CICID 10th Anniversary Conference

**Innovation, Integration and Implementation**

# Enhancing **Productivity** Through **Off-Site Prefabrication**

**Dr Wei Pan**

The University of Hong Kong

31 May 2013

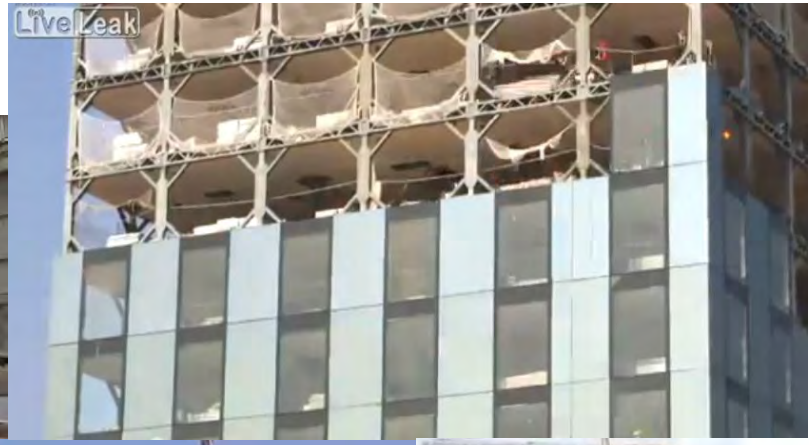
The University of Hong Kong


可建 远大可持续建筑

9度抗震 5倍节能 20倍净化

BSB BROAD SUSTAINABLE BUILDING

9M earthquake resistant 5x energy efficient 20x purer air








# The Aim or The Mean?

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

$$\text{Input} \times \text{Productivity} = \text{Output}$$

# Single or Total Factor?

Value of the Commodities, i.e. goods and services produced

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

Equivalent value sum of all Partial Factors of Production consumed, e.g.:

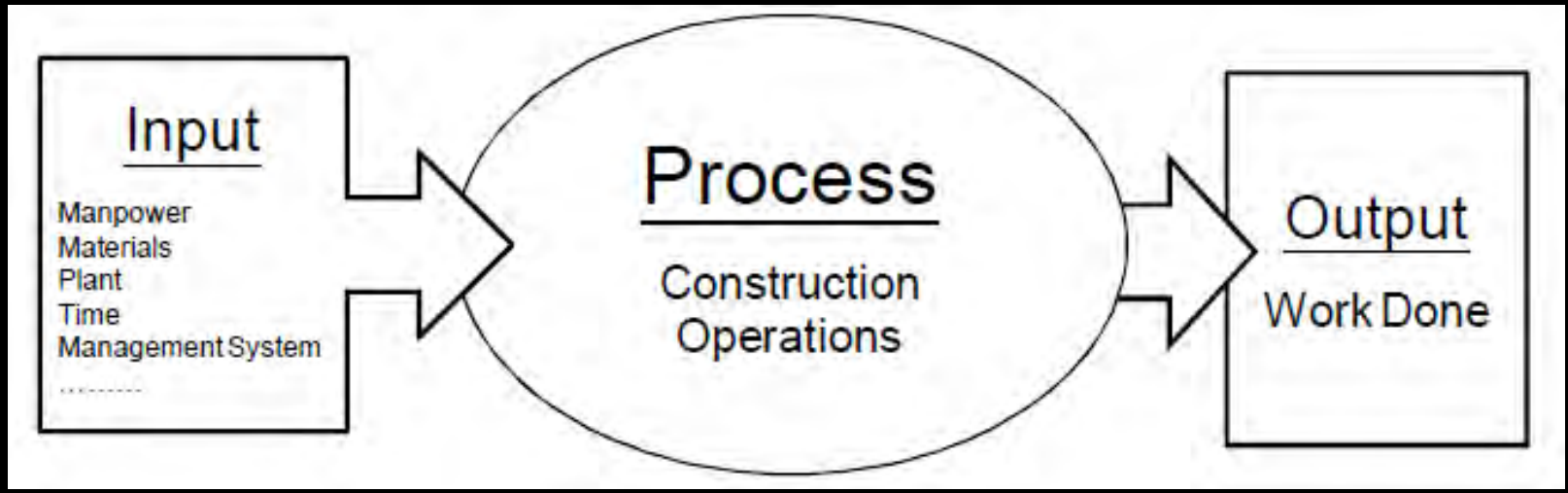
- Natural Resources
- Labour
- Capital Goods
- Entrepreneurship

*Samuelson and Nordhaus (2004)*

- ~ 45% of energy consumption and carbon emissions
- 20% of water use
- 30-40% of solid waste generation
- 40% of total global raw material use
- 111m people directly employed

*Butler (2008); UNEP (2012)*

# Integration or Bolted-on?



# Population in HK

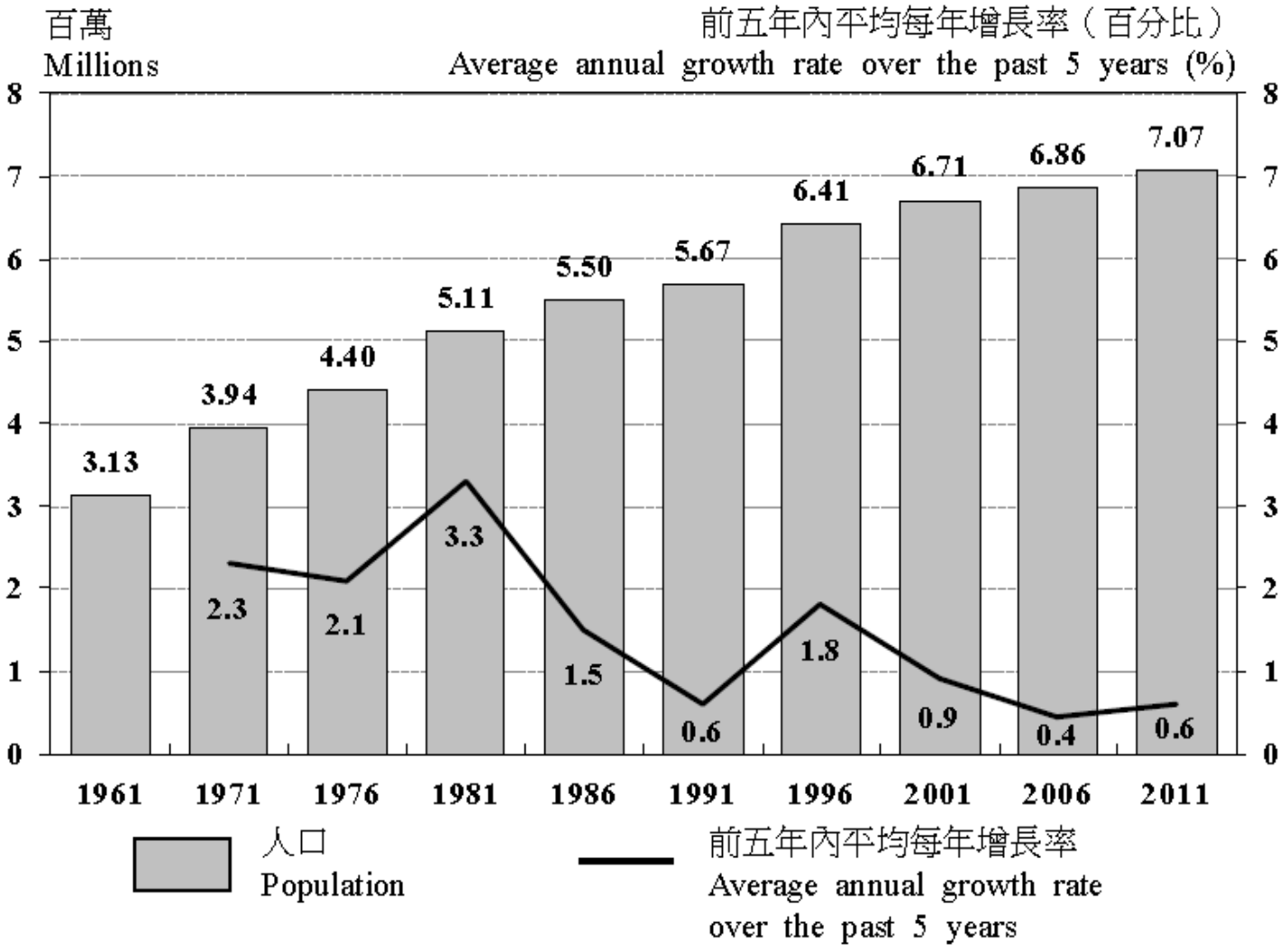



**Chart 1 Population and Average Annual Growth Rate, 1961 – 2011**

**(Source: 2011 population census, Census and Statistics Department)**

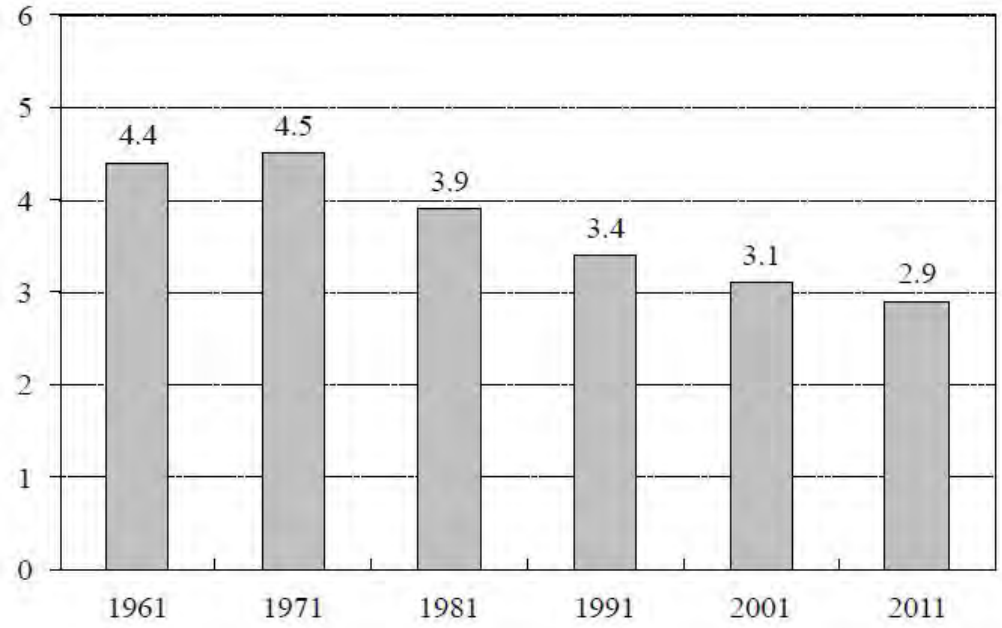
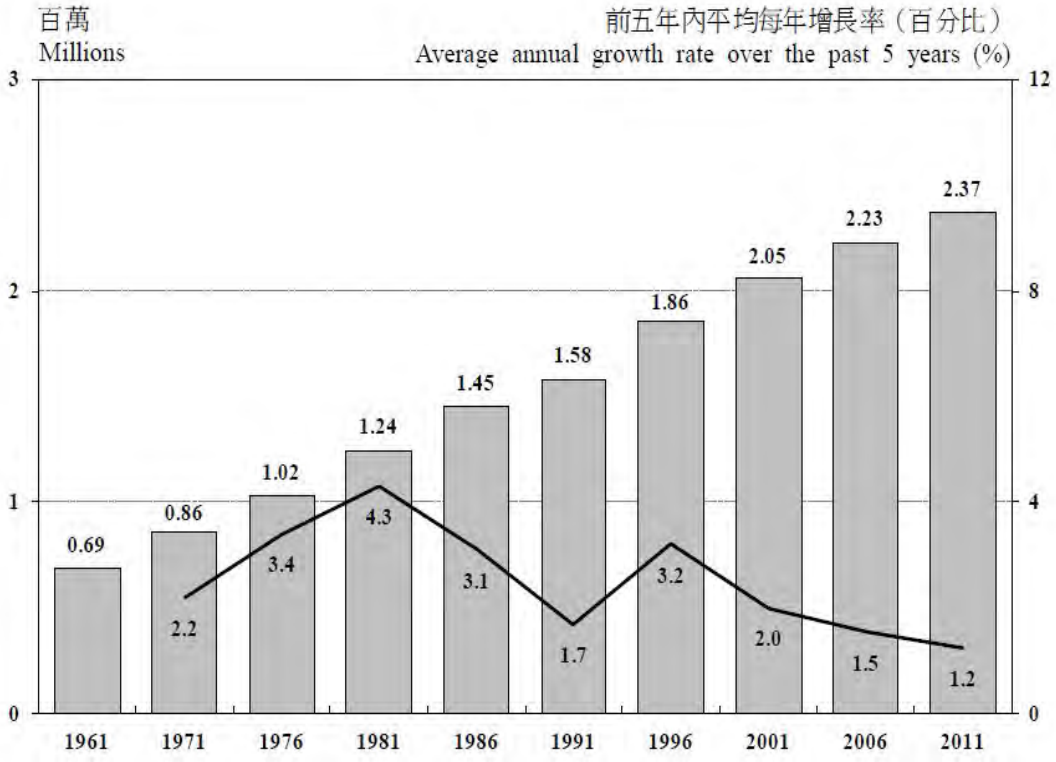



Chart 3 Average Domestic Household Size

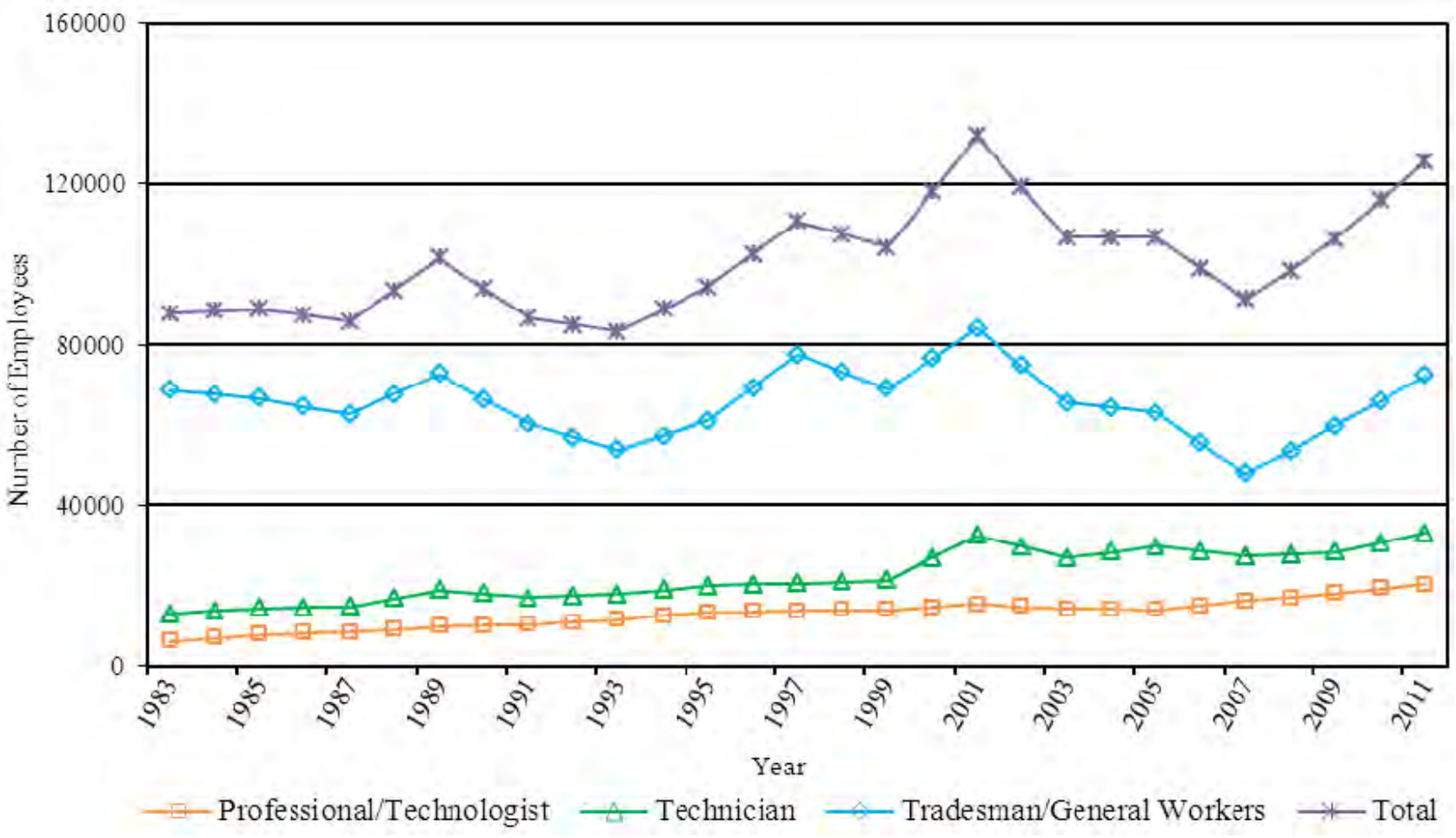
(Source: Hong Kong Monthly Digest of Statistics, April 2012)

# Domestic Households in HK

Chart 2 Number of Domestic Households and Average Annual Growth Rate



# Construction Workforce (HK)




Manpower Trends 1983 to 2011 (Excluding sub-contractors/ self-employed workers) (source: Building and Civil Engineering Training Board)

# Labor Input in Construction (HK)

| Job Level | Number of Vacancies | |
|---|---|---|
| | 2009 (%) | 2011 (%) |
| Professional/Technologist | 181 (1.00) | 379 (1.86) |
| Technician | 604 (2.13) | 579 (1.76) |
| Skilled and Semi-skilled Worker | 79 (0.18) | 1 933 (3.90) |
| General Worker | 79 (0.48) | 295 (1.30) |
| **Total** | **943 (0.89)** | **3 186 (2.54)** |

Distribution of Job Vacancies by Job Level
(Source: Building and Civil Engineering Training Board)

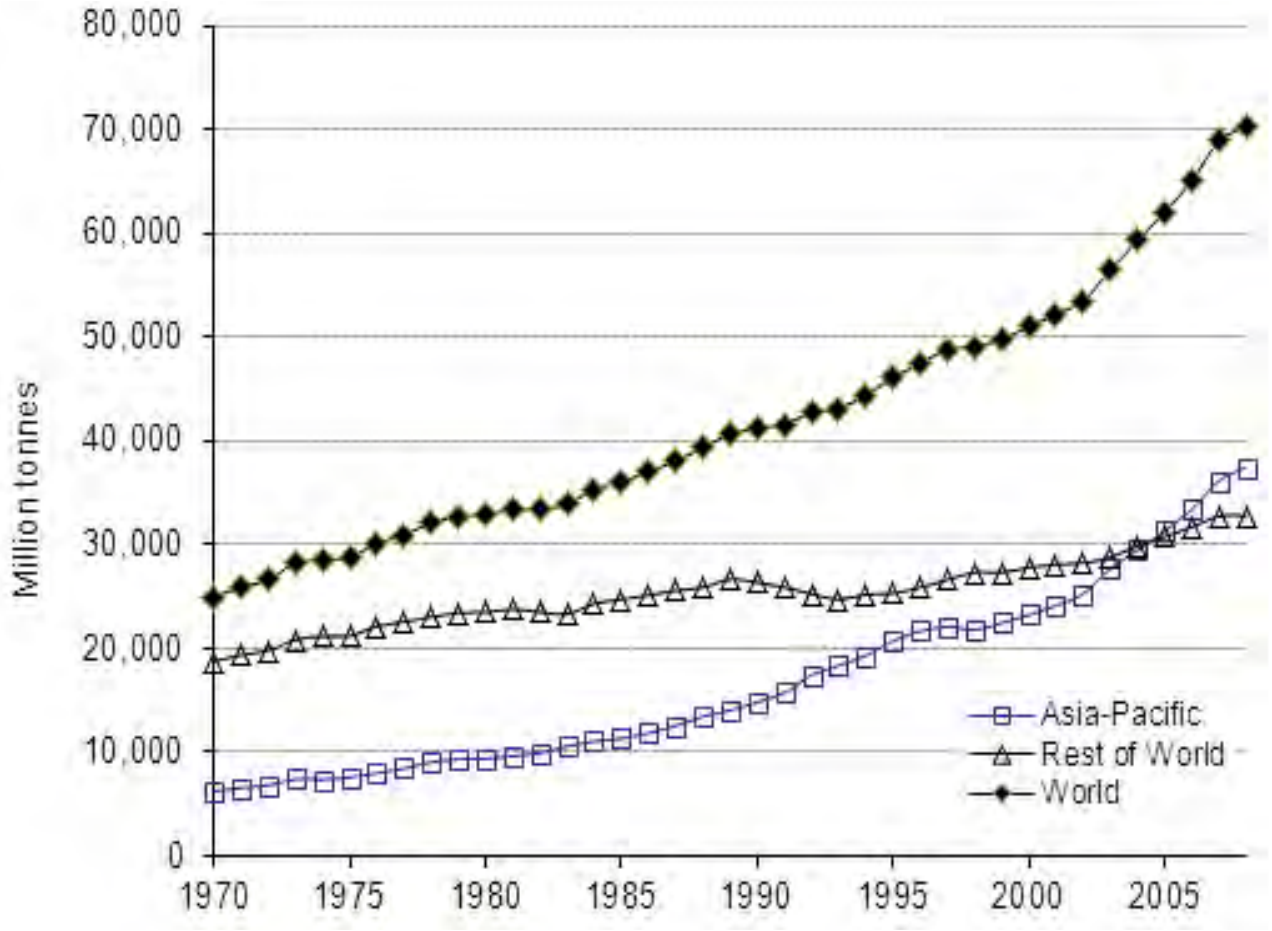
# Aging Labour in Construction (HK)

- Shortage of skilled labour:
- Over 40 years old: 68% (construction industry workforce)
- Over 50 years old: 43%
- Over 60 years old: 10%

(10 000 persons)

| Industry (based on HSIC Version 1.1) | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|
| Manufacturing | 22.4 | 21.7 | 20.0 | 16.6 | 15.0 | 13.3 | 13.3 |
| Construction | 26.4 | 26.9 | 27.5 | 26.5 | 26.2 | 26.5 | 27.7 |
| Wholesale, Retail and Import/Export Trades, Restaurants and Hotels | 109.4 | 110.5 | 114.2 | 58.9 55.2 | 56.2 54.5 | 54.7 55.8 | 53.9 57.8 |
| Transport, Storage and Communications | 35.7 | 36.9 | 37.2 | 43.4 | 42.3 | 42.2 | 43.4 |
| Financing, Insurance, Real Estate and Business Services | 50.3 | 52.6 | 54.6 | 63.9 | 63.7 | 64.1 | 67.6 |
| Community, Social and Personal Services | 87.0 | 89.2 | 92.0 | 84.3 | 86.7 | 88.5 | 91.5 |
| Others | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 | 2.3 | 2.4 |
| **Total** | **333.7** | **340.1** | **347.7** | **350.9** | **346.8** | **347.4** | **357.6** |

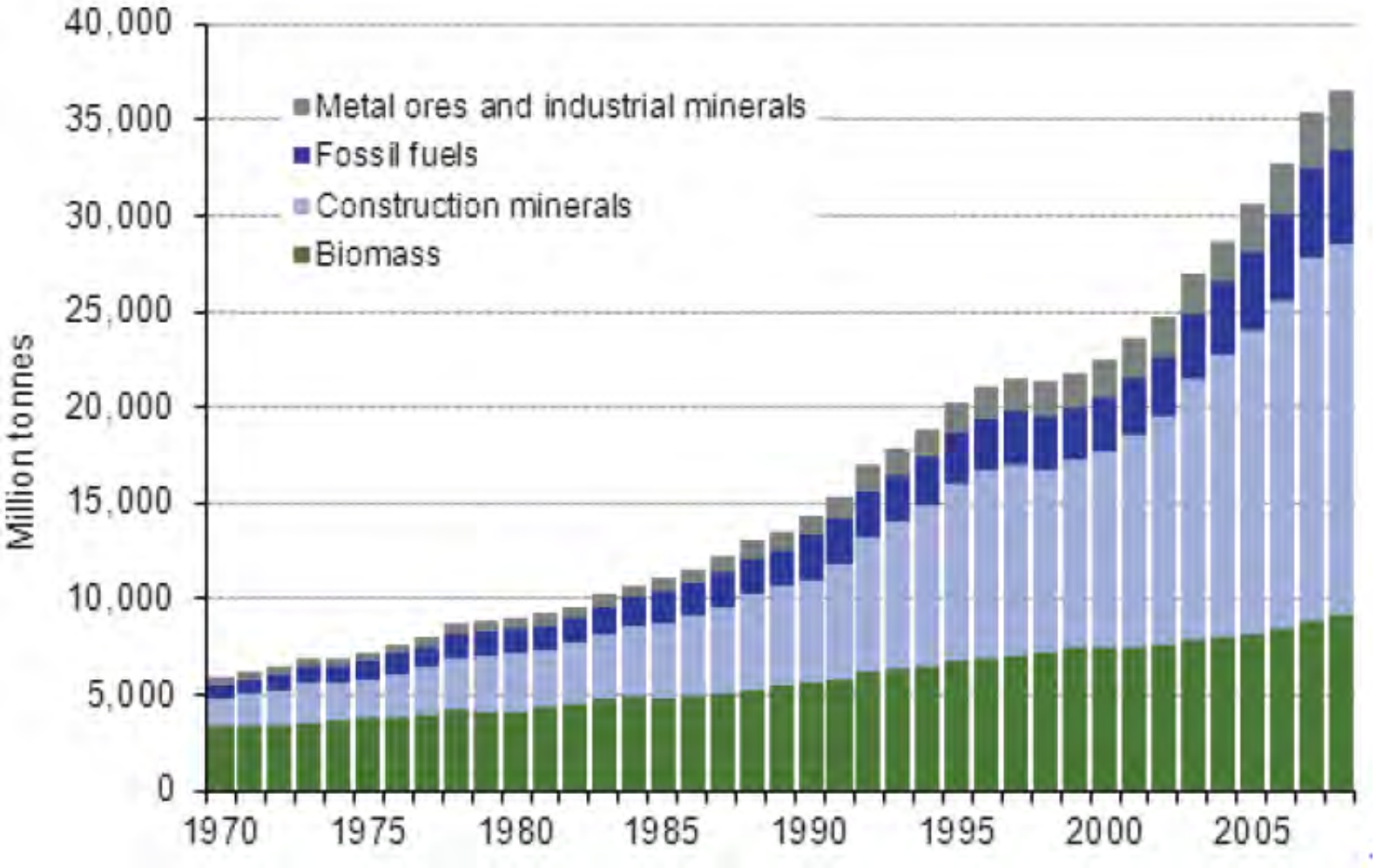
# Resources Input




Domestic material consumption (DMC) for the Asia–Pacific region, Rest of the World, and World, for the years 1970–2008

(Source: Recent trends in material flows and Resource productivity in Asia and the pacific 2013)

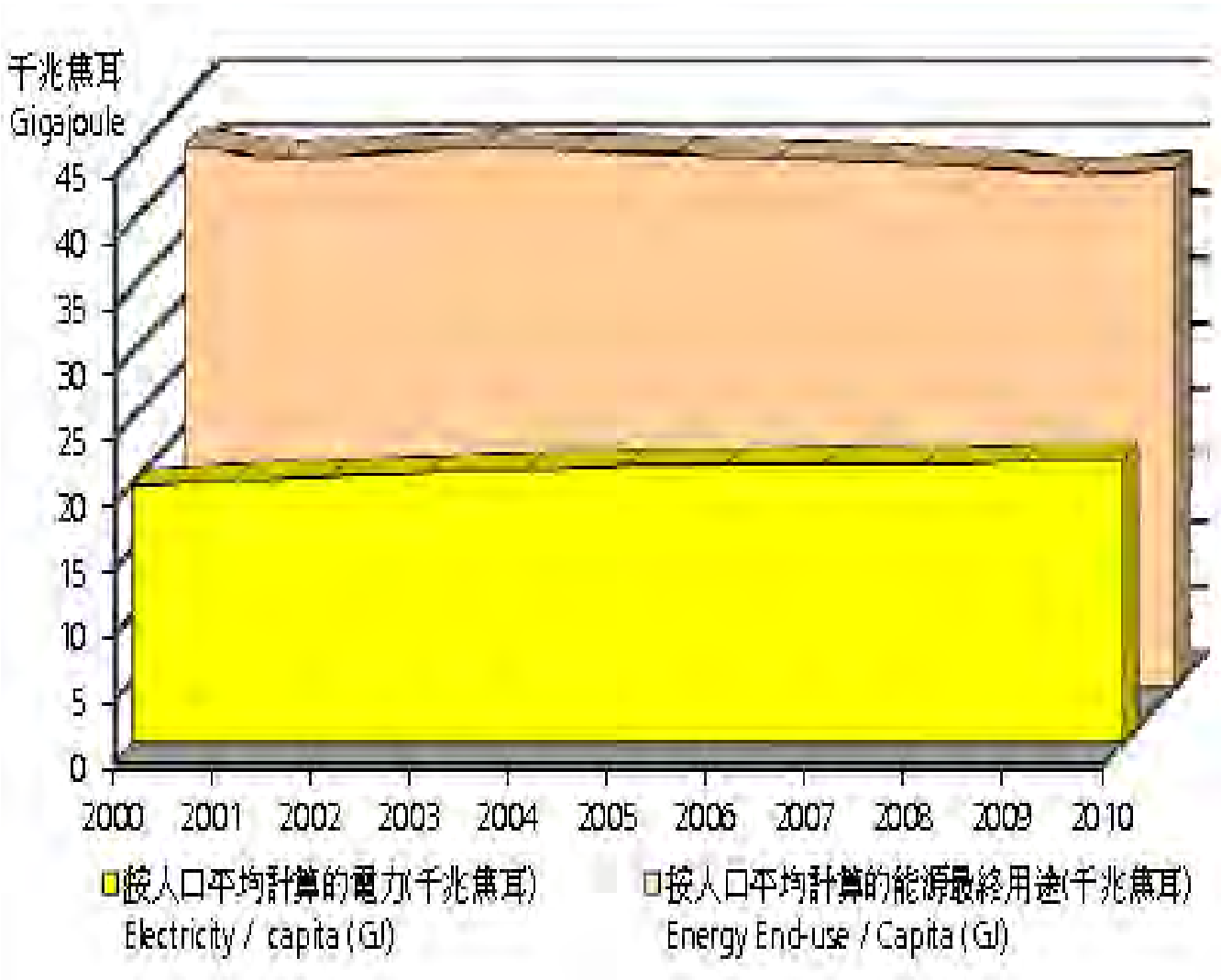
# Resources Input




Domestic material consumption (DMC) for the Asia–Pacific region, by major category of material for the years 1970–2008, in million tonnes

(Source: Recent trends in material flows and Resource productivity in Asia and the pacific 2013)

# Energy Input (HK)

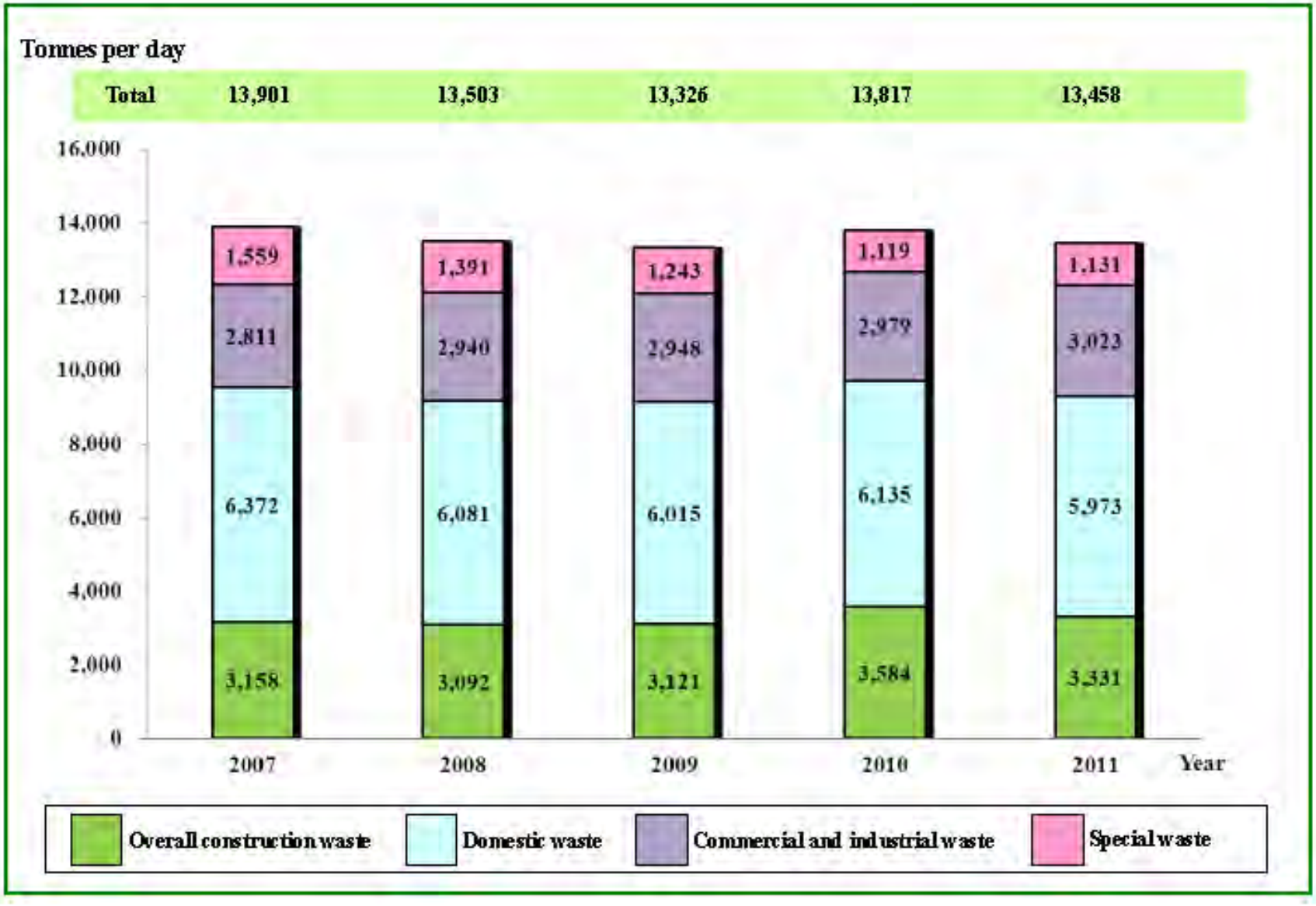



Energy End-use Per Capita in Hong Kong

# GDP & Construction Industry (HK)

| Year | Gross Value of Construction Works (HK$Mn) | | | | Construction industry | |
|---|---|---|---|---|---|---|
| | Private Sector sites | Public sector sites | Locations other than sites | All groups | GDP share (%) | Employment Share (%) |
| 2001 | 40,497 | 41,793 | 31,696 | 113,986 | 4.53 | 8.89 |
| 2002 | 42,292 | 32,070 | 31,638 | 106,000 | 4.15 | 8.80 |
| 2003 | 35,187 | 32,378 | 31,468 | 99,032 | 3.69 | 8.16 |
| 2004 | 28,021 | 28,533 | 36,618 | 93,171 | 3.17 | 8.04 |
| 2005 | 26,356 | 22,334 | 42,160 | 90,851 | 2.83 | 7.92 |
| 2006 | 24,855 | 17,135 | 48,240 | 90,230 | 2.66 | 7.94 |
| 2007 | 28,973 | 14,503 | 49,390 | 92,866 | 2.53 | 7.90 |
| 2008 | 33,495 | 15,339 | 50,765 | 99,599 | 2.99 | 7.58 |
| 2009 | 33,606 | 18,653 | 48,686 | 100,944 | 3.18 | 7.53 |
| 2010 | 30,306 | 31,216 | 49,752 | 111,274 | 3.25 | 7.52 |
| 2011 | 35,282 | 42,069 | 51,184 | 128,535 | 3.39 | 7.60 |
| 2012 | 35,441 | 37,482 | 40,495 | 113,418 | | |
| Average annual growth rate | | | | | Average Share | |
| 2000-2011 | -0.9% | -1.7% | 4.3% | 0.5% | **3.44** | **8.11** |

# Waste Management – Progress?



# Environmental Sustainability Drivers

- Building Research Establishment Environmental Assessment Method
- The Code for Sustainable Homes
- Civil Engineering Environmental Quality Assessment and Award Scheme
- Leadership in Energy and Environmental Design
- Green Star
- Building Environmental Assessment Method
- Many more...

BREEAM®

THE CODE FOR SUSTAINABLE HOMES™

U.S. GREEN BUILDING COUNCIL LEED USGBC

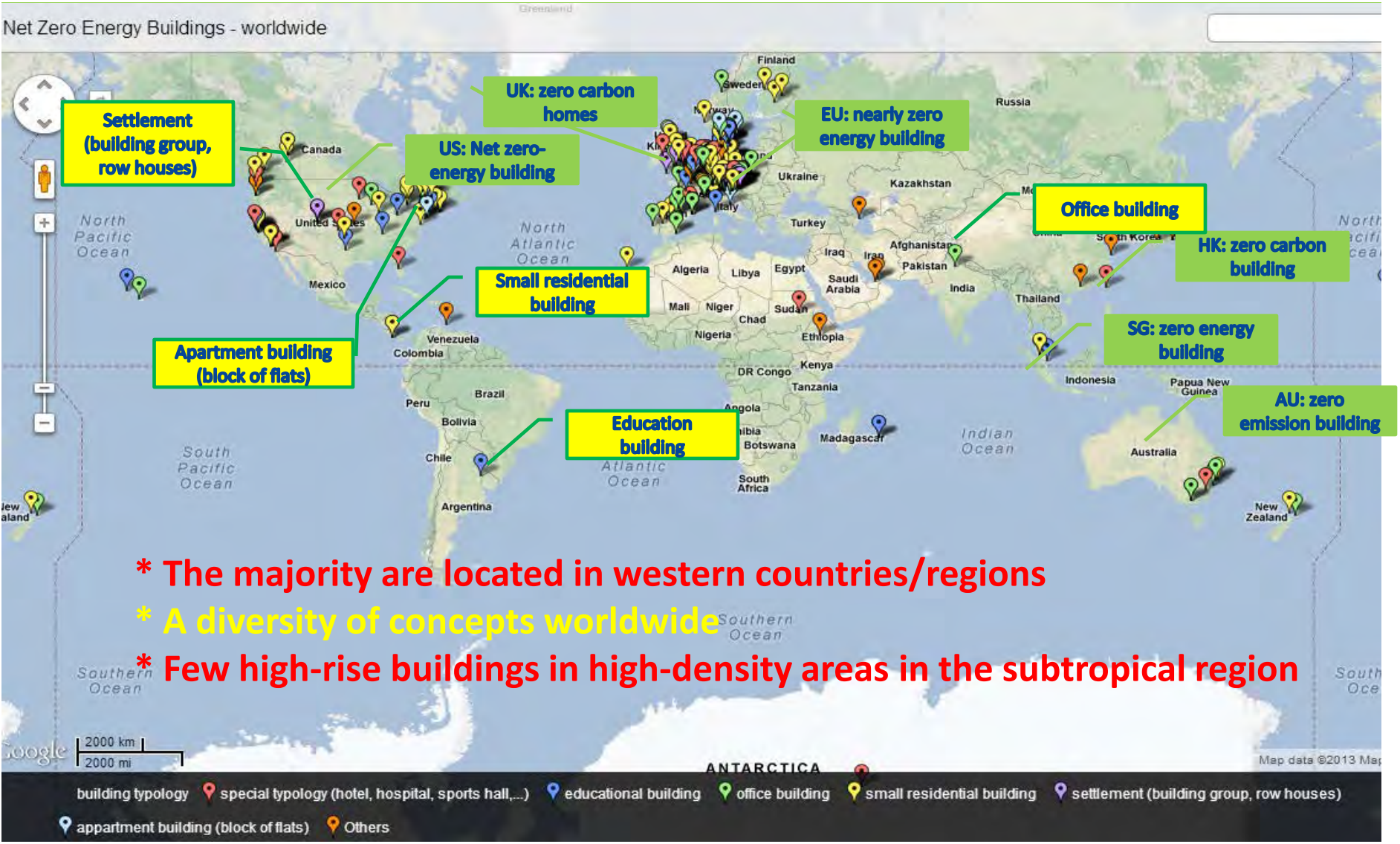
greenstar

BEAM

CASBEE 建築環境総合性能評価システム
Comprehensive Assessment System for Built Environment Efficiency

BCA GREEN MARK

# Zero Carbon Driver




*Based on: http://batchgeo.com/map/net-zero-energy-buildings as of March 2013*

# What '**zero carbon homes**' (may) look like?

European Union
European Social Fund
Investing in jobs and skills

one and all ones help all
CORNWALL COUNCIL

UNIVERSITY OF EXETER

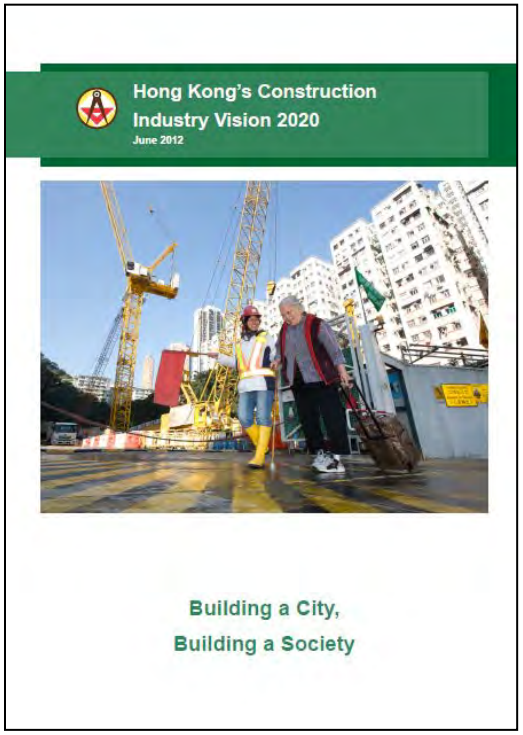
CHARTER 2020

ENVIRONMENTAL BUILDING WITH PLYMOUTH UNIVERSITY

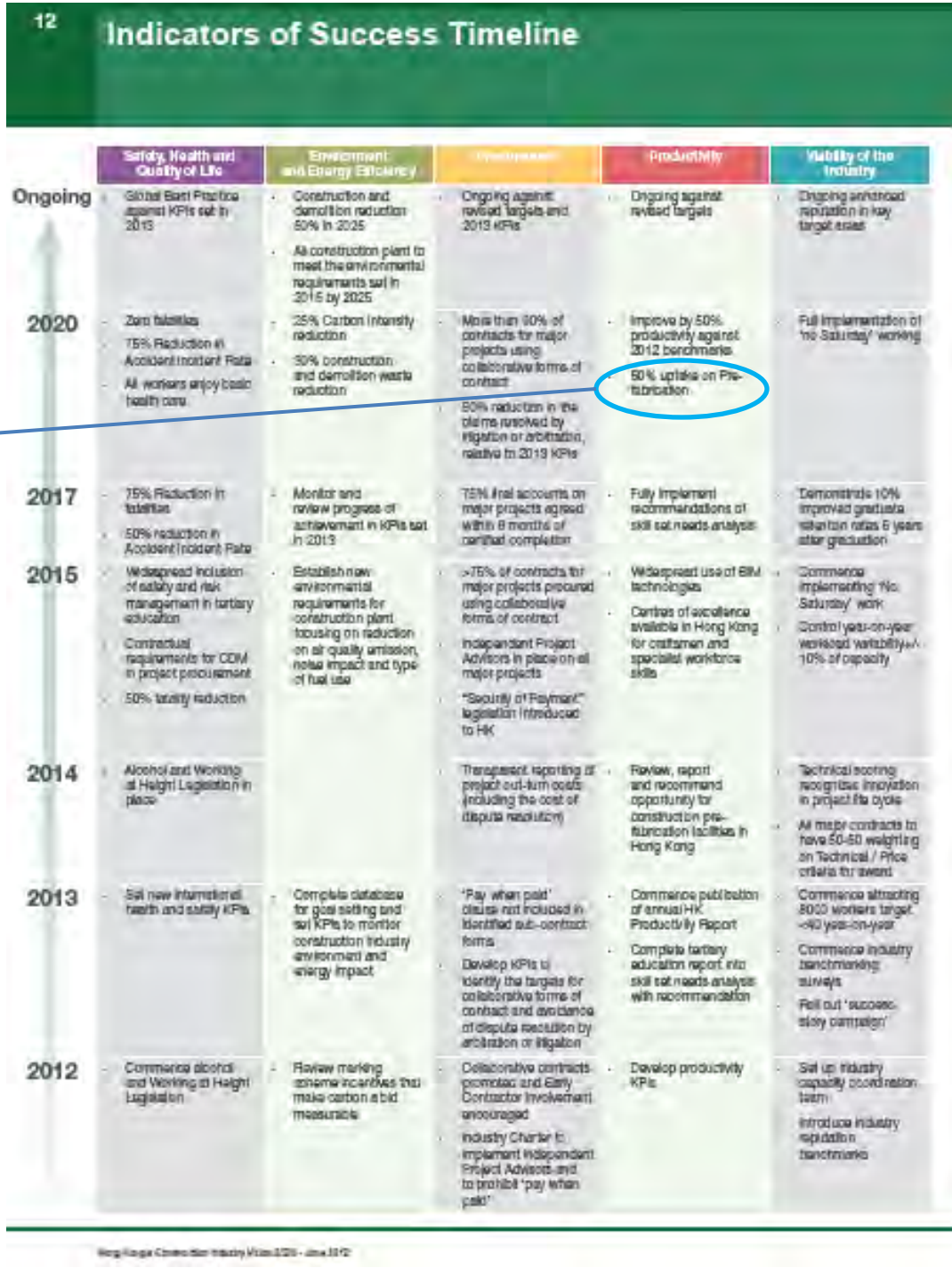
*Courtesy of E. Heffernan*

# Prefabrication Prospect

## 50% uptake on prefabrication by 2020




http://www.hkca.com.hk/front/201208hkvision_e.pdf



# Off-Site Prefabrication (OSP)

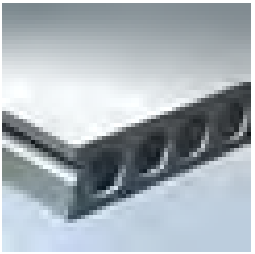
A definition of OSP:

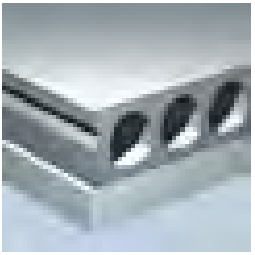
- "the manufacture and pre-assembly of components, elements or modules before installation into their final location".

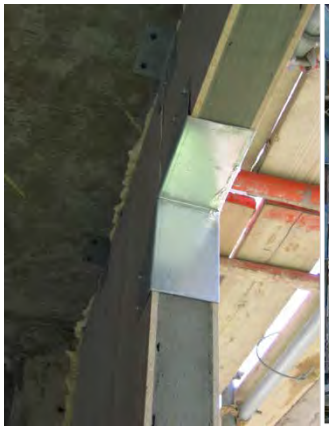
*Goodier and Gibb (2007)*

# OSP Technology

**Components & panellised systems (2D)**







# OSP Technology



**Volumetric and modular building (3D)**

# OSP – A World Map

Off-site production
Off-site manufacture
Off-site fabrication
Off-site construction
Modern methods of construction (MMC)
Standardisation

Systems building

Prefabrication


Pre-work;
Prefabrication, Preassembly, Modularization, and Off-site Fabrication (PPMOF)

Industrialised building

Off-site manufacture

*Detailed in Pan et al. (2012)*

# Offsite Terminologies

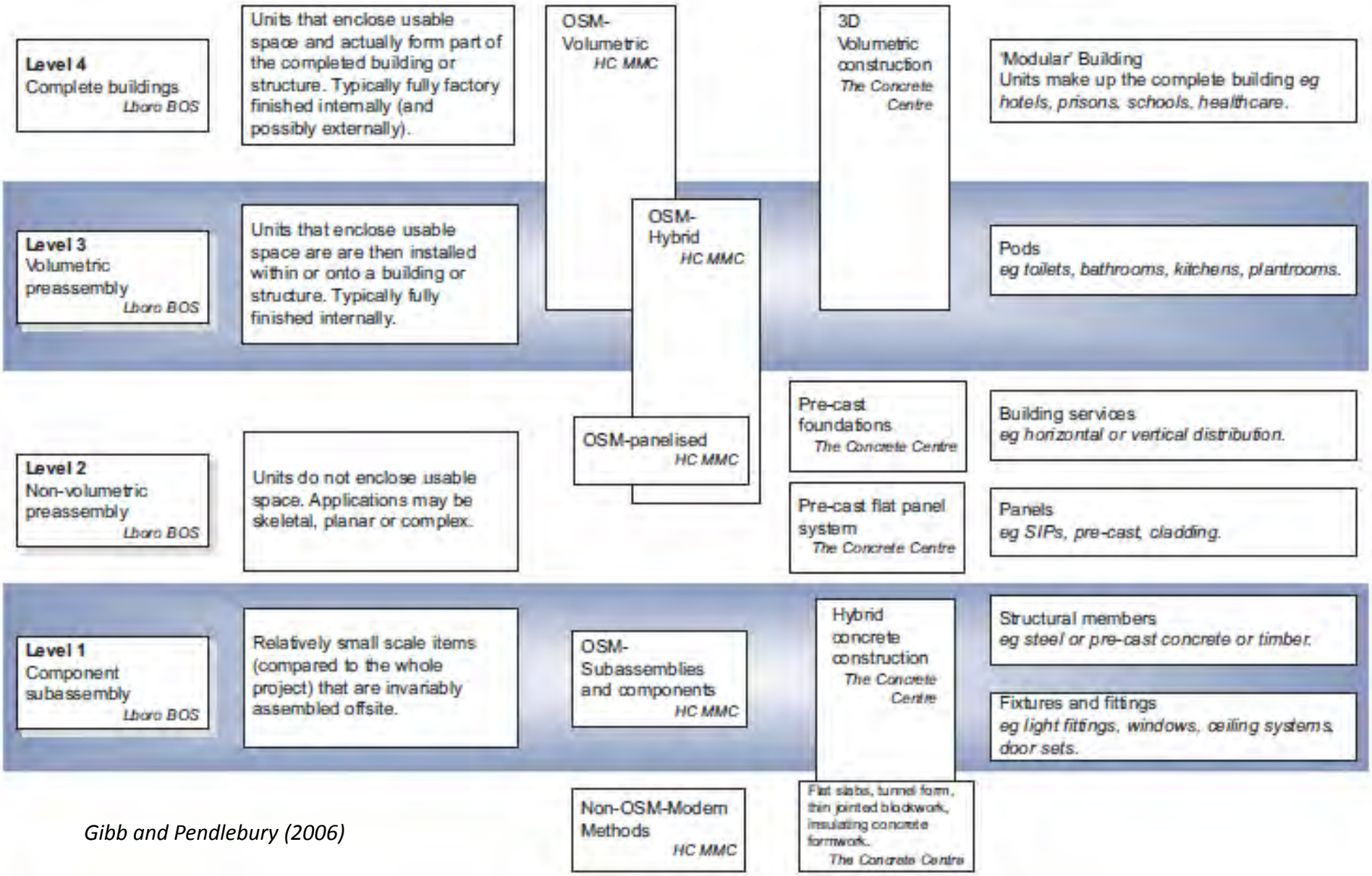
Table 2.2 Categorisations of offsite terminologies * by affix

| Terminology * | Representative literature |
|---|---|
| *OS-category terms* | |
| Offsite Production (OSP) | Gorgolewski *et al.* (2002); prOSPa^ |
| Offsite Manufacture/ing (OSM) | Ong (2004); Venables *et al.* (2004) |
| Offsite Fabrication (OSF) | Gibb (1999); Housing Forum (2002); Parry *et al.* (2003) |
| Offsite Construction (OSC) | OSC Journal |
| *PRE-category terms* | |
| Pre-assembly | Gibb *et al.* (1997); Gibb (2001b); Sparksman *et al.* (1999) |
| Prefabrication | Edge *et al.* (2002); Sheppard (1946); White (1965) |
| Prefabulous | Birkbeck and Scoones (2005) |
| Prefab | Fabprefab (2006) |
| *MM-category terms* | |
| Modern Methods of Construction (MMC) | Barker 33 Cross Industry Group (2006); Lusby-Taylor *et al.* (2004); NAO (2005b); ODPM (2003) |
| Modern Methods of House Construction | Ross (2005) |
| Modern Methods of House Building | POST (2003) |
| *Building-category terms* | |
| System Building | Finnimore (1989) |
| Non-traditional Building | Ross (2002) |
| Industrialised Building | CIDB (2003); McCutcheon (1989); Sarja (1998) |

* Only the terminologies standing for offsite *as a whole* are included. For terms related to offsite applications, the reader may refer to the recent buildoffsite Glossary of Terms (Goodier *et al.*, 2005) and the updated version (Gibb and Pendlebury, 2005). ^Promoting Offsite Production Applications (prOSPa).

*Pan (2006)*

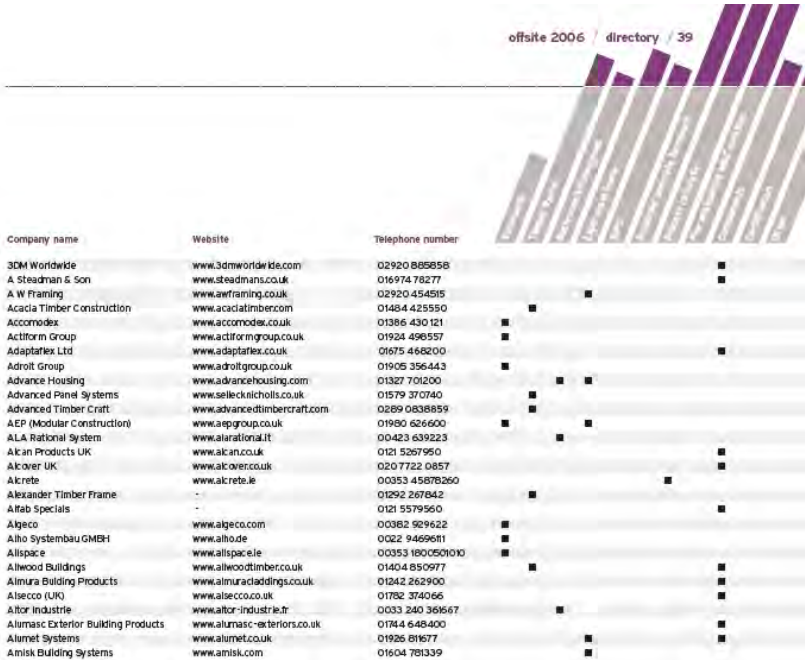
# OSP: Level Systems




*Gibb and Pendlebury (2006)*

# OSP Technology: Diversity

- Over **100** types of off-site construction technology or system marketed by about **570** manufacturers and suppliers
- Still increasing rapidly
- Available Search Engines

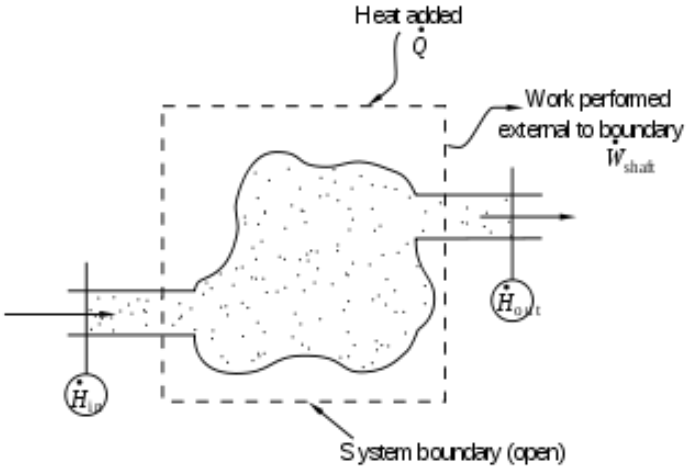



offsite online
The smarter way to find Offsite systems

mtech CONSULT

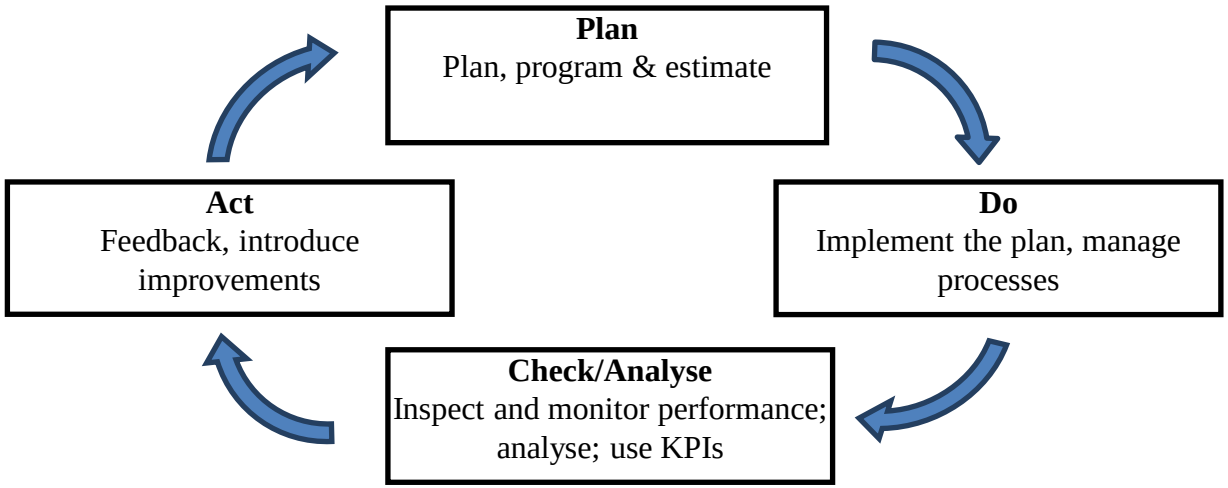
# A Systems Approach

- Elements of a system
  - Inputs and Outputs
  - Processor
  - Control
  - Environment
  - Feedback
  - Boundaries and Interfaces




# Continuously ↑ Productivity

Systems principles, e.g.
- Quality management
- Benchmarking
- Lean construction




Improved productivity, e.g.
- Earlier finish
- Lower costs
- Improved health & safety
- Less waste/environmental damage
- Improved quality
- Higher salaries
- Better market standing

# OSP Integration not bolted-on

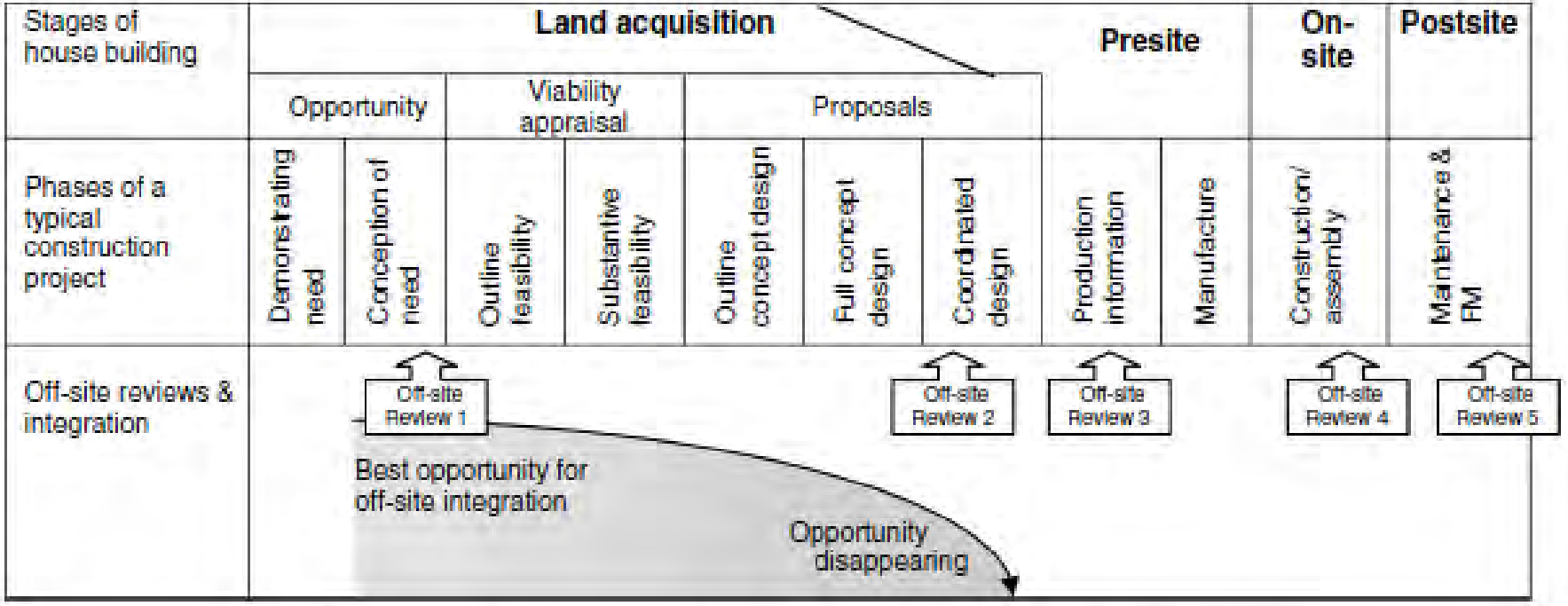



Fig. 2. Timing of opportunity for integrating the use of off-site technology

The University of Hong Kong

*Source: Pan et al. (2012)*

HKU CIVIL ENGRG. DEPT.

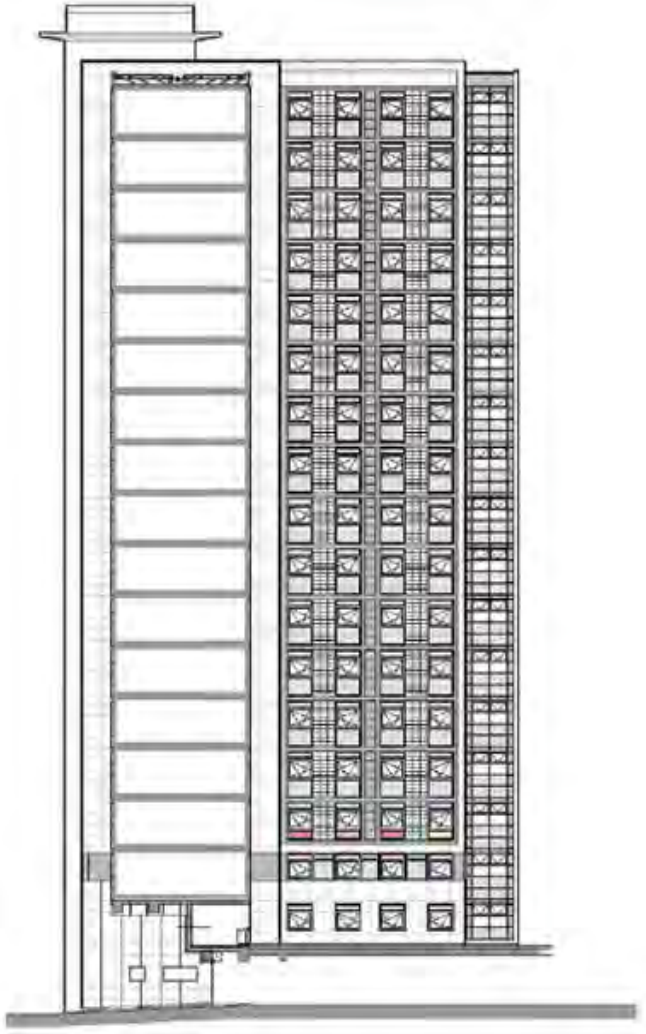
# 17-storey modular student hall West London

A year shorter than traditional construction
Erect 15 units a day; installed in a 40 minute turn-around without requiring closure of roads.
Excellent acoustic insulation: satisfied.
£26 million project- Cost Neutral because the time saving outweighs the money spent
Open sided modules provide for flexible space planning
Modules supported by steel podium

*Courtesy of SCI*

Modules attached to concrete core

Installation of module on steel podium



This elevation shows the concrete core on the left and the modular units on the right

*Source: Lawson et al (2012)*

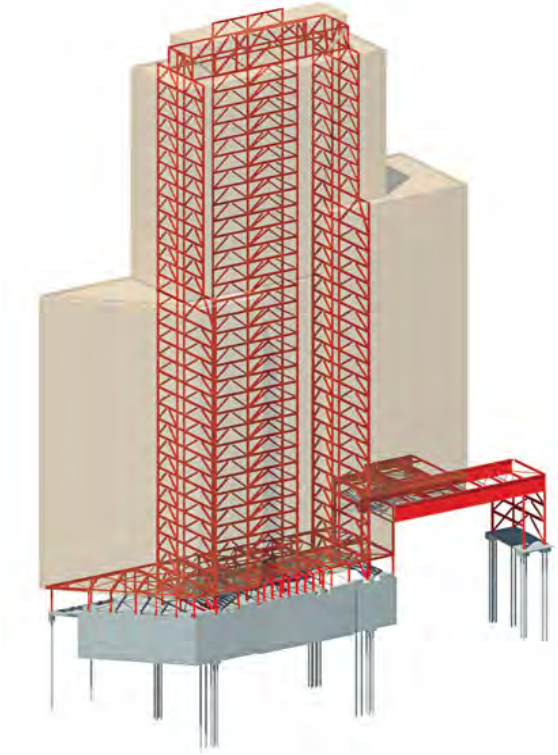
# 25-storey modular building, Wolverhampton, UK

- The installation team: 8 people plus two site managers
- Reduction in construction period relative to site-intensive concrete construction: over 50 weeks (or a saving of 45% in construction period);
- An estimated productivity increase: 80% relative to site-intensive construction.
- Reduce land fill: at least 70%


*Courtesy of O'connell East Architects*

# 32-storey Modular B2 Tower in NY

- 350-apartment includes 930 modules, each with a steel-framed chassis
- 340,000 square feet
- Move 60% of the work off-site
- Shave at least 4 months off an 18-month construction timeline
- Estimate cost 20 percent less than a conventionally constructed building with a concrete flat-slab structure

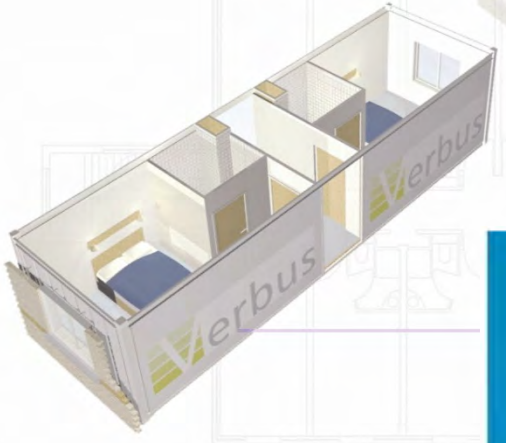


*Source: http://continuingeducation.construction.com/article.php?L=5&C=943&P=2*

# MODULAR HOTEL DESIGN

Buro Happold

Verbus

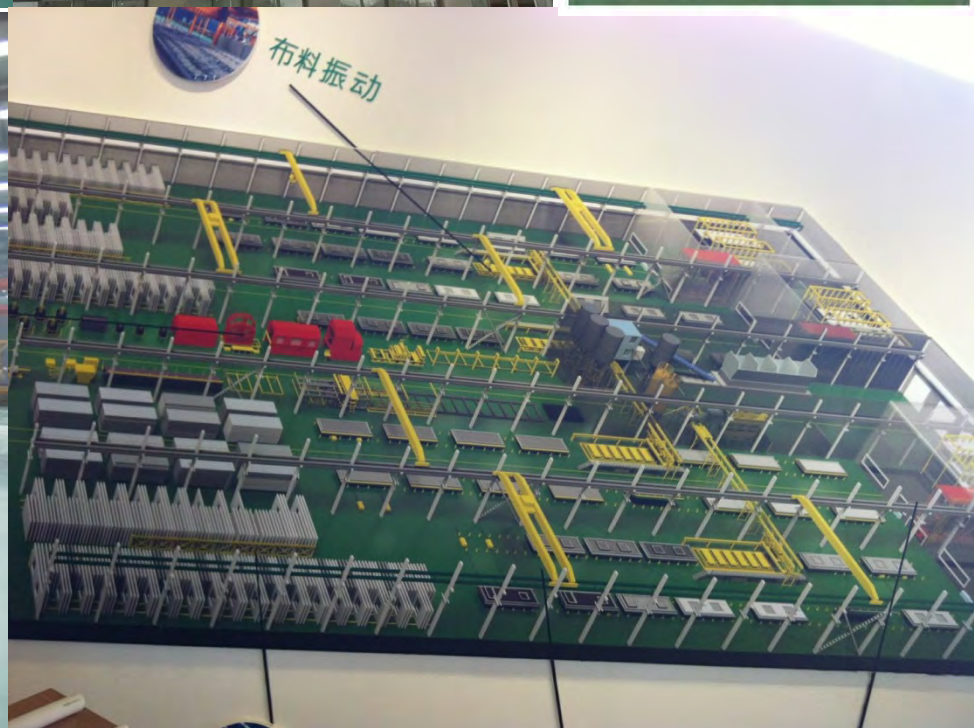

www.verbussystems.com/

*Courtesy of Dr C. Goodier*

# Precast Concrete Panel Systems

| | |
|---|---|
| Electricity Saving | 70% |
| Water Saving | 80% |
| Material Saving | 20% |
| Area Saving | 20% |
| Time Saving | 70% |


*Courtesy of Broad Home*



# **Precast Concrete Panel vs.** Traditional **Insitu**

*Courtesy of Broad Home*


CIC Zero Carbon Building


Waco UK


Kai Tak Public Housing

CICID 10th Anniversary Conference

**Innovation, Integration and Implementation**

# Enhancing Productivity Through Off-Site Prefabrication

- A mean or an aim?
- Integration not bolted-on
- Challenges but also great opportunities

Dr Wei Pan

wpan@hku.hk

The University of Hong Kong

HKU CIVIL ENGRG. DEPT.