Moving towards Low Carbon Economy - District Cooling System at Kai Tak Development and Mandatory Building Energy Codes

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Abstract

The Chief Executive of the Government of Hong Kong Special Administrative Region (HKSAR) has stated in the Policy Address 2008-09 that the Government will promote a low carbon economy in the HKSAR. One of the effective and proven means to achieve this goal is through energy efficiency enhancement. Incorporation of a district cooling system in the new Kai Tak Development to provide air conditioning service to support subsequent non-residential development and implementation of a mandatory Building Energy Codes are two major government initiatives for enhancement of the efficient use of energy at district level and individual building targets.

Successful implementation of these initiatives demands good town planning works at the infrastructure planning and development phase and at the initial building planning stage. This paper will give a brief account of these two government initiatives and their contributions towards the low carbon economy.

Keywords: BEC, DCS, Building Energy Codes, district cooling system, low carbon economy

1. Introduction

This paper outlines the HKSAR Government's proposal on introducing legislation to require the specified types of buildings to comply with the Building Energy Codes (BECs) issued by the Electrical and Mechanical Services Department (EMSD), and the implementation of a district cooling system (DCS) at the Kai Tak Development (KTD), Hong Kong. These are two major government initiatives for enhancement of energy efficiency to make Hong Kong moving towards a low carbon economy.

2. Background

One of the issues that tops the agenda of the international community is climate change. Governments from around the world have been striving to formulate measures that strike an appropriate balance between economic development and the reduction of greenhouse gas emissions so as to achieve sustainable development including low carbon economy. As the Chief Executive has outlined in the Policy Address 2007-08, Hong Kong is committed to doing its part in improving the regional environment and fulfilling the applicable convention and consensus. HKSAR Government will honor its pledge and seek to achieve the reduction goal adopted in the Asia-Pacific Economic Co-operation Leaders' Declaration on Climate Change, Energy Security and Clean Development in September 2007, i.e. to reduce energy intensity by at least 25% by 2030 (with 2005 as the base year). To meet this target, we have to enhance our energy efficiency.

Total energy consumption at end-use level in Hong Kong was 288,155 Terajoule (TJ) in 2006. There was an average annual growth of around 1.3% in absolute terms in the past years. About 50% of the energy consumed in 2006, i.e. 145,204 TJ, were electricity consumption, of which around 90% were for buildings. *Figure 1* below shows the distribution of energy consumption by sector in 2006. *Figure 2* below shows the distribution of energy consumption by types of services in a typical office building. As electricity generation is the single largest source of air pollution in Hong Kong, contributing to 89%, 46% and 28% of emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulates (RSP) respectively in 2007, it follows that improving energy efficiency would also help improve local air quality.

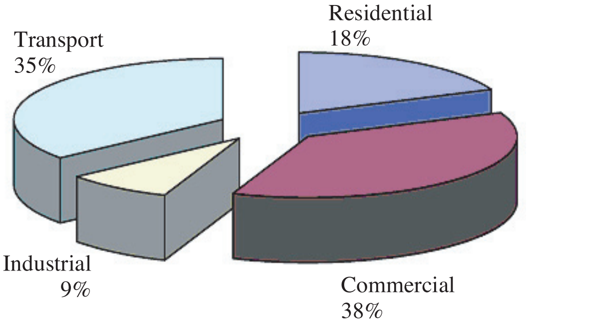

Figure 1: Energy consumption by sector in 2006

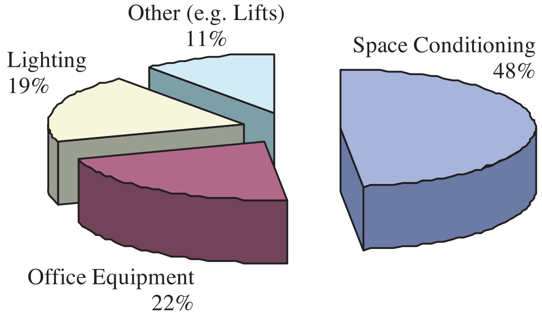

Figure 2: Energy consumption in a typical office building

It is evident from the foregoing energy consumption analysis that energy efficiency in buildings is an area where significant energy savings and greenhouse gas emission reduction can be made. There are thus very good reasons to make a strong push for its attainment to complement other Government's efforts on reducing energy intensity as well as alleviating global warming and combating air pollution. The BEC and DCS will be two effective means to contribute to reducing energy intensity by enhancing the building energy efficiency.

3. Mandatory Building Energy Codes

3.1 The voluntary Hong Kong Energy Efficiency Registration Scheme for Buildings (HKEERSB)

Considering that commercial buildings and the communal parts of residential and industrial buildings account for a significant portion of the total energy consumption, the EMSD has since 1998 developed a set of five BECs (latest edition: 2007) and at the meantime launched the voluntary HKEERSB to promote the adoption of the BECs. Under the voluntary HKEERSB, the building developers/owners may apply for certification for either one or more of the four key types of fixed building services installations, namely, lighting, air-conditioning, electrical and lift & escalator installations in their buildings provided that the relevant installations have complied with the minimum energy efficiency requirements in the respective BECs. If the submission is found satisfactory, the EMSD will issue a certificate as recognition of the energy efficiency performance of the individual installation. Together, the four key types of fixed building services installations consume up to about 80% of the total electricity consumption of a typical office building. Recognition is given by way of the issue of a certificate for compliance with any of the following BECs [1] :

Title	Key performance standards
Code of Practice for Energy Efficiency of Lighting Installations [BEC (Lighting)]	a) Luminous efficacies of various types of lamps; b) Power loss of lamp control gears; c) Lighting power densities of various indoor areas; and d) Number of lighting control points
Code of Practice for Energy Efficiency of Air Conditioning Installations [BEC (Air Conditioning)]	a) Efficiency of air conditioning equipment; b) Fan power per unit volume of air flow; c) Frictional loss per unit length of pipe run; d) Thickness of thermal insulation; and e) Air conditioning control system
Code of Practice for Energy Efficiency of Electrical Installations [BEC (Electrical)]	a) Efficiency of electric motors; b) Power loss in electrical distribution system; c) Harmonic distortion in electrical system; and d) Provision of metering devices
Code of Practice for Energy Efficiency of Lift & Escalator Installations [BEC (Lift & Escalator)]	a) Electric motor power of lifts/escalators; and b) Lift and escalator control system
Performance-based Building Energy Code [BEC (PB)]	a) Specification of the method to derive the Design Energy value from the actual design and operational characteristics of a building; and b) Specification of the method to derive the Energy Budget value, which is evaluated based on a hypothetical building of the same size and shape of the building fully in compliance with the minimum requirements in the BEC (Lighting), BEC (Air Conditioning), BEC (Electrical) and BEC (Lift & Escalator)

Table 1: Key performance standards of the BECs

The 1st four BECs are prescriptive in nature. An installation will be in compliance with the respective BEC if it satisfies the minimum energy efficiency performance requirements stipulated therein. The remaining BEC (PB) sets out an alternative performance-based means to evaluate and assess the energy efficiency performance of a building.

Since implementation of the voluntary HKEERSB, the EMSD has issued a total of 2,310 certificates, covering 2,485 services installations in 954 building venues (as at February 2009). However, only around 26% of the 954 building venues are non-government premises over the past 10 years. The participation rate of private sector is disconcertingly low.

There is no disagreement that improving building energy efficiency is a cost-effective measure to address the growing concerns of global warming, local air quality and energy security. Some

[1] The BECs can be downloaded at http://www.emsd.gov.hk/emsd/eng/pee/eersb_pub_cp.shtml.

may however argue that as energy saving measures are cost-effective, we may and perhaps should rely on market-driven forces to achieve efficiency gain, which is in fact in line with the Government's regulatory philosophy generally. Yet, such forces appear not promising over the past 10 years. There are impediments to the effective operation of the market force in Hong Kong's situation: the notable one being the split incentive between developers/landlords who make the capital investment and occupants who enjoy savings in the electricity bills later. With the pressing environmental aspiration and needs, the HKSAR Government thus proposed the mandate compliance with the BECs.

3.2 Overseas Practices

Indeed, the useful role of mandatory compliance of minimum energy efficiency requirements in promoting energy efficiency and conservation in buildings has been well established internationally. Some overseas countries, including Australia, Singapore, England, California of United States and the Mainland China have implemented minimum energy efficiency requirements for buildings by legislation. We of course make reference to the overseas practices when formulating our legislative proposal of the mandatory BEC.

A comparison of some of the latest standards adopted in our BECs with the standards adopted by some overseas countries and the Mainland China is shown in Tables 2 to 4 below (as at December 2007). Our standards on air-conditioning systems and electrical installations are broadly comparable to the standards adopted by other jurisdictions, whereas our standards on lighting installations are relatively less stringent to meet the general local preference for better-illuminated interior spaces. Besides, the EMSD has put in place the BEC (Lift & Escalator), unique to the built environment of Hong Kong which is dominated by high-rise buildings. We are not aware of other overseas practices that have introduced energy efficiency standards for lifts and escalators.

Areas	Maximum Allowable Lighting Power Density (W/m^2)					
	Hong Kong BEC	Australia BCA	Singapore SS 530	US ASHRAE 90.1	Europe (e.g. UK Approved Document L2)	China GB 50034
Open Plan Office / Cellular Office	17	7-10	15	11.8 - 16.1	Not less than 40 luminaire-lumen per circuit watt	11 - 18
Retails	20	25	25	18.3	No specific requirement	11 - 20
Restaurant	23	20	15	15		13
Atrium / Foyer	25	10	10	-		-

Table 2: Comparison of standards of lighting power density in various jurisdictions

Type/Rating of air-conditioning Chiller	Coefficient of Performance					
	Hong Kong BEC	Australia BCA	Singapore SS 530	US ASHRAE 90.1	Europe (e.g. UK Approved Document L2)	China GB 50189
Air cooled, scroll / screw	2.7 – 2.9	2.2 – 2.5	2.80	2.80	Requirement is set on overall air-conditioning system performance instead of on coefficient of performance for chillers	2.40 – 2.60
Water cooled, screw, 500 – 1000kW	4.6	4.5	4.45 – 4.90	4.90		4.30
Water cooled, screw, >1000kW	5.5	5.5	4.90 – 5.50	5.50		4.60
Water cooled, centrifugal, 500 – 1000kW	4.5	4.5	5.00 – 5.55	5.55		4.70
Water cooled, centrifugal, >1000kW	5.7	5.5	5.55 - 6.10	6.10		5.10

Table 3: Comparison of standards of coefficient of performance of typical air-conditioning chillers in various jurisdictions

Motor (4-pole) Rating, P (kW)	Minimum Efficiency (%)					
	Hong Kong BEC	Australia BCA	Singapore SS 530	US ASHRAE 90.1	Europe (e.g. CEMEP[2])	Mainland GB 50189
$1.1 \leq P < 5.5$	76.2 – 84.2	No specific requirement	83.8 – 88.3	84.0 – 87.5	76.2 – 84.2	No specific requirement
$5.5 \leq P < 22$	85.7 – 90.0		89.2 – 92.2	89.5 – 92.4	85.7 – 90.0	
$22 \leq P < 55$	90.5 – 92.5		92.6 – 93.9	92.4 – 93.6	90.5 – 92.5	
$55 \leq P < 90$	93.0 – 93.6		94.2 – 94.7	94.1 – 94.5	93.0 – 93.6	
$P \geq 90$	93.9		95.0	94.5	93.9	

Table 4: Comparison of standards of electrical motor efficiency in various jurisdictions

3.3 Our Proposal of Mandatory BEC

The HKSAR Government had conducted a public consultation on the proposal of mandatory implementation of the BEC from December 2007 to March 2009. The result indicated that there was overwhelming support from the stakeholders and the general public to the principal direction of legislation. They also supported to adopt the current BECs 2007 Edition as the basis of the future mandatory standards. The law drafting works and the fine-tuning of the BECs 2007 Edition to a legislative version is in progress at the moment of writing this paper. It is planned to submit the relevant bill to the Legislative Council of HKSAR in the 4th quarter 2009.

Below are the key points of our latest legislative proposal:

- The scope of buildings to be governed includes commercial buildings, residential buildings (common area only), industrial buildings (common area only), educational buildings, community buildings, municipal buildings, institutional buildings, hospitals and clinics etc.
- Both private and government buildings will be governed.
- For new buildings with building plans approved after the enactment of the new legislation, the concerned building services installations should comply with the energy efficiency

[2] The motor efficiency figures represent the major market share of electrical motors in European countries.

requirements in the BEC upon construction completion. A registration certificate from the EMSD should be obtained.

- For existing building with major retrofitting works (such as replacement of major component of the covered building services installations or works on the installations with an area exceeding 500m^2), the building services installations involved in the works should comply with the BEC upon works completion. A certificate from an authorized engineer should be obtained.
- For commercial buildings, an energy audit should be conducted once every 10 years. The energy audits should be certified by an authorized engineer.
- The first round of energy audit for existing commercial buildings is proposed to be completed within 4 years after the enactment of the relevant part of the proposed new ordinance.
- Authorized engineers should be registered by the EMSD under the proposed new ordinance.

4. District Cooling System at Kai Tak Development

4.1 Benefits and Challenges of DCS

Apart from the energy saving, a DCS will bring about a number of benefits as follows:

- upfront capital investment is reduced for installing chiller plants at their buildings;
- DCS is more adaptable than individual air-conditioning systems to the varying air-conditioning demand;
- user buildings do not need to install their own chillers or cooling towers thus allowing more flexible building designs. Instead, a substation for accommodating only two or three heat exchangers of much smaller size is required. More effective use of the space saved can be made;
- enhanced service quality and reliability is provided through centralized operation and maintenance performed by a competent DCS operator and overseen by the Government;
- noise and vibration arising from operation of heat rejection equipment and chillers of air-conditioning plants in buildings can be much reduced; and
- nuisance to occupants of adjacent buildings such as heat and noise generated from cooling towers or air-cooled condensers can also be eliminated. Further, the “hot island” effect in the area can be alleviated.

The implementation of DCS at KTD imposes challenges in various aspects including the following:

- DCS service for non-domestic developments
- DCS planning, design, coordination and development programme
- Operational risks and contingency arrangement
- Project procurement approach

4.2 Our Implementation Proposal of DCS at KTD

A DCS is a large scale centralized air-conditioning system to produce chilled water at its central chiller plants and distributes the chilled water to user buildings of various air-conditioning loads. The DCS is an energy-efficient air-conditioning system as it consumes up to about 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and water-cooled air-conditioning systems using cooling towers respectively.

A study on the implementation of a DCS at South East Kowloon Development (SEKD) had been commissioned in 2001. An updated study on DCS based on the Kai Tak development plan was conducted in 2007. As announced in the 2008-09 Policy Address, the Government plans to implement a DCS at the KTD.

The proposed DCS at KTD comprises two central chiller plants, a seawater pump house, chilled water distribution piping network, seawater supply and discharge pipes, and DCS substation to interface with customers' chilled water circulation systems (see *Figure 3* for general KTD layout and plant rooms locations). The southern chiller plant and the seawater pump house will be underground below the planned open space at the runway precinct.

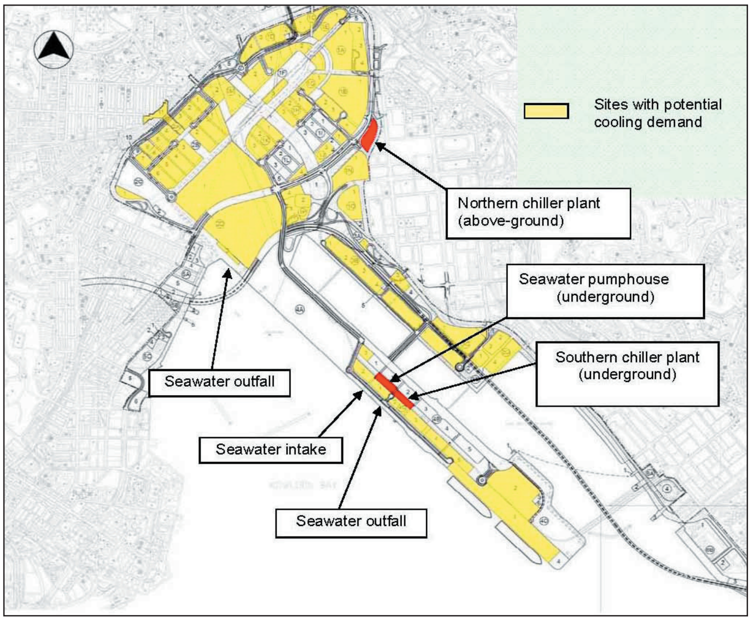

Figure 3 Site layout and plant locations of DCS at KTD

The estimated ultimate cooling capacity of the proposed project is about 284 MW cooling energy for planned non-domestic air-conditioned floor area of about 1.73 million m^2. The project is planned to commence in early 2010 and to be commissioned for operation in three phases from 2013 to 2021 to suit the development schedule of the KTD. By implementing the proposed project, the maximum annual saving in electricity consumption will be up to 85 million kWh and a reduction of 59,500 tonnes of carbon dioxide emission per annum.

The project will provide DCS service to public and private non-domestic developments at KTD for air-conditioning purpose. As a demonstration of Government's determination to reduce energy consumption, public developments in the region will connect to the DCS provided that their implementation programme can match the development schedule of DCS. The connection to the proposed DCS for private non-domestic developments would be on a voluntary basis. It is noted that voluntary connection to DCS service is quite common and successful in a number of overseas jurisdictions despite individual examples of mandatory connection in Marina South in Singapore and La Defense in Paris. As mentioned above, the DCS services will render a number of benefits which will attract the owners of the developments to make subscription to DCS. The connection to the DCS at KTD on a voluntary basis will be the approach to be adopted for the private non-domestic developments. Despite some uncertainty of the voluntary approach, the arrangement will provide an opportunity to demonstrate the success of the approach based on the appealing benefits to customers coupled with a competitive DCS tariff strategy.

4.3 DCS Planning, Design, Coordination and Development Programme

DCS at the KTD is an infrastructural development comprising construction of three major components: central chiller plant rooms, seawater pump house and distribution chilled water and substations in user buildings. Early planning and initial design of the system are critical to the success of implementation. Some of the challenges include the coordination of piping alignments with other underground utilities, blending of above-ground facilities of underground plant rooms with surrounding environment, and initial low cooling load conditions in early operation years.

Similar to other new town development, the spaces in carriageways and footpaths in KTD will accommodate various underground utility services. However, the spaces concerned in KTD need to accommodate DCS chilled water distribution mains pipes and seawater supply and discharge pipes in addition to other new and existing conventional underground utilities such as power cables, telecom cables, town gas pipes, fresh and salt water mains, and sewers etc. It is understood that the KTD will be developed under different packages and the engineering study on civil, infrastructural and utilities for the whole KTD is carried out first and then followed by detail design for respective areas under different packages. This requires our early input of initial DCS piping alignments and spatial requirements for coordination by the KTD engineering study consultants (see *Figure 4*). This will help DCS pipes be fit into the underground spaces allocated for utilities and be routed in an effective configuration for construction and maintenance (see *Figure 5*). Further, we have also coordinated the DCS pipe runs with the managing departments of other existing underground utilities or services such as drainage culverts and Kai Tak tunnel to early sort out the potential issues and agree on the protective and contingency measures to prevent interference to their facilities during construction. The early coordination on the infrastructural aspects of DCS will certainly minimize part of the project risks in the later construction process.

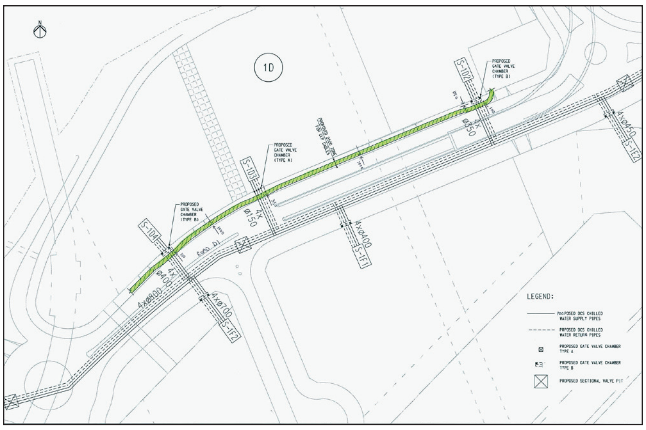

Figure 4 Illustration of DCS piping alignment at north apron of KTD

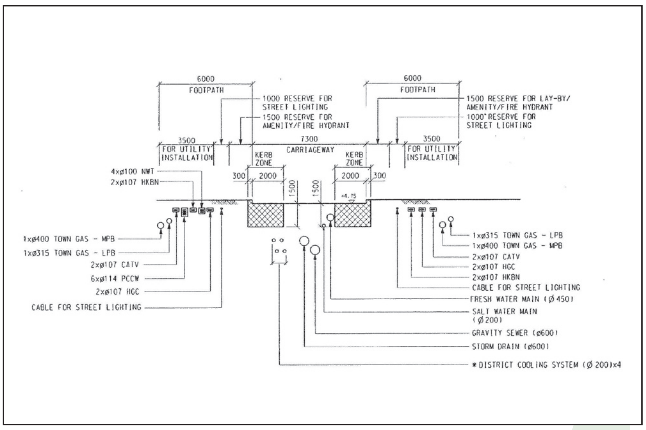

Figure 5 Illustration of underground utilities at a road section

The southern chiller plant and the seawater pump house fall mainly under the future open space area at middle of the existing runway. For safety and operational and maintenance needs for the underground plants, the above-ground operational facilities are required to be built on the open space: ventilation shafts, ground accesses to underground plants, raised platform for headroom of underground plant equipment (travelling band screen), and service cabinet housing flue pipe and FS inlet etc. (see *Figure 6*). Being regarded as a Public Utility Installation, the underground plant rooms need to be permitted by Town Planning Board for their development under the open space area. In this connection, we have set principles of arrangements for minimizing the impact of the said facilities on the open space for public enjoyment and blending them in with the surrounding environment. The arrangements include minimizing the visual effect on surrounding areas without compromising the safety and operational requirements, minimizing the number, maintaining low-level design, and siting the facilities away from the major central open space area. For example, only a minimum number of ground accesses will be provided, with low-level design, for normal access for operation and maintenance or as means of fire escape for DCS operation personnel.

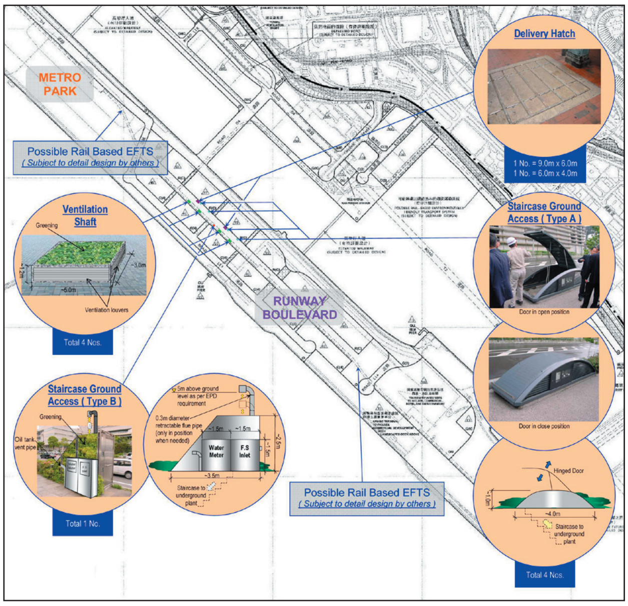

Figure 6 Above-ground operational facilities of underground plant rooms at runway boulevard

On the system design, the DCS needs to meet the low cooling loads in the early years of developments. The issue is particularly concerned with the operation efficiency of DCS to meet the cooling loads during the non-peak period in the night time and non-peak cooling demand seasons. The initial plant capacity and configuration will be carefully designed by the DCS operator for optimal operating efficiency under such low cooling load circumstances.

The project involves substantial upfront capital investment at the early stage for construction of chillers plants and pump house, and mains laying of distribution pipes and seawater pipes. The project's financial viability is therefore sensitive to the development programmes of various developments at KTD. It is also critical for the development programme of DCS to match with those of the potential DCS users. If the DCS was built in advance of other developments, the idle cost could significantly affect the project viability. If the DCS kicks in late, the potential DCS users may have installed their own air-conditioning chiller plants and may no longer be interested in connecting to the DCS until the end of the service life of their plants.

To meet the challenge, we have closely liaised with relevant departments to obtain the updated development schedule. In view of phasing development of KTD throughout the period from 2013 to 2021, the DCS facilities will be commissioned by phases to suit the cooling demand growth. As a contingency, if it turns out at a later stage that there is noticeable deviation in the actual schedules of some developments of KTD, the installation schedule of the component equipment and distribution networks may be suitably adjusted. With such approach, the upfront cost investment can be optimized to minimize the idle cost.

4.4 Operational Risks and Contingency Arrangement

No matter how robust the system has been designed and constructed, some operational risks may exist to affect the DCS service to customers no matter how remote the risks may be. We will not overlook such potential risks, and risk assessment and reliability studies had been carried out in our consultancy study. Design provisions have been allowed to assure the reliability of the system. The DCS distribution pipes will run in looped network for dual feed of supply to customers. Suitable redundancies in system plant and equipment have been built in the DCS system design to cater for the need of maintenance and predictable unavoidable failure. Systematic operation and maintenance programme supported by computerized supervisory control and data acquisition system assisted by water leakage detection system will also facilitate close monitoring of operation status of the system as well as the distribution network and early action to cope with external interference to the system. The intended reliability level of the DCS is targeted to be as good as the public utilities in Hong Kong.

Besides, contingency plans with management and operational procedures will be developed to cope with the risks anticipated. They will allow the operation team to tackle the risks in a systematic and efficient manner. The systematic risk management and associated contingency plans will certainly provide assurance to the DCS customers on the system reliability and will attract more potential customers to connect to the DCS.

4.5 Project Procurement Approach

For this large scale pilot infrastructural development of DCS, the design-build-operate (DBO) approach has been selected as a suitable procurement arrangement. Experience gained will serve as a reference for possible development of DCSs in other districts. .In selecting this DBO contract arrangement of delivering DCS under ownership of the Government, we have taken the following factors into account:

- Higher level of Government involvement in the design and operation of the proposed DCS so as to ensure system reliability as well as reasonable service quality and price
- More flexibility for Government in determining the charges and introducing necessary future adjustments according to the actual system development will be higher if the proposed DCS is under our ownership
- In comparison with the build-operate-transfer (BOT) approach, procurement process of DBO approach should be relatively simple and speedy to guarantee DCS service availability at an early stage of KTD
- Financial analysis undertaken for the project has identified that the proposed investment in the project would be able to achieve a positive net present value within the average service life of the equipment and building structures of the proposed DCS

In view of the above, the private sector will be engaged for the design, construction and operation of the DCS at the KTD through the DBO contract model. It is believed that the arrangement will render more certainty and flexibility in taking forward this pioneering initiative.

5. Way forward

HKSAR Government is committed to promoting a low carbon economy with mandatory BEC and DCS as two of the major initiatives. While implementing these two initiatives, we should at the meantime evaluate the responses from the public and the market, and the impacts on the resources and financial affordability of the building professions and building users. We should step up the publicity on innovative energy efficient technologies to support the compliance with BEC and application of DCS. In the future, the BEC and DCS should also be reviewed from time to time with reference to worldwide experience. As a long-run strategy to drive the stakeholders and the public to enhance the energy efficiency of their buildings in Hong Kong, development of a comprehensive local building energy benchmarking system may be considered after enactment of the ordinance relating to mandatory BEC through which energy performance data of buildings may be more effectively collected.

In conclusion, energy efficiency and conservation is no doubt an essential means for a low carbon economy and a better tomorrow.

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