1-Page Summary

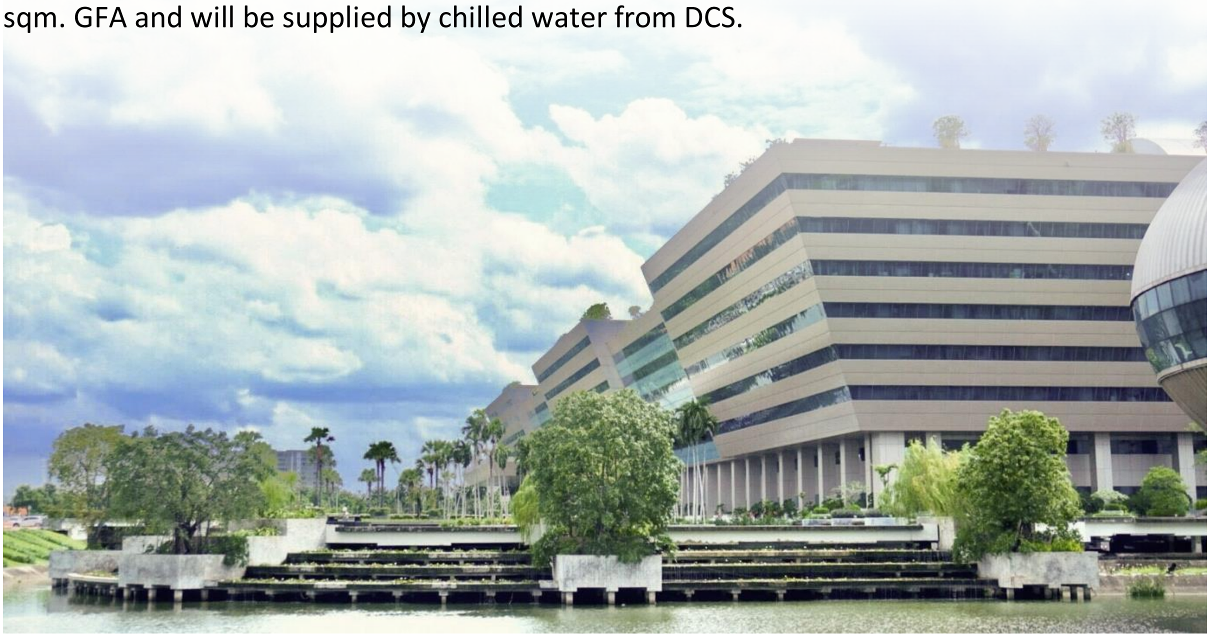
Thailand is considering the climate change issue as a crisis and is responding by implementing various measures to reduce greenhouse gase (GHG) emissions. From 2005-2017, Thailand has reduced GHG emissions by more than 57.84 million TonCO_2eq. By 2030, Thailand aims to reduce GHG emissions by 20% from the projected Business-as-Usual level. To meet this goal, DAD (Dhanarak Asset Development Co., Ltd.) who is responsible for the development and management of The Government Complex Commemorating His Majesty the King's 80th Birthday Anniversary, 5th December, B.E. 2550 (2007) or The Government complex, aims to contribute to the goal by making The Government complex a well-organized, well-operated, and well-managemented real estate. The property aims to be a green, low-carbon, and sustainable government complex and a role model for Thailand.

The Government complex is a large mix-use project with a GFA of 929,900 sqm. located at Changwattana Rd., Nonthaburi. The project is divided into 2 zones: A and B. The project was designed to response to occupants' requirements and energy efficiency to support various space types, and a high occupant volume. The architecture and landscape was designed to reduce external heat gain which leads to lower energy consumption for the HVAC systems.

A District Cooling System (DCS) and chilled water storage were also implemented due to various benefits of the system including space flexibility, ability to support various functions, energy demand reduction during on-peak period, and reduction of anthropogenic heat which contributes to the greenhouse effect. In 2020 the DCS of the Government Complex including all buildings could achieve a reduction of

- Electricity consumption of 107,305.3 MWh,
- Electricity costs of 4.07 Million Baht and
- CO_2 emissions of 46,892.41 TonCO_2.

Because of the achievements in energy efficiency, environmental benefits, investment and management costs of the existing DCS, a new DCS will also be implemented for a future extension of the Government Complex called Zone C. The area consists of more than 660,000 sqm. GFA and will be supplied by chilled water from DCS.



Background

The Government Complex Commemorating His Majesty the King's 80th Birthday Anniversary, 5th December, B.E. 2550 (2007) or The Government complex was erected in 2013 with the objective to house 29 governmental organizations. It is considered as a mix-use project and it is divided into 2 zones: zone A and zone B which provide around 929,800 sqm of GFA.

Three well concepts (well-organized, well-operated and well-managed) are implemented into the design of the project through architectural, landscape, and system design. Layout planning was done to achieve ease of management and system operation, minimize energy use, and flexibility of the space and land use. As a consequence, the unused areas are reduced and turned to shared facilities. Business areas have been designated to facilitate permanent and temporary occupants. The success of the Government Complex Zone A and B also attract other organizations. To respond with the increasing demand, The Government Complex extension (Zone C) is planned.

Figure 1 Site Area of The Government Complex

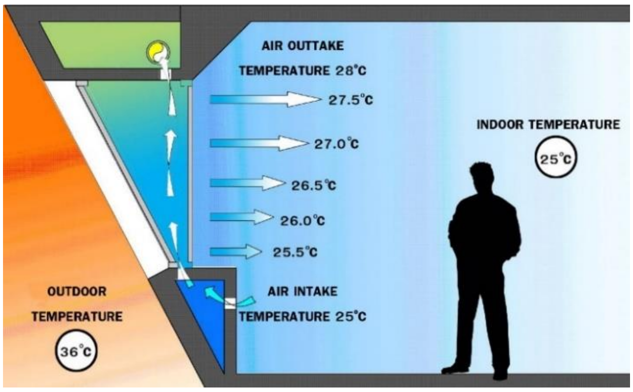
Basis of Design

The Government Complex Zone A and B were mainly designed to respond to requirements of various occupant types including permanent, temporary, and special occupants. Architectural, interior, and engineering concepts of The Government Complex are designed to achieve *ENERGY SAVING BUILDINGS WITH THE LATEST TECHNOLOGY AVAILABLE*. The buildings must be able to save energy without compromising health and well-being of occupants.

Figure 2 Builing Facade

The project is designed as a cluster of buildings to support a variety of functions and building occupants which leads to high energy demanded for the cooling systems. The district cooling system (DCS) has been used to supply chilled water to the buildings because there are a lot of advantages especially a higher energy efficiency of the cooling systems. Also, it reduces the area of mechanical rooms, consume lower energy than conventional air-conditioning systems, reduce CO_2 emission, minimize greenhouse effect by emitting lower anthropogenic heat to atmosphere, and it is easier to manage compared to multiple separated chiller plants.

Landscape, architecture, and HVAC systems of the project have been designed and integrated to provide maximum benefits to occupants and achieve energy efficiency, living quality, and greenhouse gas reduction target. First, the landscape design focuses on maximizing green areas which provide several benefits such as reducing heat island effect and ambient temperature of the site. Second, a high performance envelope has been implemented to the main building to reduce heat gain. The envelope design also reduces the ratio of building envelope to floor area. The ratio has been reduced from 2.4 to 1.7 which is 29% less than another building with similar floor area. Third, the envelope was also designed to limit infiltration which is a major burden on cooling



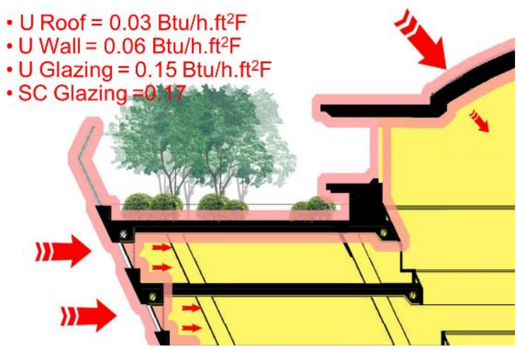


Figure 4 Building Envelope and Heat Transmittance Value

load ,especially in tropical climate. To achieve this, the building has been pressurized and air flow window system (Figure) has been installed. All measures mentioned can, as a result, significantly reduce cooling demand and energy consumption in HVAC system.

For ease of operation and maintenance, the DCS is located separately at the Energy Building (BE). The building is operated by an organization that is responsible for the management of the DCS. Chillers and cooling towers are located on the first floor of the building and the roof level respectively.

The DCS of The Government Complex uses electricity as a primary energy source. The systems of the DCS consist of:

- Electrical chiller capacity 7033.6 kW and 3516.8 kW
- Primary chilled water pump capacity 240 LPS and 120 LPS
- Primary condenser water pump capacity 350 LPS and 175 LPS
- Cooling tower capacity 265 LPS and 175 LPS
- Chilled water pump for Zone A capacity 185 LPS
- Chilled water pump for Zone B capacity 380 LPS

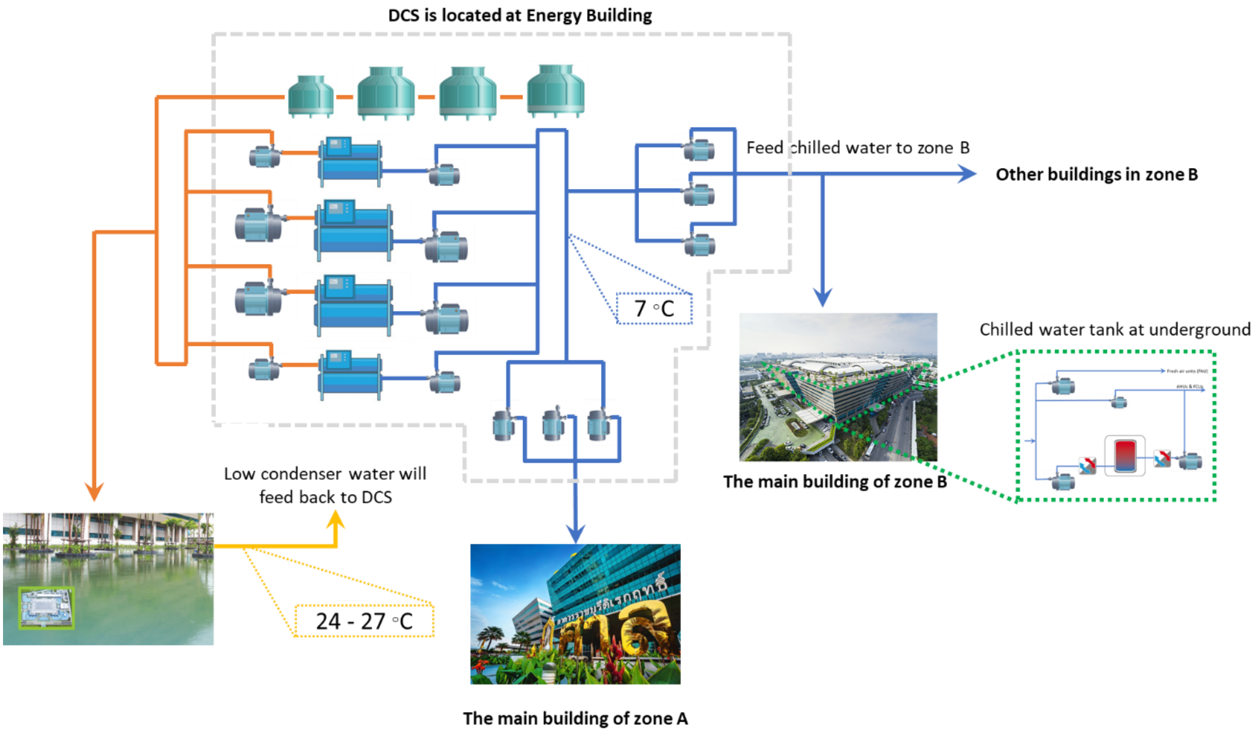


Figure 5 Schematic Diagram of District Cooling System and Its Network

The DCS features can be described briefly as follows:

- The heat rejection system of the DCS is special because it is utelising a cooling pond. The cooling pond which is one kilometer in circumference can reduce condenser water temperature from 30-32 °C to 24-27 °C by evaporation, which increases chiller efficiency.

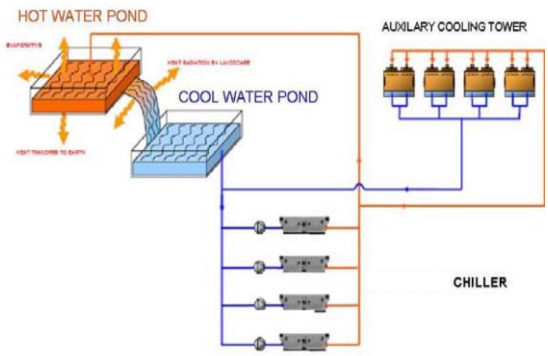


Figure 6 Heat Rejection Concept of DCS

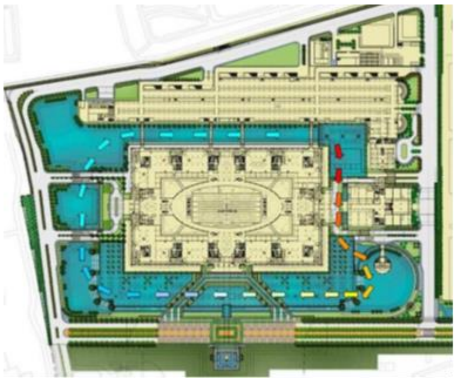


Figure 7 Cooling Pond around The Main Building (BM) - Plan

Figure 8 Cooling Pond around The Main Building (BM)

- The DCS supplies chilled water to the buildings with a guaranteed supply temperature of 7°C.
- The MEP designers were concerned about latent heat of fresh air which has a negative impact on indoor humidity. To solves this issue, FAUs (fresh air units) directly receive chilled water from DCS to ensure that the units' coils are cold enough to remove moisture from fresh air (Figure).

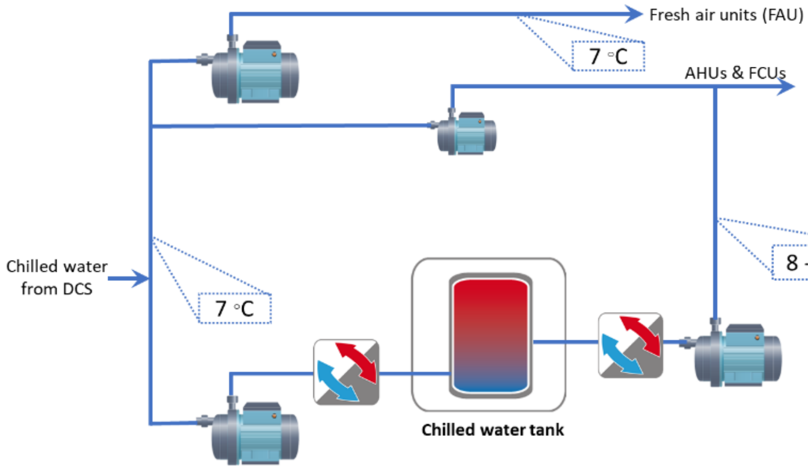


Figure 9 Schematic Diagram of The Chilled Water Storage Tank at Underground of The Main Building in Zone A and B

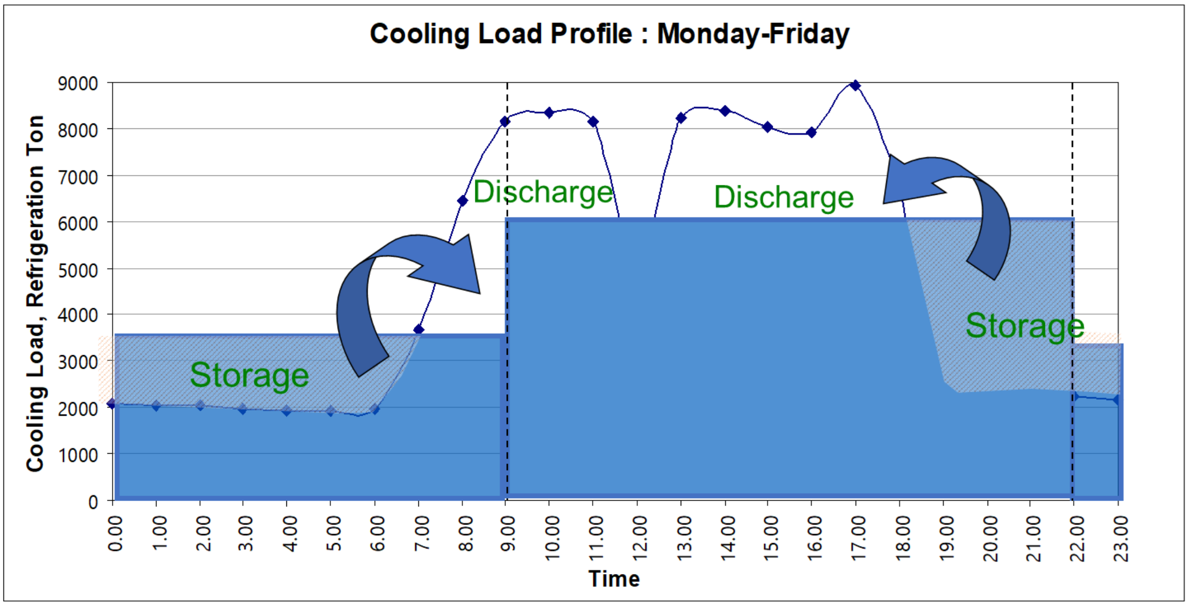


Figure 2 Cooling Profile and Chilled Water Tank Operation

- Chilled water storages are located at the underground level of the main building of Zone A and B which are the largest buildings of the Government Complex. The chilled water storage is 14,000 m^3 in size and can store cooling energy of around 65,061 $kWh_{thermal}$. The stored chilled water can support maximum demand for 3 hours, compensating a chiller capacity of 7,034 kW for 9 hours. The chilled water is charged to the tank at nighttime and discharged with a temperature range of 8 – 12 °C to air-conditioning units in order to reduce sensible heat in the buildings. The benefit of storing chilled water in a tank is to reduce electricity demand during daytime or on-peak time without negative effects on occupants' thermal comfort (figure 8).

The research paper on the district cooling system of The Government Complex conducted by Chulalongkorn University shows the benefits of the DCS and integrated design as shown at bullets and figure 9:

- Electricity substation sized 65 MW has been reduced to 35 MW.
- Since the main building of the government complex requires lower cooling demand than a typical building, chiller plant size has been reduced from 140,672 kW (40,000 tons) to 17,584 kW (5,000 tons).
- 2,100 million Baht for HVAC equipment cost has been saved
- 350 million Bath of saving from energy cost is expected per year

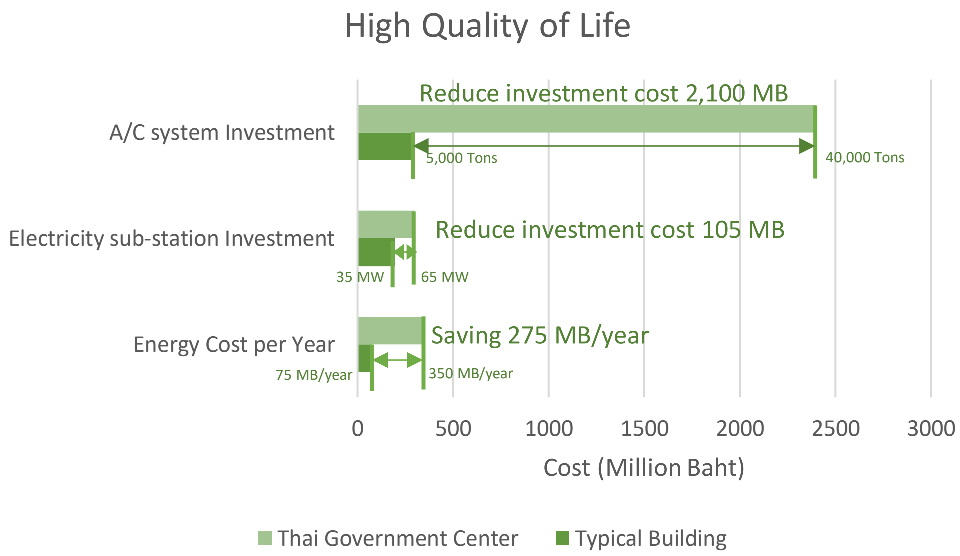
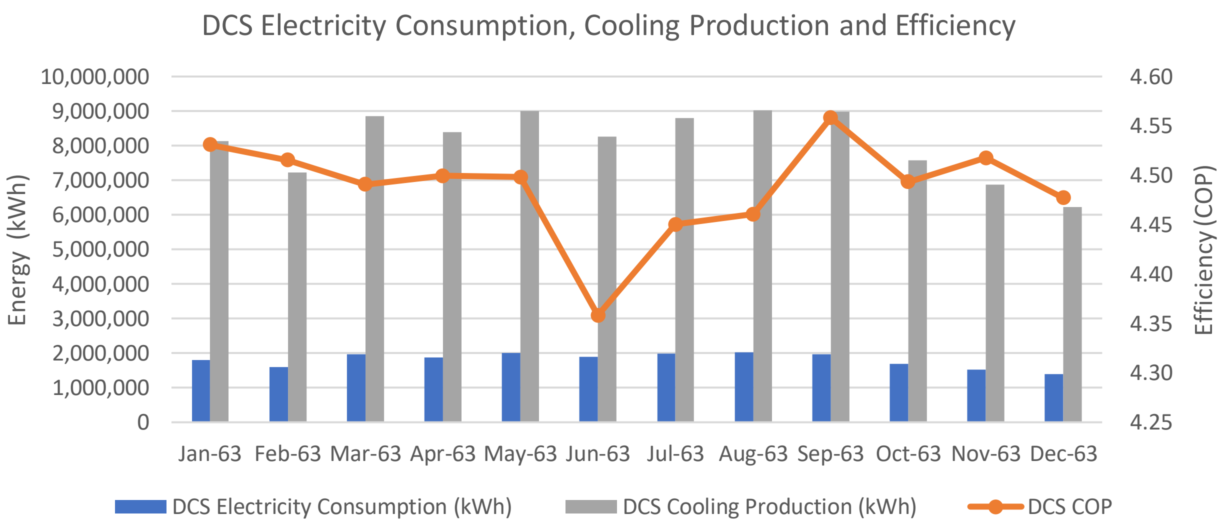


Figure 3 Comparison of Benefits of Integration-Designed of The Government Complex and A Typical Building

The Government Complex is a large mix-use project which inspires many large mix-use projects in Thailand to develop and invest in DCS. The implementation of DCS has more benefits than traditional chiller plants for each building such as investment returns, cost-effective operation, better system performance, and positive impact on the environment and carbon emission.

Efficiency and CO_2 reduction of The DCS operation in 2020

In 2020, the DCS of The Government Complex performed at a COP between 4.36 – 4.56 (0.772 – 0.807 kW/Ton) or an average of 4.49 (0.784 kW/Ton). It was shown that the plant can perform in a good range according to ASHRAE. Although the plant has been performing more than 7 years, its performance is consistent.



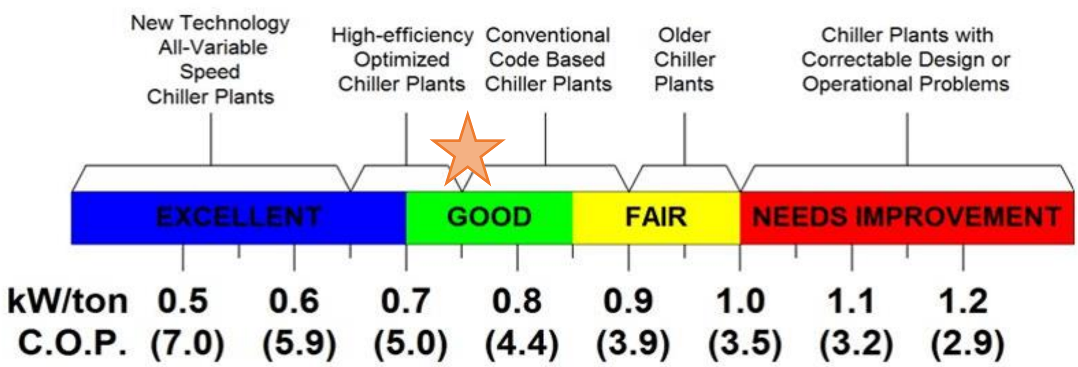
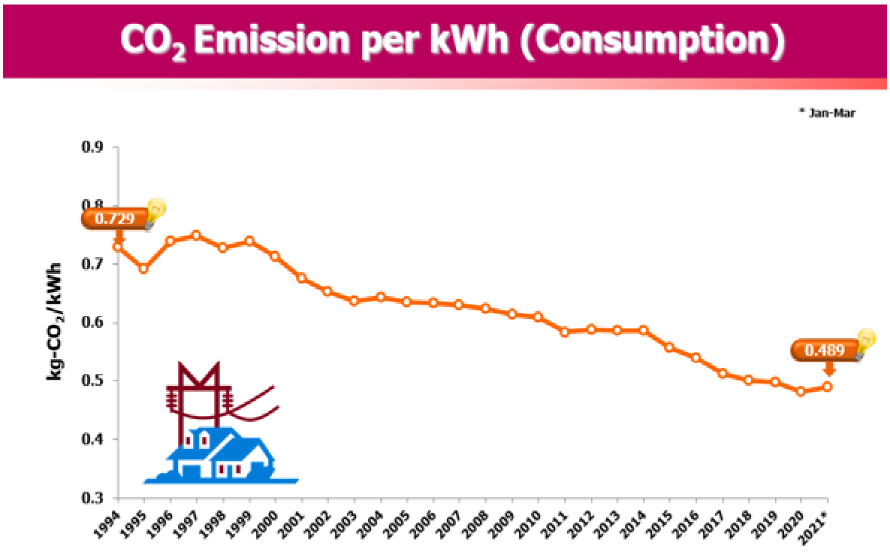


Figure 4 DCS Energy Consumption and Performance in 2020



Unit : kg-CO_2/kWh

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO_2	0.739	0.748	0.727	0.739	0.713	0.676	0.652	0.636	0.644	0.634	0.634	0.630	0.624
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021***
CO_2	0.614	0.609	0.584	0.588	0.586	0.587	0.558	0.539	0.512	0.501	0.497	0.481	0.489

Figure 5 CO_2 Emission per kWh

As a result of the integrated design, the project requires low cooling and electricity demand. The DCS reduces electricity by around 107,305 MWh compared to a typical decentralised system. A statistic conducted by Thailand Energy Policy and Planning Office shows that Thailand's grid emission is at 0.437 kgCO_2/kWh in 2020. Thus, electricity reduction of 107,305 MWh results in 46,892 TonCO_2 savings. Less electricity consumption also reduces SOx and NOx emissions.

Key parameters used to evaluate the DCS performance are shown below:

- Cooling intensity – a ratio between cooled-area and cooling power which presents how much area could be cooled by one kW of cooling power.
- Cooling production – cooling energy that the DCS produces.
- Maximum electricity demand at peak-time – electricity demand during on-peak time that the DCS requires.
- Electricity consumption – electricity that the DCS consumes.
- Average COP – the average DCS efficiency
- CO_2 emissions – Amount of CO_2 that is emitted by the DCS.
- NOx reduction – Amount of NOx reduction of a typical building of the Government Complex.
- SOx reduction - Amount of SOx reduction of a typical building of the Government Complex.

The information about cooling intensity of a typical building is derived from a study conducted by Chulalongkorn University. It shows that a typical building has a higher cooling demand than the Government Complex. Thus, cooling production, maximum electricity demand on peak-time and electricity consumption of a typical building will be higher than The Government Complex's requirements according to their cooling intensity.

Table 1 Comparison of Cooling Demand, Energy Consumption, CO2 emission in 2020 between the government complex zone A and B to General DCS

Key Parameters		A Typical Building	The Government Complex Energy Data in 2020
a) Cooling intensity	sqm/kW of cooling	4.265*	25.35
b) Cooling Production	kWh	578,212,586**	97,395,177
c) Maximum Electricity Demand on Peak-time	kW	31,330**	5,261
d) Electricity Consumption	kWh	129,013,296**	21,708,000
e) Average COP	kWout/kWin	N/A	4.487 (4.36 – 4.56)
f) CO_2 emission	TonCO2	56,378.81	9,486.40
g) NOx emission reduction	Tonne	0	0
h) SOx emission reduction	Tonne	0	0
*According to the study from Chulalongkorn university **Key parameters b) – d) of A Typical Building in this remark are derived from The Government Complex Energy Data in 2020 x (25.35 / 4.265)			

Conclusion

In conclusion, through the design integration of landscape, envelope, and DCS the Government Complex is a model for a green , low carbon, and sustainable city of Thailand. Good design concepts, health and well-being, and working performance of occupants has a positive impact on the surrounding environment and people as well. Reducing energy consumption, especially in HVAC systems which is ine of the highest energy consumption systems in Thailand, is another important outcome of the integrated design. In 2020, The Government Complex reduced energy consumption 5.94 times compared to a typical building. 46,892.41 TonCO_2 of greenhouse gase emissions were reduced. The Government Complex has become a model for developing a mix-use project in term of ecomonic land management, convinent transportation, cost-efficient constuction and operation. These achievements encourage the Thai Government to invest in a new expansion area called The Government Complex Zone C with a new DCS to supply chilled water for more than 660,000 sqm.