Proposal for the HKGBC Advancing Net Zero Ideas Competition (Future Building)

1. Brief description

A novel scheme for achieving net-zero-carbon development of new buildings is proposed in this proposal for attending the HKGBC Advancing Net Zero Ideas Competition. Traditional approaches are adopted in this proposal, i.e. to adopt renewable energy development (開源) and energy saving (節流) methods for proposing practical technologies for this scheme. Real net-zero-carbon commercial buildings can be developed if this scheme is used.

Firstly, applicable renewable energy production and energy storage technologies are proposed to obtain a reliable green power supply to commercial buildings. The building-integrated photovoltaic (BIPV) technology and novel solar photovoltaic vacuum glazing (SPVG) technology are recommended for applications on the rooftop area and curtain walls of the commercial building with improved thermal-electrical-lighting performances of building façade including windows. Offshore wind power generation is utilized with optimal design strategies so that enough renewable power can be produced. Flexible energy storage technologies such as battery, hydrogen and pumped hydro energy storages are introduced with optimal planning and management strategies.

Secondly, energy efficient technologies are proposed to reduce the building's electrical energy demand. As shown in Figure 1, air-conditioning and lighting account for about 82% of the total energy consumption in a typical commercial building in Hong Kong. To reduce this amount of energy use in the new building, advanced smart air-conditioning systems are utilized together with indirect evaporative cooling (IEC), heat recovery wheel (HRW) cooling, and fresh air dominated supply strategy during transition seasons. Smart lighting and devices with motion and CO_2 sensors considering occupants' behaviors will be adopted for reducing energy consumption of air-conditioning, indoor lighting and appliances. Passive building envelops with nano and radiative coatings are also used to improve the indoor thermal environment. A low energy consumption building can thus be developed, which may reduce about 50% of the annual energy consumption of the building.

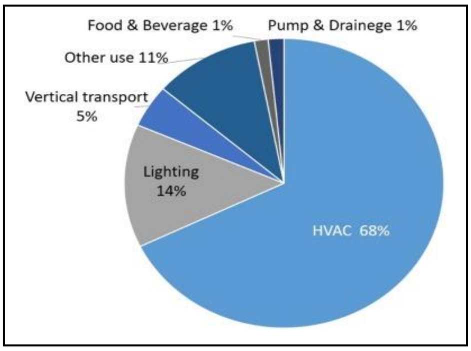

Figure 1 Energy end-use breakdown of a typical commercial building [1]

Finally, a holistic feasibility study will be conducted to demonstrate the techno-economic environmental performances of the proposed zero carbon framework for the building, and to further promote its applications in other high-density urban contexts.

2. Goals

- To propose an optimized reliable renewable energy production and storage system for power supply to the building including BIPV, SPVG and offshore wind power technologies based on our research and development experiences and deliveries. Robust system planning and optimization approaches of hybrid renewable energy systems are proposed with flexible energy storage technologies (battery/hydrogen/pumped hydro) for power economy and grid flexibility.
- To propose advanced building energy saving technologies including the novel indirect evaporative cooling, heat recovery wheel cooling, passive building envelops with nano and radiative coatings, smart lighting and devices with motion and CO_2 sensors to significantly reduce the electrical demand of the building.
- To propose a practical net-zero-carbon scheme of the new commercial building development based on a holistic techno-economic-environmental feasibility study for using the proposed renewable energy production and energy saving technologies to achieve a carbon neutral design of the building and promote the energy framework to buildings in other high-density cities.

3. Assumptions

It is assumed that an off-site renewable energy system is part of the new building development with limited number of wind turbines, i.e. an offshore wind turbine system could be established together with the development of the new building for supplying electricity to the building through local utility grid. The offshore wind turbine system could be part of a wind farm which may be invested jointly with others. A similar assumption is also made for pumped hydro energy storage system in this proposal.

4. How the proposed design solution(s) approach net zero carbon performance

Figure 2 demonstrates the working principle of this proposed scheme which includes the proposed renewable energy production (開源) and energy saving (節流) technologies:

(1) *Renewable power supply integrated with flexible energy storages*. Both onsite solar PV systems [1] and offsite optimal wind turbine system [2] are adopted for a complementary power supply to the building for maintaining an annual energy balance between electrical power supply and consumption in building. Flexible battery, hydrogen and pumped hydro storage technologies are integrated to complement the intermittence of renewable energy sources to achieve high energy autonomy and grid resilience [3].

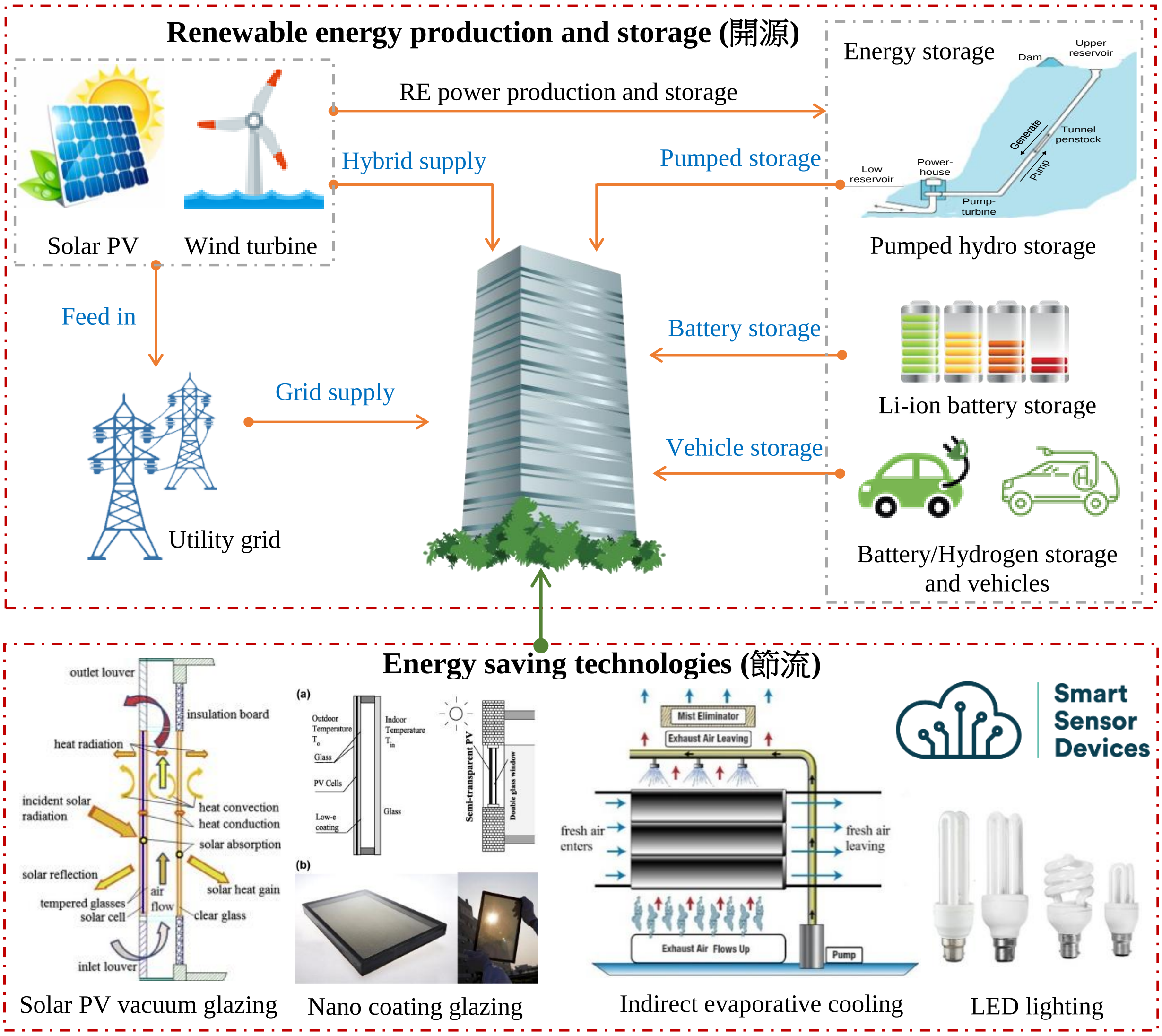

Figure 2 Framework of the proposal with renewable energy and energy saving technologies

(2) *Advanced energy saving technologies with both active and passive designs*. Energy-efficient indirect evaporative cooling and heat recovery wheel techniques are proposed with fresh air dominated control during transition seasons to reduce air-conditioning energy demand [4]. Smart lighting and devices with motion and CO_2 sensors are used for reducing air-conditioning and lighting energy demand considering occupants' behaviors. Passive building envelops with BIPV/SPVG, nano and radiative coatings are utilized to reduce cooling demand and improve indoor thermal environment of the building [5].

5. Targeted EUI achieved

The main targeted Energy Utilization Intensity (EUI) of the new building after the proposed energy saving measures are adopted will be reduced from 222 kWh/m^2/year (typical EUI for a commercial building in Hong Kong) to 120 kWh/m^2/year, 46% reduction of energy consumption due to the energy saving technologies. The total annual energy consumption of the building will be reduced to 11,297,280 kWh/year, which can be supplied by the proposed renewable energy sources for achieving a real net-zero-carbon commercial building on an annual basis. The BIPV system plus one 8 MW offshore wind turbine is enough to provide the required electrical power. Details of the EUI and other parameters are shown below.

Targeted energy use intensity (EUI)	120 kWh/m^2/year (reduced by 46%)	Permitted gross floor area of the building	94144 m^2
Traditional EUI of office buildings (BEAM)	222 kWh/m^2/year	Annual electrical demand	11,297,280 kWh/year
Building energy saving (節流)		**Renewable energy production (開源)**	
Passive design (layout, envelope thermophysics, geometry, infiltration)	Saving: 30%	Solar PV on rooftop and curtain wall	1,694,592 kWh (15%)
Solar PV vacuum glazing	Saving: 15%	Offshore wind turbine	9,602,688 kWh (85%)
LED lighting with motion sensors	Saving: 5%	Battery (vehicle) storage	--
Smart devices (e.g. chiller, fresh air controller) with CO_2 sensors	Saving: 25%	Hydrogen (vehicle) storage	--
Indirect evaporative cooling & heat recovery wheel	Saving: 25%	Pumped hydro storage	--
Annual building energy consumption	**11,297,280 kWh/year**	**Annual renewable energy production**	**11,297,280 kWh/year**

6. Reduction in operational carbon

As shown in the table, the annual renewable energy production for the net zero energy building will be 11,297,280 kWh/year, which would otherwise be imported from the utility grid. The reduced carbon emission is: 11,297,280 kWh/year × 0.6 kgCO_2-e/kWh = 6,778.37 tons/year!

This net-zero-carbon scheme can also be used in other sectors in Hong Kong so that the government's carbon neural target can be realized before 2050 if 20-30% nuclear energy can still be used in the territories in the future.

7. Expected embodied carbon performance

Advanced low-carbon materials and technologies are adopted across the life cycle phases of the building including material production, transportation, on-site construction and whole life performance and operation. A lifecycle impact assessment on a typical high-rise building in Hong

Kong indicates that the alternative design strategies and materials explored can effectively reduce the embodied energy use and carbon emission by 19.91% and 15.23%, respectively [6].

8. Considerations of health and wellbeing aspects

(1) The solar PV vacuum glazing technology is promising to achieve high thermal-electrical-daylighting performances. The quality of indoor thermal environment can be greatly improved with a solar irradiation transmittance of 0.08 for blocking majority of incoming solar irradiation [7].

(2) Smart lighting and Air-conditioning systems with control devices are equipped in the building with motion and CO_2 sensors to ensure a comfortable indoor environment with high energy efficiencies.

References

(7 references are not shown here due to the Anonymity of Submissions policy)