Building Carbon Footprint (BCF) Method for Nearly Zero-Energy Building Design Assessment

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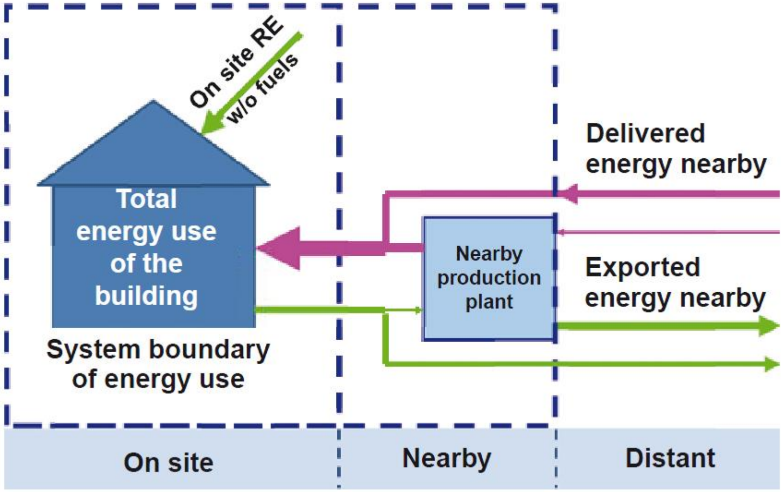
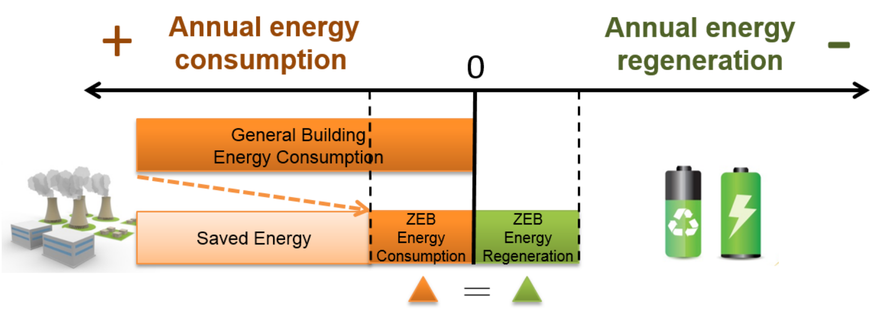
1. INTRODUCTION

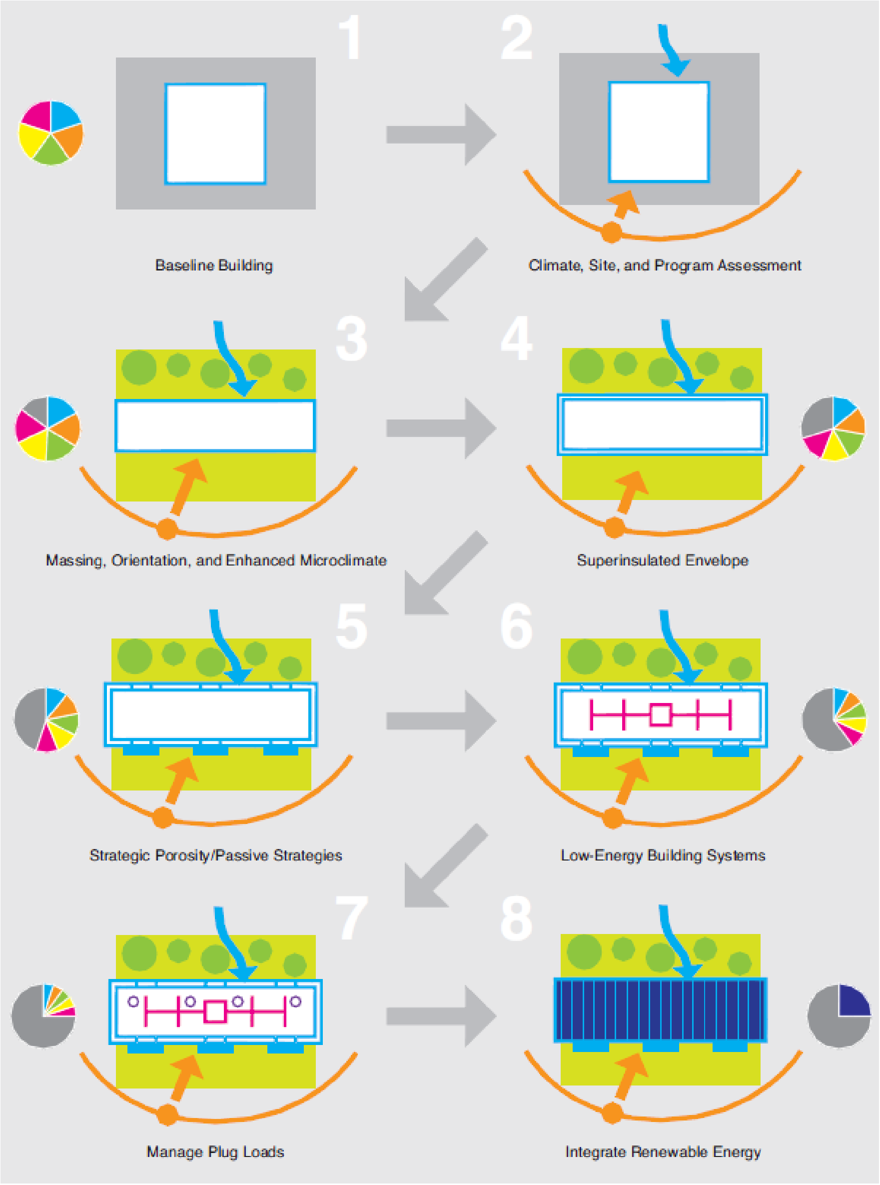
Introduction of ZEB

- **ZEB (Zero-Energy Building)** is an energy efficient, grid connected building enabled to generate energy from renewable sources to compensate its own energy demand.
- EU has declared that the energy conservation standard of all of new buildings must conform to the standard of "nZEB" in 2020.
- In USA, by Executive Order 13514, 100% of all new Federal buildings be Zero-Net-Energy in 2030.



Definition of ZEB (prEN 15603:2013-05)





Design Progress of ZEB

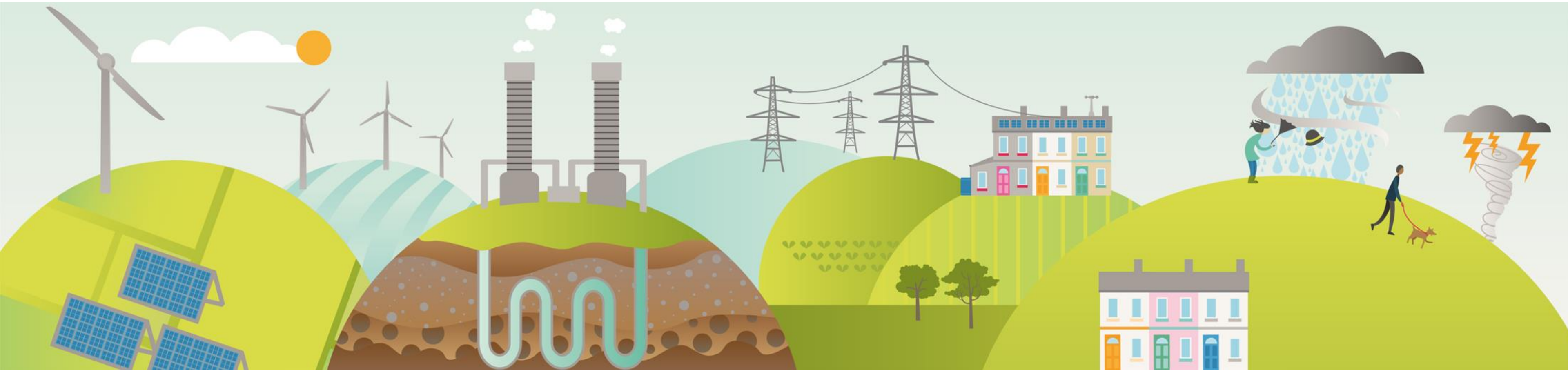
1. Energy Target Setting
2. Climate, Site, and Program Assessment
3. Massing, orientation and Enhanced Microclimate
4. High Performance Envelope
5. Passive Strategies
6. Low-Energy Building Systems
7. Plug Loads Management
8. Integrate Renewable Energy

2. RESEARCH PURPOSES

nZEB feasibility in Taiwan

1. This study aims to estimate the feasibility of zero-energy design for green buildings under the precondition of developing nZEB(nearly Zero-Energy Building) in hot-humid Taiwan.

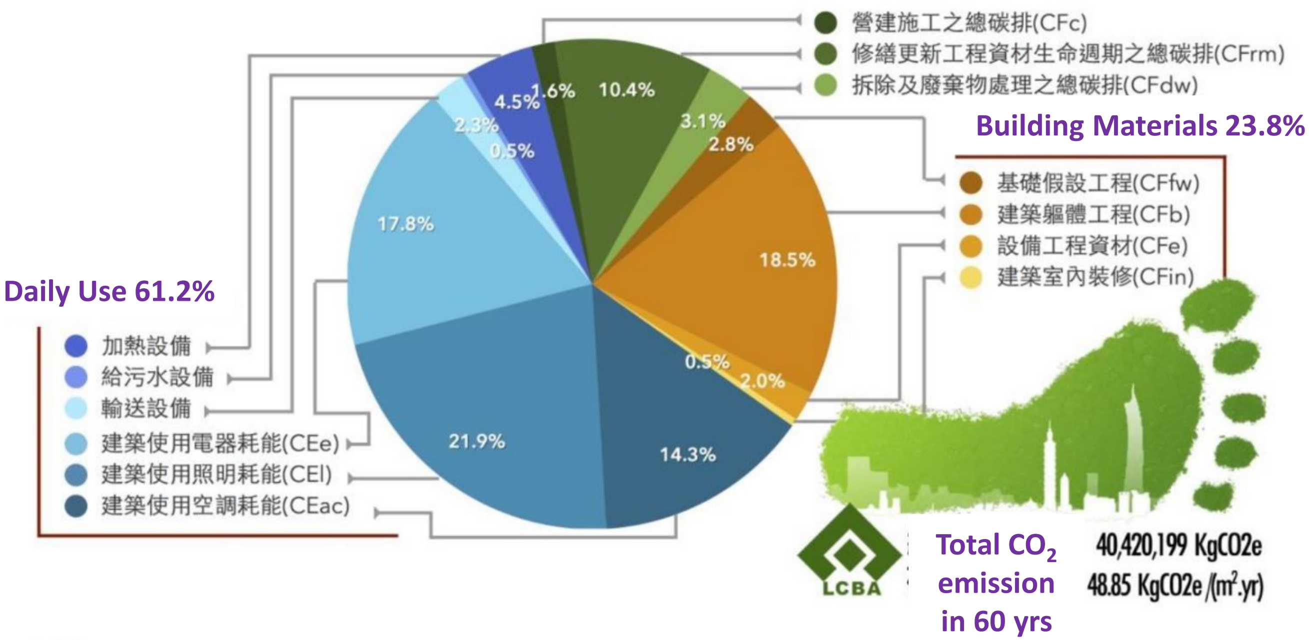
2. Three-oriented energy-saving technologies, including passive design, active design and renewable energy were analyzed. Then **“Building Carbon footprint Method (BCF)”** was used for nZEB quantify and feasibility of Taiwan’s residential building.



3. BCF method and application

BCF (Building Carbon Footprint Evaluation Method)

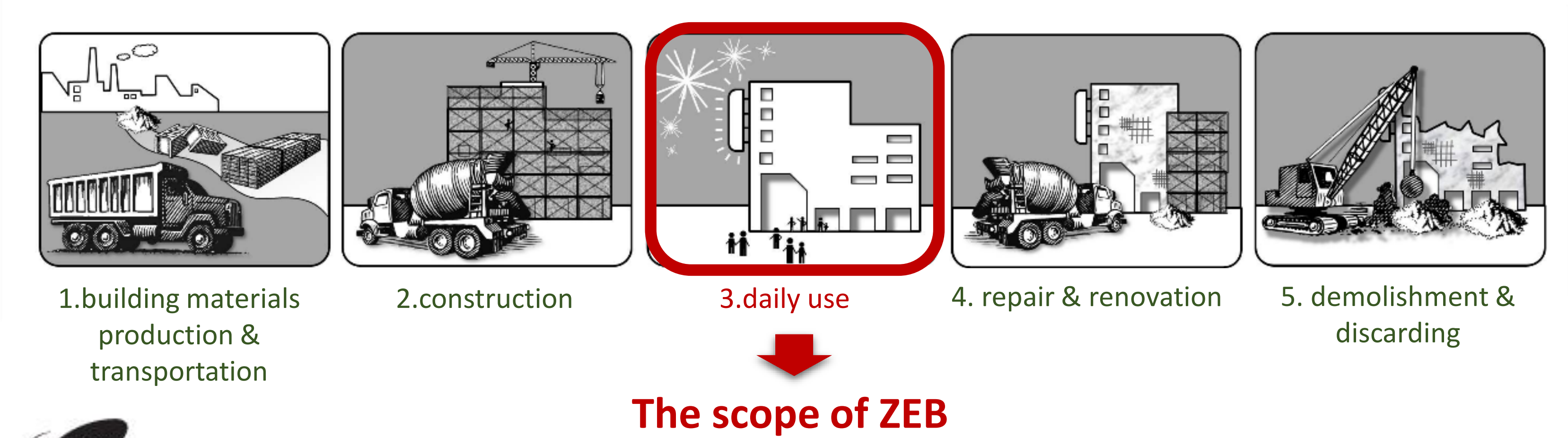
BCF method is developed by LCBA (Low Carbon Building Alliance) which uses "Standard Scenario" to standardize and estimate the building carbon footprint in 60-year life cycle in Taiwan.



3. BCF method and application

BCF (Building Carbon Footprint Evaluation Method)

- As BCF method is completely established on the carbon investigation data of Taiwan's building industry, BCF is a local, effective and reliable method.
- As the electricity and carbon emission can be converted into primary energy, in this study, BCF method helps standardize complex building users and equipment by dynamic simulation of energy, and calculate energy consumption with different energy-saving techniques in the period of daily use.



3. BCF method and application

"Standard Scenario" for Residential Daily Energy Consumption

- The "Standard Scenario" means the complex users, equipment and operating hours are "standardized" by dynamic simulation of energy.
- In "Standard Scenario," the standard population of each household is set as 2 adults and 2 children, who have standardized work and rest in daily lives. The average EUI is 50 (kWh/□ .yr).

Table 1: Standard Scenario of Household Equipment (Lin, 2015)

Hours of operation (hr)	Annual operating hours (hr/yr)		
	Air conditioning	Lighting	Home appliance
8760	1132	2920	2555

Table 2: Standard Residential EUI (Lin, 2015)

Residential Type	EUI reference (kWh/m^2.yr)			EUI (kWh/m^2.yr)
	Air conditioning	Lighting	Home appliance	
Single house, townhouse, housing	10	18	22	50

4. BCF for Quantitative Evaluation of Taiwan's nearly Zero-Energy Houses

Daily Energy Conservation Factors of Residential Buildings

AC Energy Saving Factors

- **d**: depth in short direction of building
- **VP** : natural ventilation potential
- **EEV** : Building envelop efficiency
- **S_{EL}:** AC energy label correction coefficient

Lighting Energy Saving Factors

- **Bi** : ballast coefficient
- **Ci** : lighting control coefficient
- **Di** : luminaire coefficient

Appliance Energy Saving Factors

- **Uei :** Home appliance management efficiency

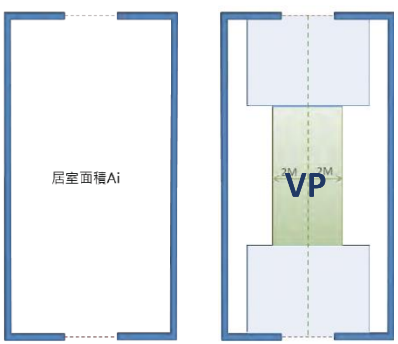
4. BCF for Quantitative Evaluation of Taiwan's nearly Zero-Energy Houses

4.1. Energy conservation potential : Air Conditioning

In BCF method, if the energy consumption (kWh/□ .yr) is not converted into carbon footprint equivalent ($kgCO_2e$), annual air conditioning energy consumption can be calculated by Eq. (1).

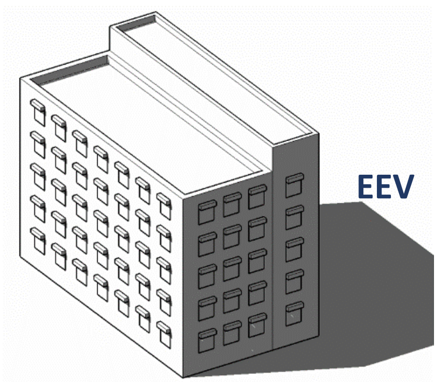
$$\text{Annual energy consumption of AC} = (\Sigma EUI \times AF) \times Vac \times Bac \times S_{EL} \quad \text{................ (1)}$$

Vac: Ventilation energy-saving Potential



Vac = 1.0 - (VP-0.7) × 0.75

Bac：Envelope Design

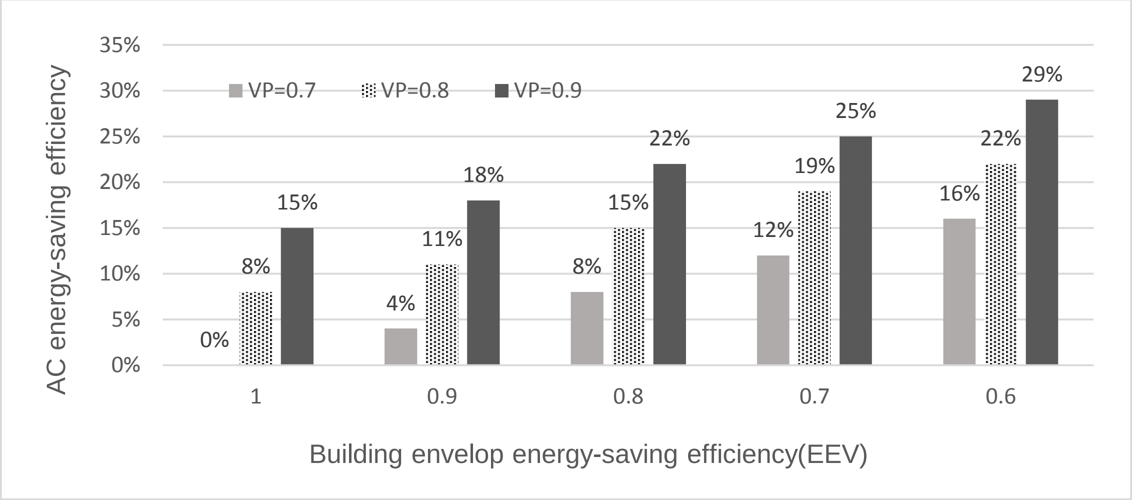


Bac = 1.0 - (2/d) × (1.0-EEV)

S_{EL}：AC Efficiency Grade

Passive Design

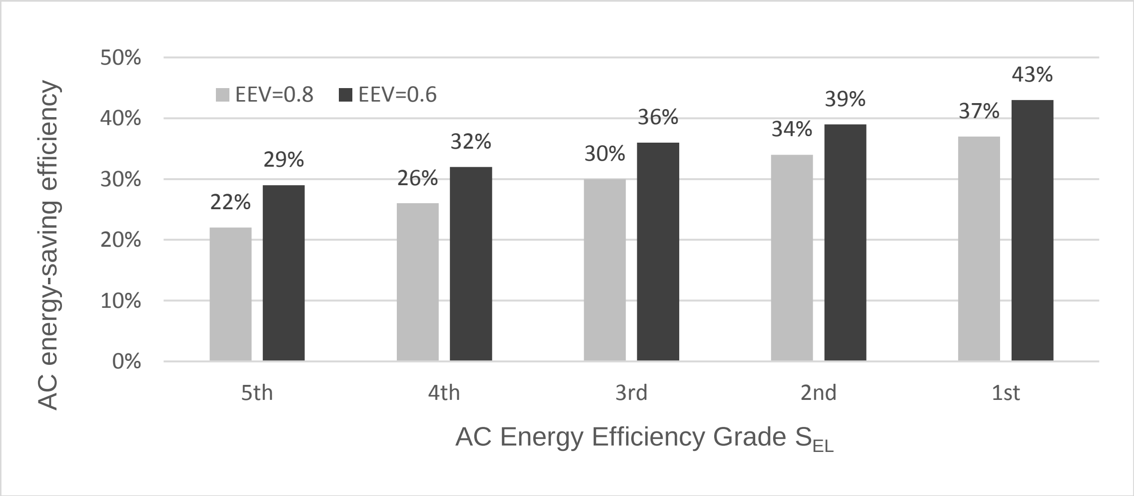
- This study assumes the energy-saving scenario baseline to be VP=0.7, Vac=1, EEV=1, S_{EL}=1 without using any energy conservation design technique for building envelope.
- The natural ventilation potential is the best when VP = 0.9, the Vac is 0.85. If EEV = 0.8, approaching the daily energy saving design value of most Taiwan's green buildings, the air conditioning energy-saving benefit increases to 22%.
- If VP=0.9, Vac=0.85, EEV = 0.6, it is approximately the optimum performance of envelope energy saving of current green building design, about 30% of AC energy consumption can be reduced.



AC Energy-Saving Efficiency and Building envelop energy-saving efficiency EEV

Passive Design + Active Design

- Using excellent passive design and air-conditioning equipment (VP=0.9, EEV=0.6, d=5m, 1st S_{EL}=0.85), it can reduce the routine AC energy consumption by 43% in residential buildings in Taiwan.
- Therefore, if the annual EUI of residential air conditioning is 10 (kWh/□ .yr), the minimum energy consumption is 10*0.6=6 (kWh/□ .yr).



AC Energy-Saving Efficiency and AC Energy Efficiency Grade S_{EL}

4. BCF for Quantitative Evaluation of Taiwan's nearly Zero-Energy Houses

4.2. Energy conservation potential : Lighting

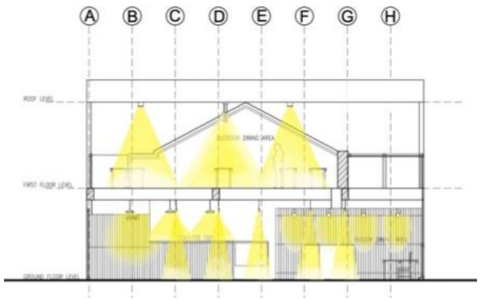
- BCF estimates the lighting energy consumption as Eq. (2). It is the combined lighting energy-saving index in Taiwan's green building Indicator "EEWH".
- Referring to EEWH system, this study uses minimum 0.4 of EL for evaluation, namely, the minimum annual energy consumption of lighting can be 40% of standard residential building.

$$\text{Annual energy consumption of lighting} = (\Sigma EUIai \times AFIi) \times EL \quad \ldots\ldots\ldots\ldots (2)$$

Lighting Efficiency

Lighting Control System

Lighting Power Density

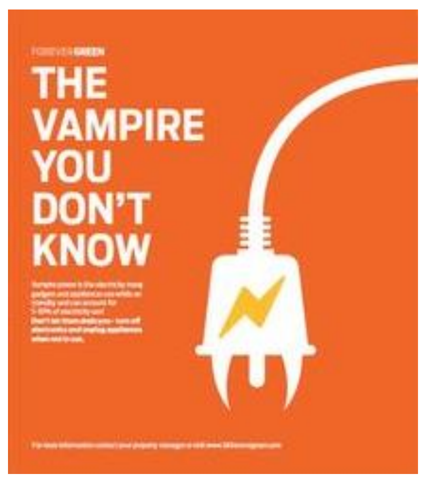


4. BCF for Quantitative Evaluation of Taiwan's nearly Zero-Energy Houses

4.3. Energy conservation potential : Appliance

The energy consumption of appliance is estimated as Eq. (3). The Uei means appliance management efficiency. If using effective night standby power off management, the Uei is 0.9.

$$\text{Annual energy consumption of appliance} = (\Sigma EUIai \times AFIi) \times Uei \;\ldots\ldots\ldots\ldots\ldots\; (3)$$

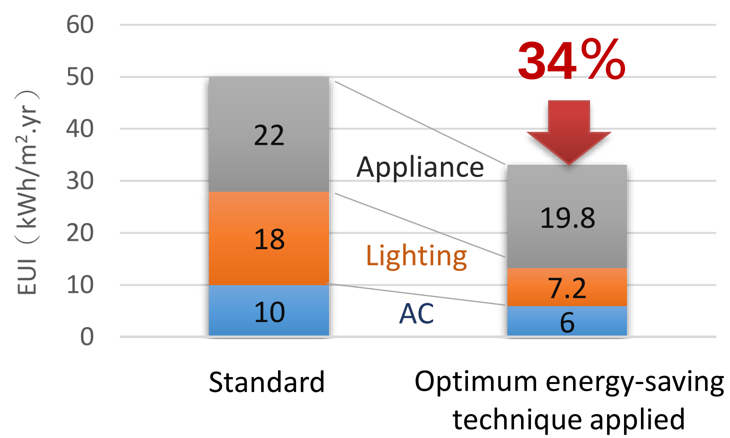


5. Total residential energy conservation potential

If we use the optimum energy conservation design techniques, the residential AC EUI can be reduced from 10 (kWh/□ .yr) to 6 (kWh/□ .yr), the lighting EUI can be reduced from 18 (kWh/□ .yr) to 7.2 (kWh/□ .yr), the appliance EUI can be reduced from 22 (kWh/□ .yr) to 19.8 (kWh/□ .yr), the total EUI can be reduced from 50 (kWh/□ .yr) to 33 (kWh/□ .yr), the maximum energy-saving benefit is 34%.

Table 3: The Maximum Energy Conservation Potential

Title	EUI (kWh/m².yr)			Total EUI (kWh/m².yr)
	AC	Lighting	Appliance	
Original standard value	10	18	22	50
Optimum energy-saving technique applied	6	7.2	19.8	33
Maximum energy conservation potential	40%	60%	10%	34%



6. Renewable Energy Assessment

- The renewable energy is estimated by using photovoltaics in this study. In Taiwan, the average household area is about 150 □ , the annual total power consumption is 4950 kWh while the best EUI is 33 (kWh/□ .yr).
- A household in northern Taiwan needs at least 62□ photovoltaic panel, that in the central Taiwan needs at least 52□ , and that in southern Taiwan needs at least 45□ photovoltaic panel. The investment recovery period is 14~19 years.

Table 4: Photovoltaic Substitution Potential Calculation (Area per Household 150□)

Site	Daily average solar radiation quantity (kWh/m².day)	Annual power generation per unit capacity (kWh/kW)	Total installed capacity (kW)	Required area (m²)	investment recovery period (yr)
Northern	2.75	803	6.2	62	19
Central	3.25	949	5.2	52	16
Southern	3.75	1095	4.5	45	14

nZEB feasibility in Taiwan's Residential Building

- If the individual dwelling is a 2-story building, 60%~80% of rooftop area shall be reserved for mounting photovoltaic panels.
- If it is a 3-story building, as the rooftop area decreases, all the rooftop area shall be used, the shortage renewable energy will be made up by ground open area or building facade, so as to meet the goal for nZEB.

7. Conclusion and Suggestion

Conclusion

- This study uses the BCF method to evaluate the feasibility of nZEB in Taiwan. The results show that under the present general energy-saving techniques, the total residential EUI can be reduced from 50 (kWh/□.yr) to 33 (kWh/□.yr), the maximum energy-saving benefit is 34%.
- This study uses "photovoltaic" as main renewable energy to evaluate the nZEB feasibility. The dwelling scale is about 150□ per household in Taiwan, under the precondition of EUI 33 (kWh/□.yr), the small-scale "individual house" is potential to implement ZEB at present. However, if dwelling scale is increased , the BIPV (Building Integrated Photovoltaic) design and high conversion efficiency solar cell shall be developed, then it is potential to be ZEB.

Suggestion

- In the promotion of related policies in the future, it is suggested to promote the improvement of the existing building energy efficiency, reward excellent green building design, and encourage the application of BIPV, so as to attain the goal for nearly ZEB.

Thank you

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