ENERGY AND ECONOMIC ANALYSES OF DISTRICT COOLING ICE THERMAL STORAGE SYSTEMS IN MALAYSIA

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Abstract
As a result of rapid economic growth in Malaysia, usage of air-conditioning equipments has become a necessity for household, shopping complexes and offices. Constitute approximately 60 to 70 percents of total electricity usage in commercial buildings; air conditioning systems have posed challenges to Heating Ventilation and Air-Conditioning (HVAC) engineers and designers to find solutions to minimize usage of air-conditioning energy and costs without sacrificing the thermal comfort. This dissertation focuses on selecting and carrying out economic analyses on the type of air-conditioning systems that provides minimum costs for the same cooling conditions. Three types of air-conditioning system were used for comparison, district cooling ice thermal storage system or DCSITSS (full and partial storage), conventional chillers, and package unit systems. Due to current government incentives by offering a cheaper electricity tariff and no maximum demand charge at night (off-peak period), DCSITSS partial storage system proves to be the most economical air conditioning system. A set of chilled water supply tariff was also determined and the results reflect that not only DCSITSS partial storage plant can be commercialised in Malaysia but also its economic gains were quite attractive as the capacity of DCSITSS plant increases.

Keywords: District Cooling Ice Thermal Storage System (DCSITSS), Full and Partial Storage, and Life Cycle Cost

1.0 Introduction
Malaysia, being a hot and humid country all year round, would require air-conditioning systems for creating thermal comfort zone. As an important entity in daily life, air-conditioning equipment in any commercial sectors consume approximately 60% to 70% of the total electricity consumption (Ministry of energy, water and communication, 2006).

There are several types of air of air-conditioning system presently used in Malaysia. Most promising type is ice thermal storage system (ITSS). ITSS shift the maximum running of electricity from peak period to off-peak period normally at night. This paper will analyze the life cycle cost and energy of District Cooling ITTS compare with centralized chiller and package units. Then the chilled water supply tariff determination for the District Cooling Ice Thermal Storage System (DCSITSS) of the potential commercial service provider and economic analyses of DCSITSS plant at higher cooling capacity upon applying the chilled water supply tariff and determination of minimum DCSITSS plant capacity for potential commercialization.

An ice thermal storage air conditioning system (ITSS) or simply a thermal storage system (Wang, 2000), consist of central plant, a chilled water or brine system incorporated with a thermal storage system, a hot water system, an air system including AHUs, terminals, return air system, smoke control systems and mechanical exhaust systems. In addition the electric driven refrigeration compressors in the central plant are operated at off-peak and on-peak hours. According to Pacific Gas and Electric Company (1997), ice thermal storage system is most suitable when:

a) The buildings' peak cooling load is much higher than the average daily cooling load and occurs only during a short period. This situation is most suitable in Malaysia.
b) The electric service providers impose higher demand charges

c) Low electric charges during off-peak period as currently in Malaysia.
d) Potential buildings expansion. This situation fits district cooling scenario.

2.0 Research Methodology

In order to carry out the feasibility studies on the implementation of DCSITSS plants in Malaysia, some engineering calculations were carried out in developing the hypothetical plants equipment's', capacities and input power. Some data from an existing district cooling ice storage and centralized chillers plants were used for the calculations.
Hypothetical buildings were created for comparisons between four types of air conditioning systems. The equipment's' capacities will be calculated based on the hypothetical building cooling loads. The list of the buildings is shown in Table 2.1.Each floor cooling load is estimated to be 0.2 kWr/m^2 (60 Btu/hr/ ft^2) (Bell, 2002). Each office floor is estimated to be 1750 m^2 per floor (William et al. 2003).

	Building A (No. of Floor)	Building B (No. of Floor)	Building C (No. of Floor)	Building D (No. of Floor)	Building E (No. of Floor)	Total
Capacity (ton)	3,500 (37)	2,700 (29)	4,000 (42)	750 (8)	6,000 (63)	16,950

Table 2.1: Cooling capacities of the hypothetical buildings used in the analyses

2.1 Air conditioning plant configurations

The following are the hypothetical plants used for energy and life cycle cost comparisons.

2.1.1 DCSITSS full and partial storage system

DCSITSS plant is divided into mode; full and partial storage system. For full storage system, the entire daily cooling load requirements are provided by the stored ice. The chillers charge the ice only at night during the off-peak period i.e. 9 p.m. to 8 a.m. on the following day. As for partial storage system, load leveling mode will be employed with the chillers and their auxiliary equipment's are operating for 24 hours a day. The chillers will charge the ice during off–load period i.e. 6 p.m. to 8 a.m. and they provide direct cooling during the on-load period i.e. 8 a.m. to 6 p.m. The additional load during the on-load period will be handled by the ice. The type of storage system is an encapsulated ice storage system which is similar to 'Pantai District Cooling. The advantages of the configurations for partial storage system are the chiller will be operating with highest possible evaporating temperature with higher COP. The plant configuration for the full and partial storage system showed as below:

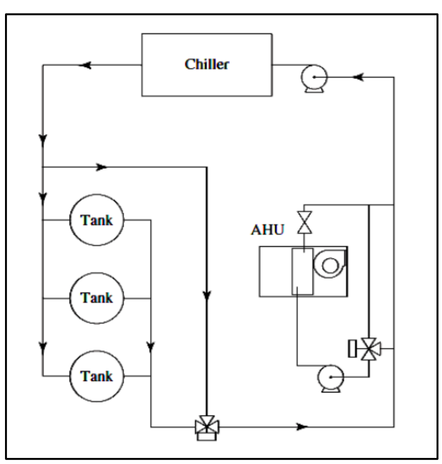


Figure 2.2: Full and partial storage configuration (Wang, 2000)

2.1.2 Centralised chillers system

The centralised chillers system used of centrifugal types with the efficiency of 0.147 W/kWr (0.65kW/ton) (similar to 'Pantai District Cooling'). The chillers will only be operated during the on-load period i.e 8 a.m to 6 p.m. Every building provided with multiple chillers connected in parallel. Every floor of the buildings will be served by 2 numbers of air-handling units. The capacity of every AHU is half of the floor capacity.

2.1.3 Package units system

Two number of package units will serve every floor of the buildings. Therefore the capacity of each package unit will be equal to the capacity of the AHU in the centralised chillers system.

2.2 Energy usage of the systems

Prior to calculating the energy consumption of the air conditioning systems, their input powers being calculated and their energy consumptions will be compared based on:

1. Total energy consumed per month in kWhr.
2. Total energy used during peak period i.e. 9 a.m. to 9 p.m. in kWhr.

2.3 Life cycle cost calculations

Life cycle cost used in these studies is equal to capital cost plus running cost involved during the equipments life span. The capital cost is considered to be total equipments and buildings constructions' loan repayment during the life span of the equipments whereas for the running cost is the electricity, rental of land or spaces for the equipments usage, maintenance and labour costs. The total equipments and buildings' costs for full and partial storage systems were based on 'Pantai District Cooling' plant cost. For centralised chillers system and consumers' buildings air handling units were based on the contract prices of 'Institute Bioscience' at Universiti Putra Malaysia (UPM, 2003). The package units system was based on the quotation by an air conditioning contractor in Malaysia.

The electrical costs were taken from the data provided by 'Pantai District Cooling'. For the maintenance and labour cost, the data were taken either from 'Pantai District Cooling' or schedule of maintenance of Universiti Teknologi Malaysia (UTM, 2004). The life cycle costs were further divided by the equipments capacities and lifespans in order to compare their life cycle cost per ton per year. For life cycle cost analyses of DCSITSS at higher capacities, only the capital costs and running costs of DCSITSS inclusive of their consumers' buildings were calculated. Higher capacities for centralised chillers and package units systems translate to additional buildings rather than increase in equipments' sizes whereas for DCSITSS plant, higher capacities translate to increase in equipments sizes. The higher capacities used for DCSITSS plant are 77,900 kWr (20,500 ton), 87,750 kWr (25,000 ton), 105,300 kWr (30,000 ton), 122,850 kWr (35,000 ton) and 140,400 kWr (40,000 ton).

2.4 Tariff determination

Tariff structures were determined from both DCS plant and consumers' buildings and their tariffs were compared. If the tariff calculated from the consumers' buildings are higher than the tariff calculated from the DCS plant, then the DCS plant has the potential for commercialisation in Malaysia and vice versa.

2.4.1 Tariff structure for consumers' buildings

The expenditure differences per year between the usage of the conventional chillers and the district cooling for the consumers' buildings were calculated. The amount calculated is the amount the consumers will be willing to pay to the district cooling operator for the chilled water usage. By imposing the chilled water charges (unit tariff plus capacity charge), the expenditure incurred on the consumers must be smaller than expenditure incurred in using the conventional chillers systems. Otherwise, it might be economical for them to utilise the conventional chillers systems. The calculated amounts were further divided by 12 months and deducted from the monthly capacity charge. The resulted amounts i.e. tariff per month were finally divided by amount of usage in ton-hour per month. Its unit is in RM/RThr.

2.5 Economic analyses of DCSITSS plant at higher capacities

The analyses involved at higher capacities of DCSITSS plant are:

1. Life cycle cost between DCSITSS and centralised chiller system.
2. Return of investments.
3. Payback periods.
4. Real net saving per year.

3.0 Results and Discussion

The results on the energy and economic analyses of district cooling ice thermal storage systems (DCSITSS) were based on hypothetical buildings' cooling loads. Tariff determination and higher cooling capacities were also imposed on DCSITSS to study their economic performances for potential commercialization in Malaysia. The cost efficiency curves were analyzed and compared with other HVAC system currently installed in Malaysia. With thorough energy and cost analyses each system capital (fixed) and running costs shows as in table 3.1 and figure 3.2, 3.3, 3.4 and 3.5 below:

		DCSITSS Partial storage	DCSITSS Full storage	Centralized Chillers	Package Units
System capacity	kWr (RT)	59495 (16,950)	59495 (16,950)	59495 (16,950)	59495 (16,950)
A. Electricity usage					
On-peak energy consumption	Kwhr/day	138524	81798	163711	266465
Off-peak energy consumption	Kwhr/day	76327	201827	-	-
Max demand	Kw/Month	12647	8448	16371	26646
Total energy consumption	Kwhr/day	214851	283625	163711	266465
B. Capital Cost					
Equipment Price	RM	87357514	103090294	89326500	45890556
Building cost	RM	21043673	37945296	-	-
Total Capital Cost	RM	108401187	141035590	89326500	45890556
C. Running cost					
Building rental	RM/ Month	25272	25272	101088	466349
Maintenance	RM/Year	1846438	3804541	2626088	2081905
Electrical Cost	RM/Month	1430904	1394590	1432467	2331567
Total Running Cost	RM/Year	19320555	20842883	21028754	35656895

a- building rental represent opportunity cost for mechanical plant room allocation in the respective buildings

Table 3.1: Electricity usage, capital and running costs for the air conditioning systems

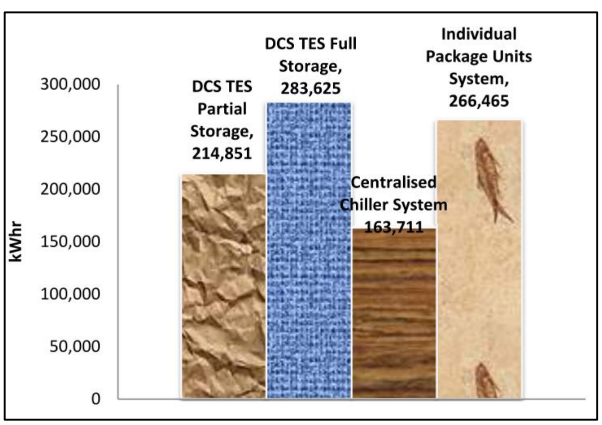


Figure 3.2: Electricity consumption per day (kWhr) for the systems

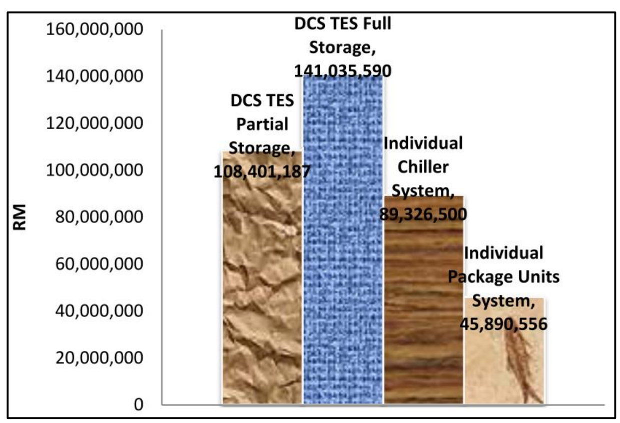


Figure 3.3: Capital costs for the systems

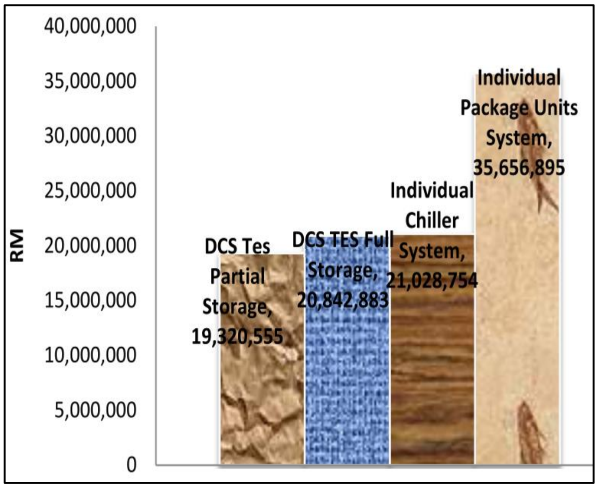


Figure 3.4: Total running cost per year for the systems

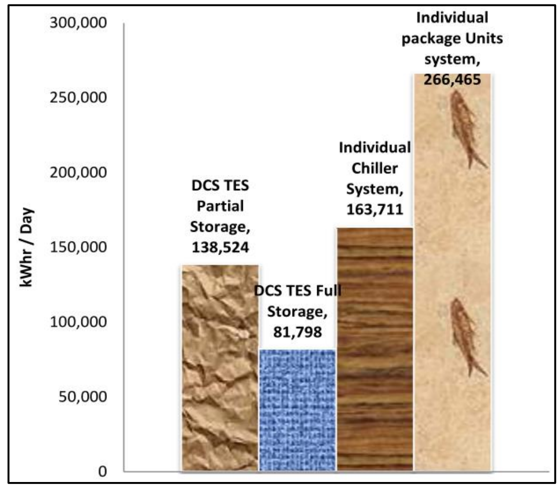


Figure 3.5: Energy usage during on-period per day for the systems

3.1 Capital and running costs analyses of the system

Before the systems selection, cost efficiency of life cycle cost (LCC) was presented and the table 3.6 and figure 3.7 shows as below.

Description	Value	DCSITSS (Part Storage)	DCSITSS (Full Storage)	Centralized Chillers	Package units
CPI 2007	1.05				
CPI 2005	0.98				
Discount factor	0.04				
PWF for 20 years	14.20				
PWF for 15 years	11.51				
Bank interest per year	0.07				
CRF for 10 years	0.14				
CRF for 20 years	0.09				
CRF for 15 years	0.11				
Equipments life span	Yrs	20	20	20	15
Yearly loan repayment		10232305.23	13312761.93	8431789.68	5038536.32
Total loan repayment during equipments life span		204646104.60	266255238.62	168635793.63	75578044.87
Operating cost x life span		86411095.26	416857669.01	520575075.53	534853428.57
LCC		591057199.85	683112907.64	589210869.15	610431473.44
LCC per year		29552859.99	34155645.38	29460543.46	40695431.56
LCC per year per kwr (RT)		496.7 (1743.53)	574.1 (2015.08)	495.2 (1738.09)	684.0 (2400.91)

Table 3.6: Life cycle cost per year per RTon for the systems

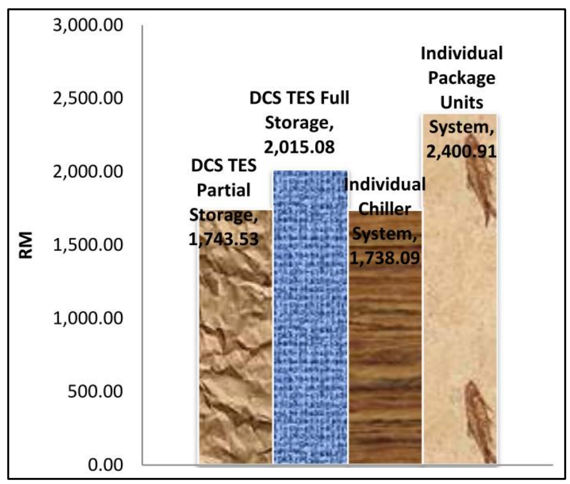


Figure 3.7: Life cycle cost (RM) per year per RTon for the system

For full storage system, the daily electricity consumption is 73% and 6% higher than centralised chillers and package units systems respectively and for partial storage system; it's 31% higher than centralised chillers system and 19% lower than package units systems respectively. Full and partial storage systems consume higher energy than centralised chillers system due to its extra pumps used (glycol pumps) and lower chillers COP when use for ice making at night. However, their consumption is still much lower than package units system.

However, for full storage system its on-peak energy consumption is 50% and 69% lower compared to centralised chillers and package units systems and for partial storage system, its on-peak energy consumption is 15% and 48% lower compared to centralised chillers and package units systems. Chillers for full storage system are only operated during the off-peak period while for partial storage system, the chillers operation are divided equally between on and off-peak periods. For the capital costs, full storage system is 57% and 207% higher than centralized chillers and package units systems. For partial storage system, it's 21% and 136% higher than centralised chillers and package units systems respectively. This is again due to extra equipments required such as brine pumps, ice tanks, heat exchangers and additional pumps at the consumers' buildings. Package units system proved to be the lowest due to its simplicity. Total running costs for full storage system is 1% and 42% lower than centralized chillers and package units systems respectively.

For partial storage system, it's 8% and 46% lower than centralised chillers and package units systems respectively. The reason is due to the lower time of use (TOU) electricity tariff at night and reduced maximum demand electricity consumption during the on-peak period. As mentioned before, full storage chillers are only operated at night while partial storage chillers capacities are smaller compared to centralised chillers. Part of the ice stored is used to cool the buildings during the on-peak period.

Finally for the life cycle costs, full storage system is 16% higher and 16% lower than centralised chillers and package units systems respectively and for partial storage system; it is 0.3% higher and 27% lower than centralised chillers and package units systems respectively. Total running cost for full storage system which is lower by 1% cannot compensate its capital cost which is 57% higher than centralised chillers system. However for partial storage system, its capital cost which is higher by 21% is compensated by its running cost which is 8% lower than centralised chillers system.

Based on the above analysis, centralised chillers system consumes the lowest energy consumption (kWhr) compared to the other air conditioning systems studied. However, DCSITSS consumed the least energy during on-peak period. Whereas DCSITSS partial storage system is the least running cost compared to the others. Further, DCSITSS partial storage system life cycle cost is almost equal to the centralised chillers system. Both being the lowest life cycle cost compared to the DCSITSS full storage and package units systems.

DCSITSS partial storage system is selected to be the suitable air conditioning system to be implemented in Malaysia due to:

1) Its life cycle cost is almost equal to centralised chillers system i.e. 0.3% higher than centralised chillers system. Both are being the lowest compared to DCSITSS full storage and package units systems.
2) Lower on-peak energy consumers. The system is 15% and 48% lower than centralised chillers and package units systems respectively.

Even though centralised chillers system is the lowest energy consumer, its energy consumption occurs during the on-peak period which will incur additional load on power plants for any new commercial building construction. From the studied systems, it can be also concluded that the centralised chiller system is the next efficient cooling system in Malaysia. In the next sub-chapter, potential DCSITSS (partial storage) to be a general utility service provider calculated and centralised chillers system used as comparison.

3.2 DCSITSS partial storage and consumers' buildings supply cooling tariff

The calculated tariffs are presented in table below. The tariff calculated on the DCSITSS plant is lower than the tariff accepted by the buildings. For instance, the calculated tariff form the DCSITSS plant is RM 0.19 per RThr whereas the lowest tariff accepted by the consumers' buildings is RM 0.20 per RThr for office E. Therefore, DCSITSS plant is feasible to be implemented as a commercial district cooling utility service provider. Furthermore, the consumers' buildings expenditures will be reduced by approximately RM17,000.00 to RM23000.00 per month or 2% to 6% in using the chilled water supplied by the DCSITSS plant as compared to using centralised chillers system.

Some economic analyses such as payback periods, return of investment, net saving etc. presented for DCSITSS partial storage systems at various capacity as table 3.8 below.

		DCSITSS	Office A	Office B	Office C	Office D	Office E
Capacity charge	RM/month kWr (RT)	14.25 (50.00)	-	-	-	-	-
Supply chilled water tariff	RM/kWrHr (Tonhr)	0.05 (0.19)	-	-	-	-	-
Minimum acceptable tariff by buildings	RM/kWrHr (Ton hr)		0.06 (0.22)	0.07 (0.23)	0.06 (0.22)	0.09 (0.32)	0.05 (0.20)
Expenditure using centralized chillers system	RM/year		6050212.08	4745416.2	6871090.97	1592582.61	10201241.61
Expenditure using supplied chilled water	RM/year		5782050.60	4468685.02	6611590.22	1337612.61	9998203.23
Saving for using supplied chilled water	RM/Year		268161.48	276731.18	259500.75	254970.00	203038.38

Table 3.8: Supply chilled water tariff from DCSITSS plant and its consumers' building

3.3 Economic analyses for DCSITSS plant at various capacities

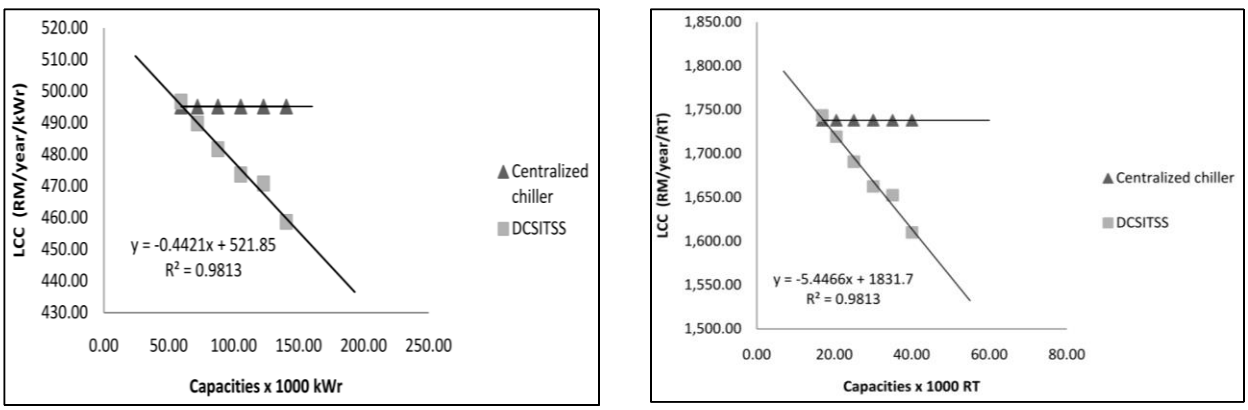
Life cycle cost, payback period, net saving and return of investment presented in tabular and graphical forms. These analyses are to be carried out to determine DCSITSS partial storage's potential as a utility service providers in Malaysia. Life cycle costs are presented in graphical format between DCSITSS partial storage system and centralised chillers system. Summary of economic analyses carried out on DCSITSS plant at various capacities showed in table 3.8 and figure 3.9, 3.10, 3.11 and 3.12 below.

System capacity	**RT (kWr)**	**16,950 (59494)**	**20,500 (71955)**	**25,000 (87750)**	**30,000 (105300)**	**35,000 (122850)**	**40,000 (140400)**
Plant life span	**Years**	20	20	20	20	20	20
A. Electricity usage inclusive of consumers' buildings							
On-peak energy consumption	kWhr/day	138524	170440	209767	252287	298830	335992
Off-peak energy consumption	kWhr/day	76327	92312	112576	135091	157606	169441
Max demand	kW/Month	12647	15586	19198	23094	27393	30932
Total energy consumption	kWhr/day	214851	262753	322343	387378	456437	505433
Unit energy consumption	kW/RT (kWr)	12.68 (3.61)	12.82 (3.65)	12.89 (3.67)	12.91 (3.68)	13.04 (3.72)	12.64 (3.60)
Off-peak to total electricity	%	35.53%	35.13%	34.92%	34.87%	34.53%	33.52%
B. Capital Cost							
Equipment Price	RM	40,248,579	45,112,931	50,817,434	56,691,961	62,185,561	67,372,820
Building cost	RM	21,043,673	23,586,964	26,569,521	29,640,975	32,513,263	35,225,383
Total First Cost	RM	61,292,252	68,699,895	77,386,956	86,332,936	94,698,824	102,598,203
C. Running cost							
Maintenance	RM/Year	1,308,666	1,467,385	1,660,377	1,866,573	2,066,001	2,259,986
Electrical Cost	RM/Month	926,439	1,120,472	1,366,430	1,639,716	1,913,002	2,062,481
Total Running Cost	RM/Year	2,235,105	2,587,857	3,026,807	3,506,289	3,979,003	4,322,468
D. Tariff							
Capacity charge	RM/kwr (RT) month	14.25 (50.00)	14.25 (50.00)	14.25 (50.00)	14.25 (50.00)	14.25 (50.00)	14.25 (50.00)
Supply chilled water tariff	RM/kWr (Ton hr)	0.054 (0.19)	0.054 (0.19)	0.054 (0.19)	0.054 (0.19)	0.054 (0.19)	0.054 (0.19)

Table 3.8: Economic analyses for DCSITSS plant at various capacities

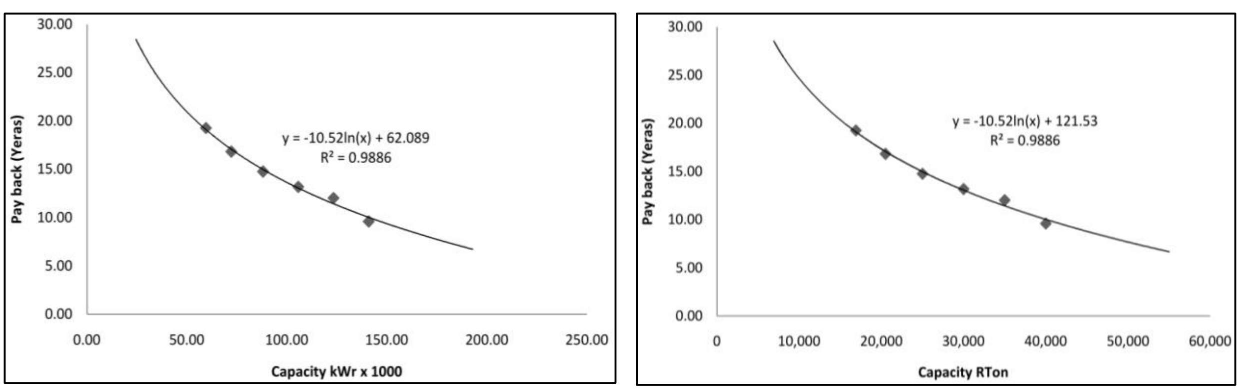
System capacity	RT	16,950 (59494)	20,500 (71955)	25,000 (87750)	30,000 (105300)	35,000 (122850)	40,000 (140400)
Plant life span	**Years**	20	20	20	20	20	20
E. Saving to investment ratio							
Income	RM/year	16,856,775	20,387,250	24,862,500	29,835,000	34,807,500	39,780,000
Expenditure	RM/year	18,211,493	21,397,838	25,362,315	29,692,379	33,960,919	36,694,306
Investment without CRF	RM/year	5,785,555	6,484,784	7,304,781	8,149,218	8,938,899	9,684,545
STI	%	-23.42%	-15.58%	-6.84%	1.75%	9.47%	31.86%
F. Pay back period							
Investment		61,292,252	68,699,895	77,386,956	86,332,936	94,698,824	102,598,203
Saving		4,430,837	5,474,197	6,804,966	8,291,839	9,785,480	12,770,238
Payback (yrs)	Years	19.27	16.83	14.77	13.18	12.03	9.60
G.(Total Net Saving)r							
Yearly loan repayment		5,785,555	6,484,784	7,304,781	8,149,218	8,938,899	9,684,545
Saving		4,430,837	5,474,197	6,804,966	8,291,839	9,785,480	12,770,238
PWF for 20 years		14.20	14.20	14.20	14.20	14.20	14.20
Net Saving		(19,236,682.09)	(14,350,106.13)	(7,097,258.29)	2,025,178.51	12,021,247.01	43,816,129.45
Average net Saving per year		(961,834.10)	(717,505.31)	(354,862.91)	101,258.93	601,062.35	2,190,806.47
H. Life cycle cost							
LCC per year	RM/year	29,552,859.99	35,244,270.02	42,266,884.93	49,875,355.57	57,837,534.77	64,399,950.43
LCC per year per Kwr (RT)	RM/year RT	496.73 (1,743.53)	489.81 (1,719.23)	481.67 (1,690.68)	473.65 (1,662.51)	470.80 (1,652.50)	458.69 (1,610.00)

Table 3.8: (Continued)



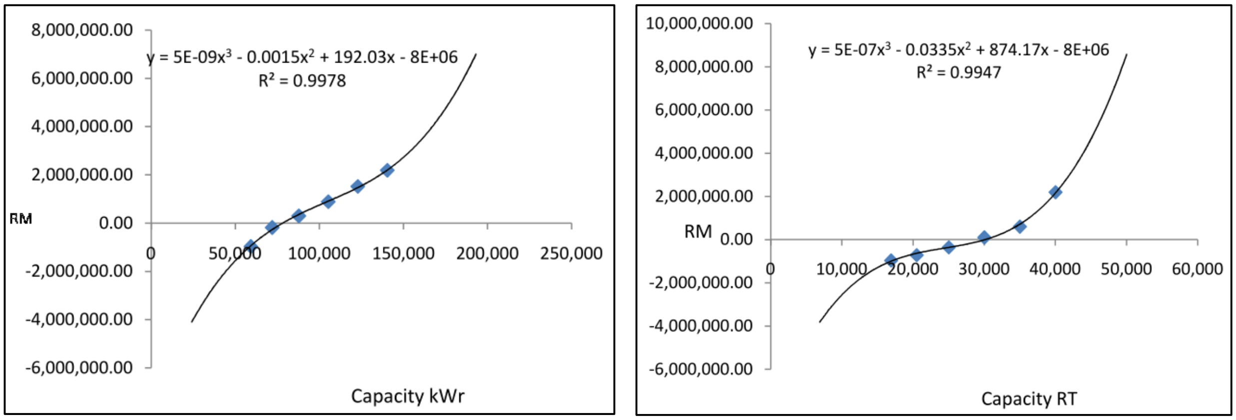
(a) RM /year/kWr (b) RM/year/RT

Figure 3.9: Life cycle cost analyses between DCSITSS and centralized chillers system



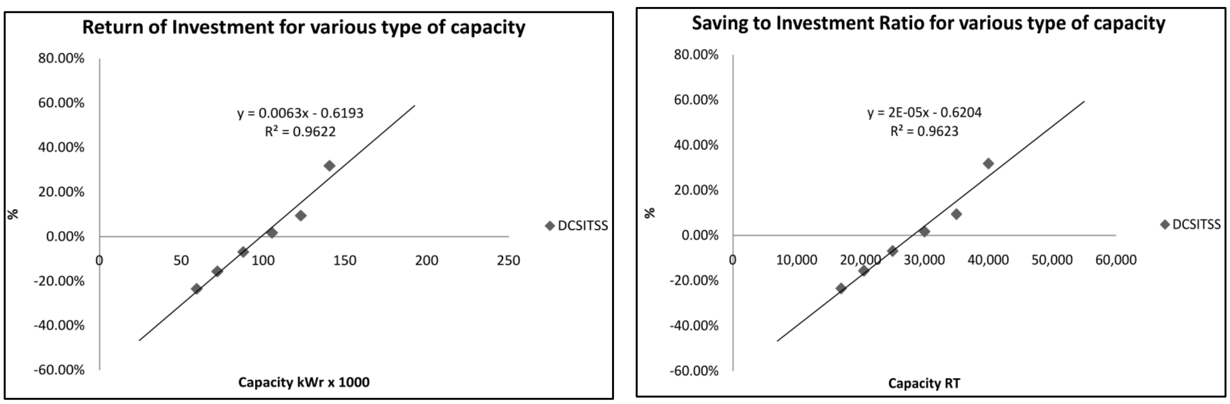
(a) Payback vs capacities kWr (b) Payback vs capacities RTon

Figure 3.10: Payback period for DCSITSS plants at various capacities.



(a) Net saving vs capacities kWr (b) Net saving vs capacities RTon

Figure 3.11: Net saving $(NS)_{ryr}$ per year for DCSITSS plants at various capacities



(a) Percentage % vs capacities kWr (b) Percentage % vs capacities RTon

Figure 3.12: Saving to investment ratio for DCSITSS plants at various capacities

In Figure 3.9, the plant life cycle cost (capital costs plus running costs) amount are cheaper compared to centralised chillers system for plant capacity of more than 70,000 kWr (20,000 ton). Plant payback period shall not exceed thae plant life spans. For partial storage system, the plant life span which is inclusive of its equipments is approximately 20 years (ASHRAE, 2007). A ten to fifteen-year payback period is worth due consideration for any investments. For lower than fifteen-year payback period, the plant capacities have to be larger than 88,000 kWr (25,000 RTon) as shown in Figure 6.7. Payback period is the duration that amounts invested in the plant equipments and building construction is recovered by its income.

Plant real net saving (NS)r is income minus the expenditures. The expenditures are inclusive of plant's running cost plus the amount payable to the bank for loan taken in investing in the plant's equipments and building construction. For a positive real net saving or economic gain, the plant capacity has to be above 105,000 kWr (30,000 RTon) as shown in Figure 3.11. Whereas, the saving to investment ratio (STI) ie. plant's incomes in selling the chilled water to the consumers' buildings divided by amount invested (in taking into account all the interest paid) in installing the plant remain above 0% for the plant's capacity of 105,000 kwr (30,000 RTon) and above as shown in Figure 3.12. Positive values of STI reflect the economics gain or profit to the plant.

4.0 Conclusion

Based on the energy and economic analysis of the systems lead to the following conclusions:

1) DCSITSS full and partial storage systems reduce on-peak power consumption by 50% and 15% respectively compared to the centralised chillers system. However, the most energy efficient system is centralised chillers system. By reducing the on-peak electricity consumption, the electric power providers in Malaysia will utilise its plant effectively by maximising its investment capital. Another advantage, operation of the plant at night will boost gas turbine efficiency due to the cooling inlet temperature to the compressor (Al Hazmy et al. 2004).
2) DCSITSS partial storage system is selected to be the most suitable air conditioning system in Malaysia due to its life cycle cost (LCC) is 16% lower than full storage system. Even though its LCC is 0.3% higher than the centralized chillers system, DCSITSS partial storage consumes 15% of its daily electricity consumption at night and this is an obvious advantage compared to centralized chillers system.
3) A suitable tariff of RM0.05 per kWrhr (RM0.19 per RThr) is selected for the DCSITSS partial storage system. By applying the tariff to the commercial buildings studied, their running expenditures reduce to 2% to 7% as compared to using centralised chilllers system.
4) However, to operate the plant commercially, a minimum plant capacity of 105000 kWr (30000 RTon) is required. Operation of the plant which is below this capacity will result in economic losses. Economic analyses that carried out on the plant reveal that for operating a 105000 kWr (30000 RTon) plant, its payback period is 13 years, it net saving is RM 101000.00 yearly, saving to investment ratio is 1.75% and its LCC (capital plus operating costs) is RM47.00 per RT per year lower than centralised chillers system.
5) For commercial buildings of grand total capacity less than 105000 kWr (30000 RT), it is more justified to utilise centralised chillers as the air conditioning sytem.

5.0 Recommendation

These studies provide as a framework for implementation of district cooling system utilising ice storage as the medium. Even though the studies only involve with commercial sectors that operate during day time only (8 a.m. to 6 p.m.), the same benefits can also be extended to other sector that operate for more than 10 hours daily such as shopping centres, hospitals etc.

It is beneficial to implement the plant at downtown Kuala Lumpur where high cluster of commercial buildings are present. As the size of the clusters reduced to be below 30,000 ton or 105,000 kWr, centralized chillers system is more economical to be operated. Other recommended studies to be carried out in the future are for the economic analysis between centralized chilled water chillers and centralized ice storage chillers system in buildings in Malaysia. Its objectives are investigation of the economic feasibility of HVAC operation for individual buildings.

6.0 Reference

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