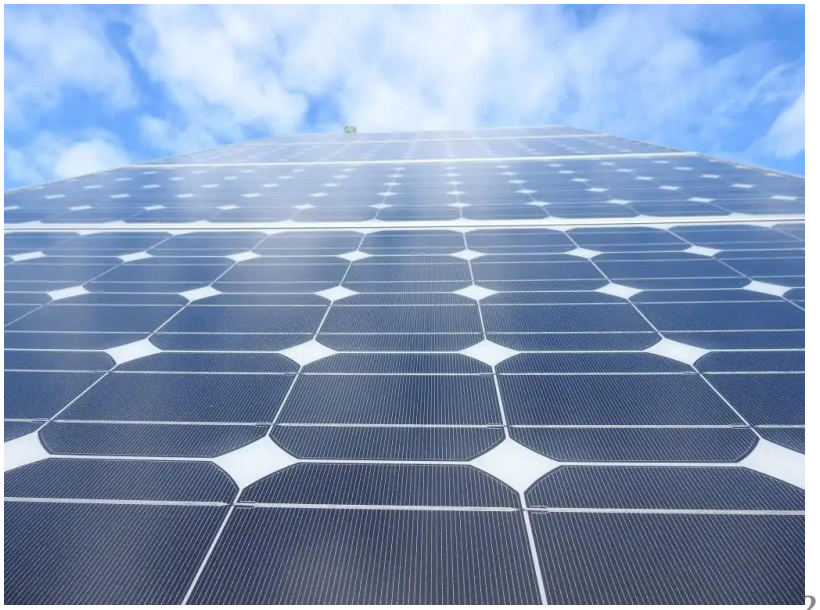
Registration code : 123762

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

Outline

1. Our ideas for achieving a net-zero-carbon development of the new building
2. Renewable energy production
3. Energy saving measures
4. Optimized energy management
5. Energy use intensity (EUI)
6. Embodied carbon reduction
7. Occupant experience
8. Conclusions



BIPV facade

Source： Advanced Science News by Prisca Henheik

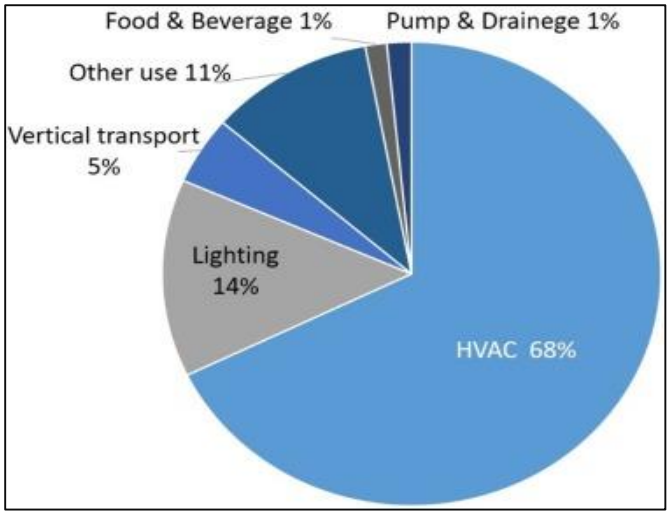
1. Our ideas for achieving a net-zero-carbon development of the new building

(1) Renewable energy production (開源）

- Onsite solar photovoltaics for power generation from building roof and facades
- Offsite offshore wind power generation

(2) Energy saving measures（節流）

- Energy efficient air-conditioning
- Energy saving lighting
- Reduced energy use of other equipment
- Optimized energy management

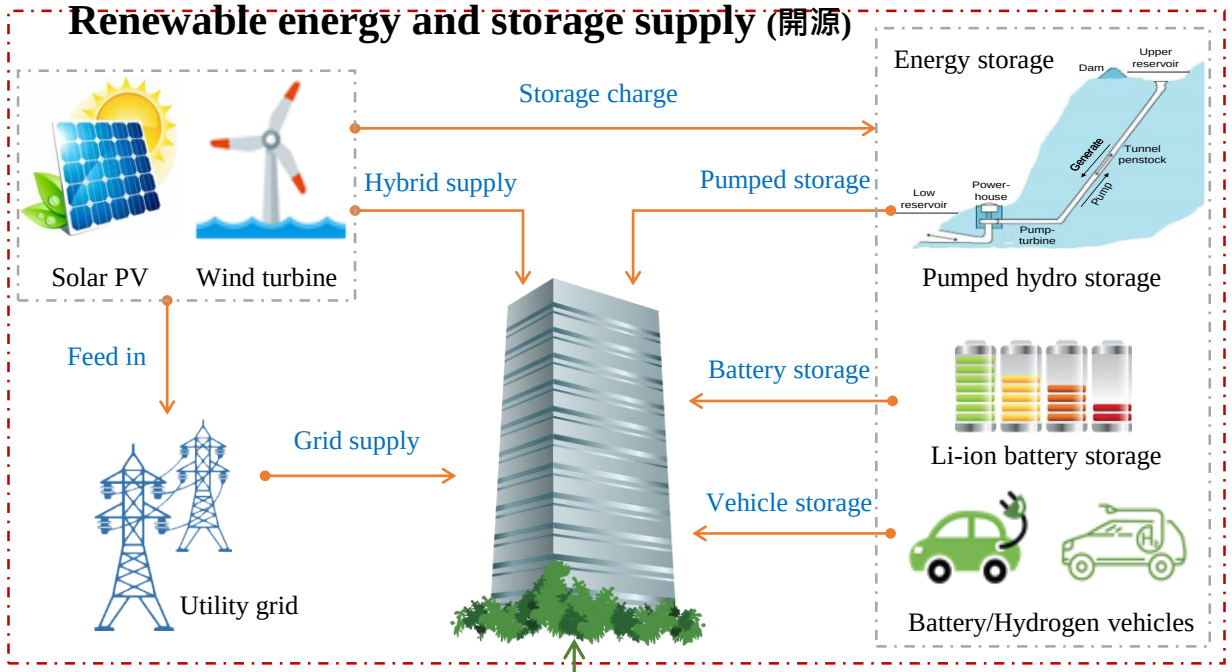


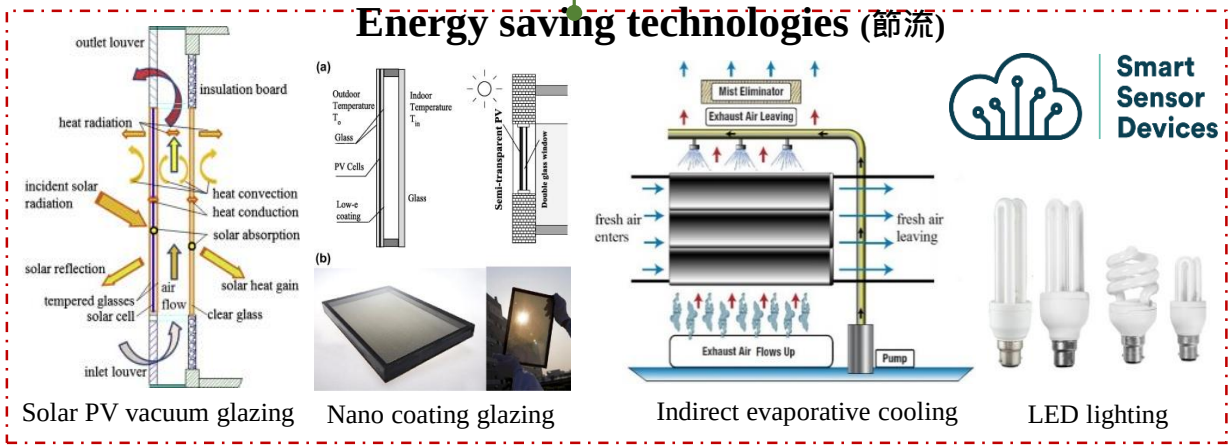
Energy end-use breakdown of a typical existing commercial building [1]

(3) Net-zero-carbon:

Annual renewable energy production = Annual energy demand

1. Our ideas for achieving a net-zero-carbon development of the new building





Renewable energy supply:

- Solar BIPV and SPVG systems
- Offshore wind power
- Flexible energy storage (battery/hydrogen/pumped hydro)

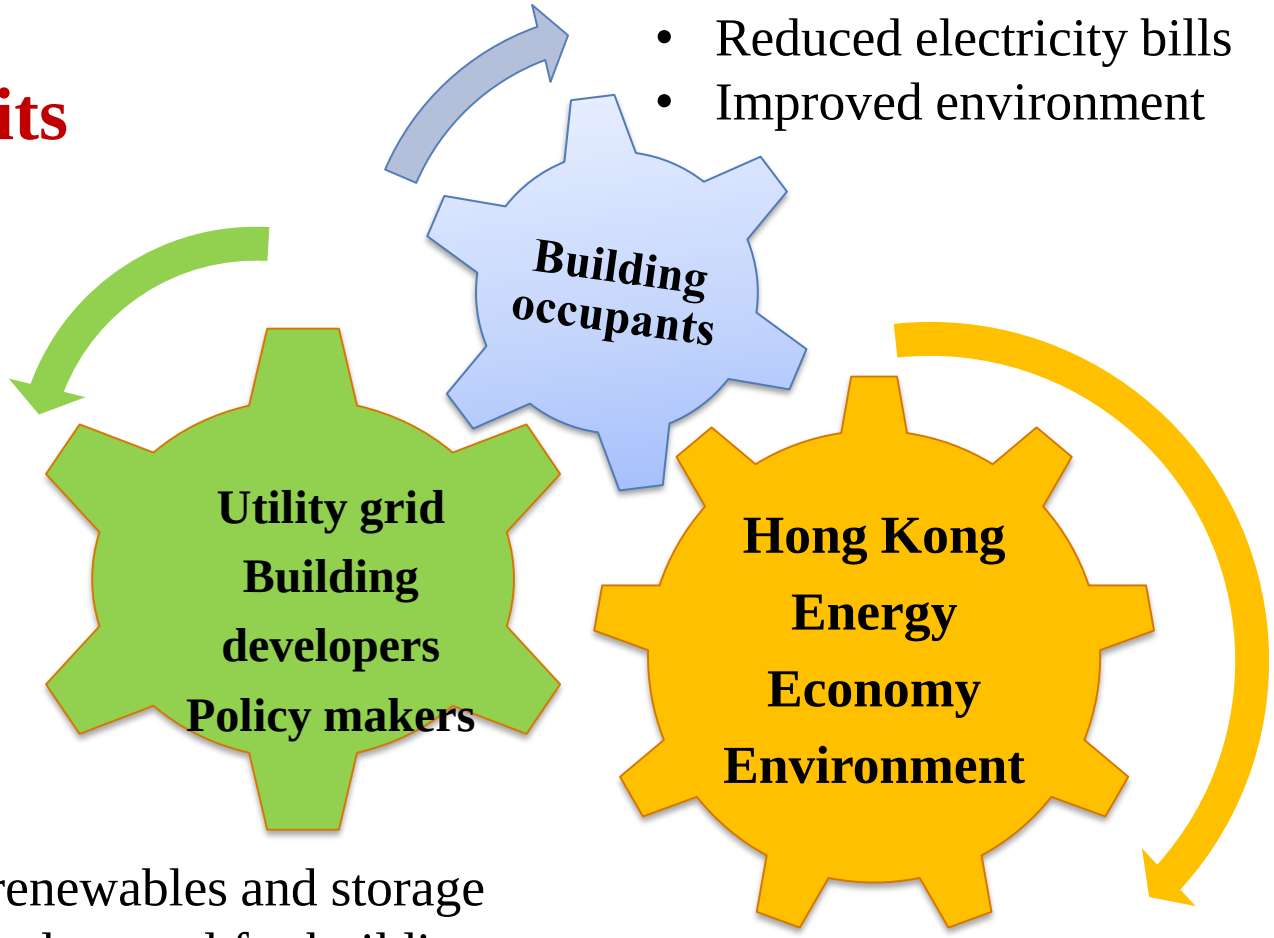
Building energy saving:

- Indirect evaporative cooling
- Heat recovery wheel
- Passive building design
- LED lighting with motion sensors
- Smart air-conditioning chiller and fresh air controls with CO2 sensors

1. Our ideas for achieving a net-zero-carbon development of the new building

➢ Benefits

- Reduced electricity bills
- Improved environment



- Grid relief by renewables and storage
- Smart design and control for buildings
- Guidelines for building efficiency

- Reduce greenhouse gas emissions
- Improve energy sufficiency and flexibility
- Increase local employment opportunities

2. Renewable energy production

➢ Building-integrated solar photovoltaics (BIPV)

Solar PV shading

https://re.emsd.gov.hk/english/solar/solar_ph/images/solar_ph_ep02.jpg

Solar PV glazing

Solar PV façade

Source: https://i.pinimg.com/474x/80/3f/9d/803f9d31944c96bb514c8f7029f4fb6f.jpg

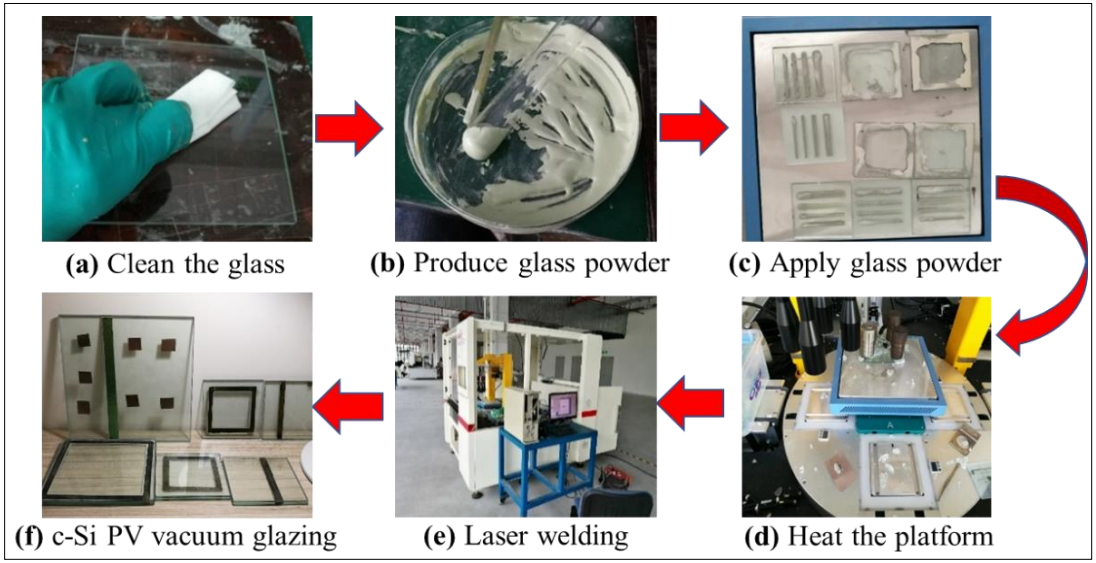
PV roof

https://encryptedtbn0.gstatic.com/images?q=tbn:ANd9GcQ0v0bLzs5dvktXnBY89ugPlPkE_By1LVs1XQ&usqp=CAU

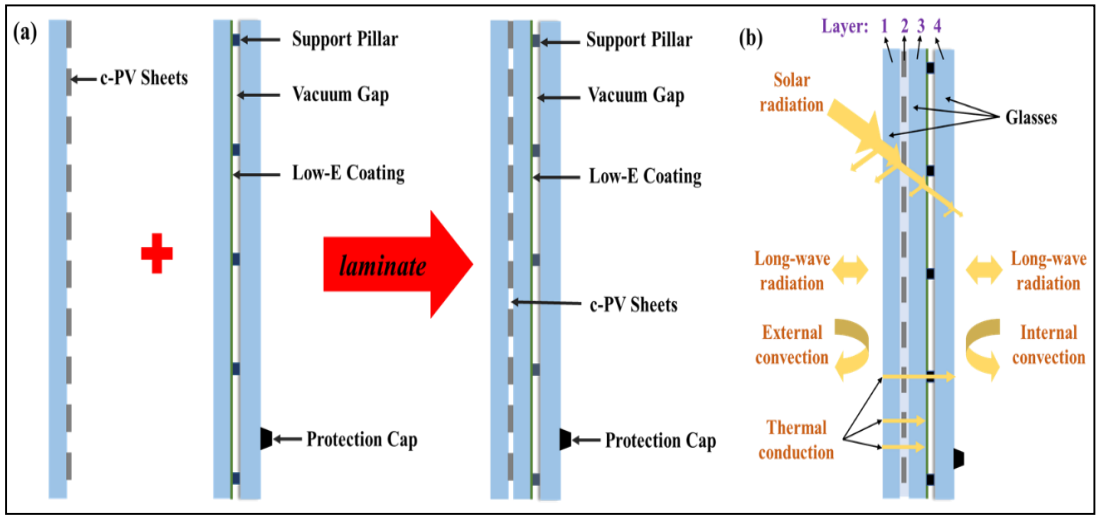
3. Energy saving measures

➢ Novel solar PV vacuum glazing for reducing cooling load from building envelope

Advanced fabrication of solar PV vacuum glazing (SPVG)



Layer structure of PV vacuum glazing



3. Energy saving measures

➢ Solar PV vacuum glazing (SPVG) for RE power production:

BSPVG technology has very good thermal-electrical-daylighting performances. About 81.63% of heat gain and 31.94% of heat loss can be reduced by a trial BIPV vacuum glazing applied in Hong Kong. About 48.72% of net energy consumption reduction can be achieved for buildings with the trial project.

Type	Thermal insulation performance	SHGC	Daylighting performance	Visual comfort and aesthetics	Utilization of solar radiation	Reliability and safety
Vacuum glazing	★★★	★	★	★★★	✕	★
Amorphous silicon PV glazing #1	★	★★	★	★	★	★★
Amorphous silicon PV glazing #2	★	★★	★★★	★★★	★	★★
Crystalline silicon PV glazing	★	★★★	★	★	★★★	★★
Crystalline silicon PV integrated vacuum glazing	★★★	★★★	★★★	★★★	★★★	★★★

Anodic bonding-assisted laser sealing technique

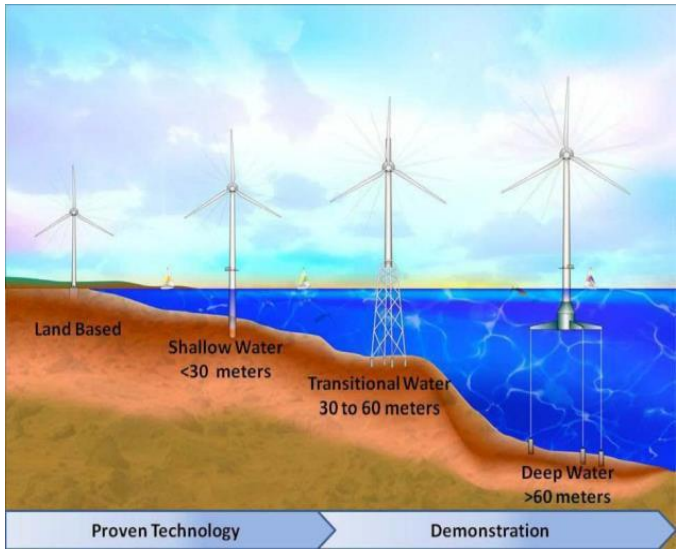
Laser cutting and anisotropic etching techniques

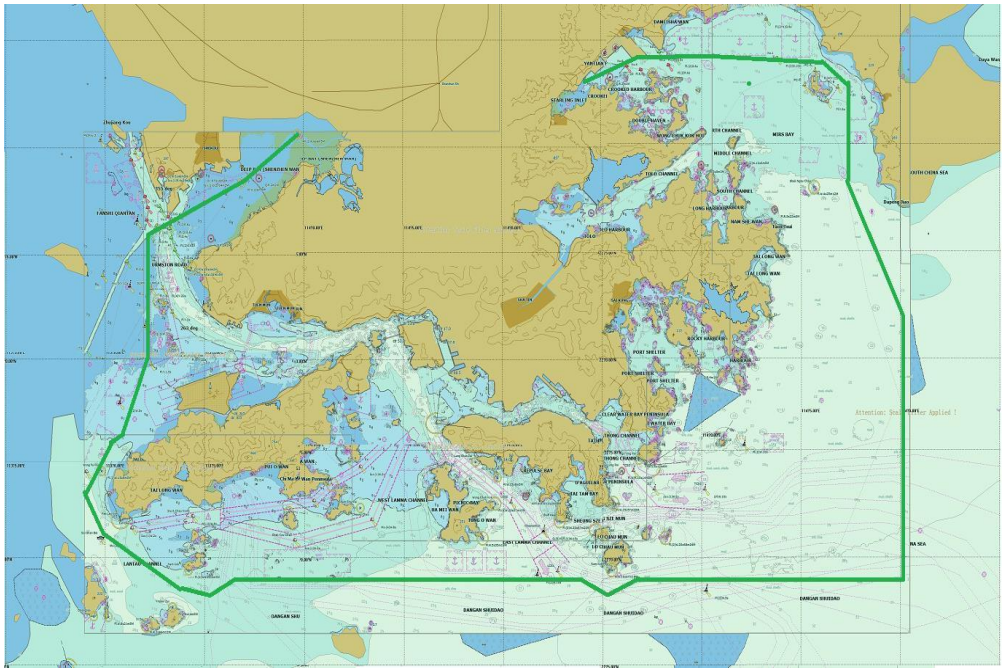
Outperformance of the novel green PV vacuum glazing over other glazing

2. Renewable energy production

➢ Offshore wind power for RE power supply:

- Literatures show that the total potential offshore wind power generation is 6409 GWh (15.3% of the 2010 power demand).
- ***One 8MW wind turbine can supply enough power to this building after the energy saving measures and solar PV power are considered.***

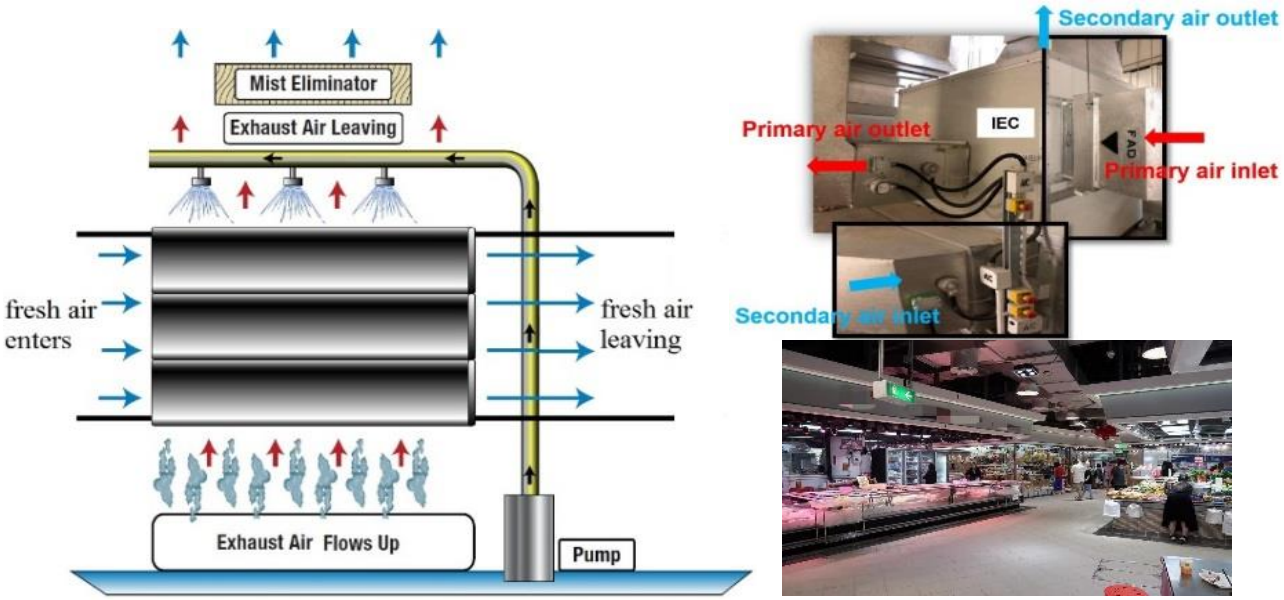




Hong Kong water area for offshore wind power generation

3. Energy saving measures

- **Indirect evaporative cooling and heat recovery wheel for high-efficiency air-conditioning systems**

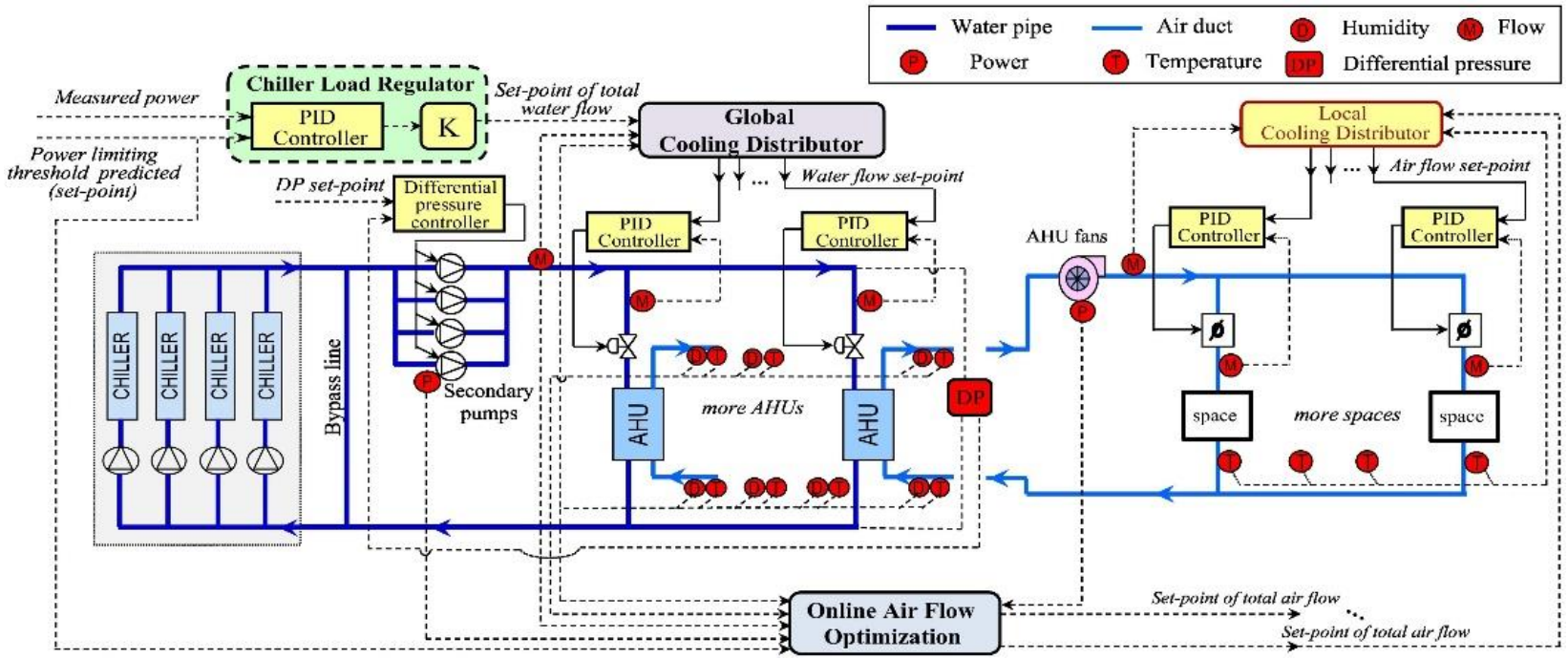


The Indirect evaporative cooler (IEC) applied in a Hong Kong wet market

The annual net energy saving and pay back period of an IEC are more economical than that of traditional heat recovery wheel (44.6 kWh/m^2, 4.3 years vs 28.9 kWh/m^2, 7.1 years). The annual energy-saving ratios of around 15% - 25% can be achieved for applications in Hong Kong.

3. Energy saving measures

- **Smart system controls for energy saving of air-conditioning systems and lighting**

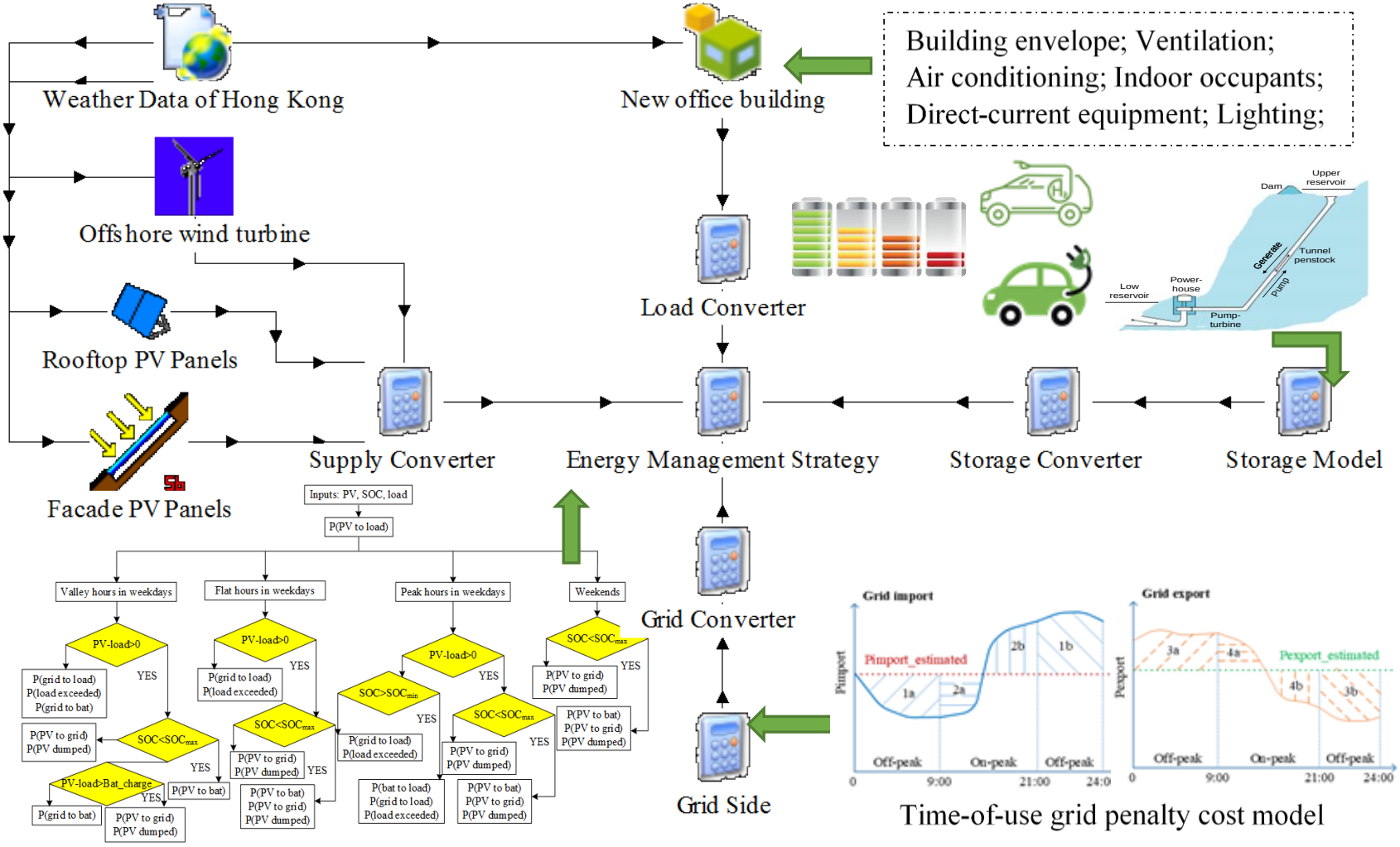


Proactive fast demand response control strategy

Motion sensor for lighting control (EMSD)

4. Optimized energy management

➢ Integrated flexible energy storage

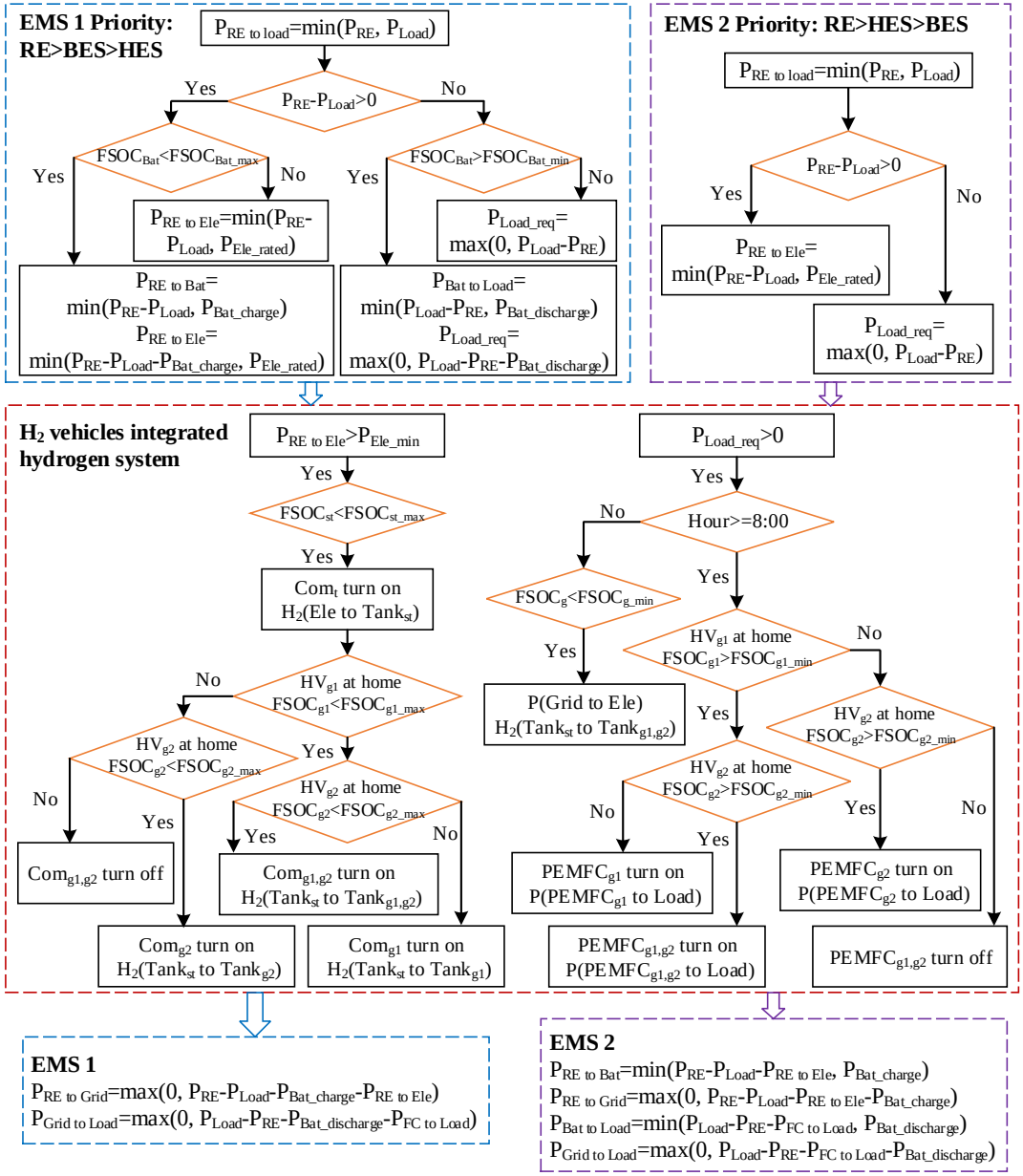


4. Optimized energy management

Fitout/user strategies:

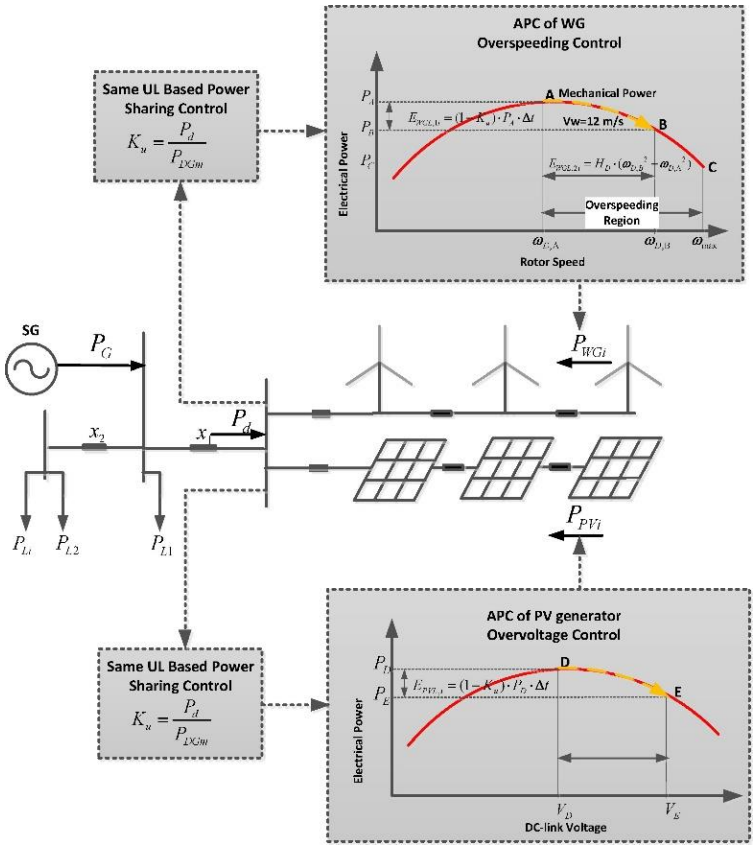
Different system energy management strategy:
EMS 1: RE > battery > hydrogen
EMS 2: RE > hydrogen > battery

The optimal energy management strategy can be selected by the multi-objective optimizations for major stakeholders with different preferences.

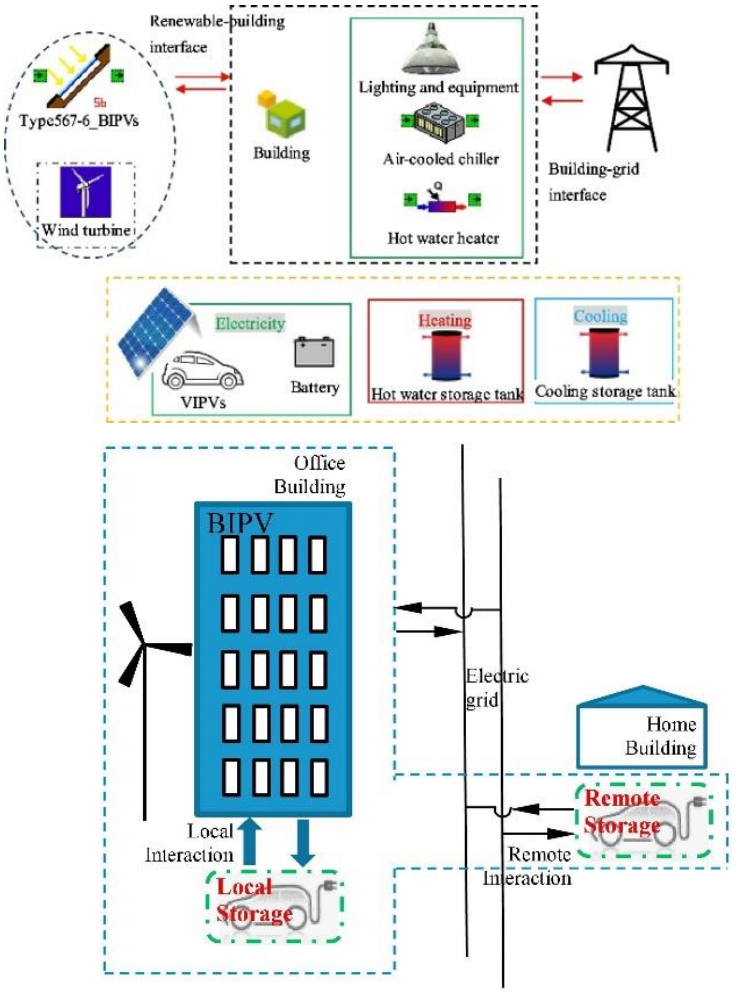


4. Optimized energy management

Fitout/user strategies



Cascading control of AC microgrid integrating PV and wind energy



Grid integration of renewable energy and storage systems for a commercial building

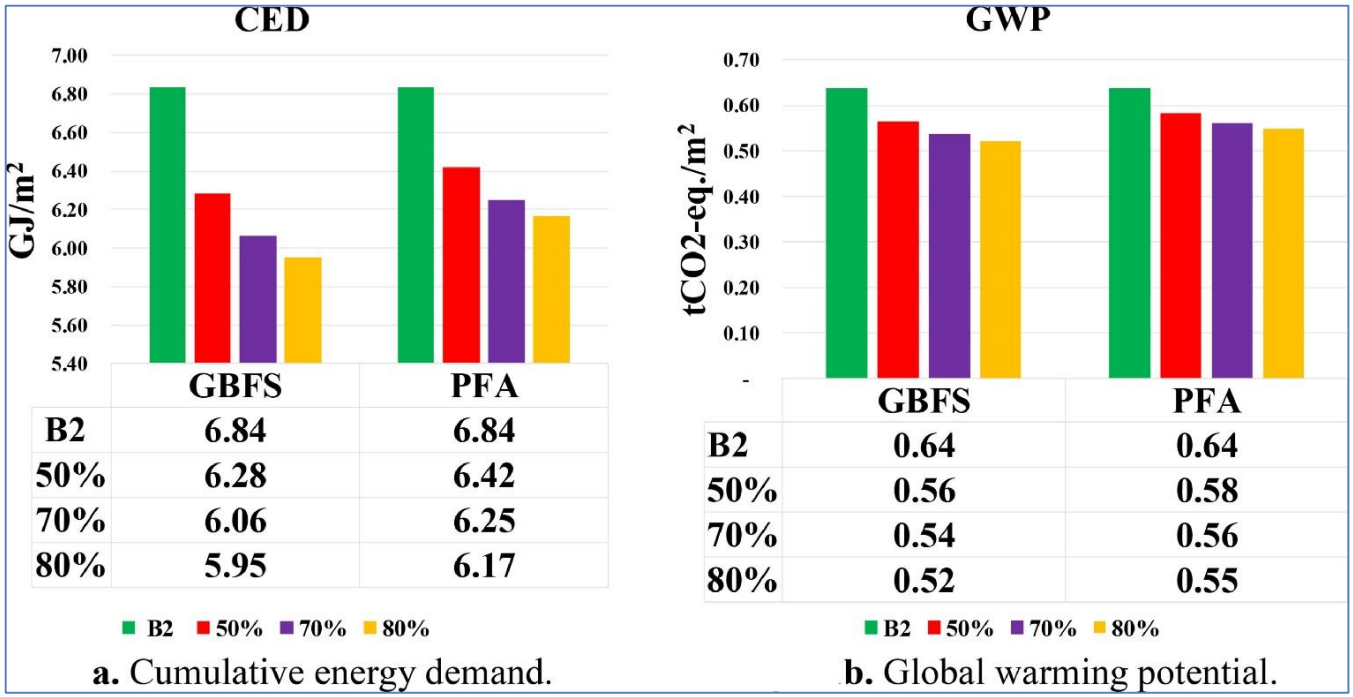
5. Energy use intensity (EUI)

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	Saving: 5%	Battery (vehicle) storage	--
Smart devices (e.g., chiller, fresh air controller) with motion sensors	Saving: 25%	Hydrogen (vehicle) storage	--
Indirect evaporative cooling & heat recovery wheel	Saving: 25%	Pumped hydro stroage	--
Annual building energy consumption	11,297,280 kWh/year	**Annual renewable energy production**	11,297,280 kWh/year

The result shows that the reduced annual building energy consumption and annual renewable energy production are the same so that the net-zero-carbon target can be realized! The reduced carbon emissions is: 11297.28 MWh/year * 0.6 kgCO_2-e/kWh = 6778.37 tonsCO_2/year.

6. Embodied carbon reduction

Impact from the use of alternative cementitious materials:



	GBFS	PFA
B2	6.84	6.84
50%	6.28	6.42
70%	6.06	6.25
80%	5.95	6.17

a. Cumulative energy demand.

	GBFS	PFA
B2	0.64	0.64
50%	0.56	0.58
70%	0.54	0.56
80%	0.52	0.55

b. Global warming potential.

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 energy use and carbon emissions by 19.91% and 15.23%, respectively. Prefabricated PV façade is proposed as an effective approach to further reduce the embodied carbon impact.

7. Occupant experience

- The solar PV vacuum glazing technology can not only produce electricity, but also achieve high thermal-electrical-daylighting performances of the building. The quality of indoor thermal environment and lighting comfort can be greatly improved with lower solar irradiation transmittance for blocking majority of solar irradiation.
- The semi-transparent glazing with smart coating can also reduce glare and improve visual comfort.
- Smart lighting with motion sensors and smart air-conditioning with CO2 sensors are used in the building to ensure a comfortable indoor environment with high energy efficiencies.

8. Conclusions

- To achieve the net-zero-carbon target, both energy saving and renewable energy production measures must be adopted;
- If the proposed energy saving measures can be used for the new building design, the EUI can be reduced to 120 kWh/m^2/year from 222 kWh/m^2/year (typical EUI for a commercial building in Hong Kong);
- The onsite solar PV system and one large offsite offshore wind turbine (8 MW) can produce enough electricity (11,297,280) kWh/year for the building's energy consumption on an annual basis;
- A real net-zero-carbon building can be developed if the above practical energy-saving and renewable energy production technologies can be realized. The reduced carbon emission is: 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.