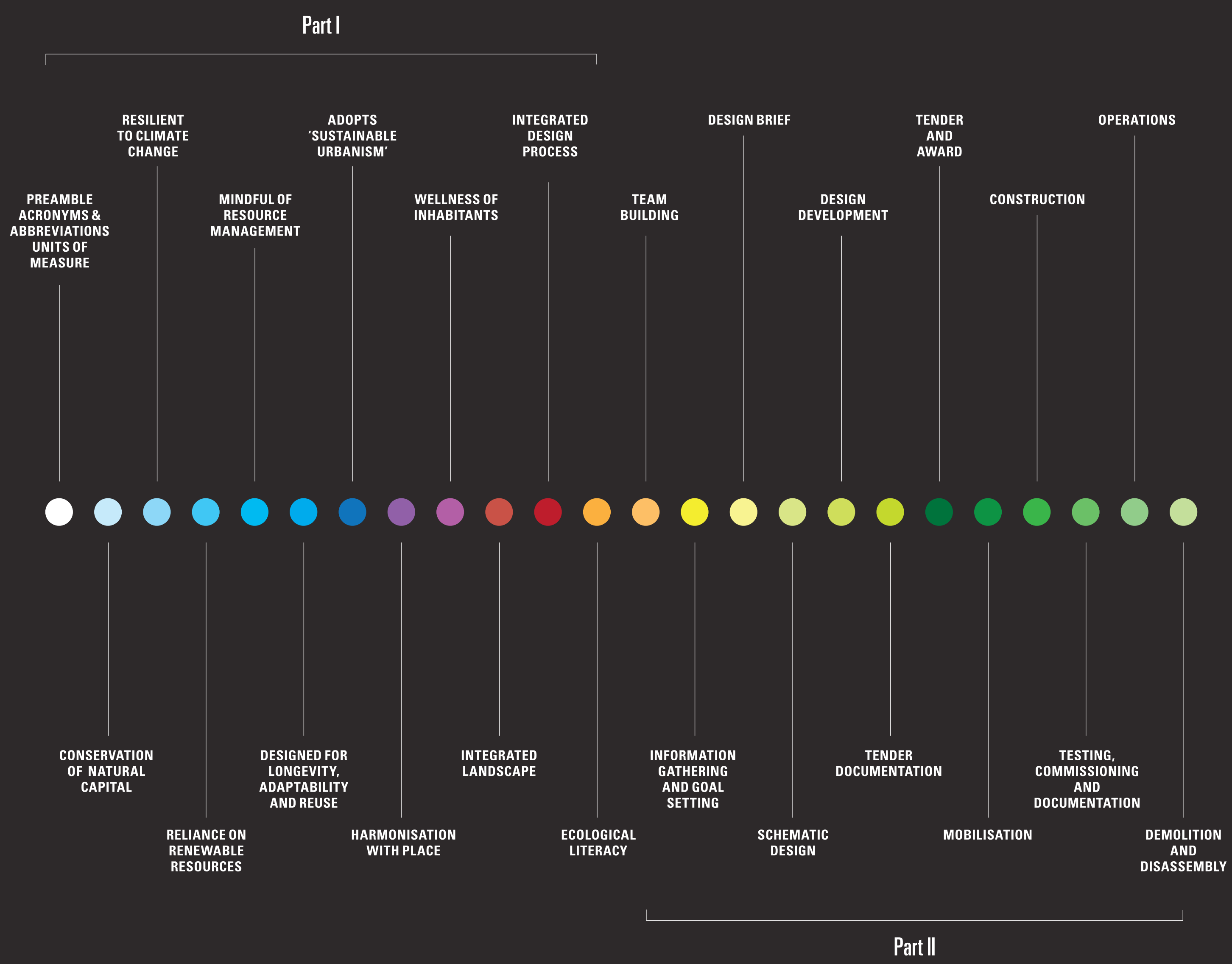

ATTRIBUTES OF A SUSTAINABLE BUILT ENVIRONMENT

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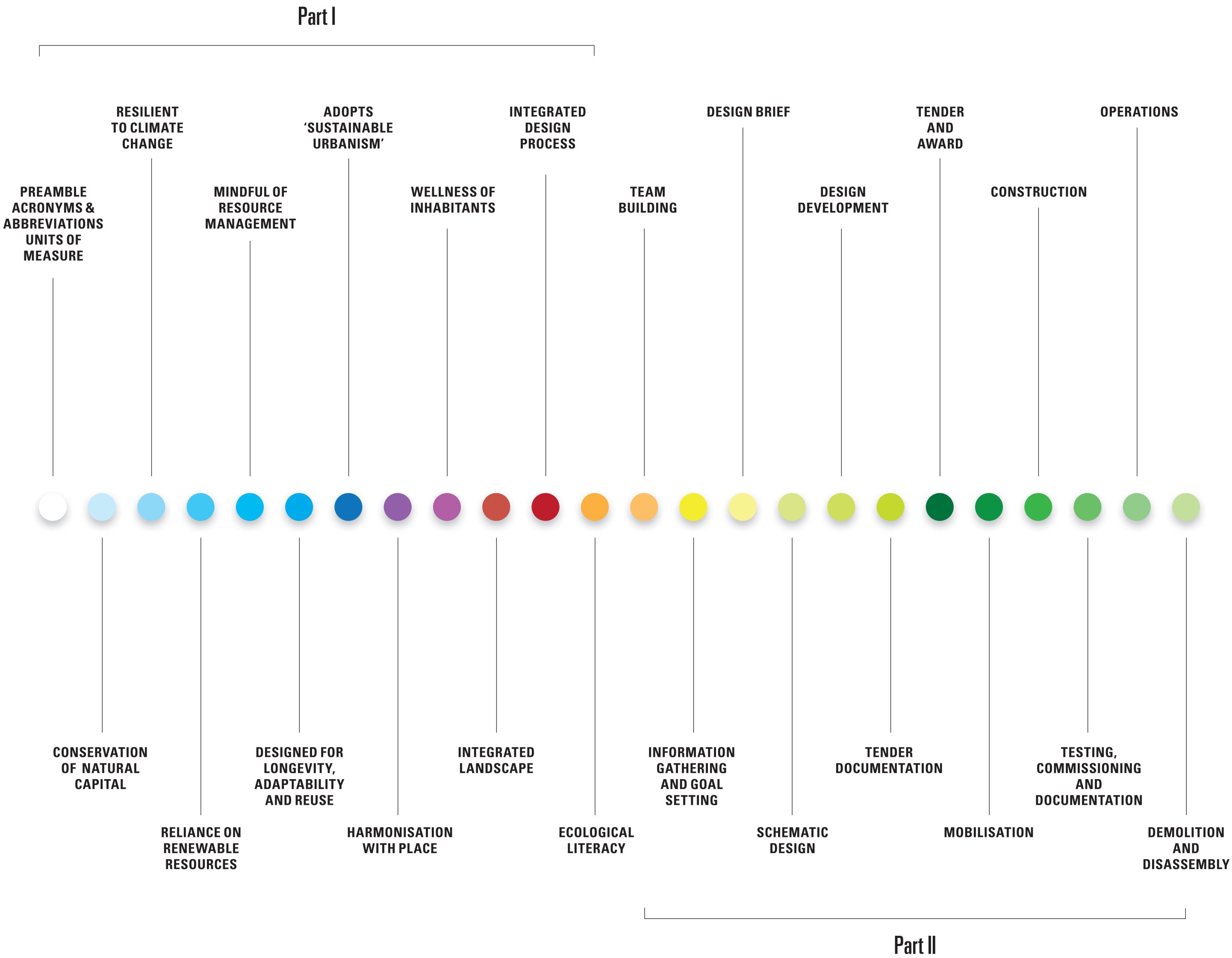

ATTRIBUTES OF A SUSTAINABLE BUILT ENVIRONMENT

PRESS

Contents

Acronyms & Abbreviations

ABC	Active, Beautiful and Clean
BCA	Building and Construction Authority (Singapore)
CFC	Chlorofluorocarbons
CFD	Computational Fluid Dynamic
CO_2	Carbon dioxide
EIA	Environmental impact assessment
ESD	Ecologically Sustainable Development
GAI	Green area index
GHG	Greenhouse gas
GnP	Greenery provision
GPR	Green plot ratio
GWP	Global warming potential
HDB	Housing Development Board (Singapore)
HVAC	Heating, Ventalilation and Air-Conditioning
IAQ	Indoor air quality
IDP	Integrated design process
IEQ	Indoor environmental quality
IMCSD	Inter-Ministerial Committee for Sustainable Development (Singapore)
IPCC	Intergovernmental Panel on Climate Change
LAI	Leaf area index
LCA	Life cycle assessment
LULCC	Land use and land cover change
MEP	Mechanical, electrical and plumbing
NEA	National Environment Agency (Singapore)
NParks	National Parks Board (Singapore)
ODP	Ozone depletion potential
PM	Particulate matter
PMV	Predicted mean vote
PPD	Percentage of persons dissatisfied
PUB	PUB, The Water Agency (Singapore)
RE	Renewable Energy
ROI	Return on investment
SO_2	Sulphur dioxide
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle kilometres travelled
VOC	Volatile Organic Compounds

Units of Measure

°C	Degree Celsius
gha	Global hectare[2]
ha	Hectare
kg	Kilogram
km	Kilometre
kWh	Kilowatt hour
m^2	Square metre
m^3	Cubic metre
MJ	Megajoule
t	Metric ton
W	Watt

[2] A global hectare is a hectare with world-average biological productivity.

Preamble

This policy paper, developed by the Singapore Institute of Architects, describes a sustainable built environment, framed as a set of attributes relating to the design, construction, operation and disassembly of buildings, neighbourhoods and cities.

Implicit in these attributes is a multi-disciplinary, multi-stakeholder, whole-life perspective, reflecting the complexities of how the built environment is managed from concept to end-of-life.

This paper is presented in two parts.

PART I

Definitions and Descriptors

Part 1, **Definitions and Descriptors**, is premised on scientific findings that make the case that buildings and settlements – directly or indirectly – impact our planet by consuming resources, emitting waste and displacing natural habitats. Evidence of this has been documented by the United Nations Intergovernmental Panel on Climate Change (IPCC) and referred to by governments, notably the Singapore Inter-Ministerial Committee for Sustainable Development (IMCSD). The attributes listed in this part are drawn from numerous expert opinions; they describe, in effect, a global consensus on how a sustainable built environment should behave in a world of limited resources.

PART II

Process Considerations

Part 2, **Process Considerations**, describes potential actions by a project team that support the attributes described in Part 1. This list of prompts is organised around the stages of a typical design-construction process. This part of the policy paper has been crafted by experienced practitioners in the Singapore building industry; it represents a real world outlook of what should be considered by a project team, and how it might be positioned within process framework that the industry is familiar with.

1 Metrics are a means of quantifying performance

There are several qualifiers to the list of attributes in its present form:

1. The role of the architect, and the importance of design as an integrating framework, is implicit in all attributes even if, in some instances, the architect may not drive the process.

2. Some attributes speak of impacts that are quantifiable for which there are known metrics[1] (for instance, carbon footprint); others do not offer ease-of-quantification yet. Both are, in our view, equally important. We maintain that for an environment to be valued, it must engage emotions and senses in addition to managing resources, waste and emissions.

3. Many developments will not address all attributes equally. This paper offers a framework for what to consider at the drawing board, offering us a means of comparing one development with another.

4. The Institute acknowledges that in time, as our knowledge deepens and perceptions evolve, the list of attributes will change.

It is our desire that this paper contribute to the dialogue on sustainability already taking place in Singapore. This dialogue, thus far, has evolved rapidly in recent years, led by policy and marketplace, driven by successive Building and Construction Authority Green Building Master Plans and the Inter-Ministerial Sustainability Blueprint of 2009. In returning to the question, 'what is a sustainable built environment?' we seek to further articulate the desired future state, one that is consistent with what we know today of how the built environment impacts the well-being of our nation and planet.

The aim of this paper is to state what we – the Institute – know at present and, in that context, argue for what we believe to be important. Looking ahead it will offer the Institute a framework for collaboration with policymakers, experts and other stakeholders of the built environment in addressing future design and implementation.

PART I

Definitions and Descriptors

Conservation of Natural Capital
Resilient to Climate Change
Reliance on Renewable Resources
Mindful of Resource Management
Designed for Longevity, Adaptability and Reuse
Adopts 'Sustainable Urbanism'
Harmonisation with Place
Wellness of Inhabitants
'Integrated Landscape'
'Integrated Design Process'
Ecological Literacy

Conservation of Natural Capital

A sustainable built environment seeks to conserve its natural capital which encompasses natural resources and ecosystem services that sustain life.

1.1 OVERVIEW

Natural capital is the **biosphere's** capacity to maintain the **ecosystem services**. These services encompass "all the familiar resources used by humankind: water, minerals, oil, trees, fish, soil, air" and "living systems, which include grasslands, savannas, wetlands, estuaries, oceans, coral reefs, riparian corridors, tundras, and rainforests"[1]. Degradation of natural capital threatens an irreversible damage to the ecosystem services and a permanent loss of biodiversity. **Biodiversity** is defined as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems."[2]

The last five decades have seen an exponential rate of loss of planetary biodiversity. The Convention on Biological Diversity is a key international treaty that seeks to halt this trend. It argues the case for developing strategies for conserving biodiversity, sustaining its use, and ensuring the fair sharing of benefits from its use.[3]

1.2 IMPLICATIONS ON BUILT ENVIRONMENT

Development of the built environment at the expense of natural capital has both short term and long term consequences. To ensure that a development stays within resource constraints, the following options should be considered:

1.2.1 Impact avoidance

Impact avoidance might, for instance, oblige a team to seek out **greyfield** or **brownfield** sites as opposed to **greenfield** sites. Land that is ecologically sensitive, for instance, wetlands or mangroves, is avoided.

1.2.2 Judicious intervention

At the drawing board, ecological impact can be minimised through site selection, site planning, the careful procurement of raw building materials and products that do not compromise natural environments elsewhere. Where a building is sited close to ecologically sensitive land, a pre-design **environmental impact assessment (EIA)** helps assess risks and suggest ways of mitigating negative consequences resulting from the construction and/or operation of the development.

1.2.3 Strategic regeneration

On sites where an ecosystem has been damaged by prior activity, a development can restore the health of natural systems, adopting a **regenerative** approach. Sites that are, for instance, contaminated by landfills or industrial waste, can be cleansed and restored. Damaged habitats, such as mangrove colonies, can be regenerated and revitalised.

1.2.4 Injection of biodiversity

The introduction of **biodiversity** – the symbiotic relationships between plants and animals – into human settlements should be considered. The selection and placement of flora and fauna, for instance, into urban parks and green spaces can attract colonies of butterflies and birds, creating a viable, self-sustaining ecosystem.

1.3 SINGAPORE CONTEXT

Within Singapore's highly urbanised context there is conscious effort in policy and planning to retain and/or introduce biodiversity. Adding up all nature reserves and green spaces, for instance, inclusive of roadside greenery and park connectors, it appears that about half of the island is covered with greenery.[4] As the authority responsible for greenery and natural habitats, National Parks Board (NParks) has explicitly articulated the following actions[5] –

- → Implement species conservation and recovery programmes
- → Rehabilitate areas that have previously been degraded
- → Extend green corridors to counter fragmentation
- → Utilise parks for ex-situ conservation and to house or re-create ecosystems that have been lost

Singapore's ecological footprint – based on its demand on planetary ecosystems – was estimated at 4.51gha per person[6] in 2009, more than four times the world average[7]. Singapore's biocapacity, on the other hand, stands at 0.04gha, resulting in a self sufficiency rating of only 0.9%. Self-sufficiency rating is a measure of what percentage of footprint is supported by the biocapacity. Lacking a hinterland, Singapore's population consumes resources far greater than its land mass can support.

1.4 METRICS

1.4.1 Biocapacity[8]

Biocapacity refers to the capacity of the ecosystem to supply biological materials to support life and its potential to absorb waste, and the potential of terrestrial and aquatic areas to provide these services. Biocapacity is measured as global hectares (gha) per person.

1.4.2 Ecological footprint[9]

Ecological footprint is a measure of the earth's biocapacity in productive land area – for example, cropland, pastures, forest and fisheries – to meet human needs.[10] Ecological footprint is measured as global hectares (gha) per person.

1.4.3 Green Area Index (GAI)[11]

Green Area Index (GAI) is the ratio of the area on plan of green canopy to the area of ground on which the crop is growing.

1.4.4 Greenery Provision (GnP)[12]

Greenery provision (GnP) refers to the ratio of total green area to total site area. It is calculated by considering the three-dimensional volume filled by plants using GAI.

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Resilient to Climate Change

A sustainable built environment seeks to minimise its contribution to the underlying causes of climate change. In addition, it is designed to adapt to the predicted local consequences of this global phenomenon.

2.1 OVERVIEW

The United Nations Framework Convention on Climate Change (UNFCCC)[13] defines climate change as being directly or indirectly attributable to human activities that alter "the composition of the global atmosphere"[14] to levels beyond naturally occurring fluctuations. Two anthropogenic contributors to climate change are related to human activity: greenhouse gas (GHG) emissions, and land use and land cover change (LULCC)

GHG emissions result from the burning of fossil fuels, decomposing organic waste (typically in landfills), and food industries such as cattle-farming. Incremental increase in atmospheric GHGs (CO_2, methane, nitrous oxide and ozone) can raise global temperatures; seemingly small changes in global temperature average can significantly alter climates and stress the 'health' of ecosystems.[15]

Land cover is "the observed (bio)physical cover on the earth's surface"[16] encompassing "soil material, vegetation, and water status"[17]. Historically, Man has modified the earth's terrestrial surface to obtain food and to create environments conducive for habitation; processes leading to **land cover change**. The planet's vegetative cover, such as rainforests, is a **carbon sink**[18], a natural buffer that regulates carbon levels in the atmosphere. Loss of carbon sinks – for instance, logging or forest clearing for agriculture – limits Nature's options for future carbon sequestration.

Compounding the problem of **land cover change**, forests are often cleared with slash-and-burn techniques; the release of CO_2 from this further contributes to GHG build-up[19]. Where vegetative cover is replaced with hard urban landscapes, this also results in increased surface absorption of solar radiation leading to local hotspots in a phenomenon known as **urban heat island**.

Climate change is deemed inevitable by the global scientific community; its effects, in the coming years, will be evident and, in some places, severe. These effects include sea level rise, erratic weather and flooding, food and water shortages; these will place stress on, resulting in the displacement of, entire communities.

The Intergovernmental Panel on Climate Change (IPCC) summarises climate change impacts under several criteria. 'Freshwater resources and their management' refers to the question of **water availability**, incidences of drought alternating with flood. 'Ecosystems' speaks of the diminished capacity of natural resources to support life resulting in the **extinction of species**. 'Food, Fiber and Forest Products' is concerned with **crop productivity** which will be severely hit by sea level rise and extreme weather. It is predicted that changes to temperature and weather systems will generally affect **human health and mortality.**

Poorer communities are especially vulnerable as they are more dependent on local food and water sources that require replenishment[20]. Developing countries in Asia will bear much of the brunt of climate change as they seek to become more urbanised and industrialised. Asia will substantially add to the underlying causes of climate change as its share of GHG emissions increases and it continues to deplete its carbon sinks.

2.2 IMPLICATIONS ON BUILT ENVIRONMENT

Mitigation and Adaptation are two important and complementary strategies that make up resilience to climate change. **Mitigation** tackles the cause of climate change, seeking to reduce a development's contribution to GHG emissions; **Adaptation** addresses the consequences of climate change, through design and/or human behaviour.

A sustainable development actively seeks to reduce its GHG emissions. Buildings, for instance, must be designed for reduced dependence on the power from the grid in particular where the centralised production of electrical power is via burning of fossil fuels. These developments seek out primary energy sources that are low-carbon or carbon-neutral such as certain biofuels and photovoltaic (see also Attribute 3: Reliance on Renewable Resources).

At the urban scale, cities will seek to increase reliance on public transport, cycling and walking (see also Attribute 6: Adopts 'Sustainable Urbanism'). Precinct level technologies, such on-site combined heat and power systems, will be sought out as these offers higher yields of energy per unit of GHG emission.

In seeking adaptation, a sustainable built environment will anticipate conditions that it will face over its lifetime, for instance, extreme weather or floods. This will vary with location; some parts of Asia, such as Vietnam, are particularly vulnerable to sea level rise, others, like the Philippines, are already seeing signs of extreme weather.

2.3 SINGAPORE CONTEXT

Singapore has a coastline that is 193 kilometres in length[21]. A rising sea level (ranging from 18cm to 59cm by the year 2100) combined with heavy rainfall, would result in substantial flooding and saltwater intrusion. Singapore is also vulnerable to many of the health-related problems resulting from water intrusion such as dengue fever. Food, energy and water security would emerge as top priorities if there are regional disturbances in crop productivity, resource availability and surge of climate refugees.

Singapore was responsible for 0.2% of global CO_2 emissions in 2005; buildings accounted for 16% of its CO_2 emissions.[22] In the same year, Singapore's population was 0.0006% of the total world population.[23]

2.4 METRICS

2.4.1 Greenhouse Gas Emissions/ Equivalent Carbon Footprint

Major greenhouse gases are CO_2, methane and nitrous oxide. Equivalent Carbon Footprint is a means of gauging the impact of all GHG gases weighted to carbon equivalents. Equivalent Carbon Footprint is measured as 'metric tons CO_2 equivalent' ($MTCO_2e$).

2.4.2 Ozone Depletion Potential (ODP)

ODP is the ratio of the impact of a chemical on ozone (total amount of ozone destroyed) relative to an equivalent mass of CFC-11(ODP of 1.0).

2.4.3 Global Warming Potential (GWP)

GWP is the ratio of the heat absorbing capacity of each gas per unit of weight relative to CO_2 (GWP of 1). It also accounts for the decay rate relative to CO_2. One area of application in the built environment is the ODP and GWP of refrigerants.

2.4.4 Life Cycle Assessment

Life cycle assessment (LCA) is applied to gain a whole-life perspective. LCA is a more effective evaluation of the impact or potential impact of a development beyond short-term concerns. It comprises four stages: goal and scope (methods applied and impact categories), life cycle inventory (modelling of product systems, collection and verification of data), life cycle impact assessment (evaluating performance based on each impact category) and interpretation (conclusions). Each material and product selection is analysed in terms of its impact on the environment across its life cycle. Examples of impact categories include "*global climate change, stratospheric ozone depletion, acidification, photochemical smog, eutrophication, human toxicity, ecological toxicity, and resource depletion*".[24] LCA is a component in various rating tools, including LEED, BREEAM, Green Star and CASBEE.

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Reliance on Renewable Resources

A sustainable built environment opts for renewable resources over non-renewable ones. This operating principle extends to its demand for energy, water and materials.

3.1 OVERVIEW

We consume resources at a rate faster than the planet can replace them. Our dependence on non-renewable resources, such as fossil fuels, is problematic for two reasons. First, the resource will eventually run out, in the process precipitating economic and social crises. Energy prices, for instance, escalate sharply each time oil production is curtailed. Second, consumption itself can have devastating effects. Oil and coal are Nature's way of storing carbon; burning these to power homes and vehicles releases CO_2 and other **GHGs** into the atmosphere (see also Attribute 2: Resilient to Climate Change).

Renewable resources are natural resources, such as "trees, water, sun and wind that can be replenished at about the same rate at which they are used."[25]

3.2 IMPLICATIONS ON BUILT ENVIRONMENT

3.2.1 Energy

A sustainable built environment sources its energy from renewable repositories that never run out or can be naturally replenished. There are two sources of renewable energy (RE): generative technology and passive design.

3.2.1.1 **Generative technology** refers to systems that can tap into natural flows of energy – solar, wind, water, geothermal – converting them to electrical power, or direct cooling and/or heating. These include photovoltaic cells, solar hot water systems, wind turbines, geothermal pumps, hydropower turbines, etc.

3.2.1.2 **Passive design** is the adoption climate-responsive strategies for the making of indoor comfort without assistance from electro-mechanical devices. This depends on the attributes of local and site climate and includes daylight access and natural ventilation, managing solar exposure for heating or shading, the integration of plants and water elements.

3.2.2 Materials

Many natural materials, such as mud, clay (for bricks) and bamboo, offer alternatives to commonly used nonrenewable building products. Bamboo, for example, is a fast-growing plant that can be replenished faster than tropical hardwoods, which are commonly used for building fit-outs. Rammed earth construction, reliant on locally sourced, compressed mud, consumes less energy to make than say concrete or bricks, and can be easily returned to the ground or reused when the building is demolished.

3.2.3 Water

Onsite capture and use of **rainwater** is a key renewable strategy. Rainwater collection is advantageous in that it requires little treatment before it can be deployed for non-potable use. Another renewable source of water is seawater. **Desalination** of seawater is a purification process which removes salt to produce freshwater. This option does however consume energy which – depending on the source of energy – should be factored as a trade off.

3.3 SINGAPORE CONTEXT

Through its various test-bed projects, Singapore is preparing for implementation of solar technology on a large scale at the point when the cost of this technology drops closer to conventional energy.[26] There is however no target for when or how much national demand will be met with RE. To encourage the uptake of RE in new buildings, BCA's Green Mark[27] accords points for "% replacement of electricity by RE source."[28]

Rainwater catchment and storage area by 2011 will cover two-thirds of the island's surface area. Due to its finite land mass limiting Singapore's catchment potential, future emphasis on water sourcing will focus on recycling.[29]

3.4 METRICS

3.4.1 Carbon Credits

Carbon credits can be purchased by a development to offset its non-renewable energy usage by investing in a carbon sink elsewhere as a means of establishing carbon-neutrality. This in effect means there is removal of an equivalent amount of CO_2 from the atmosphere as is emitted by the development. 1 carbon credit is the equivalent of 1 metric ton of CO_2.

3.4.2 Rainwater Harvesting Potential

Calculating rainwater harvesting potential [area of catchment x amount of rainfall runoff coefficient = rainwater volume (m^3)], is a tool for assessing feasibility at the drawing board. It is dependent on rainfall quantity, patterns and the catchment surface properties.

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Mindful of Resource Management

A sustainable built environment optimises the use of non-renewable resources by managing demand, minimising waste and optimising resource efficiency. This operating principle extends to energy, water and materials, and describes efficient use and reuse.

4.1 OVERVIEW

Mindful resource management is the optimisation of resource use through **demand reduction**, **waste minimisation** and **maximisation of systemic efficiency**. In other words, use less, and where consumption is inevitable, use wisely. This principle applies to both construction and building in-use.

The key to this is, first, framing a **whole-life perspective** of building components and systems from fabrication to operations and disassembly. Questions asked would be how much materials and energy are consumed by a component or system, how efficient is this when compared to another equivalent component or system. What is its estimated life, i.e. what is the expected maintenance and replacement regime?

Second, resource flow should be viewed as **cycles** or **closed loops**[30] within larger systems, both man-made and natural. This means that materials discarded by one development can become the resource of another.

4.2 IMPLICATIONS ON BUILT ENVIRONMENT

4.2.1 Energy

Energy management begins with decisions made at the drawing board on the basis of a whole-life perspective of building or its system, i.e. a mapping of predicted energy use based on programme, climate and lifestyle. The project team seeks an optimal fit between system selection and occupant needs for comfort and control, balancing various modes such as passive strategies and active, electro-mechanical systems. Within each system, resource efficacy is maximised and waste minimised.

4.2.2 Materials

Material management is the act of reducing embodied energy, extending the useful life of materials and eliminating waste.

Embodied energy of a building material or product is the quantum of the energy consumed in raw material extraction, transportation, processing, assembly through to end-of-life. Where such data is available, selection should favour use of materials with lower embodied energy.

Extending the life of materials or raw materials through **reuse** and **recycling** reduces the embodied energy of a building component or system. Selection of materials with recycled content or opting for reconditioned materials are two ways of achieving this. At the drawing board this obliges the project team to consider **Design for Disassembly**, i.e. the use of a material or product in a manner that permits it to be later reused elsewhere.

Waste elimination at its simplest begins with a strategic view of **construction and demolition**. **Modularisation** and **prefabrication** for instance can reduce construction waste; the careful removal and sorting of materials from a building to be demolished increases the potential for reuse which in turn reduces the demand for landfills and incineration.

4.2.3 Water

Mindful water management starts with a respect for natural **hydrological systems** of a site, i.e. flows and cycles linking rain, surface and ground water. The built environment should plug into these flows, without interrupting or contaminating surface water discharge.

The quantity of greywater and blackwater produced by a development should be firstly reduced through reliance on water-efficient fitments, such low-capacity tanks in toilets with dual-flush option. What waste water emerges from these systems should be treated and redeployed, for instance for non-potable uses such as irrigation and toilet flushing.

4.3 SINGAPORE CONTEXT

The Singapore Sustainable Blueprint 2009[31] outlines specific targets for resource management at both consumer and national levels by the year 2030. Energy efficiency of buildings is targeted to improve by 35% over 2005 levels. This is elaborated as a 30% improvement in mature HDB estates and 20% in newer residential developments. The recycling rate is expected to rise to 70%. Per capita water consumption in that same period should have dropped by more than 10%.

Version 4 of the Green Mark for 'New Non-Residential' projects shows an emphasis on energy efficiency in buildings, accounting for 60% of credit points available. Water and material-related categories account for 9 and 0.03 percent respectively.

4.4 METRICS

4.4.1 Energy

Energy Usage per capita (kg/capita): Energy usage per person is expressed as an equivalent of kilograms of oil consumed.

Energy Intensity (kWh/m²/year): This accounts for energy consumption during the end use of the building. A subset of this is incorporating the occupant into the equation to be **kWh/o/year.**[32] The energy intensity value is used in GHG emission calculations where it is multiplied by the GHG emission coefficients for each fuel source.

Envelope Thermal Transfer Value (W/m²): Amount of thermal energy transmitted through a building envelope.

Lighting power (W/m²): A measure of the energy demand for lighting design.

4.4.2 Water

Water Index (m³/person/year): The volume of water consumed per capita per year.

4.4.3 Materials

Concrete Usage Index (m³/m²): Volume of concrete in cubic meters needed to cast one square meter of the constructed floor area. It includes structural and non-structural elements but excludes external and sub-structural works. [33]

Recycled content can be expressed as a percentage (%) of total material content by weight or volume.

30. Yeang, K. 2006. Ecodesign: A Manual for Ecological Design. London. Wiley-Academy.

31. MEWR and MND. "Sustainable Development Blueprint." Sustainable Singapore. 2009. http://app.mewr.gov.sg/data/ImgCont/1292/sustainbleblueprint_forweb.pdf (accessed October 6, 2010).

32. UNEP. "Common Carbon Metric. ." Sustainable Buildings and Climate Initiative. 2009. www.unep.org/sbci/pdfs/UNEPSBCICarbonMetric.pdf (accessed October 6, 2010).

33. Building and Construction Authority. " Code for Environmental Sustainability of Buildings." April 2008. http://www.bca.gov.sg/EnvSusLegislation/others/Env_Sus_Code.pdf (accessed October 6, 2010).

Designed for Longevity, Adaptability and Reuse

A sustainable built environment is designed for adaptability and reuse, with a view to extending the life of whole buildings and their components. It seeks to reduce the risk of obsolescence by anticipating changes in programme, technology and land use.

5.1 OVERVIEW

Designing for longevity begins with intent, at the drawing board, to extend the building's life beyond the industry average, anticipating changes and pressures that a building is likely to face. Where these are not self-evident the strategy then is to create flexibility for growth through easy reconfiguration of space and replacement of systems and fitments. **Preservation**, **rehabilitation** and **adaptive reuse** are approaches that extend the life of the building and its components, thereby lowering their embodied energy cost. A building that endures longer is also more likely to muster **emotional affinity** from its occupants and the community at large.

5.2 IMPLICATIONS ON BUILT ENVIRONMENT

5.2.1 Precinct

The **longevity** of a building, as affected by its economic value, often depends on **land use** controls which are typically decided by planning authorities. Where changes to land use, density and height limits, occur frequently, there is pressure to tear down and build again to exploit the new value of the land on which a building sits. **Planning guidelines**, conceived as long-term propositions, can alleviate this pressure of obsolescence.

5.2.2 Building

Longevity, in part, results from the selection of building materials and systems that are durable, resource efficient, and low-maintenance. A building that is inefficient and prone to repair is likely to be valued less over time.

It is important to consider that elements within a building will have their own **lifespans**. The building envelope which is exposed to the elements, and key mechanical systems can have a life expectancy of 20 years; structural systems, made from concrete and/or steel can last 100 years or more. Interior elements, such as furniture and finishes, may need more frequent replacement and/or repair, say once every 10-20 years. A critical understanding of these differences is important in determining ease of replacement and reuse.

The risk of **functional obsolescence** must be dealt with through spatial design; spaces should be planned for flexibility and changeable use. With rapid technological change, many older buildings will suffer **technical obsolescence**. This can be countered by providing flexible building infrastructure such as raised floors, accessible or oversized ducts. Change can enforced with minimal disruption to operations.

5.2.3 Component

The lifespan of building components depend on several factors, including the ease of disassembly and durability of materials. Dimensions should be standardized to facilitate ease of replacement; materials selected should be slow to deteriorate (dependent on use and exposure to climate) for instance, emergence of rot or rust.

5.3 SINGAPORE CONTEXT

There is a tendency to tear down and rebuild in Singapore, in particular with private residential developments. Building longevity is compromised by changes to land use which create economic pressure for developments that sit on 'undervalued' land. In the 80s and 90s, the move to save historically significant buildings and precincts resulted in conservation of many old structures. This however affects only a small percentage of the building stock.

5.4 METRICS

5.4.1 Embodied Energy/lifespan

Embodied Energy (MJ/kg or MJ/m²) refers to the total primary energy consumed over a building's life cycle (amount of carbon released) in extraction, manufacturing, transportation, installation, waste, use, reuse etc. It is typically expressed as a quantity of non-renewable energy per weight or area of the product. There are two types of embodied energy: initial embodied energy (non-renewable energy used in raw material extraction, processing, manufacturing, transportation and construction) and recurring embodied energy(non-renewable energy used to maintain, repair, restore, refurbish or replace components, systems and materials over the course of a building's lifespan. The ratio of embodied energy to lifespan measures the value of a building's longevity in increasing/ reducing its embodied energy/year and is an indication of its energy efficiency.[34]

5.4.2 Existing Structure Percentage

The Singapore Green Mark rating tool awards points for the percentage of area of existing structural elements and building envelope preserved. In the case of 'Residential' buildings, 2 points are awarded if a minimum of 50% of existing structural elements or building envelope is conserved.[35]

34. 'Measures of Sustainability'
http://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_embodied.htm
(accessed August 30th, 2010)

35. BCA. "BCA Green Mark for New Residential Building Version RB/4.0." Building Construction Authority. December 2010.
www.bca.gov.sg/GreenMark/others/gm_resiv3.pdf (accessed October 6, 2010).

Adopts 'Sustainable Urbanism'

A sustainable built environment is one that has in place principles and infrastructure that support an efficient use of resources and a low-carbon lifestyle.

6.1 OVERVIEW

Sustainable urbanism describes an approach to urban design and planning with several key outcomes. **Larger precinct level systems** can be built into urban infrastructure – as opposed to smaller scale building systems – permitting more efficient management of space, resources and waste. **Integrated landscaping** can improve ambient conditions for well-being and comfort, reducing the need for building level cooling and lighting. Low-carbon choices can reduce carbon footprint of a community, for instance, by offering residents the option to switch from private cars to **public transport** access, purchase of **locally sourced food** and goods, switching to **Green energy** sources.

6.2 IMPLICATIONS ON BUILT ENVIRONMENT

Sustainable **urban planning** principles can create conditions enabling its inhabitants to live "ecologically aware, low carbon lifestyles".[36]

A main characteristic of a low-carbon city lifestyle is its **connectivity**. Transportation has become a global issue in relation to sustainability as the global vehicular transport sector accounts for 23% of global **carbon emissions**[37]. Of the various modes of transport including air, maritime, rail and road, road transport accounts for 73% of the global carbon emissions[38]. Studies have also shown that as the urban density increases, the private transport **energy use per capita** decreases[39]. In a high density **mixed-use development** where transportation networks are well-designed such that occupants have high accessibility to facilities by walking, cycling and public transport, carbon emissions and traffic congestion can be substantially reduced. This also leads to **wellness** of the inhabitant, lower social security costs and a more liveable city.

The inclusion of precinct level networks for energy, water and waste also affect the carbon footprint of a city. There is an economy of scale, for instance, in district cooling systems that could potentially reduce energy waste. Precinct level systems are critical because they are potentially more cost effective and efficient than decentralised systems at the building scale.

A sustainable community reduces its **carbon footprint** through local sourcing. Locating food production, for instance, within city boundaries is gaining credence as emissions due to shipping and food security are seen to be increasingly important. The presence of **urban agriculture**, plus other forms of urban landscaping such as parks, gardens and green connectors, contributes to carbon sequestration, reduced urban heat island effect and qualitative aspects of a liveable city.

6.3 SINGAPORE CONTEXT

The combination of high density housing, constraints on private car usage and the extensive and reliable public transportation system has had a measurable impact. In 2005, Singapore's transport accounted for 19% of the **overall carbon emissions**[40] and 52.4% of Singapore residents commuted to work by public transport[41]. By 2030 the government has targeted 75% public transport use out of all motorized trips[42]. To encourage the use of green transportation such as the use of bicycles, there are increasing provisions for designated cyclists' paths; there are also plans to heighten **connectivity** for pedestrians and cyclists through the increase of **park connectors** from 100km in 2007 to 360km by 2020[43].

The handling of energy, water and waste in Singapore is centralised. In the context of water and waste recycling, centralisation offers building owners convenient options for a Greener lifestyle. In the context of energy however there will be inefficiencies due to transmission losses. The move towards decentralised, onsite energy production is slow; and even though it is now possible to return energy to the grid.

6.4 METRICS

6.4.1 Vehicle Kilometres Travelled (VKT)

Vehicle Kilometres Travelled (VKT) is measured in kilometres. It gives a measure of the pressure that transport puts on the environment. For example, by measuring the total vehicle kilometres travelled by all types of vehicles, the carbon emissions associated with transportation can be estimated.

6.4.2 Carbon Footprint

Carbon footprint refers to the total set of greenhouse gases (GHG) emissions caused by an entity. It helps to provide a reference for the ecological footprint and is measured as metric tons (t) of CO_2.

6.4.3 Floor area per person

Floor area ratio is measured as ratio of total living space to the number of inhabitants (m^2/inhabitants). It provides a reference for urban density.

36. The Prince's Foundation for the Built Environment. "Valuing sustainable urbanism." The Prince's Foundation for the Built Environment. 2007. http://www.princes-foundation.org/files/0707vsuoverview.pdf (accessed July 30, 2010).
37. International Energy Agency (IEA), COı Emissions from Fuel Combustion 1971-2005, (IEA, 2007).
38. Ibid.
39. Peter Newman and Jeffrey Kenworthy, Urban Design to Reduce Automobile Dependence, Opolis: An International Journal of Suburban and Metropolitan Studies; Vol.2: No.1, Article 3, 2006. http://repositories.cdlib.org/cssd/opolis/vol2/iss1/art3 (accessed July 30th, 2010).
40. MEWR, Singapore's National Climate Change Strategy, (Singapore: Ministry of the Environment and Water Resources, 2008), available online at: http://app.mewr.gov.sg/data/ImgUpd/NCCS_Full_Version.pdf (accessed July 30th, 2010).
41. Singapore Department of Statistics, General Household Survey 2005, Statiscal Release 2: Transport, Overseas travel, households and housing characteristics, (Singapore: Department of Statistics, Ministry of Trade and Industry, Republic of Singapore, 2005), available online at http://www.singstat.gov.sg/pubn/popn/ghsr2/chap1.pdf
42. Lim Swee Say, "Commuting Sustainably (Singapore)," Transport and Communications, UNEP, 2001, available online at http://www.unep.org/ourplanet/imgversn/121/say.html2001(accessed July 30th, 2010).
43. MEWR and MND. "Sustainable Development Blueprint." Sustainable Singapore. 2009. http://app.mewr.gov.sg/data/ImgCont/1292/sustainbleblueprint_forweb.pdf (accessed October 6, 2010).

Harmonisation with Place

A sustainable built environment is in harmony with its setting; acknowledging and responding to the pre-existing conditions that physically define a site or describe its social and cultural context.

7.1 OVERVIEW

A sustainable built environment is in harmony with its setting. In seeking to insert a new development into a site or context, it seeks to be sensitive to pre-existing conditions such as history and culture, local craft and knowledge, ecology and terrain, climate and microclimate, urban spaces and connectivity, all of which collectively define **Place**. Harmonisation is therefore the act of integration and assimilation, of actively reducing the ecological and social burden that a new development will place on existing natural and man-made environments.

7.2 IMPLICATIONS ON BUILT ENVIRONMENT

'**Place**' refers in part to the natural attributes of a location – its terrain, ecology and climate – and in part to man-made conditions, such as history, culture and local wisdom, urban and community networks. Even though these two descriptors – natural and man-made – rely on separate knowledge domains, they are equally important. There are three aspects of place that a sustainable built environment must address:

History, culture and local wisdom[3]. Developments that ignore these contextual factors have limited local acceptance; there is therefore value to be had in adopting principles and practises that have strong local precedence. Vernacular buildings and associated crafts, for instance, are a means through which to understand what works best in a particular context.

Terrain, ecology and climate. Each site has its own flows and cycles. These can be, for instance, hydrological, the movement of water resulting from a combination of terrain and climate. These can be seasonal, patterns of annual/diurnal air and sun path movement. They can be ecological, for instance, the exchange of resources and waste between plant and animal life. Sites can be ecologically mature or immature[44], a hybrid of natural and man-made or wholly man-made. In all cases it is important to understand, via site studies, how a new development can be least disruptive, how it can utilise onsite resources in a sustainable manner.

Urban and community networks. Where a development seeks to integrate within pre-existing community settings, it must respect the connections and ties that exist. Respecting existing community spaces and pathways, for instance, can become a way of integrating old with new.

7.3 SINGAPORE CONTEXT

Over 80% of Singaporeans reside in public housing[45] which over the years has become the defining element in urban and community networks. Public housing offers a broad-based shared experience of what it means to be in Singapore; through its design and administration, it channels public behaviour and expectations on quality of life and social cohesion.

The integration of Singapore's built environment with extensive landscaping and historical conservation precincts is an act of harmonisation, each augmenting local identity and place-making

3. Buchanan, P, 2000, Ten Shades of Green, Architecture League of New York

Wellness of Inhabitants

A sustainable built environment ensures the **wellness** of its inhabitants, taking into account the physiological and psychological needs of its users, addressing their expectations and preferences relating to comfort and health.

8.1 OVERVIEW

Health and comfort are central to the notion of a sustainable environment. Where the design or operation of an environment fails to deliver these outcomes, this may result in misuse, premature obsolescence or repeat retrofits.

Wellness may be understood through two broad descriptors – **avoidance** and **affordance**.

Avoidance describes the act of designing within prescribed bandwidth of conditions. Where these boundaries are overstepped, there are known consequences to physiological health and/or comfort, for instance, excessive solar gains leading to thermal stress or exposure to harmful substances such as volatile organic compounds (VOCs). **Affordance** describes the pursuit of environmental qualities that are emotionally and psychologically satisfying, for instance, access to daylight or exterior views.

Avoidance delineates limits in design while **affordance** describes design potential.

8.2 IMPLICATIONS ON BUILT ENVIRONMENT

There are several aspects of wellness that must be addressed:

a. **Physiological Wellness** – Pertaining to quantitative ambient conditions such as temperature and air quality. Through design one seeks to avoid stressors such as excessive air movement or presence of harmful substances or chemicals in the indoor air.

b. **Psychological Wellness** – Pertaining to qualitative attributes of the environment, such as daylight and views. Act of design seeks to avail these to as many occupants as possible.

c. **Emotional Satisfaction** – Pertaining to calming and/or arousing attributes of the environment which appeal to an occupant's need for order and cohesion.

Examples of conditions affecting physiological wellness include air movement, thermal and visual conditions, air quality, noise and light pollution. These are collectively described as **indoor environmental quality (IEQ)**; they have been known to affect workplace productivity and absenteeism. **Indoor air quality (IAQ)**, as a subset of IEQ, goes on to describe the level of microbes, pollutants such as VOCs and particulates. Exposure to these can affect the health of occupants, sometimes resulting in sick building syndrome. There are many design factors affecting IEQ and IAQ, for instance, material selection, lighting distribution. There are also many operational factors affecting a space, for instance, maintenance of its air supply ducts.

Examples of conditions affecting psychological wellness include visual and physical access to nature, access to natural light, etc. Studies have shown that these have beneficial effects on the building's occupant, both in the short and long term. These can translate to higher levels of productivity or a state of satisfaction.

Examples of conditions affecting emotional satisfaction are colour, pattern and artefact. The ease with which a building is understood is described as its level of legibility; which in turn depends on the cohesion of its constituent parts. Cohesion and legibility are critical to the way in which we make sense of an environment.

8.3 SINGAPORE CONTEXT

Guidelines by authorities in Singapore, such as National Environment Agency (NEA and BCA generally delineate limits of avoidance, stipulating for instance what is the acceptable bandwidth of conditions for IEQ[4].

At the national level, Singapore has consistently managed air quality by regulating and monitoring pollution at source. According to the Sustainable Development Blueprint (2009)46, Singapore has targeted by 2020 reductions in fine particles levels in the air to (PM2.5) to 12µg/m3, capping Sulphur Dioxide (SO_2) levels at 15µg/m3.

8.4 METRICS

8.4.1 Operative Temperature

Operative temperature describes the combined effect of air and radiant temperature as sensed by the human body. It is measured in degree Celsius (°C).

8.4.2 Predicted Mean Vote (PMV) Percentage of Persons Dissatisfied (PPD)

PMV is the 'predicted mean vote' (on the thermal sensation scale) of a large population of people exposed to a certain environment. PMV is derived from the physics of heat transfer combined with an empirical fit to sensation. PMV establishes a thermal strain based on steady-state heat transfer between the body and the environment and assigns a comfort vote to that amount of strain. PPD is the predicted percent of dissatisfied people at each PMV. As PMV deviates from zero in either the positive or negative direction, PPD increases.

8.4.3 Level of fine particulate matter (PM2.5) in the air

Particulate matter 2.5 (PM2.5) are fine particles in the air that are 2.5 microns or less in width. The level of fine particles in the air can cause health concerns when it is high. As the particles are small enough to travel deep into the respiratory tract of human lungs, exposure to them can cause serious health issues. Sources of fine particles include vehicular exhausts, chemical reactions such as burning of fuels, volcanic eruptions, and even tobacco smoke. PM 2.5 is measured in micrograms per cubic meter of air (µg/m³).

4. Singapore Standard SS 554: 2009 | Code of practice for indoor air quality for air-conditioned buildings: The Singapore Standard document entitled "Code of practice for indoor air quality for air-conditioned buildings" addresses protection from harmful substances in the indoor environment, which if present in excessive concentrations, can adversely affect the health and comfort of occupants. The document outlines an audit methodology which includes recommendations for acceptable limits and measurement or analytical methods for the following IAQ parameters - thermal comfort, chemical and biological.

44. Ken Yeang, Ecodesign: A Manual for Ecological Design, (London: Wiley-Academy, 2006)
45. HDB. "HDB Annual Report 2008/2009: Key Statistics ." Housing Development Board. 2009. http://www.hdb.gov.sg/fi10/fi10221p.nsf/0/d4a0f107613b79944825766200236310/$FILE/Key%20Statistics.pdf (accessed October 6, 2010).
46. MEWR and MND. "Sustainable Development Blueprint." Sustainable Singapore. 2009. http://app.mewr.gov.sg/data/ImgCont/1292/sustainbleblueprint_forweb.pdf (accessed October 6, 2010).

Integrated Landscape

A sustainable built environment integrates greenery and other landscape elements into urban masterplans, site design and building envelope.

9.1 OVERVIEW

At the urban scale, integrated landscape refers to the early consideration and inclusion of features such as water bodies, gardens, parks and green connectors into the urban fabric. At project level, this refers to the integration of water features and plants into site layout, plus the use of horizontal and vertical surfaces of the building, such as roof and façade, to grow vegetation.

9.2 IMPLICATIONS ON BUILT ENVIRONMENT

An integrated approach to landscaping is one in which these elements are considered early in the design process with the objective that building and landscaping are better synergised. There are several other important outcomes to this:

- Landscaping systems and elements can contribute to **microclimate**, for instance lowering ambient temperatures. Building integrated plants are also known to improve the thermal insulation of facades and roofs, reducing thermal transmission into the building interior. In warm climates these can reduce demand for mechanical cooling within buildings, lowering energy demand.
- There can be symbiosis between natural and man-made **flows and cycles**. The channelling and retention of rainwater, for instance, has potential for on-site sourcing and recycling, plus stormwater management. Natural elements, such as bioswales and phytoremediation ponds, augment mechanical systems such as swimming pools and irrigation systems.
- Plants are a form of **carbon sequestration**; they absorb CO_2 from the atmosphere and store it.
- Plants can be a source of **food**. Where onsite food production is substantial, it can lower the carbon footprint of the population by reducing its food miles, i.e. emissions resulting from transportation of food items from farms and production centres situated beyond the city limits.

The net effect of integrated landscaping is that it reduces the environmental burden that a development has on its immediate environment. It can also have a direct bearing on the well-being of the population, adding delight, relieving stress and offering nutrition.

9.3 SINGAPORE CONTEXT

Singapore is extensively landscaped which contributes to lower **heat island effect**. The policy of urban landscaping, which has been in place for several decades, is ramping up with strategies for green park provision of 0.8ha per 1,000 populations by 2030, and the introduction of 50ha of skyrise greenery by 2030[47]. The qualitative aspects of sustainable urbanism are pursued through strategies of integrating landscape within the built environment, providing equitable access to public infrastructure. Singapore aims to have 900ha of reservoirs and 100km of waterways open for recreational activities by 2030.[48]

At the building level, the Green Plot Ratio requirement earns credits under the Green Mark rating scheme, promoting the drive towards site and building integrated greenery.

9.4.1 Green Plot Ratio (GPR)

The Green plot ratio (GPR) is measure of the amount of greenery found within a development's site boundaries. The computation of GPR begins with leaf area index (LAI) of different types of plantings – stipulated within Green Mark – which are added and weighted against site area. A GPR of 1, for instance, implies that the development has greenery equivalent to that of the site surface area covered with grass. GPR allows for the regulation of greenery on site, providing flexibility to the designer while simultaneously encouraging a higher green component to the design.[49]

Leaf Area Index (LAI) is defined as the single-side leaf area per unit ground area and is a dimensionless number. More information on LAI values and its application in Singapore can be sought via NParks' 'Floraweb'[50] (an online plant-reference database) or '*Leaf Area Index of Tropical Plants*'[51].

47. Ibid.
48. MEWR and MND. "Sustainable Development Blueprint." Sustainable Singapore. 2009. http://app.mewr.gov.sg/data/ImgCont/1292/sustainbleblueprint_forweb.pdf (accessed October 6, 2010).
49. Ong Boon Lay, Green plot ratio: an ecological measure for architecture and urban planning, Landscape and Urban Planning, Volume 63, Issue 4, Pages 197-211, 15 May 2003.
50. National Parks Board. NParks FloraWeb. 2010. http://floraweb.nparks.gov.sg/ (accessed October 6, 2010).
51. Tan, Puay Yok, and Angelia Sia. Leaf area index of tropical plants: a guidebook on its use in the calculation of green plot ratio. Singapore: Centre of Urban Greenery and Ecology, 2009.

Integrated Design Process

A sustainable built environment is a product of a collaborative framework known as the integrated design process (IDP). The IDP seeks to bridge the gap between the various stakeholders across all phases of the design-construction process, driven by a singular focus on targets and performance.

10.1 OVERVIEW

The IDP starts with the project team setting benchmarks and targets at the drawing board; it obliges them to address the needs of all stakeholder including the building occupants and operators, over the life of the building. In a sense, the IDP is a reversal of the fragmented, partisan and capital-expenditure driven approach that the industry adopts today, pushing process towards a symbiosis of systems and strategies towards long-term outcomes.

There are several key conditions of an IDP:

a. Appointment of all project consultants early in the design process

b. Collaborative and consultative approach to decision-making in which each person's contribution is valued. The project timeline is typically punctuated by periodic charrettes or workshops at which the team collectively reviews progress and outcomes. Through this act of collaboration & peer review, tradeoffs and conflicts between goals are managed

c. Process is driven by performance targets, many of them quantifiable and verifiable.

d. The needs and expectations of building users and operators are articulated in an IDP ensuring that the development is designed as it will be used by its occupants, and vice versa.

10.2 IMPLICATIONS ON BUILT ENVIRONMENT

Buildings designed with the IDP are more likely to result in an efficient use of resources during their operation. Various outcomes and deliverables, such as accessibility, safety and security, functionality, aesthetics and cost effectiveness52, are optimised and negotiated, in particular where the needs of one conflicts with another. This optimisation process results in a holistic outcome, where one feature or strategy reinforces the other.

The IDP also obliges the project team to adopt a whole-life view of building performance, from concept to disassembly. This perspective shifts the question of cost from upfront budgeting to a life-cycle analyses through which long term operations expenditure and environmental costs can be factored in.

10.3 SINGAPORE CONTEXT

The design-construction process in Singapore is driven by pressures of capital expenditure and construction schedule. Mindsets and disciplinary boundaries between architects and engineers often limit drawing-board communication that is necessary for design of high performance buildings. User feedback of a completed project is rarely solicited. Many projects are subject to iterative re-design when conflicts of cost and schedule become apparent; these short-term exigencies can compromise long term performance.

52. WBDG Sustainable Committee. "Sustainable | Whole Building Design Guide." WBDG - The Whole Building Design Guide. 2010. http://www.wbdg.org/design/sustainable.php (accessed October 6, 2010).

Ecological Literacy

Ecological literacy is the awareness in a population of the consequences of its behaviour and/or inaction towards its environment at large. A built environment, seeking to be sustainable, must factor in the degree of this awareness. It can conversely, through its design and interfaces, seek to promote it.

11.1 OVERVIEW

The built environment and its users are in continuous interaction. Buildings affect behaviour; occupants, through behaviour, shape their environments. Where a population is ecologically literate and committed to action, this conversation between occupant and building results in sustainable outcomes. Where a building is designed to promote ecological literacy, it heightens this awareness and helps align occupant behaviour.

11.2 IMPLICATIONS ON BUILT ENVIRONMENT

Ecological literacy is a prerequisite for a sustainable built environment. There are three ways in which buildings become educators[53]: demonstration, experience and involvement. 'Demonstration' is a formal channel of education, for instance through smart meters. 'Experience' connotes learning acquired via a passive form of interaction and observation. 'Involvement' implies active interaction with the building.

In other words, ecological literacy can be promoted by the built environment in several ways:

a. **Formal and informal learning**. Buildings can be commissioned with explicit instructions on appropriate use, with operational manuals on the features and systems that are in place. There are also formal industry-wide training programmes for building operators that equip them with the skills necessary for managing building performance.

b. **Building-occupant interface**. How an occupant should behave can also be inferred from the way a building's elements and controls are designed. The clarity of how certain elements are to be operated, such as windows and shading devices, is important. Decentralisation of controls, for instance, desktop task lighting or personalised ventilation systems, allows occupants to regulate their own comfort conditions without having to light or cool the entire space, all the time.

c. **Awareness raising**. A building can communicate the essence of ecological design[54]. This can be inferred from the degree to which it engages and respects the natural environment on site, for instance its relationship with nearby ecosystems. It can be perceived in the way it engages with the climate, for instance, the extent of daylight reliance and solar shading. This can also be inferred from the selection of some materials and avoidance of others. The combined effect of these ideas is that it will alter the feel and appearance of a sustainable building, setting it apart from one that is not.

11.3 SINGAPORE CONTEXT

Formal channels of learning are available to the Singapore building sector. Green education, by way of seminars, conferences and workshops, is targeted at the industry players, such as architects, engineers and builders. Informal channels of learning, affecting building users, are less common. There appears to be limited awareness in the public domain on the importance of the occupant's behaviour and lifestyle in the context of a Green building. This results in disjuncture between design and behaviour, bringing into question if a building designed to be Green at the drawing board is also Green in its operations.

53. Bonnett, E., & V. W. Olgyay 2009. Crytallised Pedagogy: Architecture as a Medium for Sustainability Education. Plea 2009: 2. 26th Conference on Passive and Low Energy Architecture. Quebec City: Rocky Mountain Institute.

54. The AIA Sustainability Discussion Group 2007. "AIA 50 to 50 Version 1." The American Institute of Architects . 2007. http://www.aia.org/groups/aia/documents/pdf/aiab051123.pdf (accessed October 6, 2010).

PART II

Process Considerations

Team Building STAGE 1

Information Gathering and Goal Setting STAGE 2

Design Brief STAGE 3

Schematic Design STAGE 4

Design Development STAGE 5

Tender Documentation STAGE 6

Tender and Award STAGE 7

Mobilisation STAGE 8

Construction STAGE 9

Testing, Commissioning and Documentation STAGE 10

Operations STAGE 11

Demolition and Disassembly STAGE 12

Team Building

STAGE 1

INTEGRATED DESIGN: organise a team (involve the client) for integrated project design and delivery.

ARCHITECT'S ROLE: leverage on the expertise within the firm among the consultants and client group.

SEARCH for a core team of specialised consultants (urban planners, architects, landscape architects and engineers) who have prior experience with projects that demonstrate sustainable community, urban and site planning as well as landscape design, such as (but not limited to):

- → Code reviewers
- → Ecologically Sustainable Development (ESD) designers or consultants
- → Biodiversity consultants
- → LCA consultants
- → Carbon consultants
- → Grey water consultants
- → Energy consultants
- → Geothermal engineers
- → Sustainable timber consultants
- → Computational Fluid Dynamic (CFD) analysis consultants
- → Facilities management
- → Engineers
- → Acoustics consultants.

INCLUDE people who are familiar with the codes (to have a balance between innovative design and meeting agency requirements).

BALANCE innovative design with cost (specialised consultants).

ORGANISE the client, from infrastructure/ masterplanning (campus situation) and user groups to facility managers and maintenance/final demolition team if available.

ORGANISE a consultant and future construction team that mirror the client's team or vice versa.

EIA

DEVELOP ESD strategy during design charettes with all stakeholders to identify and endorse targets and goals.

CHECK AND CONFIRM government regulations on ESD aspects and applicable rating systems. Local rating systems should prevail over international systems.

ESTABLISH specific aims such as low carbon/low energy to establish better understanding and focus of ESD measures.

RAISE ESD ASPECTS with clients that are not typically associated with the classic construction process such as post-occupancy evaluation and LCAs.

ESTABLISH ESD ASPECTS to form part of project deliverables and create a responsibility matrix among the client/consultant team so that additional costs and fees can be established early on.

Design Brief

STAGE 3

REVIEW ESD GOALS from the project brief and develop cost estimates and Return on Investments.

CONDUCT INFORMATION GATHERING to obtain existing site information such as:

- → Climatic conditions (wind, rain, temperatures, humidity, sun path/radiation)
- → Traffic conditions
- → Site preservation and conservation assessment including flora, fauna and geographic, cultural and historical resources
- → Natural resource availability including hydrology reports
- → RE opportunities on and around the site.

INTEGRATE FINDINGS into the concept design in regards to building forms, massing orientation and location on site.

CONSIDER using local and natural materials in the design.

CONSIDER the use and rehabilitation of existing buildings on the site.

MAXIMISE the utility of open spaces for natural ventilation that can be used as common/public spaces.

DEVELOP AN ESD ACTION PLANS based on a responsibility matrix and concept design.

Schematic Design

STAGE 4

EIA

REVIEW ESD goals through regular design meeting and charettes.

IDENTIFY ownerships based on ESD action plans and rating system requirements.

DEVELOP a transport plan to minimise vehicular traffic and advocate public/pedestrian and bicycle network solutions.

CONDUCT studies on microclimate, solar heat impact and daylight based on software analysis and integrate findings into the design to avoid heat islands and solar heat impact on occupied spaces.

DESIGN for flexibility and future adaptation.

IDENTIFY areas for natural ventilation or mixed-mode air treatment.

EXPLORE recycling possibilities for on-site building components and materials.

DEVELOP stormwater management strategies to encourage and promote water recycling and conservation. Use government or local programmes where applicable [PUB, the Water Agency (PUB) Active, Beautiful and Clean (ABC) water programmes etc.].

EXPLORE embodied carbon for structural options and consider cement replacement options.

DEVELOP shading and glazing strategies for façades.

DEVELOP rain and shading strategies for natural ventilated spaces.

CARRY OUT initial energy modelling based on the above strategies.

Design Development

STAGE 5

REVIEW
ESD strategies and action plans including regular reports and monitoring of targets.

SELECT
materials with low (VOC) emissions and other harmful chemicals.

PROVIDE
acoustic separation between sources of noise in adjacent areas.

DEVELOP
detailed plans to conserve, reinstate or create habitats on site.

CARRY OUT
detailed energy modelling.

CHECK
if government incentives or funding programmes are available for specific goals.

PROVIDE
operable windows and shading, and Heating, Ventilation and Air-Conditioning (HVAC) systems where possible/ practical for end user control.

SIZE
structural members efficiently.

DEVELOP
detailed waste management systems including recycling stations and explore the use of waste for energy use (co-gen plants etc.).

SELECT
environmentally friendly and recycled materials.

DEVELOP
a detailed façade system to address solar heat gain, glare, natural lighting, air tightness and moisture control.

SIZE
and locate Mechanical, Electrical and Plumbing (MEP) equipment efficiently, including metering and monitoring systems.

DEVELOP
a detailed strategy for integrated greening.

EXPLORE
innovations and identify synergies to enhance building performance and environment.

Tender Documentation

STAGE 6

CLEARLY DOCUMENT
ESD goals, strategies and mandatory requirements in the contract drawings and specifications.

DEVELOP
material specification with particular reference to green products.

DOCUMENT
ESD aspects to minimise erosion or habitat destruction during construction.

STIPULATE
how a contractor should run the site.

Tender and Award

STAGE 7

CONVEY
ESD strategy and goals to the tenderers.

ESTABLISH
pre-qualification based on suitable experience.

ESTABLISH
assessment evaluation methods to evaluate contractor experience and conformance to tender documents.

REVIEW
tenderers' sustainable proposals and submissions including:

- Experience and capability
- Conformance and understanding
- Overall achievement of ESD and certification goals
- Maximising opportunities to explore sustainable strategies.

ENSURE conscientious planning for the entire construction process.

ENSURE adequate and safe working space around areas that require conservation.

ENSURE conserved areas are not isolated during construction.

ENFORCE sustainable practices in the contractor's setting-up of temporary buildings and in the demolition of existing structures, disposal and handling of demolished (salvaged) material.

EMPLOY just-in-time delivery and proper and safe storage to reduce wastage of storage space and damage to materials/equipment.

LOCATE the site office with due consideration for existing structures, storage, plant and manoeuvrability of heavy equipment required for construction.

CONSIDER the effects of vibration, dust and noise pollution generated by construction equipment, especially where existing structures are deemed 'fragile'.

ENSURE safety recommendations are enforced.

ENDEAVOUR to protect and maintain the existing landscape where possible.

USE sustainable construction methods including silt fences or bioswales to prevent soil erosion and sedimentation.

PROTECT existing landscape features such as trees, turfing or water bodies to avoid damage during construction.

Construction

STAGE 9

INTEGRATE
ESD strategies and goals into the agenda for site meetings.

DEVELOP
a monitoring plan to monitor the contractor's performance against tender/contract requirements.

ENSURE
the proper protection of on-site vegetation, habitats or cultural/ historic installations.

ENSURE
all HVAC and façade systems are installed properly with full documentation and manuals.

ENSURE
HVAC systems are protected from dust/ microbes during construction.

ENSURE
materials and finishes are protected from moisture and heat impact.

Testing, Commissioning and Documentation

STAGE 10

DOCUMENTATION (include brochures)

ENSURE green features are implemented and working effectively.

ENSURE complete documentation for certification requirements.

ENSURE user guidelines and training plans are in place.

REVIEW design documentation, and complete thorough testing to key specifications.

REVIEW key documents for completion such as logging, plant efficiency, performance and equipment.

Operations

STAGE 11

RECOMMEND
and fine-tune the integrated system.

CHECK
operation manuals for HVAC, façade and waste systems and ensure that maintenance staff is properly trained.

MONITOR
and check building performance against goals established during DD through full post-occupancy evaluation.

ADVISE
the client to carry out occupant surveys to confirm IEQ standards and address any comments or concerns.

PROMOTE
the sharing of building data with occupants and the public to create better benchmarks.

INSTALL
'dashboard' monitors to educate building users on the impact of their actions.

ENSURE
recycling points are properly located and maintained, and that users are educated on their use.

Demolitions and Disassembly

STAGE 12

ASSESS
the building for adaptive reuse.

UPDATE/EVALUATE
and re-establish the demolition protocol.

MAKE PROVISIONS
for proper disassembly and safe disposal or recycling.

DEMOLITION AND DISASSEMBLY
of the building should not affect
the Natural Capital.

Credits

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SIA Council 2012/13

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