Building Life Cycle Carbon Emissions: A Review

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1 Background

EFFECTS OF GLOBAL WARMING

Global Warming

➢Increased sea level
➢Changes in water supply
➢Rising temperature
➢Damage to habitats

Greenhouse Gases

Carbon Dioxide
Methane
Ozone
Water Vapour
Nitrous Oxide
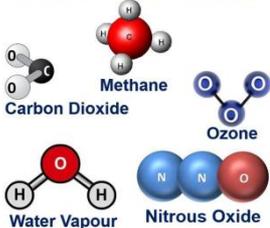
Greenhouse Gases (GHGs)

The excessive releasing of **greenhouse gases** (GHGs) is the **largest causes of global warming** (Soetanto et al., 2014)

oxygen   oxygen
carbon

Carbon Dioxide (CO$_2$)

Carbon Dioxide is **the primary component** of the GHG (Li et al., 2016)
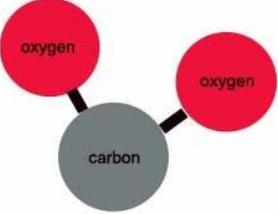
Buildings

Buildings account for **one third** of the energy-related CO$_2$ emissions. In Hong Kong, this figure can be as high as 60% (EPD, 2010; EMSD, 2009).

1 Background

Research Problem:
Life Cycle Carbon Assessment ($LCCO_2A$) Method have been widely used in evaluating carbon emissions from the construction industry. However, **the use of $LCCO_2A$ for high-rise prefabricated buildings remains unclear.**

Aim

To achieve a systematic understanding of $LCCO_2A$ of buildings in Hong Kong

Objectives

(1) to reveal the **profiles of previous studies** on $LCCO_2A$ of buildings;

(2) to investigate the **implications of $LCCO_2A$ for high-rise prefabricated buildings in Hong Kong**;

(3) to explore the **research gaps and recommendations**.

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2 Research Method

Engine: Scopus
Year: 1996 to 2016
Keywords: "Life Cycle" and "Carbon Emission" and "Building"
Specific terms: Title/Abstract/Keyword
Document types of articles:
"engineering", "environmental science", "energy", "social and management"
13 journals

TABLE 2 DIMENSIONS AND VARIABLES FOR REVIEW

Dimensions	Variables	Description of variables
Temporal	Life span	The service life of the buildings
	Life cycle phase	Full life cycle or not
Spatial	Research area	Location of the buildings
	Research scope	Building as a whole; components; materials; system; others
Functional	Building type	Residential buildings; non-residential buildings
	Building height	High-rise; medium-rise; low-rise buildings
Methodological	LCA Methods focus	Input-output; process based; hybrid method

Focused Examination of Research within Hong Kong

Six papers focusing on $LCCO_2A$ of buildings
From the dimensions of **case study, building type, life cycle phase, LCA method, research method and key data input**.

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3 Review Results and Analysis

Temporal Dimension

(1) Buildings' life cycle phase

- Papers specified the life cycle phase of the cases studied
- Papers did not specify the life cycle phase of the cases studied

22.5%

77.5%

Full life cycle 43%

Partial life cycle 57%
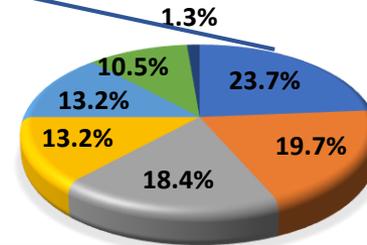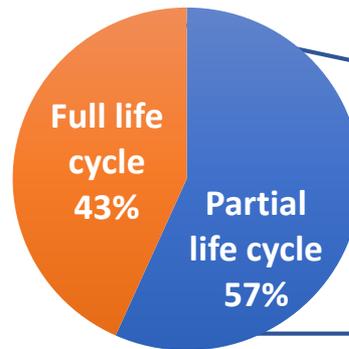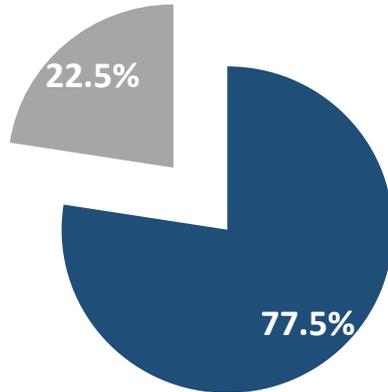
- cradle to end of construction
- cradle-to-gate
- operation
- cradle to site
- cradle to grave
- cradle to operation
- Deconstruction

23.7%

19.7%

18.4%

13.2%

13.2%

10.5%

1.3%

(2) Buildings' life span

- Papers specified the service life span
- Papers did not specify the service life span

30.1%

69.9%

22%

51%

27%
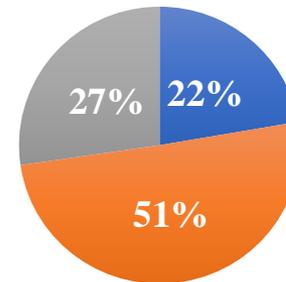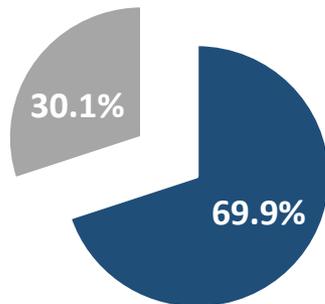
- (0,25] years
- (25,50] years
- (50,+∞) years

3 Review Results and Analysis

Spatial Dimension

(1) Research area

- Papers specified the cases' locations
- Papers did not specify the cases' locations

Pie chart: 89%, 11%

Bar chart (horizontal):
- Other regions: 33.20%
- Hong Kong: 3.90%
- Korea: 10.40%
- Mainland China: 12.30%
- U.S.: 13.60%
- Europe: 26.60%

Axis: 0.00% 5.00% 10.00% 15.00% 20.00% 25.00% 30.00% 35.00%
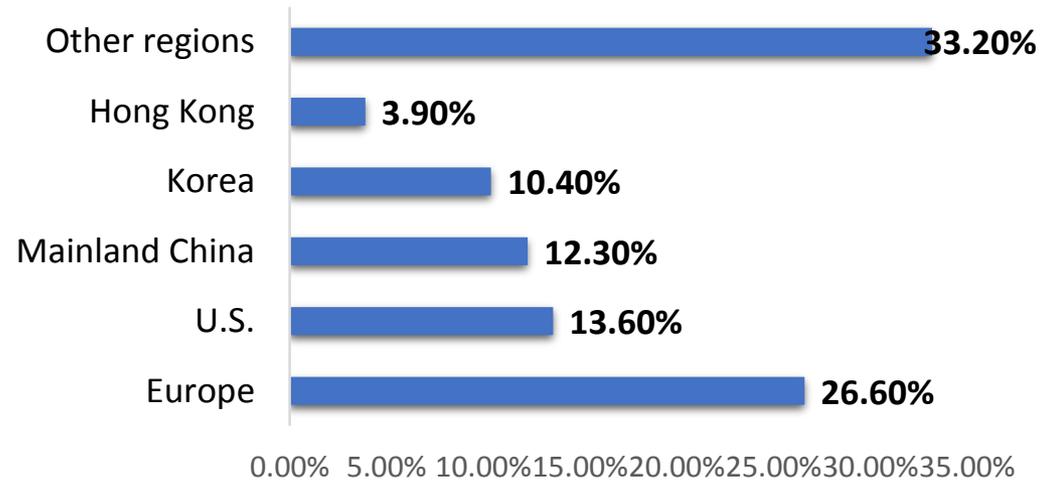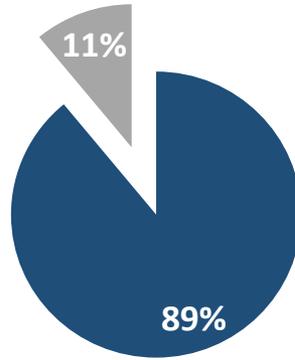
(2) Research scope

- Papers specified the research scopes
- Papers did not specify the research scopes

Pie chart: 75.1%, 24.9%

Bar chart (horizontal):
- Buildings as a whole: 16.92%
- Systems: 17.69%
- Components: 21.54%
- Materials: 43.85%

Axis: 0.00% 10.00% 20.00% 30.00% 40.00% 50.00%
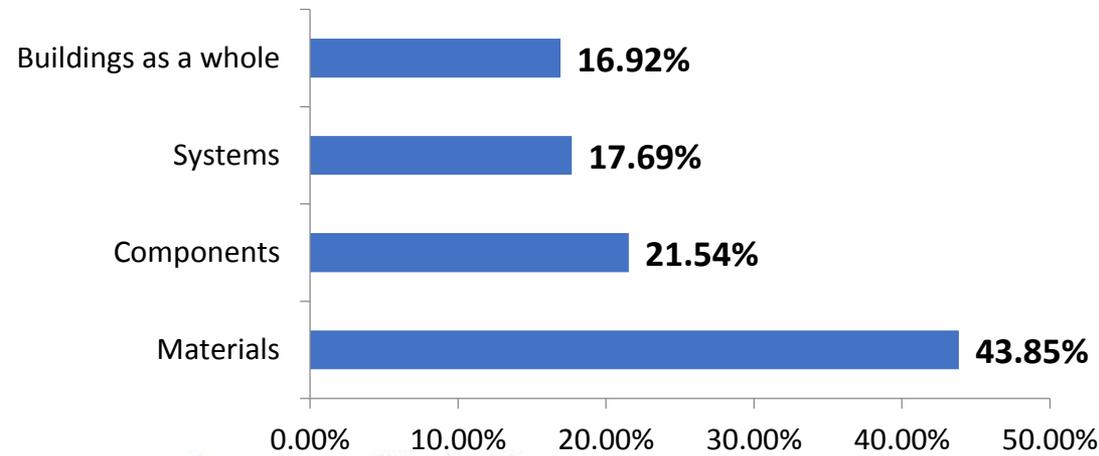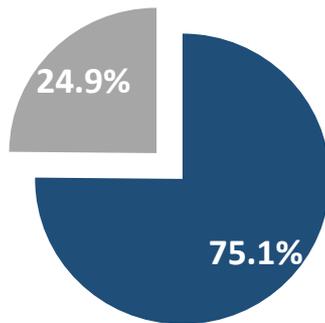
3 Review Results and Analysis

Functional Dimension

(1) Building type

■ Papers specified the buildings' types of the cases

■ Papers did not specify the buildings' types of the cases

38.7%
61.3%

31.1%
68.9%

3%   3%
21%
49%
24%

■ Non-residential buildings
■ Residential buildings

■ Office buildings
■ Educational buildings
■ Commercial buildings
■ Health buildings
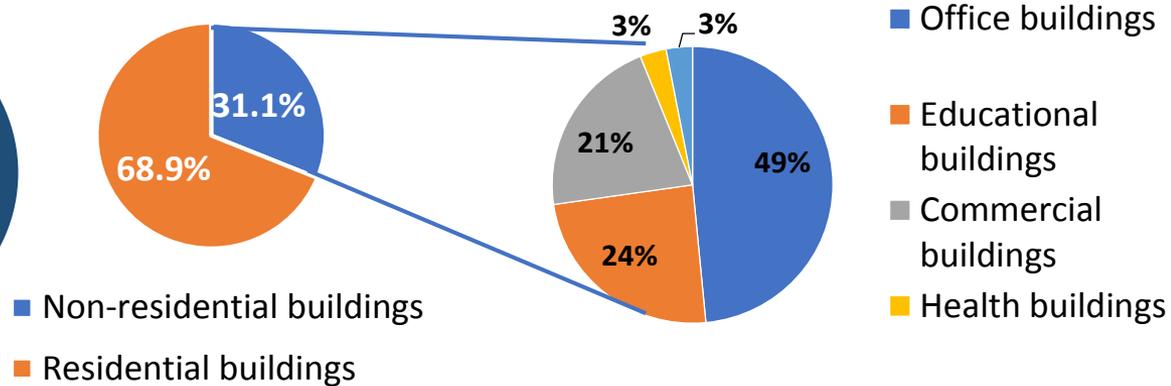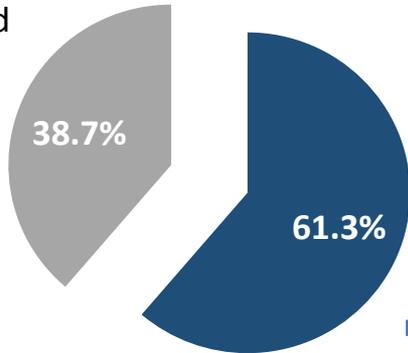
(2) Building height

■ Papers specified the height of the cases

■ Papers did not specify the height of the cases

43.9%
56.1%

High-rise (greater than 10 stories) — 25.80%
Medium-to-high-rise (7 to 9 stories) — 7.20%
Medium-rise (4 to 6 stories) — 22.70%
Low-rise (less than 3 stories) — 44.30%

0.00% 10.00% 20.00% 30.00% 40.00% 50.00%

3 Review Results and Analysis

Methodological Dimension

- **Papers specified the calculation process and adopted one of the three methods**

- **Papers did not specify the calculation process and adopted one of the three methods**

41.6%

58.4%
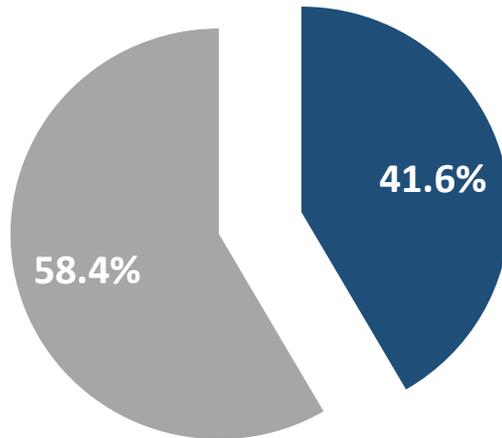
Method	Number	Percentage
Process-based	31	43.10%
Input-output analysis	34	47.20%
Hybrid analysis	7	9.70%
Total	72	100%

WORLD SBE
2017 HONG KONG
WORLD Sustainable Built Environment Conference

Organisers:
CONSTRUCTION INDUSTRY COUNCIL 建造業議會
HKGBC 香港綠色建築議會

International Co-owners:
SBE SERIES
CIB
iiSBE
UNEP Sustainable Buildings and Climate Initiative
FIDIC
Global Alliance for Buildings and Construction

3 Review Results and Analysis

Focused Examination within the Hong Kong Context

	Authors	Case study	Building type	Life cycle phase	LCA method	Research method	Key data input
1	Chau et al. (2012)	CB [a]	HR office	cradle-to-end of construction	process-based	Monte Carlo method	First hand data; Reference; Published information.
2	Zhang et al. (2013)	CB	a thirty-story commercial	Full life cycle	process-based	inventory analysis; case study	Report by the Electrical Mechanical Service Department of Hong Kong; Literatures.
3	Chiang et al. (2014)	CB	residential	cradle to site	NA	NA	ICE database
4	Jaillon and Poon (2014)	review	HR residential	deconstruction phases	NA	Questionnaire survey	Questionnaire survey; Face-to-face interviews; Site observations.
5	Dong et al. (2015)	CB and PB	HR residential	cradle-to-end of construction	process-based	SimaPro	Questionnaire survey; Semi-structured interview; Ecoinvent.
6	Pan et al. (2016)	NA	PRH	NA	Simulation	BEA software	Literature review; Technical analysis; Case study;

[a] CB means the conventional buildings and PB means the prefabricated buildings.

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4 Discussion

From the temporal dimension
- There is **inconsistent of cases' service life span**.
- **Non-full life cycle** was carried on by more scholars, especially the phase of "cradle to end of construction", "cradle-to-gate", and the "operation".

From the spatial dimension
- The demand for **further research in Hong Kong**.
- **The materials selection** for reducing the carbon emission is important.

From the functional dimension
- **Residential buildings** were demonstrated as the main research objectives.
- A lack of understanding on the **mid high-rise and high-rise buildings** needs to be optimised in further research.

From the methodological dimension
- Research on **hybrid method** is inadequate.

4 Discussion

- ✓ Carbon emissions in the **operation phase** has been overlooked in Hong Kong.
- ✓ Studies on **high-rise prefabricated buildings in Hong Kong** are inadequate.
- ✓ The direct implications were considered while the **indirect ones were ignored.**

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5 Conclusions

The uncertainties and inconsistency in the methods contribute to a fragmented understanding of the $LCCO_2A$ of high-rise prefabricated buildings.

There is a lack of understanding of $LCCO_2A$ relevant to the building's **operational stage and prefabricated buildings**' indirect implications

There is **a severe gap** in the knowledge of the $LCCO_2A$ of high-rise prefabricated buildings **in Hong Kong**.

Acknowledgements

Thank you