

**CICID 10<sup>th</sup> Anniversary Conference**

# **Novel Zero Carbon Building Design Initiative**

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**Arup Fellow & Director of Arup**

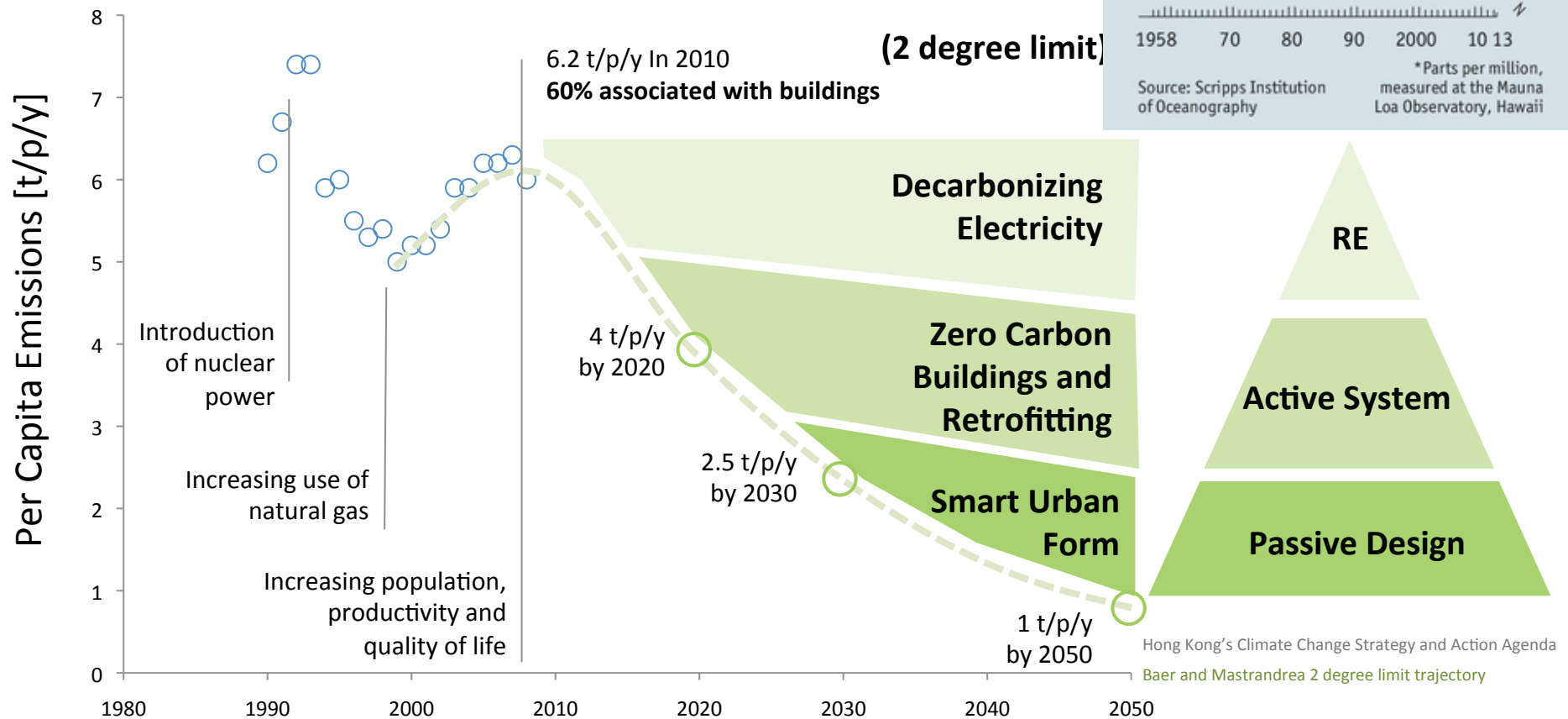
**31<sup>st</sup> May 2013**

**ARUP**

# The ZCB and Hong Kong's Carbon Road Map

- The ZCB demonstrates the attempt to answer the question:

What are the necessary measures to avoid catastrophic climate change?



# Innovation, Creativity, and Originality

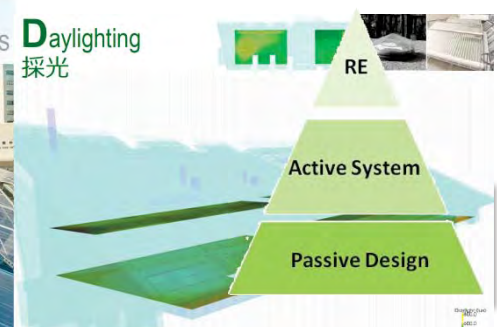
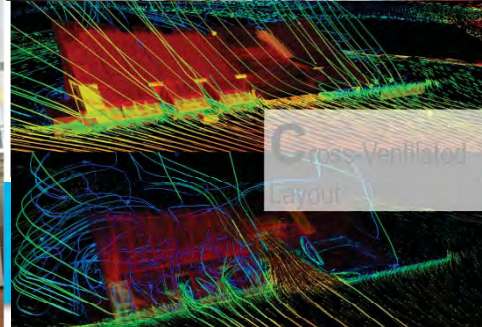
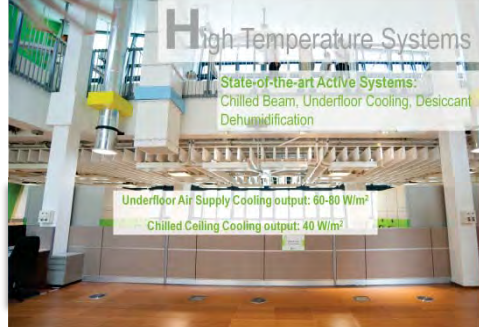
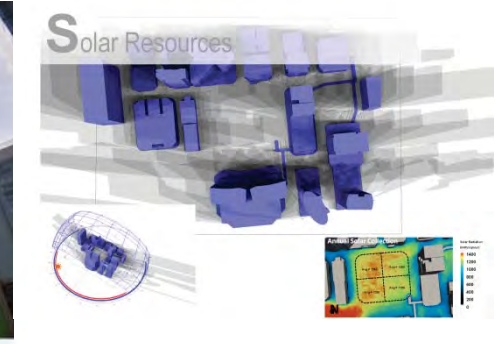
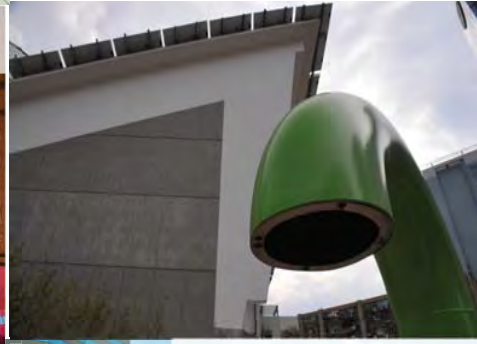
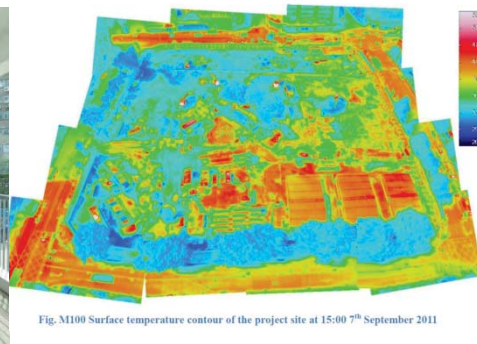
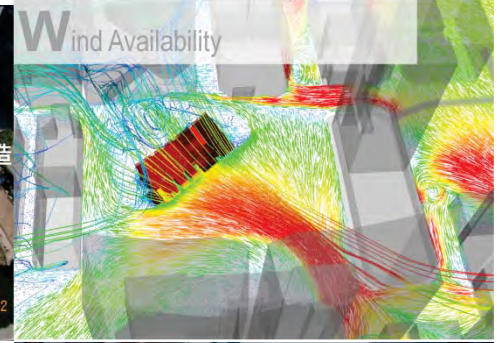
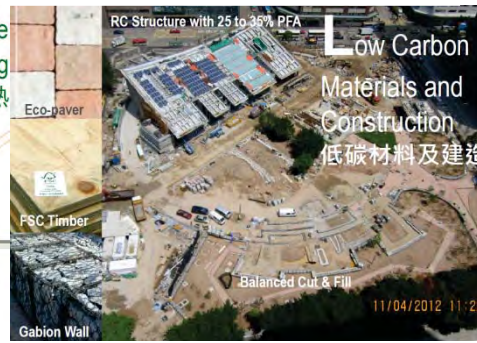
- **Innovation in utilizing new technologies and creative approaches to improve the built environment**
- **Showcase state-of-the-art zero carbon building design and technologies** to the construction industry internationally and locally
- **Promote sustainable construction, living, and behavioral changes** which can achieve the carbon targets necessary for averting catastrophic climate change

- **HKGBC Green Building Award – Grand Award 2012**
- **HKIE Innovation Award for Engineering Industry 2013 – Champion of Construction Category**





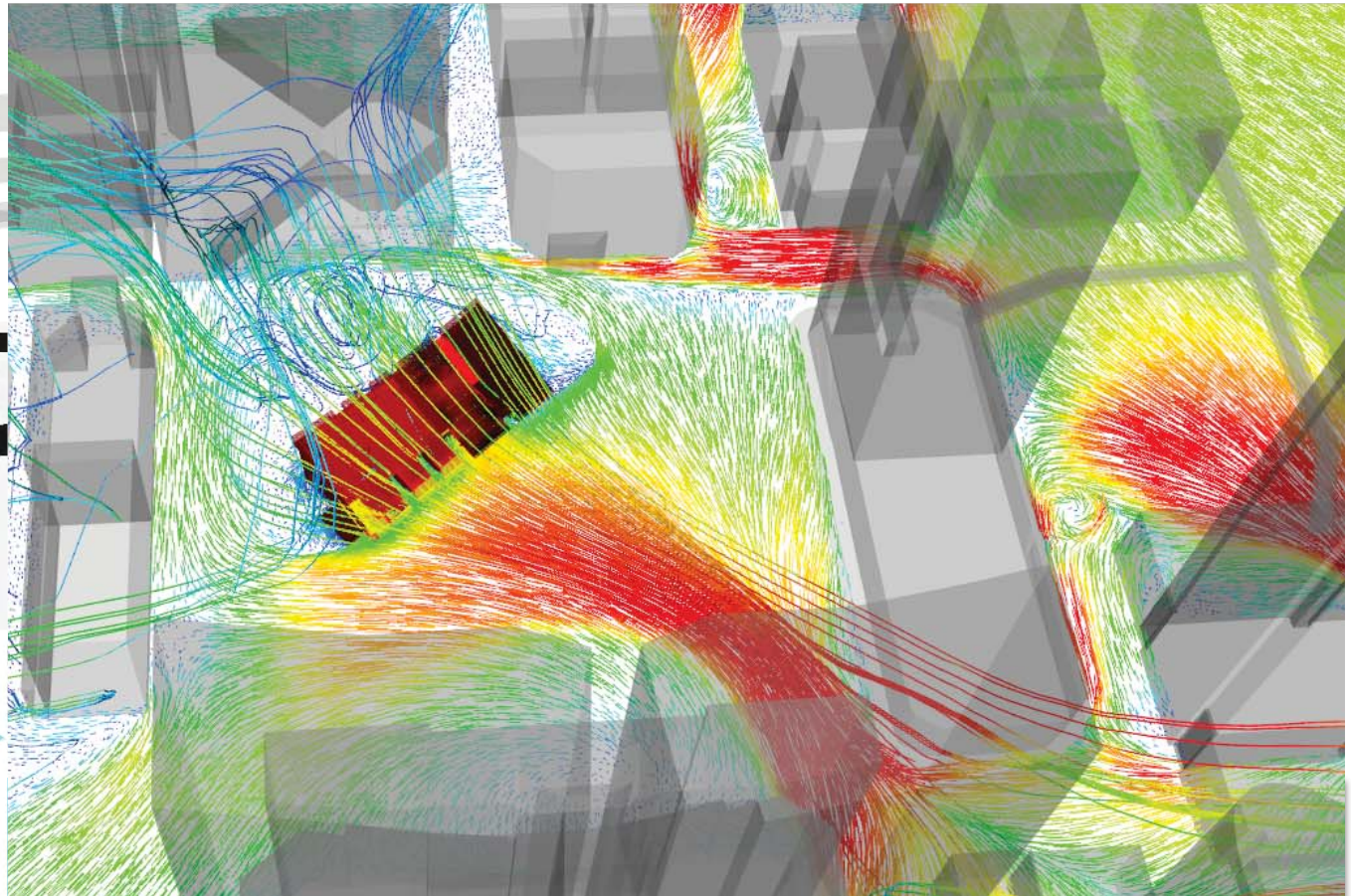
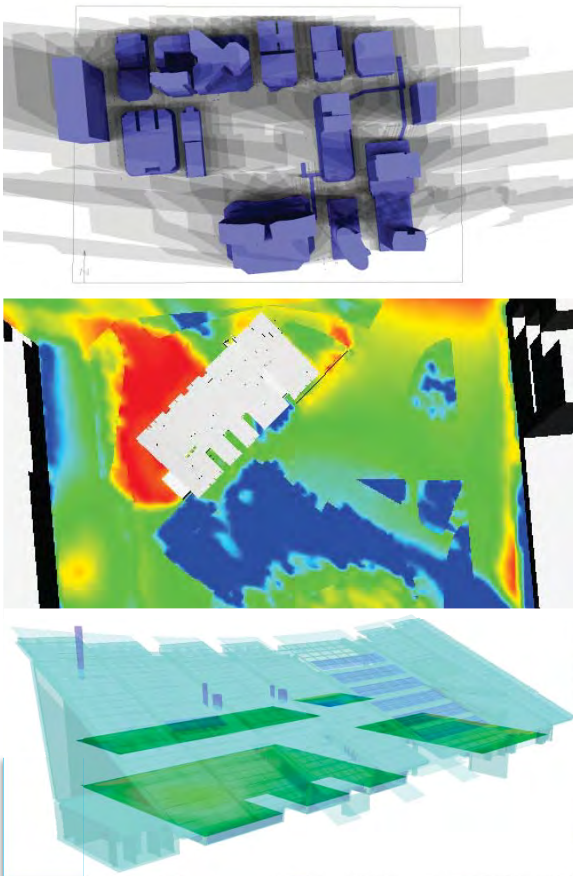
*The project features more than 80 sustainability measures, each an innovation in its own right.*





# Urban Form and Passive Design for Hong Kong Environment

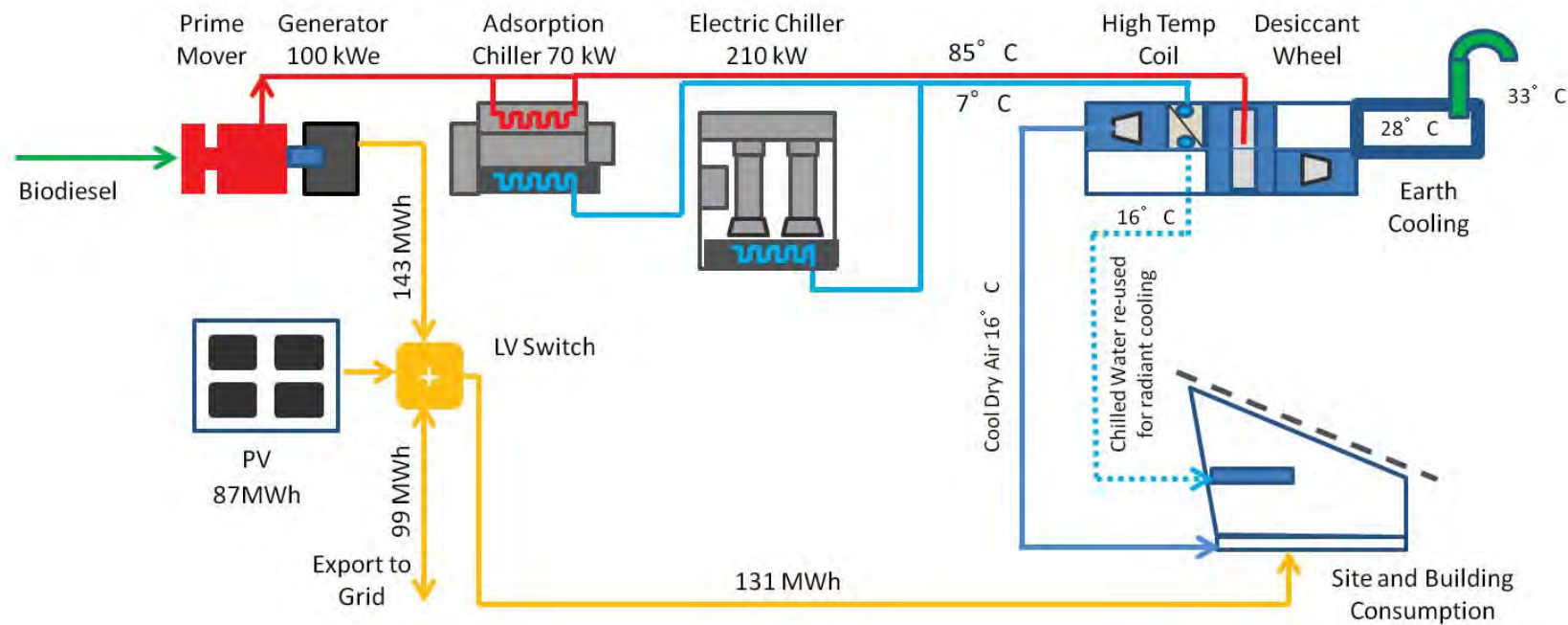
- **An exemplary benchmark for designing passive buildings** in Hong Kong
- **Reverse the Urban Heat Island Effect** through smart build form and cool materials
- **Maximize cross ventilation and lighting** through planning





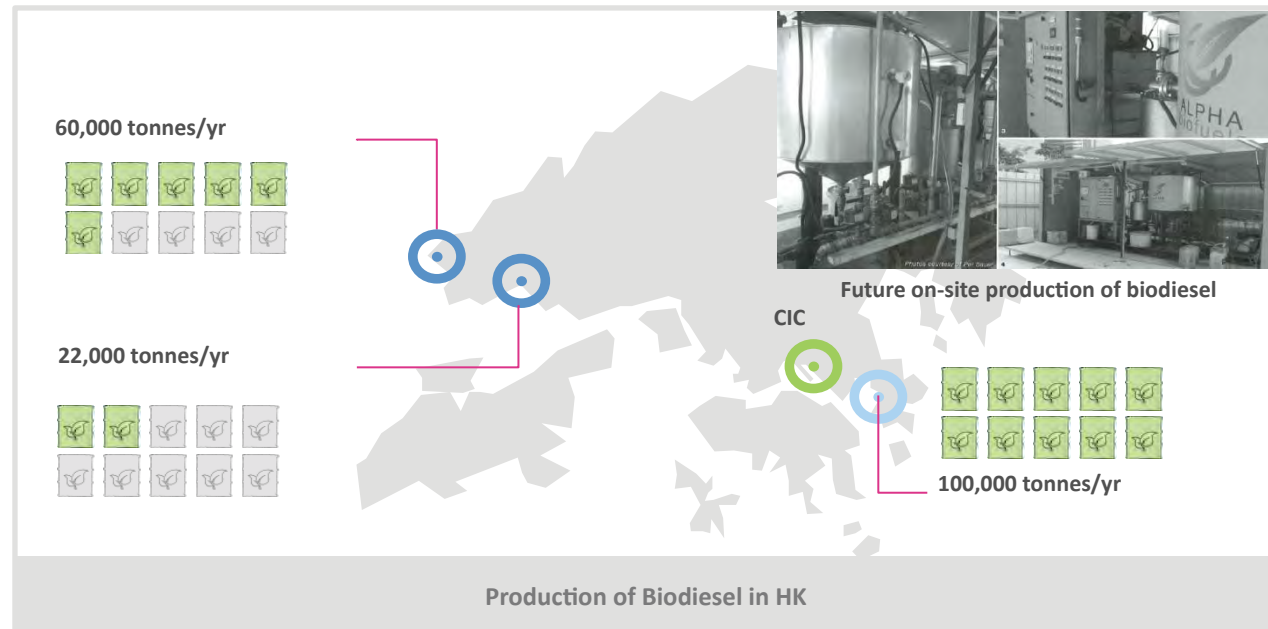
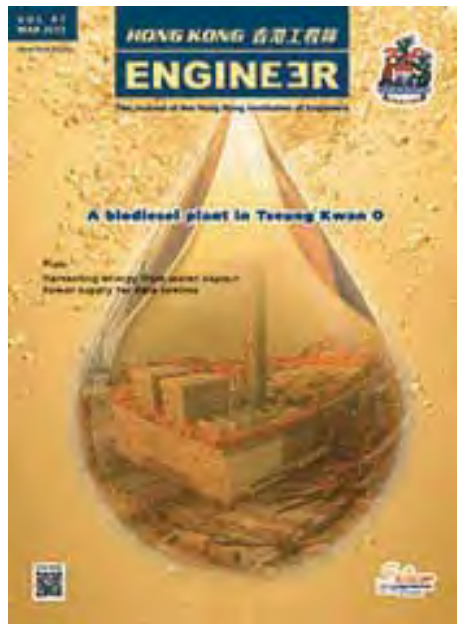
# Up-scaleable Active Systems – The Energy Cascade

- We developed an **energy strategy** that can find application in many of the high **rise buildings** in Hong Kong.
- Energy cascade strategy maximizes energy utilization by using each resource multiple times



# A Renewable Energy Experiment for Hong Kong

- Biodiesel is a form of renewable energy. The carbon dioxide emitted during its combustion will be absorbed via photosynthesis by plants producing the feedstock for making biodiesel.
- The emission factor for the use of biodiesel from waste cooking oil is lower since it not only displaces the combustion of fossil fuel, it also avoids the generation of methane gas at landfills.



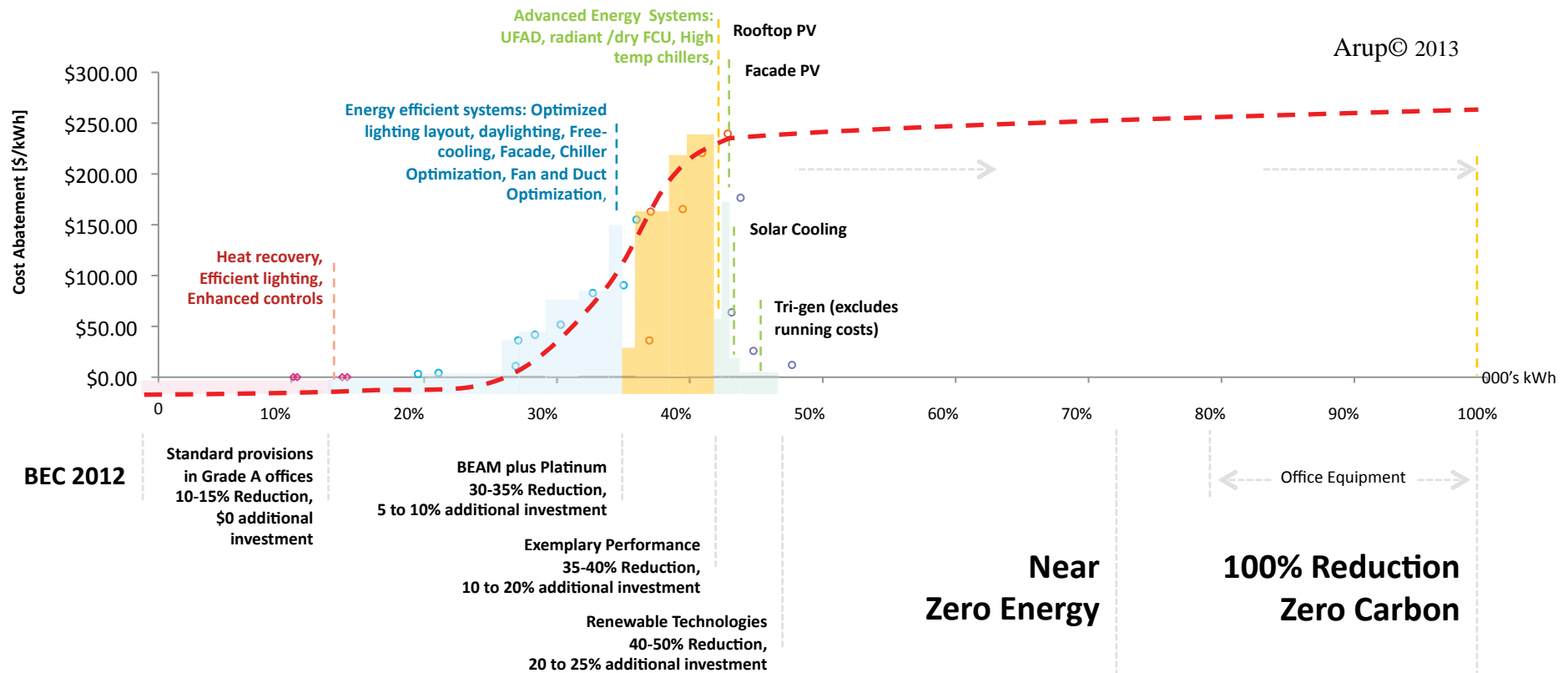
# Sustainability Performance – Building Environmental Performance Dashboard

- More than 2800 sensors monitoring every aspect of the building performance.
- This system allows the users, designers and facility managers to quantitatively assess the environment and the comfort level, and track down any issues in operation.



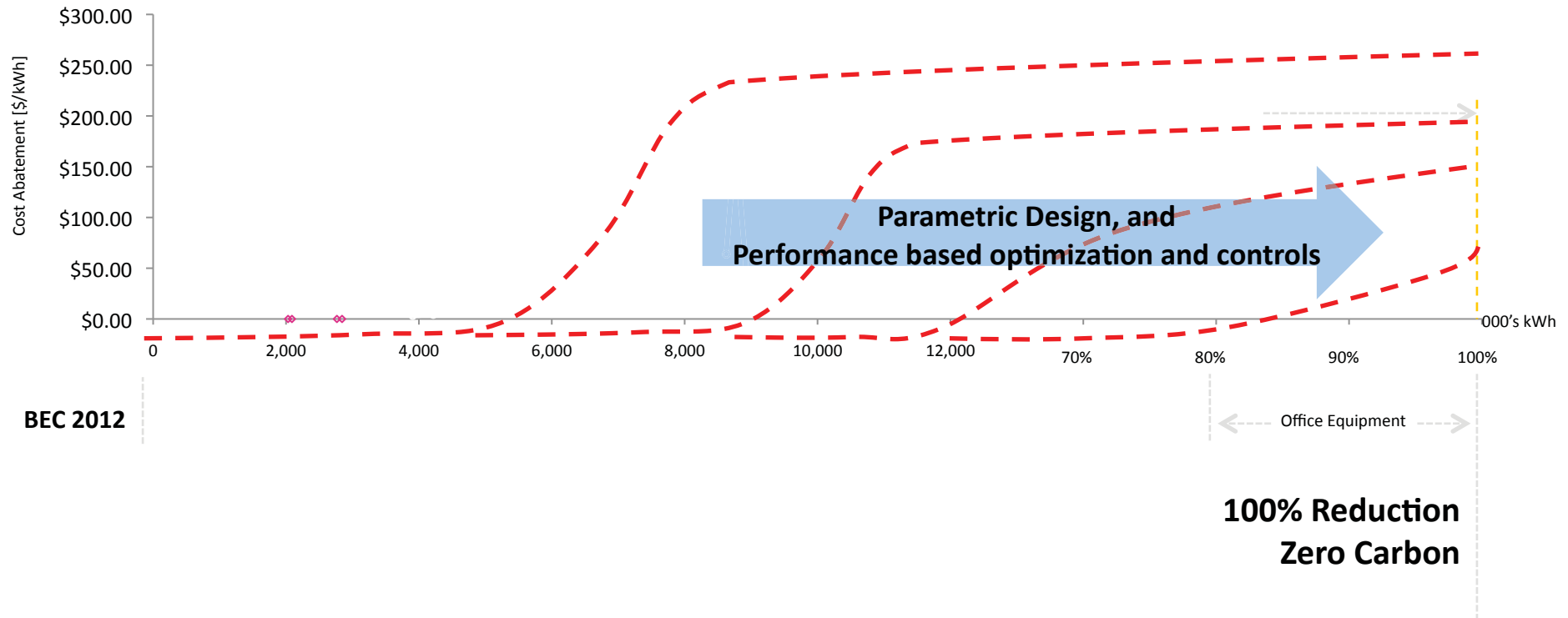


# Cost Abatement Curve for Typical Office Buildings in Hong Kong



- Currently, zero carbon is costly
- Cost rises steeply after 30 to 50%
- The EU has been exploring “Near Zero Energy” as an interim solution

# Cost Abatement Curve for Typical Office Buildings in Hong Kong

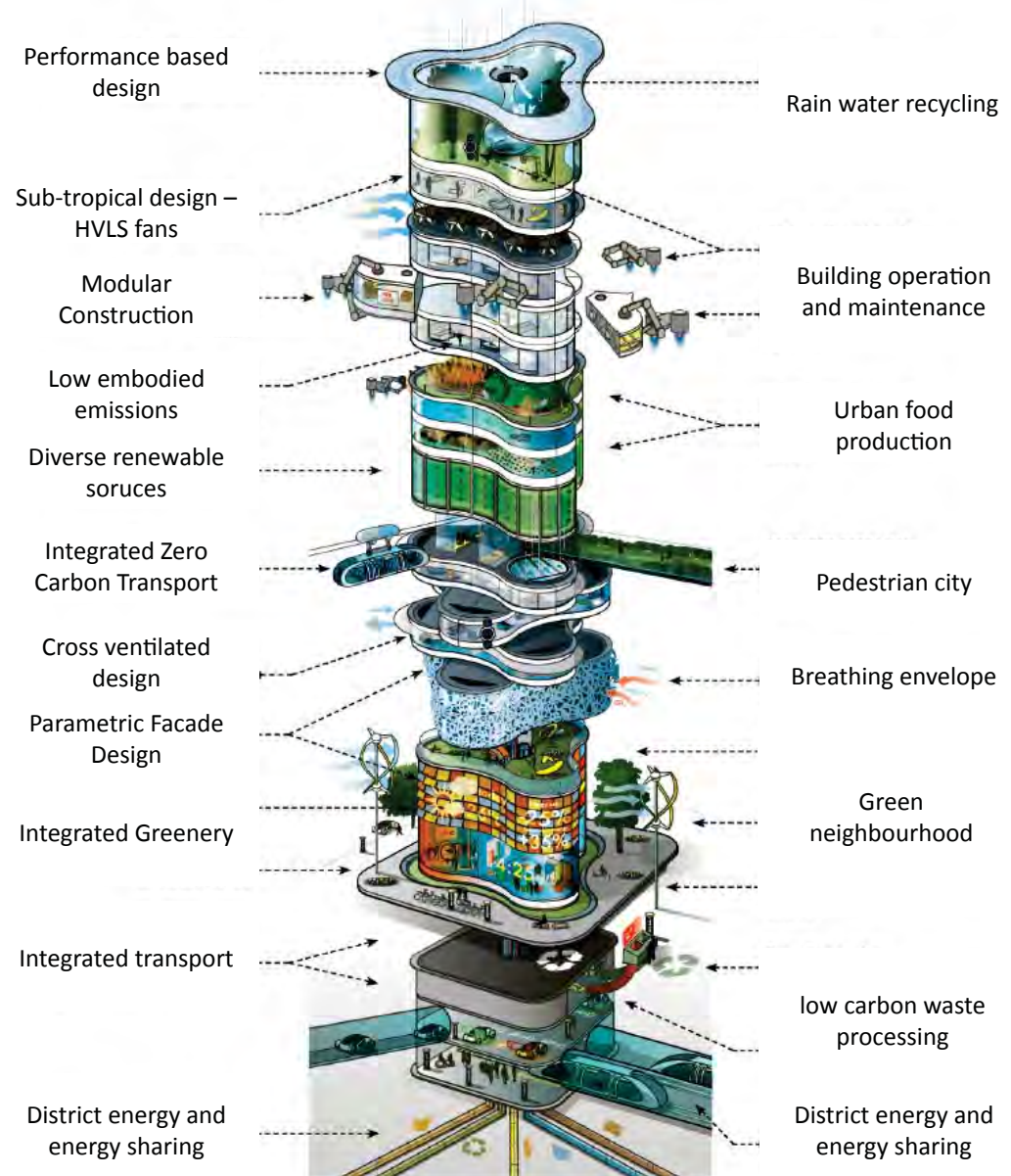


- In the long run, we are exploring design techniques and Zero Carbon technologies that allow us to push the cost curve down towards zero carbon
- Performance based building system design – optimization and controls
- Parametric design – low cost passive performance
- Zero Carbon Technologies



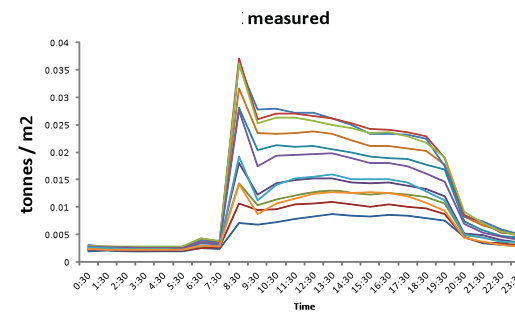
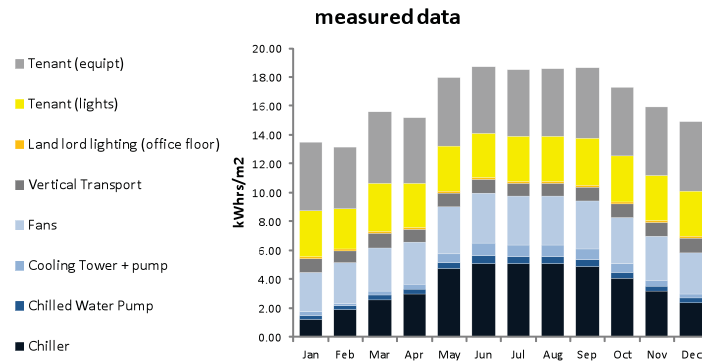
## Next Step on the Road Map

- Pulling together a range of innovations, each an increment, but together produces a step change
- Picture for reference only – *don't take the flying BMU too seriously.*

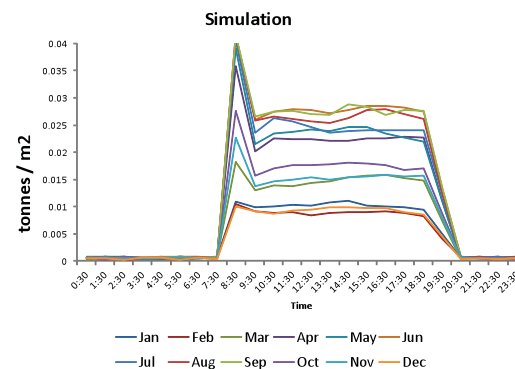
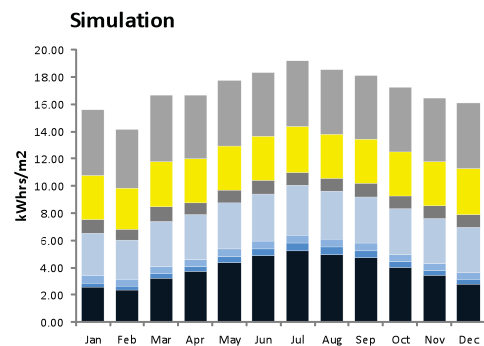


# Performance Based Approach

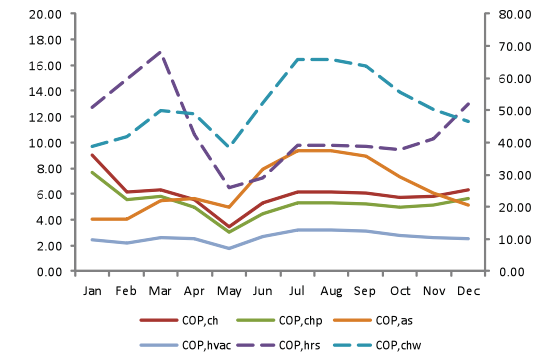
- Design developed and benchmarked against actual operation data
- Through detailed modeling, we increase our understanding of opportunities in integrating energy efficiency in design with operations and controls



kW	Tons	% of load	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1761	900	10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2441	750	1%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3521	1000	20%	4.00%	4.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4401	1250	25%	8.00%	10.00%	3.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5282	1500	30%	12.00%	12.00%	4.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6162	1750	35%	17.00%	16.00%	6.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
7042	2000	40%	18.00%	11.00%	8.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
7922	2250	45%	22.00%	15.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8803	2500	50%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
9683	2750	55%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10563	3000	60%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11444	3250	65%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12324	3500	70%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
13204	3750	75%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
14085	4000	80%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
14965	4250	85%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
15845	4500	90%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16725	4750	95%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
17606	5000	100%	22.00%	17.00%	10.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%



## Calibrate schedules



Calibrate energy consumption

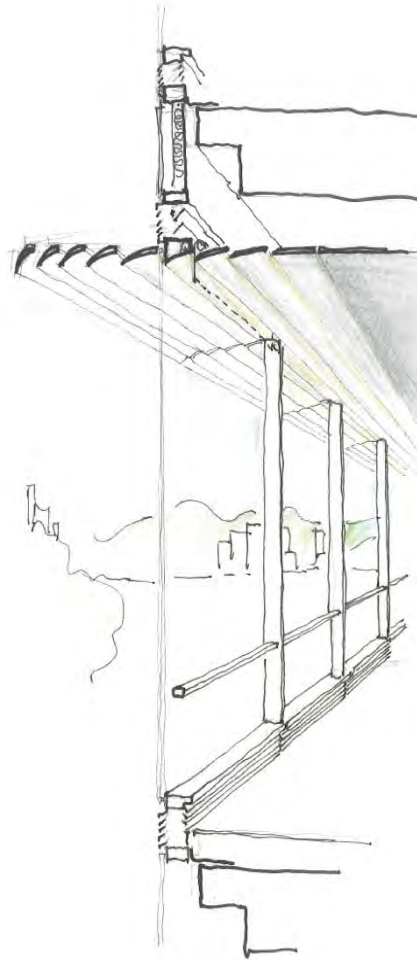
Calibrate building loads

Calibrate equipment performance

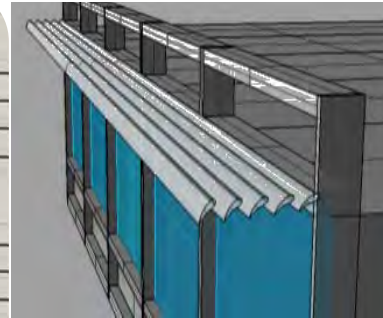
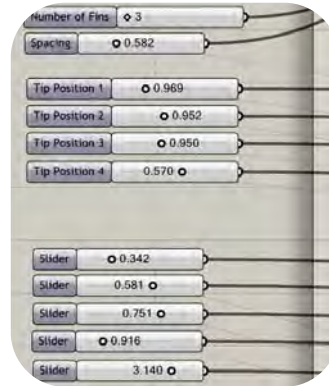


# Driving Design through Parametric Analyses of Facade

## Concept design

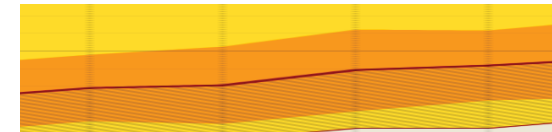


## Parametric digital modeling

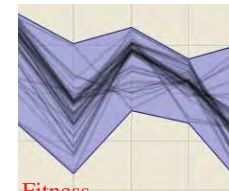


Parametric model

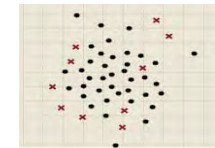
## Performance evaluation and optimization



Performance evaluation

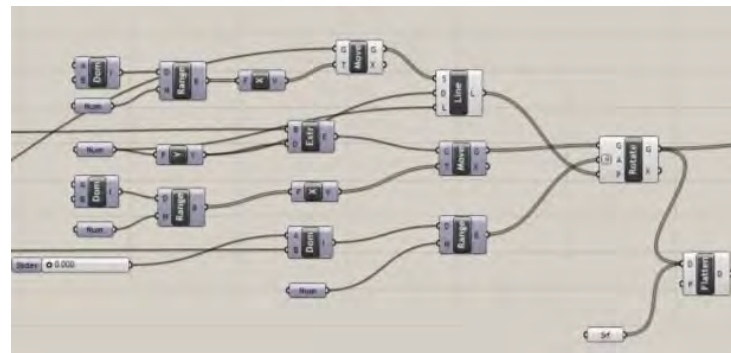


Fitness

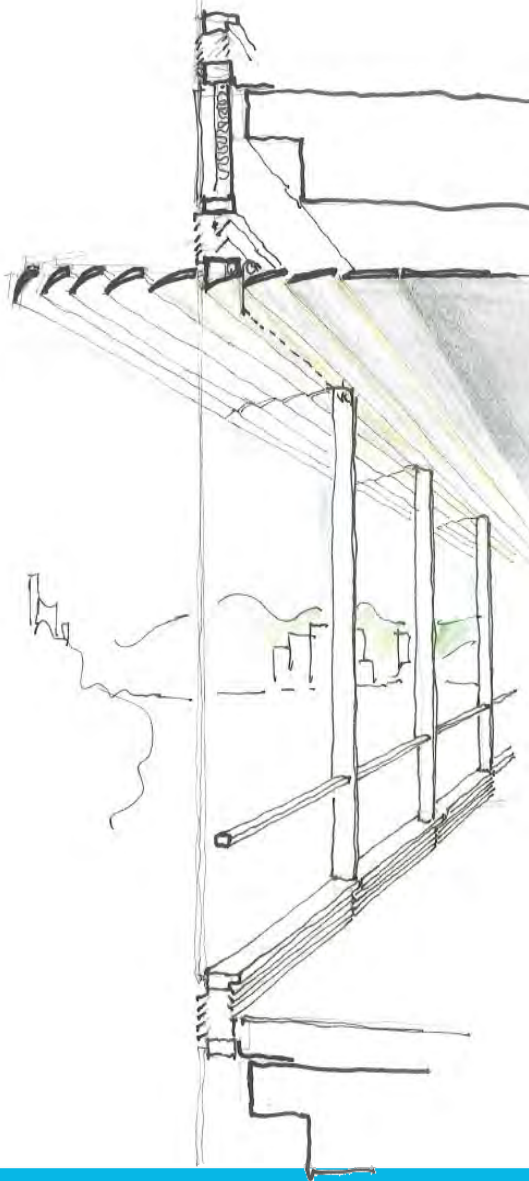


Gnorm

## Logic implementation

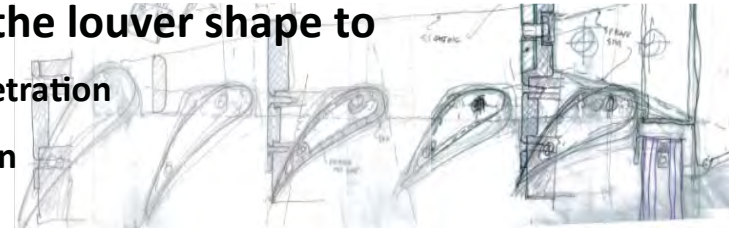


# Digital Design Optimization of Passive Shades



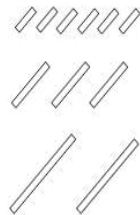
**Objective: Optimize the louver shape to**

- Maximize daylight penetration
- Minimize solar heat gain

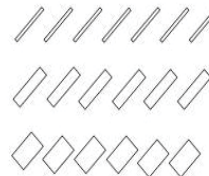


## Variables

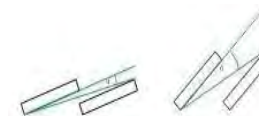
Number of fins



Blade thickness & spacing



Blade angle



Fin curvature

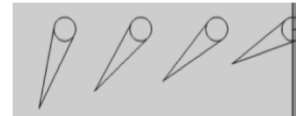


## Results

Initial shape



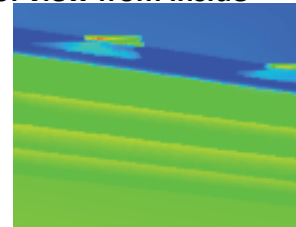
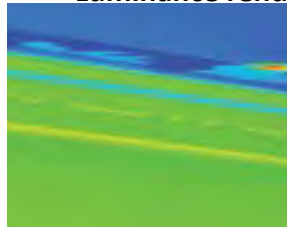
Optimized angle



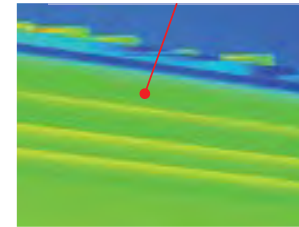
Optimized curvature



Luminance render of view from inside



Brighter blade (view from inside)



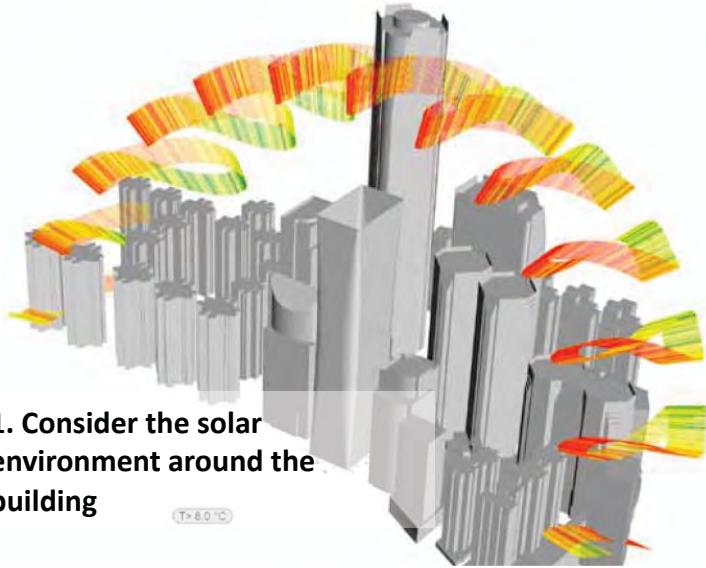
Luminance



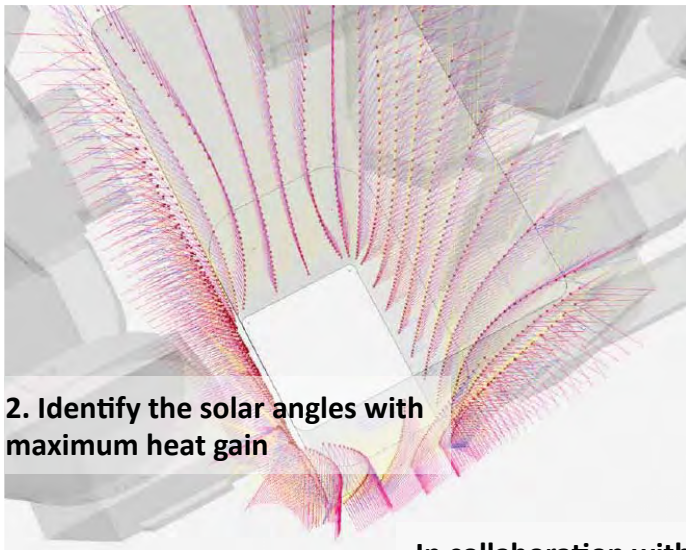


# Driving Design through Parametric Analyses of Facade

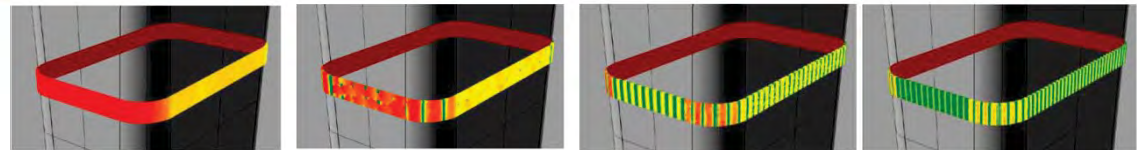
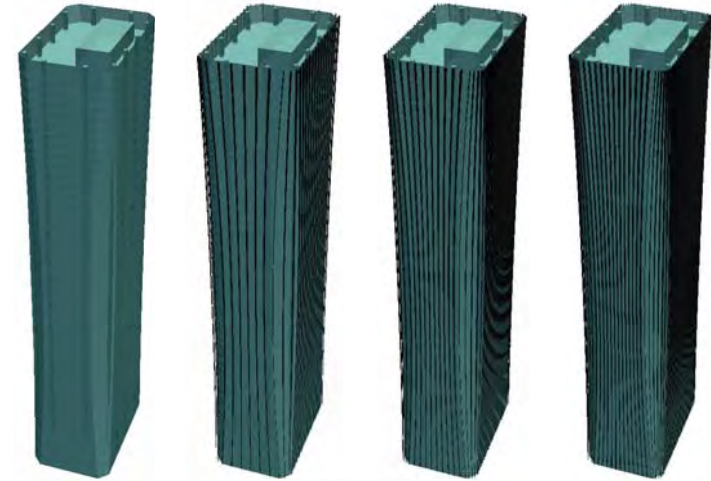
1. Consider the solar environment around the building



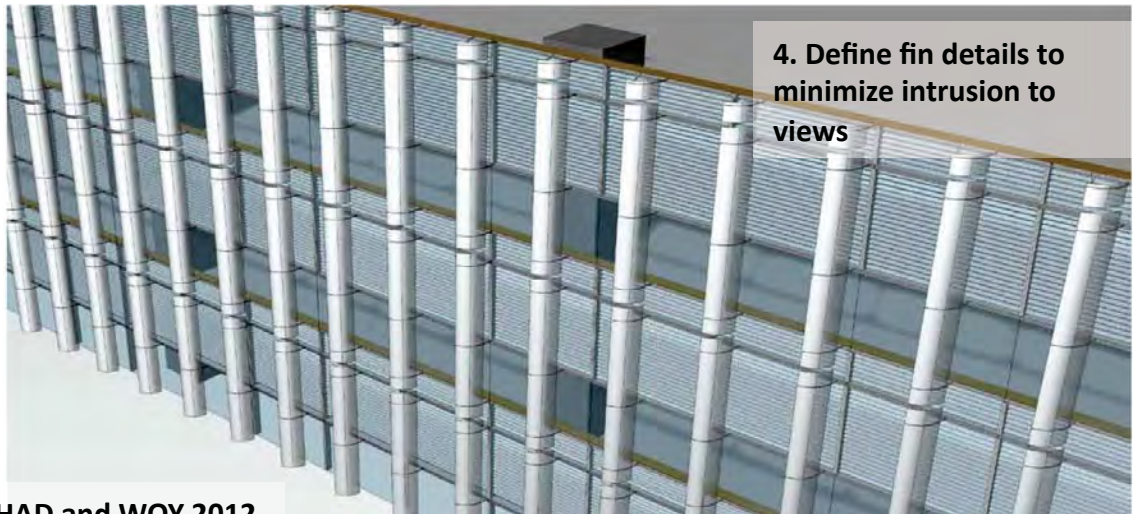
2. Identify the solar angles with maximum heat gain



3. Experiment with different vertical fin parameters – rotation, length, densities



4. Define fin details to minimize intrusion to views

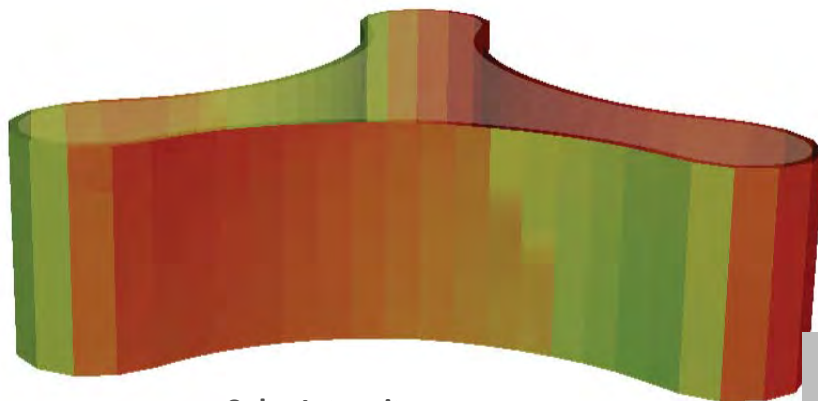


In collaboration with HAD and WOY 2012

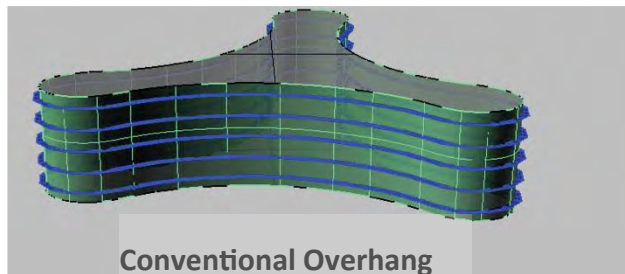
# Parametric Design for Facade of a Campus Building

Ultra wide modules gives superior views and leasing benefits, but comes with challenges in constructability and environmental performance

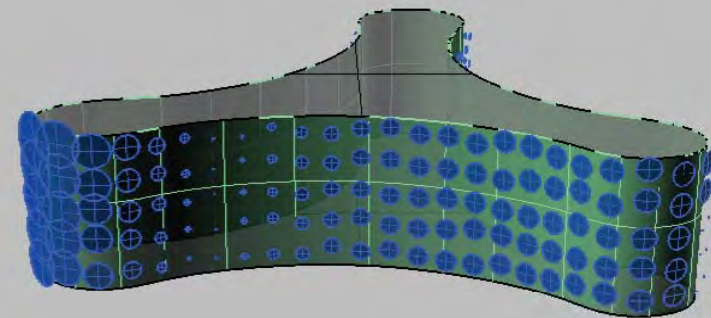
The design is “evolved” virtually through a series of optimization during the design process



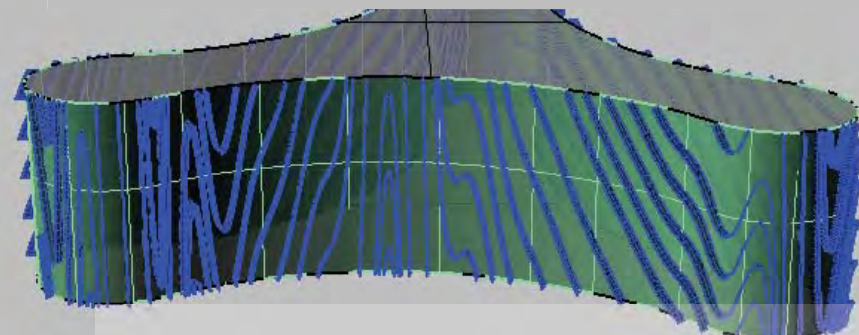
Solar Intensity



Conventional Overhang



Window Packing Based on Irradiation Intensity



Shading Ribbon Based on Irradiation and Orientation



## Summary

- **The CIC ZCB is a starting point in the solution to the climate change problem**
- **The building demonstrated some key elements for zero carbon in our sub-tropical hi-rise hi-density context**
  - Sub-tropical microclimate ventilation design
  - Energy cascade
  - Diversity renewable resources
- **Further development for zero carbon design should be supported by policy initiatives, with clear road-map for waypoints (near zero carbon) to wide-scale zero carbon application**
- **A number of new design initiatives are required to deliver zero carbon within a feasible budget**
  - Parametric design
  - Performance based design

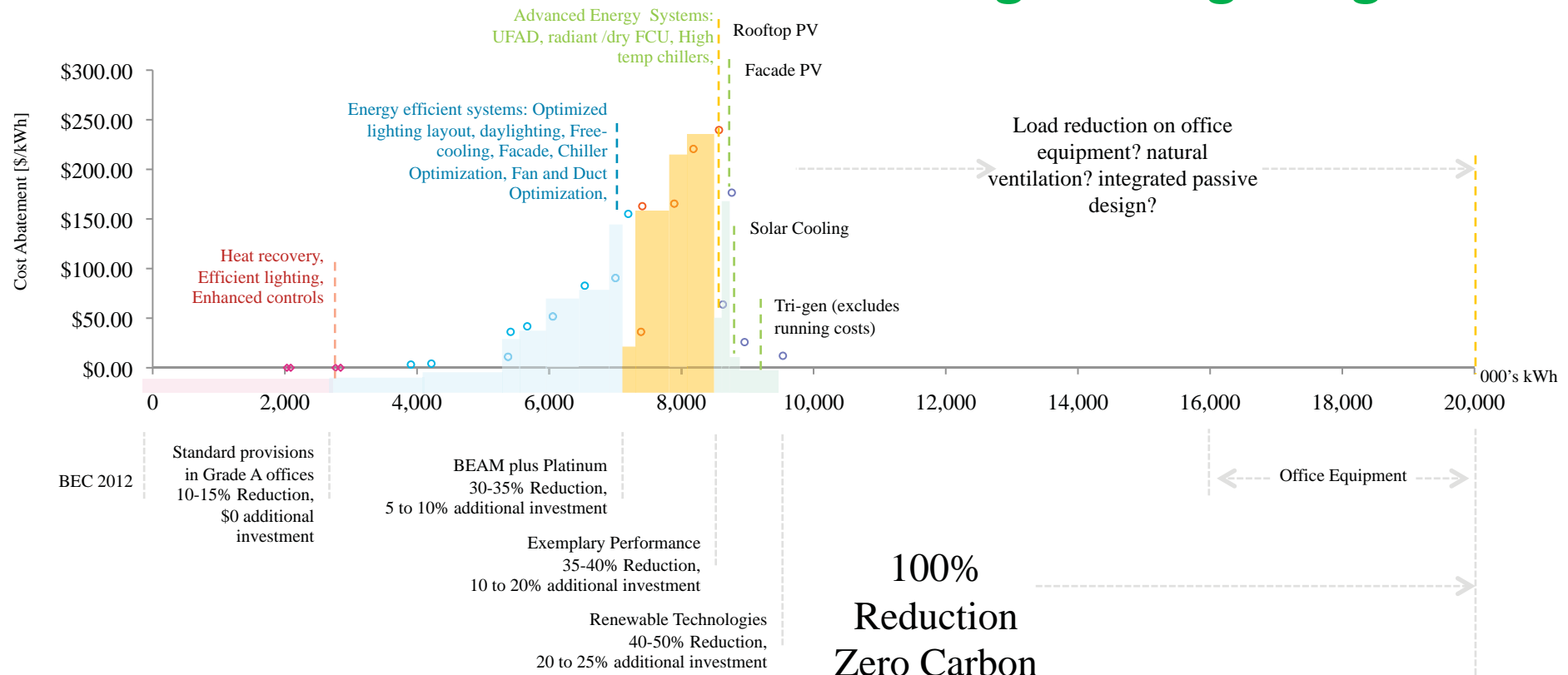


**Thank You**

**Contact:** [raymond.yau@arup.com](mailto:raymond.yau@arup.com)

**ARUP**

# Cost Curve for Grade A office building in Hong Kong



- A cost evaluation exercise to assist the management decision making process
- Typically, first 10 to 15% are free – considered standard for Grade A offices
- To get platinum, typically 5 to 10% increase in investment
- Cost increases rapidly after that
- More recently, we have been working on projects that approaches cost reduction for zero carbon in a more aggressive manner – target to achieve with close to zero cost uplift