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COMPARISON OF EXISTING AND NEWLY PROPOSED ELECTRICITY TARIFF AND REBATE SCHEMES IN HONG KONG

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ABSTRACT

Potential future cooling energy savings can be achieved through the use of incentives. This study proposes a new electricity tariff and rebate scheme to enhance the existing scheme in Hong Kong and encourage cooling energy savings during the summer months. In the study, the per–area cooling energy consumption for the public housing sector during the summer months (May to October) is benchmarked using a 5–star rating system to the determine its incentive level on the proposed tariff list. Under the proposed scheme, 5–star households will get a higher rebate rate while those with a star only will not receive any rebate. For the same amount of energy reduced, the application example demonstrates that the proposed scheme can save money as much as two times more than the existing scheme.

Keywords: electricity tariff, rebate schemes, cooling energy index, 5–star cooling energy consumption benchmarking system

NONMENCLATURE

Abbreviations	
m	May to October
Symbols	
λ_m	cooling energy index (kWh m^{-2})
$E_{c,m}$	monthly cooling energy consumption (kWh)
A_{fl}	apartment floor area (m^2)
$\tilde{\lambda}_m$	distribution of monthly cooling energy consumption
$\mu_{\lambda,m}$	estimators of mean
$S_{d,\lambda,m}$	standard deviation
$B_{m,i}$	cooling energy consumption benchmark
λ	cooling energy indices (kWh m^{-2})

1. COOLING ENERGY OUTLOOK FOR PUBLIC HOUSING DEVELOPMENT

Hong Kong's population is projected to increase to over 8 million by year 2021. To house the growing population, expanding public housing is inevitable. Hence, promoting cooling energy conservation in public housing can be a simpler way to a greener future. Table 1 summarizes the annual cooling energy use projections for the additional public housing units needed to accommodate 600,000 residents in 2021 (taking existing public housing characteristics with an annual cooling demand of 1044TJ yr^{-1} as a base case) and the potential energy savings in terms of building materials, constructions and occupant behaviours (Cheung *et al.* 2014).

2. BENCHMARKING WITH COOLING ENERGY INDEX

In view of the limitations of existing energy saving rebate method, a modified scheme that takes cooling energy savings into account is suggested. As presented in Eq. (1), a cooling energy index λ_m (kWh m^{-2}) determined from the monthly cooling energy consumption $E_{c,m}$ (kWh), for m = May to October, and the apartment floor area A_{fl} (m^2) is proposed for benchmarking household cooling energy use. The energy consumption is normalized by the floor area to ensure a fair rebate rate for both large and small flat sizes. A higher value of λ indicates more cooling energy demands in the corresponding apartment.

$$\lambda_m = \frac{E_{c,m}}{A_{fl}} \tag{1}$$

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Taking $\lambda_{m,j}$ as a representative value of cooling energy demands for an apartment j from all public housing flat samples, and $\tilde{\lambda}_m$ as the distribution of monthly cooling energy consumption for the public housing sector with $\mu_{\lambda,m}$ and $S_{d,\lambda,m}$ as the estimators of mean and standard deviation respectively for the index, the cooling energy consumption benchmark $B_{m,i}$ for the i–th apartment is expressed by Eq. (2). An apartment with $B_{m,i}$ ≤ 1% has the lowest cooling energy consumption, while that with $B_{m,i}$ = 100% has the highest.

$$B_{m,i} = \int_{-\infty}^{\lambda_{m,i}} \tilde{\lambda}_m d\lambda_m \quad ; \quad \tilde{\lambda}_m \sim \tilde{\lambda}_m\left(\mu_{\lambda_m}, S_{d,\lambda_m}\right) \quad (2)$$

2.1 A 5–star cooling energy consumption benchmarking system for the public housing sector in Hong Kong

A simple and easily understood 5–star cooling energy consumption benchmarking system is recommended. Following the assessment criteria for a continuous benchmarking parameter by Blume (1998), the top 10% flat samples (i.e. with $B_{m,i}$ ≥ 0.9) are awarded 1 star in the system, the next 22.5% (i.e. with 0.675≤ $B_{m,i}$ <0.9) 2 stars, the next 35% (i.e. with 0.325≤ $B_{m,i}$ <0.675) 3 stars, the next 22.5% (i.e. with 0.1≤ $B_{m,i}$ <0.325) 4 stars and the remaining 10% (i.e. with $B_{m,i}$ < 0.1) 5 stars. The corresponding benchmark values $B_{m,i}$ of the cooling energy consumption findings by Cheung (2015) for the public housing sector in Hong Kong are summarized in Table 2.

3. DESCRIPTION OF A NEW ELECTRICITY TARIFF AND REBATE SCHEME WITH COOLING ENERGY REDUCTION INCENTIVES

An effective strategy for reducing total residential cooling energy consumption is to offer incentives to encourage residential consumers to save energy on air conditioning. Table 3 shows the current electricity tariff and rebate scheme for the residential sector in Hong Kong (CLP 2015). The tariff is based on bimonthly meter–readings and increasingly higher prices will be charged as consumption levels rise. The rebate is only applicable to a bill with total bimonthly consumption of 400 units or less. There is also a minimum charge of HK$36 for each bill. Obviously, incentives to reduce cooling energy use during the summer months are not available.

A new electricity tariff and rebate scheme, as shown in Table 3, is thus proposed to offer cooling energy conservation incentives throughout the summer. In the new scheme, the consumption charge is changed from bimonthly to monthly and the number of energy units for each rate is halved. Moreover, the energy saving rebate levels are star–rated: 1 star for no incentive, 2 stars for excluding the minimum charge per bill (HK$18), 3 stars for 5 cents per unit (i.e. 1 kWh) on total consumption, 4 stars for 10 cents per unit on total consumption, and 5 stars for 20 cents per unit on total consumption.

The cooling energy index λ_m for each summer month, determined via Eq. (1), is compared with the benchmark values in Table 2 for star–rating level matching. The corresponding rebate rates can then be obtained using the newly proposed star–rating incentives listed in Table 3. Assuming that electricity used for space heating in summer is negligible in all public rental apartments because of the sub-tropical climate in Hong Kong (HKO 2014), the electricity used for cooling in each summer month $E_{c,m}$, which is the difference between total electricity used that month E_m and average electricity used from last November to April E_{N-A_ave} as shown on the latest electricity bill, can be predicted using Eq. (3).

$$E_{c,m} = E_m - E_{N-A\_ave} \quad ; \quad \begin{cases} m = May \quad to \quad Oct \\ E_{N-A\_ave} = \dfrac{\sum_{m=Nov}^{Apr} E_m}{6} \end{cases} \quad (3)$$

3.1 Application example for the proposed energy saving rebate scheme

To demonstrate the application of the cooling energy consumption benchmarking system, a household with an apartment floor area of 39.3m^2 and an electricity usage profile showing monthly totals (kWh) from January to December (i.e. 380, 390, 390, 410, 510, 600, **750, 760,** 580, 520, 420, 410) can be used as a case study. According to the profile, the average electricity usage is 400 kWh per month from November to April. Taking the electricity consumed in the months of July and August as the base case scenario, the corresponding cooling energy demands (kWh), cooling energy indices λ (kWh m^{-2}), star ratings, charges by the proposed scheme (HK$), and the calculated charge difference (HK$) between the existing and the proposed schemes are summarized in Table 4. A flow diagram demonstrating the calculations for Test 2 is illustrated in Figure 1.

In the base case scenario as shown in Table 4, the star ratings for both July and August are 1, i.e. no incentives, and hence there is no charge difference between the existing and the proposed schemes. For Test 1, the electricity consumption values for July and August are both reduced to 700 kWh for a 2–star rating. As the minimum charge per month (HK$18.0) can be excluded in this case, the charge difference is HK$36. In Test 2, the electricity consumption values for July and August are 650 kWh (a 4–star rating) and 670 kWh (a 3–star rating) respectively. In other words, the rebates in July and August are '10 cents per unit on total consumption' and '5 cents per unit on total consumption' respectively, giving a sum of HK$135 and thus a charge difference of the same amount. Detailed calculation procedures for this test are exhibited in Figure 1. In Test 3, the electricity consumption values for July and August are 600 kWh (a 5–star rating) and 620 kWh (a 5–star rating) respectively. As the rebate for a 5–star rating is '20 cents per unit on total consumption', the calculated charge difference is HK$280.

Furthermore, for an average cooling energy reduction of 145 kWh in each month, the existing scheme can save HK$318 (21.4% of the primary charge) while the proposed scheme can save HK$599 (40.4% of the primary charge).

4. CONCLUSION

This study proposed a new electricity tariff and rebate scheme to enhance the existing scheme in Hong Kong and encourage cooling energy savings during the summer months. In the study, the per–area cooling energy consumption for the public housing sector during the summer months (May to October) was benchmarked using a 5–star rating system to the determine its incentive level on the proposed tariff list. Under the proposed scheme, 5–star households will get a higher rebate rate while those with a star only will not receive any rebate. For the same amount of energy reduced, the application example demonstrated that the proposed scheme can save money as much as two times more than the existing scheme.

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Table 1 **Cooling energy use projections for additional public housing units in year 2021**

Case		Conditions	Annual Cooling Energy Ec (TJ yr^{-1})
Base case		➢ 600000 occupants ➢ *Indoor air temp.* = 23°C; Outdoor air temp. as per 1989 weather data ➢ *U value of wall,* U_{wl} =2.2–2.9 W $K^{-1}m^{-2}$ (heavy concrete) ➢ *U value of window*, U_{wd} =5.6–6.9 W $K^{-1}m^{-2}$; S_c = 0.9–0.97 (clear glazing) ➢ Flat sizes same as 'the existing case', Total area = 7379745m^2 ➢ Using existing public housing AC operation schedule	1044
		Materials	
External wall and window materials alternatives	(a)	U_{wl} = 0.7–1.5 W $K^{-1}m^{-2}$ (lightweight concrete)	984 (–5.7%)
	(b)	U_{wd} = 4.2–5.7 W $K^{-1}m^{-2}$, S_c = 0.53–0.8 (tinted glazing)	981 (–6.0%)
	(c)	Both of the above	910 (–12.8%)
		Constructions	
Window area and vertical shading angle (σ_v) reductions	(a)	10% window reduction	1030 (–1.3%)
	(b)	20% window reduction	1017 (–2.6%)
	(c)	σ_v of 68.5° (i.e. 0.75m overhang extension)	1031 (–1.2%)
	(d)	σ_v of 62.2° (i.e. 1m overhang extension)	1021 (–2.2%)
	(e)	20% window reduction + σ_v of 57.0° (1m extension)	988 (–5.4%)
Flat size variations	(a)	All small flats (< 30m^2) (9045045m^2)	1330 (27.4%)
	(b)	All medium flats (30m^2–50m^2) (6955829m^2)	953 (–8.7%)
	(c)	All large flats (>50m^2) (5785459m^2)	909 (–12.9%)
		Occupant behaviours	
Outdoor and indoor temperature (T_a) variations	(a)	T_a = 22°C; T_o increased by 1°C	1263 (20.1%)
	(b)	T_a = 24°C; T_o unchanged	806 (–22.8%)
	(c)	T_a = 24°C; T_o increased by 1°C	997 (–4.5%)
	(d)	T_a = 26°C; T_o unchanged	591 (–43.4%)
	(e)	T_a = 26°C; T_o increased by 1°C	765 (–26.7%)
Cooling energy saving awareness	(a)	Low energy saving AC schedule	1104 (5.8%)
	(b)	Medium energy saving AC schedule	825 (–21.0%)
	(c)	High energy saving AC schedule	697 (–33.1%)
Hour(s) reduction with AC timer	(a)	1 hour reduction	992 (–4.9%)
	(b)	2 hours reduction	944 (–9.5%)
	(c)	3 hours reduction	932 (–10.7%)

Table 2 **Benchmarks with star ratings of the cooling energy consumption findings by Cheung (2015) for the summer months**

Star rating	Benchmark value	May	Jun	Jul	Aug	Sep	Oct
★★★★★	$B_{m,i} < 0.1$	$\lambda_{may} \leq 1.48$	$\lambda_{jun} \leq 3.90$	$\lambda_{jul} \leq 5.61$	$\lambda_{aug} \leq 5.72$	$\lambda_{sep} \leq 4.66$	$\lambda_{oct} \leq 2.24$
★★★★	$0.1 \leq B_{m,i} < 0.325$	≤ 1.72	≤ 4.40	≤ 6.37	≤ 6.46	≤ 5.08	≤ 2.47
★★★	$0.325 \leq B_{m,i} < 0.675$	≤ 2.00	≤ 4.95	≤ 7.21	≤ 7.27	≤ 5.53	≤ 2.73
★★	$0.675 \leq B_{m,i} < 0.9$	≤ 2.25	≤ 5.46	≤ 7.97	≤ 8.01	≤ 5.95	≤ 2.96
★	$B_{m,i} \geq 0.9$	> 2.25	> 5.46	> 7.97	> 8.01	> 5.95	> 2.96

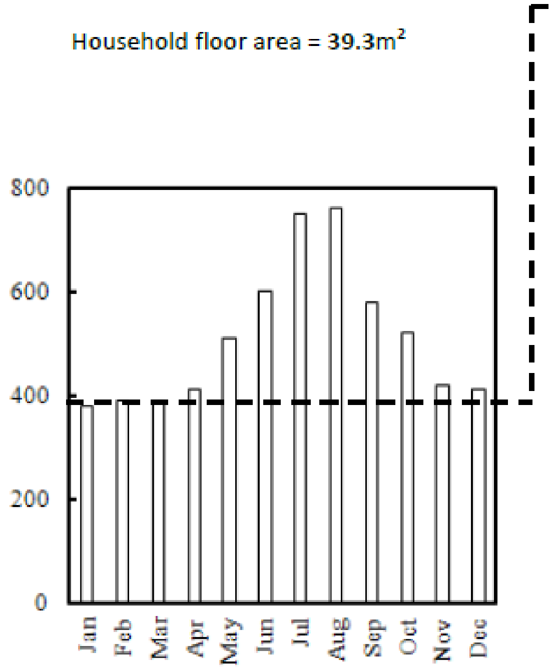
Table 3 **Existing and newly proposed electricity tariff and rebate schemes**

Electricity Charge (existing)		**Energy Saving Rebate (existing)**	
Bimonthly consumption per apartment	Rate (Cents/Unit)	Consumption range	Incentive description
Each of the first 400 units	80.5	1–200 units	17.2 cents per unit on total consumption
Each of the next 600 units	93.9	201–300 units	16.2 cents per unit on total consumption
Each of the next 800 units	109.7	301–400 units	15.2 cents per unit on total consumption
Each of the next 800 units	140.5	> 400 units	No incentive
Each of the next 800 units	163.4		
Each of the next 800 units	173.8		
Each unit over 4200	175.0		
Electricity Charge (newly proposed)		**Energy Saving Rebate (newly proposed)**	
Monthly consumption per apartment	Rate (Cents/Unit)	Star rating	Incentive description
Each of the first 200 units	80.5	★★★★★	20 cents per unit on total consumption
Each of the next 300 units	93.9	★★★★	10 cents per unit on total consumption
Each of the next 400 units	109.7	★★★	5 cents per unit on total consumption
Each of the next 400 units	140.5	★★	Excluding the minimum charge per bill (HK$18)
Each of the next 400 units	163.4	★	No incentive
Each of the next 400 units	173.8		
Each unit over 2100	175.0		

Note: 1 Unit = 1 kWh

Table 4 **Comparison of electricity charges by CLP and the proposed scheme**

Case	**Month**	**Electricity consumption (kWh)**	**Cooling energy demand (kWh)**	**Cooling energy index, λ (kWh m^{-2})**	**Star rating**	**Original charge (HK$)**	**Proposed charge (HK$)**	**Charge difference (HK$)**
Base	Jul	750	350	8.91	★	1481	735	0
	Aug	760	360	9.16	★		746	
Test 1	Jul	700	300	7.63	★★	1360	662	36
	Aug	700	300	7.63	★★		662	
Test 2	Jul	650	250	6.36	★★★★	1272	542	135
	Aug	670	270	6.87	★★★		596	
Test 3	Jul	600	200	5.09	★★★★★	1163	432	280
	Aug	620	220	5.60	★★★★★		450	



Step 1:
Calculates average electricity consumption by Eq. 3, from November to April

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Step 2:
Cooling electricity demands in Test 2
Jul : 650 – 400 = 250kWh
Aug : 670 – 400 = 270kWh

↓

Step 3:
Calculates cooling energy index by Eq. 1
Jul : 250 / 39.3 = 6.36kWh m^{-2}
Aug : 270 / 39.3 = 6.87kWh m^{-2}

↓

Step 4:
Check benchmarking value for star–rating
Jul : ★★★★
Aug : ★★★

↓

Step 5:
Check incentives from the newly proposed energy saving rebate scheme in Table 2
Jul : 10 cents per unit rebate
Aug : 5 cents per unit rebate

↓

Step 6:
Calculates electricity charge corresponding to the awarded incentives

Jul :
Original electricity charge
200×0.805 + 300×0.939 + 150×1.097 + 18 (min. charge)
= 625.2 HK$

With 10 cents per unit rebate
200×0.705 + 300×0.839 + 150×0.997 (no min. charge)
= 542.2 HK$

Aug:
Original electricity charge
200×0.805 + 300×0.939 + 170×1.097 + 18 (min. charge)
= 647.2 HK$

With 5 cents per unit rebate
200×0.755 + 300×0.889 + 170×1.047 (no min. charge)
= 595.7 HK$

Figure 1 Application procedures for proposed energy saving rebate scheme