Transforming Cities in Hot and Humid Climates
Towards more Efficient and Sustainable Energy Use

Future Challenges of Cities in Hot and Humid Climates

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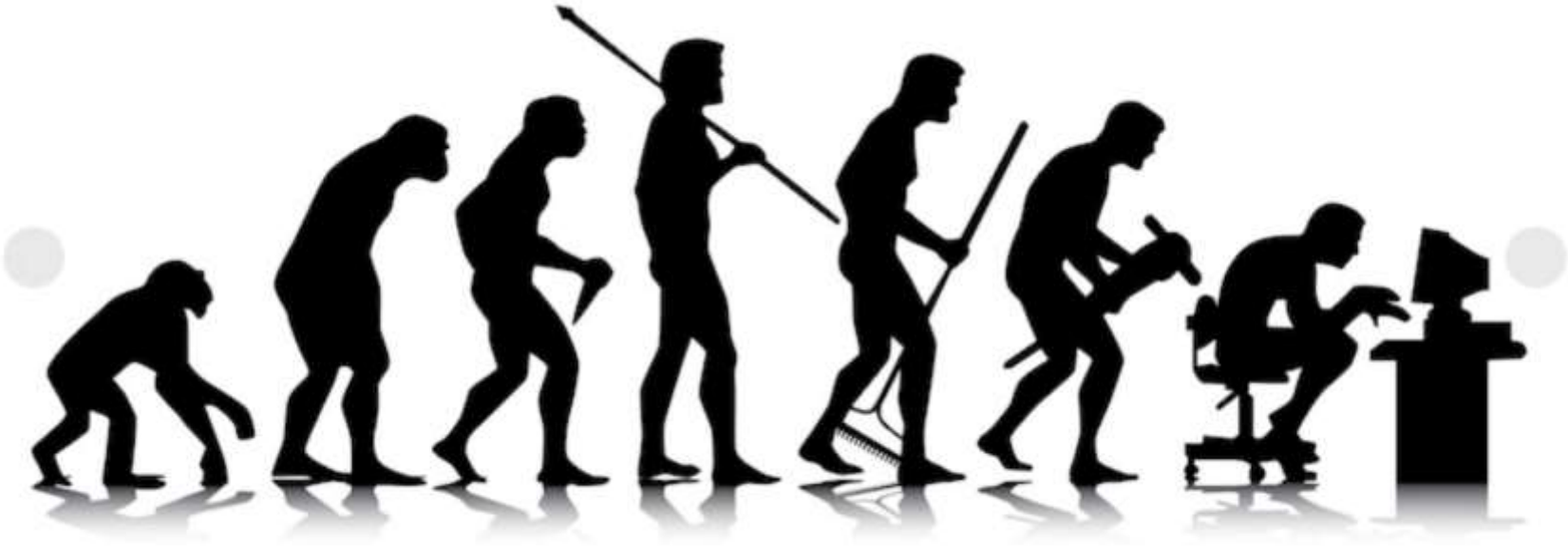
Dean, School of Design and Environment
National University of Singapore
24 October 2017

Nature of the Built Environment

"When you build a thing you cannot merely build that thing in isolation, but must also repair the world around it, and within it so that the larger world at that one place becomes more coherent and more whole; and the thing which you make takes its place in the web of nature as you make it."

Christopher Alexander
Architect, Theorist, Educator
Author of "A Pattern Language",1977, and "The Timeless Way of Building", 1979.

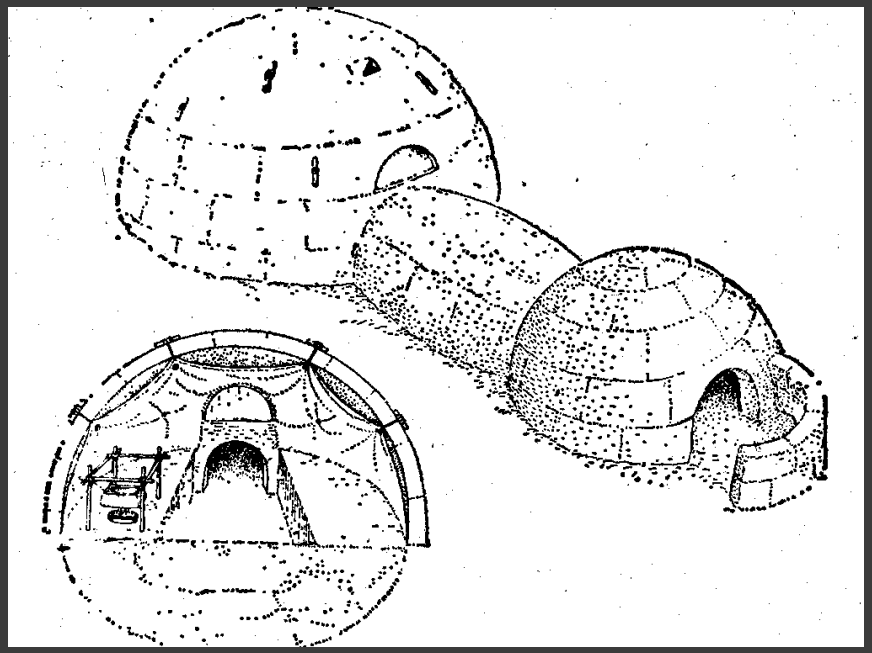


By elevysi / Posted 20 May 2017

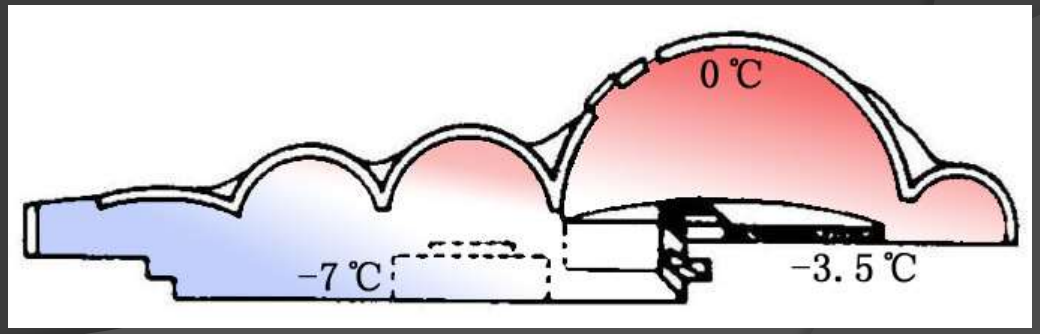
ADAPTABILITY AND RELATIVITY (A STORY OF DARWIN, EINSTEIN AND THE SHAQ)

"*It is not the most intellectual of the species that survives; it is not the strongest that survives; but the species that survives is the one that is able to adapt to and to adjust best to the changing environment in which it finds itself*". Charles Darwin

Eskimos' Ice House

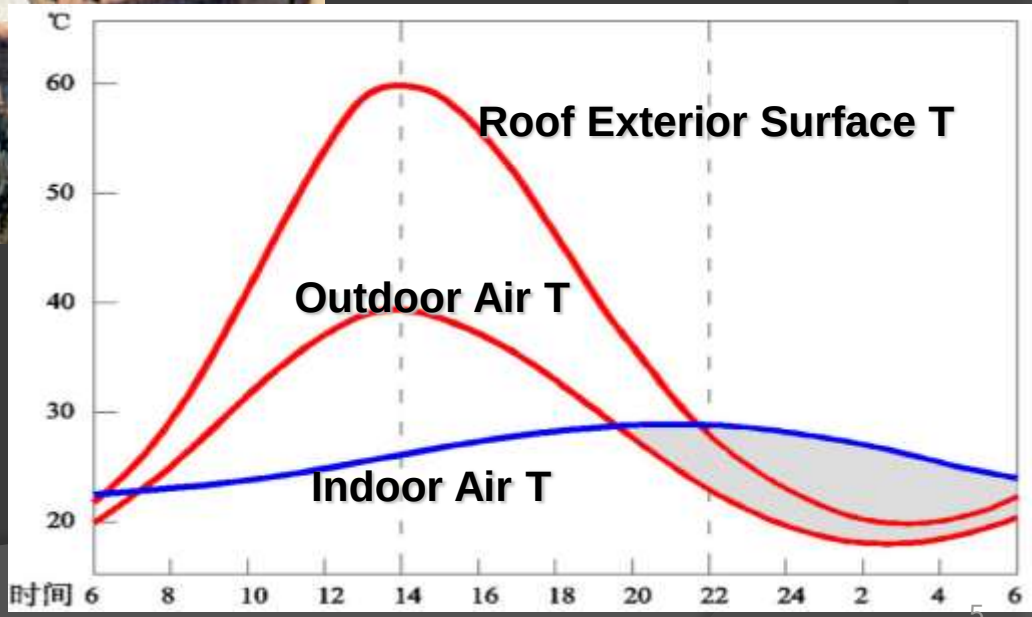


Made of ice bricks with thickness of about 500mm. The indoor temperatures can be maintained at above －5℃ when the outside temperature is－30℃.

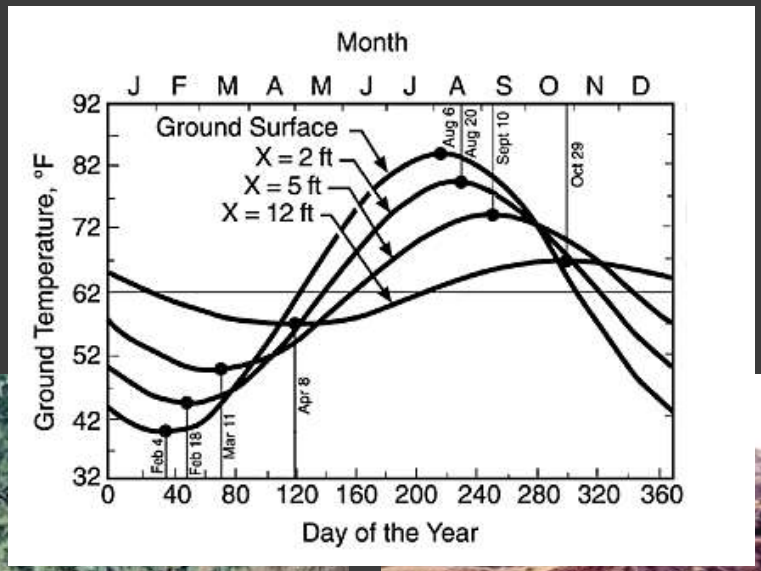


Egyptian Residence

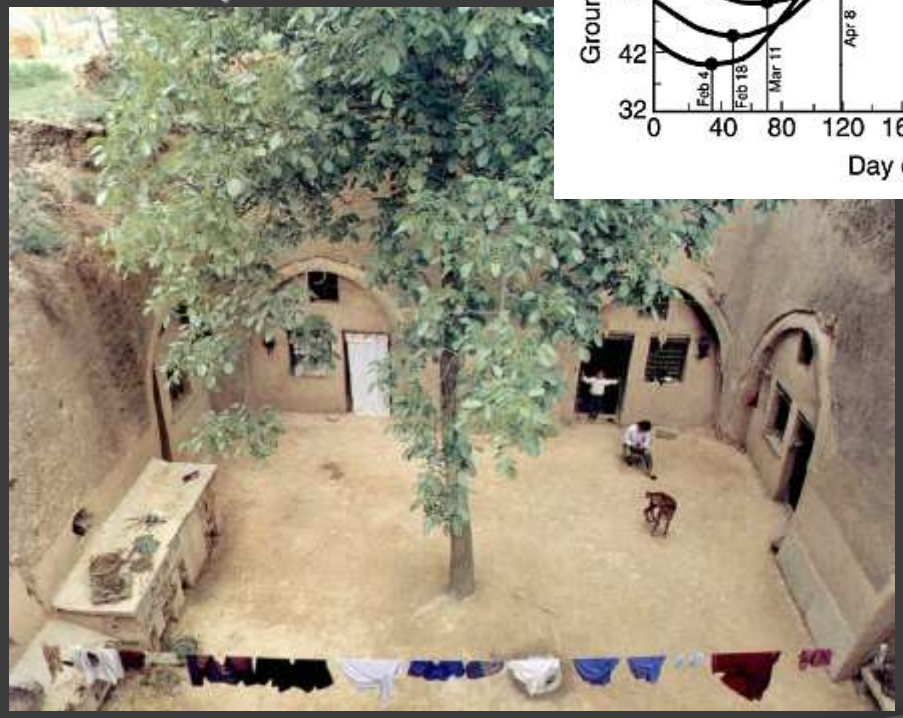
Brick thickness is more than 400mm. Due to the big thermal mass, indoor temperature difference in a day is less than 6℃, while outdoor temperature difference is more than 24℃.



Cave Houses

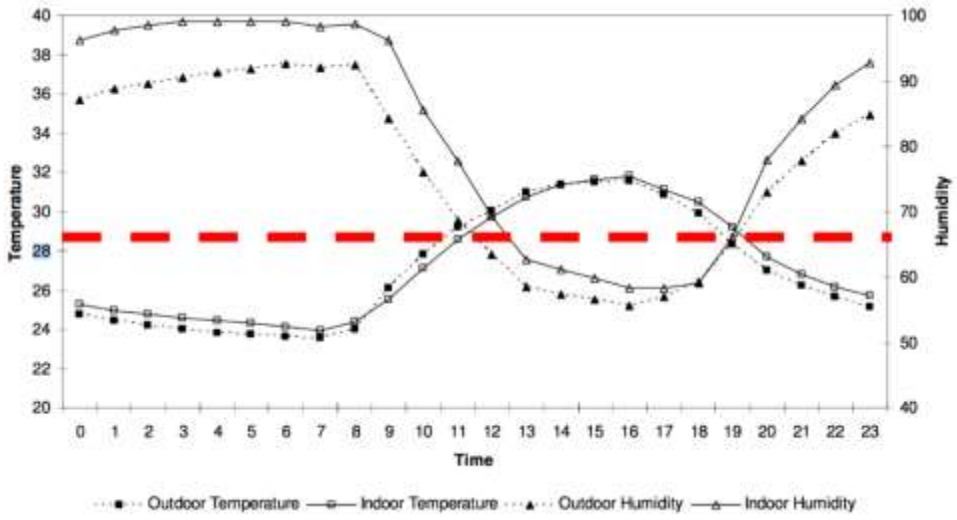


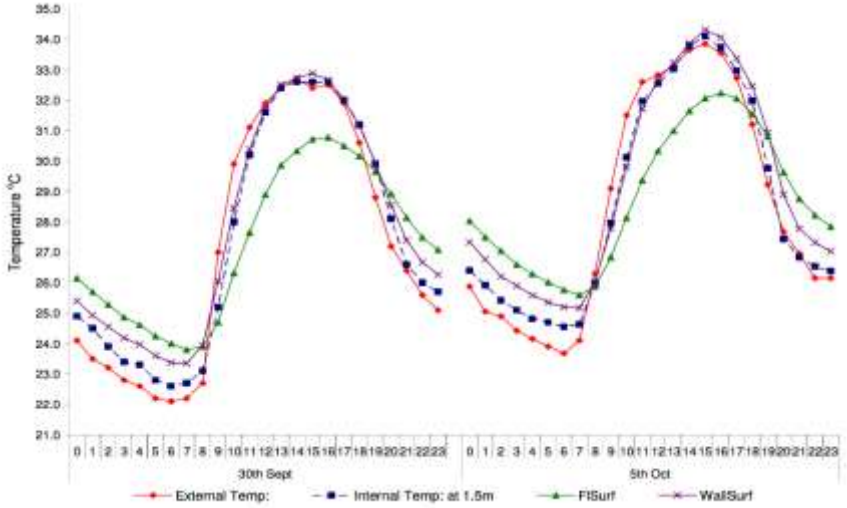
Cave House in Shaanxi, China



Cave House in Tunis

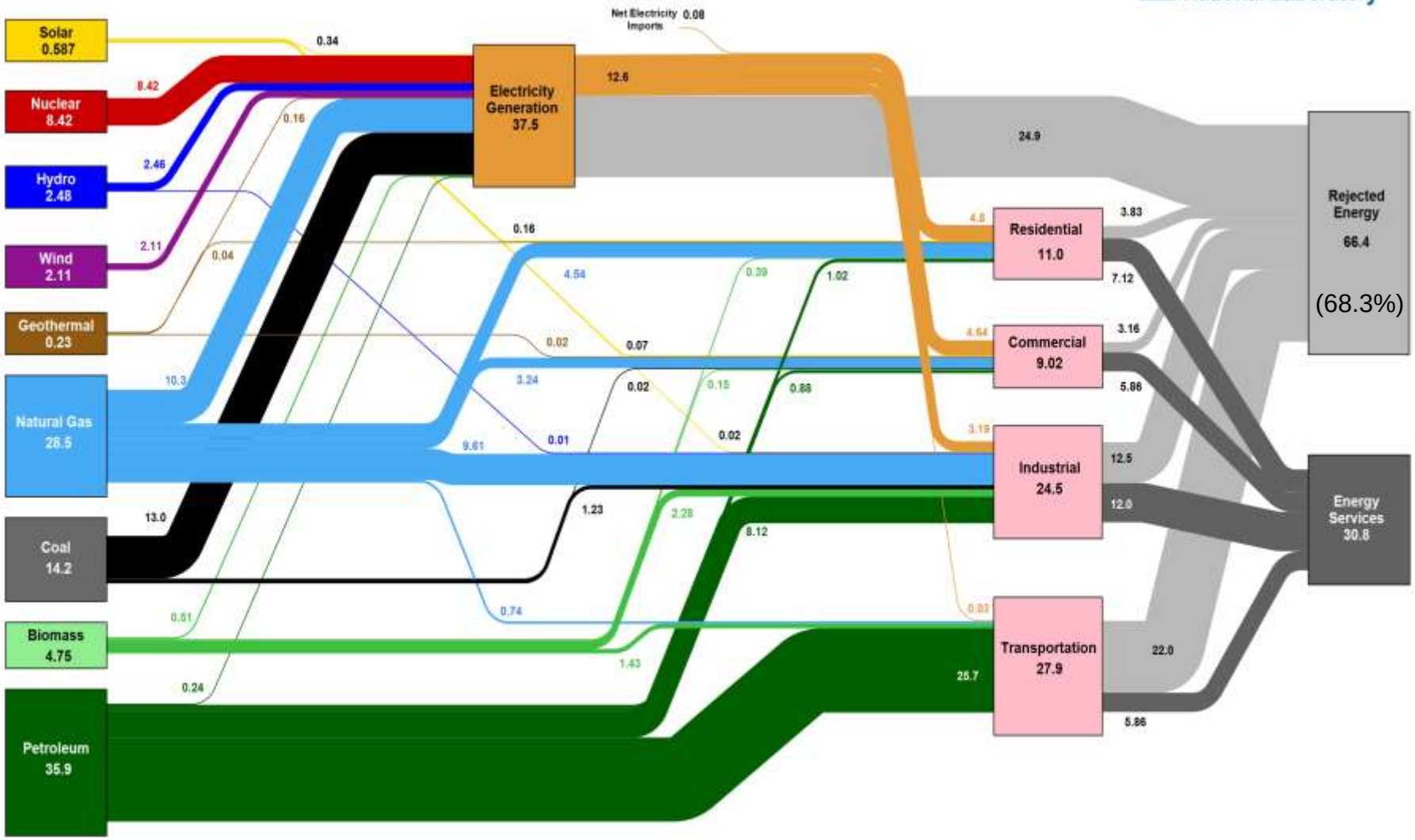
Taman Tropika House, Universiti Teknologi Malaysia



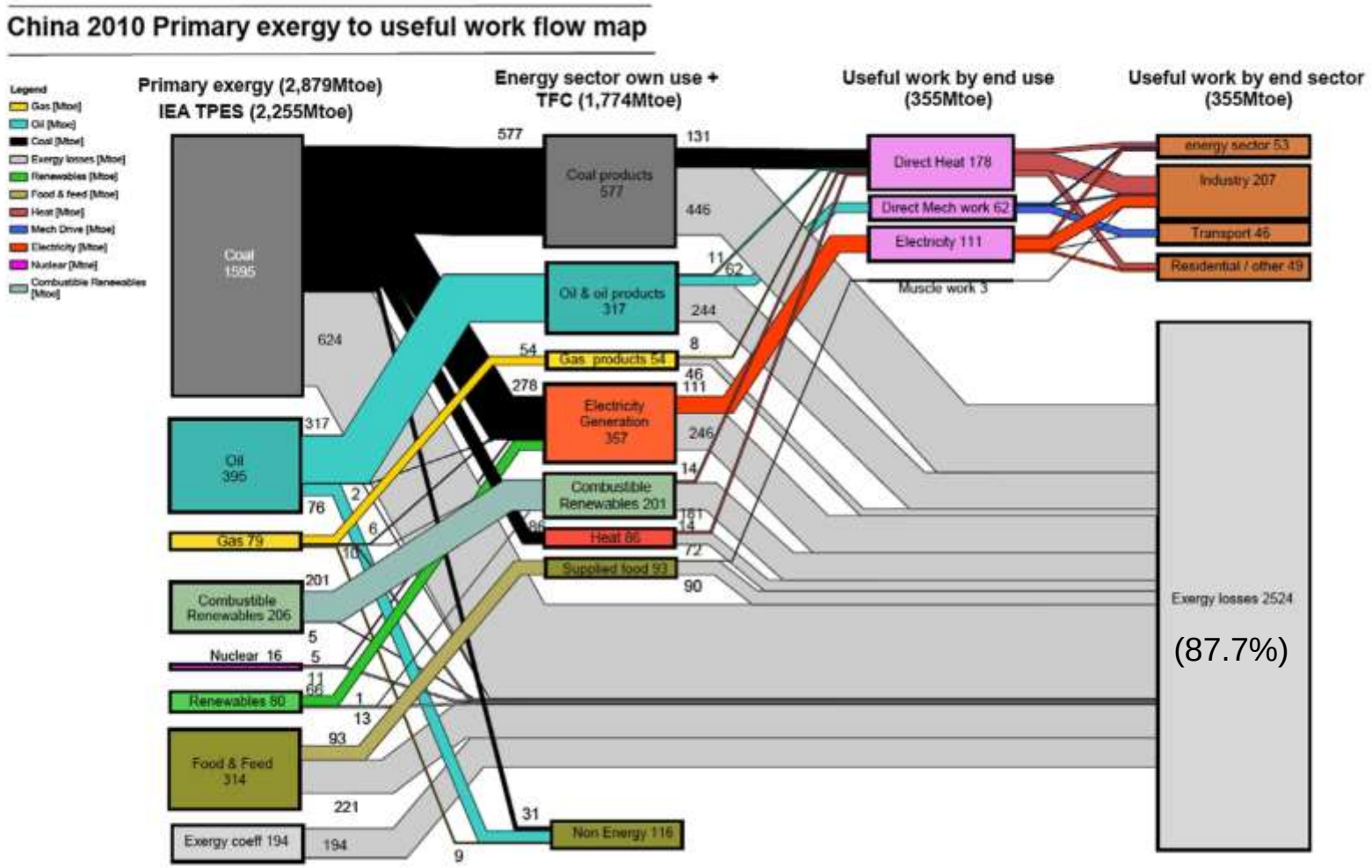


Ossen, D R, et al., Thermal Performance of Prototype Malaysian Traditional Timber House, 9th SENVAR & 2nd ISESEE 2008 International Seminar. Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia on 1-3 December 2008

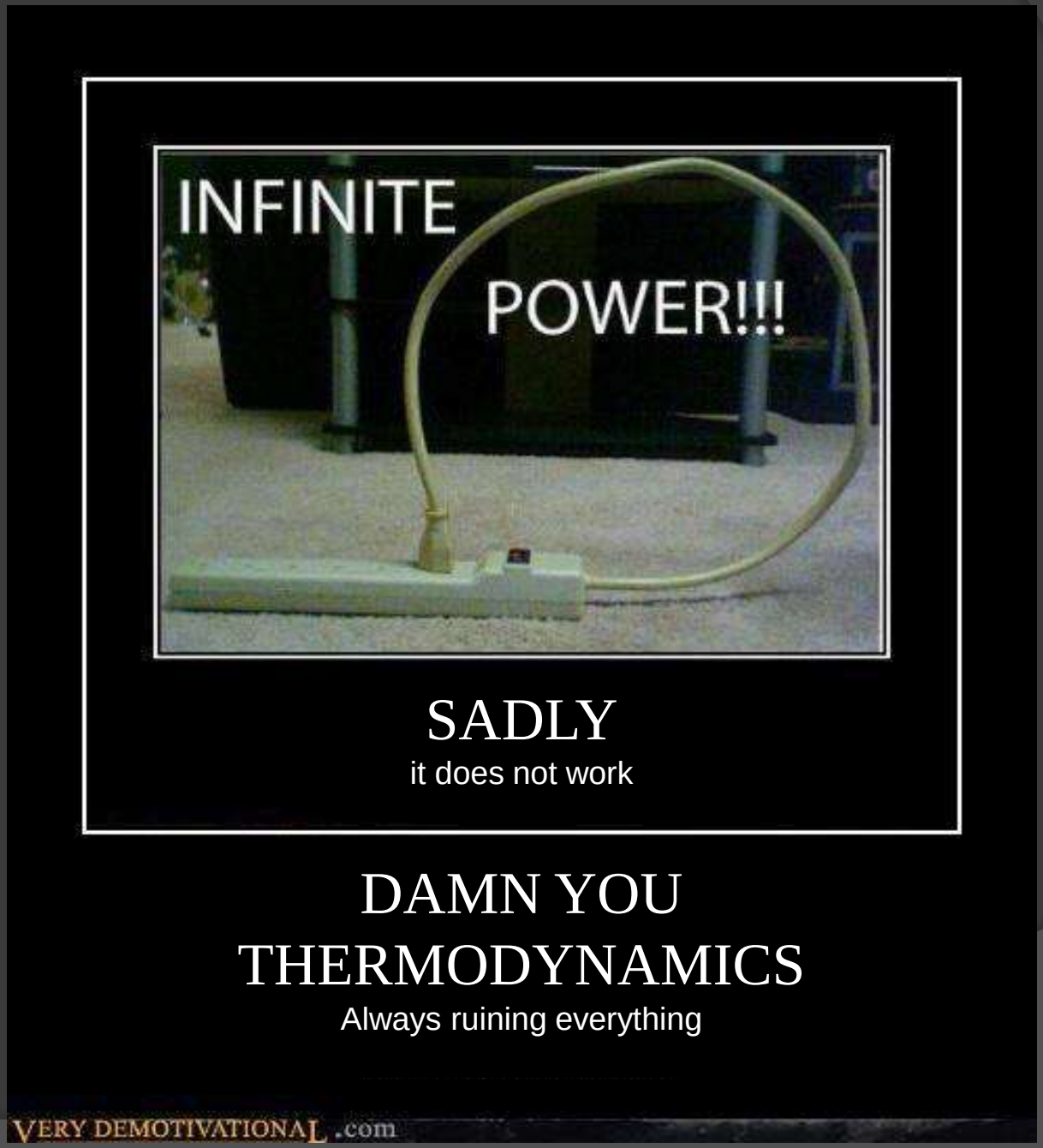
Estimated U.S. Energy Consumption in 2016: 97.3 Quads

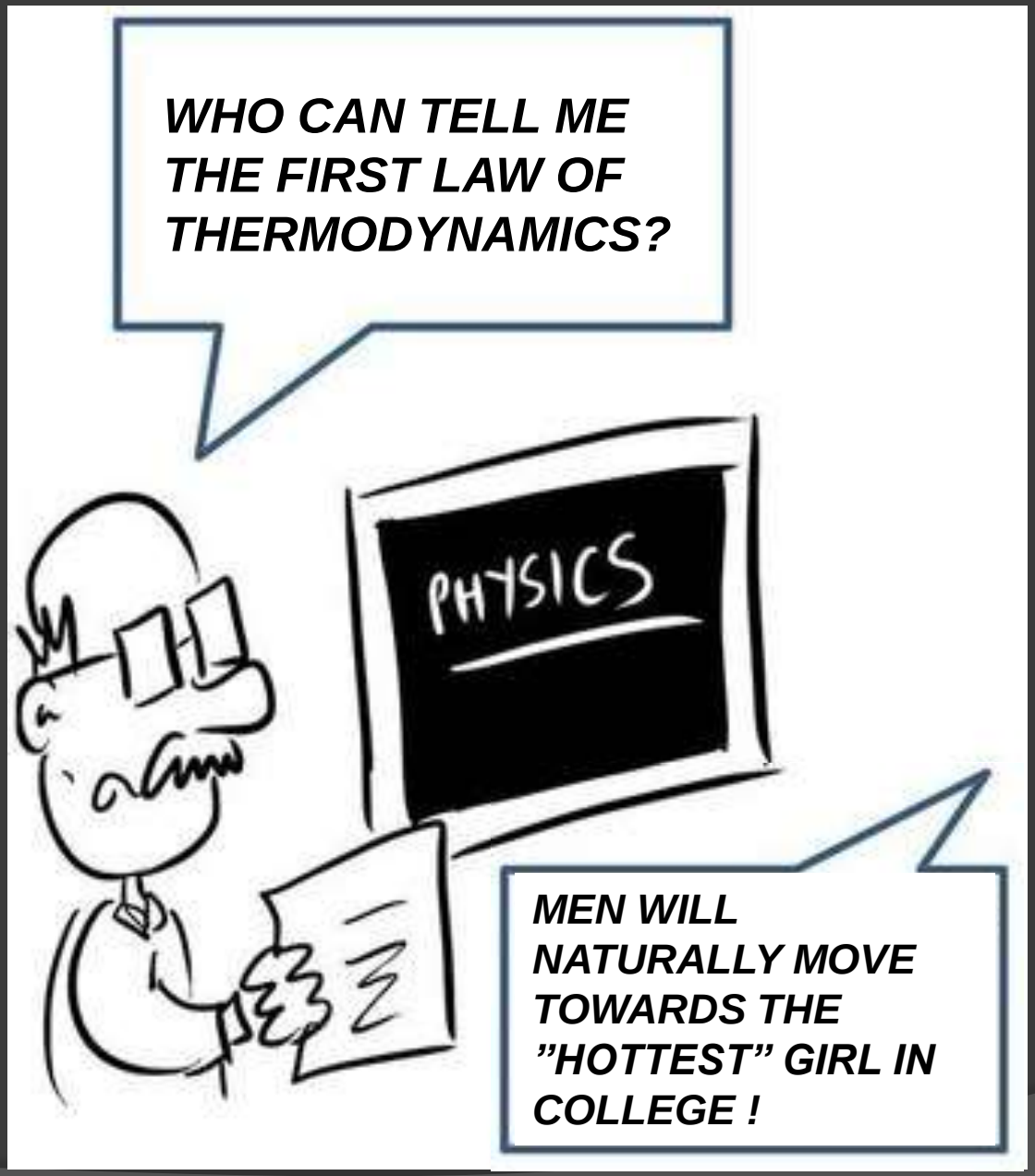


Source: LLNL March, 2017. Data is based on DOE/EIA MER (2016). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527



Brockway, et al, Understanding China's past and future energy demand: An exergy efficiency and decomposition analysis. Applied Energy, October 2015


INFINITE
POWER!!!
SADLY
it does not work
DAMN YOU
THERMODYNAMICS
Always ruining everything
VERY DEMOTIVATIONAL .com



Zeroth Law:
You must play the game

First Law:
You can't win

Second Law:
You can't even break even

Third Law:
You can't quit the game

So…..we need more SCIENCE !

Building Energy Flow-paths

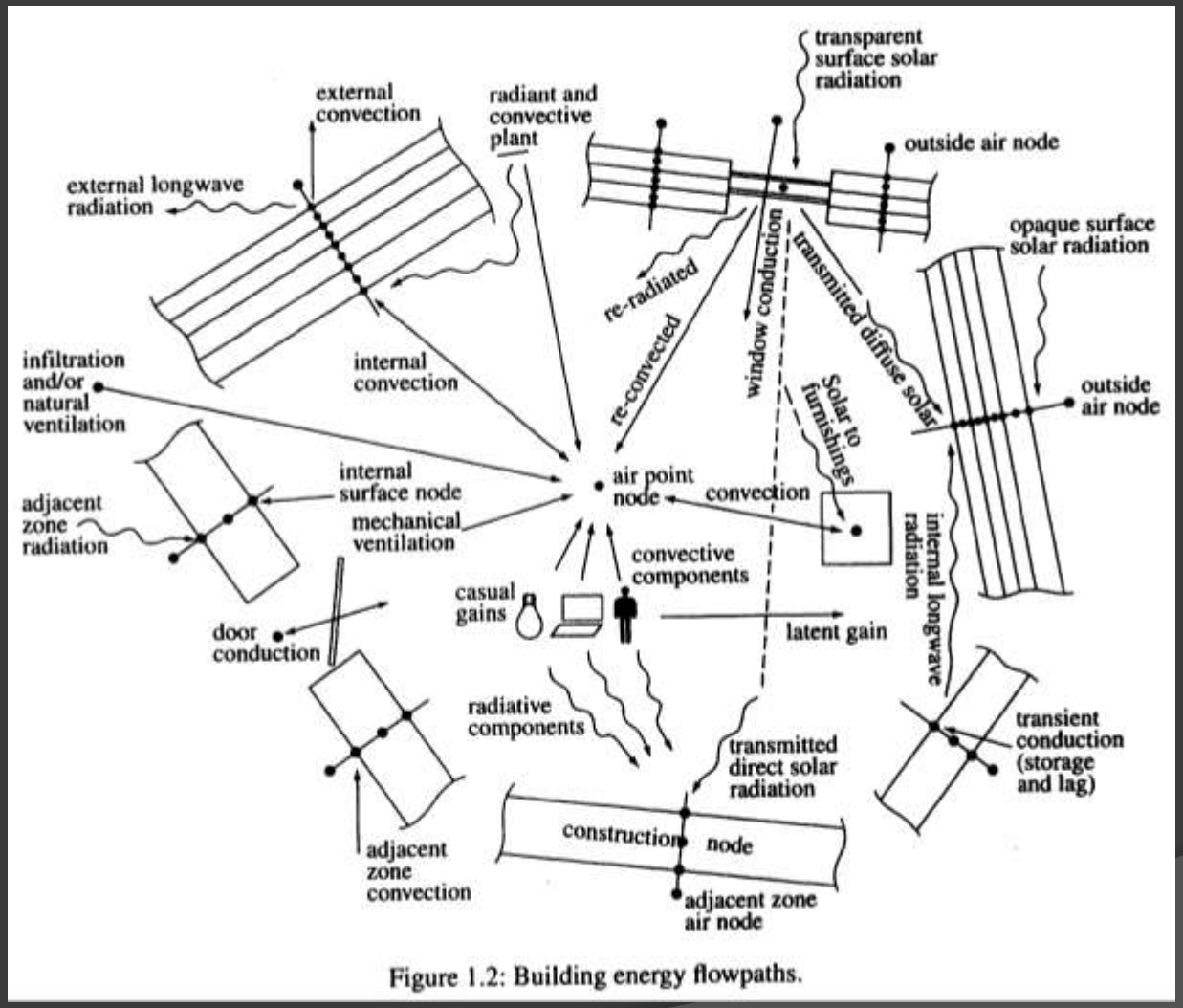
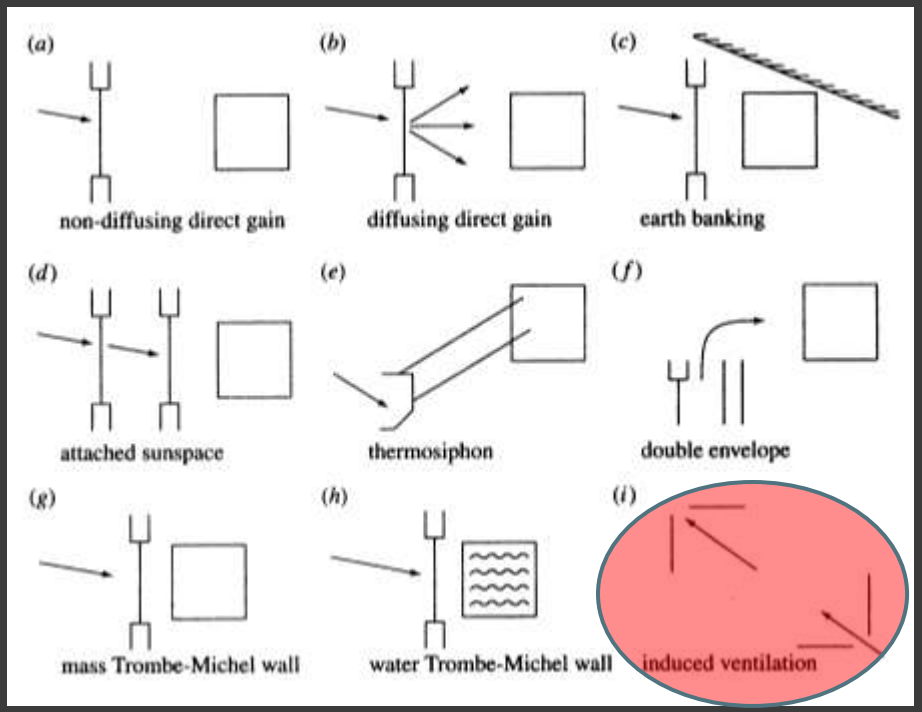


Figure 1.2: Building energy flowpaths.

Clarke, 1985: Energy Simulation in Building Design

Passive Solar Elements



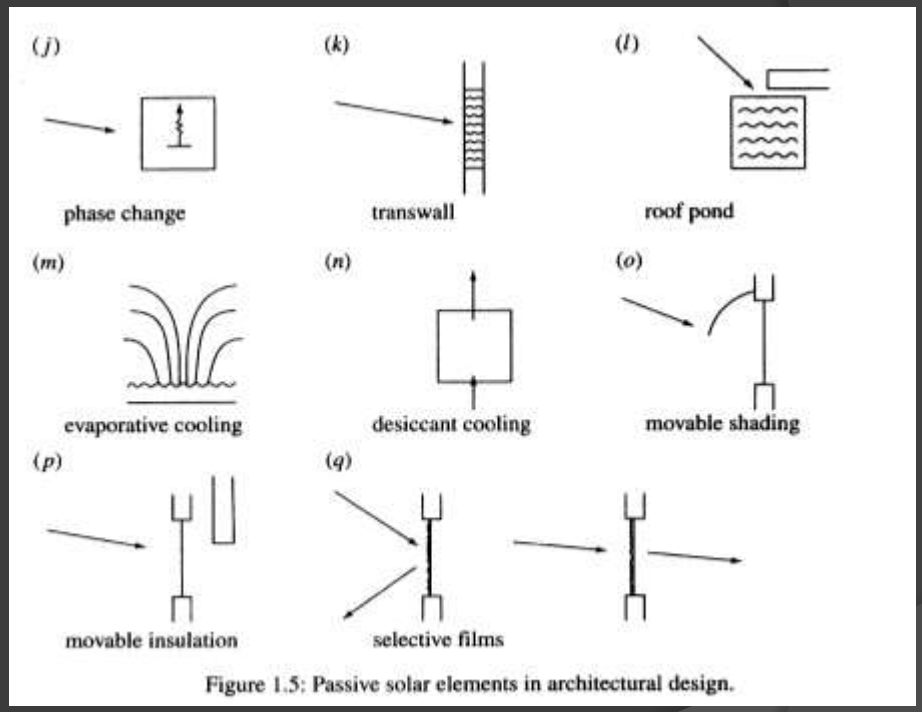
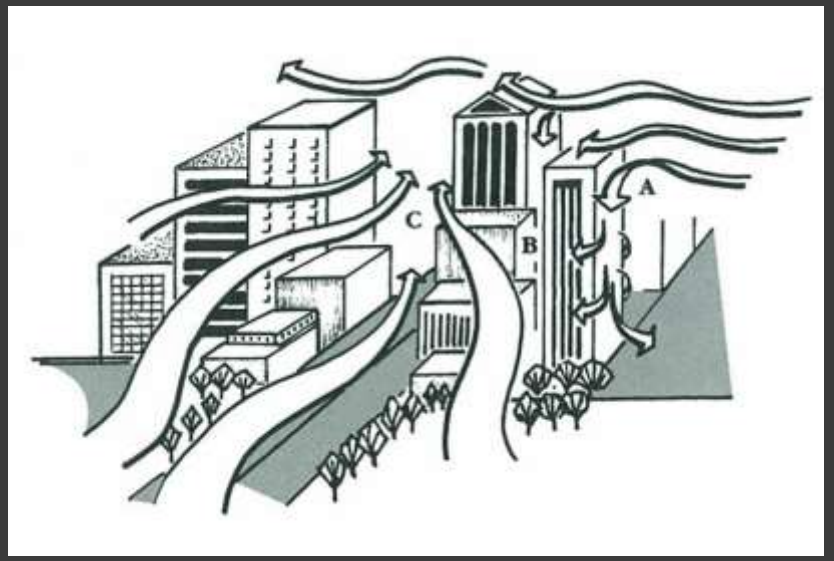
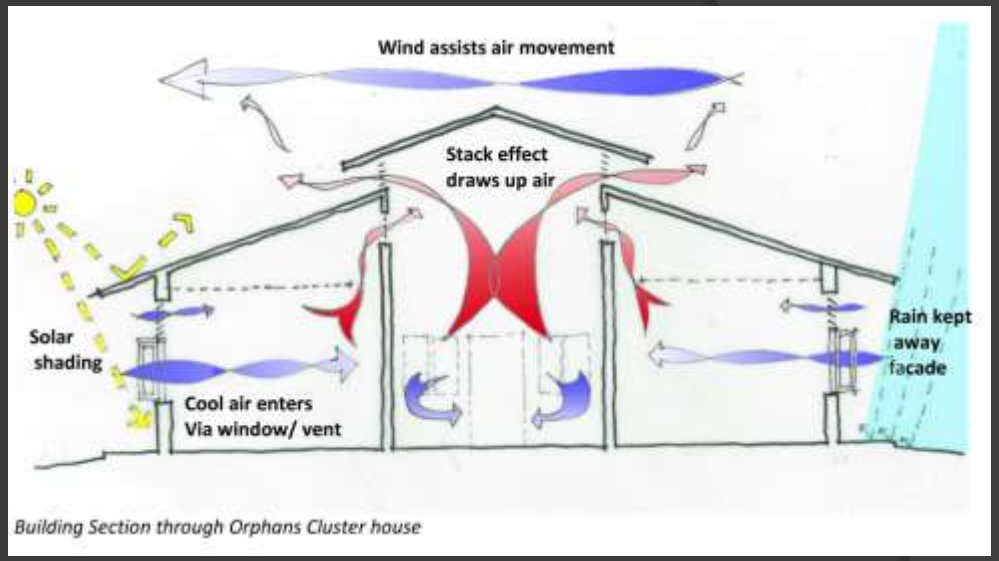


Figure 1.5: Passive solar elements in architectural design.

Clarke J, 1985: Energy Simulation in Building Design

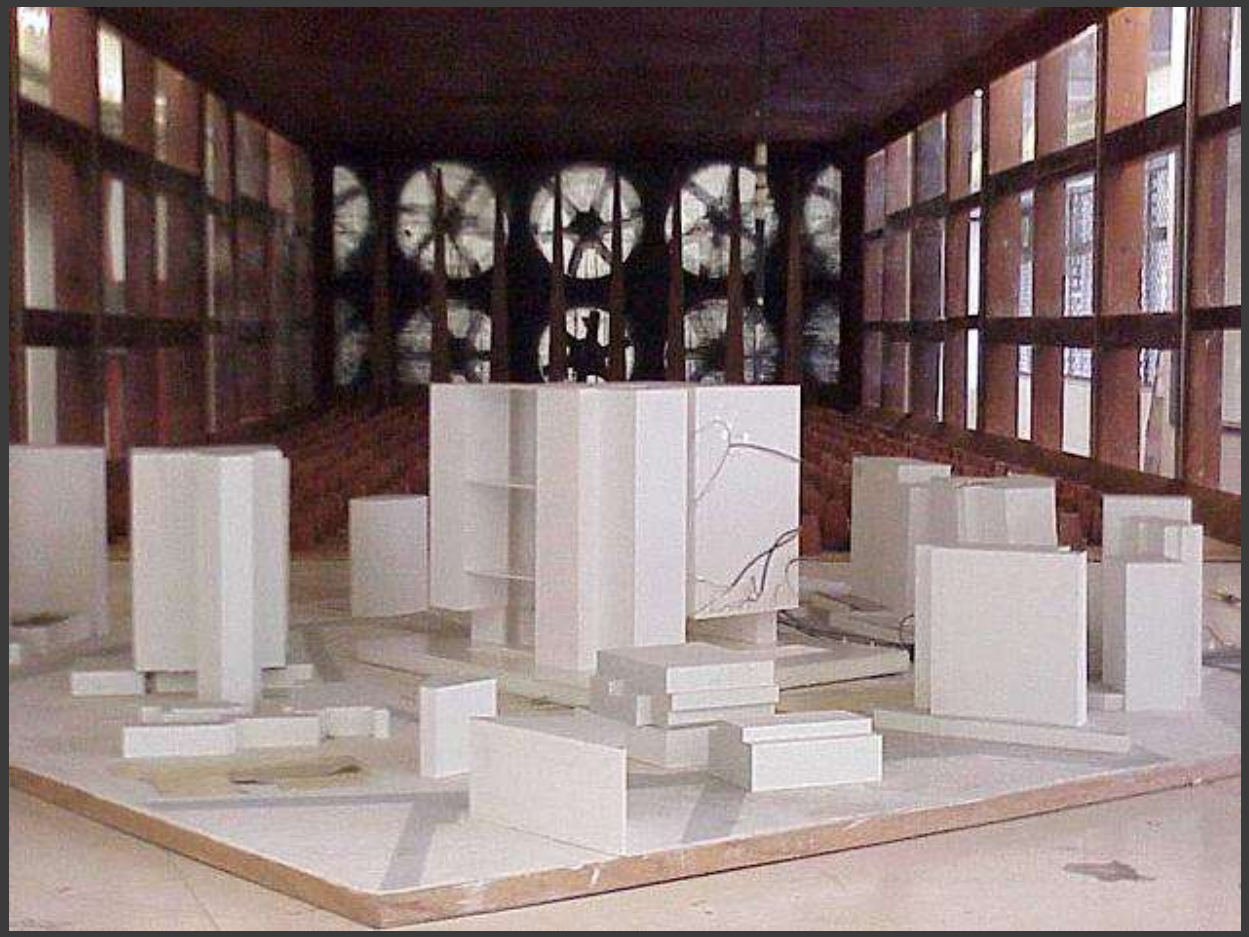


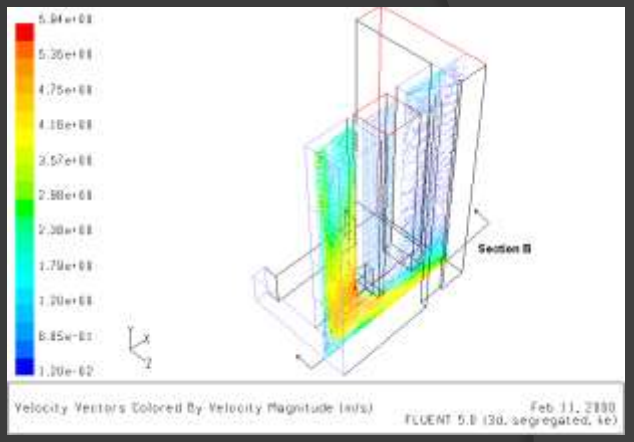


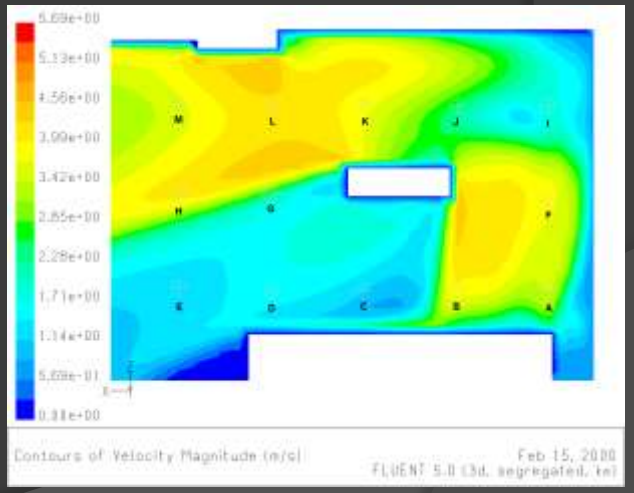
Building Section through Orphans Cluster house

Magic Arrows

Air Flow Modeling

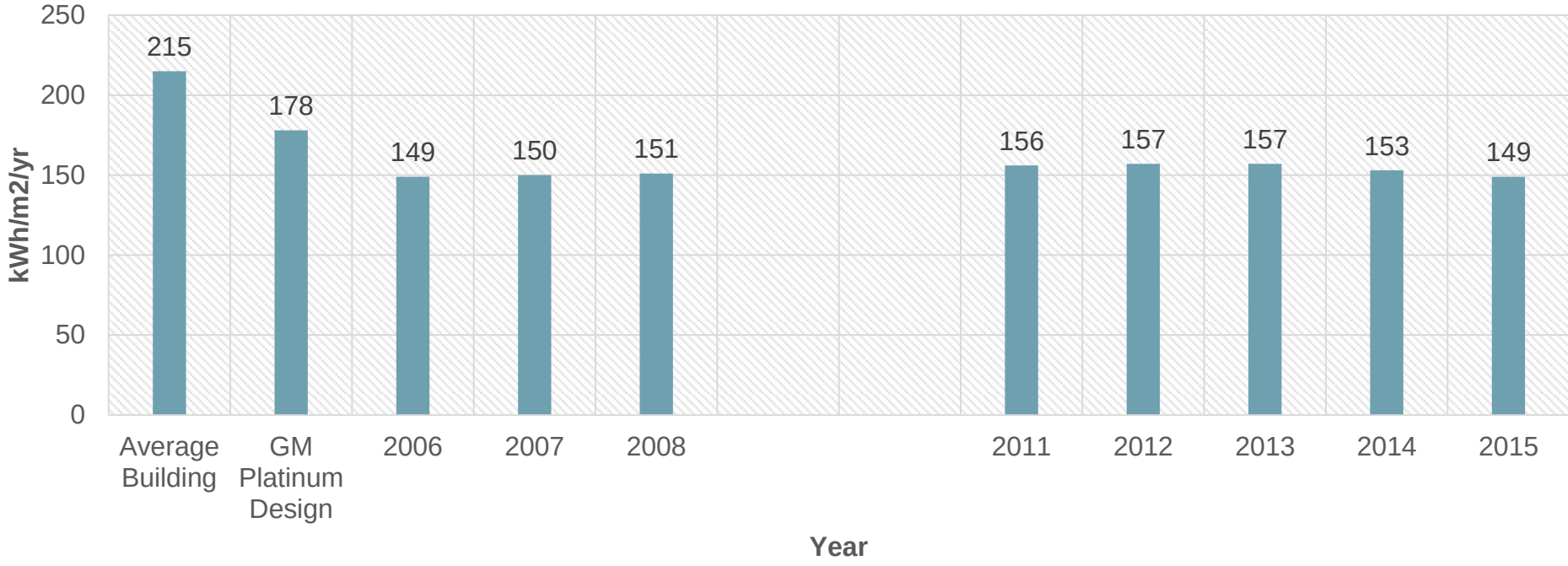




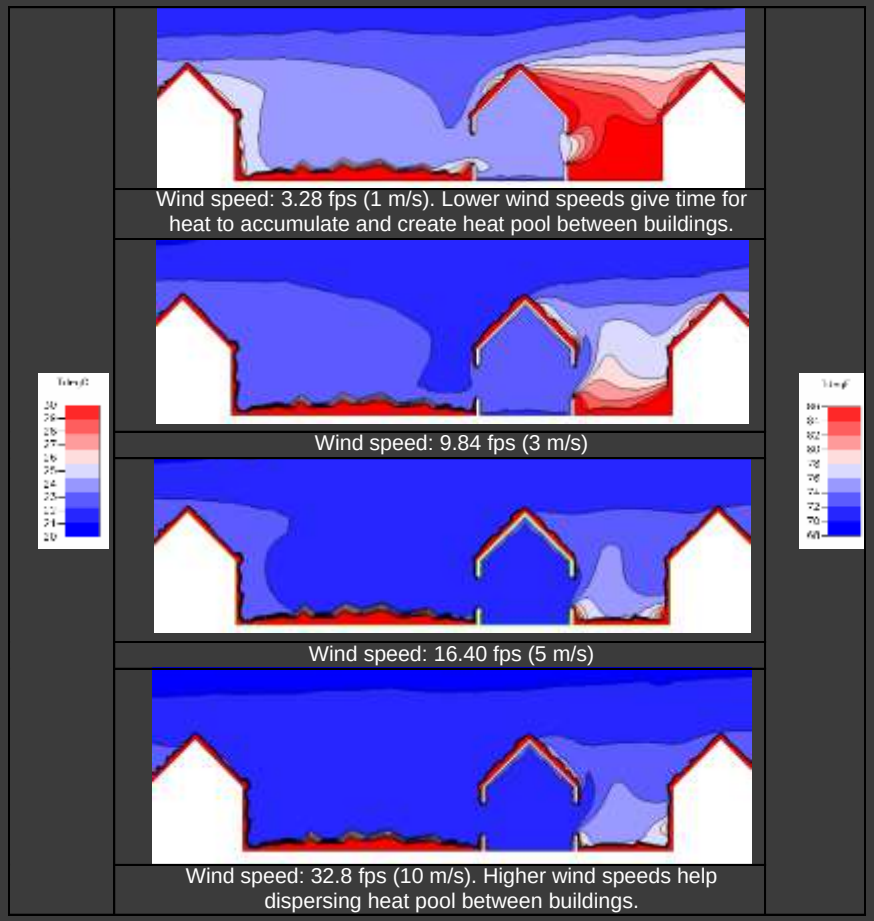


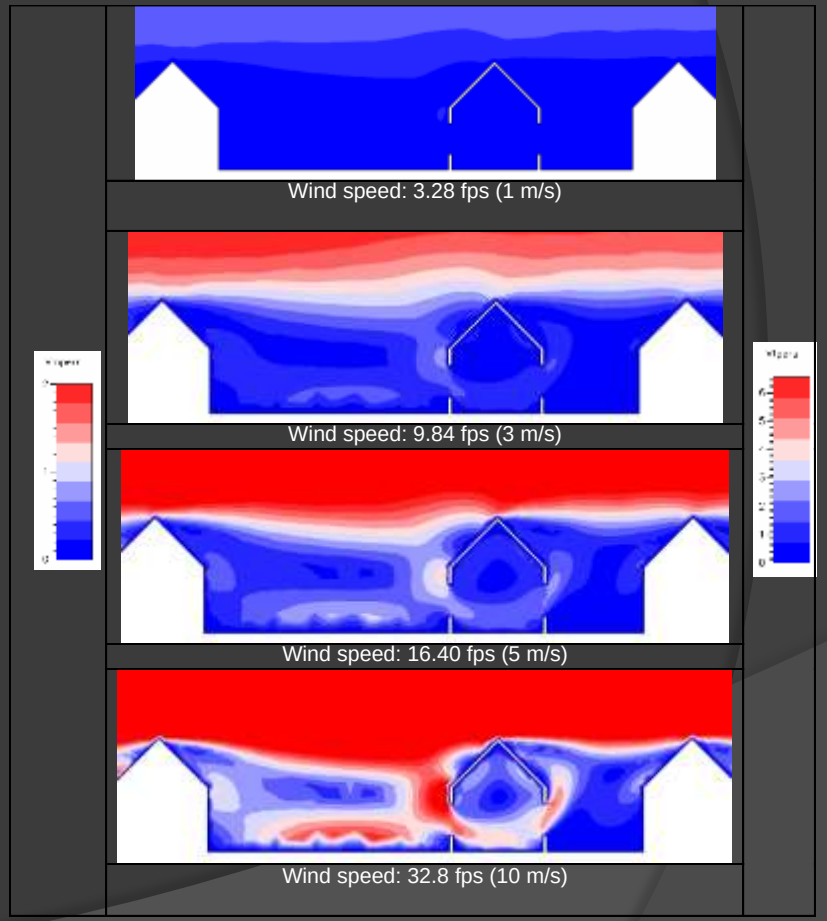
Wind tunnel experiment to establish the boundary conditions for CFD computational analysis

National Library Singapore

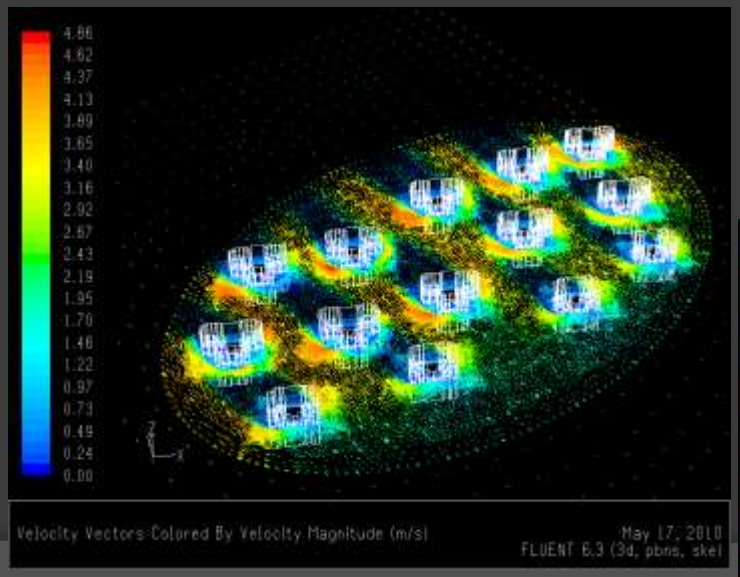


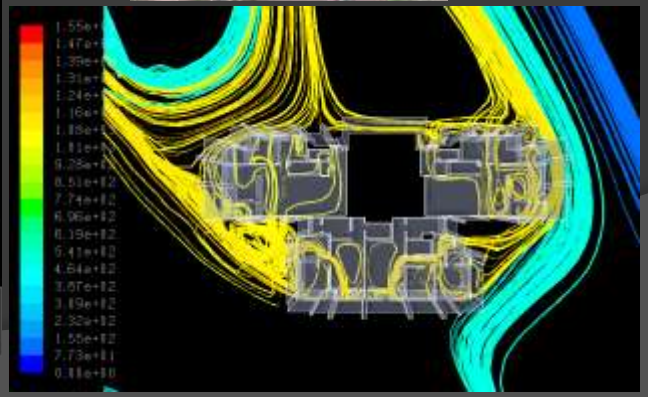
Concurrent Temperature and Air Velocity Profiles Outside and Inside Building

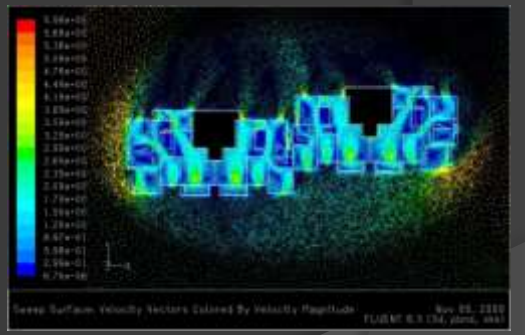


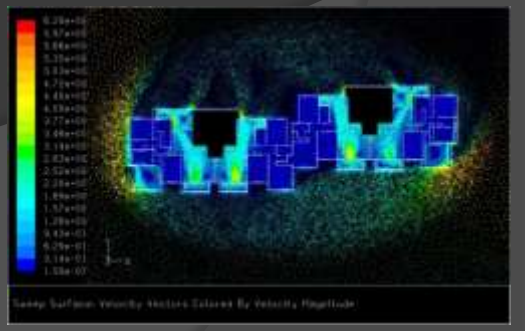


Sustainable Urban Development - Tianjin Eco-City









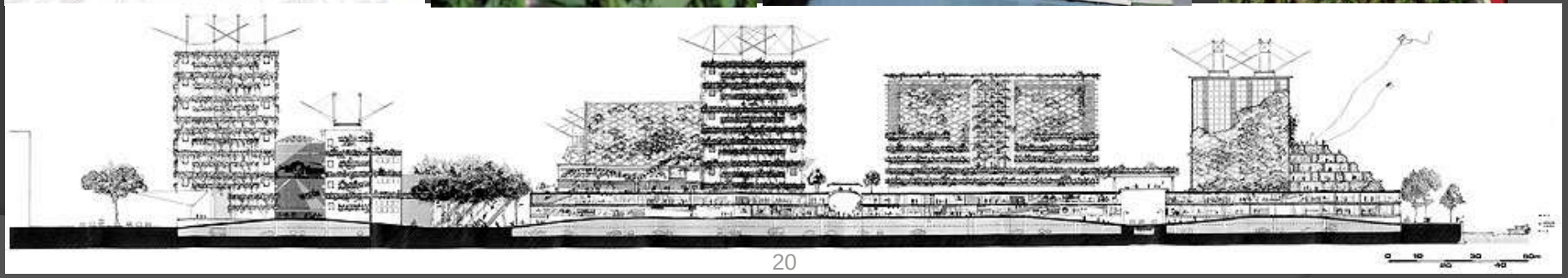
Technology (alone) is not the answer.....

Tropical City Concept
Kampong Bugis Dev't Guide Plan Proposal 1989







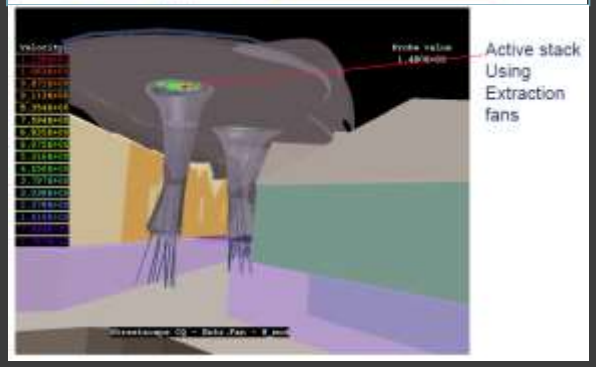
Tropical High-rise

Bio-Climatic Skyscraper – TRHY

Pinnacle@Duxton – ARC Studio A&U

Pinnacle@Duxton - WOHA

“Urban Shades” - Clarke Quay



Sustainability

Singapore's Energy Policy

Energy Market Authority
Smart Energy, Sustainable Future

Challenges

Resource & alternative energy disadvantaged

Energy importer and price taker

Small, urbanised environment poses constraints on fuel sources we can use

Our Approach

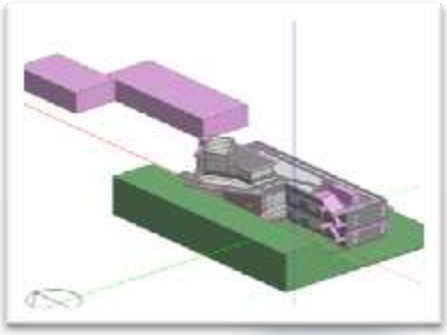
God is in the details?

The devil is in the details?

An ***n-gram*** is a contiguous sequence of *n* items from a given sequence of text or speech [computational linguistics and probability]

http://grammarist.com/wp-content/uploads/2014/09/details.jpg

Life-cycle Process



BUILDING DELIVERY PROCESS

Design → Construction

Codes & Standards

Evaluation, Measurem

TBP Design and Procurement

Structural System
Envelope System
Interior System
Mech & Elec Systems
External/Landscape

Total Building Performance Mandates

- Spatial
- Thermal
- Indoor Air Quality
- Visual
- Acoustical
- Building Integrity

Physiological
Psychological
Sociological
Economical

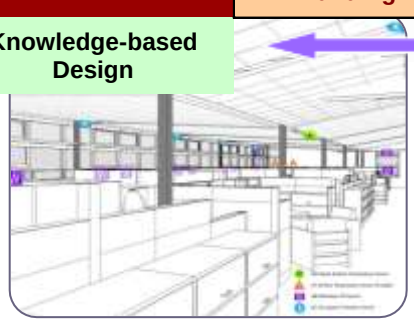
Framework ensures comprehensive and integrative design consideration for high performance and sustainable solutions

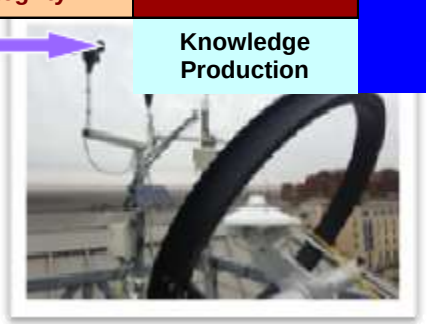
Diagnostic methodology for measuring building performance, evaluating impacts and establishing benchmarks

Knowledge-based Design

Knowledge Production

TBP Commissioning and POE

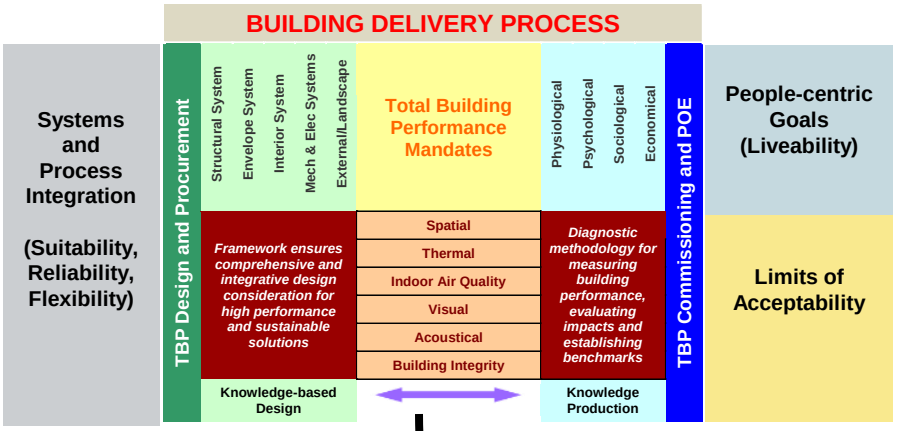




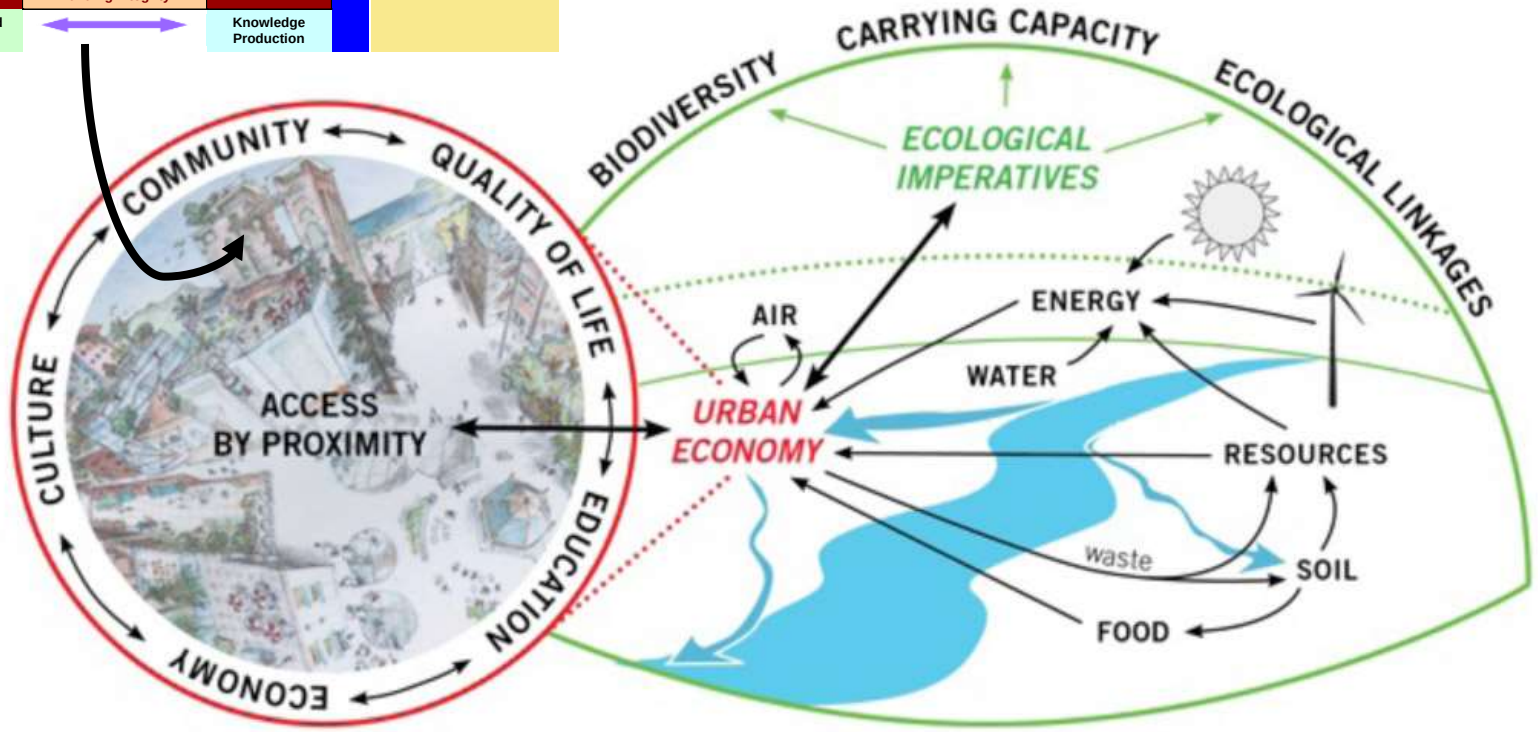
Occupant Comfort, Health, Well-being

Indoor – Outdoor Environmental Interaction

Total Building Performance



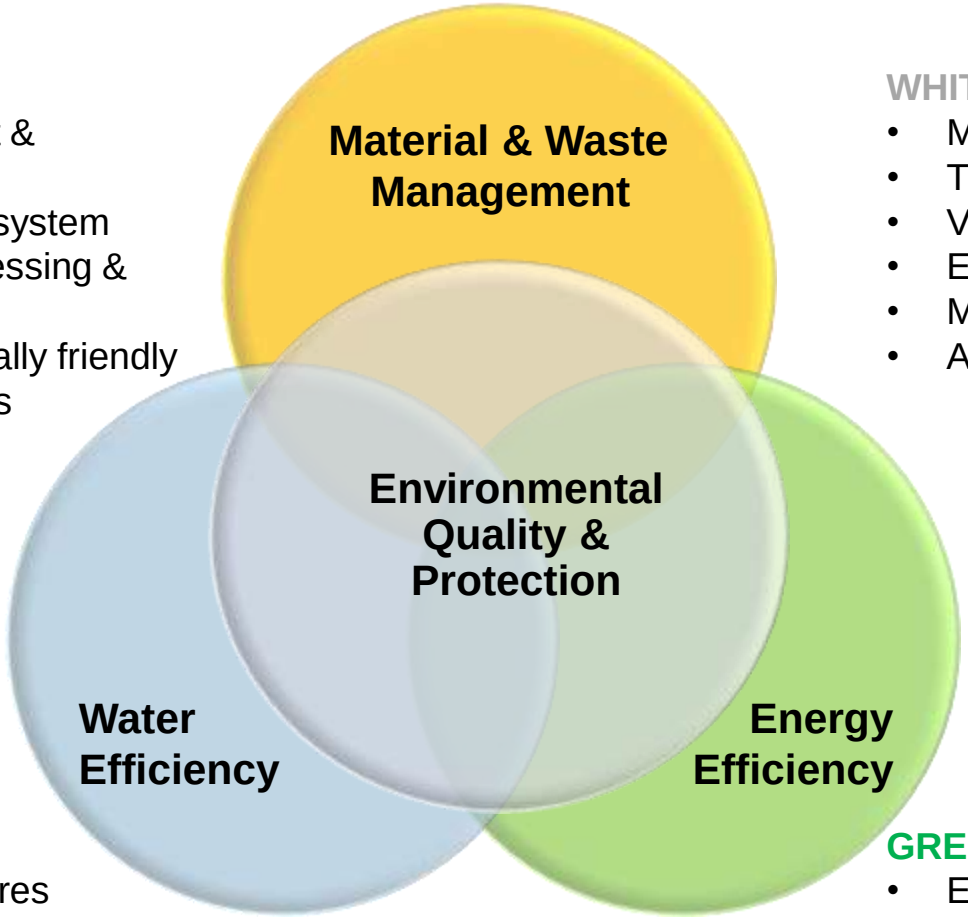
Total Environmental Performance



http://ecocitizenworldmap.org/fr/about/the-project/

HOLISTIC APPROACH TO ENVIRONMENTAL SUSTAINABILITY

BROWN STRATEGIES
- Waste management & segregation
- Waste conveyance system
- On-site refuse processing & composting
- Use of environmentally friendly or recycled materials



WHITE STRATEGIES
- Micro climate management
- Thermal comfort
- Ventilation
- Eco biodiverse habitat
- Minimize site disturbance
- Alternative transportation

BLUE STRATEGIES
- Water efficient features
- Storm water management
- Rainwater harvesting
- Grey water recycling

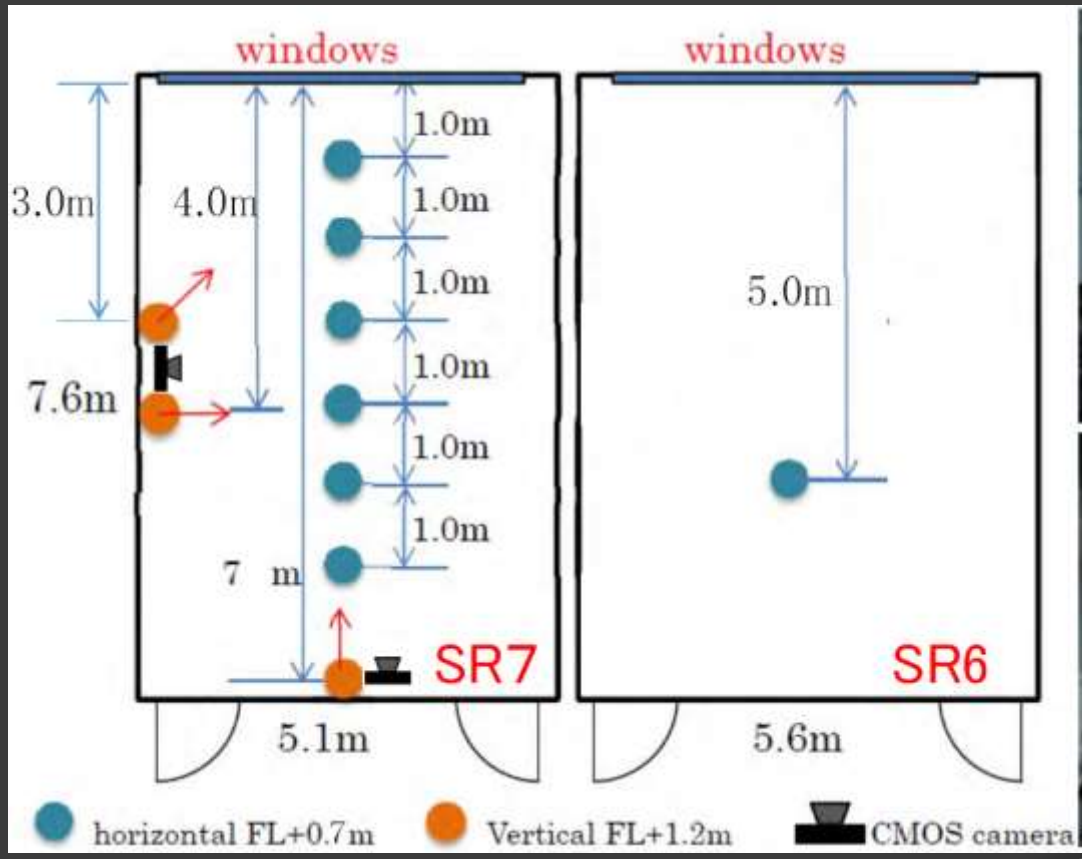
GREEN STRATEGIES
- Energy efficient infrastructure
- & public amenities
- On-site energy generation
- Use of renewal energy
- District cooling plant
- Hybrid ACMV system

Net-Zero Energy Building in the Tropics

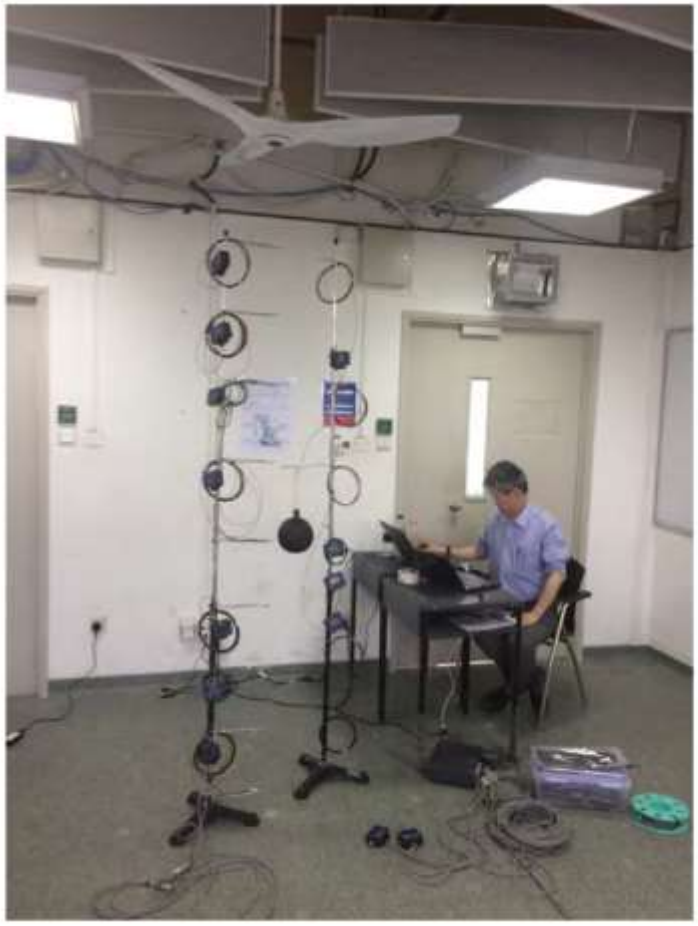
“Walk the Talk”

SDE 4 – Under Construction

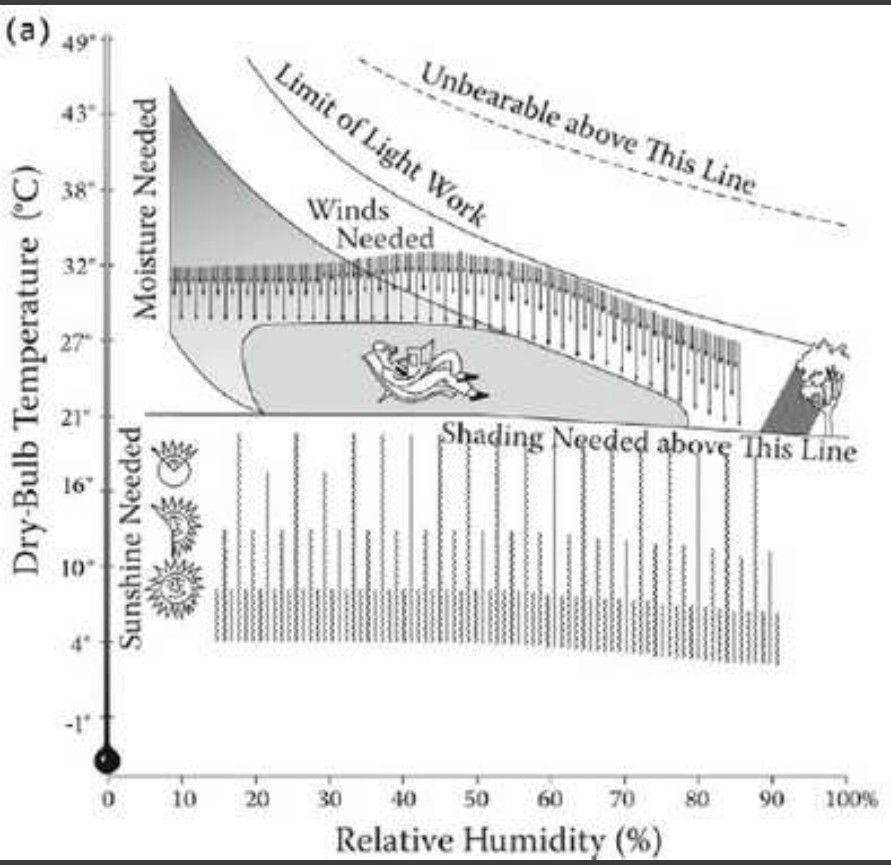
SDE 4 – Hybrid System
Daylight Measurement

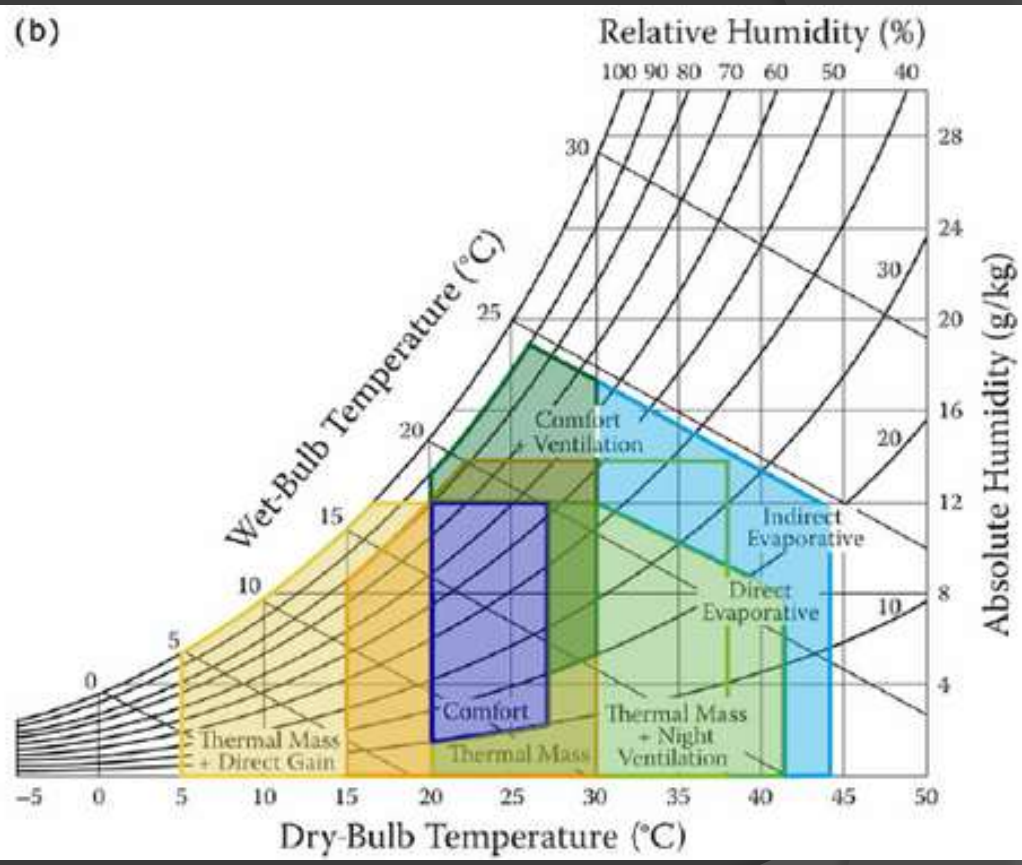


SDE 4 – Hybrid System
Thermal Measurement



Human Centric Design





Olgyay's bioclimatic chart, adapted from (Olgyay 1963).

Givoni's building bioclimatic chart, adapted from (La Roche 2012)

Schiavon, et al (2014) Web application for thermal comfort visualization and calculation according to ASHRAE Standard 55 . Building Simulation

SCIENCE

Chilly at Work? Office Formula Was Devised for Men

By PAM BELLUCK AUG. 3, 2015

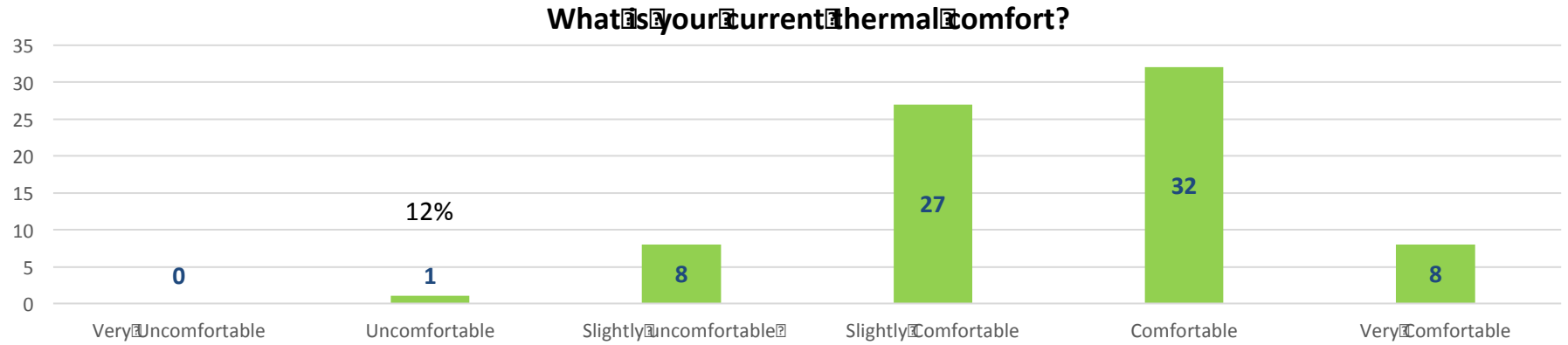
Molly Mahannah wears a sweatshirt and blanket at w
Chris Machian for The New York Times

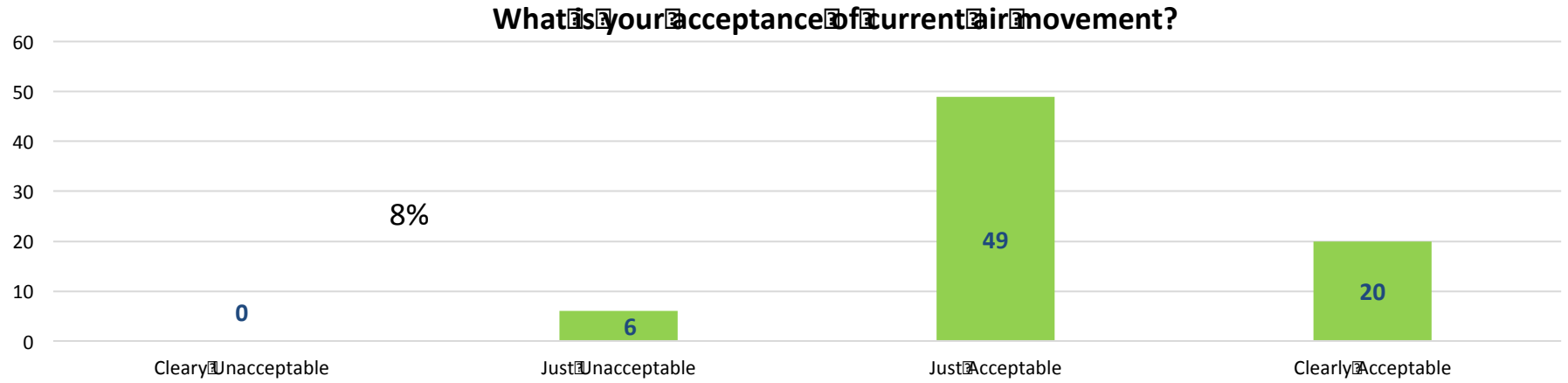
Confirmed: Men Are to Blame for Your Freezing Cold Office

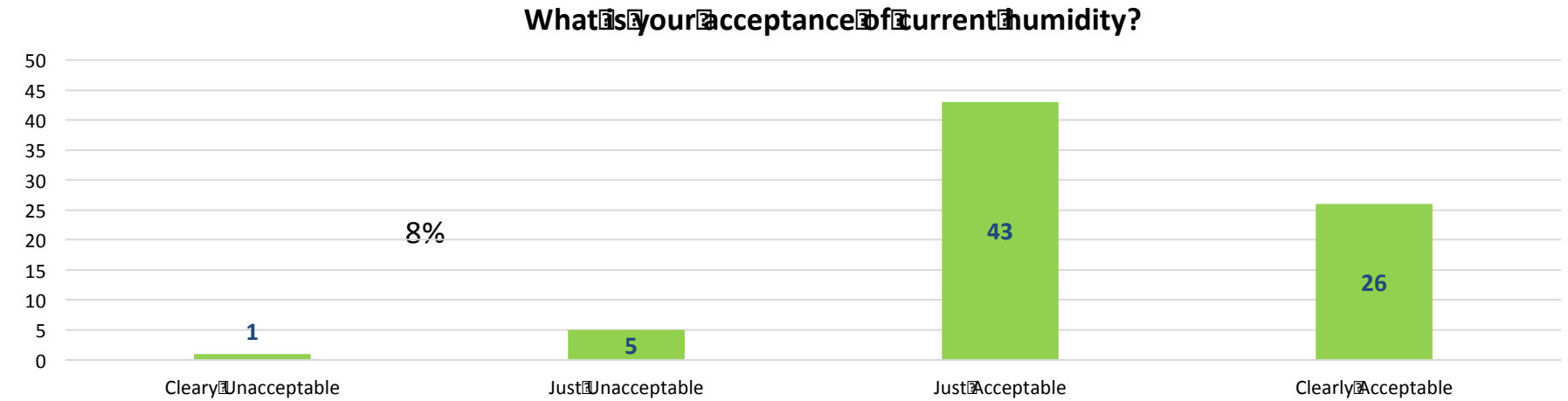
Joanna Rothkopf
Filed to: THE CLEAVAGE 8/03/15 1:40pm

27,212 14

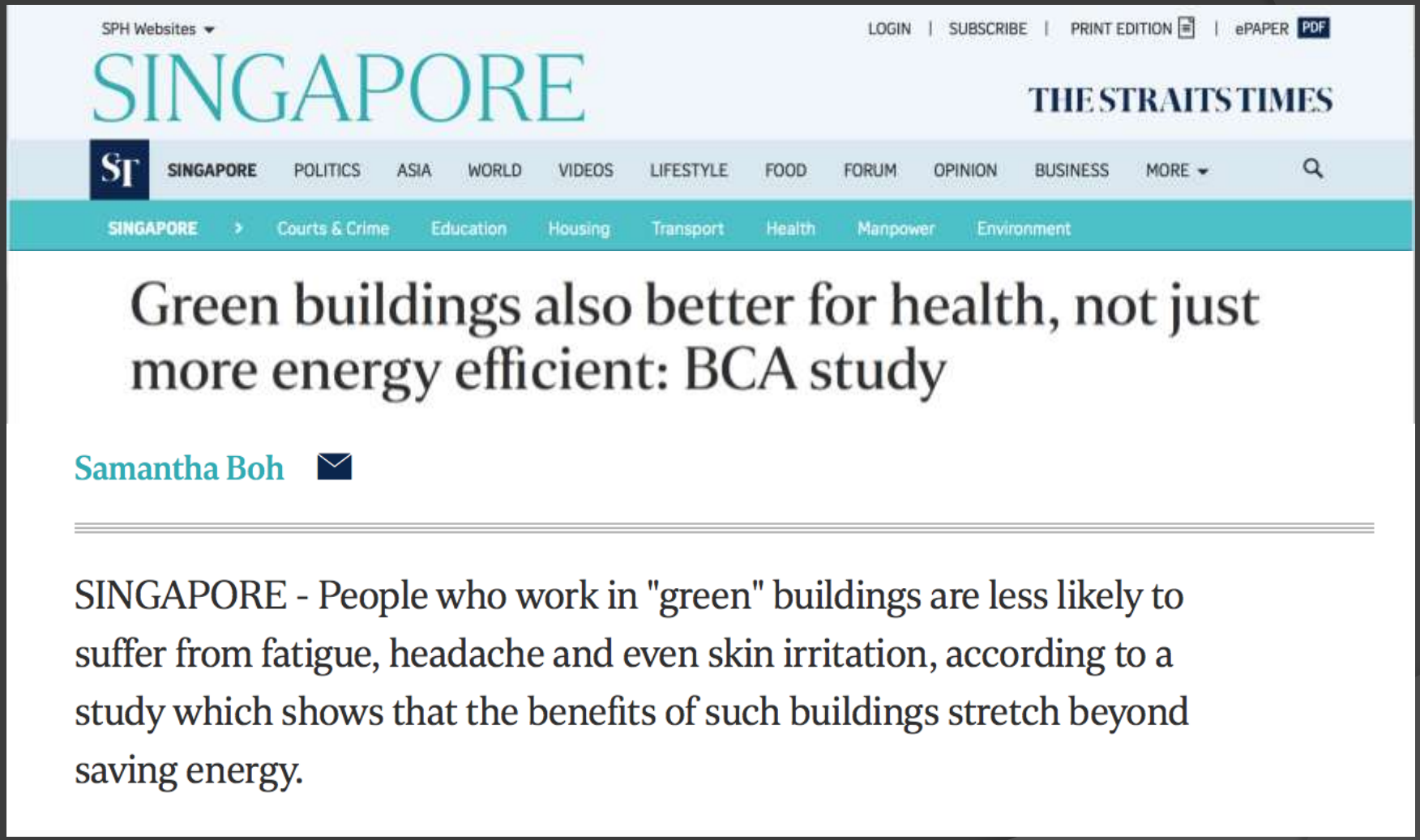
http://blog.gridium.com/3241/are-your-set-points-sexist/


What is your current thermal comfort?
35
30
25
20
15
10
5
0
12%
0
1
8
27
32
8
Very Uncomfortable
Uncomfortable
Slightly uncomfortable
Slightly Comfortable
Comfortable
Very Comfortable


What is your acceptance of current air movement?
60
50
40
30
20
10
0
8%
0
6
49
20
Cleary Unacceptable
Just Unacceptable
Just Acceptable
Clearly Acceptable


What is your acceptance of current humidity?
50
45
40
35
30
25
20
15
10
5
0
8%
1
5
43
26
Cleary Unacceptable
Just Unacceptable
Just Acceptable
Clearly Acceptable

What's next?



Study conducted by BCA and NUS from Jan 2014 for 3.5 years

WELL LIVING LAB™

WELL LIVING LAB

The first lab exclusively committed to researching the real-world impact of the indoor environment on human health

To deepen our understanding about the indoor environment's affect on human health and well-being, Delos and Mayo Clinic have collaborated to create the Well Living Lab™.

AIR

WATER

NOURISHMENT

LIGHT

FITNESS

COMFORT

MIND


OUTATIME
THE FUTURE IS NOW!