Executive blocks (about 2 kWh/flat), which is probably due to the relatively lower number of flats per block and higher usage for lifts and pumps.

Type of block	Average daily kWh/flat
3 / 4 / 5 room (not upgraded)	1.68
3 / 4 / 5 room upgraded under MUP	1.50
3 / 4 / 5 room upgraded under IUP	1.37
Executive	1.96
Blocks with commercial units / walk-up apartments	1.41

Table 4.2 Average daily kWh consumption for common utilities per flat

4.2 LIGHTING

Electricity consumption by lighting systems is summarised in Tables 4.3 and 4.4.

Type of block	Common area lighting as a % of the total	Outdoor lighting as a % of the total	Average daily kWh / flat for common area lighting
3 / 4 / 5 room (not upgraded)	38 %	6%	0.67
3 / 4 / 5 room upgraded under MUP	43%	7%	0.62
3 / 4 / 5 room upgraded under IUP	41%	0%	0.64
Executive	38%	2%	0.75
Blocks with commercial units / walk-up apartments	63%	28%	0.79

Table 4.3 Percentage of lighting consumption and average consumption / flat

Type of block	Lighting (lux) level	Average daily kWh/flat	Type of lighting
3 / 4 / 5 room (not upgraded)	20 to 300 lux	0.67	Mainly 18W & 36W
3 / 4 / 5 room upgraded under MUP	20 to 180 lux	0.62	Mainly 28W -2D
3 / 4 / 5 room upgraded under IUP	20 to 190 lux	0.64	Mainly 18W with some 36W
Executive	20 to 150 lux	0.75	Mix of 18W, 36W and 28W-2D
Blocks with commercial units / walk-up apartments	30 to 90 lux	0.79	Mainly 18W & 36W

Table 4.4 Lighting levels and consumption based on type of lighting

Tables 4.3 and 4.4 show that block lighting account for about 50% of the total electricity consumption for 3/4/5 room blocks. The average daily lighting consumption per flat ranges from 0.62 to 0.67 for 3/4/5 room blocks. For

Executive blocks which generally have less flats per block and blocks with commercial units which have markets, the value is higher.

The 3/4/5 room blocks which have not been upgraded use 36W and 18W linear fluorescent lamps while blocks which have undergone IUP use mainly 18W fluorescent lamps. The blocks which have undergone MUP use mainly 28W – 2D fluorescent lamps.

The lighting levels (lux) for common areas such as void decks, common corridors and staircases range from about 20 lux to about 300 lux. The higher lux levels are for areas which use 36W linear fluorescent lamps. Table 4.4 shows that when comparing blocks after MUP and IUP, similar lighting levels can be achieved using 18W linear (IUP) and 28W 2D lamps (MUP). Since the average spacing between 18W and 28W lamps is very similar for corridors (about 5 to 7 m apart), common area lighting consumption is expected to be higher for blocks using 28W lamps. This is supported by data in Table 4.3 which indicates that MUP blocks have the highest common area lighting consumption of 43% (compared to 38% for not-upgraded blocks and 41% for IUP blocks).

It was also noted that there is some degree of overlapping of lighting in some outdoor applications. A few specific examples such as lamp posts being too close to each other, outdoor lamps situated very close to blocks and too many lamps in one location are shown in photographs E1 to E7 in Appendix E.

Further, it was found that the lighting level in the market (Block 209) was very high (130 to 320 lux) due to the use of 3 x 36W tube fixtures (photograph E8 in Appendix E).

4.3 PUMPS

Energy consumption of transfer water pumps and booster pumps is summarised based on the 5 categories of blocks in Table 4.5.

Type of block	Transfer pumps		Booster pumps	
	% consumption	Average daily kWh/flat	% consumption	Average daily kWh/flat
3 / 4 / 5 room (not upgraded)	12%	0.18	8%	0.12
3 / 4 / 5 room upgraded under MUP	7%	0.1	7%	0.1
3 / 4 / 5 room upgraded under IUP	13%	0.15	9%	0.1
Executive	12%	0.24	6%	0.12
Blocks with commercial units / walk-up apartments	0%	0	0%	0

Table 4.5 Summary of pump energy consumption

Table 4.5 shows that transfer water pumps and the booster pumps account for about 11% and 7.5% of the total block electricity consumption, respectively. The electricity consumption per flat for transfer pumps range from 0.1 to 0.18 kWh/flat except for Executive blocks which have a higher usage of 0.24 kWh/flat most probably due to their higher water usage. The electricity consumption by the booster pumps is consistent for all types of blocks at 0.1 to 0.12 kWh/flat.

The rated efficiency of transfer pumps was found to be generally about 60% while the rated efficiency for the booster pumps ranged from 49% to 76%. Since all transfer pumps have similar rated efficiencies, it is not possible to see the impact of efficiency on motor power consumption. However, for booster pumps, data in Table 3.5B indicate that pumps with higher rated efficiency (76%) have a 15% lower motor power consumption than pumps with lower efficiency (49%).

Since energy consumption of pumps can depend on factors such as total block water usage, number of flats and the capacity of storage tanks, graphs were plotted to identify possible relationships and are presented in Figures 4.7 to 4.10.

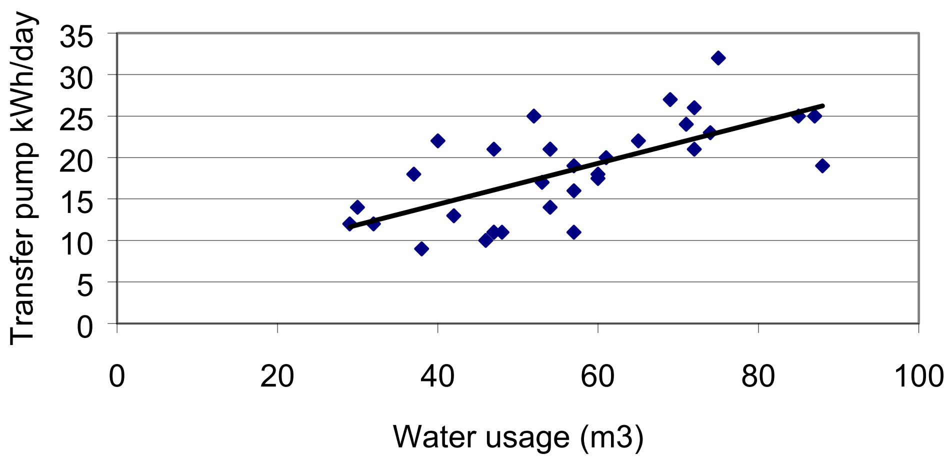

Figure 4.7 Block water usage vs pumping kWh/day

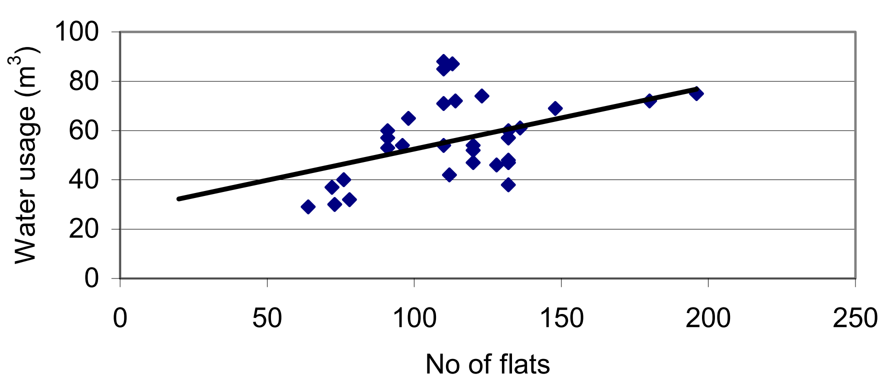

Figure 4.8 No of flats vs block water usage m^3

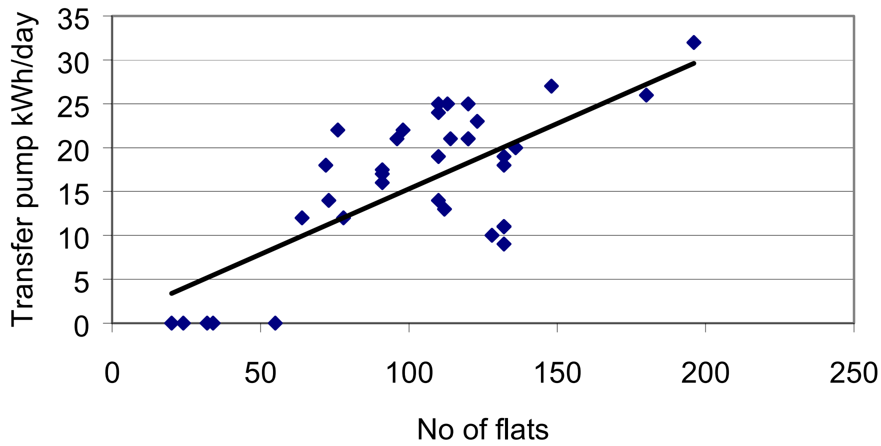

Figure 4.9 No. of flats vs pumping kWh/day

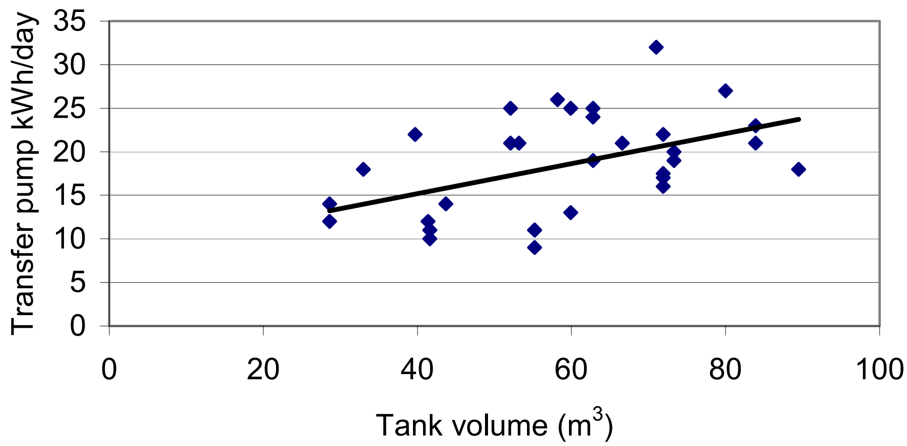

Figure 4.10 Storage water tank size vs pumping kWh/day

As expected, Figure 4.7 show that the pumping electricity consumption is proportional to the block water usage while Figure 4.8 shows that water usage of blocks is proportional to the number of flats. As a result, pumping electricity consumption is proportional to the number of flats in the block (Figure 4.9).

The consumption of transfer pumps was also plotted against the capacity of the roof storage tank. Figure 4.10 shows that in general, pump consumption is higher when the storage tank volume is more. Further detailed analysis of the data confirmed that this is because tanks with higher storage volume are used for blocks with higher water usage (more flats). However, data do not indicate that for blocks with the same number of flats (similar water usage), increasing the storage tank volume leads to lower energy consumption by the pumps (pump energy consumption does not depend on the frequency of pump operation).

Booster pumps installed at the roof level of blocks are used to provide water to the top 3 levels of each block. Typically there are two booster pumps for each block which operate alternately and are triggered by water flow. A schematic drawing of the piping arrangement of the booster water pumps is included in Appendix C.

Investigation into the operation of the booster pumps showed that about 45% (13 lpm out of 29 lpm) of the water is bypassed back into the rooftop tank through the bypass pipes (Plot C.1 in Appendix C). Further, it was also noted that although the pressure developed by the pumps is above 1.4 bar (Plots C.2 and C.3 in Appendix C), the actual header pressure which supplies water to the residents varies from 0.7 bar to 1.4 bar (Plot C.4 in Appendix C), indicating that it is possible to reduce the pump discharge pressure. As such, it would be possible to reduce the capacity of booster pumps to lower the discharge pressure and eliminate bypassing of water.

4.4 LIFTS

Energy consumption by the lifts is summarised based on the 5 categories of blocks, the Make / Brand of lifts and type of drive in Tables 4.6 and 4.7.

Type of block	% consumption	Average daily kWh/flat
3 / 4 / 5 room (not upgraded)	26%	0.43
3 / 4 / 5 room upgraded under MUP	23%	0.34
3 / 4 / 5 room upgraded under IUP	28%	0.35
Executive	30%	0.58
Blocks with commercial units / walk-up apartments	0%	0

Table 4.6 Summary of lift energy consumption

Brand - Type of drive	Approximate age of lifts (years)	Average daily consumption (kWh/day) per block	Average daily consumption (kWh/day) per lift
Otis - ACVF	6 – 6.5	46	20
Fujitec - ACVV	13 - 20	46	19
Fujitec – AC2	23 - 24	39	20
Fujitec - VVVF	6	35	18
Dong Yang - ACVF	7 - 8	63	32

Table 4.7 Lift energy consumption, lifts brands and type of drives

Based on Table 4.6, the electricity consumption by lifts range from about 23% to 28% except for Executive blocks for which lift consumption is much higher at 30%. This is mainly due to the use of 3 lifts for some blocks (compared to the average of 2 lifts per block). The average daily lift electricity consumption per flat is also about 0.35 to 0.4 kWh/flat except for Executive blocks which have a higher rate of 0.58 kWh/flat.

Table 4.7 clearly indicates that the average daily electricity consumption per lift is about 20 kWh/lift, irrespective of the type of drive (AC2, ACVV, ACVF or VVVF) for Otis and Fujitec lifts. However, the average consumption is 60% higher for Dong Yang lifts (only 7 – 8 years old) compared to Otis and Fujitec lifts which include lifts which are over 20 years old (AC2).

As energy consumption by lifts can depend on factors like the number of floors, number of flats and number of lifts per block, graphs were plotted to identify possible relationships and are presented in Figures 4.12 to 4.14.

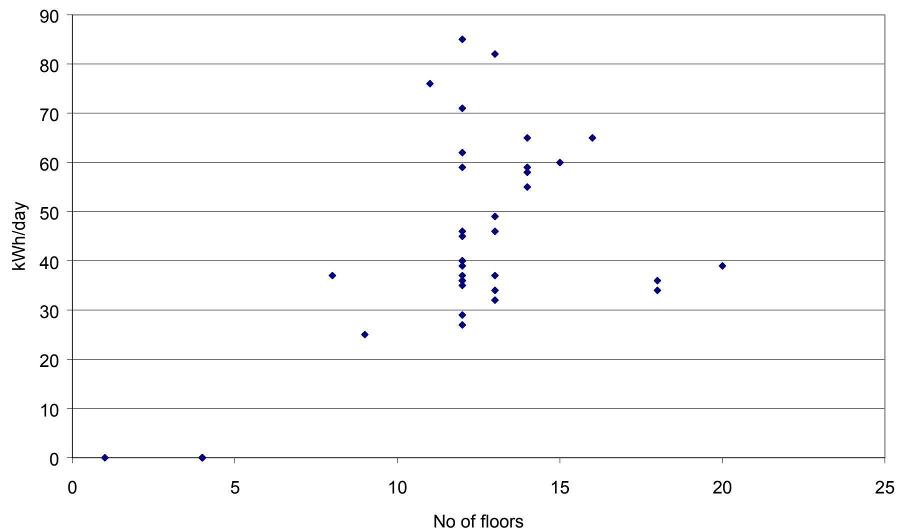

Figure 4.12 Number of floors vs lift kWh/day

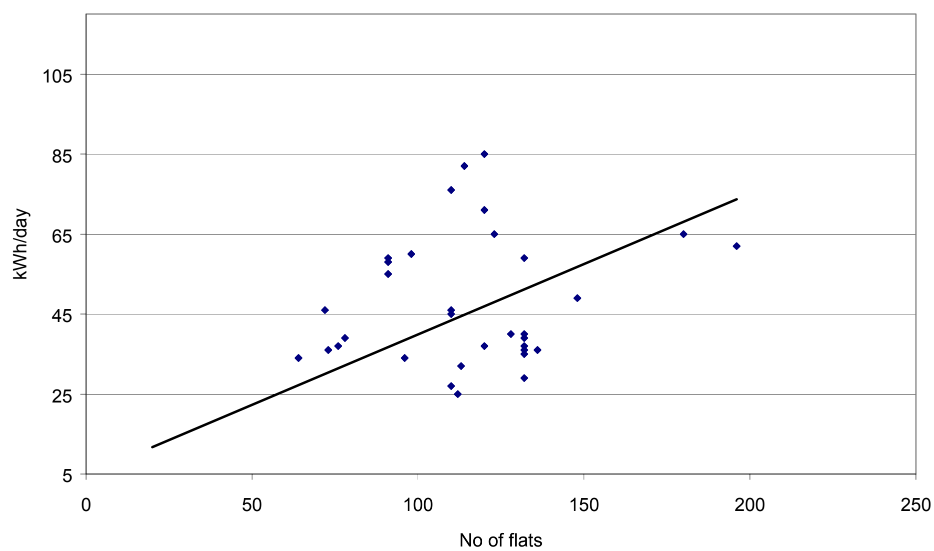

Figure 4.13 Number of flats vs Lift kWh/day

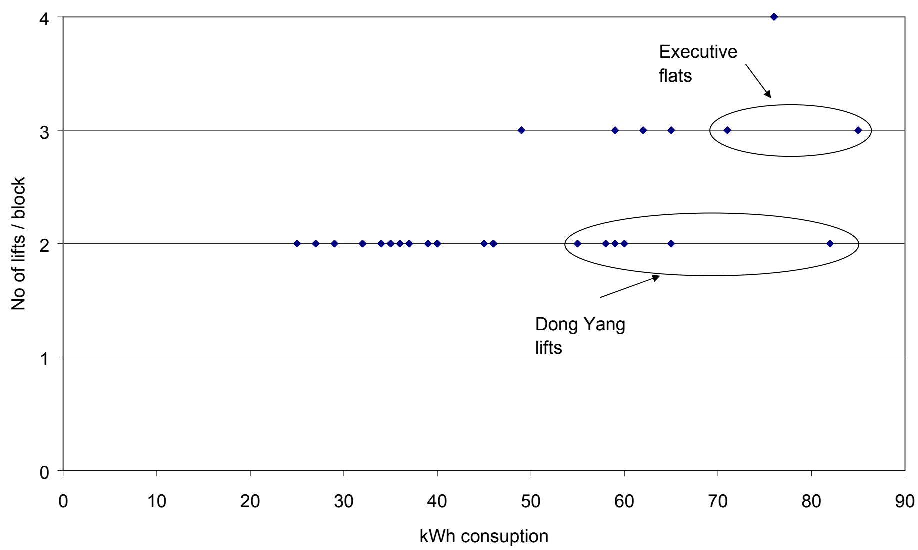

Figure 4.14 Lift kWh/day vs number of lifts per block

Figure 4.12 shows that there is no direct relationship between the energy consumption of lifts and the number of floors in the block. However, Figure 4.13 shows that the energy consumption of lifts is generally proportional to the number of flats in the block. This is as expected because higher number of flats usually leads to more lift users.

Figure 4.14 shows that in general, the total consumption by lifts is dependent on the number of lifts installed in the block. The average usage is about 20 kWh/ lift per day with the exception of Executive blocks and Dong Yang brand lifts.

4.5 Summary Of Findings

Following are the main findings :

- The average electricity consumption per block is 62,000 kWh/year while the average cost of electricity per block is $10,300/year.
- Lighting, lifts and pumps are the three main energy users.
- Common area lighting (void deck, staircase and corridor) account for about 40% of the total consumption.
- Lifts account for the second biggest usage consuming about 23% of the total.
- Water pumps account for about 15% of the total consumption made-up of 9% by transfer pumps and 6% by booster pumps.
- The end-user breakdown is generally consistent for all mixed 3/4/5 room blocks, irrespective of whether they have undergone upgrading.
- Water pumps and lifts account for higher percentages in Executive blocks as compared to normal 3/4/5 room blocks. The higher percentage for lifts is due to the use of 3 lifts in some blocks compared to the average of 2 lifts per block while the higher percentage for pumps is due to higher water usage per flat in Executive blocks.

- For walk-up blocks and blocks with commercial units, common area lighting accounts for 63% of the total due to the absence of the other users such as lifts and pumps in these blocks.
- The average daily electricity consumption for common utilities range from 1.4 to 1.7 kWh/flat except for Executive blocks which have higher consumption of 2 kWh/flat. The higher value for Executive blocks is due to higher usage for lifts and pumps and the lower number of flats per block.
- For common area lighting, 18W and 36W linear fluorescent lamps and 28W-2D lamps are used. Electronic ballast are generally not used for lighting.
- The lighting levels (lux) for common areas such as void decks, common corridors and staircases range from about 20 lux to about 300 lux. The higher lux levels are for areas which use 36W linear fluorescent lamps.
- Blocks after MUP and IUP indicate that similar lighting levels can be achieved using 18W linear (IUP) and 28W 2D lamps (MUP). However, data indicates that use of 28W 2D lamps (instead of 18W lamps) for common area lighting results in higher electricity consumption as the lamp spacing used is similar for both types of lamps.
- There is overlapping of lighting from different sources in some outdoor lighting applications.
- Lighting level in the market block (209) is relatively much higher than other areas due to the use of 3 x 36W lamp fixtures.
- Transfer water pumps are used to pump water to the rooftop tank which then supply water to the residents by gravity flow. Booster pumps are used to serve the top 3 floors of each block.
- Transfer pumps operate based on the water level of the storage tank while the booster pumps operate based on flow in the supply pipe.
- Electricity consumption by transfer water pumps per flat range from 0.1 to 0.18 kWh/flat except for Executive blocks which have higher usage of 0.24 kWh/flat. This is due to the higher water usage in these blocks.
- Consumption by booster pumps range from 0.1 to 0.12 kWh/flat for all types of blocks.
- The rated efficiency of transfer pumps range from 55% to 62% while the rated efficiency of booster pumps range from 49% to 76%. It was also found that the average electricity consumption of booster pumps with higher rated efficiency is about 15% lower than that of the lower efficiency pumps.
- Electricity consumption by transfer pumps is proportional to block water usage and the number of flats in each block.
- Transfer pump electricity consumption is not dependent on the frequency of pump operation.
- Although the delivery pressure of the booster pumps is 1.4 bar, the actual pressure at the supply header varies from 0.7 to 1.4 bar. There is also

constant by-passing of water from the delivery of the pump to the storage tank when the pumps are in operation.

- Lifts use different types of drives such as AC2, ACVF, ACVV and VVVF.
- The average daily electricity consumption per lift is about 20 kWh/lift, irrespective of the age and type of drive for Otis and Fujitec lifts. However, the average consumption is 60% higher for Dong Yang lifts.
- There is no evidence of a direct relationship between energy consumption of lifts and the number of floors in the block. However, lift consumption is proportional to the number of flat in the block.
- CATV systems of blocks generally consume about 70 to 100 W of power although most flats now have cable TV connections.

5. Identified Savings Measures & Recommendations

The potential energy saving measures identified based on the findings of the audit are presented in this chapter with estimated savings and associated costs followed by our recommendations.

5.1 Lighting

Present Situation

The lighting is designed to provide essential lighting for common areas such as corridors, void decks, car parks and lift landings. Lamps used are energy efficient fluorescent type lamps. The lighting circuits are turned on from about 6.40pm till 7.00am the next morning by means of timer control.

Based on the measurement of lighting (lux) levels in the blocks, the lux levels were noted to be generally within the values recommended in the code of practice (CP38) for lighting.

Further, the data collected shows that the power consumed by lighting increases in the night, possibly due to the increase in mains supply voltage.

Proposed Improvements

a) One of the simplest ways to reduce lighting energy consumption is to reduce the lighting operating hours such as switching-off earlier on switching-on later. However, this could compromise lighting levels during certain days (cloudy / rainy days) and is therefore not recommended for general implementation.

b) Based on the measured data which indicate that similar illuminance levels can be achieved with both 18W and 28W lamps, it would be possible to reduce lighting electricity consumption for common area lighting by using 18W lamps instead of 28W lamps (and 36W lamps). Further savings can be achieved if T5 lamps are used instead of T8 lamps.

c) It is also possible to reduce lighting energy consumption by reducing losses in lighting systems. This can be achieved through the use of electronic ballast and power saving devices.

   Electronic ballast are an alternative to the conventional magnetic ballasts which have core and coil assemblies compared to electronic ballasts which have electronic components. Electronic ballasts operate at high frequencies between 20,000 and 60,000 Hz, which makes power-to-light conversion more efficient than for magnetic coil ballasts. Electronic ballast can reduce the lighting energy consumption by 15% to 20% depending on the type of ballast currently used.

d) Another alternative is the use of power saving devices. There are a number of “lighting power saving devices” which when installed help to reduce lighting energy consumption. The design of these equipment vary from one to another but generally contain transformers to reduce the voltage to a pre-determined value after the lamps are switched-on. This helps to reduce the power drawn by the lighting but result in a drop in lighting level.

A comparison of savings and cost for options b, c and d is provided in Table 5.1 for a typical block with 150 nos. 18W or 28W lamps (details are in Appendix D).

Option	Option b) Replacing 28W lamps		Option b) Replacing 18W lamps with T5 lamps	Option c) Using Electronic ballast	Option d) Using Power saving devices
	With T5	With T8			
Typical savings achievable	53%	31%	32%	14 to 18%	30 to 40%
Annual savings for a typical block with 150 lamps	$1,700	$1,000	$700	$300 to $400	$650 to $900
Cost for a typical block with 150 lamps	$6,750	$3,750	$6,750	$3,000	$1,700 to $3,400
Simple payback period	4 years	3.8 years	9.6 years	7.5 to 10 years	2.6 to 3.8 years

Table 5.1 Comparison of lighting options

Based on the above, it is financially feasible to replace the 28W lamps with either T8 or T5 (2 feet lamps). However, this is only applicable to the blocks that have undergone MUP and use 28W lamps. Although Table 5.1 indicates that it is not financially viable to replace 18W lamps with T5 lamps purely as an energy savings measure, it can be considered for new blocks and for blocks being upgraded where lighting is replaced as part of the upgrading program.

Out of all the options, using power saving devices (option d) is preferred as it is financially more attractive due to higher savings and lower cost.

Table 5.2 shows some typical data collected from a trial carried out using a power saving device (trial data is included in Appendix D).

Voltage reduction	17%	21%	29%
Power (kW) reduction	32%	37%	51%
Lighting level (lux) reduction	19%	22%	31%

Table 5.2 Results of trial carried out with a lighting power saving device

Various tests have been conducted in the U.S. on such power saving devices including under the National Lighting Product Information Program (NLPIP) which is sponsored by U.S. Environmental Protection Agency (EPA) and other state organisations. Based on the report (see Appendix D), lighting power saving devices using transformers to reduce voltage are able to reduce lighting power while lowering light output. The report states that ballast life can improve due to lowering of ballast temperature by power saving device and that there are no published reports documenting effect on lamp life at lower than rated power.

Fluorescent lamp life can be affected by lamp current crest factor (CCF) and electrode starting temperature. Since power saving devices limit lamp current, they do not increase lamp CCF. Power saving devices also provide the normal voltage during starting and therefore do not alter the starting temperature. Therefore, power saving devices are not expected to have a significant impact on lamp life if the voltage is not reduced significantly. Further, feedback from owners and operators of buildings which have had such power saving devices (with voltage reduction of approximately 20%) in operation for more than 1-year indicate that there is no noticeable increase in lamp usage (reduction in lamp life).

Trials were carried out by installing a lighting power saving device in a few HDB blocks to estimate the savings achievable with voltage reduction of approximately 20% and the findings are given in Table 5.3 (test data is included in Appendix D).

Block	Average demand before (kW)	Average demand after (kW)	Average daily consumption before (kWh)	Average daily consumption after (kWh)	Savings (%)
928 Hougang Av 4	5.6	3.6	67.2	42.8	36
201 (Bukit Batok)	5.7	3.3	69.3	42.1	39
105 Jurong East St 13	3.6	2.5	43	30.4	29

Table 5.3 Results of trial with a lighting power saving device for HDB blocks

Estimation of Savings and Cost

The amount of savings achievable can be estimated as follows:

% kWh Savings achievable = % of lighting energy consumption for blocks x estimated saving % achievable

Average common area lighting consumption for blocks = 40% (Figure 4.1)

Estimated average savings achievable = 35% (from Table 5.3)

% savings achievable = 40% x 35%

= 14%

(therefore, for a typical HDB block, the electricity consumption can be reduced by 14% by installing power saving devices for the common area lighting)

Average annual electricity cost for common area lighting

= average annual electricity cost for blocks x average consumption % of common area lighting

= $10,300 (from Table 3.1) x 40%

= $4,120

Average annual savings

= average annual electricity cost for lighting x estimated savings % achievable

= $4,120 x 35%

= $1,442

The cost of a power saving device is about $1,700. Since typically, HDB blocks have 2 switch rooms (2 lighting DBs), the estimated cost for power saving devices for a block is $3,400.

Therefore, simple payback for a typical block

= cost of implementation per block / annual savings

= $3,400 / $1,442

= 2.4 years.

5.2 TRANSFER WATER PUMPS

Present Situation

As described in section 3.4, transfer water pumps and booster pumps are used to meet the domestic water needs of each block. The system is designed to transfer water from the water tank located at level 1 of each block to the roof top tank and provide water by gravity feed to all flats except the top 3 floors which are served by the booster pumps.

The transfer water pumps are operated based on water level of the roof top tank and operate intermittently.

Proposed Improvements

Energy savings can be achieved normally for pumping systems under the following conditions :

- Replacing over-sized pumps
- Eliminating unnecessary pressure losses (if there are devices such as globe valves or flow control valves installed)
- Variable flow pumping (if demand varies such as in central air-conditioning systems).

In this application, the water pumps are used only intermittently to transfer water from the ground floor tank to the roof top tank. There are also no devices which induce unnecessary pressure losses in the system. Therefore, reducing pump capacity or installing variable speed drives which will reduce the instantaneous power demand will not help as the pumps will need to operate for longer periods of time to meet the demand for water. Hence, it will result in no significant energy savings.

There are also energy saving devices in the market which claim to reduce the energy consumed by pumps and fans. These devices normally help to save energy by optimising the current and voltage drawn by motors in variable torque applications. However, for intermittent water pumping which is a constant torque application, the device has not been able to achieve energy savings.

Another possible energy saving strategy is to replace the pumps and motors with high efficiency units. The efficiency of the pumps ranges from about 55% to 62% (based on available pump specification data). These pumps can be replaced with higher efficiency pumps which have an efficiency of 65% to 70%.

Based on manufacturers' data, the power consumption for higher efficiency water pumps (65% to 70%) will be at least 10% lower than of the existing pumps.

Estimation of Savings and Cost

The amount of savings achievable can be estimated as follows:

% kWh Savings achievable = % of transfer pump energy consumption for blocks x estimated saving % achievable

Average transfer pump consumption for blocks = 9% (Figure 4.1)

Estimated average savings achievable = 10% (based on manufacturer data)

% savings achievable = 9% x 10%

= 0.9%

(therefore, for a typical HDB block, the electricity consumption can be reduced by 0.9% by using higher efficiency transfer water pumps)

Average annual electricity cost for transfer water pumps

= average annual electricity cost for blocks x average consumption % of transfer pumps

= $10,300 x 9%

= $927

Average annual savings

= average annual electricity cost for operating pumps x estimated savings % achievable

= $927 x 10%

= $93

The cost of a new pump is about $2,000. Since typically, HDB blocks have 2 pumps, the estimated total cost for a block is $4,000. Therefore, it would not be financially viable to replace the pumps to achieve energy savings. However, for new blocks or for existing blocks where pumps are to be replaced due to age, then only the incremental cost for the high efficiency pumps need to be considered.

The simple payback for such a scenario (based on incremental cost)

= (incremental cost for new pumps x number of pumps per block) / annual savings

= ($300 x 2) / $93

= 6.5 years. (Therefore, this measure is not recommended for general implementation)

5.3 BOOSTER PUMPS

Present Situation

As described in section 3.4, booster pumps are used to meet the domestic water needs of the top 3 floors of each block.

The booster pumps are operated based on water flow and use flow sensors installed on the supply pipe to trigger them. It is also noted (see schematic in Appendix C) that the piping system is designed to continuously bypass water from the discharge side of the pump to the water tank. This is probably done to prevent over-pressurising of the system due to over sizing of the booster pumps. Due to this, the pressure at the pump discharge of more than 1.4 bar is reduced to between 0.7 and 1.4 bar at the supply header indicating that it is possible to satisfy the water requirements of the flats by maintaining about 0.7 bar pressure at the supply header.

Further, it was found that the rated efficiency of the booster pumps varied between 49% and 76%. Measured data for pump motor power indicate (as expected) that pumps which lower efficiency (49%) consume more power than pumps selected with higher efficiency (76%).

Proposed Improvements

Improving pump efficiency

It is recommended to use pumps with higher rated efficiency (76% as used in some blocks) which will lead to lower motor power consumption. Although it is not financially viable to replace the existing low efficiency pumps with higher efficiency pumps purely based on energy savings, this recommendation can be implemented when replacing existing pumps and when selecting pumps for new blocks.

Reducing pump operations

As explained previously, bypassing of water back to the tank and lower header pressure (than at the pump discharge) also indicate that the capacity of the booster pumps is more than that necessary to meet the demand requirements. Therefore the capacity of the pumps can be reduced. This can be achieved by replacing the pumps with lower capacity ones or reducing the pump speed by using variable speed drives.

Estimation of Savings and Cost

Improving pump efficiency

As the achievable energy savings for this measure depends on the rated efficiency of each existing pump (some existing pumps have high rated efficiency), it is not possible to estimate the savings in general. However, some of the measured data indicate that the reduction in power consumption can be as high as 40%.

Reducing pump operations

The average daily energy consumption for the booster pumps is 13.4 kWh/day.

For the proposed system, when the pressure is reduced from 1.4 bar to 0.7 bar and the flow is reduced by more than 45% (eliminating water bypassing) the energy consumption of booster pumps is expected to reduce by more than 50%.

The amount of savings achievable can be estimated as follows:

% kWh Savings achievable = % of booster pump energy consumption for blocks x estimated saving % achievable

Average booster pump consumption for blocks = 6% (Figure 4.1)

Estimated average savings achievable = 50% (conservative estimate)

% savings achievable = 6% x 50%

= 3%

(therefore, for a typical HDB block, the electricity consumption can be reduced by 3% by optimising the operation of the booster pumps)

Average annual electricity cost for booster pumps

= average annual electricity cost for blocks x average consumption % of booster pumps

= $10,300 (from Table 3.1) x 6%

= $618

Average annual savings

= average annual electricity cost for operating pumps x estimated savings % achievable

= $618 x 50%

= $309

The cost of each installation for the proposed system is estimated to be about $1,700.

Therefore, the simple payback for this measure

= cost x annual savings

= $.1,700 / $309

= 5.5 years. (it is recommended to carryout a trail to further evaluate this measure as the achievable savings percentage may be much higher)

5.4 LIFTS

From the data collected, it is evident that the energy consumption by lifts is relatively high accounting for about 23% of the total usage. This is mainly due to the fact that they operate 24 hours a day. For lifts, energy is consumed by the lift motor, brake system, lights and fans. The lift motor generally consumes the most amount of power. However, under certain conditions, the lift motor operates in regenerative mode such as when the weight of the lift car and passengers is less than the weight of the counterweight when travelling up. It was also found that the lifts have an energy saving feature where the lights and fans are automatically switched-off when not used for a fixed period of time.

Although it is expected that lifts using newer types of drives such as variable voltage & variable frequency drives would use less electricity than lifts with older type of drives, the data shows that the average consumption does not vary very much between the different types of drives. However, the data does indicate that the energy consumption by lifts depend on the brand (some brands of lifts consume 60% more energy than others).

Therefore it is recommended to consider this finding when selecting lifts for new blocks and when replacing existing ones.

5.5 OTHERS

Following are some general recommendations that can be made based on the findings of the study :

- It was found that power is connected to CATV systems (central antenna for TV) in most blocks and consume about 70 to 100 W although most residents now have cable TV connections. Therefore, it would be possible to switch-off CATV systems in most blocks. If it can be switched-off, annual savings will be about 600 kWh (about 1% of consumption) which translates to $100/year in savings.
- Common area lighting is currently operated based on pre-set timers which normally switch-on lighting at 6.40pm and switch-off lighting at 7.00am. This timing is set to satisfy ambient lighting levels encountered during different periods of the year. However, if lighting is operated based on actual ambient lighting levels (using light sensors), it may be possible to reduce the operating hours of lighting.
- There are instances where lighting from different sources such as outdoor lamp post lighting, garden lighting and block lighting overlap in some areas resulting in higher than required lighting levels. This can be avoided if the effect of other nearby lighting sources are taken into account when designing specific lighting systems.
- Reduce the number of lamps from 3 to 2 per fixture for the market block (209).

5.6 RECOMMENDATIONS AND PROPOSED ACTION PLAN

The energy saving measures identified above together with recommendations for implementation are summarised in Table 5.4.

Measure	Cost & savings for a typical block			
	% savings	Estimated annual savings	Estimated cost	Simple payback (years)
Lighting (option d)	14%	$1,442	$3,400	2.4
Transfer water pumps	0.9%	$93	$600*	6.5*
Booster pumps	3%	$309	$1,700	5.5
Switching –off CATV	1%	$100	0	-

Table 5.4 Summary of recommendations

* incremental cost

Based on the above, the following recommendations can be made:

Lighting

The savings achievable by installing power saving devices for lighting is very attractive as they are able to reduce the lighting consumption by 35% and the total block consumption by 14%. Further, the financial payback based on the investment required is less than 2.5 years. Therefore, it is recommended to implement this measure immediately.

For MUP blocks using 28W lamps, it is recommended to replace them with 2ft T5 or T8 lamps (with new fixtures).

Transfer Pumps

For this measure, the savings achievable do not justify the cost of replacing the pumps with higher efficiency ones. Therefore, it is recommended to implement this measure when the existing pumps are upgraded as then, only the incremental cost for the higher efficiency pumps need to be incurred. This recommendation should also be considered when selecting pumps for new blocks.

Booster Pumps

Based on the conservative estimate of being able to reduce motor power by 50%, the financial payback period for this measure is not very attractive. However, the actual savings achievable can be much higher due to the reduction in flow capacity by 45% (elimination of by-passing). Therefore, it is recommended to undertake a trial to study the feasibility of this measure and to accurately estimate the savings possible. Thereafter, it can be decided whether to implement it for existing and new blocks.

Lifts

Since the study data indicate that certain brands of lifts consume significantly more energy than others, this finding should be considered when selecting lifts for new blocks and when replacing existing ones. In addition, it should be ensured that energy saving features and variable frequency drives are included when purchasing new lifts.

Other Measures

- CATV systems can be switched-off in blocks where all flats have cable TV connections. This will help to save about $100/year for each block without having to incur extra cost.
- Since data shows that use of lower wattage lamps (18W instead of 28W and 36W) for common area lighting results in reduced lighting energy consumption while maintaining lighting levels, it is recommended to use this type of lighting for new blocks and when retrofitting lighting in existing blocks. It is further recommended to evaluate the use of T5 lamps for the same application for new blocks and those being upgraded due to their higher efficacy.
- It is also recommended to reconsider the spacing between lamps when designing lighting to ensure that lighting energy consumption can be minimised while maintaining the required lighting (lux) levels.
- When designing lighting for outdoor applications, care should be taken to prevent overlapping of lighting from different sources.

5.7 BENCHMARKING DATA

The data collected for percentage consumption and average daily consumption per flat for the different users is summarised in Table 5.5. This data can be used as benchmarking data when evaluating the performance of systems for existing or new blocks.

Parameter	Overall	3/4/5 room (not upgraded)	3/4/5 room after MUP	3/4/5 room after IUP	Executive blocks	Other blocks
Lighting consumption	40%	38%	43%	41%	38%	63%
Lift consumption	23%	26%	23%	28%	30%	0%
Transfer pump consumption	9%	12%	7%	13%	12%	0%
Booster pump consumption	6%	8%	7%	9%	6%	0%
Average total daily consumption (kWh/flat)	1.72	1.68	1.5	1.37	1.96	1.41
Average daily lighting consumption (kWh/flat)	0.68	0.67	0.62	0.64	0.75	0.79
Average daily transfer pump consumption (kWh/flat)	0.15	0.18	0.1	0.15	0.24	0
Average daily booster pump consumption (kWh/flat)	0.11	0.12	0.1	0.1	0.12	0
Average daily lift consumption (kWh/flat)	0.4	0.43	0.34	0.35	0.58	0

Table 5.5 Benchmarking data

The above data can also be used for estimating savings potential for other blocks and in future for verification of savings.

6. CONCLUSIONS

- Energy audit of 40 sample HDB residential blocks was carried out over a 4-month period from March 2004 to June 2004.

- Consumption profiles for the blocks show that lighting, water pumps and lifts are the three main users of electricity.

- Possible energy saving measures were identified for common area lighting and pumps.

- It was found that about 14% savings can be achieved from the overall consumption by using power saving devices for common area lighting circuits. Based on the estimated savings and cost, the simple payback period for this measure is 2.4 years.

- Overall savings of about 1% can be achieved by improving the efficiency of transfer pumps. However, due to the cost of implementing this measure, it is recommended to consider it only when replacing existing pumps or when selecting pumps for new blocks.

- It is estimated that further savings of 3% can be achieved by reducing the capacity of booster pumps. It is recommended to carry out a trial to study the feasibility of this measure and to evaluate the actual savings achievable before implementing it.

- Savings of about 1% can also be achieved if CATV systems can be switched-off for blocks where all flats have cable TV connections.

- Based on the above, total energy savings of 14% to 19% can be achieved for HDB blocks. This translates to total savings of about 70,000 to 95,000 MWh/year for all HDB blocks in Singapore.

Appendix A - DATA PLOTS

Appendix B - DETAILS OF INSTRUMENTATION

Appendix C - **BOOSTER PUMP PLOTS**

Appendix D - LIGHTING DATA

Appendix E - **PHOTOGRAPHS**