

CICID 10th Anniversary Conference
Innovation, Integration and Implementation

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

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31 May 2013

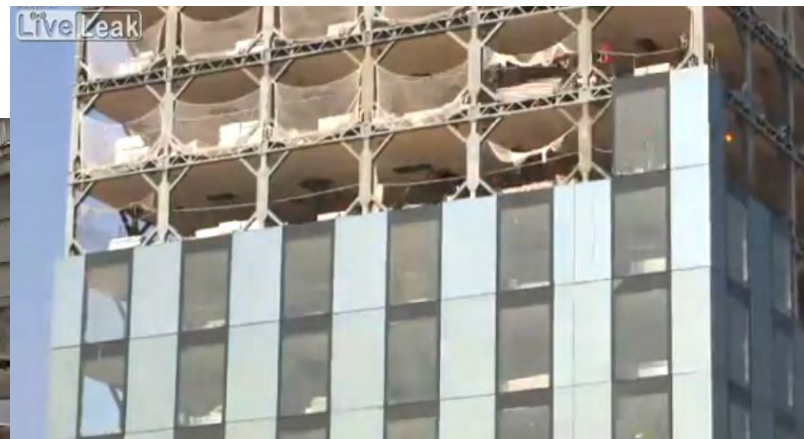


The University of Hong Kong



LiveLeak

30-storey hotel built in 15 days
5 times more earthquake-resistant
5 times more energy efficient
20 times purer air



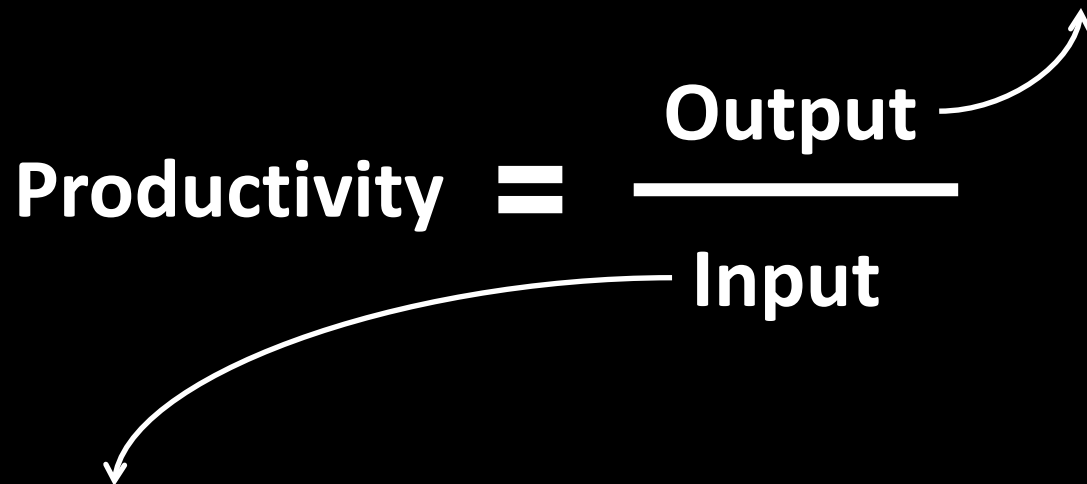
The Aim or The Mean?

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


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

Single or Total Factor?

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

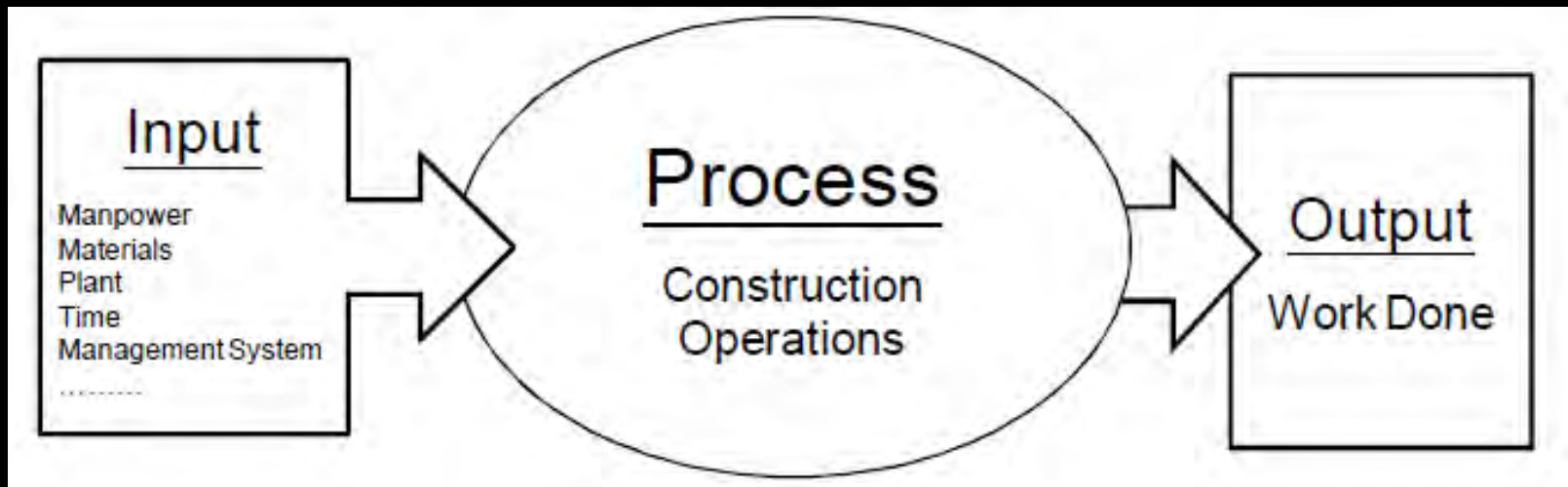
$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$
The diagram shows the formula 'Productivity = Output / Input'. A curved arrow points from the word 'Output' to the definition 'Value of the Commodities, i.e. goods and services produced' located at the top right. Another curved arrow points from the word 'Input' to the definition 'Equivalent value sum of all Partial Factors of Production consumed, e.g.:' located at the bottom left.

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

- Natural Resources
- Labour
- Capital Goods
- Entrepreneurship

- ~ 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

Integration or Bolted-on?



Population in HK

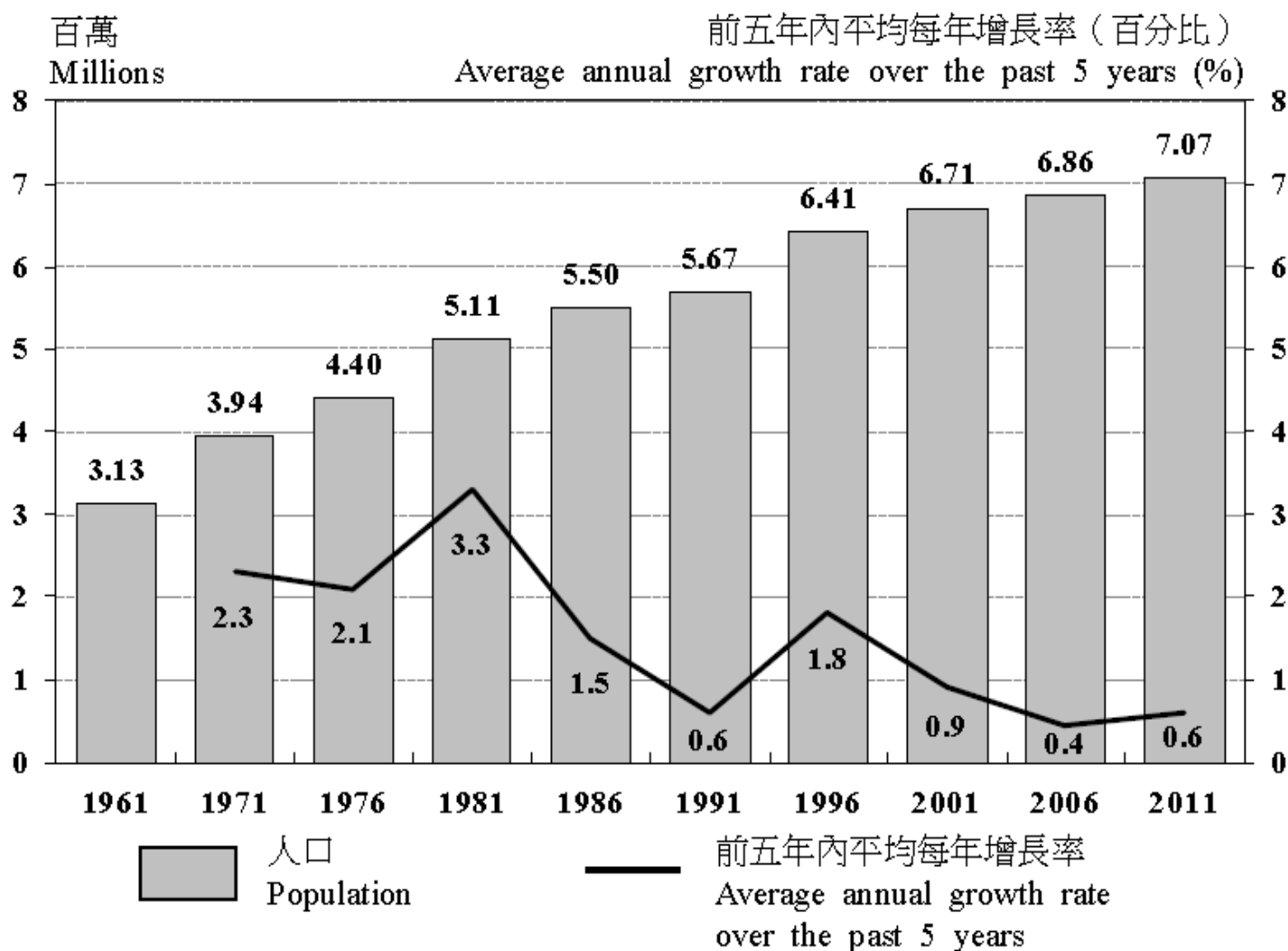


Chart 1 Population and Average Annual Growth Rate, 1961 – 2011

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

Domestic Households in HK

Chart 2 Number of Domestic Households and Average Annual Growth Rate

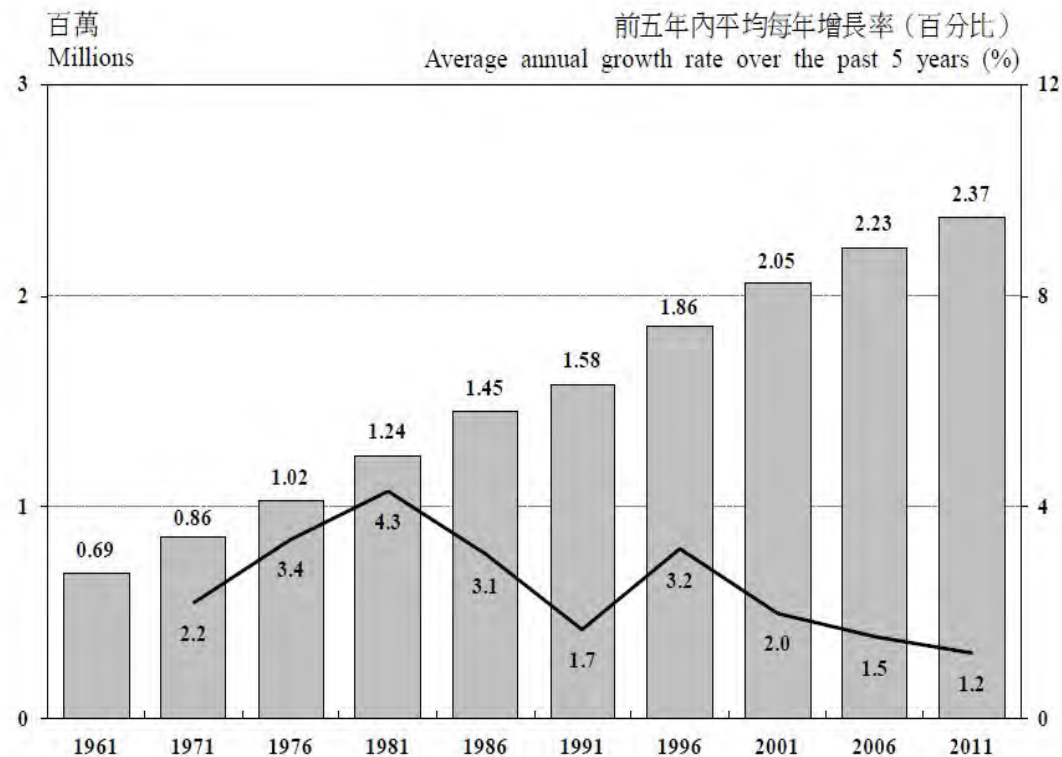
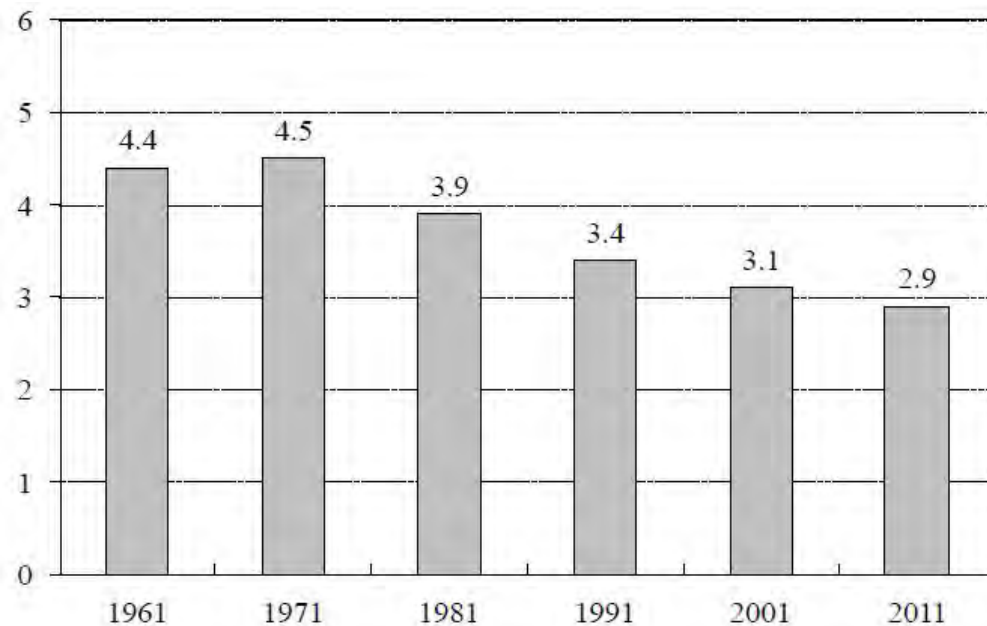
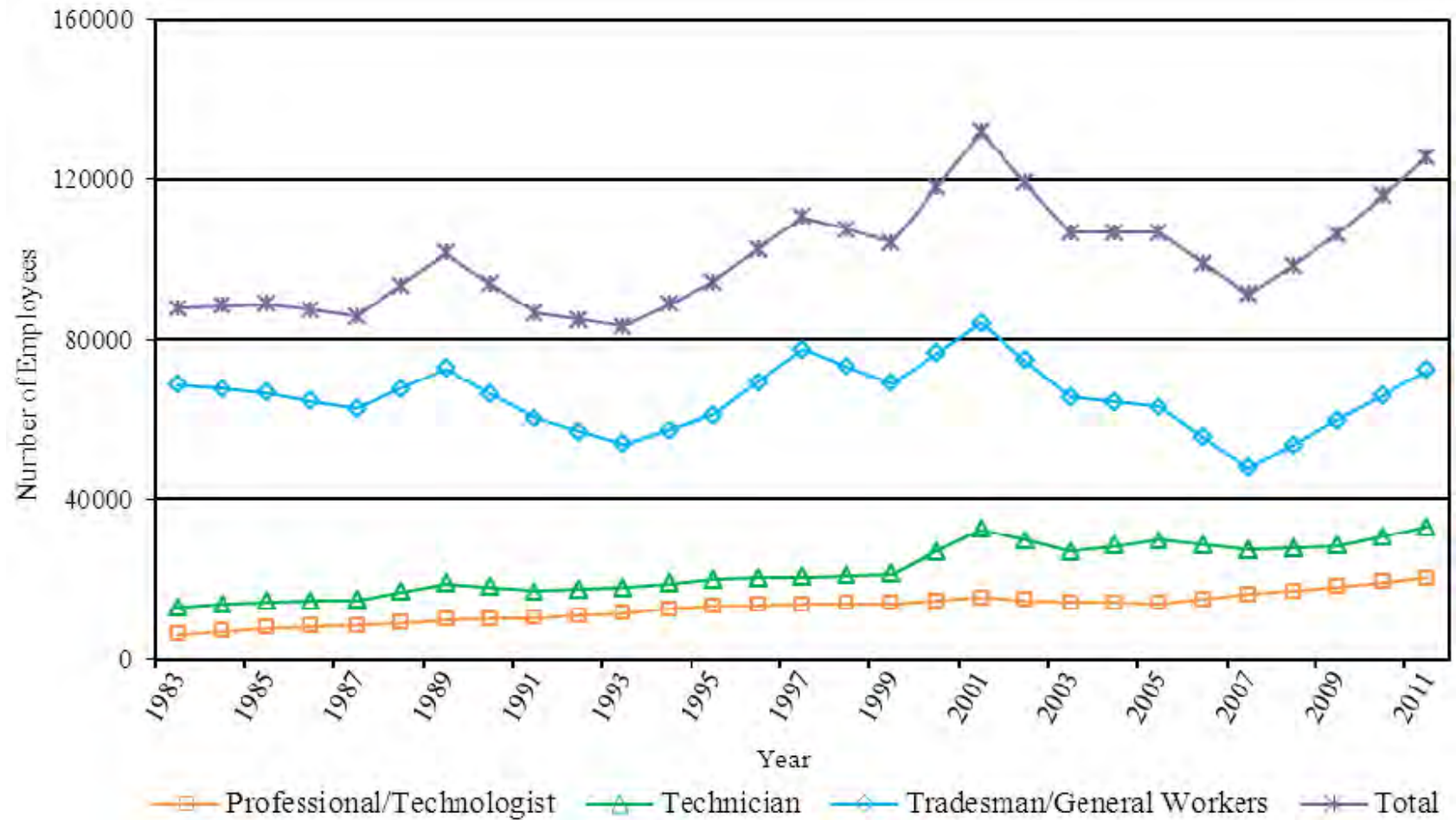


Chart 3 Average Domestic Household Size

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



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)

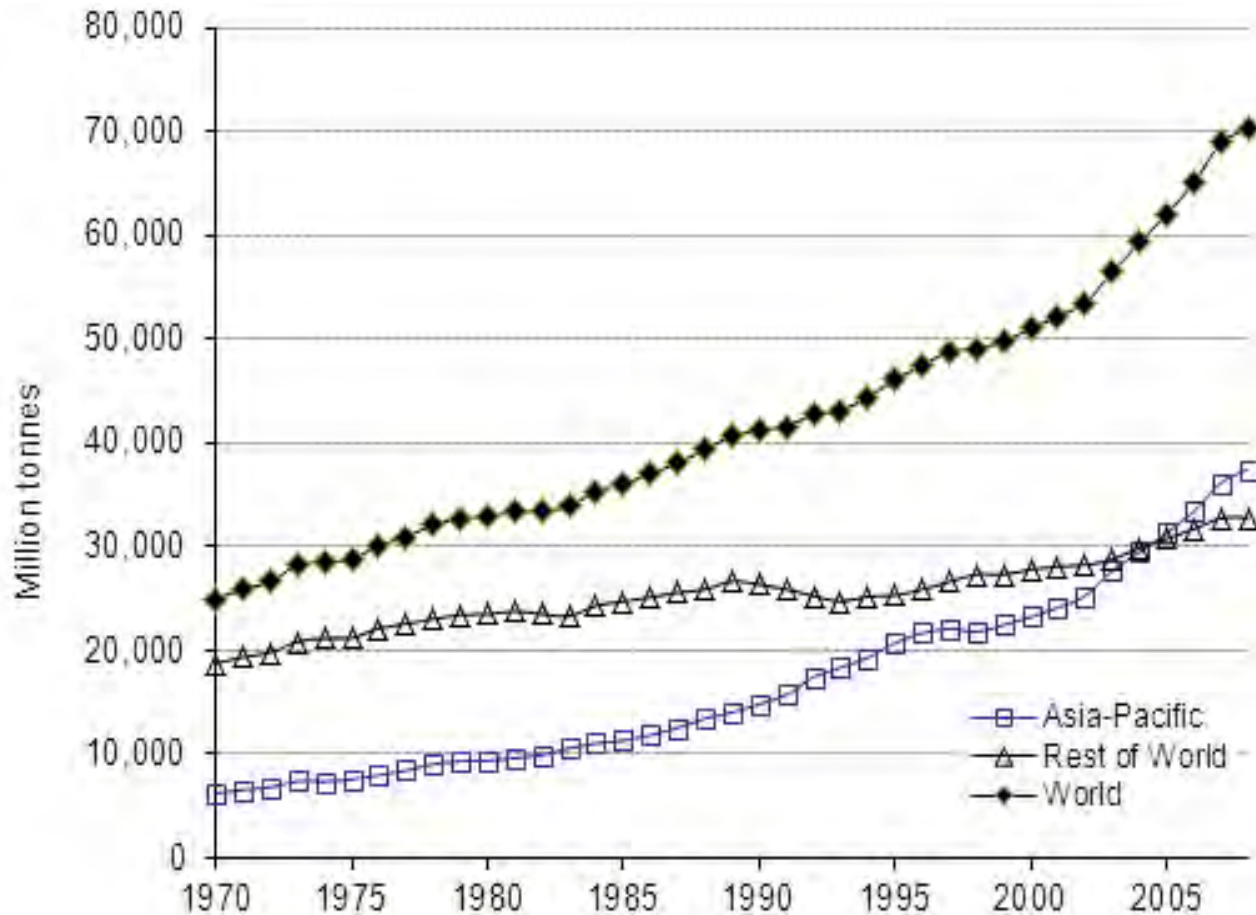
Aging Labour in Construction (HK)

- 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	109.4	110.5	114.2	58.9	56.2	54.7	53.9
Trades, Restaurants and Hotels				55.2	54.5	55.8	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

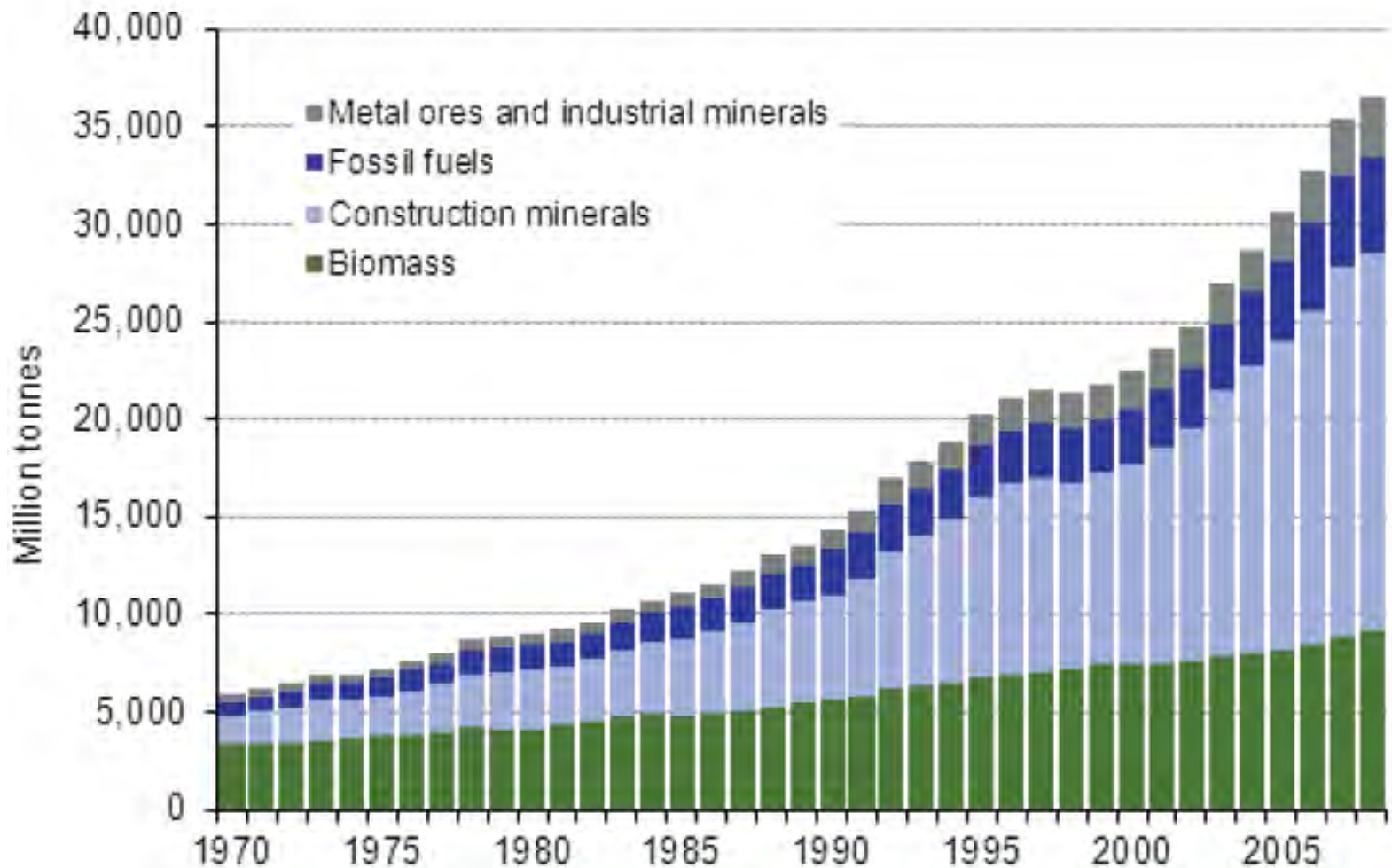
Resources Input



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)

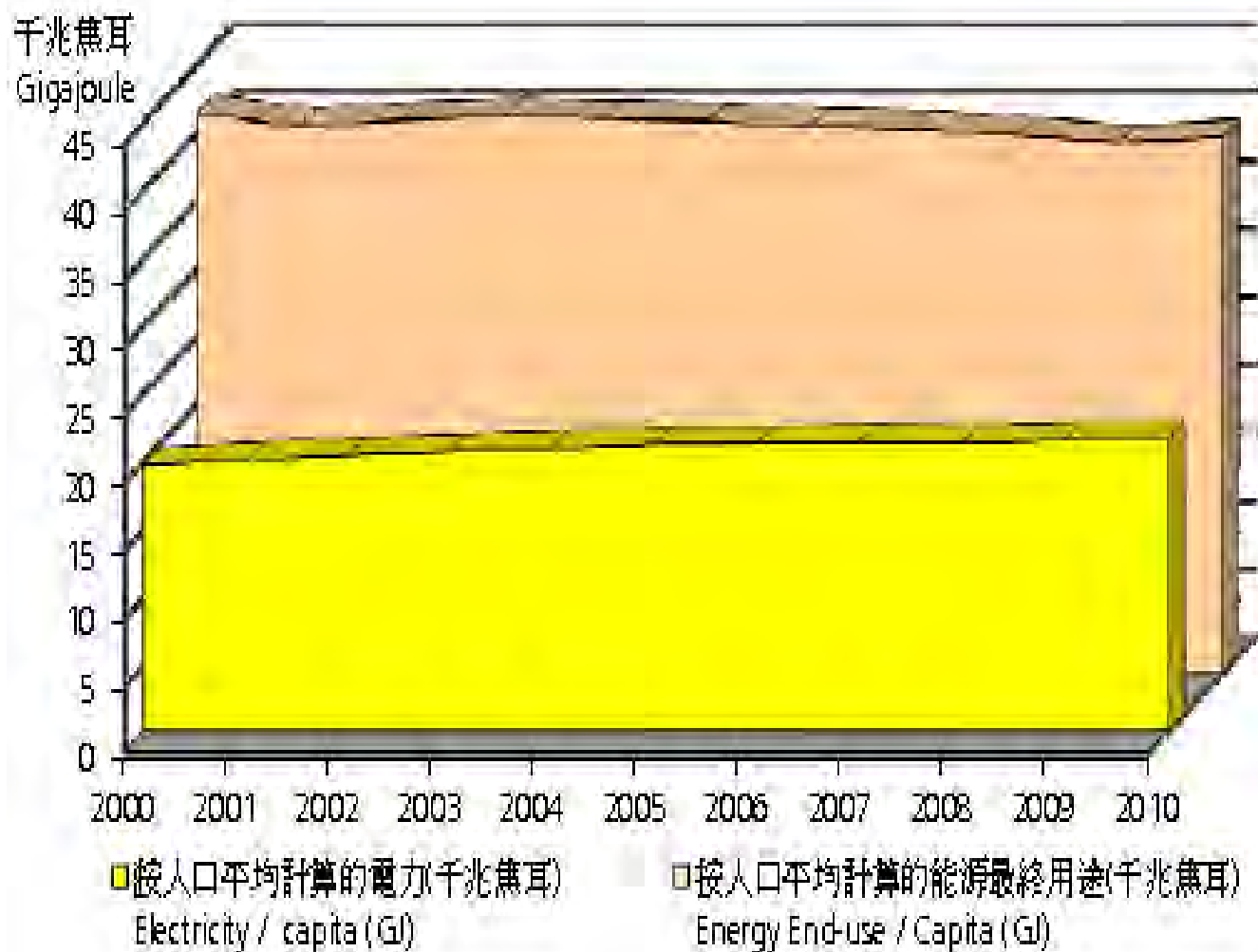
Resources Input



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)

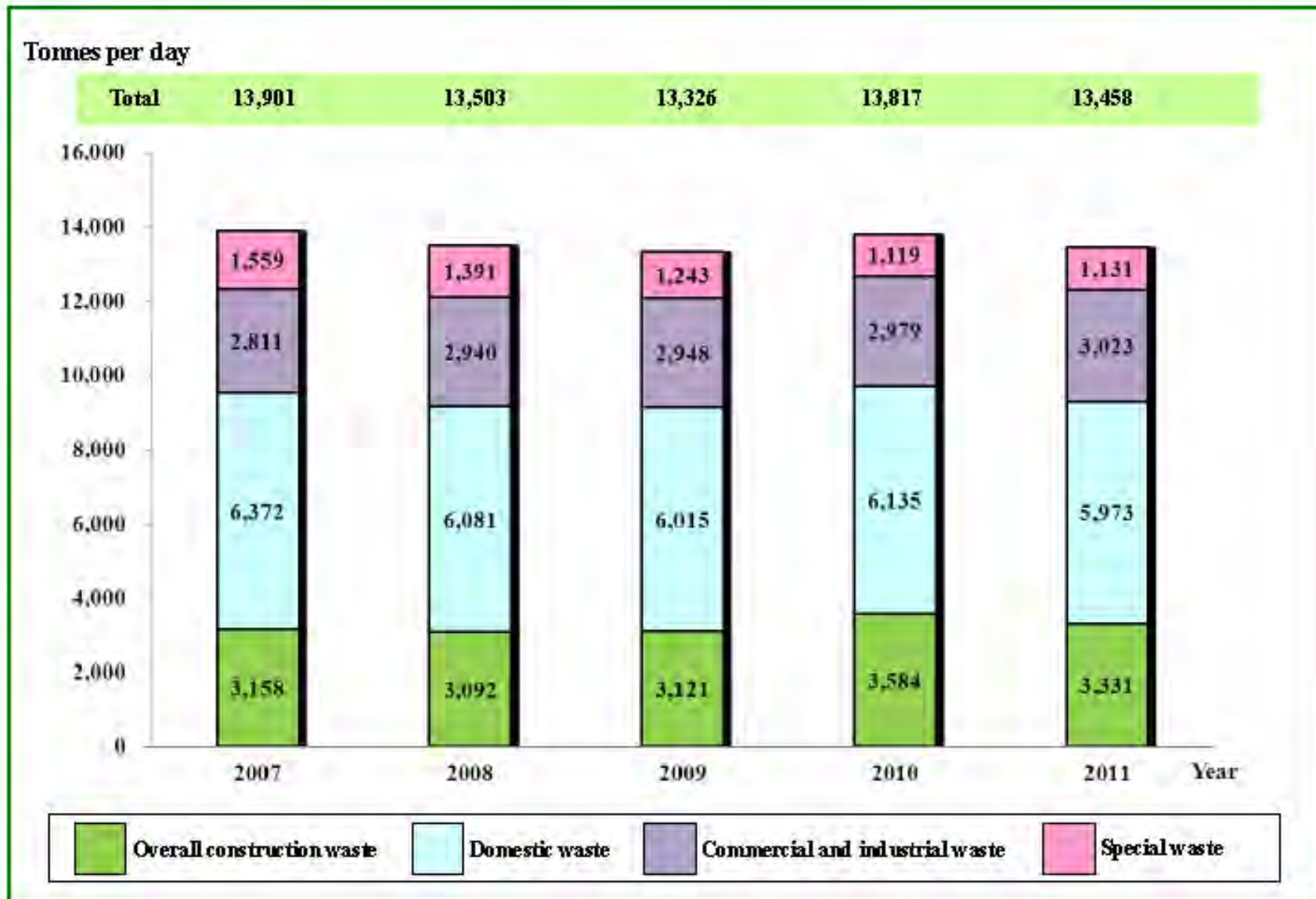


Energy End-use Per Capita in Hong Kong

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®

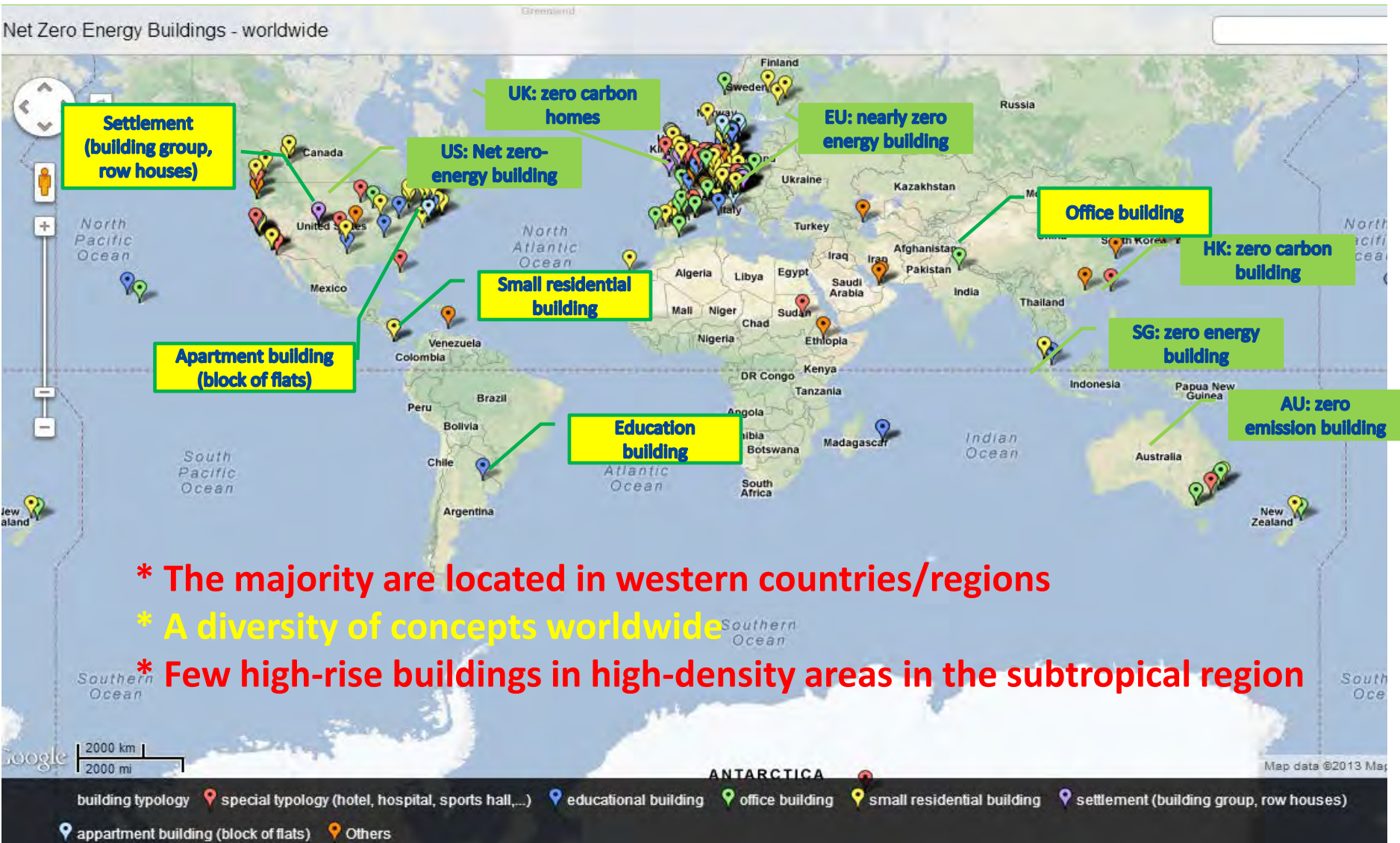


greenstar

BEAM



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



ENVIRONMENTAL
BUILDING
WITH
PLYMOUTH
UNIVERSITY

Courtesy of E. Heffernan



Prefabrication Prospect

50% uptake on prefabrication by 2020



Hong Kong's Construction Industry Vision 2020
June 2012



Building a City,
Building a Society

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Indicators of Success Timeline

	Safety, Health and Quality of Life	Environment and Energy Efficiency	Cooperation	Productivity	Viability of the Industry
Ongoing	Global Best Practice against KPIs set by 2013	Construction and demolition reduction 50% in 2025 All construction plant to meet the environmental requirements set in 2015 by 2025	Ongoing against revised targets and 2013 KPIs	Ongoing against revised targets	Ongoing enhanced reputation in key target areas
2020	Zero fatalities 75% Reduction in Accident Incident Rate All workers enjoy basic health care	25% Carbon Intensity reduction 30% construction and demolition waste reduction	More than 80% of contracts for major projects using collaborative forms of contract 50% reduction in the claims resolved by litigation or arbitration, relative to 2013 KPIs	Improve by 50% productivity against 2012 benchmarks 50% uptake on Prefabrication	Full implementation of 'No Saturdays' working
2017	75% Reduction in fatalities 50% reduction in Accident Incident Rate	Monitor and review progress of achievement in KPIs set in 2013	75% final accounts on major projects agreed within 8 months of certified completion	Fully implement recommendations of skill set needs analysis	Demonstrate 10% improved graduate retention rates 6 years after graduation
2015	Widespread inclusion of safety and risk management in tertiary education Contractual requirements for CDM in project procurement 50% fatality reduction	Establish new environmental requirements for construction plant focusing on reduction on air quality emission, noise impact and type of fuel use	>75% of contracts for major projects procured using collaborative forms of contract Independent Project Advisors in place on all major projects "Security of Payment" legislation introduced to HK	Widespread use of BIM technologies Centres of excellence available in Hong Kong for craftsmen and specialist workforce skills	Commence implementing 'No Saturdays' work Control year-on-year workload variability < 10% of capacity
2014	Alcohol and Working at Height Legislation in place		Transparent reporting of project out-turn costs (including the cost of dispute resolution)	Review, report and recommend opportunity for construction pre-fabrication facilities in Hong Kong	Technical scoring recognise innovation in project life cycle All major contracts to have 50-60 weighting on Technical / Price criteria for award
2013	Set new international health and safety KPIs	Complete database for goal setting and set KPIs to monitor construction industry environment and energy impact	'Pay when paid' clause not included in identified sub-contract forms Develop KPIs to identify the targets for collaborative forms of contract and evidence of dispute resolution by arbitration or litigation	Commence publication of annual HK Productivity Report Complete tertiary education report into skill set needs analysis with recommendation	Commence attracting 8000 workers target <40 year-on-year Commence industry benchmarking surveys Roll out 'success story campaign'
2012	Commence alcohol and Working at Height Legislation	Review marking scheme incentives that make carbon a bid measurable	Collaborative contracts promoted and Early Contractor Involvement encouraged Industry Charter to implement Independent Project Advisors and to prohibit 'pay when paid'	Develop productivity KPIs	Set up industry capacity coordination team Introduce industry reputation benchmarks

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

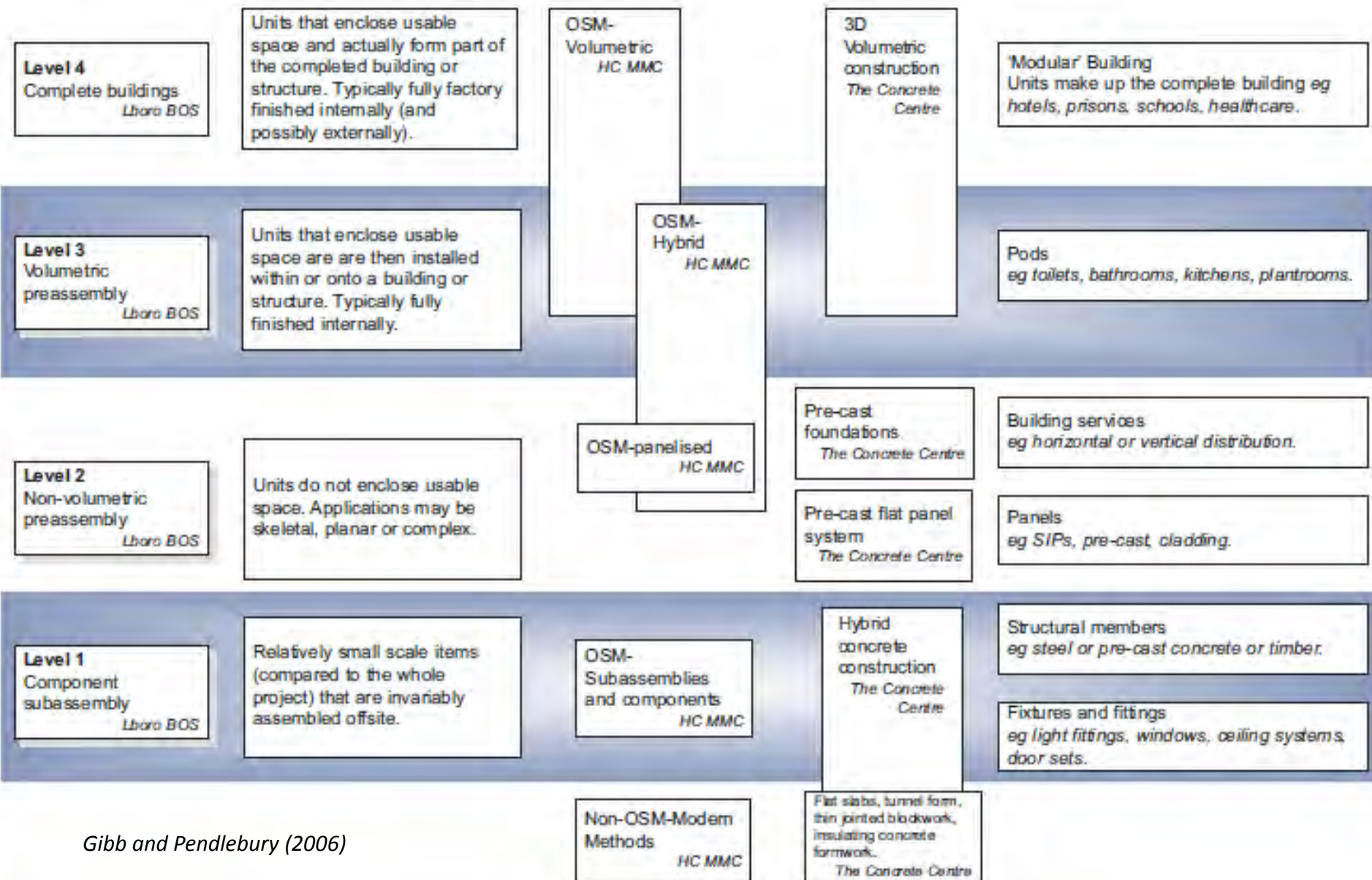
Offsite Terminologies

Table 2.2 Categorisations of offsite terminologies * by affix

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

OSP: Level Systems



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



The smarter way to find Offsite systems

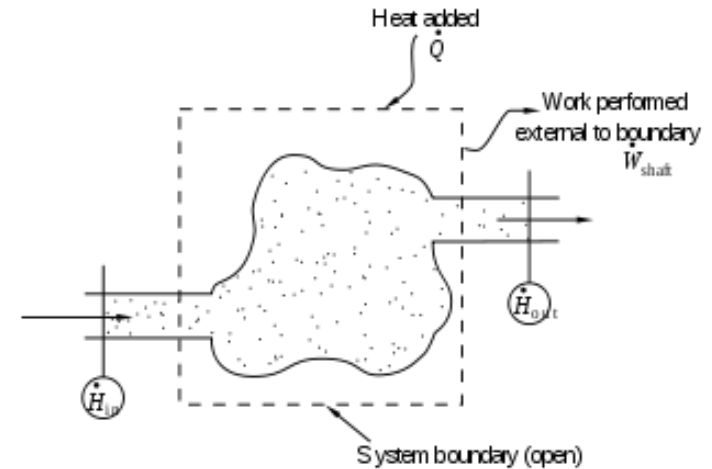


Company name	Website	Telephone number
3DM Worldwide	www.3deworldwide.com	02920 885858
A Steadman & Son	www.steadmans.co.uk	01674 76277
A W Framing	www.aawframing.co.uk	02920 545495
Acacia Timber Construction	www.acaciatimbercon.com	01664 433550
Accomodes	www.accomodes.co.uk	01386 430 421
Actiform Group	www.actiformgroup.co.uk	01924 496557
Adaptatex Ltd	www.adaptatex.co.uk	0675 468200
Adroit Group	www.adroitgroup.co.uk	01905 356443
Advance Housing	www.advancehousing.com	01327 701200
Advanced Panel Systems	www.sepincnhiols.co.uk	01519 370740
Advanced Timber Craft	www.advancedtimbercraft.co.uk	01592 660000
AFU Modular Construction	www.afuappgroup.com	01890 626600
ALA Rational System	www.alarational.it	04423 639223
Akan Products UK	www.akan.co.uk	0121 5267950
Akover UK	www.akover.co.uk	020 7722 0855
Akrete	www.akrete.ie	00353 45876260
Alexander Timber Frame	-	02962 267642
Alph Specials	-	0181 5579650
Alpeco	www.alpeco.com	00382 921622
Alho Systembau GMBH	www.alhode	0022 9469811
Allspace	www.allspace.ie	00353 180050701
Allwood Buildings	www.allwoodtimber.co.uk	01404 050977
Almura Building Products	www.almuradaddings.co.uk	01424 262900
Alrecco (UK)	www.alreccoco.uk	01788 370406
Altor Industrie	www.althor-industrie.de	0030 330 96667
Alumasc Exterior Building Products	www.alumasc-exterior.co.uk	01744 648400
Alumet Systems	www.alumet.co.uk	01926 816177
Amisk Building Systems	www.amisk.com	01604 781339

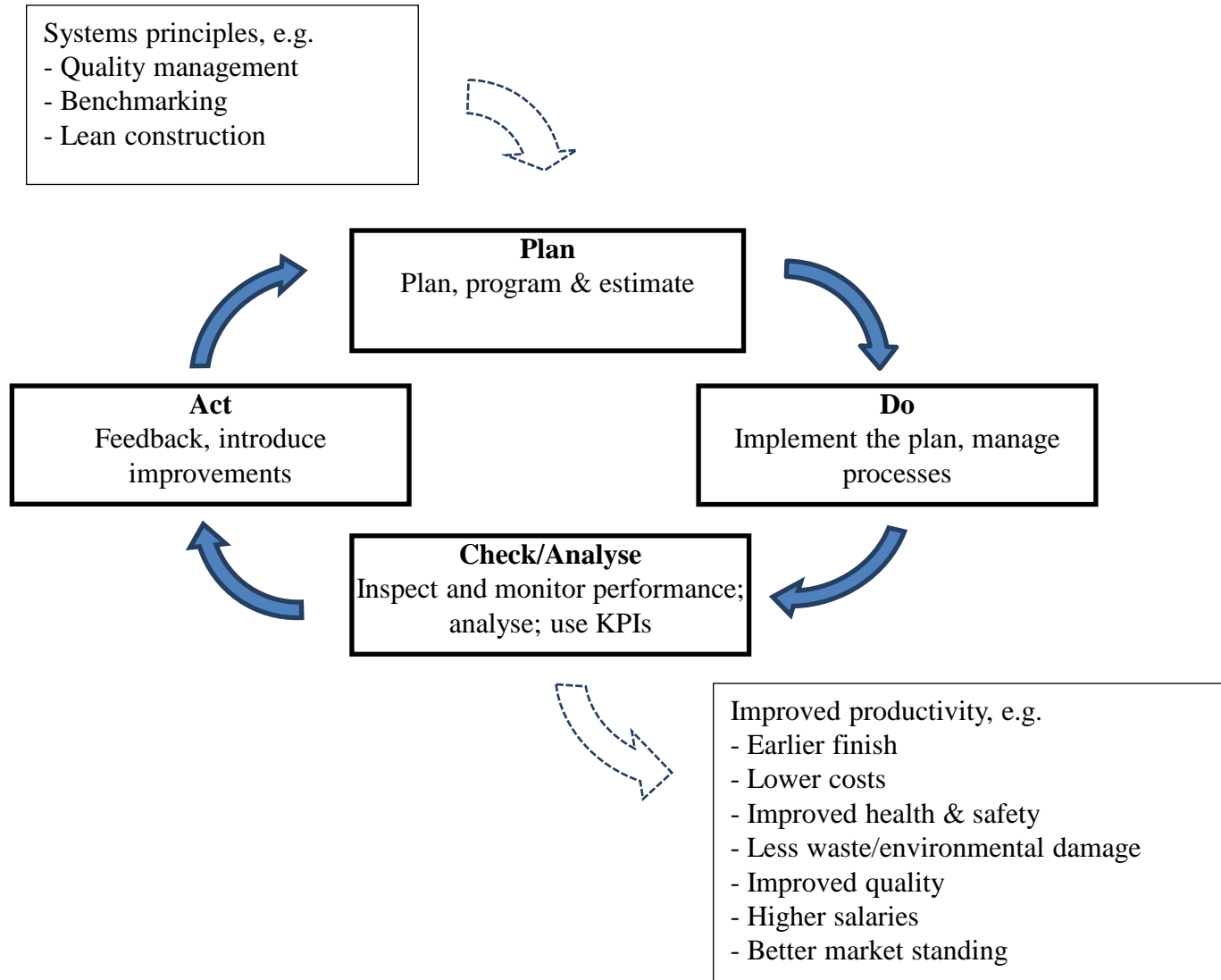


A Systems Approach

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



Continuously Productivity



OSP **Integration** not bolted-on

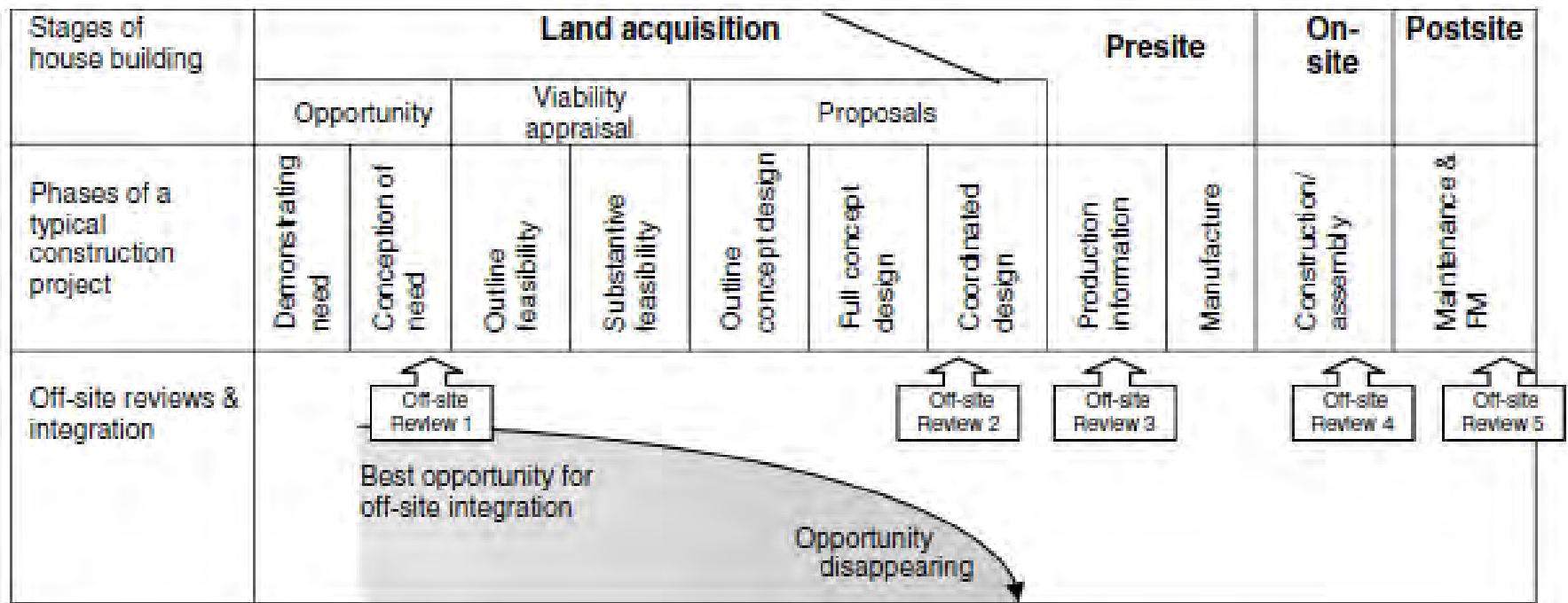


Fig. 2. Timing of opportunity for integrating the use of off-site technology

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



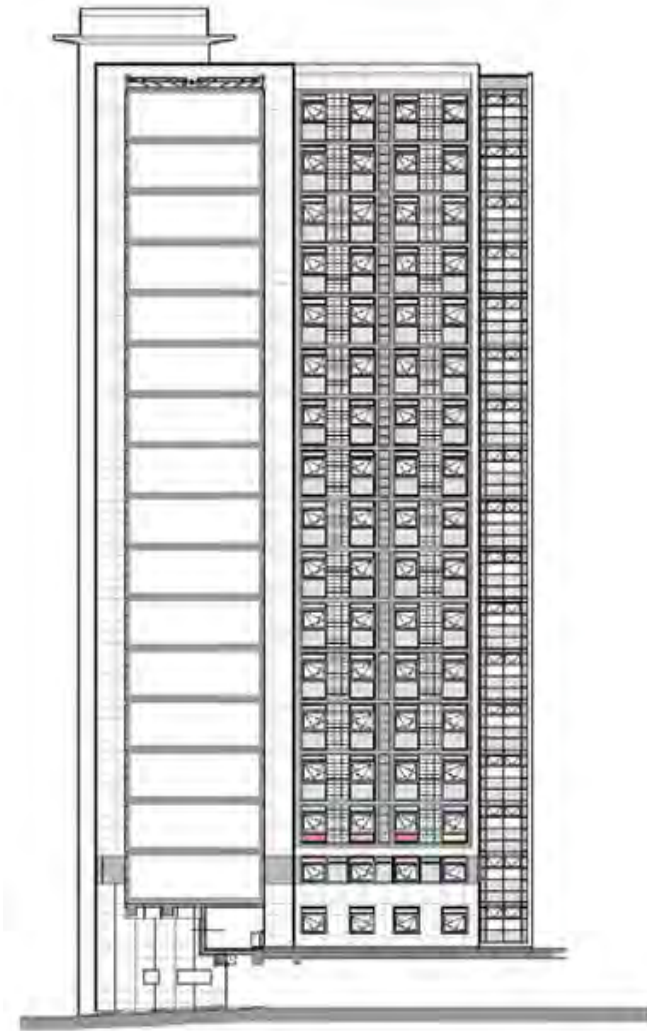
Courtesy of SCI



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

25-storey modular building, Wolverhampton, UK

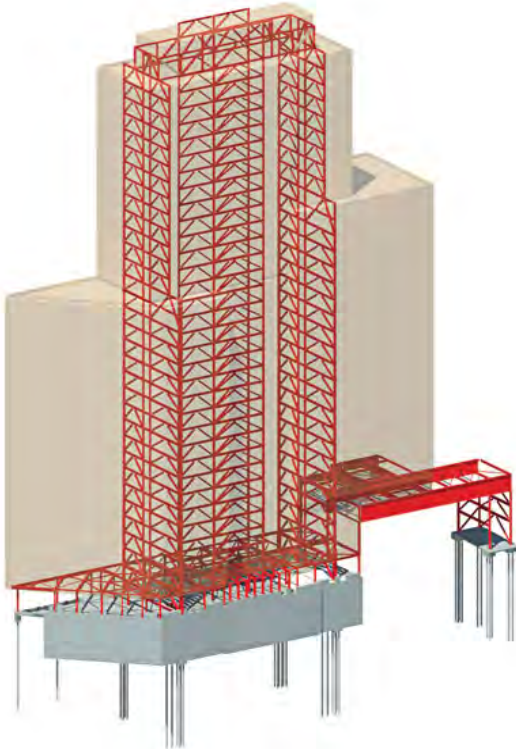
- The installation team: 8 people plus two site managers
- Reduction in construction period relative to site-intensive concrete construction: over 50 weeks (or a saving of 45% in construction period);
- An estimated productivity increase: 80% relative to site-intensive construction.
- Reduce land fill: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



Courtesy of O'connell East Architects

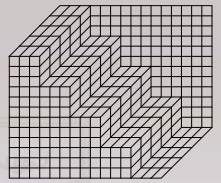
32-storey Modular B2 Tower in NY

- 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

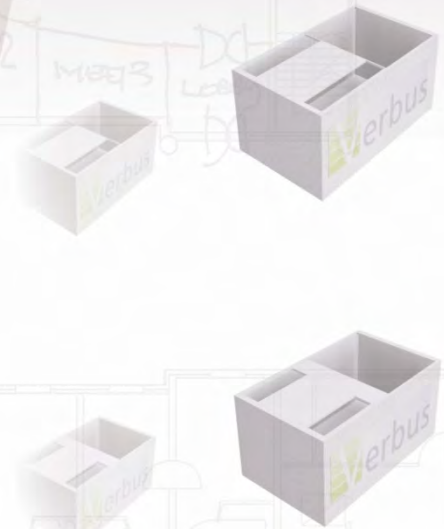
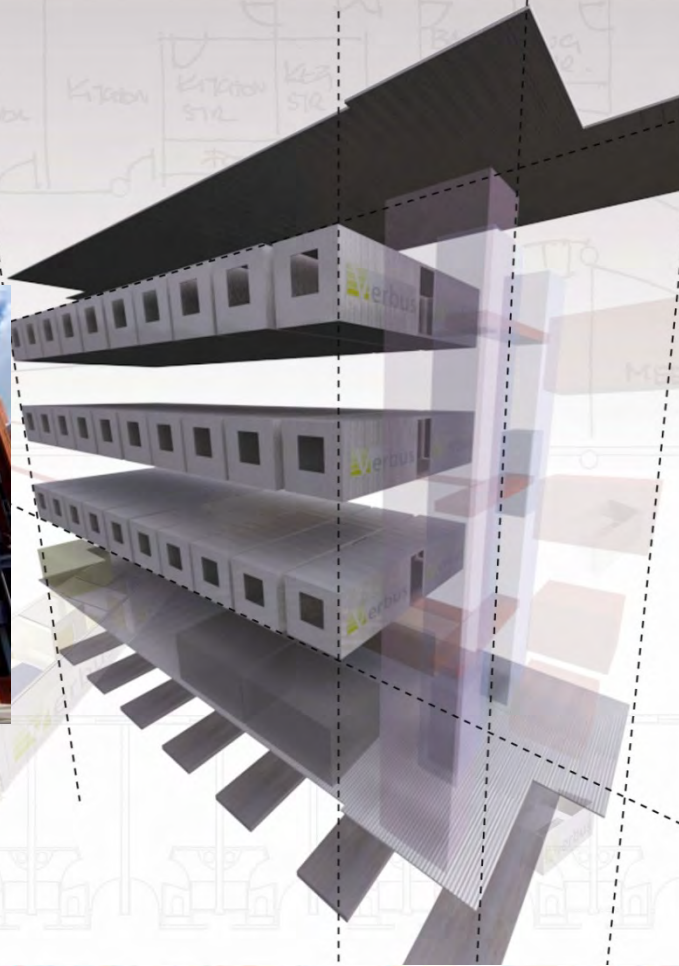


Source: <http://continuingeducation.construction.com/article.php?L=5&C=943&P=2>

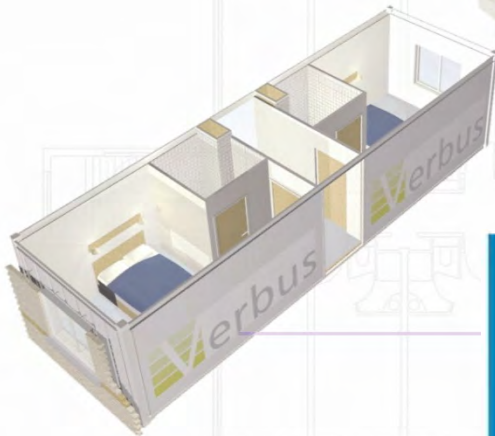
MODULAR HOTEL DESIGN



Buro Happold



www.verbussystems.com/



Courtesy of Dr C. Goodier



Precast Concrete Panel Systems

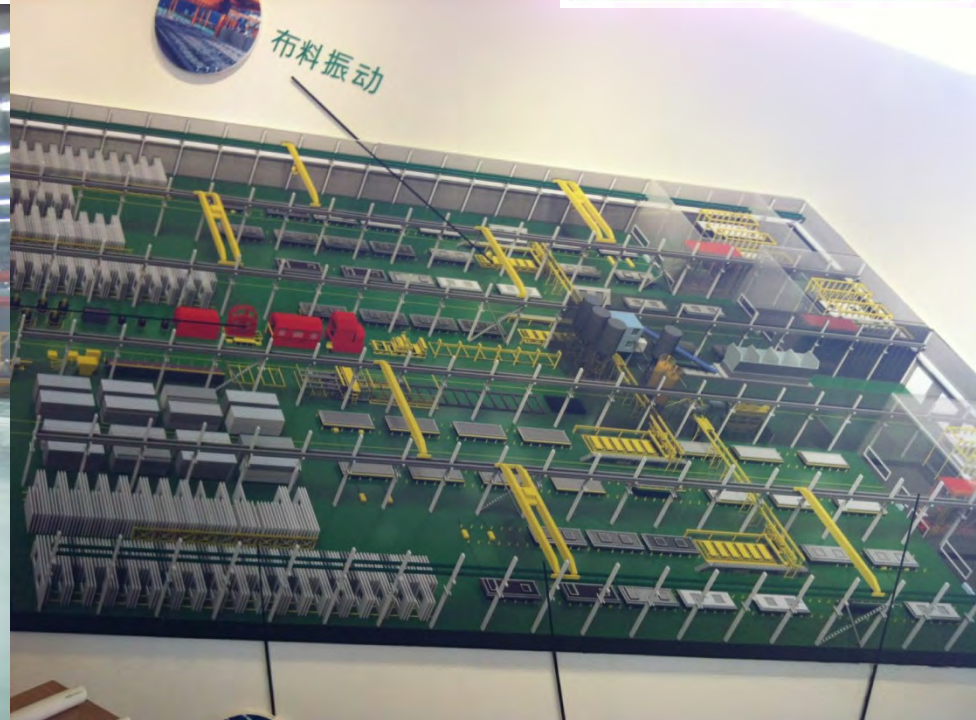
Electricity Saving 70%

Water Saving 80%

Material Saving 20%

Area Saving 20%

Time Saving 70%



Courtesy of Broad Home

Precast Concrete Panel vs. Traditional Insitu





CIC Zero Carbon Building



Kai Tak Public Housing



Enhancing Productivity Through Off-Site Prefabrication

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

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